Late Cretaceous-Early Palaeogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium — Part 4: Echinoids

John W.M. Jagt

Jagt, J.W.M. Late Cretaceous-Early Palaeogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium — Part 4: Echinoids. — Scripta Geol., 121: 181-375, 23 figs., 30 pls; Leiden, December 2000.
John W.M. Jagt, Natuurhistorisch Museum Maastricht, Postbus 882, NL-6200 AW Maastricht, The Netherlands, E-mail: mail@nhmmaastricht.nl

Key words: Echinodermata, Echinoidea, Late Cretaceous, Early Palaeogene, taxonomy, stratigraphy.
All Campanian, Maastrichtian and Danian echinoids known to date from the extended type area of the Maastrichtian Stage are listed and, with a few exceptions, also illustrated. The geographic and stratigraphic distribution of these echinoderms are documented. A total of 55 (sub)genera and 119 (sub)species (inclusive of formae), two of which are new, are recognised. A number of taxa are reassigned, while others have to remain in open nomenclature for the time being. Recorded for the first time from the area are representatives of *Hagenowia* and *Zeuglopleurus*, as well as juvenile specimens of *Hemipneustes striatoradiatus*. *Cidaris gigas* (= *Temnocidaris (Stereocidaris) gigas*) is accepted as a valid species. The name *Cyphosoma rutoti* is shown to be based on the spines of *C. corneti*, now reassigned to *Trochalosoma*?. New are *Plagiochasma lammersmaxi* Jagt & van der Ham, sp. nov. and *Micropsis*? *caementum* Jagt & van der Ham, sp. nov. The scope of the present paper is taxonomic and stratigraphic; the palaeobiology and palaeoecology of the echinoid faunas will be discussed in a forthcoming paper, part 6 in the present series.

Contents

Introduction

Of Late Cretaceous and Early Palaeogene echinoderms from the Maastrichtian type area, the well-preserved and conspicuous echinoids have received by far the closest attention. Despite this, new records are still being published regularly. These new records refer either to species new to science or to taxa known from elsewhere in Europe or North Africa.

In the present paper, 119 (sub)species (inclusive of formae) in 55 (sub)genera are listed and, with few exceptions, illustrated. Descriptions are brief, except for those species which have repeatedly been misinterpreted or confused in the literature, as well as for the new species. An additional three new species from the area will shortly be described by Smith & Jeffery (in press). With very few exceptions, the taxonomic framework proposed by these authors is followed in the present paper. Lists of synonyms include references to papers in which material is described in (more) detail.

Most of the material was collected during the past eight years in a number of quarries, both working and disused, and in a few other (natural) outcrops in the area between Aachen, Liège and Maastricht. Included are also museum collections (Natuurhistorisch Museum Maastricht, Institut royal des Sciences naturelles de Belgique/Brussels, and Institut für Paläontologie der Rheinische Friedrich-Wilhelms-Universität/Bonn, although it is realised that these, and finds made prior to 1975 in particular, often suffer from lack of stratigraphic details. Specimens contained in private collections, notably those of M.J. van Birgelen, M.J.M. Deckers, R.W. Dortangs, D. Eysermans, R.W.J.M. van der Ham, L. Indeherberge, M.M.M. Kuypers, R. Meuris, and R. Pieters have also been considered, since these comprise stratigraphically well-documented material. Specimens from these collections, and material from the author's collection illustrated herein, have been donated and transferred to the collections of the Natuurhistorisch Museum Maastricht, and have the prefix NHMM.

The present paper is the fourth in a series of contributions documenting echinoderm faunas of Late Cretaceous and Early Palaeogene age from the extended Maastrichtian type area (see Jagt, 1999a-b; Kutscher & Jagt, 2000). For a discussion of the geographic-stratigraphic setting and general references see Part 1, and for a brief outline of the project Part 2.

The present paper also comprises a historical account of the research into echinoids, which precedes the systematic descriptions, and includes citations from literature sources not easily accessible.

Material and methods

In comparison to crinoid, ophiuroid and asteroid skeletons which, upon death, rapidly disintegrate into jumbles of many thousands of small to diminutive ossicles, echinoid tests are mostly preserved more or less whole. This holds true especially for burrowing species (some holasteroids, and all spatangoids), which occasionally also preserve parts of their spine canopies, inclusive of pedicellariae. Of cidaroids mostly test segments, or isolated interambulacral plates and numerous primary and scrobicular spines remain. More or less complete specimens are rare, and such preserving the apical disc highly exceptional. This holds true also for phymosomatoids. On account of their peculiar apical structure, saleniids are comparatively sturdy, and are thus commonly found entire. Specimens associated with spines and lantern, however, are extremely rare. In certain storm-generated strata, such as those of the basal Gronsveld Member and upper Nekum Member (Maastricht Formation, ENCI-Maastricht BV quarry), spectacular finds have recently been made. These include phymosomatids with lanterns and spines preserved. Rapid burial (obrution) explains the fairly common occurrence of peristomial and periproctal plating in specimens of *Hemiaster prunella* and *Hemipneustes striatoradiatus*. Of *Hemiaster aquisgranensis* and *Hemipneustes oculatus* also specimens preserving (parts of) this plating are now available.

Extensive bulk sampling at a few levels has yielded material of the bizarre holasteroid *Hagenowia*, and of *Zeuglopleurus*, and has resulted in the discovery of juvenile tests of *H. striatoradiatus* and *H. prunella*.

A single species from just outside the Maastrichtian type area, between Zichen

and Tongeren (see Indeherberge et al., 1993, 1996), is also listed. Echinoid faunas in that area have been shown to differ in species composition and include forms not yet recognised in the type area. With very few exceptions, material from so-called residual flint deposits (e.g. the Haccourt-Lixhe area) is not included, mainly since the stratigraphic provenance of these faunas is still unresolved. Papers documenting these echinoids have just appeared and are in preparation (van der Ham, 1999, in prep.).

A fair number of specimens included in the present paper have previously been illustrated by Geys (1979, 1980, 1981, 1982, 1983), van der Ham (1984, 1985b, 1988a, 1995), and van der Ham & van Birgelen (1992), but the majority of illustrations is new.

In a few cases, photomicrographs were prepared by Mrs S.M. Kars at the Vrije Universiteit (Amsterdam) using a JEOL JSM-6400 scanning electron microscope. Specimens illustrated are generally the best preserved and/or most typical in the numerous samples studied, on which the descriptions are based.

Previous work

Echinoids from the study area were first recorded in the literature during the first half of the eighteenth century. Klein (1734) illustrated a specimen of *Hemipneustes striatoradiatus* found near Bemelen (southern Limburg) in 1715.

Leske (1778), as first revising author, formally named Klein's echinoid taxa, and presented the first scientific descriptions of well-known species from the Maastrichtian type area, such as (in original nomenclature) *Echinites pyriformis*, *Spatangus striatoradiatus*, and *Echinites lapis cancri*.

Although the engravings leave much to be desired, plates 29 and 30 in Faujas Saint Fond's (1799) monumental work on the St Pietersberg do allow a number of echinoids typical of the type Maastrichtian to be recognised, e.g. a small, globular hemiasterid, *Salenia maestrichtensis*, *Oolopygus pyriformis*, *Faujasia apicalis*, and *Procassidulus lapiscancri*. The galeritid echinoid in plate 30 cannot possibly have come from the St Pietersberg proper, since such forms are found only in the lower Gulpen Formation (see below). The small hemiasterid was later named *Spatangus prunella* by Lamarck (1816).

Goldfuss (1829) contributed substantially to contemporary knowledge of the echinoid faunas from the Maastrichtian type area, and introduced as new species (in original nomenclature): *Cidaris regalis*, *Cidarites granulosus*, *Galerites sulcato-radiatus*, *Nucleolites scrobiculatus*, *Ananchytes conoideus*, *Spatangus granulosus*, and *S. bucardium*.

Müller's (1847-1859) papers on Cretaceous faunas from the environs of Aachen have never been widely cited. He erected four new echinoid species (*Salenia anthophora*, *Catopygus goldfussii*, *Goniophorus pentagonalis*, and *Spatangus hieroglyphicus*), of which only the first named has survived to this day. The others have been shown to constitute junior synonyms of other species: Müller's *C. goldfussii* is *Faujasia apicalis* and *G. pentagonalis* is the internal flint mould of a small phymosomatid of the genus *Gauthieria* (see van der Ham, 1987), while *S. hieroglyphicus* represents a worn internal mould of *Cardiaster granulosus*.

With the publication of the first issues of the Paléontologie française (d'Orbigny,

1854-1860; Cotteau, 1861-1867) a fair number of species were added. The following taxa were (in part) based on material from the environs of Maastricht (in original nomenclature): *Goniopygus heberti*, *Hemiaster koninckí*, *H. breviusculus*, and *Cassidulus elongatus*. Species known from elsewhere, such as *Temnocidaris danica*, *Tylocidaris hardouini*, *Orthopsis miliaris*, *Oolopygus pyriformis*, *Procassidulus lapiscancri*, and *Rhynchopygus marmini*, were then also recorded from Maastricht.

From a number of localities in southern Limburg and contiguous German territory, Binkhorst van den Binkhorst (1859a) recorded the following echinoids (in original spelling):

from the 'Coupe de Heunsberg près de Fauquemont' (pp. 29-30 = Valkenburg aan de Geul): *Hemiaster prunella*, d'Orb, en grand nombre, *Cassidulus lapis cancri*, Lam., *Cassidulus marmini* très rare, Desm., *Cidaris regalis*, Goldf., and *Cidaris Faujasii*, Desor,

from the 'Craie de Schaasberg' (p. 54): radioles de *Cidaris Faujasii*, Des.,

from the 'Marne de Kunraad' (pp. 55, 59): *Hemipneustes radiatus*, Ag., *Holaster granulosus*, Ag., *Micraster coranguinum* id., *Cidaris lingualis*, Desor, and *Cidaris Faujasii*, id.,

from the 'Marnes de Simpelveld et Vetschau' (pp. 65, 69): *Micraster cor-anguinum*, Ag., and *Cidaris Faujasii*, Desor, *Discoidea subuculus*, Leske, and *Hemipneustes radiatus*, Ag.

Of note are the records of *Micraster*, which undoubtedly are based on (a) representative(s) of the superficially similar genus *Diplodetus*, and of *Discoidea*, which could well refer to the only holectypoid known from Maastricht, *Coenholectypus macrostomus* (Engel, 1964b).

Binkhorst's list (pp. 120-121) of species which he held to characterise the 'Maastricht tuffaceous chalk' proper, includes the following echinoids (in original nomenclature): *Cidaris regalis*, Goldf., *Cidaris Hardouini*, Des., *Cidaris lingualis*, id., *Pseudodiadema Kleinii*, id., *Diadema* sp., *Goniopygus Menardi*, Ag., *Hyposalenia heliophora*, Des., *Salenia minima*, id., *Hemiaster prunella*, id., *Hemiaster pygmæa*, v. Hag., *Echinocyamus placenta*, Ag., *Fibularia subglobosa*, Des., *Caratomus Gehrdensis*, Roem., *Nucleolites scrobiculatus*, Goldf., *Nucleolites analis*, Ag., *Rhynchopygus Marmini*, d'Orb., *Cassidulus lapiscancri*, Lam., *Cassidulus elongatus*, d'Orb., *Faujasia apicalis*, id., *Faujasia Faujasii*, id., *Hemiaster Koninckianus*, d'Orb., *Hemiaster breviusculus*, id., *Conoclypus Leskei*, id., and *Hemipneustes radiatus*, Ag.

A similar list is found in Binkhorst van den Binkhorst (1859b), but this time for the 'Kreide des Schaesberges' (see above) it comprises four echinoids (*Hemipneustes radiatus*, Ag., *Hemiaster granulosus*, Desor, *Catopygus pyriformis*, Ag. and *Hemiaster coranguinum*, id.); the cidarid is missing.

Other local workers, and Bosquet (in Staring, 1860) in particular, listed (in original nomenclature):

Echinocorys vulgaris Breyn.	g 21-23	
et Var. *ovata*	g 23	
gibba	g 21-23	
hemisphaerica	g 21	
subconica	g 21 ?	
E. papillosus d'Orb.	g	
E. sulcatus d'Orb.	g	
Hemipneustes striato-radiatus		
Leske sp.	m 10-18	g 20
Spatangus? *hieroglyphicus* Müll.	m ?	

Cardiaster Ananchytis Leske sp.	m 18′	g 20-24	h 25-28
C. bicarinatus Ag. sp.	g		
Micraster cor-anguinum Leske sp.	m 18′	g 20-23	
M. Leskei Desm. sp.	g		
Hemiaster prunella Lamk. sp.	m 2-17	g ?	
H. breviusculus d'Orb.	g 20		
H. Koninckianus d'Orb.	g 20		
Isaster amygdala Goldf. sp.	m ?		
Periaster bucardium Goldf. sp.	m ?		
P. lacunosus Goldf. sp.	m ?		
Faujasia apicalis Desor sp.	m 2-10		
F. Faujasi d'Orb.	m 10		
Pygaster depressus Agass.	g ?		
Rhynchopygus Marmini Desm. sp.	m 2-10		
Cassidulus lapis-cancri Leske sp.	m 2-10		
C. elongatus d'Orb.	m 10		
Conoclypus ovatus Leske sp.	m ?		
Caratomus sulcato-radiatus Goldf. sp.	g 23-24		
C. hemisphaericus Desor	g ?		
C. Gehrdensis Roem.	m ?		
Fibularia subglobosa Goldf. sp.	m ?		
Echinocyamus placenta Goldf. sp.	m 10		
Trematopygus analis Ag. sp.	m ?		
T. ovulum Goldf. sp.	m ?		
Echinobrissus scrobiculatus Goldf.	m 9, 10	g 20	
Catopygus laevis Ag.	m 17	g 20-24	
Catopygus fenestratus Ag.	m ?	g 20	
Catopygus conformis Desor	g 20		
Catopygus elongatus	m 14-17		
Pyrina nucleus d'Orb.	g ?		
Echinoconus conicus Breyn sp.	g ?		
E. globulus d'Orb.	m ?		
Tetragramma variolare Ag.	g 23		
Pseudodiadema Kleini Desor	m 10-11		
Salenia anthophora Müll.	m 15-17	g 20-23	h 28
S. minima Desor	m 4-8		
S. Bourgeoisii Cotteau	m 8		
Goniophorus? *pentagonalis* Müll.	m ?		
Hyposalenia heliophora Desor	m 4-8 ?		
Goniopygs Menardi? Ag.	? m		
Glypticus Koninckı Desor	m ?		
Cyphosoma spathuliferum Forb.	m ?		
Cidaris Hardouini Desor	m 2		
C. Faujasi Desor	m 2-12 g 23 ?		
C. Forchhammeri Desor	m 4		
C. regalis Goldf.	m 2-12		
C. lingualis Desor	m 4-12		
C. subvesiculosa d'Orb.	g 23		
C. pistillum Quenst.	m 8		

Although listings such as the above have but limited value, they do demonstrate 'taxonomy at work' and reveal those authors' doubts about the stratigraphic prove-

nance of some of their material. It should be borne in mind that in Bosquet's days, the Palaeocene Geulhem Member (Houthem Formation) was still included in the Upper Cretaceous 'Maastrichtian tuffaceous chalk'.

Bosquet (in Dewalque, 1868) published a slightly updated list, to which is added (in original nomenclature): *Oolopygus piriformis* d'Orb. In Ubaghs (1879, pp. 227-228) a comparable list is found, with additions based on personal field work by that author.

From the 'partie supérieure du tuffeau de Maastricht' (= 'les couches à Bryozoaires'), C. Ubaghs (1879, p. 65) recorded *Hemipneustes striato-radiatus* Leske sp., *Hemiaster prunella* Desor, *Faujasia apicalis* Desor sp., *Rhynchopygus Marmini* Desm. sp., *Cassidulus lapis cancri* Leske sp., *Echinobriscus* [sic] *scrobiculatus* Goldf. sp., *Salenia minima* Desor, *Salenia Bourgoisi* [sic] Cotteau, *Cidaris Hardouini* Desor, *Cidaris Faujasi* Desor, and *Cidaris regalis* Goldf.;

for the 'Calcaire de Kunraad', he (p. 117) noted *Hemipneustes striato-radiatus* Leske sp., *Micraster coranguinum* Agassiz, *Cardiaster Ananchytes* d'Orb., *Cardiaster minor* Cotteau, *Cidaris lingualis* Desor, *Cidaris Faujasi* Desor, *Cidaris pistillum* Quenst., and *Phymosoma meandrinum* nov. sp. Schluter [Footnote: Ce bel et unique échantillon qui fait partie de notre collection et que nous avons trouvé dans la 3me division du Maastrichtien, le Calcaire de Kunraad, sera décrit par M. le prof. Schluter de Bonn, qui l'a nommé *Phymosoma meandrinum*],

for the 'craie blanche à silex noir' he listed (p. 127): *Catopygus piriformis* Ag., *Catopygus lævis* Ag. and *Cardiaster Ananchytis* d'Orb.;

and, for the 'craie blanche d'Heure-le-Romain' (p. 129): *Ananchytis ovata (Echinocorys vulgaris)* Lamk., *Micraster cor-anguinum* Agassiz, *Cyphosoma perfectum* Agassiz, *Cidaris subvesiculosus* d'Orb., and *Cidaris lingualis* Desor.

In a catalogue of his collection, C. Ubaghs (1885, p. 27) listed the following species, noting that he had 'nombreux et beaux échantillons, parmi beaucoup d'espèces, rare et unique': *Salenia authophora* [sic], Muller, *Salenia geometrica*, Ag., *Hemipidina meliaris* [sic], Cotteau, *Faujasia apicalis*, Orb., *Faujasia Delanoyi*? Orb., *Rhynchopygus Marmini*, Desmoul. sp., *Phymosoma meandrinum*, Schlüter, échant. typ., *Hemipneuster* [sic] nov. sp., etc. Most intriguing here is the last-named form, which might well refer to *Hemipneustes oculatus*, a species to be described later by Cotteau (1890) from the Lower Maastrichtian of southern Belgium (Mons Basin).

In a catalogue of Beissel's collection, C. Ubaghs (1888, p. 3) enumerated the following:

Phymechinus (Desor) nov. spec. unicum, *Coptosoma granulosum*, *Cidaris* idem, Goldf. Kreidemergel Gulpen, *Coptosoma Spatuliferum* Kreidemergel Slenaken, *Cidaris subvesiculosa*, *Cardiaster Ananchytis*, 5 Tafeln mit den verschiedenen Varietäten, *Echinocorys vulgaris*, var. *ovata*, var. *striata*, var. *conoidea*, *Catopygus pireformis* [sic], *Catopygus fenestratus*, *Carotomus* [sic] *sulcato-radiatus*, *Carotomus* species, *Salenia antophora* [sic] (in prachtvoller Erhaltung). Of particular note in this list is *Phymechinus*, which may refer to *Phymotaxis tournoueri* (see below). Amongst fossils from the 'Gyrolithen-Kreide' (= Lower Campanian, Vaals Formation) he mentioned *Cardiastes* [sic] *Ananchytis* and *Hemiaster prunella*, and from the 'Grünsand von Vaals', *Cardiaster Anachytis* and *Micraster* sp. The hemiasterid referred to is no doubt closely related to or conspecific with *Hemiaster* gr. *aquisgranensis* as here interpreted, and the micrasterid is likely to be a species of *Diplodetus*.

Schlüter (1883) described *Phymosoma maeandrinum* Schlüter, based on a single test from the Kunrade Limestone facies (Maastricht Formation) in C. Ubaghs's collection. In a sequel to the 1883 paper, Schlüter (1892) discussed (pp. 136-142 [208-214]) *Pleurocidaris regalis* Goldfuss sp. at length, noting that, 'Eigenthümlich ist das Verhalten der Zickzacknaht in der Mitte der Felder; ob dieselbe, nicht bedeckt von Granulen, nackt war, wie bei der recenten *Goniocidaris* Desor, und der jurassischen *Polycidaris* Quenstedt lässt sich bei der gegenwärtigen Erhaltungsart nicht feststellen.' He also remarked (p. 138) that, 'Das Gehäuse von *Pleurocidaris regalis* bietet so ausgeprägte Eigenthümlichkeiten dar, dass es unter den Cidariden der Kreide eine Sonderstellung einnimmt, ...'. While referring to stout primary spines of cidarids from the Maastrichtian type strata, Schlüter (1892, p. 139 [211]) entered the discussion on the proper assignment of the type of spine Desor (1855, p. 33, pl. 5, fig. 13) had named *Cidaris Faujasi* (see Faujas Saint Fond, 1799, pl. 30, figs. 13-14). In Schlüter's view this type of spine could only have belonged to either of two 'sich scharf characterisirender Arten' from Maastricht. The first of these has interambulacral plates of which height almost equals width, with large and deeply excavated areoles, occupying almost the entire plate. Of this form, he noted that generally only dissociated plates were found. He did, however, refer a near-complete test (his pl. 21, figs. 7-8) from the 'Maestricht-Schichten' in the collections of the Museum für Naturkunde (Berlin, Binkhorst Colln ?) to this species, naming it *Cidaris* cf. *mamillata* Cotteau, 1863 (p. 330, pl. 179, figs. 11-14). The second form is characterised by having very large plates with wide miliary zones. The width of two articulated interambulacral plates in the Berlin collections measured 25 and 30 mm, which would lead to an overall test diameter of more than 100 mm. He coined the name *Cidaris gigas* (p. 142 [214], pl. 21, fig. 6) for this material; similar interambulacral plates are here illustrated in Pl. 2, figs. 14-15. Schlüter (p. 142 [214]) noted that, according to Goldfuss (1829), *P. regalis* came from the 'obere Kreide von Maestricht.' In August 1994, I re-examined material contained in the Goldfuss type collection at the Rheinische Friedrich-Wilhelms Universität (Bonn) and found the original (RFWUIP, Goldfuss no. 303) of his pl. 39, fig. 2 (1829) to be embedded in a type of matrix not found in the Maastricht area. For that reason, I strongly doubt that this specimen came from Maastricht.

Schlüter (1892) considered *Salenia bonnissenti* [sic] Cotteau to be a junior synonym of *S. anthophora* J. Müller. For saleniid tests from Maastricht, which Cotteau (1861) had previously referred to *S. bourgeoisi*, he coined the name *Salenia maestrichtensis*, although he noted (p. 198) that, 'Es wird noch das nähere Verhältniss der Rügener und Maestrichter Gehäuse zu ermitteln und festzustellen sein, ob letzterem ebenfalls die Bezeichnung *Salenia pygmaea* zukomme'. Cotteau (1875, p. 643) later revised his opinion, and noted that the small Maastricht material could be conspecific with *S. bonissenti*.

A few years later, Schlüter (1897a) erected *Hemiaster maestrichtensis* (p. 32, pl. 2, figs. 3-4) based on a specimen contained in the collections of Liège University, noting simply that it came from the Maastricht tuffaceous chalk.

Schlüter (1899) commented in detail on holasteroid and spatangoid taxa introduced by Goldfuss (1829), amongst which is (in original nomenclature) *Plesiaster bucardium* Goldf. sp. Schlüter was of the opinion that the type lot of that taxon actually contained two species, one of them new, for which he erected *Plesiaster*(?) *parvistella*

Schlüter. From the same locality (Aachener Wald) and also preserved as internal flint moulds, he also recorded as new *Hemiaster*(?) *aquisgranensis*.

Based on a single specimen from the environs of Maastricht, of unknown stratigraphic provenance, Lambert (1902) erected *Micraster maestrichtensis*, which may well be conspecific with *Diplodetus duponti* (Lambert, 1911). To determine this, the type of *M. maestrichtensis* needs to be redescribed; however, its present whereabouts is unknown.

In 1902, Schlüter described *Caratomus muelleri* Schlüter, now assigned to *Echinogalerus*, from the 'obere Kreide von Vetschau bei Aachen', co-occurring at that locality with *C. vetschauensis* Schlüter. These, and other species from the extended type area formerly referred to *Caratomus* or *Echinogalerus*, are currently being revised by Dr R. van der Ham (Delft, The Netherlands; see also van Birgelen & van der Ham, 1999).

Although describing material from the Mons Basin (southern Belgium), Lambert's 1898 paper is here also listed, since many of his taxa have subsequently been recorded from the Maastricht area as well. Lambert (pp. 148-149) commented on *Salenia bonissenti*, noting that it was a poorly known species, and resumed the discussion on its possible conspecificity with *S. anthophora*, concluding that, '... il n'est pas établi pour moi que le *S. Bonissenti* Cotteau soit identique au *S. anthophora* Muller, et l'espèce de Ciply, évidemment différente de ce dernier, peut toujours être rapportée au premier, ainsi que l'avait proposé Cotteau, qui devait mieux que personne connaître son *S. Bonissenti*.' It is this interpretation of *S. bonissenti* that is followed in the present paper (see below). Lambert (p. 150) also erected *Salenia belgica*, on the basis of material from the 'Poudingue de la Malogne', a conglomeratic deposit at the base of the 'Tuffeau de Ciply', containing remanié faunas from all underlying Cretaceous strata (see Robaszynski, 1995). This 'Poudingue' also yielded Lambert's (1898) *Gauthieria broecki*, an often misinterpreted form, and *Rachiosoma grossouvrei*. From the 'Craie phosphatée de Ciply' (= Lower Maastrichtian, *obtusa* Zone; see Robaszynski & Christensen, 1989), Lambert erected two new species on the basis of isolated primary spines, *Cyphosoma inops* and *C. rutoti*, noting for the latter that, 'd'après M. Peron, paraît venir de la craie phosphatée'. From that same unit, he described (p. 157) as new *Caratomus rutoti*, noting that it was distinct from co-occurring *C. peltiformis* var. *belgica*.

In a revision of species of *Echinocorys*, Lambert (1903) described as new *E. limburgicus*, *E. duponti*, and *E. humilis*, listing the various localities and levels in Liège-Limburg at which these forms occurred (see below).

All Late Cretaceous echinoids then known from Belgium were commented upon by Lambert (1911), who amongst 'Échinides du Sénonien du Limbourg' (p. 50) described as new: *Micraster duponti*, *Hemiaster rutoti*, *Cassidulus mortenseni*, *Echinoconus wollemanni*, *Echinogalerus belgicus* (see below), *Echinogalerus pusillus*, *Salenia rutoti*, and *Salenidia schluteri*. He also commented on *Catopygus suborbicularis*, a manuscript name given by Bosquet to a large form from the Kunrade Limestone facies. It should be noted that Lambert (1898) had already described a species of *Echinogalerus* from the 'Craie phosphatée de Ciply' under the name *Caratomus peltiformis* var. *belgica*. In his 1911 paper, he added considerably to the confusion, by introducing (p. 45, pl. 1, figs. 28-31) *Echinogalerus belgicus*, Lambert, n. sp., noting as synonym (!) his own *C. peltiformis* var. *belgica*. Further on (p. 64, pl. 1, figs. 32-35), he again listed *Echinogalerus belgicus*, Lambert, n. sp., this time referring to material from the 'craie marneuse' at Slenaken (southern Limburg, Vijlen Member inferred).

Lambert's (1911, p. 37) notes on 'Échinides de la Craie de Nouvelles' are also important, since these include species well known from the Zeven Wegen and Vijlen members (Gulpen Formation) in the Haccourt-Lixhe area. For instance, his record of *Plesiaster* cf. *bucardium* (pl. 1, fig. 15) is of note (see below, under *Diplodetus* sp.), as is his new species *Typocidaris arenata*.

Smiser (1935a-b) added a considerable number of new species. In his revision (Smiser, 1935a) of Late Cretaceous *Echinocorys* from Belgium, he followed Lambert's (1903) interpretation of the various 'species', and in addition, erected *E. belgicus* var. *pruvosti*, and *E. lamberti*. New species from the type Maastrichtian as well as from coeval and slightly younger strata penetrated in boreholes in the Belgian Campine area, described by Smiser (1935b) include (in original nomenclature): *Codiopsis pierrensis* (= *C. disculus* herein), *Pseudopyrina minuta*, *Pygorhyncus ovalis*, *Phyllobrissus oblongus*, *Catopygus subcircularis*, *C. irregularis*, *Oolopygus jandrainensis*, *O. convexus*, *Rhynchopygus macari*, *Faujasia*? *transversa*, *Spatagoides striatoradiatus* var. *elevatus*, var. *conicus*, and var. *depressus*, *Isopneustes eysdenensis*, and *I. montensis*.

Engel (1945) discussed intraspecific variation of *Hemipneustes striatoradiatus*, concluding that it was an extremely variable species.

On the basis of newly collected material, Meijer (1955) provided a detailed description of *Hemiaster maestrichtensis*, and noted its stratigraphic provenance for the first time. In a number of short contributions, Meijer (1956, 1965a) and Engel & Meijer (1957) subsequently revised *Nucleopygus scrobiculatus* and *Echinogalerus transversus* (Smiser), and recorded the occurrence of two species of *Plagiochasma* in the Maastricht area, one of Palaeocene age (*P. analis* = *P. cruciferum*, herein) and the other, apparently new, of Late Maastrichtian age (= *P. lammersmaxi* herein). Meijer's (1965b, fig. 1) paper was based on extensive fieldwork in the Maastrichtian type area; it provided the first overview of the stratigraphic ranges of the various echinoid species, recognising three sequences. Notable additions include:

from unit Cr4 (= Lanaye Member in current terminology): *Micraster* sp. (= *Diplodetus* herein);

from the base of the Nekum Member (Mc): *Linthia* sp.;

from the lower Meerssen Member (Md): ?*Porosoma* sp. (= *Phymotaxis tournoueri* herein) and *Goniopygus heberti* (= *G.* sp. nov. herein);

from the highest units Me, r and Pa (= Geulhem Member in current terminology): *Procassidulus chalmasi* Lambert, *P.* aff. *chalmasi*, *P.* sp. (all three probably referring to *P. elongatus*), *Pygopyrina houzeaui* (Cotteau) (= *Adelopneustes montainvillensis* herein), *Linthia* sp. (spp.?), *Cidaris forchhammeri* Desor, *Salenia* sp., and *Tylocidaris brünnichi* (Ravn).

From the 'Post-Maastrichtian' (= Geulhem Member in current terminology), Rasmussen (1965, pl. 8, figs. 5, 14; pl. 9, figs. 1-2) recorded *Tylocidaris hardouini*, *T. bruennichi*, and *Temnocidaris faujasi*. The last-named refers to indeterminate cidarid spines and an adapical interambulacral plate of what appears to be *Temnocidaris (T.) danica*.

One year earlier, Engel (1964a-b) had described a new genus and species of phymosomatoid, *Winkleria maastrichtensis*, and a holectypoid, *Holectypus (Caenholectypus?) macrostomus*, from the lower Meerssen Member. A second, new holectypoid, *H. boschmai*, described by Engel is definitely not from the Maastrichtian type area, and may have been mislabelled.

Kier (1962) revised cassiduloid echinoids, amongst which are a few species from the type Maastrichtian, viz. *Faujasia apicalis*, *Rhynchopygus marmini*, *R. lapiscancri*, and *Nucleopygus scrobiculatus*. For *Echinolampas faujasii* Desmoulins, 1837 (p. 346), Kier (p. 140, pl. 17, figs. 7-8) erected a new genus, *Eurypetalum*. What the relationship between this taxon and *F. apicalis* actually is, still needs to be determined.

W.M. Felder (1963, 1973) commented on the fact that he had never found juvenile specimens of *H. striatoradiatus*, and that there was a well-marked change in test size and lateral profile between the Mc and Md (= Nekum and Meerssen members in current terminology, respectively).

From occasional outcrops of Palaeocene strata at the Belvédère gravel pit (Maastricht-Caberg), Engel (1972) described *Phymosoma maastrichtensis*.

In a larger European framework, Ernst (1970a, 1972) discussed echinoid phylogeny, morphology and biostratigraphy, and illustrated material of *Galerites sulcatoradiatus* and *Echinocorys conica*, collected by Max Meijer.

Stokes (1979) briefly commented upon the various species of the genus *Diplodetus* and listed from the Maastrichtian type area *D. bucardium*, and *D. duponti*, but reassigned *Plesiaster parvistella* to *Hemiaster*. In the present paper, *P. parvistella* is considered to belong to *Diplodetus*.

In a revision of all Maastrichtian saleniid echinoids from the Maastricht area, Geys (1979) provided detailed descriptions of *Salenidia maestrichtensis*, *Salenidia* cf. *bonissenti*, *Salenidia schlueteri*, *Salenia anthophora*, *Salenia belgica*, and *Salenia sigillata* (= *Salenia rutoti*), and erected the new species, *Salenidia sanctipetri*, based on a single specimen from an unknown level at St Pietersberg. Of these, *S. sigillata* may actually be of Late (?latest) Campanian age (see below).

Later, Geys (1980) revised all Campanian-Maastrichtian phymosomatoids from Belgium and The Netherlands, inclusive of material from the Mons Basin. Recorded are *Phymosoma corneti*, *P. granulosum*, *P. princeps*, *P.*? *maastrichtensis*, *Gauthieria radiata broecki*, *G. pseudoradiata*, *G.*? *spatulifera*, *Porosoma*? *maeandrinum*, *Winkleria maastrichtensis*, as well as the new species, *Gauthieria*? *mosae* from the Zeven Wegen Member (Upper Campanian) at Heure-le-Romain.

Geys (1981) described the arbaciids from the Maastrichtian type area and adjacent Belgian Campine (Zwartberg colliery boreholes), recording *Codiopsis bruni* (= *C. pierrensis*), *Goniopygus minor* and *G. eravillensis*, for both of which sexual dimorphism is documented. Geys considered the two last-named species to be distinct and of Maastrichtian age. In fact, I consider them conspecific and of Early Palaeocene age. There is a Late Maastrichtian species of *Goniopygus*, occurring in the Meerssen Member and differing from both *G. minor* and *G. heberti*, which are both well known from the overlying Geulhem Member (see below).

In his 1982 paper, Geys rightly concluded that the saleniids *Salenia minima* and *Hyposalenia heliophora* were good index fossils for the Early Palaeocene Geulhem Member in the Maastricht area. However, what he illustrated as *S. minima* (pl. 29, figs. 1-4; compare Pl. 4, figs. 5-6 herein) is in fact *S. belgica*.

Van der Ham (1982) recorded *Hemipneustes oculatus*, a species originally described from the Lower Maastrichtian of the Mons Basin (southern Belgium; Cotteau, 1890), for the first time from southern Limburg (Vijlenerbosch, Cottessen).

From the Vijlen or Lixhe 1 member at Lixhe (near the CBR-Lixhe quarry), Geys

(1983) recorded the new species, *Rachiosoma gigasei*. A re-examination of the matrix in the peristomial area of this specimen suggests it could have come from the Zeven Wegen Member, and is thus of Late Campanian age.

In 1984, van der Ham recorded copious material of *H. koninckanus*, and discussed the differences between this species and the closely related *H. prunella*. A year later, he (1985a-b) commented on the echinoid faunas from residual flint deposits in the Haccourt-Lixhe area, and described *Hemiaster aquisgranensis* from various types of lithology, noting that *H. rutoti* Lambert, 1911 was a junior synonym, and demonstrating the wide range of variation for this material.

Schulz (1985) reassigned Lambert's (1911) *Echinoconus wollemanni* from the Kunrade Limestone facies to *Galerites stadensis* (Lambert, 1911), and noted that a number of species previously assigned either to *Galerites* or *Echinogalerus*, could in fact not be assigned to either, and could represent an undescribed genus. Two of these forms, *Echinogalerus*(?) *hemisphaericus* (Desor, 1842) and *E.*(?) *sulcatoradiatus* (Goldfuss, 1829) occur in the study area, the former in the lower Zeven Wegen Member, the latter apparently confined to the basal part of the Vijlen Member.

From the upper Zeven Wegen Member at Haccourt (CPL SA quarry), Michels & Jagt (1985) recorded *Micraster stolleyi*, thus enabling an echinoid-based correlation with the NW German *stobaei/basiplana* (= *vulgaris/stolleyi*) Zone for the first time.

Jagt (1985), in a short note on *Hemipneustes striatoradiatus*, noted that in well-preserved material of this species a partial anal fasciole could be seen, and recorded *H. oculatus* from the Nekum Member, the highest occurrence of that taxon known to date (see below).

From the Zeven Wegen Member (Late Campanian) as exposed in the Haccourt-Lixhe area, Geys & Jagt (1986) described three species not recorded previously from the area, viz. *Salenidia heberti*, *Salenia obnupta* and *Rachiosoma corollare*. For the last-named species, they adopted Cotteau's (1865, p. 669, pl. 1165) interpretation of Leske's (1778) *Cidarites corollaris*, considered this taxon to be conspecific with Goldfuss's (1829) *Cidarites granulosus*, since both were stated to have a uniserial adapical pore arrangement, and designated a neotype for *R. corollare* sensu Cotteau, 1865. This matter is discussed in greater detail below (under *Phymosoma granulosum*).

From the Zeven Wegen and Lanaye members (Gulpen Formation), Geys (1987) recorded *Typocidaris pistillum*, from the Maastricht Formation *T. sceptrifera*, from the Maastricht and Houthem formations *T. serrata*, and from the Zeven Wegen Member at Heure-le-Romain the new species, *T. ubaghsi*. Of note is his observation (p. 209) that *Typocidaris forchhammeri* is 'most probably .... confined to Danian and Montian deposits'.

Jagt & Bongaerts (1986a-b) recorded representatives of the genus *Echinocorys* from the so-called smectite facies of the Vaals Formation at the CPL SA quarry (Haccourt), and commented on various echinoid species from the overlying Zeven Wegen Member. The echinocorids were compared to material from the (Lower) Campanian of Münsterland (Germany), from where Lambert (1903) recorded the var. *porosa* Lambert, and referred to these as *E. humilis* sensu germanico (non Lambert, 1903).

The mode of life of the holasteroids *Cardiaster granulosus* and *Cardiotaxis heberti* from the Gulpen Formation was discussed by Jagt & Michels (1986). A year later, *Cyclaster platornatus* Kutscher, 1978, originally described from the Lower Maastricht-

ian of Rügen (NE Germany) was recorded from the Vijlen Member for the first time, and the species was shown to be sexually dimorphic (Jagt & Michels, 1987, 1990).

Van der Ham et al. (1987) illustrated all taxa known at that time, including the highly diverse Palaeocene faunas from the temporary Albertkanaal sections between Vroenhoven and Veldwezelt (Limburg, Belgium). A year later, van der Ham (1988a) provided the first detailed documentation of these Palaeocene faunas, which were shown to comprise numerous species not recorded previously from the area, many of which were recorded in open nomenclature.

From the Maastricht Formation at various localities in the Maastricht area, Geys (1990) described *Temnocidaris baylei*, referring the only known complete cidarid test from that formation known to date to that species, as well as *T. danica*, restricting that species to Palaeocene strata.

Dortangs (1990) discussed peristomial and periproctal plating in *Hemipneustes striatoradiatus* and *Hemiaster prunella* in some detail.

Van der Ham & van Birgelen (1992) described and illustrated all echinoids then known from the classical Schneeberg area (Dutch-German border area), and designated a neotype for *Salenia anthophora*.

On the basis of recently collected material from the Vijlen Member at the CPL SA and CBR-Lixhe quarries, Jagt & Michels (1994) presented a preliminary reconstruction of the mode of life of all echinoid taxa known to date from that unit.

Of the diverse Palaeocene faunas from the temporary Albertkanaal sections, Jagt & van der Ham (1994) selected the two species of which females showed brood pouches, and offered an explanation for the occurrence of such pouches.

Defour et al. (1994) commented on the range of variation of *H. striatoradiatus*, and illustrated peristomial and periproctal plating of that species and of *Hemiaster prunella*.

Van der Ham (1995) recorded a new species, *Hemiaster (Leymeriaster) eluvialis*, from the upper Gulpen and Maastricht formations, and commented on a co-occurring species (*H. (L.) maestrichtensis*).

From the basal Meerssen Member at the ENCI-Maastricht BV quarry, Jagt & van der Ham (1995) described the first Late Maastrichtian representative of the psychocidarid *Tylocidaris* in the area, *T. inexspectata*.

Jagt et al. (1995) commented briefly on the echinoid fauna of the *sumensis* Zone (Lower Maastrichtian, Vijlen Member) of Altembroeck, listing among other species, *Galerites stadensis*, an indeterminate saleniid and a paedomorphic hemiasterid close to *H. prunella*.

For outcrops of the Vijlen Member in the Aachen area, Keutgen (1996) listed a number of echinoid taxa, the most interesting of which is *Temnocidaris (Stereocidaris)* cf. *herthae*.

Indeherberge et al. (1998) summarised current results of a detailed study of representatives of the genus *Diplodetus*, using mostly flint-preserved material, and showing *D. bucardium*, *D. duponti*, and *D. parvistella* to be well-defined species.

Van der Ham & Jagt (1998) reviewed hemiasterids, and noted the occurrence of a new species of *Leymeriaster* from the Vaals Formation.

From the Nekum Member at the CBR-Romontbos quarry, Jagt et al. (1999) recorded a representative of the group of *Salenia nutrix*, which is well known from the

Upper Campanian-Maastrichtian of the Arab peninsula, North Africa, southern Spain, and Cuba.

All Maastrichtian and Palaeocene echinoid taxa, known to date worldwide, are reviewed by Smith & Jeffery (in press), who attempt to stabilise nomenclature and document echinoid diversity across the Cretaceous/Tertiary boundary. In that work, three new species of the (sub)genera *Salenia (Pleurosalenia)*, *Diplotagma*, and *Thylechinus* from the Maastrichtian type area are formally named.

Systematic palaeontology

Abbreviations — The following abbreviations are used to indicate the repository of specimens illustrated and/or referred to in the text:

BMNH	Natural History Museum, London (formerly British Museum of Natural History);
GPIG	Geologisch-paläontologisches Institut Greifswald;
GSM	Geological Survey Museum, London;
IRScNB	Institut royal des Sciences naturelles de Belgique, Brussels;
MGUH	Geological Museum of Copenhagen University;
MNB	Museum für Naturkunde der Humboldt Universität, Berlin;
NHMM	Natuurhistorisch Museum Maastricht, with individual collections bearing the following prefixes: MB - M.J. van Birgelen Colln BL - L. Blezer Colln HB - H.L. Bongaerts Colln AC - A. Claessens Colln MD - M.J.M. Deckers Colln RD - R.W. Dortangs Colln DE - D. Eysermans Colln RF - R. Frijns Colln RH - R.W.J.M. van der Ham Colln JJ - J.W.M. Jagt Colln PK - P.H.M. van Knippenberg Colln K - M.M.M. Kuypers Colln TL - T. Lammers Colln MA - F. Maatman Colln MM - M. Meijer Colln GM - G. Michels Colln VN - H. van Noordenburg Colln HS - H. Sipman Colln JS - J. Snellings Colln;
RFWUIP	Rheinische Friedrich-Wilhelms-Universität, Institut für Paläontologie, Bonn;
RGM	Nationaal Natuurhistorisch Museum, Leiden (formerly Rijksmuseum van Geologie en Mineralogie);
SGPIH	Geologisch-paläontologisches Institut der Universität Hamburg;
SGWG	Sektion geologische Wissenschaften, Ernst-Moritz-Arndt Universität,

Greifswald;
TM Teylers Museum, Haarlem;
USNM United States National Museum, Washington DC.

Terminology — This follows Fell (1966a-b), Fischer (1966), Melville & Durham (1966), Smith (1984), and Wagner & Durham (1966).

Class Echinoidea Leske, 1778
Subclass Cidaroidea Claus, 1880
Order Cidaroida Claus, 1880
Family Psychocidaridae Ikeda, 1936
Genus and subgenus *Tylocidaris* Pomel, 1883
[= *Psychocidaris* Ikeda, 1935]

Type species — *Cidaris clavigera* Mantell, 1822, under the plenary powers (ICZN Opinion 1459).

Tylocidaris (T.) gr. *bruennichi* Ravn, 1928
Pl. 1, figs. 1-15.

*1928 *Tylocidaris vexillifera* Schlüt. var. *Brünnichi* Ravn, p. 33, pl. 4, figs. 16-25.
1935b *Balanocidaris schlüteri* Lambert — Smiser, p. 20, pl. 1, fig. 8a-c.
?1959 *Tylocidaris ravni* Brotzen, p. 47, pl. 2, figs. 2-16; text-fig. 14c-d.
1959 *Tylocidaris brünnichi* Ravn, p. 49, pl. 1, figs. 31-38; text-figs. 15a-d, 16e.
?1970 *Tylocidaris* aff. *vexillifera* Schlüter — Rosenkrantz, p. 444, fig. 16/1-2.
1988a *Tylocidaris bruennichi* Ravn, 1928 — van der Ham, p. 136, pl. 2, figs. 1-6.
?1993 *Tylocidaris (Tylocidaris) ravni* Brotzen, 1959 — Gravesen, p. 53.
1996 *Tylocidaris* gr. *bruennichi* — Jagt, p. 154, fig. 1c.

Type — Unfortunately, Ravn (1928) did not select a type specimen (see Brotzen, 1959, p. 48); his 'type series' of *T. bruennichi* is contained in the MGUH collections.

Material — Numerous primary spines and test segments, as well as a single complete test (NHMM: JJ 1168, 4349, MM 1055, PK 759, and RH 285/1-6).

Description — The only complete test available (Pl. 1, figs. 8-10) measures 9 mm in diameter; 5-6 interambulacral plates in a column, with little, but distinct, extrascrobicular granulation, tubercles comparatively large, imperforate, and noncrenulate. Ambulacral plates have a single primary tubercle and one or two perradial secondaries. Primary spines up to c. 20 mm in length, some broadly clavate with short neck and dense, thorny ornament (Pl. 1, figs. 12-14), others more 'typical' (Pl. 1, figs. 1-7, 11) with longer neck, and more abrupt transition to head, distally pointed, and with crown-like extensions or more or less well-developed flanges.

Remarks — Smith & Jeffery (in press) synonymised *T. bruennichi* and *T. rosenkrantzi* Brotzen, 1959 (p. 45, pl. 2, figs. 17-36, text-fig. 15a-b) with *T. vexilifera* Schlüter, 1892 (p. 54 [126], pl. 17, figs. 3-4), noting that the fine ornament of dense irregular granulation, rather than ribbing, links that form to the late Late Maastrichtian *T. (Oedematocidaris) baltica* (Schlüter, 1892). However, material from the upper Geulhem Member as here described does show distinct ribbing, the more bulbous forms even

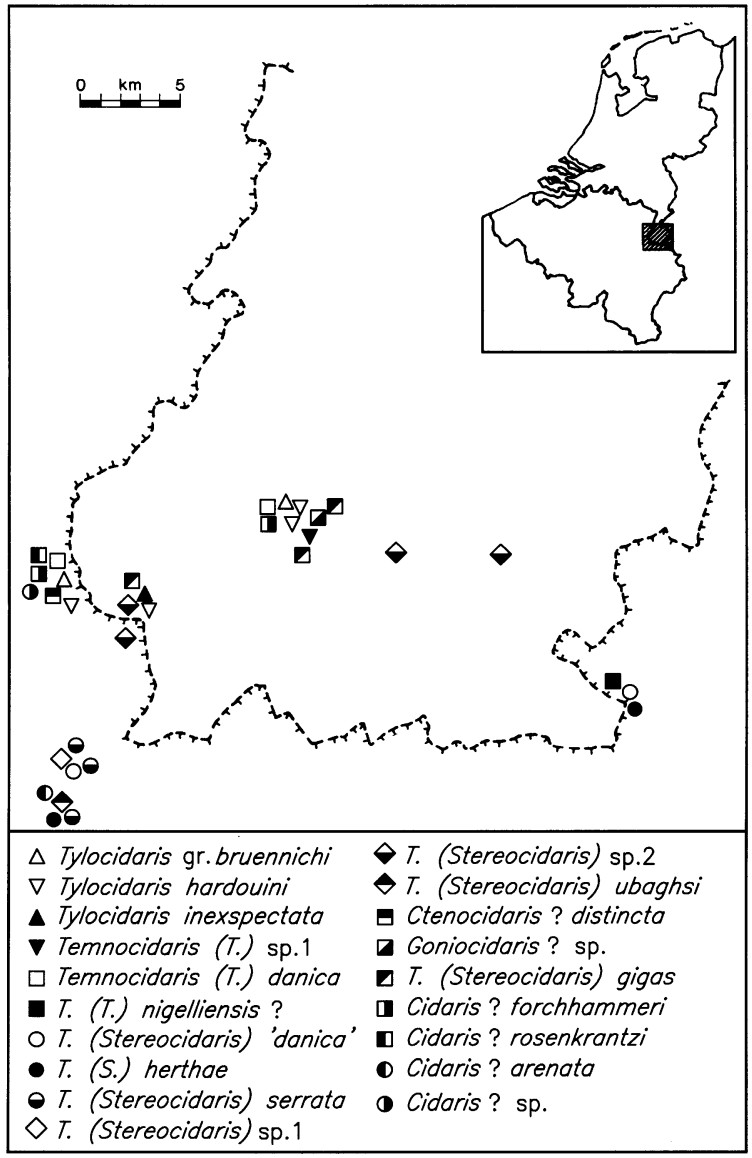


Fig. 1. Geographic distribution of Late Cretaceous-Early Palaeogene cidaroid echinoids in the type area of the Maastrichtian Stage.

showing a dense ornament of thorn-like granules. This is why the more 'traditional' interpretation is followed here.

Hucke & Voigt (1967, pl. 42, fig. 1) recorded two well-preserved tests with spines attached in an erratic boulder collected at Oldendorf (northern Germany), which on spine morphology they referred to *T. rosenkrantzi*. Unfortunately, this important find does not seem to have been described in detail subsequently.

Occurrence — Material here referred to *T. (T.)* gr. *bruennichi* is confined to the upper Geulhem Member, occurring first at the base of section Va-3 at the Ankerpoort-Curfs quarry (Geulhem), and in the upper part of this member in the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Figs. 1, 23).

Tylocidaris (T.) hardouini (Desor, 1855)
Pl. 1, figs. 16-31.

*1855 *Cidaris hardouini* Desor, p. 35, pl. 6, fig. 6.
?*1938 *Tylocidaris ødumi* Brünnich Nielsen, p. 126 (?partim).
?1970 *Tylocidaris* aff. *oedumi* Brünnich Nielsen — Rosenkrantz, p. 444, fig. 16/3-5.
1988a *Tylocidaris hardouini* (Desor, 1855) — van der Ham, p. 138, pl. 2, figs. 7-9.
?1993 *Tylocidaris (Tylocidaris) oedumi* Brünnich Nielsen, 1938 — Gravesen, p. 50 (?partim), pl. 1, figs. 17-19, 25-26; pl. 2, figs. 4-6 (?partim).
1996 *Tylocidaris hardouini* — Jagt, p. 154, fig. 1f.

Type — Desor (1855) failed to designate a type; the present whereabouts of this material is unknown. Lectotype of *T. oedumi*, designated by Gravesen (1993, p. 50), is the specimen illustrated by Ødum (1926, pl. 1, fig. 3b).

Material — Thousands of primary spines and several dozens of test segments, including IRScNB 9072-9076 (IG 4285); NHMM: JJ 4456-4457, K 1732, RH 436/1-2; and RGM 428 053.

Description — According to van der Ham (1988a), test segments (Pl. 1, figs. 22, 31) are virtually indistinguishable from those of the previous species, an observation confirmed by Smith & Jeffery (in press). Primary spines (Pl. 1, figs. 16-21, 23-30) are up to 20 mm in length, with the shaft differentiated into a distal, rounded head and a comparatively long neck. The transition into the neck varies from very gradual to more abrupt (e.g. Pl. 1, figs. 16-17 and 20), or neck and head are not clearly separated (e.g. Pl. 1, figs. 24-25, 29). Ornament consists of thorn-like granules, arranged in stout ribs, with narrow interspaces.

Discussion — Previous authors (Desor, 1855; Cotteau, 1861-1867; Schlüter, 1892) recorded this form from the 'Sénonien supérieur' of Ciply and Maastricht. At that time, Lower Palaeocene strata (Houthem Formation, Geulhem Member) were still included in the type Maastrichtian. *Cidaris hardouini* is in fact the first Early Palaeocene species of *Tylocidaris* to be described, long before strata of that age were subdivided in the type area of the Danian Stage (Stevns Klint, and Fakse). The stratigraphically oldest species of *Tylocidaris* from the type Danian is *T. (T.) oedumi*. Gravesen (1993, pl. 1, figs. 17-19, 25-26; pl. 2, figs. 4-6) illustrated material from the Korsnæb section, north of Rødvig (Stevns Klint), of what he termed the oldest *oedumi* populations, occurring in the basal Bryozoan Limestone of Early Danian age. Comparable spines from the lowermost Bryozoan Limestone, collected south of Højerup (Stevns Klint) are illustrated here in Pl. 1, fig. 32. These spines are virtually indistinguishable from those of *T. hardouini*. Of note in this respect also is Cotteau's (1875, p. 642) record of *T. hardouini* from 'Hoerup' (= Højerup). Material of what Gravesen (1993, pl. 1, figs. 20-24, 27-30) referred to as the 'second *oedumi* population' in the Korsnæb section is of larger size and generally bears a denser ornament of smaller, thorn-like granules, aligned in rows extending on to the neck.

Gravesen (1993) presented the most detailed picture of the stratigraphical distribution of the earliest Palaeocene species of *Tylocidaris* at Stevns Klint to date. He documented the occurrence of so-called 'overlap forms' between *T. oedumi* and the next species in the lineage, *T. abildgaardi* Ravn, 1928 (p. 33, pl. 4, figs. 26, 28, 30, ?31, 32-35, non 27, 29). The first, 'typical' representatives of that species (see e.g. Gravesen, 1993, p. 51, pl. 3, figs. 1-13; pl. 4, figs. 1-4) occur between 2.5 and 3.5 m above the K/T boundary. Such forms do not occur in the Lower Palaeocene of the Maastricht area, which could mean that the change in lithology within the Geulhem Member in fact represents a hiatus comprising strata of *abildgaardi* and *rosenkrantzi* zone (i.e. late Early and early Late Danian) age.

Smith & Jeffery (in press) synonymised *T. abildgaardi*, *T. oedumi*, *T. pomifer* (Boll) var. *masoviensis* Kongiel, 1958 (p. 5, pl. 1, figs. 4-15, partim), and *T. windi* Brotzen, 1959 (p. 47, pl. 1, figs. 20-23; text-fig. 16a-b) with *T. hardouini*, noting that these undoubtedly represented stages in a continuous lineage, and that clear-cut differential features were difficult to find.

Although both forms cannot be distinguished on test features, the fact that *T. hardouini* is confined to the lower Geulhem Member (sections Va1 and Va2), and *T.* gr. *bruennichi* to the upper part of that unit (sections Va3, Va4 and ?higher), is reason enough to consider them distinct, at least for local correlations.

Two other forms recorded in the literature, *T. herupensis* Wind, 1954 (p. 84, pl. 13, figs. 55-58) and *T.*(?) *hilmari* Brotzen, 1959 (p. 49 = *T. vexilifera* forma ß of Ødum, 1926) appear to be best included in *T. vexilifera*. Representatives of that species or species group do not occur in the Maastrichtian type area, suggesting that the uppermost part of the Geulhem Member not be younger than late Middle Danian.

Occurrence — Known only from the lower Geulhem Member, as exposed at the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and at the Ankerpoort-Curfs quarry. The occurrence of abraded specimens in the uppermost Meerssen Member (IVf-5/ to IVf-7) at the ENCI-Maastricht BV and Blom quarries, attests to the former presence of Lower Palaeocene strata at those localities (Figs. 1, 20, 22-23).

Tylocidaris (T.) inexspectata Jagt & van der Ham, 1995
Pl. 1, figs. 33-35.

*1995 *Tylocidaris (Tylocidaris) inexspectata* Jagt & van der Ham, p. 234, fig. 2.
in press *Tylocidaris (Tylocidaris) inexspectata* Jagt & van der Ham, 1995 — Smith & Jeffery, fig. 3h.

Type — Holotype is NHMM 1993149 (Jagt & van der Ham, fig. 2/1a-c).

Material — TM 16006, and NHMM DE 050.

Description — See Jagt & van der Ham (1995).

Discussion — So far, only three species of *Tylocidaris* have been described from the Maastrichtian, viz. *T. (Sardocidaris) ramondi* (Leymerie, 1851) (Lower and Upper Maastrichtian, northern Spain; Palaeocene, France and Kopet Dag), *T. (Oedematocidaris) baltica* (Schlüter, 1892) (Upper Maastrichtian, Denmark and northern Germany), and *T. (T.) hemmoorensis* Salah & Schmid, 1982 (p. 187, pl. 7, figs. 1-4) from the lower Upper Maastrichtian of northern Germany. Morphologically, *T. inexspectata* is easily distinguished from spines of these three species, but in the absence of test material of the present taxon, it cannot be determined where its relationships lie. As Smith & Jef-

fery (in press) note, it does, however, appear to be the Maastrichtian sister taxon of *T. hardouini*, which in those authors' view includes *T. oedumi*.

Exactly which Late Cretaceous forms may be linked to Early Palaeocene species also remains to be determined. There appear to be two lineages, one characterised by stout, glandiform aboral spines which are never strongly ribbed (subgenus *Oedematocidaris* Smith & Wright, 1989, p. 33), the other by ribbed and clavate spines with well-developed cortical hairs (*Tylocidaris* proper). The ?Late Santonian-earliest Campanian *T. (T.) gosae* Schlüter, 1892 (p. 52 [124]) (see also Ernst, 1973, fig. 2b; 1975b, p. 372; Smith & Wright, 1989, p. 33, pl. 5, fig. 9) could well be have been in the same lineage as the present species. However, *T. gosae* is rather poorly known, having been described on the basis of primary spines, but never figured. The Schlüter type collection at Bonn (RFWUIP, Schlüter Coll, no. 240a-c) contains 21 specimens from Adenstedt-Groß Bülten and Sudmerberg/Goslar. These include squat forms with short necks as well as larger, gently tapering ones, with well-developed, beaded ribs.

Occurrence — Apparently confined to the Meerssen Member with records from the very base as well as sections IVf-4/-5 (? or higher) as exposed at the ENCI-Maastricht BV quarry (Figs. 1, 20). Smith & Jeffery (in press) recorded material (BMNH collections) referred to the present species from the Maastrichtian of Santander (Cantabria, Spain).

Family Cidaridae Gray, 1825

Remarks — In general, the identification of cidarid echinoids presents problems, not only in view of the fact that most fossils consist of isolated interambulacral plates, or at best, of test segments with ambulacral plates attached, but also because many names used in the literature for Late Cretaceous cidarids were in fact erected for dissociated primary spines. Smith & Wright (1989) and Smith & Jeffery (in press) are followed here, in using only species names (with very few exceptions) that relate the test material.

Important for a first grouping of Late Cretaceous-Early Palaeogene cidarids from the study area, are the width of the extrascrobicular zones and its tuberculation, the nature of pore pairs (conjugate or not), height/width ratio of ambital interambulacral plates, and absence/presence of sutural and extrascrobicular pits. Spines are not considered any further here; however, a few typical forms are illustrated in Pl. 2, figs. 10-12.

The material studied for the present paper comprises at least ten cidarid taxa, but it should be noted that a fairly wide range of variation is accepted for some of these.

Tribe Stereocidarini Mortensen, 1928
Subtribe Stereocidarina Mortensen, 1928
Genus and subgenus *Temnocidaris* Cotteau, 1863

Type species — *Temnocidaris magnifica* Cotteau, 1863, by original designation.

Temnocidaris (T.) danica (Desor, 1855)
Pl. 2, fig. 3.

*1855 *Cidaris danica* Desor, p. 15.

1892 *Temnocidaris danica* Desor sp. — Schlüter, p. 125 [197], pl. 17, figs. 1-2.
1928 *Temnocidaris danica* Des. sp. — Ravn, p. 26, pl. 3, figs. 1-4, 6 (non 5).
1988a *Temnocidaris danica* (Desor, 1855) — van der Ham, p. 134, pl. 1, fig. 7.
1990 *Temnocidaris danica* (Desor, 1855) — Geys, p. 109, pl. 2, figs. 4-6.
in press *Temnocidaris danica* (Desor, 1858) — Smith & Jeffery, fig. 7c-d.

Type — The present whereabouts of Desor's (1855) material is unknown.

Material — NHMM: MB 681, MM 104, 106, 896, 909, 917, 1007, and 1183-1184.

Description — The available material consists exclusively of test fragments and isolated interambulacral plates, occasionally with ambulacral plates. Ambulacra are narrow, with 2-3 (?4) near-equal tubercles in a row, and virtually no perradial pitting. Seven interambulacral plates in a column, much wider than tall, with primary tubercle occupying almost entire plate height. Extrascrobicular tuberculation coarse, consisting of granules arranged in rows with narrow grooves in between; shallow pitting scattered over entire plate.

Discussion — The coarseness of extrascrobicular tuberculation in particular distinguishes the present species from Late Maastrichtian congeners.

Occurrence — Van der Ham et al. (1987) recorded *T. danica* for the Kunrade Limestone facies, and the Nekum and Meerssen members of the Maastricht Formation, as well as for the Geulhem Member (Houthem Formation). However, van der Ham (1988a, p. 134) noted that Maastrichtian material had in the meantime been referred to *T. baylei* by Geys (1987) (see below). This means that *T. danica* is confined to the Geulhem Member with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 1, 23).

Temnocidaris (T.) nigelliensis (Lambert, 1909a) ?

*1909a *Cidaris nigelliensis* Lambert, p. 6.
1992 *Temnocidaris* sp. 1 — van der Ham & van Birgelen, p. 143, pl. 4, figs. 1-2.
in press *Temnocidaris nigelliensis* (Lambert, 1909) — Smith & Jeffery, fig. 7g-j.

Material — Cidarid material from Aachen-Schneeberg, contained in the Schlüter Colln (RFWUIP), as figured by van der Ham & van Birgelen (1992), may belong here. Those authors noted ambulacral plates with 2 (3) large granules in a row, and similarity to *T. schlueteri* Salah, 1982 (= *T. nigelliensis*).

Occurrence — Vijlen Member at Aachen-Schneeberg (Fig. 1).

Temnocidaris (T.) sp. 1
Pl. 2, fig. 1.

1990 *Temnocidaris baylei* Cotteau, 1863 — Geys, p. 108 (partim), pl. 1, figs. 1-6; ?pl. 2, figs. 1-3.

Material — Amongst cidarid material from the Maastrichtian type area which is referable to *T. (Temnocidaris)*, NHMM 1982153 occupies a special position. Not only does it represent the only complete cidarid ever found in the type Maastrichtian, preserving even scrobicular and ambulacral spines and showing a few pathological plating irregularities, but its relatively wide interradial extrascrobicular areas with fine tuberculation set it apart from the other material.

Description — Test large (diameter 60 mm, height 46 mm; H/D ratio 0.77), with subcircular peristome (diameter 23.5 mm) and subpentagonal periproct (diameter 24 mm); no apical disc plates preserved. Seven interambulacral plates in a colum; adapical plates bearing rudimentary tubercles. Interambulacral plates wider than tall, with primary tubercles occupying almost entire plate height. At ambitus, scrobicular tubercles are almost tangential. Extrascrobicular tuberculation fine, with 4 abreast adradially, 14 interradially, consisting of fine rows of tubercles with narrow, shallow grooves in between. Pitting fine, only interradially, scattered over entire plate. Ambulacra with large primary tubercle, followed by two subequal tubercles and more irregular perradial tuberculation in one or two rows. Apparently no perradial pitting.

Discussion — Although closely related to *T. magnifica* and *T. baylei*, the present specimen cannot be confidently assigned to either of those species.

Temnocidaris magnifica was first described (Cotteau, 1863, pl. 1085, figs. 1-2; pl. 1086, fig. 1) from the 'Étage sénonien' (= ? Lower Maastrichtian) of Aurignac, Haute-Garonne (France). Cotteau's specimen has a height/diameter (H/D) ratio of 0.57, and shows particularly wide interradial extrasrobicular areas. Smith & Jeffery (in press) recorded material referred to *T. magnifica* from the Maastrichtian of Haute-Garonne, Santander (NW Spain) and Cotentin (France). Salah's (1982, p. 209, pl. 1, fig. 1) record of *T. magnifica* from the upper Lower Maastrichtian of Hemmoor (northern Germany) is in fact a representative of *T. (Stereocidaris)*, closely allied to Ravn's (1928) *Typocidaris danica* Ravn.

First described from Royan (Charente) and Ribérac (Dordogne), *T. baylei* (Cotteau, 1863, p. 359, pl. 1087; pl. 1087bis, figs. 1-6), apparently is of Late Campanian age, has a H/D ratio of 0.66, and has interambulacral tubercles clearly separated, i.e. not occupying almost the entire plate height. Cotteau (1863, p. 362) also referred isolated test material from 'la craie d'Orglande' (= early Late Maastrichtian, see Kennedy, 1986) and Ciply.

A third species of *Temnocidaris*, *T. nigelliensis* (Lambert, 1909a) (p. 6), is of Maastrichtian and Early Palaeocene age, with records from France (Cotteau, 1863, p. 318, pl. 1077, figs. 1-7, as *Cidaris faujasi*), Denmark (Ravn, 1928, p. 13, pl. 1, fig. 7, as *C. faujasi*; p. 26 (partim), pl. 3, fig. 5, as *T. danica*), Germany (Salah, 1982, p. 210, pl. 3, fig. 1, as *T. baylei*; p. 212, pl. 2, fig. 1-1a, as *T. schlueteri* Salah; van der Ham & van Birgelen, 1992, p. 143, pl. 4, figs. 1-2, as *Temnocidaris* sp. 1) and southeast England (Smith & Wright, 1989, p. 47, pl. 20, fig. 7). This is characterised by having ambulacral tubercles arranged in horizontal series, and in having more widely separated interambulacral tubercles at the ambitus (Smith & Jeffery, in press, fig. 7g-j).

All three species referred to above thus differ from NHMM 1982153, which is here left in open nomenclature for the time being. More material is needed to decide whether this form ought to receive a new name.

Occurrence — Based on the present record, this form is exclusively known from the basal Meerssen Member (Maastricht Formation) at the Ankerpoort-'t Rooth quarry (Bemelen) (Figs. 1, 21).

Temnocidaris (T.) sp. 2
Pl. 2, fig. 2.

1987 *Temnocidaris danica* (Desor, 1855) — van der Ham et al., p. 19, pl. 1, fig. 3 (partim).

1990 *Temnocidaris baylei* Cotteau, 1863 — Geys, p. 108 (partim), pl. 1, figs. 7-8.

Material — NHMM: JJ 2282, 7115, K 702, 752a, 2944, MM 103, 911, 915, 918, 920, 975, 7374, and NHMM 001791.

Description — Only few test segments (Pl. 2, fig. 2) and fairly numerous isolated interambulacral plates, occasionally preserving ambulacral plates, are available. Although this material differs from *Temnocidaris (T.)* sp. 1, described above, showing generally less wide interradial extrascrobicular areas and coarser tuberculation, the range of variation is still fairly wide.

Based on test segments, tests must have been large, with six (? seven) interambulacral plates in a column, fairly coarse extrascrobicular tuberculation, 3 abreast adradially, and 8-11 interradially (i.e. coarser than in *T. (T.)* sp. 1, but less coarse than in *T. (T.) danica*), with the primary tubercle occuoying almost the entire plate height, and scrobicular tubercles almost tangential at the ambitus. Pitting only interradially and along sutures, extended over entire plate. Ambulacra with one large primary tubercle, followed by 1 or 2 (subequal) secondary tubercles and irregularly scattered perradials. Perradial pitting noted in few specimens only.

Discussion — Referred here is all material not closely corresponding to *T. (T.)* sp. 1 (see above), and of the type figured by Geys (1990, pl. 1, figs. 7-8). More articulated material, i.e. test segments preserving ambulacral plating, is needed to determine whether *T. (T.)* sp. 1 represents just an extreme variation. The present material differs from *T. magnifica*, *T. baylei*, and *T. nigelliensis* for the same reasons as outlined above.

Occurrence — As here understood, *T. (T.)* sp. 2 is known to date from the Kunrade Limestone facies, Nekum and Meerssen members of the Maastricht Formation, at the CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Ankerpoort-'t Rooth, and Blom quarries, as well as from the temporary Albertkanaal sections near Kanne (Figs. 1, 18-22).

Subgenus *Stereocidaris* Pomel, 1883
[= *Typocidaris* Pomel, 1883]

Type species — *Cidaris cretosa* Mantell, 1835 (= *C. sceptrifera* Mantell, 1822) by subsequent designation of Lambert & Thiéry (1909) [ICZN pending].

Temnocidaris (Stereocidaris) gigas (Schlüter, 1892)
Pl. 2, figs. 13-15; Pl. 3, fig. 1.

*1892 *Cidaris gigas* Schlüter, p. 142 [214], pl. 21, fig. 6.
1935b *Typocidaris serrata* Desor (*Cidaris*) — Smiser, p. 23, pl. 1, fig. 12b only.
1935b *Typocidaris subvesiculosa* d'Orbigny (*Cidaris*) — Smiser, p. 23, pl. 2, fig. 1b-c only.
1987 *Typocidaris sceptrifera* (Konig in Mantell, 1822) [sic] — Geys, p. 204, pl. 1, figs. 7-9.

Remarks — Amongst the most spectacular cidarids, mainly on account of the size of interambulacral plates, from the type Maastrichtian, are specimens closely comparable to what Schlüter (1892) referred to as *Cidaris gigas*. Previous authors (Lambert, 1911; Smiser, 1935b; Engel, unpubl. manuscript; Geys, 1987) have ascribed such material to (in original nomenclature): *Dorocidaris faujasi* (Desor, 1855), *Cidaris forchhammeri*

Desor, *Typocidaris serrata* Desor, *Stereocidaris subvesiculosa* (d'Orbigny), and *Typocidaris sceptrifera* (König, in Mantell, 1822).

Another species which figures prominently in the present discussion is *Cidarites regalis* Goldfuss (1829, p. 116, pl. 39, fig. 2). As outlined in the section 'Previous work' (see above), after having reexamined the type specimen, I strongly doubt that this came from the Maastricht area.

However, Schlüter's (1892) name *Cidaris gigas* is available, being based on two articulated interambulacral plates from southern Limburg, housed in the collections of the Humboldt University (Berlin; Binkhorst Colln ?). Unfortunately, this test fragment does not preserve ambulacral plating, but the large scrobicular circles which occupy almost the entire plate height, and the wide extrascrobicular zone with dense, uniform cover of granules, and conspicuous neural grooves is highly typical. Abrasion of material brings out these neural grooves even better (see e.g. material illustrated by Smiser, 1935b). Interambulacral plates closely comparable to Schlüter's type specimen are here illustrated in Pl. 2, figs. 13-15 and Pl. 3, fig. 1.

Smith & Jeffery (in press) accepted Goldfuss's *regalis*, and assigned it to the genus *Phyllacanthus* Brandt, 1835, the type of the Phyllacanthina Smith & Wright, 1989, characterised by, amongst other features, conjugate or subconjugate pore pairs. Those authors synonymised, albeit with a query, Schlüter's *C. gigas* with *Temnocidaris (T.) nigelliensis*. This course of action is not followed here; instead, *Cidaris gigas* is accepted as the oldest available name for these large cidarids. Assigning this form to genus is much more difficult, since specimens preserving ambulacral plating are rare. However, a single specimen in sample NHMM K 752 (Pl. 3, fig. 1) preserves a few ambulacral plates, showing the pore pairs to be nonconjugate.

Material — IRScNB 10250-10252; NHMM: BL 0163/1-7, K 752, 1117a, 1402, and MK 4092 (W.M. Felder Colln).

Discussion — In NHMM MK 4092, pitting can be seen along the sutures, near the adradial margin and near the interradial plate junction; assignment to *Temnocidaris (Stereocidaris)* is therefore preferred. Adapical interambulacral plates (Pl. 3, fig. 1) have a dense extrascrobicular ornament, 2 granules abreast adradially, 2-3 adapically, 1 adorally, and 6-7 interradially. Neural grooves are well developed. Scrobicular circle large, virtually occupying entire plate height, consisting of 15 scrobicular tubercles. Ambulacrals with one large marginal tubercle, followed by one or two subequal tubercles and irregular miliaries. Adoral interambulacral plates (NHMM: K 1117a, MK 4092) are wider than tall, scrobicular tubercles being tangential, scrobicular circles confluent. Extrascrobicular area with dense ornament, 7 granules abreast interradially, 2 adradially. Ambital interambulacral plates (Pl. 2, figs. 14-15) are much wider than tall; extrascrobicular area with dense tuberculation, of 3-4 granules adradially, and 7-8 interradially, c. 25 ambulacral plates opposite ambital interambulacral plate.

Additional material is needed, preferably test segments preserving the full complement of interambulacral and ambulacral plates, in order to determine whether this form may remain distinct, and, if so, what its relationship to other cidarids is. Salah's (1982, pl. 1, figs. 1-3) *Temnocidaris magnifica* (= *T. (Stereocidaris) danica* according to Smith & Jeffery, in press), from the upper Lower Maastrichtian of Hemmoor (northern Germany), appears to be very close.

Occurrence — Apparently confined to the upper Maastricht Formation, with

records from the ?Nekum and Meerssen members at St Pietersberg (Maastricht) and at the ENCI-Maastricht BV, Blom and Ankerpoort-'t Rooth quarries (Figs. 1, 20-22).

Temnocidaris (Stereocidaris) herthae (Schlüter, 1892)

*1892 *Dorocidaris herthae* Schlüter, p. 81 [153], pl. 16, figs. 1-4.
1989 *Temnocidaris (Stereocidaris) herthae* (Schlüter, 1892) — Smith & Wright, p. 67, pl. 19, figs. 1-4; text-fig. 11h.
1992 *Temnocidaris* sp. 3 — van der Ham & van Birgelen, p. 143, pl. 4, fig. 4.
?1996 *Temnocidaris (Stereocidaris)* cf. *herthae* (Schlüter, 1892) — Keutgen, p. 196.
in press *Temnocidaris (Stereocidaris) herthae* (Schlüter, 1892) — Smith & Jeffery, fig. 8a-b, e-f.

Type — Holotype, by monotypy, is the specimen illustrated by Schlüter (1892, pl. 16, figs. 1-4), stated (p. 84 [156]) to be part of the collections of the university museum at Breslau (= Wrocław, Poland), and not at Bonn as claimed by Smith & Wright (1989, p. 67).

Material — The specimen illustrated by van der Ham & van Birgelen (1992) from the Lamberts Collection, appears to belong here. NHMM JJ 6526, a complete test (diameter 27 mm, height 15.5 mm), and NHMM K 606a, a test segment, both from the Zeven Wegen Member at Heure-le-Romain, are also placed here.

Description and discussion — Smith & Wright (1989) and Smith & Jeffery (in press) characterised this form as having five (rarely six) interambulacral plates in a column, with primary tubercles relatively small, wide extrascrobicular zones and scrobicular circles well separated on ambital and adapical plates. Extrascrobicular tuberculation fine and dense, 4-6 granules abreast adradially, 6-9 interradially, generall well aligned and with neural grooves, especially interradially. Sutural pit on horizontal sutures, close to adradial margin.

NHMM JJ 6526 has but four interambulacral plates in a column, but is otherwise similar to material illustrated by Smith & Wright (1989, pl. 19, figs. 1-4). It differs from co-occurring *T. (S.) serrata* (see below) in having less wide, but more coarsely ornamented extrascrobicular zones, and better developed sutural pits, occurring also on interradial plate junctions. NHMM K 606a is closely comparable.

For the single test fragment from Aachen-Schneeberg, assignment is tentative at best, despite the fact that there is a good match with material from Denmark illustrated by Ravn (1928, p. 14, pl. 1, figs. 1-3, as *Cidaris herthae*; p. 17, pl. 2, figs. 1-8, as *C. hagenowi*), and from England figured by Smith & Wright (1989, p. 66, pl. 19, figs. 1-4). Smith & Jeffery (in press) are followed in using the first name to have been applied to more or less complete test material. Van der Ham & van Birgelen (1992, p. 143) noted the similarity of their *Temnocidaris* sp. 3 to *T. serrata*. In that species, however, extrascrobicular tuberculation is even finer.

Occurrence — Known to date only from the Zeven Wegen at Heure-le-Romain, and from the Vijlen Member at Aachen-Schneeberg (Fig. 1).

Temnocidaris (Stereocidaris) serrata (Desor, 1858)
Pl. 2, figs. 4-5.

*1858 *Cidaris serrata* Desor, p. 450.

1987 *Typocidaris pistillum* (Quenstedt, 1852) — Geys, p. 203, pl. 1, figs. 1-5.
1989 *Temnocidaris (Stereocidaris) serrata* Desor, 1858 [sic] — Smith & Wright, p. 66, pl. 18, figs. 4-7; pl. 19, fig. 6; pl. 32, figs. 1, 6; text-fig. 11f.

Material — NHMM: JJ 1180, 6390, 7288, K 606b, 2571.

Description — Referred here is material from the lower Upper Campanian Zeven Wegen Member at Heure-le-Romain and at the CPL SA and CBR-Lixhe quarries, previously assigned by Geys (1987) to *Typocidaris pistillum*. Several, more or less complete tests, a few of them preserving (parts of the) apical disc, scrobicular, ambulacral and primary spines, as well as portions of the lantern and peristomial plating, are known from these localities.

Test relatively small (diameter up to c. 34 mm, but isolated interambulacral plates suggest larger specimens to have occurred), with 4-5 interambulacral plates in a column, mostly with one of the columns having a rudimentary tubercle, rarely two. Areoles circular and relatively wide (Pl. 2, fig. 4), becoming elliptical adorally. Extrascrobicular zones well developed, with dense cover of small miliaries, 6-10 abreast adradially, 5-6 adapically and 2 adorally, on ambital plates. Miliaries arranged in distinct rows, with neural grooves occurring in most specimens, although not always well developed. Small pits occur along horizontal sutures on all plates, but are largest and deepest adapically, close to the adradial margin. Ambulacra narrow, pores nonconjugate, with raised interporal partition; 14-16 ambulacral plates per ambital interambulacral plate, each with large marginal tubercle and 5-8 much smaller, subequal miliaries, mostly arranged in two rows, perradially.

Discussion — Desor (1858) erected the present species for cidarid material preserved in the Michelin Collection, from the chalk of Meudon (= ?lower Upper Campanian) and Rügen (= upper Lower Maastrichtian). Smith & Wright (1989, p. 66) provided the following diagnosis: 'A *Stereocidaris* with five interambulacral plates in a column and one small adapical plate with an atrophied tubercle in each zone. Miliary tuberculation is very fine and well developed, with neural grooves', and recorded only material from the Upper Campanian (*Belemnitella mucronata* Zone) of England. It is this interpretation of the species that is followed here.

Smith & Jeffery's (in press) diagnosis differs considerably, in that seven interambulacral plates in a column are mentioned, with scrobicular circles contiguous subambitally, but separated by narrow band of adapical granules adapically.

In the literature, a third species of cidarid has been recorded from the Zeven Wegen Member in the Heure-le-Romain/Haccourt-Lixhe area: *Typocidaris arenata* Lambert, 1911 (p. 42, pl. 2, figs. 14-15), based on a single interambulacral plate from Heure (holotype is IRScNB 9092, IG 5185). Smith & Wright (1989, p. 87) recorded this form (erroneously) from 'the Upper Cretaceous of France and England', placed it in Cidarinae, genus uncertain, considered it to be a probable member of the Goniocidarina, and referred a test segment (BMNH E82346, pl. 19, fig. 8a-c) from the lower *B. mucronata* Zone at Whitecliff (Isle of Wight) to it. Of note in this form is the irregular, clumped distribution of miliary tuberculation on the interambulacral plates, and the naked patches especially near the sutures. Geys (1987, p. 208) considered '*Typocidaris*' *arenata* to be indeterminate, and noted the similarity of this form to co-occurring *T. pistillum* (= *T. (S.) serrata* herein). M.J. van Birgelen (pers. comm., January 1999) has additional material of this interesting form from Heure-le-Romain; this will be

described in a forthcoming paper.

Occurrence — Apparently restricted to the Zeven Wegen Member, with records from Heure-le-Romain and the CPL SA and CBR-Lixhe quarries (Figs. 1, 16-17).

Temnocidaris (Stereocidaris) sp. 1
Pl. 2, fig. 6.

Material — NHMM JJ 5953.

Description — In extrascrobicular tuberculation, the present specimen (Pl. 2, fig. 6) is close to co-occurring *T. (S.) herthae*, but as fas as interambulacral plating is concerned, it is reminiscent of *Cidaris*? *arenata*. However, there are no naked patches in the present test segment. Sutural pits are confined to adapical plates, close to the adradial margin. Ambulacra narrow, with one large tubercle and 2-3 smaller subequal miliaries in a row, occasionally with two even smaller miliaries associated. The adapical interambulacral tubercle in the right-hand colum shows well-developed crenulation.

Discussion — The present specimen is apparently close to *C.*? *arenata*. However, definite assignment must await the description of recently collected, additional material of the latter form (see above).

Occurrence — Known only from the Zeven Wegen Member at the CPL SA quarry, Haccourt (Figs. 1, 16).

Temnocidaris (Stereocidaris) sp. 2

1935b *Typocidaris serrata* Desor (*Cidaris*) — Smiser, p. 23, pl. 1, fig. 12c only.
1987 *Typocidaris serrata* (Desor, 1858) — Geys, p. 205 (partim), pl. 2, figs. 1-2.
1987 *Stereocidaris forchhammeri* (Desor, 1846) — van der Ham et al., p. 19 (partim).

Material — IRScNB IST 9086; NHMM: K 3053, KK 48 (W.M. Felder Colln), PK 363; and TM 16014.

Description — With the exception of a poorly preserved, fragmentary test with a few associated primary spines (NHMM PK 363), only a limited number of test segments and isolated interambulacral plates are available. It is probably on such material that previous records from the type Maastrichtian of the typically Early Palaeocene *Cidaris*? *forchhammeri* were based. The following description is based on the best preserved specimen available, NHMM KK 48.

Test small, depressed, 4 (rarely 5) interambulacral plates in a column; primary tubercles of moderate size, with rather narrow extrascrobicular zones and scrobicular circles well separated, especially on adapical and ambital plates. Extrascrobicular tuberculation dense and comparatively coarse, well aligned but no neural grooves; 1 granule adradially, 4 abreast interradially, and 1-2 adapically. Sutural pits poorly developed, and more or less confined to interradial plate junctions. Ambulacra narrow, with one large marginal tubercle and up to 5 much smaller, subequal miliaries.

Discussion — The structure of the ambulacra and of the scrobicular ring, as well as the width and tuberculation of the extrascrobicular zone shows these specimens to be distinct from *Cidaris*? *forchhammeri* (see below). Spines associated with NHMM PK 363 are long, cylindrical, fairly dense, and thorned, also demonstrating that these test

segments cannot be referred to that species, the spines of which are short and fusiform (see van der Ham, 1988a, pl. 1, fig. 10).

The present form is left in open nomenclature for the time being, since it cannot be assigned with confidence to any of the Late Cretaceous cidarids known to date. There is, however, a resemblance to what Smith & Wright (1989, p. 49, pl. 11, figs. 1-12) illustrated under the name *Temnocidaris (Stereocidaris) lardyi* (Desor, 1856), of Late Aptian age.

NHMM JJ 2283 (see Geys, 1987, pl. 2, figs. 3-4) is referred here with a query. It is partially recrystallised, obscuring details of ornament. However, this specimen does show shallow sutural pits along plate sutures, has less well-developed scrobicular rings, and extrascrobicular tuberculation appears to be more uniform.

Occurrence — To date known from the Kunrade Limestone facies and the Schiepersberg and Meerssen members of the Maastricht Formation, in the Kunrade area, at the ENCI-Maastricht BV quarry, and at the temporary Albertkanaal sections just north of Kanne (Limburg, Belgium) (Figs. 1, 20).

Temnocidaris (Stereocidaris) sp. 3

compare

*1909a *Dorocidaris arnaudi* Lambert, p. 133, pl. 1, figs. 10-11.
*1928 *Typocidaris danica* Ravn, p. 23, pl. 2, figs. 9-12; text-fig. 7.
?1987 *Typocidaris pistillum* (Quenstedt, 1852) — Geys, p. 203, pl. 1, fig. 6 only.
1989 *Prionocidaris arnaudi* (Lambert, 1909) — Smith & Wright, p. 98, pl. 30, figs. 2-4, 7-8; text-fig. 18d.
1992 *Temnocidaris* sp. 2 van der Ham & van Birgelen, p. 143, pl. 4, fig. 3.
in press *Temnocidaris (Stereocidaris) danica* (Ravn, 1928) — Smith & Jeffery, fig. 8g-j.

Types — Type of *Dorocidaris arnaudi* is the specimen figured by Lambert (1909a, pl. 1, figs. 10-11), now in the Lambert Collection (Université Paris); Ravn (1928) did not designate a type; of the two test segments he illustrated (pl. 2, figs. 10-11), the best preserved (fig. 11) is here designated lectotype of *Typocidaris danica* (MGUH collections).

Description — Smith & Jeffery (in press) characterised this form as having seven or eight interambulacral plates in a column, with the uppermost in each column small and bearing a rudimentary tubercle. Areoles relatively large; as a consequence scrobicular circles (near)contiguous ambitally; extrascrobicular tuberculation best developed adradially and interradially, and slightly coarser than in *T. (S.) herthae*, with only 4-6 granules abreast interradially. Sutural pits on horizontal sutures, close to adradial margin and interradially.

Discussion — The specimen from Aachen-Schneeberg illustrated by van der Ham & van Birgelen (1992, pl. 4, fig. 3) in the Lamberts Collection, corresponds well with Ravn's (1928) illustrations and with NHMM JJ 8967 and JJ 10895, test segments from the Lower Palaeocene of Stevns Klint (Denmark) and from the upper Lower Maastrichtian of Boneberg (Jasmund, Rügen, NE Germany), respectively, in showing large scrobicular circles which are near-contiguous ambitally. A single fragment, preserved in flint from the Lanaye Member (Gulpen Formation) illustrated by Geys (1987, pl. 1, fig. 6), shows comparable features and may belong here as well.

In the present paper, Smith & Jeffery (in press) are followed in using only those names that relate to test material of cidaroids. This means that names such as *Cidarites pistillum* Quenstedt, 1852 (p. 578, pl. 49, fig. 20) and *Cidaris hagenowi* Desor, 1858 (p. 32, pl. 5, fig. 16), which are based on isolated spines and have been applied regularly to Early Maastrichtian cidarid species of Rügen (see e.g. Nestler, 1972) are here considered nomina dubia. Names erected on the basis of test material include *Dorocidaris arnaudi*, which Smith & Wright (1989) placed in *Prionocidaris* on account of the ambulacral pores being conjugate, and *Typocidaris danica* Ravn. The latter is based on material from the Lower Palaeocene of Denmark. The relationship between these and similar species such as *T. (S.) herthae* (see above) remains to be determined. In any case, assignment of *Typocidaris danica* Ravn to *Temnocidaris* makes that name unavailable on account of homonymy with *Temnocidaris danica* (Desor). In view of the fact that this matter is still unresolved, the available material is here listed in open nomenclature.

Occurrence — Currently only known from the Vijlen Member at Aachen-Schneeberg (Fig. 1); as Geys's (1987) material may also belong here, the Lanaye Member/lower portion of residual flint strata at the CPL SA quarry (Haccourt) could be added.

Temnocidaris (Stereocidaris) ubaghsi (Geys, 1987)

*1987 *Typocidaris ubaghsi* Geys, p. 206, pl. 2, figs. 5-9.

Type — Holotype is IRScNB IST 10253 (Ubaghs Colln) (Geys, 1987, pl. 2, figs. 5-9).

Material — No other material known.

Discussion — This record is based on a large, deformed test with five interambulacral plates in a column, from the Zeven Wegen Member at Heure-le-Romain. As outlined above, this unit has also yielded the following cidarids: *T. (S.) herthae*, *T. (S.) serrata*, *T. (S.)* sp. 1, and *Cidaris*? *arenata*. Interambulacral structure is comparable to that of the first two named species, and it could well be that the extreme width of the ambulacral perradial and interambulacral extrascrobicular zones, as well as the distinctiveness of neural grooves is size related. In the absence of specimens of intermediate size between this species and representatives of the '*serrata-herthae*' group, it is considered to be distinct for the time being.

Occurrence — Known to date only from the Zeven Wegen Member at Heure-le-Romain (Fig. 1).

Subtribe Goniocidarina Mortensen, 1928
Genus *Ctenocidaris* Mortensen, 1910

Type species — *Ctenocidaris speciosa* Mortensen, 1910, by original designation.

Ctenocidaris? *distincta* (Sorignet, 1850)
Pl. 1, fig. 36.

*1850 *Cidaris distincta* Sorignet, p. 14.
1935b *Cidaris distincta* Sorignet — Smiser, p. 19, pl. 1, fig. 6.
1988a *'Cidaris' distincta* Sorignet, 1850 — van der Ham, p. 134, pl. 1, fig. 6.

Type — Holotype, by monotypy, is (are) the specimen(s) described by Sorignet (1850); its (their) present whereabouts is unknown.

Material — NHMM MB 432VV-1.

Description — Of this species only test fragments and isolated (inter)ambulacral plates are known. The width of interambulacral plates is almost twice their height; tubercles are large, perforate and noncrenulate; areoles circular, occupying most of the plate height but well separated. Areoles lack sharp rim, and scrobicular tubercles are only very slightly larger than extrascrobicular tubercles, which are dense and near-evenly sized. Ambulacral pore zones narrow, perradial zone wide with primary tubercle and two smaller perradial ones, in a horizontal series. Associated primary spines are cylindrical with strong thorns, scattered along shaft, and may be distally expanded into a crown (see van der Ham, 1988a, pl. 1, fig. 12).

Occurrence — Known only from the upper Geulhem Member as exposed at the temporary Albertkanaal sections near Kesselt (Limburg, Belgium) (Fig. 1).

Genus *Goniocidaris* Desor, in L. Agassiz & Desor, 1846

Type species — *Cidarites turbaria* Lamarck, 1816, by subsequent designation of Mortensen (1928).

Goniocidaris? sp.

in press *?Goniocidaris* sp. A Smith & Jeffery, fig. 4a-b.

Description — In sample NHMM K 752, Smith & Jeffery (in press) apparently recognised a test fragment, in which an ambital interambulacral plate has prominent sutural pits, including one at the interradial point of the plate. Ambulacra have non-conjugate pores, approximately ten plates to an interambulacral plate, and tuberculation comprises one large primary and one, occasionally two, small noncontiguous granules. I failed to trace the original of their fig. 4a-b amongst the various cidarid test plates in this sample.

Occurrence — Known only from the Meerssen Member (IVf-4) at Blom quarry, Berg en Terblijt (Figs. 1, 22).

Tribe Cidarini Gray, 1825
Genus *Cidaris* s. lat.

Remarks — Many extant cidaroid genera with closely similar test morphologies are distinguished mainly on the structure of pedicellariae; since fossil forms only rarely preserve these, they are here grouped together as *Cidaris* s. lat.

Cidaris? *forchhammeri* Desor, in L. Agassiz & Desor, 1846
Pl. 2, fig. 9.

*1846 *Cidaris forchhammeri* Desor, in L. Agassiz & Desor, p. 328.
1987 *Typocidaris forchhammeri* (Agassiz & Desor, 1846) — Geys, p. 209.

1988a *Stereocidaris forchhammeri* (Desor, 1846) — van der Ham, p. 131, pl. 1, figs. 1-3.
in press *Cidaris forchhammeri* Desor, 1855 — Smith & Jeffery, fig. 12a-b (cum syn.).

Type — So far as known, a lectotype has not yet been designated; the present whereabouts of Desor's original material is unknown.

Material — IRScNB 9055-9058 (IG 8696); NHMM: JJ 494, 2259, K 3316c, MB 846, and RH 285-8.

Description — Of this species, portions of test and test segments, as well as isolated (inter)ambulacrals are known; 4-5 (?6) interambulacral plates in a column, almost as tall as wide; adapical mamelons comparatively large. Primary tubercles and scrobicular circles coarse, occupying almost the entire plate, with only few extrascrobicular tubercles interradially; no sutural pits. Ambulacra rather narrow, pore pairs nonconjugate, a large marginal primary tubercle and one (in small specimens) or two (in larger individuals) much smaller perradial granules. Associated spines are short, fusiform and have coarse, beaded ribs.

Discussion — Geys (1987, p. 209) is followed here in considering *C. forchhammeri* to be confined to Lower Palaeocene strata, and not occurring in the Maastricht Formation. Material from that unit, including the Kunrade Limestone facies, is herein referred to as *Temnocidaris (Stereocidaris)* sp. 2 (see above).

Occurrence — As here understood, the present species is confined to the Geulhem Member, with records from the temporary Albertkanaal sections at Vroenhoven-Riemst/Kesselt and the Ankerpoort-Curfs quarry (Figs. 1, 23).

Cidaris? *rosenkrantzi* Ravn, 1928
Pl. 2, fig. 7.

*1928 *Cidaris rosenkrantzi* Ravn, p. 21 (partim), pl. 1, fig. 9.
1988a *Stereocidaris* sp. — van der Ham, p. 132, pl. 1, fig. 4.
in press *Cidaris rosenkrantzi* Ravn, 1928 — Smith & Jeffery, fig. 12c-d, g-h.

Type — Ravn (1928) failed to designate a type; the specimen in pl. 1, fig. 9, a test segment, is here designated lectotype (MGUH collections).

Material — NHMM RH 285-7.

Description — Only test segments and isolated (inter)ambulacral plates are known, fewer in number than for *C.*? *forchhammeri*. The present species is close to that species, but has less coarse scrobicular tubercles and slightly wider extrascrobicular (interradial) zones, covered in evener granulation. Four or five (? 6) interambulacral plates in a column; primary tubercles large, occupying most of the plate, with 2-3 extrascrobicular miliaries interradially; elsewhere miliaries are virtually absent. At ambitus, scrobicular circles are tangential. Ambulacra are narrow with 2 subequal tubercles on each plate, and nonconjugate pore pairs.

Discussion — Van der Ham (1988a, pp. 132-133) remarked that this form closely resembled *T. (S.) rosenkrantzi* (Ravn, 1928), and was probably conspecific with Geys's (1987, p. 206) record of *Typocidaris serrata* from the Geulhem Member, as based on NHMM JJ 494. That specimen is here referred to *Cidaris*? *forchhammeri*. Smith & Jeffery (in press) synonymised Geys's *Typocidaris serrata* (1987, pl. 2, figs. 1-4) with the present taxon, albeit with a query. In the present paper, those specimens are referred

to as *Temnocidaris (Stereocidaris)* sp. 2 (see above).

Occurrence — Apparently confined to the Geulhem Member, with records from the temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt (Fig. 1).

Cidaris? sp.
Pl. 1, fig. 37.

1988a '*Cidaris*' sp. — van der Ham, p. 135, pl. 1, fig. 5.

Material — NHMM MB 432VV-2.

Description — Of this form, only test fragments and isolated (inter)ambulacral plates are known. Interambulacral plates wider than tall, with dense cover of granules on extrascrobicular zones, well aligned, and scattered pits; scrobicular circles well separated. Pore zones of ambulacral plates narrow, with double rows of 3-4 tubercles.

Discussion — On the basis of features of extrascrobicular tuberculation, this form might be considered to represent juveniles of *Temnocidaris (T.) danica*. However, the nature of the present form's ambulacral tuberculation would contradict such an assignment.

Occurrence — Known to date only from the upper Geulhem Member of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 1).

General remarks — Although an attempt has been made above to assign most cidaroids of Campanian, Maastrichtian, and Palaeocene age to species, other cidarid material has to remain indeterminate, at least for the time being. Examples are the isolated interambulacral plates illustrated in Pl. 2, fig. 8 and Pl. 3, fig. 2, as well as spines of various shapes and sizes (Pl. 2, figs. 10-12), which occasionally preserve traces of coloration.

The stratigraphic distribution of cidarids is patchy. The Zeven Wegen Member in particular is quite rich in specimens as well as taxa, whereas in the Vijlen, Lanaye, Valkenburg, Gronsveld, Schiepersberg, and Emael members (Gulpen and Maastricht formations) cidarids are (virtually) absent.

Subclass Euechinoidea Bronn, 1860
Infraclass Echinothurioidea Claus, 1880
Cohort Echinothuriacea Jensen, 1981
Order Echinothurioida Claus, 1880
Family Echinothuriidae Wyville Thomson, 1872
Genus *Echinothuria* Woodward, 1863

Type species — *Echinothuria floris* Woodward, 1863, by monotypy.

Echinothuria? sp. (spp.)
Pl. 3, fig. 7.

compare

1925 *Echinothuria* sp. — Brünnich Nielsen, p. 29, pl. 1, figs. 26-27.

*1928 *Araeosoma*(?) *brünnichi* Ravn, p. 36, pl. 4, figs. 36-38.

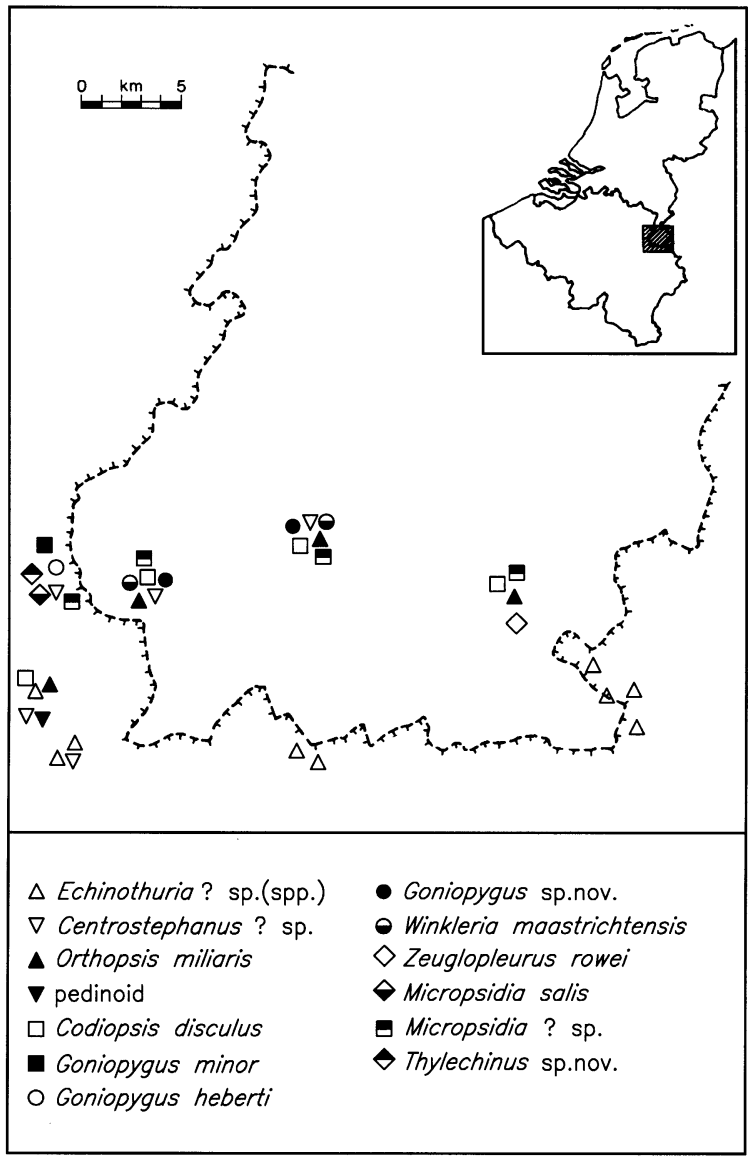


Fig. 2. Geographic distribution of Late Cretaceous-Early Palaeogene echinothuriid, diadematid, orthopsid, pedinoid, arbaciid, acropeltid, stomopneustid, zeuglopleurid, and temnopleurid echinoids in the type area of the Maastrichtian Stage.

*1928 *Araeosoma*(?) *Mortenseni* Ravn, p. 37, pl. 4, figs. 42-45.
*1928 *Asthenosoma*(?) *striatissimum* Ravn, p. 39, pl. 4, figs. 40-41.
1985a *Hygrosoma brünnichi* (Ravn, 1928) — Kutscher, p. 235, pl. 1, figs. 2-10.
1992 *Hygrosoma brünnichi* (Ravn, 1928) — van der Ham & van Birgelen, p. 143, pl. 3, fig. 1.
1990 *Echinothuria floris* Woodward, 1863 — Smith & Wright, p. 105, pl. 33, figs. 1-7; pl. 34, figs. 1-6; text-figs. 20-23.

in press *?Echinothuria* sp. or spp. — Smith & Jeffery, fig. 13a-b.

Material — NHMM: MB 93-2, 387-3, 591-1, 873-8, 1044-2, 1211-2, and 1239-15.

Description — Since echinothuriids have no rigid tests, but are characterised by fragile plates set within a collagenous matrix, more or less complete tests are extremely rare. In various sediment samples, the thin interambulacral plates and compound, usually trigeminate, ambulacral plates have now been recognised; these will be described and illustrated elsewhere. Only a single, highly typical spine with a distal conical, hyaline hoof is here figured (Pl. 3, fig. 7). Spines generally are sender, and hollow.

Discussion — Although fossil material cannot be confidently assigned to genus, the lack of sutural gaps between interambulacral plates, according to Smith & Jeffery (in press), suggests placement with either *Echinothuria* or *Hygrosoma* Mortensen, 1903.

Occurrence — Isolated test plates and spines are known to date from the Zeven Wegen, Vijlen, Lixhe, and Lanaye members (Gulpen Formation) of Mamelis-Selzerbeek, the Aachen city area (Hans Böckler Allee, Schurzelterstraße), Altembroeck (Voer), and the CBR-Romontbos and CPL SA quarries (Figs. 2, 16, 19).

Infraclass Acroechinoidea Smith, 1981
Cohort Diadematacea Duncan, 1889
Order Diadematoida Duncan, 1889
Family Diadematidae Peters, 1855
Genus *Centrostephanus* Peters, 1855
[= *Palaeodiadema* Pomel, 1887; *Helikodiadema* Gregory, 1896]

Type species — *Diadema longispina* Philippi, 1845, by original designation.

Centrostephanus? sp. (spp. ?)
Pl. 3, figs. 3-6, 8-9; Pl. 4, fig. 1.

compare
*1928 *Palaeodiadema multiforme* Ravn, p. 49, pl. 5, figs. 7-10.
1985a *Palaeodiadema multiforme* Ravn, p. 237, pl. 2, figs. 1-12; pl. 3, figs. 1-4.
1988a *Palaeodiadema* sp. — van der Ham, p. 138, pl. 2, figs. 10-15.
1990 *Centrostephanus fragilis* (Wiltshire, in Wright 1882) — Smith & Wright, p. 114, pl. 35, figs. 1-10; text-fig. 25a-d.
1992 *Centrostephanus* sp(p). — van der Ham & van Birgelen, p. 143, pl. 3, figs. 2-3.
1999c *Centrostephanus*? sp. juv. — Jagt, pl. 1, figs. 9-10.
in press ?*Centrostephanus* sp. or spp. — Smith & Jeffery, fig. 13c-e (cum syn.).

Material — NHMM: BL 0016, 0054, 0123a, JJ 10506, K 1408, MB 432-H, 770-10, 808-16, and 1044-3.

Description — Numerous test fragments, isolated ambulacral and interambulacral plates, and spines are available of diadematids, but these cannot be confidently assigned to species. Interambulacral plates are thin (Pl. 4, fig. 1), have one large, perforate and crenulate, central tubercle and up to 3 smaller adradial and interradial

tubercles, as well as scattered miliaries. Primary tubercles have confluent areoles in a column. Ambulacral plates (Pl. 3, fig. 8) have a single large, crenulate and perforate, primary tubercle which overlaps all three ambulacral compound elements, and leaves virtually no room for additional miliaries. Spines are slender, hollow and distinctly verticillate (Pl. 4, fig. 2), and when well preserved, show a prominent, oblique milled ring, and a constricted spine base, which has a perforate and crenulate acetabulum.

The present material (NHMM MB 808-16) includes a number of more or less complete juvenile tests (Pl. 3, figs. 3-4), preserving (portions of the) lanterns, and a fair number of isolated genital plates (see Pl. 3, fig. 9).

Occurrence — Currently known from the Zeven Wegen Member at the CPL SA quarry (Haccourt), the Emael, Nekum, and Meerssen members, as well as the Kunrade Limestone facies of the Maastricht Formation at the CBR-Romontbos, ENCI-Maastricht BV, and Blom quarries, and the Geulhem Member of the temporary Albertkanaal sections at Vroenhoven-Riemst/Kesselt (Figs. 2, 16, 19-20, 22).

Plesion (Order) Orthopsida Mortensen, 1942
Family Orthopsidae Duncan, 1889
Genus *Orthopsis* Cotteau, 1864

Type species — *Cidarites miliaris* d'Archiac, in d'Archiac & Haime, 1835, by original designation.

Orthopsis miliaris (d'Archiac, 1835)
Pl. 4, figs. 10-11.

*1835 *Cidarites miliaris* d'Archiac, p. 179, pl. 11, fig. 8.
1986 *Orthopsis miliaris* (d'Archiac, 1835) — Geys & Jagt, p. 102, fig. 4c-g.
1995 *Orthopsis miliaris* (d'Archiac, 1835) — Smith, p. 136, pl. 2, figs. 4-5; pl. 3, figs. 1-9; text-figs. 12-14 (cum syn.).
in press *Orthopsis miliaris* (d'Archiac, in d'Archiac & Haime, 1835) — Smith & Jeffery, fig. 15a-c (cum syn.).

Type — Holotype, by monotypy, is the specimen illustrated by d'Archiac, in d'Archiac & Haime, 1835, pl. 11, fig. 8, whose present whereabouts is unknown.

Material — IRScNB: 9098 (IG 6521), 10196 (IG 5096), 10355-10356; NHMM: BL 0024, 0042, 0154, JJ 2725, and MM 513.

Description — Test small to medium-sized (up to c. 40 mm in diameter), circular in outline, and with depressed profile, ambitus below mid-height. Small apical disc dicyclic, its plates usually bound to corona. Ambulacra relatively narrow and straight, pore pairs being uniserial except close to the peristome, where small phyllodes occur. Each ambulacral plate has a small primary tubercle straddling two elements, separated from adjacent tubercles by a simple element bearing a row of granules. Interambulacral plates are much wider than tall, have a large central tubercle and a smaller adradial and perradial secondary tubercle. Remainder of ambital plates covered with heterogeneous granules and tiny tubercles. Peristome weakly invaginated, with strong buccal notches.

Occurrence — Currently known from the Nekum and Meerssen members as well

as from the Kunrade Limestone facies of the Maastricht Formation, with records from the Blom, ENCI-Maastricht BV, and CBR-Romontbos quarries, and from the Kunrade-Benzenrade area (Figs. 2, 19-20, 22).

Order Pedinoida Mortensen, 1939
Family Pedinidae Pomel, 1883

In the Maastrichtian type area, pedinoid echinoids are extremely rare. A fine specimen, preserving apical disc plating and primary as well as secondary spines, is known from the upper Nekum Member (Maastricht Formation) as exposed at the CBR-Romontbos quarry (Eben Emael, Fig. 2). This specimen will be described in detail elsewhere (Jagt & van der Ham, in prep.).

Cohort Echinacea Claus, 1876
Superorder Stirodonta Jackson, 1912
Order Calycina Gregory, 1900
Family Saleniidae L. Agassiz, 1838
Subfamily Saleniinae L. Agassiz, 1838
Genus and subgenus *Salenia (Salenia)* Gray, 1835
[= *Trisalenia* Lambert, 1895]

Type species — *Cidarites scutigera* Münster, in Goldfuss, 1829 (= *Echinus petaliferus* Defrance, in Desmarest, 1825), by original designation.

Salenia (S.) belgica Lambert, 1898
Pl. 4, figs. 5-6, 9.

*1898 *Salenia belgica* Lambert, p. 150, pl. 3, figs. 1-6.
1979 *Salenia belgica* Lambert, 1887 [sic] — Geys, p. 316, fig. 11/3-6.
1982 *Salenia minima* Agassiz and Desor, 1846 — Geys, p. 266, fig. 7a, pl. 29, figs. 1-4.
non1983 *Salenia belgica* Lambert, 1887 [sic] — Kutscher, p. 892, pl. 1, figs. 2, 5-6; pl. 2, fig. 1; pl. 4, figs. 3-8.
1988a *Salenia belgica* Lambert, 1898 — van der Ham, p. 139, pl. 3, figs. 1-4.
1997b *Salenia belgica* Lambert, 1897 — Jeffery, p. 666, pl. 1, figs. 1-4 only; text-figs. 3c-d, ?4a (cum syn.).
in press *Salenia (Salenia) belgica* Lambert, 1898 — Smith & Jeffery, fig. 18c-e (cum syn.).

Type — Holotype is IRScNB 9109 (IG 5496, Cornet Colln) (Lambert, 1898, pl. 3, figs. 1-4).

Material — IRScNB 10162; NHMM: MB 491, and MM 895.

Description — Test small (up to 15 mm in diameter), depressed, low conical; apical disc convex, forming c. 30% of test height, smooth and low domal, with subcentral gonopores, equalling more than 80% of test diameter. Small pits occur along all plate sutures; periproct of moderate size, oval, and widely separated from ocular I, much smaller than suranal plate. Ambulacra strictly bigeminate, with small phyllodes adorally. Five interambulacral plates in a column; interradial miliary band narrow. Diameter of peristome smaller than of apical disc.

Discussion — For a small collection of saleniids from the so-called 'poudingue de la Malogne', which is a conglomeratic level at the base of the Palaeocene Tuffeau de Ciply, at Ciply, Lambert (1898) erected *S. belgica*. Geys (1979, p. 316), on the other hand, listed the so-called 'St Symphorien Gravel', as stratum typicum, and considered *S. belgica* to be a Maastrichtian species. The specimen (IRScNB 10162) from the 'Craie phosphatée de Ciply', which is of Early Maastrichtian (*obtusa* Zone) age, illustrated by Geys (1979, fig. 11/3-6) and here refigured (Pl. 4, figs. 3-4), should possibly be reassigned. In view of the fact that the apical disc is poorly preserved (see Pl. 4, fig. 3), the specimen could either represent *Salenia (S.) desori* Lambert, 1911 (p. 67) or *S. (S.) belgica*. In the latter case, the specimen was probably mislabelled in collections. Work in the Ciply area by Max Meijer in the 1950s has shown that *S. belgica* occurs in situ in the 'Tuffeau de Ciply', and also in the Maastricht area *S. belgica* is confined to the Lower Palaeocene, where it is fairly common in the lower Geulhem Member.

The only unquestionable pre-Palaeocene record of *S. belgica* is that of Jeffery (1997b), who described material from the uppermost Maastrichtian (*kazimiroviensis* Zone) of Mangyshlak (Kazakhstan).

Occurrence — Known to date from the lower Geulhem Member, with records from the temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt and the Ankerpoort-Curfs quarry (Figs. 4, 23).

Salenia (S.) gr. *nutrix* Peron & Gauthier, 1881

*1881 *Salenia nutrix* Peron & Gauthier, in Cotteau et al., p. 167, pl. 18, figs. 4-10.
in press *Salenia (Salenia) nutrix* Peron & Gauthier, 1881 — Smith & Jeffery, fig. 21 (cum syn.).
in press *Salenia (Salenia)* cf. *geometrica* Agassiz, 1838 — Smith & Jeffery, fig. 22 (cum syn.).

Type — Holotype, by monotypy, is the original of Peron & Gauthier's pl. 18, figs. 4-10 (1881); its present whereabouts is unknown.

Material — A single specimen, NHMM 1998001 (ex Meuris Colln).

Description — See Jagt et al. (1999).

Occurrence — Exclusively known from the upper Nekum Member at the CBR-Romontbos quarry, Eben Emael (Figs. 4, 19).

Salenia (S.) sigillata Schlüter, 1892
Pl. 4, figs. 7-8.

*1892 *Salenia sigillata* Schlüter, p. 185 [257], pl. 18, fig. 12; pl. 21, figs. 1-5.
*1911 *Salenia rutoti* Lambert, p. 68, pl. 1, figs. 18-21; pl. 3, fig. 24.
1967 *Salenia sigillata* Schlüter — Wright, p. 22, pl. 1, fig. 4; pl. 2, fig. 1a-c.
1979 *Salenia sigillata* Schlüter, 1892 — Geys, p. 317, fig. 12/1-5.
1990 *Salenia (Salenia) sigillata* Schlüter, 1892 — Smith & Wright, p. 159, pl. 51, figs. 3-4; pl. 52, figs. 1-2; pl. 53, figs. 1-3; text-figs. 44-46 (cum syn.).
in press *Salenia (Salenia) sigillata* Schlüter, 1892 — Smith & Jeffery, fig. 20.

Type — Holotype, by monotypy, of *S. sigillata* is the original of Schlüter (1892, pl. 21, figs. 1-5) in the collections of the Museum für Naturkunde (Berlin); holotype of *S. rutoti* is IRScNB 9104 (IG 4285, Bosquet Colln; Lambert, 1911, pl. 1, figs. 18-20, and Pl. 4, figs. 7-8 herein), paratype is IRScNB 9105 (IG 4285).

Material — No additional material is known.

Description — Test tall, with low conical, medium-sized apical disc (60-70% of test diameter), with fine radial granular ornament, obvious sutures and numerous small sutural pits. Subtrigonal periproct larger than suranal plate. Ocular plates weakly convex distally, projecting only slightly. Seven or eight interambulacral plates in a column, increasing markedly in size adapically. Primary tubercles with relatively small mamelons. Ambulacra straight, with bi- and unigeminate plating, but bigeminate plates and enlarged primary tubercles close to peristome. Perradial columns of prominent secondary tubercles. Peristome small (35% of test diameter), and sunken.

Occurrence — Of this apparently rare species no recent finds are known. Lambert's (1911) specimens from Slenaken are poorly documented stratigraphically. Since *S. sigillata* is known to occur in Upper Campanian as well as Maastrichtian strata (Wright, 1967; Smith & Wright, 1990), the Slenaken material could either have come from the Beutenaken Member or the Vijlen Member.

Subgenus *Pleurosalenia* Pomel, 1883

Type species — *Salenia tertiaria* Tate, 1877, by original designation of Pomel (1883).

Remark — Representatives of *Pleurosalenia* have strictly unigeminate ambulacra adorally, but from the ambitus adapically there may be occasional bigeminate elements. Smith & Jeffery (in press) distinguished two clades amongst the Late Cretaceous-Early Palaeogene members of this subgenus. The first group is characterised by *S. (P.) heberti*, and has a relatively thin-plated, subcircular apical disc, with only small sutural pits, and ocular plates not clearly projecting. The second clade, typified by *S. (P.) maestrichtensis*, has large, square-ended, projecting ocular plates, resulting in a characteristic outline of the thick-plated apical disc, which has large oval pits at triple suture points.

Salenia (P.) anthophora Müller, 1847
Pl. 5, figs. 1-5, 8-11.

*1847 *Salenia anthophora* Müller, p. 7, pl. 1, fig. 1.
1911 *Salenia antophora* [sic], Muller, 1847 — Lambert, p. 66, pl. 3, figs. 22-23.
*1911 *Salenidia schluteri* [sic] Lambert, 1911, p. 69, pl. 1, figs. 23-27.
1965 *Salenidia scabra* Nestler, p. 987, text-fig. 7a-f; pl. 4, figs. 4-7.
1979 *Salenidia schlueteri* Lambert, 1911 — Geys, p. 309, figs. 6/7, 10/1-4.
1979 *Salenia anthophora* Müller, 1847 — Geys, p. 313, figs. 10/5-6, 11/1-2.
1983 *Salenia anthophora* Müller, 1847 — Kutscher, p. 891, pl. 1, fig. 1; pl. 2, fig. 2, pl. 3, figs. 6-8; pl. 4, figs. 1-2.
1992 *Salenia anthophora* Müller, 1846 — van der Ham & van Birgelen, p. 143, pl. 1, figs. 1-3.
1997b *Salenia anthophora* Müller, 1846 — Jeffery, p. 671, pl. 2, figs. 5-6; text-fig. 3e (cum syn.).
in press *Salenia (Pleurosalenia) anthophora* Müller, 1847 — Smith & Jeffery, fig. 27 (cum syn.).

Type — Neotype, designated by van der Ham & van Birgelen (1992, p. 148, pl. 1, fig. 2), is an unregistered specimen in the Schlüter Colln (RFWUIP), here reillustrated in Pl. 5, fig. 11; holotype of *S. schlueteri* is IRScNB 9106 (IG 4285, Bosquet Colln) (Lambert, 1911, pl. 1, figs. 23-27); holotype of *S. scabra* is GPIG 12/7 (Nestler, 1965, text-fig. 7a-d; pl. 4, figs. 4-5).

Material — IRScNB: 9103 (IG 4285), 10161 (IG 6527); NHMM: JJ 3663, 5948, 6459, K 768, and MB 1239-13.

Description — Van der Ham & van Birgelen (1992, p. 148) provided the following description of the neotype and additional specimens from the same locality, here translated:

'Regular, 12.5-23 (mean 20) mm in diameter, height/diameter 0.68-0.78 (mean 0.73), apical disc strongly convex, also in small-sized specimens, all plates with weakly 'dimpled' surface (occasionally 'growth lines' are visible) and a very fine, partially striate pattern of granules (handlens + low angle light), genital plates with faint star-shaped patterns surrounding the genital pores, ambulacra narrow (few granules between the two rows of primary tubercles), slightly sinuous, also in small-sized specimens, with 16-24 tubercles and 18-29 pore pairs in a column (in the adapical two thirds occur 2-5 plates with two pore pairs opposite one tubercle, in larger specimens more than in smaller ones), interambulacra wide, 5-6 primary tubercles in a column, peristome only weakly sunken.'

Van der Ham & van Birgelen (1992) expressed doubts over the correct assignment of Geys's (1979) material from Gulpen and Maastricht (St Pietersberg), and noted that the specimen in his figs. 10.-10.6 and 11.1-11.2, from Slenaken, could indeed belong to *S. anthophora* (see Pl. 5, fig. 3). Those authors' interpretation of *Salenia anthophora* is here followed. Material from the Vijlen Member at the CPL SA quarry (Haccourt; see Pl. 5, figs. 1-2) matches topotypical specimens perfectly, and allows the following description:

Test small to medium-sized (up to 30 mm in diameter), domed in profile; apical disc massive, 75-90% of test diameter; plates of apical disc smooth to very faintly granulate; generally with low, blunt radiating ridges and deep wedge-shaped depressions and large sutural pits, occasionally coalescing. Periproct small to medium-sized, subtriangular, surrounded by broad rim. Ambulacra straight to slightly sinuous, with predominantly unigeminate plating, but occasional bigeminate plates from ambitus adapically; perradial zone narrow, with alternating secondary tubercles and interspersed miliaries. Five interambulacral plates in a column, interradial zone relatively narrow, zigzagged, and with double row of secondary tubercles and miliaries, broader near apex. Peristome small, circular, sunken and with small, but distinct buccal notches.

Discussion — As here interpreted, *S. anthophora* is confined to the Vijlen Member in the extended Maastrichtian type area. Saleniid material from the Lixhe and Lanaye members generally comprises juveniles only, which cannot be assigned to species with certainty, but it seems that *S. anthophora* ranges at least into the Lixhe 1 Member (Haccourt-Lixhe area). Specimens that more closely correspond to *S. bonissenti* (see below) are known from the base of the Gronsveld Member upwards, with the largest specimens having been collected from the middle Emael Member (Lava Horizon) in the Eben Emael area. On the basis of differences in test plating and details of apical disc ornament, as well as on different stratigraphic ranges, *S. anthophora* and *S. bonissenti* are here considered to be distinct species, at least for the time being.

Jeffery (1997b), who synonymised *S. bonissenti* with the present species, recorded a single specimen of *S. anthophora* from the middle *kazimiroviensis* Zone (latest Maastrichtian) of Kazakhstan, which is close to material from coeval strata in Denmark (Stevns Klint; NHMM JJ 10094).

Lambert's (1911) *Salenidia schlueteri*, based on a small specimen (14 mm diameter) from the 'craie marneuse du Sénonien' (= Vijlen Member inferred) at Slenaken, is undoubtedly synonymous with *S. anthophora*, as indicated by van der Ham & van Birgelen (1992). Nestler's (1965) *Salenidia scabra* from the upper Lower Maastrichtian of Jasmund (Rügen), which Kutscher (1983) synonymised with *S. bonissenti*, is also best placed in *S. anthophora*.

Occurrence — Known only from the Vijlen Member, with records from Mamelis-Selzerbeek, Aachen-Schneeberg, and at the CPL SA, and ENCI-Maastricht BV quarries (H.J. Janssens, pers. comm.) (Figs. 4, 16, 20).

Salenia (P.) bonissenti (Cotteau, 1866) sensu Lambert, 1898
Pl. 5, figs. 6-7, 12-13, ?14; Pl. 6, fig. 1.

*1866 *Salenia bonissenti* Cotteau, p. 110, pl. 15, figs. 4-7.
1875 *Salenia bonissenti*, Cotteau, 1866 — Cotteau, p. 643.
1898 *Salenidia bonissenti* Cotteau (*sub. Salenia*), 1866. — Lambert, p. 148, pl. 2, figs. 13-16.
1950 *Salenidia bonissenti* (Cotteau) — Kongiel, p. 311, pl. 1, figs. 1-4.
1979 *Salenidia* cf. *bonissenti* (Cotteau, 1866) — Geys, p. 306, fig. 6/3-6.
1983 *Salenidia bonissenti* (Cotteau, 1866) — Kutscher, p. 890, pl. 1, fig. 4; pl. 2, figs. 3-6; pl. 3, figs. 1-5.
1987 Salenioida? indet. — van der Ham et al., p. 22 (partim), pl. 2, fig. 6.

Type — Holotype, by monotypy, of *S. bonissenti* is Cotteau's original, the present whereabouts of which is unknown.

Material — Two dozens of specimens in various collections, including IRScNB 9107 (IG 5496, Cornet Colln); NHMM: HS 0001, JJ 10420, 10498, K 3873, 4111, and MK 1813 (W.M. Felder Colln).

Description — Test small to medium-sized (up to 26 mm in diameter), depressed with elevated apical disc to domed in profile, apical disc massive (68-80 % test diameter); plates distinctly ornamented, with series of narrow, elevated radiating ridges, 2-4 (near)equal-sized pits along all sutures, and distinctly granular patches near outer margin of ocular plates, which is a piecrust like. In larger specimens sutural pits do not coalesce. Ambulacra straight to slightly sinuous adapically, up to 34 plates in a column in large specimens, 19-20 in smaller individuals, unigeminate plating with occasional bigeminate plates from the ambitus adapically; perradial zone in large specimens wide (corresponding to two tubercles in width), with alternating secondary tubercles and well-developed miliaries in between. Five to six interambulacral plates in a column in large specimens, 4-5 in smaller individuals, interradial very wide in large specimens, with alternating secondary tubercles and close cover of miliaries, broadest near apex. Peristome small, circular and slightly sunken with distinct, but small buccal notches.

Discussion — Unfortunately, Cotteau's (1866) original figures of *S. bonissenti* are poor, and subsequent authors have had serious problems in interpreting this form. Here, Lambert (1898) is followed. That author described and figured a specimen from the 'Poudingue de la Malogne' (= base of the Tuffeau de Ciply), which was refigured by Geys (1979, figs. 6/3-6, as *Salenidia* cf. *bonissenti*), noting that it was an 'espèce de moyenne taille, médiocrement élevée (type: diam. 14, haut. 9 mill.; grand individu: diam. 20 mill.) [....] par son large apex, à bords frangés, avec périprocte subcirculaire

entouré d'un bourrelet saillant; le disque apical est comme persillé par les larges et profondes fossettes angulaires des plaques génitales et ocellaires, et par les fossettes suturales médianes sur la ligne de contact de chaque génitale avec ses voisines; ces plaques génitales, pourvues d'une perforation centrale, offrent une surface très finement chagrinée et régulièrement ondulée. Quelques individus, d'une conservation plus parfaite, montrent que ces ondulations sont occasionnées par un réseau de petites côtes rayonnant du centre des plaques et sembable à celui décrit par Cotteau chez le *S. trigonata*.' This description fits material from the Emael Member available for the present study well. Smaller specimens from that unit, e.g. Pl. 6, fig. 1, match Lambert's illustration perfectly, whereas the larger individuals (e.g. NHMM K 3873, 4111) are reminiscent of *S. trigonata* Agassiz, 1838, from the Lower Santonian to Lower Campanian of southwestern France, as illustrated by Cotteau (1861, pl. 1037, figs. 11-17) and discussed in detail by Arnaud (1897, p. 12).

Although material from the Emael Member represents two distinct size classes and test and apical disc morphologies, with no intermediates, all specimens are here referred to *S. bonissenti* sensu Lambert (1898). Additional material is needed to determine whether the large-sized specimens actually represent a different form, more closely related to, or even conspecific with, *S. trigonata*. The main difference between these forms and *S. anthophora* lies in the fact that the former have much more pronounced radiating ridges on the apical disc plates. Both forms also have different stratigraphic ranges, at least in the study area. Van der Ham & van Birgelen (1992) stressed that all material from the study area previously referred to either *S. anthophora* or *S. bonissenti* should be revised; until such a revision has been completed, these forms are here considered distinct.

Associated with tests are spines (Pl. 5, fig. 14), which undoubtedly belong here; these are stout, with a cortex, and are covered in fine, irregular thorns.

Occurrence — As here understood, *S. bonissenti* is known from the Gronsveld, Emael, and ?Nekum members, as well as the Kunrade Limestone facies (all Maastricht Formation), with records from the CBR-Romontbos, ENCI-Maastricht BV, and Ankerpoort-Marnebel quarries, and the Kunrade-Benzenrade area (Figs. 4, 18-20).

Salenia (P.) sp.
Pl. 6, figs. 2, 9-11.

?1979 *Salenidia maestrichtensis* (Schlüter, 1892) — Geys, p. 298 (?partim).

Material — NHMM: JJ 6735, K 1069, and 1183.

Description — Test small (up to 7 mm in diameter), depressed; apical disc flattened, with well-developed rim surrounding oval periproct, slightly smaller than suranal plate. Ocular plates distally raised, projecting beyond genital plates. Sutural pits at triple junctions fairly large, with smaller pits along sutures between suranal and genital plates. Ambulacra unigeminate, straight, relatively wide, with columns of contiguous primary tubercles, alternating secondaries and small miliaries. Three or four interambulacral plates in a column, wide, interradial zone with relatively large granules. Peristome large, circular, slightly invaginated, with small but distinct buccal notches.

Discussion — The present form is closely comparable to *S. (P.) maestrichtensis*, but differs consistently in having pits halfway the sutures between the suranal and genital plates (indistinct in some specimens) and well-developed radiating ridges on suranal and genital plates. Some specimens have a few central perforations on some genital plates, and are comparable to *S. (P.) pygmaea* in this respect. Similarly well-preserved specimens of *S. maestrichtensis* invariably lack these radiating ridges, and have larger sutural pits. Unfortunately, of material here assigned to *S. bonissenti* (see above) no specimens of similar size are known; at larger sizes, tests referred to that species have fewer radiating ridges and almost coalescent sutural depressions, Y-shaped at triple junctions. Whether the present form represents a distinct species cannot be determined at this moment, on the basis of such limited material.

Occurrence — So far, only material from the Meerssen Member (Maastricht Formation) has been seen, all from the Blom quarry (Figs. 4, 22).

Salenia (P.) heberti Cotteau, 1861
Pl. 6, figs. 6-7.

*1861 *Salenia heberti* Cotteau, p. 173, pl. 1040, figs. 11-24.
1967 *Salenia heberti* Cotteau — Wright, p. 21, pl. 1, fig. 3a-b.
1986 *Salenidia heberti* (Cotteau, 1861) — Geys & Jagt, p. 96, fig. 2a-e.
1990 *Salenia (Pleurosalenia) heberti* Cotteau, 1861 — Smith & Wright, p. 162, pl. 54, figs. 1-2; text-figs. 44-45, 47-48 (cum syn.).

Type — Cotteau (1861) did not designate a type; the whereabouts of his original material is unknown.

Material — IRScNB 10191; NHMM: JJ 2465, 2688, 4818, 6498, 6530, 7783, K 960, and MD 2850.

Description — Test small (up to 12.5 mm in diameter) with flat, rather thin-plated apical disc. Test height 65-80% of diameter. Apical disc about 50% of test diameter, circular in outline with subtriangular ocular plates, no projecting strongly. Periproct very large, larger than suranal plate, and in broad contact with ocular I. Genital pores subcentral. All apical disc plates smooth to naked eye, but very small sutural pites present at triple junctions and midway along plate boundaries. Ambulacra predominantly unigeminate and uniserial. Perradial band of secondary tubercles slightly wider than diameter of a primary ambulacral tubercle. Interambulacra composed of 5-7 plates in column, interradial zone only moderately developed, with some extrascrobicular granulation. Peristome about 40% of test diameter.

Discussion — All specimens available are strictly unigeminate, and thus are best assigned to *S. (P.) heberti* rather than to *Salenia (S.) magnifica* Wright, 1872 (see Smith & Wright, 1990, p. 158, pls 49, 50; pl. 51, figs. 1, 5; text-figs. 42a-b, 43a-b, 44-45), which shows alternating uni- and bigeminate plating, and is known to range from the Upper Santonian to the Lower Maastrichtian in Hampshire, Wiltshire and Norfolk, and thus in part overlaps in range with *S. (P.) heberti*.

Occurrence — Apparently restricted to the Zeven Wegen Member (Gulpen Formation), with records from Heure-le-Romain and the CPL SA quarry (Figs. 4, 16).

Salenia (P.) maestrichtensis Schlüter, 1892
Pl. 6, fig. 8.

*1892 *Salenia maestrichtensis* Schlüter, p. 196 [268].
1979 *Salenidia maestrichtensis* (Schlüter, 1892) — Geys, p. 298, fig. 1/1-7.
1983 *Salenidia pygmaea* (v. Hagenow, 1840) — Kutscher, p. 889 (partim).
in press *Salenia (Pleurosalenia) maestrichtensis* Schlüter, 1892 — Smith & Jeffery, fig. 28.

Type — Syntypes, by monotypy, are RFWUIP Schlüter Colln, no. 254; the sample actually contains six specimens. Labels associated state the following:

angeblich von Maestricht	Original Maestricht ?	Original. Maestricht
ob. Kreide	Ob. Kreide	Ober-Kreide
Salenia	*Salenia Maestrichtensis* Schlüter	*Salenia maestrichtensis*
	Kreide-Echinid.	Schlüter Kreide-Echin. 254
	Alte Sammlung 254	C.S.
	Jan. 1891	Collect. Schlüter 1884

Material — Hundreds of specimens in various collections, including IRScNB 10158-10159 (IG 4285, Bosquet Colln); NHMM K 1092, 2293, NHMM 1999007 (ex Meuris Colln); and RGM 428 054.

Description — Tests small (up to 12 mm in diameter), depressed, with height up to c. 50% of diameter. Apical disc flattened, with low rim surrounding subcircular to oval periproct, which is slightly smaller than suranal plate, and 'dimpled' plates. Ocular plates raised distally, T-shaped, and projecting beyond genital plates. Sutural pits large, broadly triangular, at triple junctions and midway along sutures between genital and ocular plates, quite angular in large individuals. Ambulacra straight, relatively wide, with two series of contiguous primary tubercles, and a perradial band of alternating secondaries and interspersed granules. Ambulacra contain occasional bigeminate elements aborally, but are mostly unigeminate, especially adorally. Four or five interambulacral plates in a column, wide, with primary tubercles close to adradius, and broad, slightly depressed interradial zone of secondary granules. Peristome (sub)pentagonal to subcircular, small and somewhat invaginated, with inconspicuous buccal notches.

Discussion — Ever since its introduction, authors have discussed this species' status. Schlüter (1892) himself noted the close similarity between his form and *S. pygmaea*. However, most recent authors (e.g. Geys, 1979; van der Ham et al., 1987; Smith & Jeffery, in press) consider it to be a distinct species. Jeffery (1997b, p. 668, pl. 2, figs. 1-4; text-figs. 3a-b, 4b) recorded specimens of *S. pygmaea* from the uppermost Maastrichtian of Kazakhstan, and noted that that species was easily recognised on account of its combination of unigeminate ambulacra and pitted apical disc (see also Nestler, 1965, p. 982, pls 1-3; pl. 4, figs. 1-3; text-fig. 1; Kutscher, 1983, p. 889, pl. 1, fig. 3; pl. 2, figs. 7-11). Some specimens show very faint radiating ridges on the suranal and genital plates, and are thus reminiscent of *S. (P.)* sp., discussed above. However, the nature of the sutural pits separates these two forms. The species was originally based on material from the coarse-grained biocalcarenites of the Meerssen Member; this has generally suffered from recrystallisation which tends to obscure details of ornament

of the apical disc. However, a well-preserved specimen from the base of the Valkenburg Member at the ENCI-Maastricht BV quarry (NHMM 1999007) shows that this 'loss of information' is negligible.

Occurrence — Known with certainty from the Valkenburg, Nekum and Meerssen members, as well as Kunrade Limestone facies (all Maastricht Formation), at many localities in southern Limburg, and Liège-Limburg, including the CBR-Romontbos, Ankerpoort-'t Rooth, Blom and Ankerpoort-Curfs quarries, as well as the temporary Albertkanaal sections (Vroenhoven-Riemst and Kanne) and the Kunrade-Benzenrade area (Figs. 4, 19-23). As outlined above, juvenile specimens from the Lixhe and Lanaye members (Gulpen Formation) cannot be assigned to either to *S. (P.) anthophora* or *S. (P.) maestrichtensis* with confidence.

Salenia (Pleurosalenia) sp. nov.
Pl. 6, figs. 3-5.

1988a *Salenidia selandica* Ravn, 1982 — van der Ham, p. 139, pl. 3, figs. 9-12.

Type — Holotype is NHMM MB 432J-1 (pl. 6, figs. 3-5).

Material — NHMM MB 432-J.

Description — Test small (up to 10 mm in diameter), flattened in profile, with nearly flat apical disc, c. 70% of test diameter, plates being (virtually) smooth, and with minute sutural pits at triple junctions only. Ocular plates project slightly beyond genital plates; periproct slightly smaller than suranal plate. Up to 22 ambulacral plates in a column, plates unigeminate, except possibly adjacent to peristome; straight and extremely wide with primary and secondary tubercles close set along outside, and broad band of granules perradially. Six or seven interambulacral plates in a column, primary tubercles displaced towards interradius, with slightly depressed, broad interradial band of granules and secondary tubercles. Mamelons of primary tubercles relatively large. Peristome large, c. 50% of test diameter, with small, but distinct buccal notches.

Discussion — This is a new species which will be formally named by Smith & Jeffery (in press), differing consistently from *'Salenidia' selandica* Ravn, 1928 (p. 48, pl. 5, fig. 6; Lower Palaeocene, Denmark).

Occurrence — Confined to the upper Geulhem Member, with records from the temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt (Fig. 4).

Genus *Salenidia* Pomel, 1883

Type species — *Salenia gibba* L. Agassiz, 1838, by subsequent designation of Lambert & Thiéry (1911).

Subgenus *Platysalenia* Smith & Wright, 1990

Type species — *Salenia dux* Wright, 1967, by monotypy.

Salenidia (*Platysalenia*?) *sanctipetri* Geys, 1979
Pl. 6, figs. 12-13.

*1979 *Salenidia sanctipetri* Geys, p. 303, figs. 5/1-6, 6/1-2.

Type — Holotype is IRScNB 10160 (IG 4285, Bosquet Colln) (Geys, 1979, figs. 5/1-6, 6/1-2).

Description — Test small (11.3 mm in diameter); apical disc relatively large, slightly convex and pentastellate in outline; sutures barely visible, sutural depressions of large size, mostly polygonal, pits triangular at ocular-genital junction, trapezoid at suranal-genital junction, elongate-oval on each suture between ocular and genital; no ornament. Genital pores offset distally. Periproct subtrapezoidal, surrounded by smooth ridge. Four or five interambulacral tubercles in a column, c. 5 scrobicular tubercles around primaries. Interradial zone with coarse granulation, becoming finer towards suture. Ambulacra straight, 18-19 in a column; plating unigeminate throughout. Adoral side flat; peristome subcircular, buccal notches inconspicuous.

Discussion — Being based on a single specimen, this peculiar species has puzzled subsequent authors. Geys (1979) isolated it from large samples of *S. (Pleurosalenia) maestrichtensis* in the IRScNB collections, bearing registration number IG 4285. This means that the sample concerned originally formed part of Bosquet's private collection. Bosquet collected in the Maastricht area himself, and despite the fact that so far only a single specimen of *S. sanctipetri* is known, there is no reason to doubt its provenance. The holotype is well preserved, and is characterised by its peculiar pattern of sutural pits, and strongly pentastellate apical disc.

Smith & Wright (1990, p. 164) noted that *S. sanctipetri* could belong to the genus *Salenidia*, and erected the subgenus *Platysalenia* for the Late Albian species, *S. (P.) dux* Wright, 1967, with strictly bigeminate ambulacral plating, and distinct perradial and interradial miliary tuberculation. However, *S. sanctipetri* has unigeminate plating, and is thus assigned to this subgenus with a query.

Occurrence — So far known from the Maastricht Formation (Meerssen Member inferred) only, at the St Pietersberg (Maastricht) (Fig. 4).

Genus *Salenocidaris* A. Agassiz, 1869

Type species — *Salenocidaris varispina* A. Agassiz, 1869, by original designation.

Salenocidaris minima (Desor, in L. Agassiz & Desor, 1846)
Pl. 7, figs. 1-2.

*1846 *Salenia minima* Desor, in L. Agassiz & Desor, p. 342.
1988a *Salenidia danica* Ravn, 1928 — van der Ham, p. 139, pl. 3, figs. 5-8.
in press *Salenocidaris minima* (Agassiz & Desor, 1846) — Smith & Jeffery, fig. 29a.

Type — The present whereabouts of Desor's original material is unknown.

Material — NHMM MB 339.

Description — Test small (up to 5.5 mm in diameter), apical disc slightly convex,

and with rather coarse granulation on each genital plate; disc margin with piecrust-like rim. Genital pores open on small mound. Four or five interambulacral plates in a column, primary tubercles close to adradial suture, secondary tubercles restricted to interradial zones, which are relatively wide; ambulacra with contiguous primary tubercles, predominantly unigeminate, except for proximalmost plates which are bigeminate. Peristome large, with inconspicuous buccal notches.

Occurrence — Confined to the Geulhem Member, but rare in the uppermost part, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 4).

Salenocidaris obnupta (Schlüter, 1892)
Fig. 3; Pl. 7, fig. 3.

*1892 *Salenia obnupta* Schlüter, p. 190 [262], pl. 19, figs. 1-6.
1986 *Salenia obnupta* Schlüter, 1892 — Geys & Jagt, p. 94, fig. 1a-g.
1990 *Salenocidaris granulosa* (Woodward, 1856) — Smith & Wright, p. 169 (partim), pl. 48, fig. 1; pl. 57, figs. 1-3; pl. 59, figs. 1-5 only.

Type — Holotype, by monotypy, is RFWUIP Schlüter Colln, no. 11 (Schlüter, 1892, pl. 19, figs. 1-6).

Material — NHMM JJ 765, 1287, and 2986a-d.

Fig. 3. *Salenocidaris obnupta* (Schlüter, 1892), NHMM JJ 2986a-b, scrobicular spines, CPL SA quarry, Haccourt (Liège), Gulpen Formation, Zeven Wegen Member. Scale bars equal 1 mm.

Description — Test small to medium-sized (up to c. 22 mm in diameter), hemispherical; apical disc large, completely covering adapical surface, strongly convex, plates separated by fine sutures, no sutural pitting, and covered by dense, coarse granulation. Genital plates hexagonal, ocular plates U-shaped, thickened around triangular periproct. Granulation of apical disc merges imperceptibly into that of miliary interambulacral areas. At least 18 ambulacral plates in a column, bigeminate at ambitus; adapically simple plates intercalate; interporiferous zone markedly swollen; perradial zone convex, with dense fine granulation. Three or four interambulacral plates in a column, tubercles large.

Discussion — Easily recognised on account of its flush, densely granulate apical disc. To date, a handful specimens are known, all of which are distorted and fragmentary. One specimen (NHMM JJ 2986a-d) preserves parts of the lantern, and a few primary and scrobicular spines (Fig. 3).

The present species is undoubtedly closely related to *Salenocidaris granulosa* (Woodward, 1856), and was synonymised with that taxon by Smith & Wright (1990, p. 169).

Occurrence — Restricted to the Zeven Wegen Member, and known only from the CPL SA quarry (Figs. 4, 16).

Subfamily Hyposaleniinae Mortensen, 1934
Genus *Hyposalenia* Desor, 1856

Type species — *Salenia stellulata* L. Agassiz, 1838, by subsequent designation of Smith & Wright (1990, p. 174).

Hyposalenia heliophora (Desor, in L. Agassiz & Desor, 1846)
Pl. 7, figs. 4-10.

*1846 *Salenia heliophora* Desor, in L. Agassiz & Desor, p. 342.
1982 *Hyposalenia heliophora* (Agassiz and Desor, 1846) — Geys, p. 269, fig. 7b, pl. 29, figs. 5-8.
1988a *Hyposalenia heliophora* (Desor, 1846) — van der Ham, p. 140, pl. 3, figs. 13-16.
1999c *Hyposalenia heliophora* — Jagt, pl. 1, figs. 1-3.
in press *Hyposalenia heliophora* (Agassiz & Desor, 1846) — Smith & Jeffery, fig. 17 (cum syn.).

Type — The present whereabouts of Desor's original material is unknown.

Material — NHMM: JJ 5637, K 1419, JS V50, MM 163, 899; and RGM 428 055.

Description — Test small (up to 12 mm in diameter), with convex or flat, highly ornamented, pentagonal disc in which genital and ocular plates have long, narrow radial slashes, obscuring the sutures. Gonopores subcentral, periproct relatively large and lozenge-shaped, surrounded by a small rim. Ambulacra bigeminate, with no pore crowding adorally. Five or six interambulacral plates in a column, primary tubercles with relatively small mamelons. Peristome small, less than 50% of diameter, with distinct buccal notches. Associated spines are long, cylindrical, and smooth.

Discussion — On account of distinct apical disc ornament, which may differ in details (compare e.g. Pl. 7, figs. 6 and 8), and periproct position (in III-5 axis), this form is easily recognised. It is the only representative of the genus *Hyposalenia* known from the area. From the temporary Albertkanaal sections, thousands of well-pre-

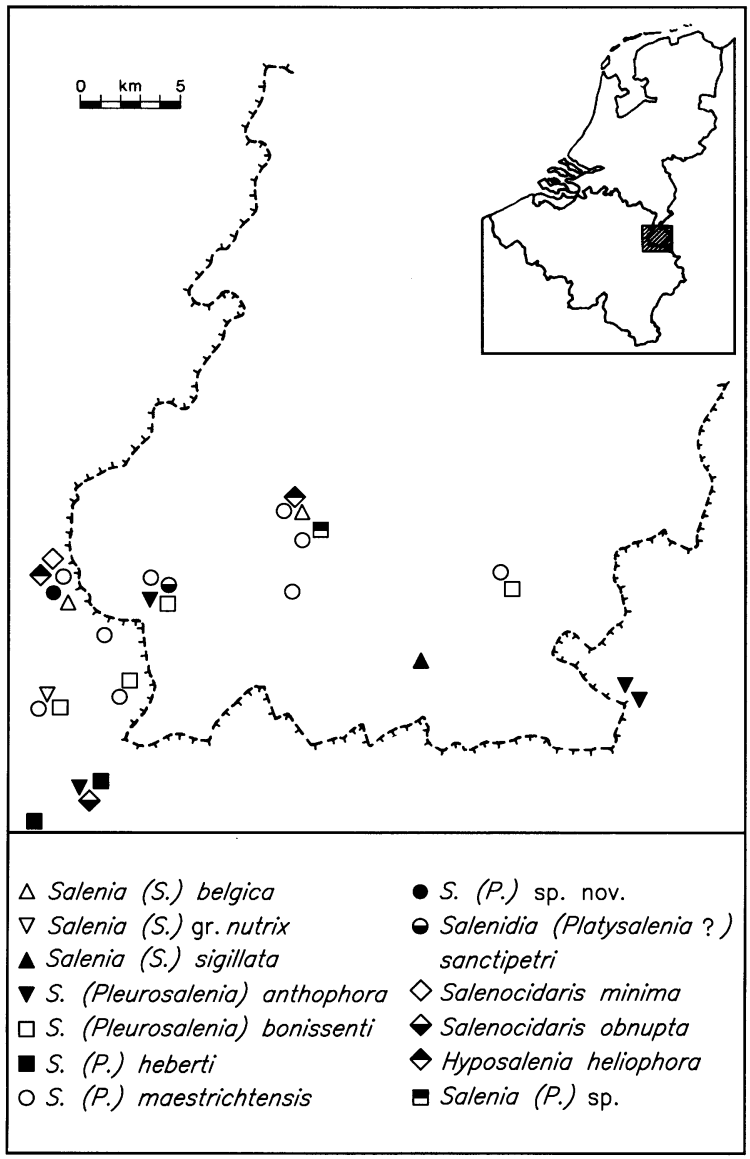


Fig. 4. Geographic distribution of Late Cretaceous-Early Palaeogene saleniid echinoids in the type area of the Maastrichtian Stage.

served individuals have been collected, and a few have been shown to preserve (parts of) their lanterns (see Pl. 7, figs. 7, 9).

Occurrence — Confined to the Geulhem Member, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 4, 23).

Order Arbacioida Gregory, 1900
Suborder Arbaciina Gregory, 1900
Family Arbaciidae Gray, 1855
Genus *Codiopsis* L. Agassiz, 1840

Type species — *Echinus doma* Desmarest, in Defrance, 1825, by subsequent designation of Lambert & Thiéry (1914, p. 263).

Codiopsis disculus Peron & Gauthier, 1881
Pl. 8, figs. 1-5.

*1881 *Codiopsis disculus* Peron & Gauthier, in Cotteau et al., p. 179, pl. 19, figs. 11-12.
*1914 *Codiopsis bruni* Lambert, in Lambert & Thiéry, p. 264, pl. 7, figs. 10-13.
*1935b *Codiopsis pierrensis* Smiser, p. 35, pl. 3, fig. 2.
1981 *Codiopsis bruni* J. Lambert, 1914 — Geys, p. 258, fig. 1/1-5.
in press *Codiopsis disculus* Peron & Gauthier, 1881 — Smith & Jeffery, figs. 39a-d, 40d (cum syn.).

Type — The present whereabouts of Peron & Gauthier's material is unknown, neither is that of *C. bruni*; holotype of *C. pierrensis* is IRScNB 9122 (IG 4285, Bosquet Colln; Smiser, 1935, pl. 3, fig. 2), paratype is IRScNB 9123 (IG 4285).

Material — IRScNB 9122, 9123; NHMM: BL 0111, K 645, 1778, MM 0073, 0251, and NHMM 1999008.

Description — Test small to medium-sized (up to 40 mm in diameter), distinctly subpentagonal in plan view, domal in profile, height equalling c. 60% of diameter. Apical disc of moderate size, lightly granular, with a single large pustule at centre of each ocular plate, but no ridges; periproctal opening pentagonal. Ambulacra trigeminate from ambitus adapically; phyllodes adorally. Primary tubercles occur only up to ambitus. Interambulacral plates have single primary tubercle on each plate up to ambitus, in a distinct V-shaped pattern. Aboral surface lacking large tubercles, but with very small sunken tubercles forming horizontal rows, and dense ridge-like epistroma; primary tubercles connected by vertical epistromal ridges, which form characteristic keels. Small calcite pegs attached to sunken tubercles, but are generally damaged. Buccal notches associated with long tongues.

Discussion — Easily recognised, even in fragmentary material, on account of tubercles being restricted to the lower test surface and the occurrence of epistromal ridges, arranged in keels.

Occurrence — Known only from the Nekum and Meerssen members, and the Kunrade Limestone facies of the Maastricht Formation, at the CBR-Romontbos, ENCI-Nederland BV, and Blom quarries, and the Kunrade-Benzenrade area (Figs. 2, 19-20, 22).

Family Acropeltidae Lambert & Thiéry, 1914
Genus *Goniopygus* L. Agassiz, 1838

Type species — *Salenia peltata* L. Agassiz, 1836, by subsequent designation of Lambert & Thiéry (1914, p. 268).

Goniopygus heberti Cotteau, 1866
Pl. 8, fig. 6.

*1866 *Goniopygus heberti* Cotteau, p. 758, pl. 1184, figs. 17-22.
1988a *Goniopygus heberti* Cotteau, 1866 — van der Ham, p. 146, pl. 6, figs. 15-18.
in press *Goniopygus heberti* Cotteau, 1866 — Smith & Jeffery, fig. 33d.

Type — The present whereabouts of Cotteau's original material is unknown.

Material — NHMM MB 432-C.

Description — Test small (up to 7 mm in diameter); similar to *G. minor* (see below), both in test and apical disc structure, but differing in having a series (3-6) of small pits, along all apical disc sutures; periproct subcentral, bordered by three depressions, each with a tubercle; ambulacra trigeminate, up to 6 interambulacral and up to 9 ambulacral plates in a column; sparse secondary tuberculation. Probably not sexually dimorphic.

Occurrence — Confined to the upper Geulhem Member, with records from the temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt (Fig. 2).

Goniopygus minor Sorignet, 1850
Pl. 8, figs. 7-8.

*1850 *Goniopygus minor* Sorignet, p. 23.
1981 *Goniopygus minor* Sorignet, 1850 — Geys, p. 264, fig. 4/1-6.
1981 *Goniopygus eravillensis* H. Arnaud (in G. Cotteau, 1889) — Geys, p. 267, fig. 8/1-6.
1988a *Goniopygus minor* Sorignet, 1850 — van der Ham, p. 148, pl. 6, figs. 1-14.
1994 *Goniopygus minor* Sorignet, 1850 — Jagt & van der Ham, p. 725, pl. 1, figs. 1-6.
in press *Goniopygus minor* Sorignet, 1850 — Smith & Jeffery, fig. 33a-c (cum syn.).

Type — The present whereabouts of Sorignet's original material is unknown.

Material — IRScNB 9100 (IG 4285, Bosquet Colln), 10181-10183 (IG 8695); and NHMM MB 432-A.

Description — Test small (up to 17 mm in diameter), subconical in profile; apical disc flat to slightly convex, smooth (no pitting), with subcentral, trigonal periproct, bordered by three depressions, each with a tubercle; gonopores at boundary between genital and interambulacral plates; ocular plates square, projecting beyond genital plates, causing the disc to appear pentastellate. Ambulacra trigeminate with large primary tubercles only, contiguous except ambitally and subambitally where small secondary tubercle may occur. Interambulacra with up to 9 plates in column, upper 3 plates having only primary tubercles, other plates with 5 small, scrobicular tubercles surrounding large primary tubercle. Peristome not sunken, relatively large, with slight pore crowding. Adapical interambulacra in females depressed (brood pouches), with gonopore at bottom.

Occurrence — Confined to the upper Geulhem Member, with records from the temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt (Fig. 2).

Goniopygus sp. nov.
Pl. 8, fig. 9.

1987 *Goniopygus* sp. — van der Ham et al., p. 26, pl. 6, fig. 7.

Material — NHMM: JJ 8336/2, K 2284, and MM 1040.

Description — Test small (up to c. 10 mm in diameter); apical disc with distinct, sunken tubercles, and 2 or 3 large pits per suture. This is the only representative of this genus to have been recorded from the Upper Maastrichtian of the study area. Van der Ham (1988a, p. 146) noted that the Early Palaeocene *G. heberti* (see above) was close to the present form, but differed in having 3-6 pits per suture.

This species will be described in the near future.

Occurrence — Confined to the Meerssen Member (Maastricht Formation), with records from the ENCI-Maastricht BV and Blom quarries (Figs. 2, 20, 22).

Order Phymosomatoida Mortensen, 1904
Family Phymosomatidae Pomel, 1883
Subfamily Phymosomatinae Pomel, 1883
Genus *Phymosoma* Haime, in d'Archiac & Haime, 1853

Type species — *Cidaris königii* Mantell, 1822, by subsequent designation of Lambert & Thiéry (1911, p. 223).

Phymosoma gr. *granulosum* (Goldfuss, 1829)
Pl. 9, figs. 1-6; Pl. 10, figs. 13-14.

*1829 *Cidarites granulosus* Goldfuss, p. 122, pl. 40, fig. 7.
*1846 *Cyphosoma tiara* Agassiz, in L. Agassiz & Desor, p. 351.
1928 *Phymosoma granulosum* Goldf. sp. — Ravn, p. 55, pl. 6, figs. 3, 6-10.
1980 *Phymosoma corneti* (Cotteau, 1874) — Geys, p. 200 (partim), fig. 1/1-5 only.
1980 *Phymosoma granulosum* (Goldfuss, 1826) — Geys, p. 204, fig. 1/7; fig. 2/1-4.
non1985b *Rachiosoma granulosa* (Goldfuss, 1826) — Kutscher, p. 525, pl. 2, figs. 7-12.
?1986 *Rachiosoma corollare* (Leske, 1778) sensu Cotteau, 1865 — Geys & Jagt, p. 99, figs. 3a-i, 4a-b.
1987 *Phymosoma* sp. 1 — van der Ham et al., p. 23, pl. 3, fig. 6.
1987 *Phymosoma* sp. 2 — van der Ham et al., p. 23, pl. 3, fig. 9.
1988a *Phymosoma* sp. — van der Ham, p. 140, pl. 4, figs. 1-4.
1992 *Rachiosoma corollare* (Leske, 1778) sensu Cotteau, 1865 — van der Ham & van Birgelen, p. 149, pl. 2, figs. 1-2.
1996 *Phymosoma granulosum* (Goldfuss, 1829) — Smith & Wright, p. 286, pl. 99, figs. 1-6; text-fig. 100 (cum syn.).
1997b *Phymosoma granulosum* (Goldfuss, 1829) — Jeffery, p. 672, pl. 3, figs. 1-5; text-fig. 5a-b (cum syn.).
in press *Phymosoma granulosum* (Goldfuss, 1829) — Smith & Jeffery, fig. 44 (cum syn.).

Type — Holotype, by monotypy, is RFWUIP Goldfuss Colln, no. 1335 (Goldfuss, 1829, pl. 40, fig. 7); the specimen is a large phymosomatid, partially embedded in matrix. After a recent re-examination of this specimen, I have serious doubts about it having come from the Maastricht area (see Discussion). A plaster cast of Cotteau's

(1865, p. 669, pl. 1165, figs. 1-5) *Phymosoma corollare* is IRScNB 10155, and lectotype of *C. tiara* is no. M6 in the Agassiz Colln (Neuchâtel).

Material — IRScNB 10172 (IG 6521), 10173 (IG 5496); NHMM: GK 4565 (W.M. Felder Colln), JJ 1098, 1286, 2462, 2464, 2656, 3475, 6043, 6334, 7857, 8256, and MB 432-U.

Description — Test medium-sized (up to 50 mm in diameter, but generally smaller), subpentagonal to circular in outline, height 35-40% of diameter, ambitus at or slightly above midheight; apical disc invariably missing, c. 50% of test diameter. Ambulacra tapering adapically and adorally; lowest 4-6 pore pairs crowd to form short phyllodes; ambital and supra-ambital plates have arcs of 5-6 pore pairs, adapically (on the highest four plates), pairs become biserially arranged; each ambulacral plate with large primary tubercle occupying almost entire plate height and width, leaving only narrow perradial granular zone. Ten or eleven interambulacral plates in a column, wider than tall, with large primary tubercle with stout, strongly crenulate mamelon. Small secondary tubercles of various sizes occur adradially, 2-4 adorally, 1 adapically. Interradial granulation only weakly developed, consisting of near-equal sized granules and miliaries, and a broad adapical naked zone. Peristome about 30-35% of test diameter, circular, only very faintly invaginated.

Discussion — As noted above, the type specimen of *Cidarites granulosus* is probably not from the Maastricht area. Smith & Wright (1996, p. 286) pointed out that there are at least two syntypes of this taxon, one from the Tourtia (= Cenomanian) of Essen (Germany) and the other from 'Maastricht'. Schlüter (1883, p. 6, pl. 2, figs. 6-10) referred Goldfuss's Cenomanian specimen to his new species, *Phymosoma goldfussi* (RFWUIP Schlüter Colln, no. 221). Of note, is that Schlüter (p. 8) remarked that, 'Von *Cidarites granulosus* Goldf. befindet sich nur ein Originalstück in Bonn. Es ist ein halbes Gehäuse, an dem die obere Partie fehlt. Dasselbe soll von Maestricht stammen, wogegen die Gesteinsbeschaffenheit nicht spricht. [.....] und das Peristom ist ein wenig eingesenkt.' In spite of these uncertainties, Smith & Wright (1996) were of the opinion that, '.... later workers have used this name (= *P. granulosum*) consistently and the species is well established.' Their view of this species as a (? Late) Campanian taxon is here followed.

Referred to this group are all Campanian, Maastrichtian and Danian phymosomatids that correspond to the above description. However, there are subtle (? gradational) differences in test ornament and ambulacral plating (e.g. phyllode structure). The most striking difference between the various specimens from the Maastricht area and material illustrated by Smith & Wright (1996, pl. 99, figs. 1-6) and Jeffery (1997b, pl. 3, figs. 1-5) is the size of the mamelons of ambulacral and interambulacral primary tubercles. Specimens from the Zeven Wegen Member, referred to *Rachiosoma corollare* by Geys & Jagt (1986) have slightly smaller mamelons than those from the Kunrade Limestone facies, recorded by van der Ham et al. (1987) as *Phymosoma* sp. 1. The specimen figured by van der Ham & van Birgelen (1992, pl. 2, fig. 1) from the ?Vijlen Member of Aachen-Schneeberg shows stout mamelons and thus corresponds closely to 'genuine' *P. granulosum*, as does material from the Geulhem Member illustrated by van der Ham (1988a, pl. 4, figs. 1-4).

Jeffery (1997b) recorded specimens of *P. granulosum* from the uppermost Maastrichtian of Kazakhstan, noted it to range from the Campanian to Palaeocene of NW

Europe, and remarked that *P. corneti* has extensive zones of miliaries adradially and interradially, thus differing from *P. granulosum*. Geys (1980) referred material from the 'Craie d'Obourg' (= Campanian) to *P. corneti*, and this is undoubtedly conspecific with specimens from the Zeven Wegen Member in the Haccourt-Lixhe area (= *Rachiosoma corollare* in Geys & Jagt, 1986). *Cyphosoma tiara* was based on material from Meudon (France) and is of Late Campanian age as well. The 'real' *Cyphosoma corneti* is here considered to be conspecific with *Cyphosoma rutoti* Lambert, 1898, and referred to the genus *Trochalosoma* (see below).

In view of the rather subtle (and ?gradational) differences between the various populations of Campanian, Maastrichtian and Early Palaeocene age, these are here all referred to a single taxon.

Occurrence — Zeven Wegen and Vijlen members (Gulpen Formation) of Heure-le-Romain, Aachen-Schneeberg, and the CPL SA and CBR-Lixhe quarries, as well as Kunrade Limestone facies of the Kunrade-Benzenrade area, and the upper Geulhem Member of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Figs. 5, 16-17).

Genus *Diplotagma* Schlüter, 1870
[= *Lambertechinus* Cossmann, 1899]

Type species — *Diplotagma altum* Schlüter, 1870, by monotypy.

Diplotagma sp. nov.

Material — Two specimens, BMNH E3186 and Snellings Colln, no. G54.

Description and discussion — Of this new species, to be formally named by Smith & Jeffery (in press), two specimens are known, one from Glons, the other from the Millen area (both Limburg, Belgium), southeast of Maastricht.

Occurrence — Probably both from the middle portion of the Maastricht Formation (? Emael Member).

Genus *Gauthieria* Lambert, 1888
[= *Hemithylus* Arnaud, 1896]

Type species — *Cyphosoma radiatum* Sorignet, 1850, by original designation.

Gauthieria grossouvrei (Lambert, 1898)
Pl. 9, figs. 7-8, 11, 14.

*1898 *Rachiosoma grossouvrei* Lambert, p. 154, pl. 3, figs. 11-15.
1987 Phymosomatoida sp. 3 — van der Ham et al., p. 25, pl. 5, fig. 1.
1987 Phymosomatoida sp. 4 — van der Ham et al., p. 25, pl. 3, fig. 4.
1988a Phymosomatoida sp. — van der Ham, p. 144, pl. 5, figs. 1-5.
1988a Phymosomatoida sp. — van der Ham, p. 144, pl. 5, figs. 6-8.
in press *Gauthieria grossouvrei* (Lambert, 1898) — Smith & Jeffery, fig. 47 (cum syn.).

Type — Holotype, by monotypy, is the original of Lambert's pl. 3, figs. 11-15, which should be in the IRScNB collections.

Material — NHMM JJ 3859, MB 432-P, and 432-Q.

Description — Test medium-sized (up to 26 mm in diameter), moderately flattened, ambitus at or slightly below midheight; periproct pentagonal. Ambulacra tapering adapically and adorally, uniserial throughout, up to 10 plates in a column. Pore pairs linear adapically, in arcs of 4-5 ambitally, compounding of 4 elements united by primary tubercle, and separated by simple element with secondary tubercles and granulation. Size of primary tubercles decreases adapically. Up to 12 interambulacral plates in a column, plates slightly wider than tall; ambital plates with large primary tubercle, adoral plates with smaller primaries and a distinct adradial row of secondaries, c. 3 per plate. Adapical plates also with smaller primary tubercles, with entire surface covered in dense miliary granulation; no naked zone interradially. Peristome relatively small and invaginated, with distinct buccal notches.

Discussion — Van der Ham (1988a) noted the dense adapical granulation, and the relatively small size of the adapical tubercles in his Phymosomatoida sp., and the barely sunken peristome in his Phymosomatoida sp. (pl. 5, figs. 6-8). These forms are here grouped together, despite slight differences. The distinguishing feature is the dense, prominent adapical granulation, and absence of a naked, aboral interradial zone.

Occurrence — Confined to the Geulhem Member, with records from the temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, and the Ankerpoort-Curfs quarry (Figs. 5, 23).

Gauthieria maeandrina (Schlüter, 1883)
Pl. 11, figs. 1-2.

*1883 *Phymosoma maeandrinum* Schlüter, p. 25, pl. 3, figs. 6-10.
1980 *Porosoma*? *maeandrinum* (Schlüter, 1881) — Geys, p. 218, figs. 5/4-5, 6/2-3.
in press *Gauthieria maeandrina* (Schlüter, 1883) — Smith & Jeffery, fig. 48.

Type — Holotype is IRScNB 9118 (IG 6521, Ubaghs Colln) (Geys, 1980, fig. 5/4-5; fig. 6/2-3).

Material — NHMM BL 0583c, 0633, and KK 499 (W.M. Felder Colln).

Description — Test medium-sized (up to 40 mm in diameter), circular in outline, inflated, height c. 40% of diameter; ambitus just below midheight. Apical disc pentagonal, small (less than 30% of test diameter). Ambulacra tapering both adapically and adorally, near peristome forming short phyllode; markedly sinuous from ambitus adapically in arcs of six; compounding consists of 4-5 elements separated by 1-3 simple elements with secondary tubercles and granules only. Primary tubercles with large circular areoles, widely separated ambitally. Nine interambulacral plates in a column, only slightly wider than tall ambitally; primary tubercles strongly crenulate, separated by relatively broad granular zones, and with equally broad adradial and interradial bands of granulation. Adapically, a distinct naked interradial zone. Peristome circular, faintly sunken, c. 35-40% of test diameter.

Occurrence — At present, known only from the Kunrade Limestone facies (Maastricht Formation) of the Kunrade/Benzenrade area (Fig. 5).

Gauthieria mosae Geys, 1980
Pl. 10, figs. 8-11.

*1980 *Gauthieria*? *mosae* Geys, p. 215, fig. 5/1-3; fig. 6/1.

Type — Holotype is IRScNB 10178 (IG 6521, Ubaghs Colln) (Geys, 1980, figs. 5/1-3, 6/1).

Material — NHMM JJ 7457, 7643, 8257, and K 1001.

Description — Test medium-sized (up to c. 27 mm in diameter), subpentagonal to subcircular in outline, depressed in profile; ambitus at midheight. Ambulacra tapering both adapically and adorally. Pore pairs uniserial throughout, in arcs of 3-4 adapically, with 1-2 intercalated single plates with granules only, and in arcs of 5-6 ambitally. Adoral surface concave; peristome circular, deeply invaginated, with small but distinct buccal notches. Seven or eight crenulate ambulacral primary tubercles in a column, with large scrobicules, smooth perradially, and with radiating grooves adradially. Pore zone very narrow; perradial extrascrobicular zones are discontinuous, and adjacent scrobicules often confluent. In same series, scrobicules are more widely spaced, separated by wide, densely but irregularly granular surface. Eight to nine interambulacral plates in a column; primary tubercles crenulate, mamelons markedly decreasing in size adapically, scrobicules large but not confluent; narrow, sinuous and denser granulate extrascrobicular zone separating them interradially; adradially a single vertical row of granules, and a single secondary tubercle. Along adradial suture, a few small secondaries adorally. Scrobicules of same series separated by very wide, densely granular zone.

Discussion — Geys (1980, p. 216), later followed by Smith & Wright (1996, p. 302), stated that the holotype did not preserve the adapical test portion. However, I have recently removed the white chalk matrix from the upper surface, which revealed the pore pairs to remain uniserial, and the absence of large secondary tubercles on the adapical interambulacral plates, which Smith & Wright (1996, p. 300, pl. 106, figs. 4-6; pl. 107, figs. 4-6; text-fig. 108) noted to be typical of *G. middletoni*, a species originally described from the Upper Campanian (*Belemnitella mucronata* Zone) of Norfolk. Thus, Smith & Wright's (1996) assumption that *G. mosae* was conspecific with *G. middletoni* cannot be confirmed, which is why the former is here considered to represent a distinct species.

Occurrence — Apparently confined to the Zeven Wegen Member (Gulpen Formation) of Heure-le-Romain, and the CPL SA and CBR-Lixhe quarries (Figs. 5, 16-17).

Gauthieria pseudoradiata auctt., non Schlüter, 1883 ?
Pl. 12, figs. 1-11; Pl. 13, figs. 1-2.

compare

1881 *Phymosoma pseudoradiatum* Schlüter, p. 216 (nomen nudum).
*1883 *Cyphosoma pseudoradiatum* Schlüter, p. 24.
1928 *Phymosoma pseudoradiatum* Schlüt. — Ravn, p. 58, pl. 6, fig. 4.
1980 *Gauthieria radiata broecki* Lambert, 1897 — Geys, p. 210, fig. 3/3-6.
1980 *Gauthieria pseudoradiata* (Schlüter, 1883) — Geys, p. 212, fig. 3/7-9; fig. 4/1-2.
?1980 *Gauthieria*? *spatulifera* (Forbes, 1850) — Geys, p. 214, fig. 4/3-7.

1985c *Gauthieria radiata* (Sorignet, 1850) — Kutscher, p. 731, pl. 1, figs. 1-3.
?1985c *Gauthieria*? *pseudoradiata* (Schlüter, 1883) — Kutscher, p. 731, pl. 1, figs. 4-8.
1987 *Gauthieria pseudoradiata* (Schlüter, 1883) — van der Ham et al., p. 23, pl. 4, figs. 1-2.
1987 *Gauthieria radiata* (Sorignet, 1850) — van der Ham et al., p. 23, pl. 4, fig. 3.
1992 *Gauthieria pseudoradiata* (Schlüter, 1883) — van der Ham & van Birgelen, p. 148, pl. 2, figs. 3-4.
1994 *Gauthieria* gr. *radiata* auctt. — Jagt & Michels, p. 719, pl. 1, figs. 5-6.
1996 *Gauthieria pseudoradiata* (Schlüter, 1881) — Smith & Wright, p. 303, pl. 106, figs. 7-9; pl. 107, figs. 2-3; pl. 113, figs 16-18; text-fig. 109 (cum syn.).
1997b *Gauthieria pseudoradiata* (Schlüter, 1883) — Jeffery, p. 674, pl. 4, figs. 1-5; text-fig. 6a-b.
in press *Gauthieria pseudoradiata* (Schlüter, 1883) — Smith & Jeffery, fig. 50.

Type — Schlüter (1883) did not select a type; as far as I know, no lectotype has yet been designated.

Material — Several dozens of specimens in various collections, including IRScNB 10176 (IG 4285), NHMM: JJ 776, 792, 1105, 3139, 3390, 3489, 3892, 4031, 6785, 6832, 6987, 6990, 8885, K 1881, 1882, 2432, 2433, 4276(1), 4276(2), MD 3467, MM 1206, 1208, and RGM 428 056.

Description — Test small to medium-sized (up to 26 mm in diameter); subpentagonal to circular in outline, low domal in profile, ambitus at or slightly below mid-height. Apical disc opening medium-sized, almost half of test diameter, pentagonal. Ambulacra tapering adapically and adorally, with pore pairs arranged in weak arcs of 4-5 at ambitus, but more linear adapically and adorally; ambulacral elements united by a primary tubercle at ambitus and separated by a simple element with granules only. Ambulacral plating trigeminate adorally and adapically, with each trigeminate plate separated by 1-2 simple plates with granules only. Ten or eleven interambulacral plates in a column, with tubercles circular ambitally, confluent or separated by narrow band of granules. Adradially occur small secondary tubercles subambitally, but absent adapically, where uniform granulation is present. Wedge-shaped, naked interradial zone distinct. Peristome relatively small, (sub)circular and invaginated.

Discussion — Grouped under this heading are all phymosomatids with strictly uniserial pore pairs throughout, a (strongly) invaginated peristome, and no or slight phyllode development. Interambulacra have single large primary tubercles with incised, either contiguous or noncontiguous areoles ambitally and adapically, and adorally an adradial band of small secondary tubercles.

Careful reading of Schlüter (1883, p. 24) shows that that author intended the name *Phymosoma pseudoradiatum* for larger-sized (27 mm) forms that had no multiple horizontal rows of granules separating ambulacral plates, but whose adapical interambulacral tubercles were displaced to the plate centre, to allow for a lateral band of granules, as well as a smaller and less deeply sunken peristome. The type came from the 'Kreidemergel mit *Belemnitella mucronata* bei Ahlten', which would mean a Late Campanian age.

Smith & Wright (1996) recorded material from the Upper Santonian to Upper Campanian of England under this name, and noted the ambitus to lie above mid-height, with the test appearing undercut in profile, and two or three ambital plates in each interambulacrum to be much enlarged with large, oval areoles. Such a morphology characterises material from the Lower Campanian of the Hannover area (Germany), and shows broad zones of granules separating ambulacral plates. Similar

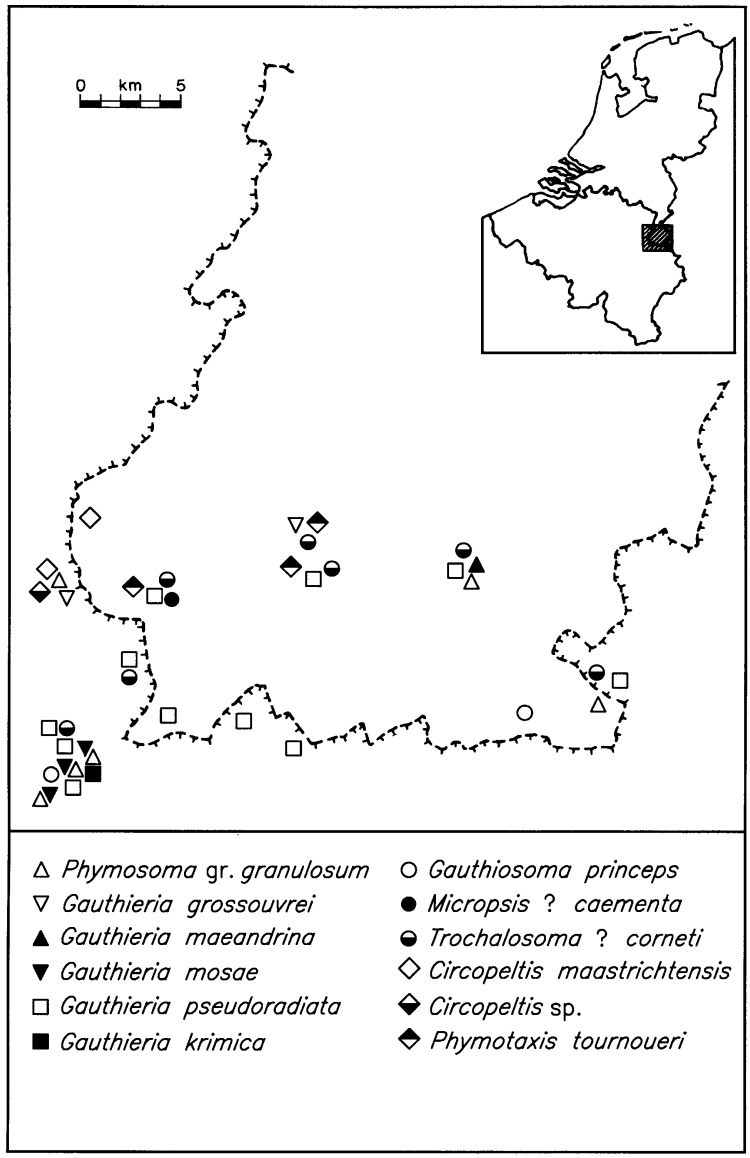


Fig. 5. Geographic distribution of Late Cretaceous-Early Palaeogene phymosomatoid echinoids in the type area of the Maastrichtian Stage.

forms were recorded by Jeffery (1997b, p. 674) from the Maastrichtian of Kazakhstan. These, obviously, do not correspond to Schlüter's original definition. Kutscher (1985c) used the name *G. radiata* for comparable specimens from the Lower Maastrichtian of Rügen, and assigned to *G.*? *pseudoradiata* forms in which pore pairs were positioned almost vertically adorally, and with a single row of granules separating ambulacral areoles.

Van der Ham et al. (1987, p. 23) noted that material from the Upper Cretaceous of the Maastrichtian type area comprised two morphologies, one assigned to *G. pseudoradiata* characterised by tests up to 25 mm in diameter, with adapical pore pairs uniserial, adorally in a wide zone (see e.g. van der Ham et al., 1987, pl. 4, figs. 1-2; van der Ham & de Wit, 1998, pl. 20, fig. 4a, c), with up to 10 crenulate interambulacral tubercles in a column, within a single series either confluent or separated by a single row of granules, and the adoralmost interambulacral plates with a few small secondary tubercles. The other form, assigned to *G. radiata*, has tests up to 23 mm in diameter, with uniserial pore pairs throughout (see e.g. van der Ham & de Wit, 1998, pl. 20, fig. 4b, d), up to 10 crenulate tubercles in a column, within a series either confluent or separated by 1-2 rows of granules, secondary tubercles hardly recognisable. Van der Ham & van Birgelen (1992, p. 148) rightly noted how difficult the identification of species of *Gauthieria* really is, and pointed out that a modern revision was called for, which should include foreign material and type specimens.

In this respect, it is of note that their material corresponds closely to specimens available for the present study, collected mainly from the Vijlen and Gronsveld members. None of these specimens corresponds to Smith & Wright's (1996) definition of *G. pseudoradiata*, but are apparently closer to Schlüter's original meaning of this form. An additional complicating factor is the occurrence of juvenile or subadult forms of other phymosomatids, which might be confused with *Gauthieria*. Kutscher (1985c) presented a number of examples.

In view of all these uncertainties, all medium-sized phymosomatids with uniserial ambulacral plating throughout (inclusive of forms with offset adoral pore pairs, and/or almost vertically arranged), and with deeply invaginated, small periproct, large pentagonal apical disc opening, and interambulacral and ambulacral areoles either confluent (especially ambitally) or separated by a single row of heterogeneous granules, are here grouped under *G. pseudoradiata*. It is realised that this is undoubtedly an oversimplification of real relationships; a modern revision should include material from as many localities and stratigraphic levels possible, and start from the original concept of the various taxa.

Occurrence — As here understood, this species is widely distributed and long ranging, with records from the ?Vaals Formation, the Vijlen, Lixhe, and Lanaye members (Gulpen Formation), the Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members, as well as Kunrade Limestone facies of the Maastricht Formation, at the CPL SA, CBR-Lixhe, CBR-Romontbos, Ankerpoort-Marnebel, and ENCI-Maastricht BV quarries, as well as at Mesch, Altembroeck, Snouwenberg, and Aachen-Schneeberg (Figs. 5, 16-22).

Genus *Gauthiosoma* Kutscher, 1985b

Type species — *Cidaris (Diadema) princeps* von Hagenow, 1840, by original designation.

Gauthiosoma princeps (von Hagenow, 1840)
Pl. 10, figs. 1, 4-7.

*1840 *Cidarites (Diadema) princeps* von Hagenow, pp. 651, 658.

non1980 *Phymosoma princeps* (v. Hagenow, 1840) — Geys, p. 207, fig. 2/5-6; fig. 3/1-2.
1985b *Gauthiosoma princeps* (v. Hagenow, 1840) — Kutscher, p. 524, pl. 1, figs. 1-5.
1996 *Gauthieria princeps* (Hagenow, 1840) — Smith & Wright, p. 305, pl. 106, figs. 1-3; pl. 108, figs. 1-6; pl. 109, figs. 1-2, 5; text-figs. 110-111 (cum syn.).
in press *Gauthiosoma princeps* (von Hagenow, 1840) — Smith & Jeffery, fig. 53.

Type — A lectotype has not yet been designated; Smith & Wright (1996, p. 305) noted that it is not clear how many syntypes von Hagenow had.

Material — NHMM: GK 1264 (W.M. Felder Colln), DE 051, and JJ 2461.

Description — Of this rare species, two forms may be distinguished in the material available, one of early Late Campanian, the other of Early Maastrichtian age.

Form 1 (Pl. 10, fig. 1): Test medium-sized (c. 40 mm in diameter), height c. 50% of diameter, subcircular in outline; ambulacra tapering adapically and adorally, with large primary tubercle with circular areole; pore pairs in arcs of six ambitally. Pore pairs irregularly biserial adapically, uniserial adorally, no phyllode development; 13-14 interambulacral plates in a column, with one small secondary tubercle on ambital and adoral plates. Adoral tubercles with relatively small mamelons. Interambulacral adradial and interradial granulation well developed, but the latter disappearing supra-ambitally; wide, naked adapical interradial zone, slightly depressed. Peristome small, deeply sunken, less than 25% of test diameter.

Form 2 (Pl. 10, figs. 4-7): Test medium-sized (c. 42 mm in diameter), height c. 50% of diameter, circular in outline, ambitus below midheight; apical disc opening large and pentagonal; ambulacra tapering adapically and adorally, with large primary tubercle with circular areole; pore pairs in arcs of 6-7 ambitally. Pore pairs irregularly biserial adapically, uniserial adorally, very slight crowding (?); 11-12 interambulacral plates in a column, with one to three small secondary tubercles on ambital and adoral plates. Adoral tubercles with relatively small mamelons. Interambulacral adradial and interradial granulation well developed, but the latter disappearing supra-ambitally; wide, naked adapical interradial zone, slightly depressed. Peristome small, deeply sunken, c. 28% of test diameter.

Discussion — On account of small, deeply invaginated peristome, uniserial ambulacral platin adorally and (irregularly) biserial adapically, the present species is easily distinguished from co-occurring phymosomatoids. Form 1 corresponds closely to material recorded from the Lower Maastrichtian of Rügen by Kutscher (1985b) and of Norfolk by Smith & Wright (1996). Form 2 corresponds to BMNH E39802 (see Smith & Wright, 1996, pl. 106, figs. 1-3) from the lower *Belemnitella mucronata* Zone of Earlham quarry, Norwich (Norfolk, England), in showing slightly coarser adradial and interradial granulation.

Geys (1980, p. 207) recorded '*Phymosoma*' *princeps* from the Kunrade Limestone facies; this record is based on a misidentification. In the present paper, such specimens are referred to *Phymosoma* gr. *granulosum* (see Pl. 10, figs. 13-14). The specimen in Geys's fig. 2/5-6 (IRScNB 10174, IG 4919), from the Lower Campanian Trivières Chalk of the Mons Basin (southern Belgium), seems better assigned to *Phymosoma koenigii* (Mantell, 1822) (compare Smith & Wright, 1996, p. 280, pl. 95, figs. 5-6; pl. 96, figs. 1-7; pl. 97, figs. 1-6; pl. 98, figs. 1-4; text-figs. 91a, 96-99), which extends to the Lower Campanian in England.

Occurrence — Form 1 of Early Maastrichtian age is known from a single fragmen-

tary test from the Vijlen Member at Vijlenerbosch, form 2 of early Late Campanian age from the Zeven Wegen Member (Gulpen Formation) at the CPL SA quarry (Haccourt) (Figs. 5, 16).

Gauthiosoma krimica (Weber, 1934) ?
Pl. 10, figs. 2-3.

*1934 *Rachiosoma krimica* Weber, p. 64, pl. 10, fig. 3.
*1983 *Rachiosoma gigasei* Geys, p. 255, pl. 1, figs. 1-6.
in press *Gauthiosoma krimica* (Weber, 1934) — Smith & Jeffery, fig. 54.

Type — Holotype of *R. krimica*, by monotypy, is the original of Weber (1934, pl. 10, fig. 3) whose present whereabouts is unknown; holotype of *R. gigasei* is IRScNB 10204 (Geys, 1983, pl. 1, figs. 1-6).

Description — Test medium-sized (c. 37 mm in diameter), subpentagonal in outline, regularly rounded in profile, ambitus just below midheight; adoral surface deeply invaginated, adapical side dome shaped and convex. Peristome apparently circular, of moderate size; apical disc opening pentagonal, relatively small. Sixteen or seventeen ambulacral plates in a column, scrobicular areoles confluent; radiating grooves prominent adradially. Pore zones unigeminate throughout, in weak arcs of 5 ambitally, and almost linearly arranged adapically. Perradial extrascrobicular surfaces narrow, with dense, coarse granulation. Sixteen or seventeen interambulacral plates in a column, scrobicular areoles confluent. Interradial extrascrobicular surfaces moderately wide and densely granular ambitally. Adradially occurs a regular series of small secondaries.

Discussion — Smith & Jeffery (in press) are followed in considering *R. gigasei* closely related, if not conspecific with *R. krimica*, of which most specimens show uniserial pore pair arrangement to the apex. Only occasionally is biseriality developed in the latter species, which was originally described from the Lower Palaeocene of Crimea (the Ukraine). Of *R. gigasei* so far, only a single specimen has been recorded, and this is rather poorly preserved and also of unknown stratigraphic provenance. Geys (1983) indicated the type to have come either from the Vijlen or Lixhe members, but it cannot be ruled out that it actually came from the Zeven Wegen Member, and would thus be of Late Campanian age. This would increase the stratigraphic gap between *R. gigasei* and *R. krimica* even further. Additional material is needed to establish the relationship between these two species in detail; for the time being, they are here synonymised.

Occurrence — Apparently confined to the ?Zeven Wegen Member of the Haccourt-Lixhe area (Fig. 5).

Genus *Micropsis* Cotteau, in Leymerie & Cotteau, 1856

Type species — *Leiosoma desori* Cotteau, in Leymerie & Cotteau, 1856, by monotypy.

Micropsis? *caementum* Jagt & van der Ham, sp. nov.
Pl. 12, figs. 12-13.

Type — Holotype is NHMM K 2681 (Pl. 12, figs. 12-13).

Type locality and horizon — ENCI-Maastricht quarry, Maastricht; Maastricht Formation, Emael Member (*junior* Zone auctt.).

Derivation of name — Lat. *caementum*, meaning stone from the quarry, in reference to the ENCI-Maastricht BV quarry.

Diagnosis — A species of *Micropsis*? with quinquegeminate ambulacral plating, pore pairs in oblique rows of four ?ambitally, and one large and one small tubercle; fairly dense secondary tuberculation and granulation on interambulacral and ambulacral plates.

Material — The Indeherberge Colln contains two fragmentary external flint moulds (nos 4602-4603, ?same individual) from Sluizen (Tongeren area, Belgium) that belong here.

Description — Although the present specimens consist of test fragments only (preserving six interambulacral and five ambulacral plates; 7 interambulacral, and part of lower portion of interambulacra and adjacent ambulacra, respectively), details of ornament and ambulacral plating are well enough preserved to form the basis of a new taxon. Judging from these fragments the test must have been inflated (compare e.g. *M. desori* and *M. microstoma* in Cotteau, 1865, pls 1171-1172). Ambulacra are uniserial in these fragments, with quadrigeminate plating, and considerably narrower than interambulacra, consisting of alternating simple element bearing granules and compound plates with primary tubercles. Interambulacral plates much wider than tall, primary tubercles centrally positioned, either more or less confluent or separated by shallow depression; all tubercles crenulate, imperforate, adapically decreasing markedly in size. Adradially of these occur secondary tubercles, half to one third the size of primaries, not decreasing in size adapically or hardly so. Remainder of plate covered with secondaries and granules of varying size, leaving conspicuous interradial and adradial naked zones on interambulacral plates. Size of ambulacral and interambulacral tubercles (nearly) equal, separated by simple elements, bearing granules; conspicuous secondary tubercle adradially; perradial zone either densely granular or with scattered granules.

Discussion — Although based on fragments of two or three specimens, the present form seems best assigned to *Micropsis*. Smith & Jeffery (in press) characterised that genus as follows: 'Test inflated. Apical disc moderately large and pentagonal; hemicyclic where plating is preserved. Ambulacra uniserial, with predominantly quadrigeminate plating. Interambulacral plates with small primary tubercles and dense and uniform adradial and interradial granulation; imperforate, crenulate tuberculation throughout. Peristome sunken, no phyllodes or pore crowding.' They referred four Maastrichtian and Palaeocene species to it, viz. *M. desori* (Cotteau, in Leymerie & Cotteau, 1856), *M.* ?*solitarium* (Peron & Gauthier, in Cotteau et al., 1881), *M. microstoma* Cotteau, 1863, and *M. batalleri* (Lambert, 1933); the two last-named have quinquegeminate plating. The new species appears close to *M. microstoma*, but the absence of a secondary tubercle close to the interradial plate margin in *M.*? *caementum* and the occurrence of dense granulation on the remainder of the plate serve to distinguish them.

Occurrence — To date only known from the Emael Member at the ENCI-Maastricht BV quarry (Figs. 5, 20), and from an unknown level (Emael Member or Nekum Member) in a temporary outcrop at Sluizen (Belgium).

Genus *Trochalosoma* Lambert, 1897

Type species — *Leiosoma rugosum* Cotteau, 1860, by original designation.

Trochalosoma? *corneti* (Cotteau, 1875)
Fig. 6; Pl. 10, fig. 12; Pl. 13, figs. 3-16.

*1875 *Cyphosoma corneti* Cotteau, p. 645, pl. 19, figs. 3-7.
*1898 *Cyphosoma inops* Lambert, p. 155, pl. 4, fig. 6.
*1898 *Cyphosoma rutoti* Lambert, p. 155, pl. 4, figs. 7-8.
1980 *Phymosoma corneti* (Cotteau, 1874) — Geys, p. 200 (partim), fig. 1/6 only.
non1985b *Phymosoma taeniatum* (v. Hagenow, 1840) — Kutscher, p. 522 (partim).
1992 *'Phymosoma rutoti'* (Lambert, 1898) — van der Ham & van Birgelen, p. 149, pl. 2, fig. 5.

Types — Holotype, by monotypy, of *C. corneti*, is IRScNB 9113 (Cotteau, 1875, pl. 19, figs. 3-7); holotype, by monotypy, of *C. rutoti*, is the original of Lambert (1898, pl. 4, figs. 7-8); its present whereabouts is unknown; holotype of *C. inops* is IRScNB 9117 (IG 4285).

Material — NHMM: BL 0123, 0815, JJ 5666, 5984, 6136, 7759, 8762, 9955, 10418, 11119, K 1000, 1153, 1177, 1409, 2184, 2528a, 3568, and MD 2924b (all spines); NHMM: AC M-100, BL 0173a, 0560(231), 0582, 0583a/b, K 614, 989, MB 782, 784, MD 3816, and Indeherberge Colln, no. 4269 (tests and test fragments).

Description — Although NHMM AC M-100 (Pl. 13, fig. 16) is amongst the best preserved regular echinoids ever to have been recorded from the type Maastrichtian, recrystallisation has obliterated many diagnostically important test characters. However, under low-angle light, this specimen does show relatively wide interambulacral plates, and conspicuous adradial granulation, allowing it to be compared well with other test material in the present collections (e.g. NHMM K 614, MB 782, 784, and MD 3816).

Test small to medium-sized (up to c. 32 mm in diameter), (sub)circular in outline, depressed in profile with height c. 35-40% of test diameter; ambitus at midheight. Apical disc opening large, but poorly preserved in all available specimens, ?pentagonal. Ambulacra quadri- or quinquegeminate, becoming (irregularly) biserial adapically, and with short phyllodes adorally; plate compounding in phymosomatid style. Ambulacral primary tubercles imperforate, only faintly crenulate, areoles confluent throughout or separated by narrow row of granules; miliaries interradially and adradially, with small tubercle separating each pore pair on ambital plates. Interambulacral plates wider than tall ambitally, with large primary tubercles, areoles contiguous adorally; broad adradial band of secondary granulation from ambitus adapically, amongst which larger and smaller secondaries can be distinguished; adapical naked zone interradially, but elsewhere granulation well developed. Adorally, 1-2 of adradial secondaries on each plate become larger than rest, forming a distinct adradial row. Eleven or twelve ambulacral and interambulacral plates in column. Peristome medi-

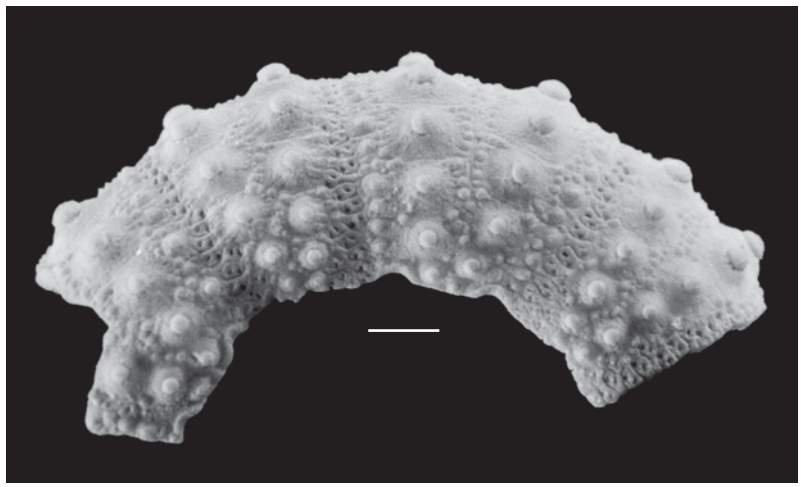


Fig. 6. *Trochalosoma*? *corneti* (Cotteau, 1875), NHMM BL 0173a, oral view of fragmentary test, Blom quarry (Berg en Terblijt), Maastricht Formation, Meerssen Member (base IVf-4). Scale bar equals 1 mm.

um-sized, circular, flush or slightly invaginated, with distinct buccal notches.

Associated spines are highly distinctive, with cortex ornamented by fine, occasionally coarse, widely spaced ribs. Spines still attached to the test in NHMM AC M-100 show the ambital ones to correspond in length to almost 80% of test diameter, adapical ones being either more slender (with less prominent ribs) and slightly shorter, or very much shorter, paddle-shaped, but with distinct ribs.

Discussion — Cotteau (1875, p. 645, pl. 19, figs. 3-7) based his *Cyphosoma corneti* on a medium-sized test (28 mm diameter) from the 'Poudingue de Malogne', which is a conglomerate at the base of the Palaeocene Tuffeau de Ciply. The type could thus well have come from the underlying Craie phosphatée de Ciply, which is of Early Maastrichtian (*obtusa* Zone) age. From that unit, Lambert (1898) described a single primary spine under the name *Cyphosoma rutoti*. These two taxa are here considered to be conspecific, with the name *corneti* having priority.

Subsequent authors have interpreted *C. corneti* in various ways. Geys (1980) referred material of Late Campanian age to this species, but this is markedly different and is here assigned to *Phymosoma* gr. *granulosum* (see above). Kutscher (1985b), however, synonymised *C. corneti* with *Cidarites (Diadema) taeniatus* von Hagenow, 1840 (p. 651), and rightly noted that Cotteau's type did not show crenulate tubercles. *Trochalosoma taeniatum* was originally described from the Lower Maastrichtian of Rügen, but ranges into the Upper Maastrichtian in Denmark (see Schlüter, 1883, p. 23, pl. 7, figs. 1-5; Ravn, 1928, p. 54, pl. 6, figs. 1-2, and pl. 5, figs. 11-12, as *Phymosoma magnificum*; Kutscher, 1985b, p. 522, pl. 1, figs. 6-11; Smith & Jeffery, in press).

For the time being, *T. corneti* and *T. taeniatum* are considered to be distinct species, which can be distinguished primarily on size, ornament and form of the primary spines.

Occurrence — Known to date from the Lixhe Member (Gulpen Formation), Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members, as well as the Kun-

rade Limestone facies (Maastricht Formation), with records from the ENCI-Maastricht BV, Ankerpoort-Marnebel, Ankerpoort-'t Rooth, CBR-Romontbos, and Blom quarries, the Kunrade-Voerendaal area, Aachen-Schneeberg, and Sluizen (Belgium) (Figs. 5, 18-22).

Subfamily Circopeltinae Smith & Jeffery, in press
Genus *Circopeltis* Pomel, 1883

Type species — *Leiosoma meridanensis* Cotteau, 1867, by subsequent designation of Lambert & Thiéry (1914, p. 254).

Circopeltis maastrichtensis (Engel, 1972)
Pl. 9, figs. 9-10.

*1972 *Phymosoma maastrichtensis* Engel, p. 540, pl. 1.
1988a *'Phymosoma' maastrichtensis* Engel, 1972 — van der Ham, p. 142, pl. 4, figs. 5-8.

Type — Holotype is NHMM 001340 (Engel, 1972, pl. 1).

Material — NHMM 1995027 (ex Regout Colln), and MB 432-R.

Description — Test small (up to c. 25 mm in diameter), circular in outline, subconical in profile, ambitus at c. one third of test height; apical disc opening small, irregularly circular. Ambulacra polygeminate, compounded in phymosomatid style, comprising four-five elements, uniserial adapically, broadened into phyllodes adorally, arranged almost linearly at ambitus. Each compound plate with a large primary tubercle; primaries more or less contiguous, with a double row of perradial granules. Up to 15 ambulacral plates in a column; up to 13 interambulacral plates in a column, plates wider than tall, with large primary tubercle placed towards interradial margin. At ambitus, primary tubercles separated by just a single row of granules, with adradially a band of variously sized secondaries, irregularly arranged; these reduce in size and disappear adorally and adapically. Interradius with dense cover of small granules; no naked adapical zone. Peristome moderately sized, slightly invaginated, with small buccal notches, and adoral phyllodes poorly developed. All tubercles imperforate and only faintly crenulate, of comparable size.

Discussion — Smith & Jeffery (in press) are followed in considering this species to belong in the genus *Circopeltis*. Its irregularly circular apical disc opening, uniserial ambulacral plating adapically and well-developed adradial interambulacral granulation make a distinction from co-occurring phymosomatids straightforward.

Occurrence — Having been first described from the 'Maastrichtian' of Maastricht-Caberg (Belvédère gravel pit), this species has subsequently been shown to be of Early Palaeocene age, being typical of the upper Geulhem Member in the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 5).

Circopeltis sp.

1987 Phymosomatoida sp. 2 — van der Ham et al., p. 25, pl. 3, fig. 8.
1988a Phymosomatoida sp. — van der Ham, p. 142, pl. 4, figs. 9-11.

Material — NHMM MB 432-O.

Description — Test small to medium-sized (up to 29 mm in diameter), adapical pore pairs uniserial, adorally in broad phyllode; up to 10 noncrenulate tubercles in a column, either confluent or separated by a single row of granules; adoral interambulacral plates with two secondary tubercles the upper of which is the larger.

Discussion — Van der Ham et al. (1987) and van der Ham (1988a) noted this form to be close to *C. maastrichtensis*, from which it differed in the pattern of secondary tuberculation and the position of pore pairs, being more oblique in the present form. Smith & Jeffery (in press) remarked that it was like the previous species, but more depressed in profile, with fewer and larger primary interambulacral tubercles, and with less well-developed adradial granulation on interambulacral plates, and was probably just a variant of *C. maastrichtensis*.

Occurrence — Apparently confined to the upper Geulhem Member of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 5).

Genus *Phymotaxis* Lambert & Thiéry, 1914

Type species — *Leiosoma tournoueri* Cotteau, 1866, by original designation.

Phymotaxis tournoueri (Cotteau, 1866)
Pl. 11, figs. 3-8.

*1866 *Leiosoma tournoueri* Cotteau, p. 768, pl. 1187, figs. 1-8.
?1980 *Porosoma*? *maeandrinum* — Geys, table 1.
1987 Phymosomatoida sp. 1 — van der Ham et al., p. 24, pl. 4, fig. 6.
*1995 *Phymechinus*? *perplexus* Smith, p. 172 (partim), pl. 15, figs. 4-10.
in press *Phymotaxis tournoueri* (Cotteau, 1866) — Smith & Jeffery, fig. 64 (cum syn.).

Type — The present whereabouts of Cotteau's (1866) original material is unknown.

Material — NHMM: BL 0173b/c, K 615, MK 625-B (W.M. Felder Colln), MM 164, and Indeherberge Colln, no. 4268, Falize Colln, unregistered (currently in NHMM collections).

Description — Test medium-sized to large (up to 66 mm in diameter), subcircular or subpentagonal in outline, broad based and subconical in profile, ambitus below midheight; height about 50% of diameter. Apical disc small, subcircular. Ambulacral plating polygeminate, in phymosomatid style, 6-7 elements ambitally, with pore pairs strongly arcuate ambitally, and in strong arcs aborally also, and broadened into phyllodes adorally, uniserial adapically. Thirteen to fifteen interambulacral plates in a column, with large crenulate, imperforate primary tubercle, and two enlarged secondary tubercles adorally, one ambitally; rest of plate with granules of different sizes. Oral surface flattened, peristome flush, subcircular with distinct buccal notches.

Discussion — Easily recognised on account of the flat oral surface, the well-developed adoral phyllodes, and polygeminate ambulacral plating in strong arcs almost throughout the entire columns. The unregistered specimen in the Falize Colln, from the lower Meerssen Member at the Ankerpoort-'t Rooth quarry, is amongst the largest of regular echinoids known to date from the Maastrichtian type area. It has

well-developed secondary interambulacral tubercles ambitally, and up to three subequally sized tubercles subambitally, with interradial granulation fairly dense and heterogeneous.

Occurrence — Apparently confined to the Meerssen Member (Maastricht Formation), with records from the Blom, Ankerpoort-'t Rooth, and ENCI-Maastricht BV quarries (Figs. 5, 20-22), and Sluizen (Belgium).

Family Stomopneustidae Mortensen, 1903
Genus *Winkleria* Engel, 1964a

Type species — *Winkleria maastrichtensis* Engel, 1964a, by monotypy.

Winkleria maastrichtensis Engel, 1964a
Pl. 14, figs. 8-10.

*1964a *Winkleria maastrichtensis* Engel, p. 207, figs. 1-4, pl. 1, figs. 1-10.
1980 *Winkleria maastrichtensis* Engel, 1964 — Geys, p. 220, fig. 6/4-7.
1999c *Winkleria maastrichtensis* — Jagt, pl. 1, fig. 8.
in press *Winkleria maastrichtensis* Engel, 1964 — Smith & Jeffery, fig. 71 (cum syn.).

Type — TM 16025/1 (Engel, 1964a, figs. 1-2, pl. 1, figs. 1-3) is holotype; the remaining 29 specimens in the type lot (TM 16025) are paratypes.

Material — IRScNB 10179; NHMM K 1135, 1180, and 2654b.

Description — Test small (up to 8 mm in diameter), (sub)circular in outline and wheel-shaped in profile, with ambitus below midheight. Ambulacral plating simple at ambitus, but becoming bigeminate both adapically and adorally; however, no phyllodes or biserial zones adorally. Tuberculation imperforate, noncrenulate. Height of interambulacral plates at ambitus decreases strongly, with concomitant reduction in size of primary tubercles and increase in number of tubercles in a column. Peristome and periproct large, subpentagonal or subcircular.

Discussion — Ambulacral plating shows *Winkleria* to be closely related to *Plistophyma*, which has trigeminate plating throughout (see Smith, 1995, p. 169, pl. 14, figs. 1-7; text-figs. 35-36).

Occurrence — Apparently confined to the Meerssen Member (Maastricht Formation), with records from the ENCI-Maastricht BV and Blom quarries (Figs. 2, 20, 22).

Superorder Camarodonta Jackson, 1912
Order Temnopleuroida Mortensen, 1942
Genus *Thylechinus* Pomel, 1883

Type species — *Cyphosoma said* Peron & Gauthier, 1881, by subsequent designation of Lambert & Thiéry (1911).

Thylechinus sp. nov.
Pl. 14, figs. 5-7.

1988a Gen. et sp. aff. ? *Arbacina* — van der Ham, p. 149, pl. 5, figs. 12-17.

1994 ?*Arbacina* sp. — Jagt & van der Ham, p. 725, pl. 2, figs. 1-6.

Type — Holotype is NHMM MB 432-M/1 (van der Ham, 1988a, pl. 5, figs. 12-14).

Material — NHMM MB 432-M.

Description — Test small (up to 7 mm in diameter), depressed, ambitus at about mid-height; apical disc small, dicylic, firmly bound to corona, and with raised, tubercle-bearing perianal ridge. Sexually dimorphic, females having depressed interambulacral zones adjacent to genital plates. Ambulacra trigeminate, pore pairs uniserial throughout; ambulacral tubercles almost of the same size as interambulacrals. Each interambulacral plate has one imperforate, noncrenulate (or barely crenulate) primary tubercle, and dense secondary granules. Peristome very large.

Discussion — This is a new species which will be formally named by Smith & Jeffery (in press).

Occurrence — Known only from the upper Geulhem Member of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 2).

Genus *Micropsidia* Pomel, 1883

Type species — *Leiosoma leymeriei* Cotteau, 1865, by monotypy.

Micropsidia salis (Cooke, 1941)
Pl. 9, figs. 12-13, 15.

*1941 *Thylechinus (Gagaria) salis* Cooke, p. 13, pl. 2, figs. 12-14.
1959 *Gagaria salis* (Cooke) — Cooke, p. 17, pl. 3, figs. 7-9.
1987 Phymosomatoida? sp. 2 — van der Ham et al., p. 25, pl. 5, fig. 2.
1988a ?Phymosomatoida sp. — van der Ham, p. 149, pl. 5, figs. 9-11.
in press *Micropsidia salis* (Cooke, 1941) — Smith & Jeffery, fig. 75.

Type — Holotype is USNM 166497 (Cooke, 1941, pl. 2, figs. 12-14; Cooke, 1959, pl. 3, figs. 7-9).

Material — NHMM MB 432-N.

Description — Test small (mostly up to 16 mm in diameter, but fragments indicate size up to 30 mm), globular in profile, circular in outline, ambitus slightly below mid-height; with small, irregularly circular periproct. Ambulacra with up to 13 plates in a column, narrow and straight, uniserial throughout, with trigeminate plating. Up to 13 interambulacral plates in a column, wide, with single, small primary, imperforate, crenulate tubercle centrally positioned; small scattered granules over the remainder of plate. Peristome hardly invaginated, with distinct buccal notches.

Occurrence — Apparently restricted to the upper Geulhem Member, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 2).

Micropsidia? sp.
Pl. 14, figs. 1-4.

1987 Phymosomatoida? sp. 1 — van der Ham et al., p. 25, pl. 5, fig. 4.

Material — NHMM RF 1998-1; NHMM BL 0108 may also belong here.

Description — Test small (up to 6.5 mm in diameter, but fragments of larger individuals are known), circular in outline, subglobular in profile, ambitus at c. one third of test height; periproct small, irregularly circular, in a few ?female specimens sunken considerably. Ambulacra trigeminate, with up to 12 plates in a column, tubercles small, interambulacral and ambulacral of same size, surrounded by numerous granules. Peristome medium-sized, subcircular, hardly invaginated.

Discussion — The present form is confined to the Meerssen Member and Kunrade Limestone facies (Maastricht Formation), and, in contrast to *M. salis*, shows sexual dimorphism (see Philip & Foster, 1971: adapical depression in temnopleurids). Smith & Jeffery (in press) treated the Maastrichtian and Palaeocene material from the Maastrichtian type area as a single lineage, but it may prove advisable in future to separate the Maastrichtian form.

Occurrence — See above, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst), the Kunrade-Benzenrade area and the ENCI-Maastricht BV and Blom quarries (Figs. 2, 20, 22). The Lammers Colln contains a specimen from residual flint deposits (?Nekum Member) at the CBR-Romontbos quarry (Eben Emael).

Superorder Camarodonta Jackson, 1912
Family Zeuglopleuridae Lewis, 1986
Genus *Zeuglopleurus* Gregory, 1899
[= *Boletechinus* Cooke, 1955]

Type species — *Zeuglopleurus costulatus* Gregory, 1899, by original designation.

Zeuglopleurus rowei Gregory, 1900
Pl. 14, figs. 11-12.

*1900 *Zeuglopleurus rowei* Gregory, p. 353, figs. 1-3.
1986 *Boletechinus rowei rowei* (Gregory) — Lewis, p. 76, fig. 8a-e.
1986 *Boletechinus rowei* (Gregory) *anglicus* Lewis, p. 78, figs. 9a-e, 10.
1996 *Zeuglopleurus rowei* Gregory, 1900 — Smith & Wright, p. 333, pl. 114, figs. 1-7, 9, 11; text-figs. 122b-d, 123-124.
1999c *Zeuglopleurus rowei* — Jagt, pl. 1, fig. 4.
in press *Zeuglopleurus rowei* Gregory, 1900 — Smith & Jeffery, fig. 77a-b, d (cum syn.).

Type — Lectotype, designated by Lewis (1986, p. 76, fig. 8), of *Z. rowei* is BMNH E39372; holotype of *B. r. anglicus* is BMNH 75556a (Lewis, 1986, fig. 9).

Material — NHMM MB 865-3.

Description — Test small (up to 4 mm in diameter), circular in outline, subconical in profile, with ambitus below midheight. Apical disc moderately large, pentagonal, with oval periproctal opening, rounded posteriorly but indented anteriorly; plating hemicyclic. A marked reduction in size of interambulacral and ambulacral tubercles, the lowest 5-6 tubercles being relatively large in all columns, other tubercles much smaller and barely diffentiated from surrounding secondary tubercles and granules, with the upper test surface thus appearing densely granular. Tubercles crenulate,

imperforate. Variation in development of sutural pitting, but generally triangular depressions along horizontal sutures. Pore pairs strongly oblique, arranged uniserially. Peristome circular, with very faint buccal notches.

Discussion — Easily recognised on the basis of tuberculation, and size and shape of the apical disc. In comparison with material from England, which is mostly of Santonian and Early Campanian age, the present specimens from the Benzenrade area are younger (early Late Campanian).

Occurrence — Apparently confined to the Beutenaken Member (Vaals Formation), at de Wingerd quarry (Welterberg; Fig. 2); however, the van Birgelen Colln also includes a rather poorly preserved internal mould from the upper Vaals Formation of the CPL SA quarry (Haccourt) which may belong here (Fig. 16).

Cohort Irregularia Latreille, 1825
Superorder Eognathostomata Smith, 1981
Order Holectypoida Duncan, 1889
Suborder Holectypina Duncan, 1889
Family Holectypidae Lambert, 1899
Genus *Coenholectypus* Pomel, 1883

Type species — *Holectypus macropygus* Desor, 1842, by subsequent designation of Hawkins (1912).

Coenholectypus macrostomus (Engel, 1964b)
Pl. 15, figs. 1-2.

*1964b *Holectypus (Coenholectypus?) macrostomus* Engel, p. 236, figs. 1-2.

Type — Holotype is the larger specimen in type lot TM 16027 (Engel, 1964b, figs. 1-2).

Material — A handful of specimens in various collections, including NHMM MB 347, 784-1, and 1362-6.

Description — Test small (not exceeding 10.5 mm in diameter), low subconical in profile; peristome and periproct very large with latter extending into the ambitus and clearly visible in apical and posterior view. Ambulacral plating simple, except for adoralmost plates (Engel, 1964b, fig. 1b-c). Five gonopores (Pl. 15, fig. 2), open (documenting sexual maturity) in NHMM MB 347.

Discussion — Smith & Jeffery (in press) noted that the small size and position of the periproct in *C. macrostomus* are typical of juvenile individuals, and that the species probably grew to a larger size. However, such material is not known, not even in fragments, so that this observation cannot be substantiated.

Engel (1964b, p. 235, pl. 14, figs. 1-2) described a second, 'new' holectypoid species, *Holectypus boschmai*, from Maastricht, although he himself explicitly stated (p. 236), 'If the label "Upper Cretaceous, Limburg" is right, this is the first *Holectypus* s.s. (with 4 genital pores) from the Senonian. Hence the possibility should be considered that these specimens have been remaniated from some older layer into this locality.

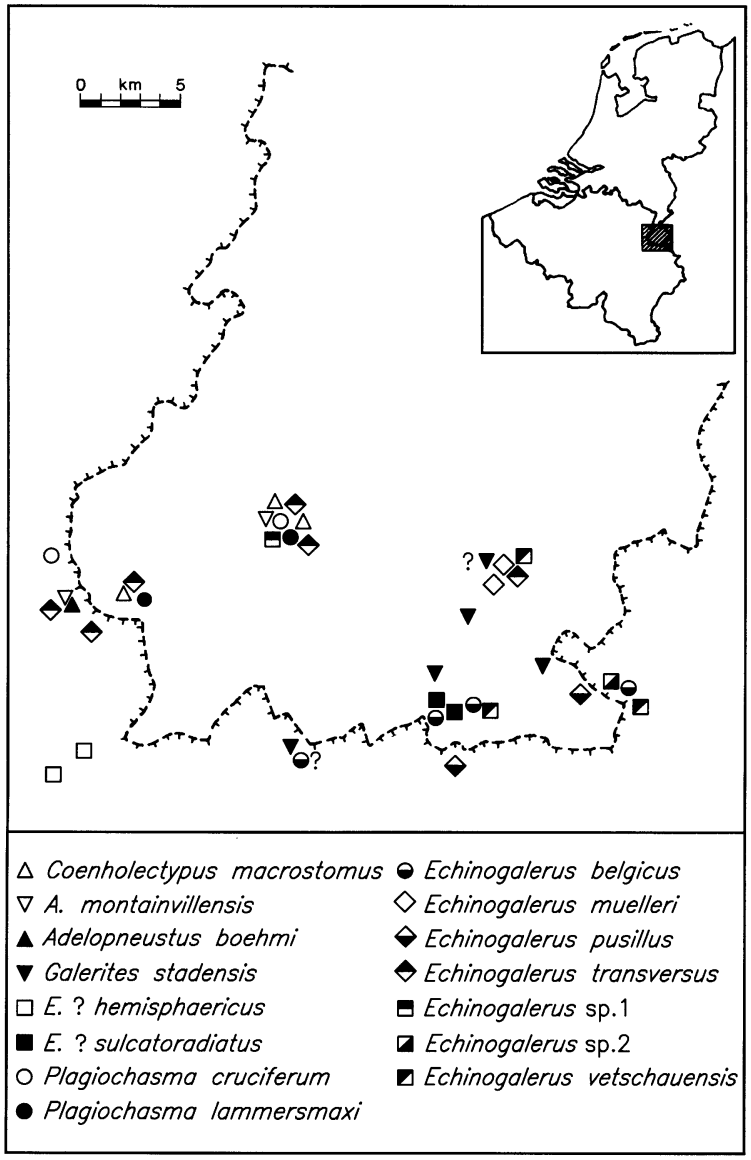


Fig. 7. Geographic distribution of Late Cretaceous-Early Palaeogene holectypid, conulid, galeritid, and plagiochasmid echinoids in the type area of the Maastrichtian Stage.

As said above, they are then most likely to belong to the Jurassic *H. corallinus* d'Orbigny, for which see Cotteau (1873, p. 436, pl. 110, 111).' Engel had two unregistered specimens from the collections of the Zoological Museum of the University of Amsterdam. These definitely are not Maastrichtian, and are not from southern Limburg.

Occurrence — Apparently confined to the Meerssen Member (Maastricht Forma-

tion), with records from the ENCI-Maastricht BV, Blom and Ankerpoort-Curfs quarries (Figs. 7, 20, 22-23).

Family Conulidae Lambert, 1911
Genus *Adelopneustes* Gauthier, 1889
[= *Neoglobator* Endelman, 1980]

Type species — *Echinoconus lamberti* Thomas & Gauthier, 1889, by original designation.

Adelopneustes montainvillensis (Sorignet, 1850)
Pl. 15, figs. 3-6.

*1850 *Pyrina montainvillensis* Sorignet, p. 40.
*1875 *Pyrina houzeaui* Cotteau, p. 649, pl. 19, figs. 8-12.
1935b *Pygorhyncus* [sic] *houzeaui* Cotteau (*Pyrina*) — Smiser, p. 48, pl. 4, fig. 8.
1988a '*Pygopyrina*' *houzeaui* (Cotteau, 1875) — van der Ham, p. 150, pl. 7, figs. 1-4.
in press *Adelopneustes mountainvillensis* (Sorignet, 1850) — Smith & Jeffery, figs. 89a-b, 90a-b, d (cum syn.).

Type — The present whereabouts of Sorignet's (1850) material is unknown.

Material — NHMM MK 770 (W.M. Felder Colln).

Description — Test small to medium-sized (up to 31 mm in length), subcircular to weakly ovate in outline, slightly pointed posterior, slightly longer than wide; low domal in profile, highest centrally. Peristome subcircular, with slight elongation along 3-I axis, subcentral in position. Ambulacral plating simple adapically, trigeminate ambitally and subambitally, with oblique pore pairs. Periproct longitudinally teardrop shaped, rounded adorally and pointed adapically, in subambital position, longer than wide. Tuberculation scrobiculate, scattered adapically, denser adorally.

Discussion — Smith & Jeffery (in press) noted that amongst species of *Adelopneustes*, the present taxon was the only one with a consistently flatter base and more circular peristome.

Occurrence — Confined to the lower Geulhem Member, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 7, 23).

Adelopneustes boehmi (Nietsch, 1921)
Pl. 15, figs. 7-10.

*1921 *Globator böhmi* Nietsch, p. 44, pl. 10, figs. 14-15, 17.
*1935b *Pygorhyncus* [sic] *ovalis* Smiser, p. 47, pl. 4, fig. 7.
1935b *Pygorhyncus* [sic] *houzeaui* Cotteau (*Pyrina*) — Smiser, p. 48, pl. 4, fig. 8.
?*1935b *Pygorhyncus* [sic] *conicus* Smiser, p. 48, pl. 4, fig. 9.
1988a '*Pygopyrina*' *ovalis* (Smiser, 1935) — van der Ham, p. 150, pl. 7, figs. 5-8.
in press *Adelopneustes boehmi* (Nietsch, 1921) — Smith & Jeffery, figs. 89c-d, 90c (cum syn.).

Type — The present whereabouts of Nietsch's (1921) material is unknown; holotype of *P. ovalis* is IRScNB 9149 (IG 8695) (Smiser, 1935b, pl. 4, fig. 7).

Material — NHMM MB 432-D.

Description — Test small (up to 20 mm in length), similar to previous species, but more elongate in outline and more rounded in profile; pore pairs less oblique; base tumid, ambitus higher (c. 40% of test height); peristome less sunken and more distinctly oblique along 3-I axis, periproct on posterior surface, but visible in oral view (subambital).

Occurrence — Known exclusively from the upper Geulhem Member at the temporary Albertkanaal sections, Vroenhoven-Riemst/Kessselt (Fig. 7).

Family Galeritidae Gray, 1825
Genus and subgenus *Galerites* Lamarck, 1801

Type species — *Echinites vulgaris* Leske, 1778, by original designation.

Galerites (G.) stadensis (Lambert, 1911)
Pl. 15, figs. 11-13; Pl. 16, fig. 1.

*1911 *Echinoconus globulus*, Klein (*Conulus*), 1734-78 Variété *stadensis* Lambert, p. 75.
1985 *Galerites (Galerites) stadensis* (Lambert, 1911) — Schulz, p. 54, pl. 6, fig. 2; pl. 10, figs. 10-15; pl. 11, fig. 4; pl. 15, figs. 1-6; text-figs. 4, 7c, 10h-k (cum syn.).
1992 *Galerites* cf. *stadensis* (Lambert, 1911) — van der Ham & van Birgelen, p. 149, pl. 3, fig. 4.
1995 *Galerites stadensis* Lambert, 1911 (sensu Schulz, 1985) — Jagt et al., p. 12.
1997b *Galerites stadensis* (Lambert, 1911) — Jeffery, p. 680, pl. 6, figs. 1-9; text-figs. 7d-e, 8.
in press *Galerites stadensis* (Lambert, 1911) — Smith & Jeffery, fig. 91a, c-d (cum syn.).

Type — Schulz (1985, p. 54) designated lectotype the specimen illustrated by Quenstedt (1873, pl. 76, fig. 1) from the Lower Maastrichtian of Rügen (NE Germany) (collections of the Institut und Museum für Geologie und Paläontologie, Universität Tübingen, Quenstedt Colln, no. 76/1).

Material — NHMM: Vijlen Groep 513, GK 33 (W.M. Felder Colln), K 2496; BL 1064 may also belong here.

Description — Test medium-sized (up to 40 mm in length), rounded in outline, (sub)hemispherical to subconical in profile, height equalling 70-100% of diameter, lower test surface flat; apical system central, four gonopores. Ambulacra non-petaloid, uniserially throughout, simple plating throughout. Tuberculation uniform and fine. Peristome small, circular, margin with vertical entrance wall, tuberculate; 2-3 ambulacral plates to an interambulacral plate adorally; adoral pore pairs form a more or less straight line up to peristome (Schulz, 1985, pl. 6, fig. 2). Periproct inframarginal, oval.

Discussion — Schulz (1985, p. 54) considered *Echinoconus wollemanni* Lambert, 1911 (p. 62, partim; pl. 3, figs. 19-21; holotype is IRScNB 9144, IG 4285, Bosquet Colln) to be a junior synonym of *G. stadensis*. Lambert (1911) had two specimens, both reportedly collected from the 'craie marneuse de Kunraad'. Whether this is correct needs to be determined. Of note in this respect is van der Ham et al.'s (1987, p. 28) observation that material from the Kunrade Limestone facies contained in the Vlieks Collection (Simpelveld-Molsberg) differed from *G. stadensis* is being smaller (up to 14 mm), relatively less tall, with more oblique pore pairs and a slightly oblique peri-

stome. In view of these uncertainties, *G. stadensis* is here recorded with certainty only from the Vijlen Member.

Occurrence — As here understood (see above), apparently restricted to the Vijlen Member (Gulpen Formation) and basal Orsbach Chalk (Wahlwiller Horizon), with records from Altembroeck (Voer), Beutenaken, Mamelis, and Wahlwiller-Kruisberg (Fig. 7).

Echinogalerus? *hemisphaericus* (Desor, 1842) sensu Schulz, 1985
Pl. 16, figs. 2-4.

*1842 *Caratomus hemisphaericus* Desor, p. 37, pl. 4, figs. 14-16 only.
1985 *Echinogalerus (?) hemisphaericus* (Desor, 1842) — Schulz, p. 57, pl. 8, figs. 4-5 (cum syn.).

Type — Lectotype, designated by Schulz (1985, p. 58), is Desor's original (1842, pl. 4, figs. 14-16); its present whereabouts is unknown.

Material — NHMM: GK 1466c/g (W.M. Felder Colln), JJ 709-710, 725, 778, and 816-817.

Description — Test small (up to 24 mm in length), (sub)circular in outline, flat base, hemispherical in profile. Ambulacra simple, uniserial adorally, but offset close to circular peristome (see Schulz, 1985, pl. 8, figs. 4-5), plating simple. Periproct teardrop shaped. Tuberculation fine, uniform; pore angle 118-140° (Schulz, 1985, fig. 12).

Discussion — Schulz (1985), who revised Campanian-Maastrichtian species of *Galerites* (inclusive of *Pironaster*), noted that a number of taxa, previously assigned either to *Galerites* or *Echinogalerus*, did not belong to either genus. Although subsequent authors have doubted the validity of this distinction, Schulz's (1985) view is followed here, since he demonstrated that galeritid faunas from the basal Zeven Wegen and basal Vijlen members differed in what he termed the 'pore angle', and in this feature corresponded closely to coeval faunas from the Eaton/Weybourne chalks of Weybourne and White Chalk/Grey Beds of Trimingham (Norfolk), respectively. Measurements of pore angle can be only be done on well-preserved and/or slightly worn or abraded material.

Occurrence — As here understood, this taxon is restricted to the lower Zeven Wegen Member, occurring up to c. 7 m above the base of that unit, and particularly common at the very base, with records from the CPL SA and CBR-Lixhe quarries (Figs. 7, 16-17).

Echinogalerus? *sulcatoradiatus* (Goldfuss, 1829) sensu Schulz, 1985

*1829 *Galerites sulcato-radiatus* Goldfuss, p. 130, pl. 41, fig. 4.
1970a *Galerites sulcatoradiatus* (Goldfuss) — Ernst, pl. 5, fig. 3.
1985 *Galerites (?) sulcatoradiatus* (Goldfuss, 1829) — Schulz, p. 59, pl. 9, fig. 2 (cum syn.).

Type — Holotype, by monotypy, is RFWUIP Goldfuss Colln, no. 324 (Goldfuss, 1829, pl. 41, fig. 4).

Material — IRScNB 9138 (IG 10511), and 9139 (IG 4285, Bosquet Colln).

Description — Similar to previous species; test small (20-35 mm in length), flat

hemispherical, more rarely subconical, and comparatively small pore angle (80-120°; Schulz, 1985, fig. 12).

Discussion — Schulz (1985, p. 59) restricted use of this specific name to material from the basal Vijlen Member at Slenaken and Pesaken (upper Lower Maastrichtian), and from coeval deposits in Norfolk (White Chalk and Grey Beds at Trimingham), and in southern Belgium (Craie phosphatée de Ciply).

Occurrence — As here understood, the present species is confined to the basal Vijlen Member (*obtusa* Zone, ?*sumensis* Zone) at Slenaken and Pesaken (Fig. 7).

Superorder Microstomata Smith, 1984
Series Neognathostomata Smith, 1981
Order Cassiduloida Claus, 1880
Family Plagiochasmidae Smith & Jeffery, in press
Genus *Plagiochasma* Pomel, 1883

Type species — *Nucleolites olfersii* L. Agassiz, 1836, by subsequent designation of Melville (1952).

Plagiochasma cruciferum (Morton, 1830)
Pl. 17, figs. 4-6.

*1830 *Ananchytes cruciferus* Morton, p. 245.
*1847 *Nucleolites analis* Agassiz, in L. Agassiz & Desor, p. 97.
1965a *Plagiochasma analis* (Agassiz, 1847) — Meijer, p. 96, pl. 1, figs. 1-4; text-figs. 1-2.
1988a *Plagiochasma analis* (L. Agassiz, 1847) — van der Ham, p. 154, pl. 8, figs. 1-3.
in press *Plagiochasma cruciferum* (Morton, 1830) — Smith & Jeffery, fig. 95.

Type — Specimen T.78 in the Agassiz Colln (Institut de Géologie de Neuchâtel) is a plaster cast of the holotype of *N. analis*; the present whereabouts of Morton's (1830) material is unknown.

Material — NHMM MB 432-E, and MM 884a-b.

Description — Test small (up to 19 mm in length), outline oval, profile rounded, height equalling c. 50% of length; oral surface tumid with rounded margins. Apical system anterior of centre, tetrabasal, 4 gonopores. Petals poorly developed with subparallel columns of pores, flush, lacking clear distal termination; ambulacral plating simple throughout, except towards peristome. Peristome strongly sunken, asymmetric, elongate along II-5 axis, moderately large and trigonal, with sloping walls, lacking small, dense miliaries. Periproct supramarginal, visible from above, large and not sunken, periproct opening about five interambulacral plates in each column. Tubercles large, scrobiculate adorally, slightly smaller and less scrobiculate adapically.

Occurrence — Confined to the Geulhem Member, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 7, 23).

Plagiochasma lammersmaxi Jagt & van der Ham, sp. nov.
Pl. 17, figs. 1-3, 10.

1965a *Plagiochasma* sp. (?nov. sp.) — Meijer, p. 99, pl. 1, figs. 5-8.

Type — Holotype is NHMM TL 1985/1 (pl. 17, figs. 1-3); paratype is RGM 76 289 (Umbgrove Colln).

Type locality and horizon — ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, lowermost Meerssen Member.

Derivation of name — The specific name honours Max Meijer, who presented the first description of this new species in his 1965a paper, and Theo Lammers (Valkenswaard, The Netherlands), who collected the holotype. In addition, it is the largest species recorded so far of the genus *Plagiochasma*.

Diagnosis — A large species of *Plagiochasma*, highest posterior of centre, with strongly tumid oral surface,

Material — NHMM BL 0173d, 0645, K 1187; the specimen illustrated by Meijer (1965a, pl. 1, figs. 5-8; NHMM 004125) appears to be lost.

Description — Grouped here are Late Maastrichtian representatives of the genus; in addition to three fragments of tests of estimated lengths of c. 25-30 mm, there are three complete tests, one described by Meijer (1956a; test length 51 mm), one illustrated here (test length 44.0 mm), and one in the RGM collections (L: 36.2 mm, W: 30.5 mm, H: 19.2 mm). Meijer's description of his *Plagiochasma* sp. (?nov. sp.) is here copied in part, and complemented by a description of the holotype (NHMM TL 1985/1).

Test large (up to 51 mm in length), oblong, test width 84-86% of length, test height 50-51% of length, rounded anteriorly, truncated posteriorly, and with concave margin corresponding to an anal sulcus. Largest length in the centre, with subparallel sides. Adapical face relatively weakly inflated, flattened across apical disc and laterally; lateral profile with highest point posterior of apical disc, regularly curved towards the frontal margin. Ambitus at lower third of height; oral surface distinctly tumid, even bulbous anteriorly, strongly depressed near peristome and with furrows corresponding to adoral portions of ambulacrals. Apical disc anterior of centre, tetrabasal, 4 gonopores. Ambulacra distinct, subparallel, without clear distal termination open, of unequal length; interporiferous zone slightly convex; weakly conjugate, subequal pores, inner row circular, row with tendency to become elongate transversely. Ambulacral plates outside petals with double oblique pores. Periproct supramarginal, relatively large (c. 30 % of test length), within a large and deep groove, which bevelled edges. Peristome sediment covered in holotype, but paratype RGM 76 289 shows it to be oblique with long axis along II-5 axis. Tubercles only slightly larger adorally than adapically, strongly scrobiculate; mamelons perforate and crenulate.

Discussion — Meijer (1965a, p. 101) noted that Maastrichtian representatives differed from *P. anale* (= *P. cruciferum*) particularly in size, and general test form, and the position of the periproct, which opens much further away from the apical disc (at least 8-9 interambulacral plates), and which is sunken over its entire length, rather than only at its base. Specimens NHMM BL 0645, 0173d, K 1187, and RGM 76 289 show the slopes leading into the peristome to be densely granulate, with dense rings of miliaries surrounding tubercles around the peristome. Adapical tuberculation appears to be denser in *P. lammersmaxi*, with many tubercles arranged in distinct rows, in particular anteriorly. Moreover, the angle between the posterior petals varies between 67 and 70°, in *P. cruciferum* between 57 and 60°.

Occurrence — Apparently restricted to the lower Meerssen Member (Maastricht

Formation), with records from the ENCI-Maastricht BV and Blom quarries (Figs. 7, 20, 22). The label with RGM 76289 states, 'Z. Limburg, Coll. Umbgrove, juni 1955'. The matrix clearly shows it to have come from the (lower) Meerssen Member, but whether it came from the St Pietersberg or not, cannot be determined.

Genus *Echinogalerus* König, 1825

Type species — *Echinites peltiformis* Wahlenberg, 1818, by subsequent designation of Lambert (1898).

Remarks — Representatives of this genus are currently being revised by van der Ham (pers. comm.); data below were supplied by that author, and are preliminary in nature. Only two species are illustrated here, and a description of one of them is provided.

Echinogalerus belgicus (Lambert, 1898)

*1898 *Caratomus peltiformis* Wahlenberg, 1818 var. *belgica* Lambert, p. 159, pl. 4, fig. 11-14.
1911 *Echinogalerus belgicus*, Lambert, *n. sp.*, pp. 45, 64, pl. 1, figs. 28-35.
1992 *Echinogalerus belgicus* (Lambert, 1898) — van der Ham & van Birgelen, p. 149, pl. 3, figs. 5-6.
1999 *Echinogalerus belgicus* (Lambert, 1898) — van Birgelen & van der Ham, p. 215, fig. 4e-h.

Type — Holotype is IRScNB 9135 (Lambert, 1911, pl. 1, figs. 28-31), paratype is IRScNB 9136 (IG 4285).

Material — NHMM: MM 808, 829, 868, GK 584, 665, 1401, 1429, 1671 (W.M. Felder Colln).

Description and discussion — See van Birgelen & van der Ham (1999) and van der Ham (in prep.).

Occurrence — Known to date from the (basal) Vijlen Member at Zeven Wegen/Vijlenerbosch, Slenaken-Kerkdel, 's Gravensvoeren (Voer), and from the base of the so-called Orsbach Chalk (Wahlwiller Horizon) at Aachen-Schneeberg (Fig. 7).

Echinogalerus muelleri (Schlüter, 1902)
Pl. 16, figs. 6-7.

*1902 *Caratomus muelleri* Schlüter, p. 316, pl. 11, figs. 14-17, pl 12, fig. 30.

Type — Probably lost; Schlüter's original came from the J. Müller Collection (Schlüter, 1902, p. 316).

Material — NHMM BL 0811, 0822.

Description and discussion — See van der Ham (in prep.).

Occurrence — Currently known from the Kunrade Limestone facies (Maastricht Formation) at Kunderberg, former Schunck quarry (Kunrade) and Benzenrade (Fig. 7).

Echinogalerus pusillus Lambert, 1911

*1911 *Echinogalerus pusillus* Lambert, p. 65, pl. 1, figs. 10-14.
1999 *Echinogalerus pusillus* Lambert, 1911 — van Birgelen & van der Ham, p. 215, fig. 4a-d.

Type — Holotype is IRScNB 9137 (IG 4285) (Lambert, 1911, pl. 1, figs. 10-14).

Material — Copious material in the van Birgelen Collection, from the lower Vijlen Member at Mamelis-Selzerbeek.

Description and discussion — See van der Ham (in prep.).

Occurrence — Known to date only from the lower Vijlen Member (*sumensis* Zone and ?lower) at Mamelis-Selzerbeek, Altembroeck, and De Plank (Fig. 7).

Echinogalerus transversus (Smiser, 1935b)
Pl. 16, fig. 5.

*1935b *Pseudopyrina minuta* Smiser, p. 42, pl. 4, fig. 3.
*1935b *Faujasia*? *transversus* Smiser, p. 65, pl. 7, fig. 1.
1956 *Echinogalerus (Rostrogalerus) transversus* (Smiser, 1935) — Meijer, p. 38, figs. 1-3, plate.

Type — Holotype of *Faujasia*? *transversa* is IRScNB 9185 (IG 6521); the holotype of *Pseudopyrina minuta* should be in the IRScNB collections.

Material — NHMM: BL 0017, JJ 9521, K 749, 750, 1067, 4174, MK 736, 1205 (W.M. Felder Colln), MM 567, and 866-867.

Description — Test small (up to 9 mm in length), outline elongate oval, with rounded anterior and more or less pointed posterior, longer than wide. Adoral surface tumid and sunken towards peristome; ambulacra have double pores adapically, single pores adorally. Peristome in anterior half, oval to very slightly oblique, longitudinally elongate. Periproct posterior or inframarginal forming posterior truncation (see *P. minuta*), transverse, rounded above and below, in aboral view only a slight indentation visible.

Discussion — See van der Ham (in prep.).

Occurrence — Current records include the Kunrade Limestone facies (Maastricht Formation) in the Kunrade area, the lower/upper Nekum Member(?) at the temporary Albertkanaal sections near Kanne, and the Meerssen Member (IVf-4, IVf-6) at the ENCI-Maastricht, Blom, and Ankerpoort-Curfs quarries and the temporary Albertkanaal sections at Vroenhoven-Riemst (Figs. 7, 20, 22).

Echinogalerus vetschauensis (Schlüter, 1902)

*1902 *Caratomus vetschauensis* Schlüter, p. 318, pl. 11, figs. 10-13, pl. 12, fig. 29.

Type — Schlüter (1902, p. 318) based his description on three specimens in the collections of the Technische Hochschule (Aachen); the present whereabouts is unknown.

Description and discussion — Reference is made to van der Ham (in prep.) for a detailed discussion.

Occurrence — Exclusively known from the Kunrade Limestone facies of the Kunrade area, and its correlatives in the Aachen area (Fig. 7).

Echinogalerus sp. 1

1987 *Echinogalerus transversus* Smiser — van der Ham et al., p. 28, pl. 9, fig. 4.

Remarks — Van der Ham (in prep.) considers material from the Meerssen Member (IVf-2/-3) at Blom quarry (Berg en Terblijt) to represent an undescribed species (Fig. 7).

Echinogalerus sp. 2

1992 *Echinogalerus muelleri* (Schlüter) — van der Ham & van Birgelen, p. 149, pl. 3, fig. 7.
1999 *Echinogalerus* sp. — van Birgelen & van der Ham, p. 217, fig. 5e-h.

Material — NNHM GK 1440 (W.M. Felder Colln).

Description and discussion — See van Birgelen & van der Ham (1999) and van der Ham (in prep.).

Occurrence — Known to date from the basal Orsbach Chalk (Wahlwiller Horizon) at Aachen-Schneeberg, and from the basal Vijlen Member at Zeven Wegen/Vijlenerbosch (Fig. 7).

Family Nucleopygidae L. Agassiz & Desor, 1847
Genus *Catopygus* L. Agassiz, 1836

Type species — *Nucleolites carinatus* Goldfuss, 1829, by subsequent designation of Cotteau (in Cotteau & Triger, 1869).

Catopygus fenestratus Agassiz, in L. Agassiz & Desor, 1847
Pl. 18, figs. 4-6.

*1847 *Catopygus fenestratus* Agassiz, in L. Agassiz & Desor, p. 4.
1935b *Catopygus fenestratus* Agassiz — Smiser, p. 54, pl. 5, fig. 4.
1935b *Catopygus conformis* Desor — Smiser, p. 55, pl. 5, fig. 5.
*1935b *Catopygus irregularis* Smiser, p. 56, pl. 5, fig. 7.
1992 *Catopygus fenestratus* Agassiz, 1840 — van der Ham & van Birgelen, p. 150, pl. 3, fig. 9.
in press *Catopygus fenestratus* Agassiz, in Agassiz & Desor, 1847 — Smith & Jeffery, fig. 96.

Type — The present whereabouts of Agassiz's original material is unknown; holotype of *C. irregularis* is IRScNB 9163 (IG 8261), paratypes are IRScNB 9164-9165 (IG 8261).

Material — IRScNB 9159-9161 (IG 4285, Bosquet Colln); NHMM JJ 567, K 914, 4150(1), GK 839 (W.M. Felder Colln), KK 590 (W.M. Felder Colln), and MM 543, 568, 809.

Description — Test small to medium-sized (up to 34 mm in length), inflated adapically, flat to slightly convex adorally; outline oval, but highly variable, height/length and height/width ratios variable (Fig. 9A-B), occasionally truncated posterior; apical system tetrabasal, 4 gonopores. All petals equal, flush to very slightly convex, open distally, but approximated, inner series small, circular, outer series elongate; wide interporiferous area. Subcircular to transverse periproct high on posterior truncation, with a slightly projecting canopy around its upper half. Peristome just anterior of centre, more or less pentagonal in outline; Posterior of peristome, a narrow tubercle-free area, smooth, not pitted. Phyllodes well developed and curved, outer series with 12-

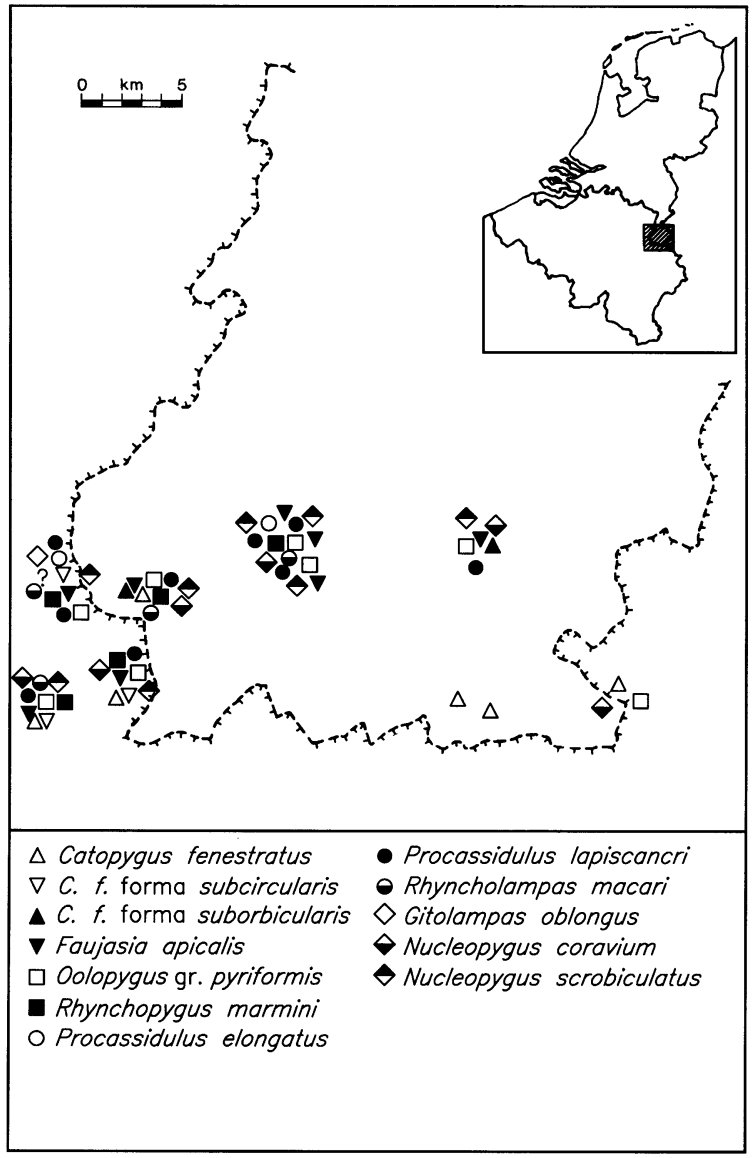


Fig. 8. Geographic distribution of Late Cretaceous-Early Palaeogene nucleopygid, faujasiid, cassidulid, and echinolampadid echinoids in the type area of the Maastrichtian Stage.

14 pore pairs, inner with 3-4 pairs, c. 5 pairs of sphaeridial pits perradially between inner pore pair series and buccal pores. Tuberculation fine, close-set, non scrobiculate.

Occurrence — The earliest representatives of the present species are known from the basal Vijlen Member of Slenaken-Kerkdel and outcrop 62D-15 (Nieuwe Weg/Zeven Wegen). Other records include the so-called Orsbach Chalk (Wahlwiller

Horizon), the Lanaye Member (Gulpen Formation), and Valkenburg, Emael, and Nekum members (Maastricht Formation) at the Ankerpoort-Marnebel, CBR-Romontbos, and ENCI-Maastricht BV quarries, and of the Aachen-Schneeberg area (Figs. 8, 18-20). Two formae (see below) are here listed as well, recording the occurrence of *C. fenestratus* also from the Kunrade Limestone facies, and from the Meerssen Member (Maastricht Formation).

Catopygus fenestratus forma *subcircularis* Smiser, 1935b
Pl. 18, figs. 1-3.

*1935b *Catopygus subcircularis* Smiser, p. 56, pl. 5, fig. 6.

Type — Holotype is IRScNB 9162 (IG 9457) (Smiser, 1935b, pl. 5, fig. 6).

Material — NHMM: JJ 5826, 5827, K 1333, 3565, MK 1274, 1277, and 1279 (W.M. Felder Colln).

Description and discussion — Material from the upper Nekum Member, as exposed in the Eben Emael-Bassenge area (CBR-Romontbos and Ankerpoort-Marnebel quarries) is characterised by a peculiar test morphology. Plotting H/L and H/W (see Fig. 9A-B) shows these to differ consistently from conspecific material collected at other levels. Smiser (1935b) considered this morphology to represent a distinct species, but it is here seen as the end member of a continuum, and referred to as a forma (i.e. ecophenotype). P.J. Felder (1963) noted that this type was apparently confined to a certain level within the Nekum Member, an observation which is here substantiated. However, NHMM MM 860 from 'racines Md4' (= upper Meerssen Member) at Vroenhoven (Albertkanaal sections) is closely comparable (see Fig. 9A-B) as far as test morphology is concerned, but this has the periproct positioned considerably lower on the truncated posterior. It is placed here with a query.

Occurrence — Nekum Member (Maastricht Formation) of the Eben Emael area (CBR-Romontbos and Ankerpoort-Marnebel quarries), and possibly Meerssen Member of the temporary Albertkanaal sections (Vroenhoven-Riemst) (Figs. 8, 19).

Catopygus fenestratus forma *suborbicularis* Bosquet, in Lambert, 1911

*1911 *Catopygus suborbicularis*, Bosquet (*in. sch.*) Lambert, p. 55, pl. 3, figs. 6-9.

Type — Holotype is IRScNB 9166 (IG 4285, Bosquet Colln) (Lambert, 1911, pl. 3, figs. 6-9). Bosquet considered a single specimen in his collection from the Kunrade Limestone facies to represent a new species, for which he proposed the (? manuscript) name *suborbicularis*. This name, however, has never been formally introduced in the literature, until Lambert (1911, p. 55) noted that the label with the specimen bore the name *suborbicularis*. Since Lambert provided a description and illustration, this is here considered to be a valid introduction of the name *suborbicularis*.

Material — NHMM MB 1362-11, which may belong here.

Description and discussion — Lambert (1911) based his description on a large, well-preserved test from Kunrade, measuring 44 mm in length, 40 mm in width, and 24 mm in height (compare Fig. 9A-B). He considered it to be a distinct species on

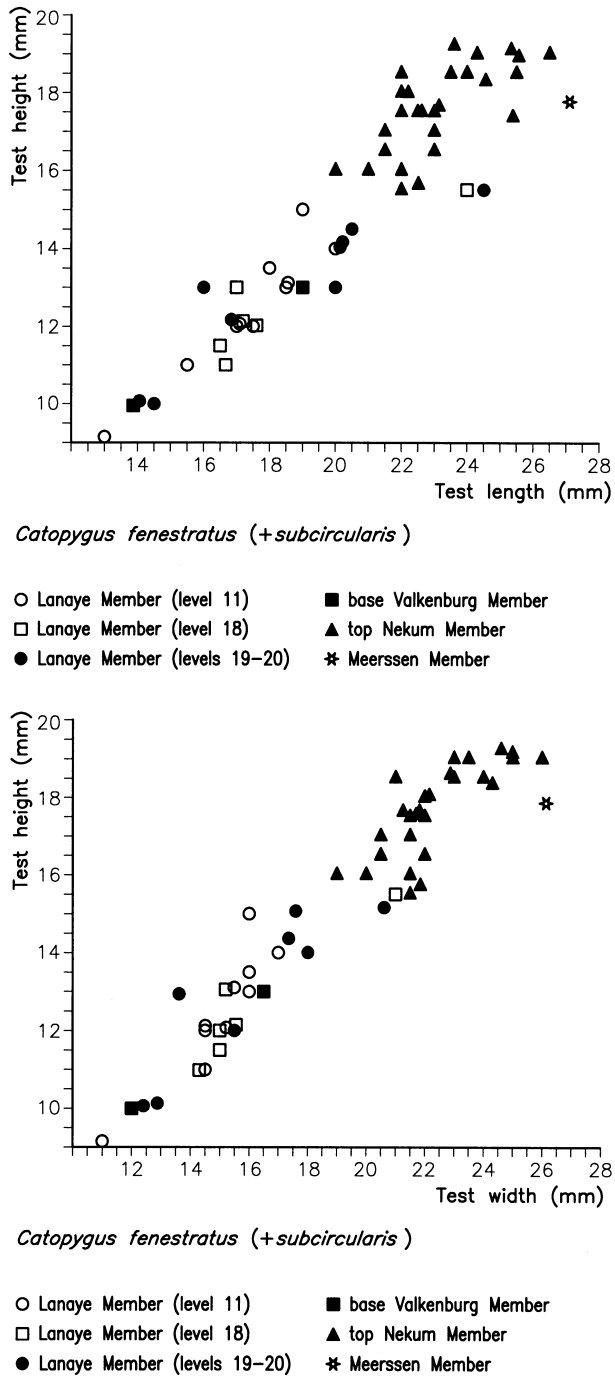


Fig. 9A-B. Relationship between test height, length, and width in *Catopygus fenestratus* (L. Agassiz, 1840), inclusive of forma *subcircularis* Smiser, 1935b.

account of size, the eccentricity of the apex and the form of the periproct. Like *C. subcircularis*, the present form may be nothing more than a variety, an end member of a continuum. A rather poorly preserved specimen from the lower Meerssen Member (IVf-2/-3) at the ENCI-Maastricht BV quarry (NHMM MB 1331-1) is of note in being close to Lambert's 'species'. Although considerably smaller (L: c. 32 mm; W: c. 31 mm; H: 17 mm), test height is about half of test length, peristome anterior of centre, sunken, pentagonal in outline, height exceeding width, and tuberculation apparently coarse, and non scrobiculate.

Additional and better preserved material is needed to establish the true status of this form; for the time being it is here referred to as a forma.

Occurrence — Kunrade Limestone facies of the Kunrade area, and possibly, Meerssen Member (Maastricht Formation) of the ENCI-Maastricht BV quarry (Figs. 8, 20).

Family Faujasiidae Lambert, in Doncieux, 1905
Genus and subgenus *Faujasia* d'Orbigny, 1856

Type species — *Pygurus apicalis* Desor, in L. Agassiz & Desor, 1847, by subsequent designation of Lambert & Thiéry (1921).

Faujasia (F.) apicalis (Desor, in L. Agassiz & Desor, 1847)
Pl. 16, figs. 8-10.

*1847 *Pygurus apicalis* Desor, in L. Agassiz & Desor, p. 162.
1962 *Faujasia apicalis* (Desor) — Kier, p. 139, pl. 17, figs. 9-11; text-figs. 113-114.
in press *Faujasia (Faujasia) apicalis* (Desor, in Agassiz & Desor, 1847) — Smith & Jeffery, fig. 104.

Type — The present whereabouts of Desor's original material is unknown; Desor stated it to have been part of the collection of the Marquis of Northampton, transferred in 1878 to the collections of the Northampton Museum (Kier, 1962, p. 139).

Material — Several dozens of specimens in various collections, including IRScNB 9184 (IG 4285); NHMM JJ 8818, K 2275, MD 0145, MM 0065, 512, 519, and 813-814.

Description — Test small to medium-sized (up to 37 mm in length), outline subangular, more or less truncated anteriorly, length exceeding width, test widest posterior of centre, pointed posteriorly. Test profile subconical, inflated adapically, apex pointed, greatest height at apical system; flat adorally, with protruding bourrelets. Ambitus relatively sharp and positioned near base. Apical system with 4 gonopores, situated in interambulacra. Pore pairs arranged in well-developed petals, equal, converging distally but open, flush to slightly raised, interporiferous zone wide. Anterior petals extending c. 2/3 of distance to margin in plan view, posterior pair extending 1/2 the distance. Subpentagonal peristome small, slightly anterior of centre, longer than wide, with projecting blunt, peg-like bourrelets. Phyllodes expanding adorally but small, 6 pores in outer and 1-2 in inner series; three pairs of sphaeridial pits at centre of phyllode, and buccal pores rudimentary. Granular tubercle-free bands both anterior and posterior of peristome. Periproct small, close to posterior margin. Adapical tuberculation dense, scrobiculate; adoral tubercles much larger.

Occurrence — Currently known from the Emael, Nekum and Meerssen members as well as the Kunrade Limestone facies (Maastricht Formation), with records from the ENCI-Maastricht BV, CBR-Romontbos, Ankerpoort-Marnebel, Blom, Ankerpoort-'t Rooth and Ankerpoort-Curfs quarries, the Kunrade-Benzenrade area, and the temporary Albertkanaal sections (Vroenhoven-Riemst) (Figs. 8, 18-20).

Genus *Oolopygus* d'Orbigny, 1856

Type species — *Oolopygus pyriformis* d'Orbigny, 1856, by original designation (non *Echinites pyriformis* Leske, 1778 = *Oolopygus gracilis* Lambert, 1909b).

Oolopygus gr. *pyriformis* (Leske, 1778)
Pl. 17, figs. 7-9.

*1778 *Echinites pyriformis* Leske, p. 255, pl. 51, figs. 5-6.
1909b *Oolopygus gracilis* Lambert, p. 20, pl. 1, figs. 17-18.
1911 *Oolopygus gracilis*, Lambert, 1909 — Lambert, p. 58, pl. 2, figs. 22-25.
1935b *Oolopygus piriformis* Leske (*Echinites*) — Smiser, p. 57, pl. 5, fig. 8.
*1935b *Oolopygus jandrainensis* Smiser, p. 58, pl. 5, fig. 9.
*1935b *Oolopygus convexus* Smiser, p. 59, pl. 6, fig. 1.
1962 *Oolopygus gracilis* Lambert — Kier, p. 95, pl. 29, figs. 5-6; text-fig. 77.
1992 *Oolopygus pyriformis* (Leske, 1778) — van der Ham & van Birgelen, p. 150.
in press *Oolopygus pyriformis* (Leske, 1778) — Smith & Jeffery, fig. 108.

Types — The present whereabouts of Leske's (1778) original material is unknown; holotype of *O. convexus* is IRScNB 9169 (IG 6521; Smiser, 1935b, pl. 6, fig. 1); holotype of *O. jandrainensis* is IRScNB 9168 (Smiser, 1935, pl. 5, fig. 9). The holotype of *O. gracilis* should be in the d'Orbigny Collection at Paris (Muséum national d'Histoire naturelle; see Kier, 1962, p. 96).

Material — Many dozens of specimens in various collections, including IRScNB 9167 (IG 6521), 9170 (IG 4285), NHMM JJ 565, K 1216, 4136(9), MM 0050, and 1210.

Description — Test small to medium-sized (up to 35 mm in length, Fig. 10A-B), generally elongate, rounded anterior, posterior margin pointed or truncate, widest posterior of centre. In profile, adapical surface smoothly rounded, highest at or posterior of apical system, adoral surface flat to slightly concave in peristomial region. Apical system tetrabasal, 3 gonopores, but generally not visible, anterior of centre. Petals only weakly developed, narrow and parallel, flush, open distally; pores equal, slightly elongated; anterior petal longest, other petals extending less than half of radial distance to margin in plan view. Well-developed bourrelets; phyllodes separated from peristome, 9-13 pores in outer and 3-4 in inner series; buccal pores minute, immediately adoral to c. 4 pairs of sphaeridial pits. Peristome small, pentagonal, with concave margins. Periproct relatively high on posterior truncated face; subcircular to distinctly transverse, with shallow subanal depression. Tubercle-free zone anterior and posterior of peristome narrow, pitted. Tuberculation dense, fine, scrobiculate.

Discussion — Representatives of the present taxon are often found in 'populations', comprising individuals of all ontogenetic stages, and displaying a wide range of variation. Based on these, various previously described 'species' (see list of syn-

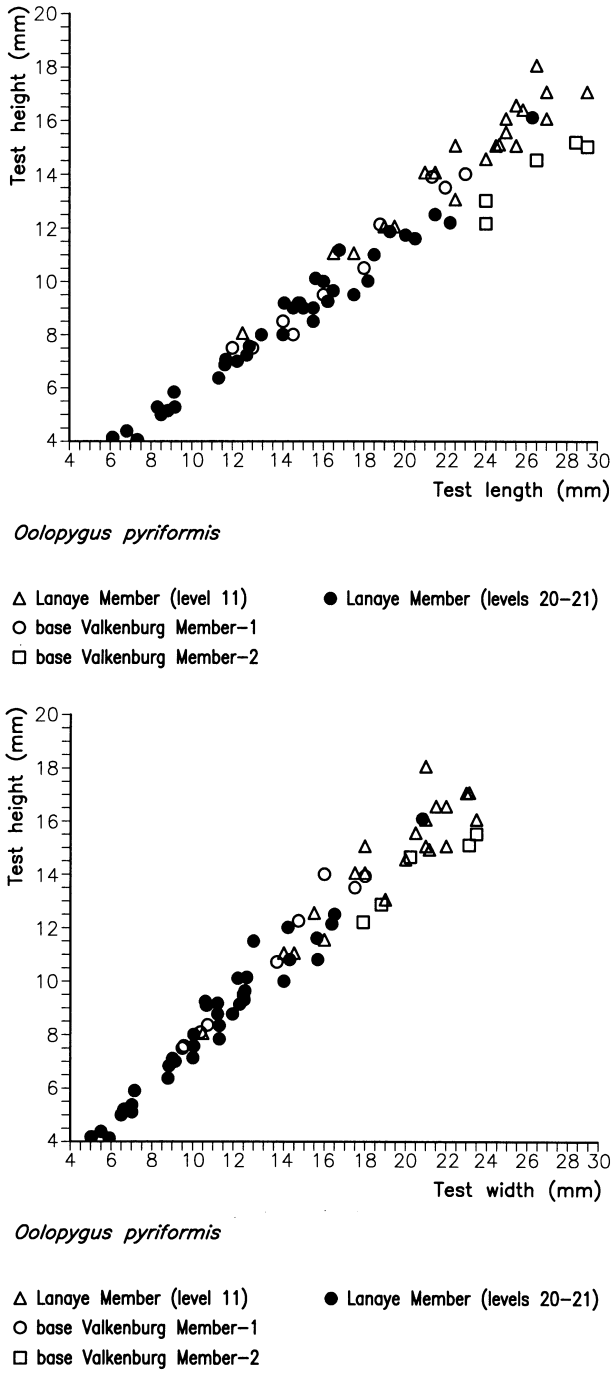


Fig. 10A-B. Relationship between test height, length, and width in *Oolopygus* gr. *pyriformis* (Leske, 1778).

onyms above), are considered to be no more than variants. Especially the shape and position of the periproct vary considerably.

Occurrence — The earliest representatives are known from the ?Orsbach Chalk of the Aachen-Schneeberg area (van der Ham & van Birgelen, 1992). Other records include the Lanaye Member (Gulpen Formation), the Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members, and Kunrade Limestone facies (all Maastricht Formation), at CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Blom, Ankerpoort-'t Rooth quarries, temporary Albertkanaal sections (Kanne, Vroenhoven-Riemst) and Kunrade-Benzenrade area (Figs. 8, 18-22).

Genus *Rhynchopygus* d'Orbigny, 1856

Type species — *Cassidulus marmini* L. Agassiz, in L. Agassiz & Desor, 1847, by monotypy (= *Nucleolites marmini* Desmoulins, 1837).

Rhynchopygus marmini (Desmoulins, 1837)
Pl. 18, figs. 7-10.

*1837 *Nucleolites marmini* Desmoulins, p. 360.
1935b *Rhynchopygus marmini* Desmoulins (*Nucleolites*) — Smiser, p. 62, pl. 6, fig. 5.
1962 *Rhynchopygus marmini* (L. Agassiz) — Kier, p. 160, pl. 24, figs. 1-4; text-figs. 134, 137.
in press *Rhynchopygus marmini* (Agassiz in Agassiz & Desor, 1847) — Smith & Jeffery, fig. 112.

Type — The whereabouts of Desmoulins's (1837) original material is unknown (see Kier, 1962, p. 161).

Material — Several dozens of specimens in various collections, including IRScNB 9178 (IG 4285), NHMM BL 0005, JJ 2683, MM 0114, 0161, 0510, 0535, and 0599.

Description — Test small (up to 18 mm in length), ovate, anterior rounded, lateral margins straight or rounded, posterior margin truncate, in profile depressed, highest posterior of apical system, base more or less flattened, peristome slightly sunken. Apical system anterior of centre, tetrabasal with four gonopores. Petals inconspicuous, narrow, short, and parallel with small, circular pore pairs. Peristome subcentral, rounded to slightly elongate longitudinally, with distinct bourrelets and short, but well-developed phyllodes widening adorally, consisting of 5-6 pores in outer and 1-2 pores in inner series. Periproct supramarginal, small, transverse, opening at base of highly distinctive, tongue-shaped projection; wide, transverse subanal shelf occurring beneath this projection. Adoral tuberculation with strong bilateral symmetry, primary tubercles in rows, decreasing in size laterally; narrow, but distinct tubercle-free zone, extending over entire length of test, pitted in places. Tuberculation dense, scrobiculate.

Discussion — Easily distinguished from other species on account of the tongue-shaped projection which conceals the periproct. Specimens illustrated here (Pl. 18, figs. 8-10) clearly show that there are differences in gonopore size, suggesting sexual dimorphism for this species as well (compare Jeffery, 1997c).

Occurrence — Known only from the Nekum and Meerssen members (Maastricht Formation), with records from the ENCI-Maastricht BV, CBR-Romontbos, and Blom

quarries, and the temporary Albertkanaal sections, Vroenhoven-Riemst (Figs. 8, 19-20, 22).

Genus *Procassidulus* Lambert, 1918

Type species — *Echinites lapiscancri* Leske, 1778, by original designation.

Procassidulus elongatus (d'Orbigny, 1856)
Pl. 18, figs. 11-16.

*1856 *Cassidulus elongatus* d'Orbigny, p. 328, pl. 926, figs. 1-5.
1988a *Procassidulus elongatus* d'Orbigny, 1856 [sic] — van der Ham, p. 154, pl. 8, figs. 9-14.
in press *Procassidulus elongatus* (d'Orbigny, 1856) — Smith & Jeffery, fig. 115.

Type — Holotype, by monotypy, is the original of d'Orbigny's (1856, pl. 926); its present whereabouts is unknown.

Material — NHMM K 3316a, and MB 432-G.

Description — Test small to medium-sized (up to 25 mm in length), elongate, longer than wide, anterior and lateral margins rounded, posterior margin truncate; depressed in profile, highest posterior of apical system. Apical system monobasal, 4 gonopores. Petals moderately developed, flush, anterior ones slightly longer than others. Oral surface slightly convex, peristome subcentral, rounded pentagonal and only slightly longer than wide, surrounded by distinct bourrelets. Phyllodes faintly swollen, outer series with 8-10, inner with 3 pores. Periproct supramarginal, with short, distinct anal groove, causing posterior test margin to appear truncated and concave, close to posterior edge, and not deviating from central axis. Adoral tuberculation rather coarse, except adambitally; adapical tubercules small, dense, scrobiculate. Narrow median zone on oral surface, tubercle free and pitted.

Discussion — Similar to *P. lapiscancri* (see below), but narrower and with a median periproct.

Occurrence — Confined to the Geulhem Member (Houthem Formation), with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 8, 23).

Procassidulus lapiscancri (Leske, 1778)
Pl. 19, fig. 1.

*1778 *Echinites lapis Cancri* Leske, p. 256, pl. 49, figs. 10-11.
*1911 *Cassidulus Mortenseni* Lambert, p. 60, pl. 3, figs. 10-13.
1935b *Procassidulus mortensoni* [sic] Lambert (*Cassidulus*) — Smiser, p. 62.
1962 *Rhynchopygus lapiscancri* (Leske) — Kier, p. 163, pl. 24, figs. 5-8; text-figs. 135-136.
in press *Procassidulus lapiscancri* (Leske, 1778) — Smith & Jeffery, fig. 114.

Types — Holotype, by monotypy, of *P. lapiscancri* is the original of Leske's (1778, pl. 49, figs. 10-11); its present whereabouts is unknown (see Kier, 1962, p. 164); holotype of *P. mortenseni* is IRScNB 9177 (IG 4285, Bosquet Colln; Lambert, 1911, pl. 3, figs. 10-13).

Material — Many hundreds of specimens in various collections, including IRScNB 9171 (IG 8696), 9172 (IG 9849), NHMM: MM 113, 136, 598, and VN 543.

Description — Test small to medium-sized (up to 22 mm in length), elongate, rounded anteriorly, pointed posteriorly, widest in posterior third, longer than wide, highest at or near apical system; adoral surface concave along central axis; posterior face oblique. Apical system ?tetrabasal, anterior of centre, but often poorly visible. Petals well developed, unequal with anterior one extending 80% of distance to ambitus; lateral petals only slightly shorter, but posterior ones 3/4 of length of anterior petal, terminating well before periproct. Peristome slightly anterior of centre, subpentagonal, surrounded by distinct bourrelets. Phyllodes expanded, but of simple structure; a marginal series of c. 10 pores and a pair of buccal pores. Periproct supramarginal, displaced towards left in posterior view, oval to transversely elongate; a shallow, subanal groove, displaced towards right in posterior view.

Discussion — The most conspicuous feature of this species is the eccentric position of the periproct. *Procassidulus mortenseni* is simply a large representative of the present species; specimens of similar size have been collected from temporary exposures in the Kunrade-Benzenrade area (H. Vlieks Colln).

Occurrence — Known to date from the Emael, Nekum, and Meerssen members, as well as the Kunrade Limestone facies (all Maastricht Formation) of the CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Blom, Ankerpoort-Curfs and Ankerpoort-'t Rooth quarries, as well as from the temporary Albertkanaal sections (Vroenhoven-Riemst, Kanne) and the Kunrade-Benzenrade area (Figs. 8, 18-23).

Family Cassidulidae L. Agassiz & Desor, 1847
Genus *Rhyncholampas* A. Agassiz, 1869

Type species — *Pygorhynchus pacificus* A. Agassiz, 1869, by subsequent designation of Lambert, in Lambert & Thiéry (1918).

Rhyncholampas macari (Smiser, 1935b)
Pl. 19, figs. 2-4.

*1935b *Rhynchopygus macari* Smiser, p. 63, pl. 6, fig. 6.
1987 *Procassidulus macari* (Smiser, 1935) — van der Ham et al., p. 30, pl. 11, fig. 6.
in press *Rhyncholampas macari* (Smiser, 1935) — Smith & Jeffery, fig. 126.

Type — Holotype is IRScNB 9179 (IG 8696; Smiser, 1935, pl. 6, fig. 6), paratype is IRScNB 9180 (IG 9849).

Material — NHMM: 1975631, BL 0643, 0644, JJ 9265, 10809, 10811, 11041, and MM 115-116.

Description — Test small to medium-sized (up to 40 mm in length, mostly much smaller), elongate, rounded anteriorly, truncated posteriorly, with slightly concave base and smoothly rounded upper surface, highest at apical system. Apical system monocyclic, four gonopores. Petals well developed, unequal (anterior one longest, open distally), lanceolate, lateral pair bowed, lateral and posterior petals strongly tapered, more or less closed distally; posterior petals ending about half the distance

from the periproct. Peristome pentagonal, sunken, slightly longer than wide, surrounded by distinct bourrelets; phyllodes with an outer, V-shaped series of 9-10 pores in each column, and inner series of 1-3 pores; 5-6 pairs of sphaeridial pits perradially. Periproct supramarginal, transversely elongate, slightly sunken, with distinct, excavated, slightly eccentric subanal shelf; this causes the subanal heel in the truncated posterior face, in lateral view. Conspicuous, wide tubercle-free, coarsely pitted zone along median axis on oral surface. Adapical tuberculation dense, scrobiculate; adoral tuberculation arranged bilaterally, with primary tubercles arranged in rows and decreasing in size towards ambitus.

Discussion — Easily recognised on account of distinct adoral tuberculation and shape and position of periproct.

Occurrence — Known to date from the Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members (Maastricht Formation) at the CBR-Romontbos, ENCI-Maastricht BV and Blom quarries, as well as from the temporary Albertkanaal sections, Vroenhoven-Riemst (Figs. 8, 19-20, 22).

Family Echinolampadidae Gray, 1851
Genus *Gitolampas* Gauthier, 1889

Type species — *Pliolampas tunetana* Gauthier, 1889, by original designation.

Gitolampas oblongus (Smiser, 1935b)
Pl. 19, figs. 5-8.

*1935b *Phyllobrissus oblongus* Smiser, p. 53, pl. 5, fig. 2.
1988a *Nucleopygus oblongus* (Smiser, 1935) — van der Ham, p. 152, pl. 8, figs. 4-8.
in press *Gitolampas oblongus* (Smiser, 1935) — Smith & Jeffery, fig. 130.

Type — Holotype is IRScNB 9157 (IG 8695) (Smiser, 1935b, pl. 5, fig. 2).

Material — NHMM MB 432-F.

Description — Test small (up to 23 mm in length, mostly much smaller), ovate in outline, truncated posterior, highest posterior of apical system, oral surface flat; apical system anterior of centre, monobasal, 4 gonopores. Petals weakly developed, subparallel, open distally, with subequal pores. Posterior petals slightly longer than others; peristome slightly anterior of centre, sunken, pentagonal, wider than long, interambulacral areas slightly raised in larger specimens. Phyllodes hardly expanded towards peristome, but differentiated into outer and inner series, with 9-12 and 3-4 pores, respectively; 2-3 pairs of sphaeridial pits perradially. Narrow, tubercle-free zone posterior of peristome. Periproct marginal, oval and longitudinal, on truncated posterior face, with shallow, short anal groove.

Occurrence — Confined to the upper Geulhem Member (Houthem Formation), at the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 8).

Incertae sedis

Smith & Jeffery (in press) considered *Nucleopygus* to represent an unnamed ple-

sion, with that genus identified as sister taxon to the combined Echinolampadidae, Plesiolampadidae and clypeasteroids.

Genus *Nucleopygus* L. Agassiz, 1840

Type species — *Nucleopygus minor* Desor, 1842, by subsequent designation of Lambert (1898).

Nucleopygus coravium Defrance, in L. Agassiz & Desor, 1847
Pl. 20, figs. 1-2.

*1847 *Nucleopygus coravium* Defrance, in L. Agassiz & Desor, p. 152.
1898 *Nucleopygus coravium* Defrance (*in* Agassiz et Desor), 1847. — Lambert, p. 168, pl. 5, figs. 1-4, 8-14.
1992 *Nucleopygus coravium* Defrance, 1847 — van der Ham & van Birgelen, p. 150, pl. 3, fig. 8.
in press *Nucleopygus coravium* Agassiz & Desor, 1847 — Smith & Jeffery, figs. 140i-k, 141b.

Type — The present whereabouts of Defrance's original material is unknown.

Material — Numerous specimens in various collections, including IRScNB 9156 (IG 8621), NHMM: BL 0822a, JJ 9557, K 988, 3343, and MK 2240 (W.M. Felder Colln).

Description — Test small (up to 10 mm in length), ovate, rounded margins, depressed, highest posterior of apical system, slightly longer than wide; oral surface strongly depressed longitudinally. Apical system anterior, tetrabasal, 4 gonopores. Petals simple, small, particularly anterior one, open ended, ending abruptly; lateral and posterior ones (near)equally developed, posterior pair not reaching periproctal opening. Peristome large, wide, oval to (sub)pentagonal, anterior of centre. Phyllodes more or less uniserial to peristome. Periproct oval, longitudinal, in well-developed anal sulcus. Tuberculation dense, scrobiculate.

Occurrence — Currently known from the base of the so-called Orsbach Chalk (Wahlwiller Horizon) at Aachen-Schneeberg, the Lanaye Member (Gulpen Formation), Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members as well as Kunrade Limestone facies (all Maastricht Formation) of the Blom, ENCI-Maastricht BV, Ankerpoort-Marnebel, Ankerpoort-'t Rooth, and CBR-Romontbos quarries, and the Kunrade area (Figs. 8, 18-22).

Nucleopygus scrobiculatus (Goldfuss, 1829)
Pl. 19, figs. 9-11; Pl. 20, fig. 3.

*1829 *Nucleolites scrobiculatus* Goldfuss, p. 138, pl. 43, fig. 3.
1962 *Nucleopygus scrobiculatus* (Goldfuss) — Kier, p. 166, pl. 25, figs. 1-4; text-fig. 142.
in press *Nucleopygus scrobiculatus* (Goldfuss, 1829) — Smith & Jeffery, figs. 140g, 141c (cum syn.).

Type — Holotype, by monotypy, is RFWUIP Goldfuss Colln, no. 332 (Goldfuss, 1829, pl. 43, fig. 3).

Material — Numerous specimens in various collections, including IRScNB 9152-9153 (IG 4285), NHMM: JJ 6735, K 2653, and MM 070-071.

Description — Test small (up to 21 mm in length, mostly much smaller), tall with steep, rounded sides, posterior truncated. Apical system anterior of centre, tetrabasal,

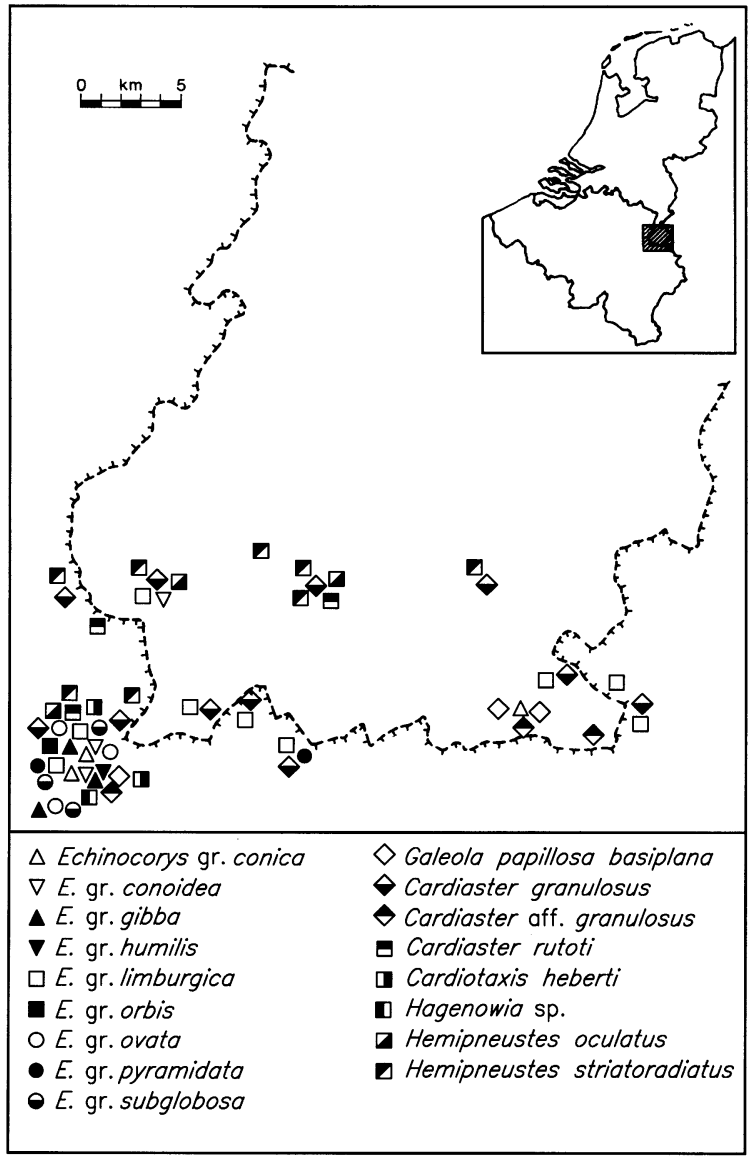


Fig. 11. Geographic distribution of Late Cretaceous-Early Palaeogene holasteroid echinoids in the type area of the Maastrichtian Stage.

4 gonopores. Petals poorly developed, anterior shortest, tending to taper distally, but remaining open; posterior pair longest, but not reaching anal sulcus. Peristome subcentral, relatively large, pentagonal, with inward sloping margins. Phyllodes simple, uniserial except close to peristome; a single pair of sphaeridial pits. Periproct near posterior margin, longitudinally oval, with short anal sulcus. Tuberculation dense, scrobiculate.

Occurrence — Recorded to date from the Lanaye Member (Gulpen Formation), the Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members, as well as Kunrade Limestone facies (all Maastricht Formation), at the CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Blom, Ankerpoort-Curfs, and Ankerpoort-'t Rooth quarries, as well as from the temporary Albertkanaal sections (Vroenhoven-Riemst, Kanne) and the Kunrade-Benzenrade area (Figs. 8, 18-23).

Series Atelostomata von Zittel, 1879
Order Holasteroida Durham & Melville, 1957
Superfamily Orthosternata Smith & Jeffery, in press
Family Echinocoridae Lambert, 1917
Genus *Echinocorys* Leske, 1778

Type species — *Echinocorytes scutatus* Leske, 1778, by subsequent designation of Lambert (1898).

Remarks — On various occasions, it has been shown in the literature that certain test morphologies amongst representatives of the genus *Echinocorys* are typical of certain stratigraphic levels (see e.g. Lambert, 1898, 1903; Ernst, 1970b, 1972, 1975a-b; Fletcher, 1977; Wright & Smith, 1987; Wood, 1988). However, the occurrence of many intermediates at all levels, including those typified by a certain test morphology, complicated matters considerably. As a result of this, palaeontologists working with species of *Echinocorys* have but two options, namely either lump all morphologies into a single species, e.g. the type species *E. scutata*, a course of action favoured by Jeffery (1997b) and Smith & Jeffery (in press), or alternatively, attempt to assign certain test morphologies to previously described species, and treat these as a sort of species group. The latter option is chosen here. The various types found in the Campanian and lower Upper Maastrichtian strata in the Maastrichtian type area, are assigned to species groups, to which the oldest available name is applied. It should be noted that these groups are not afforded the status of full, biological species, but rather are meant to illustrate the link between certain stratigraphic levels and peculiar test morphologies. Apparently, various forms of *Echinocorys* are to be seen as distinct morphotypes occurring at certain stratigraphic levels only, suggesting these to be ecophenotypes. It is these types that can be used as index fossils, at least in a NW European setting. Ernst (1970b, 1972, 1975a-b) provided numerous illustrations of this. Despite obvious drawbacks, it is this interpretation of the various types of *Echinocorys* that is followed here, in part also because the alternative would obscure matters even more. For example, to consider *E.* gr. *conica* and *E.* gr. *subglobosa* as a single species would entirely mask their stratigraphic value, since these have been shown to be typical of successive levels in the lower Upper Campanian of NW Europe.

The general description below applies to all representatives of the genus. For the species groups recognised here, only selected synonyms and current data on geographic distribution and stratigraphic range in the area are provided, the various photographs illustrating typical examples of each species group.

Description — Test of medium to large size; outline ovate or near-circular; plating generally relatively thick; (sub)conical, hemispherical or domed in profile, base flat and depressed anteriorly towards peristome; no frontal notch. Apical disc eth-

mophract and elongate with 3-4 gonopores; ambulacra with similar pore pairs, all flush, and non petaloid to subpetaloid; pores small, inconspicuous and simple. Plastron structure meridosternous, approximating orthosternous; peristome relatively small, D-shaped. Periproct either posterior on oral face, and situated in raised, teardrop-shaped portion of interambulacrum, or inframarginal; a partial marginal fasciole may be present; no other fascioles, but surrounding the above-mentioned raised interambulacral area are closely-packed miliaries, resembling a fasciole. Tuberculation scattered, fine, numerous miliaries. Adoral ambulacra with dense cover of miliaries.

Echinocorys gr. *conica* (L. Agassiz, 1847)
Pl. 20, figs. 4-5.

*1847 *Ananchytes conica* L. Agassiz, p. 136.
1903 *Echinocorys conicus*, Agassiz (*Ananchytes*), 1847. — Lambert, p. 66, pl. 4, figs. 1-2; pl. 5, fig. 6.
1935a *Echinocorys lata* Lambert — Smiser, p. 30, fig. 12a-b.
1935a *Echinocorys lata* var. *fastigata* Lambert — Smiser, p. 31, fig. 13a-c.
*1935a *Echinocorys lamberti* Smiser, p. 32, pl. 2, figs. 3-4; text-fig. 14a-b.
1935a *Echinocorys conicus* Agassiz (*Ananchytes*) — Smiser, p. 33, fig. 15a-c.
1935a *Echinocorys conicus* var. *minor* Lambert — Smiser, p. 34, fig. 16.
1970a *Echinocorys conicus* (Agassiz) — Ernst, pl. 5, fig. 4.
1972 *Echinocorys conica* (Agassiz) — Ernst, p. 174, pl. 7, fig. 1.

Type — The whereabouts of Agassiz's (1847) original is unknown. Holotype of *E. lamberti* is IRScNB 9017 (Smiser, 1935a, pl. 2, fig. 3), paratype is IRScNB 9018; holotype of *E. conica* var. *minor* is IRScNB 9016 (IG 6435); holotype of *E. lata* is IRScNB 9020 (IG 6312; Smiser, 1935, fig. 12a-b); holotype of *E. lata* var. *fastigata* is IRScNB 9021 (IG 6435; Lambert, 1903, pl. 3, fig. 5).

Material — Numerous well-preserved specimens in various collections, including IRScNB 9015 (IG 6435), NHMM GK 2655, and 6606 (W.M. Felder Colln).

Discussion — This group comprises all comparatively small, (sub)conical forms, with near-circular base, and either truncated or raised apex, typifying the upper Lower and lower Upper Campanian in NW Europe (see e.g. Ernst & Koch, 1975).

Occurrence — Restricted to the lower Zeven Wegen Member (Gulpen Formation) at the CPL SA and CBR-Lixhe quarries, as well as at Zeven Wegen/Vijlenerbosch (Figs. 11, 16).

Echinocorys gr. *conoidea* (Goldfuss, 1829)
Pl. 20, figs. 6-7.

*1829 *Ananchytes conoideus* Goldfuss, p. 145, pl. 44, fig. 2a-b.
1903 *Echinocorys conoideus*, Goldfuss (*Ananchytes*), 1826 — Lambert, p. 78.
1935a *Echinocorys conoideus* Goldfuss (*Ananchytes*) — Smiser, p. 35, fig. 18a-c.

Type — Goldfuss (1829) illustrated two specimens; in the Goldfuss Colln (RFWUIP) there are two tests (no. 343a-b), one being an internal flint mould, the other preserving test and showing typical 'Lixhe Member preservation'. The latter is here considered to be the type.

Material — Numerous specimens in various collections, including IRScNB 9038 (IG 6312), NHMM MD 1607, and MM 803.

Discussion — The test morphology represented by Goldfuss's type specimen is particularly well represented in the Lixhe 1 Member (Gulpen Formation), as exposed at the CPL SA, CBR-Lixhe, and ENCI-Maastricht BV quarries. Apparently, representatives of this group have comparatively coarse adapical tuberculation.

In view of the fact that the specimen probably came from the Lixhe Member originally, a flint-preserved test with peristomial plating (Pl. 21, fig. 11) is here illustrated. Preservation of peristomial (and periproctal) plating in holasteroid echinoids from the Maastrichtian type area is extremely rare, with the exception of some levels in the Nekum and Meerssen members which have yielded material of *Hemipneustes striatoradiatus* (see below). The type of plating preserved in the present specimen of *Echinocorys* is closely comparable to material illustrated by Lambert (1903, fig. 4) and Moskvin & Shumanskaia (1993, fig. 2).

Occurrence — Well known from the Lixhe 1 Member, but possibly extending downwards into the uppermost Vijlen Member (Interval 6) and upwards into Lixhe 2 (and 3 ?) members, at the quarries mentioned above (Figs. 11, 16-17, 20).

Echinocorys gr. *gibba* (Lamarck, 1816)
Pl. 20, fig. 8.

*1816 *Ananchytes gibba* Lamarck, p. 25.
1903 *Echinocorys gibbus*, Lamarck (*Ananchytes*), 1816. — Lambert, p. 59, pl. 2, fig. 6.
1935a *Echinocorys gibbus* Lamarck (*Ananchytes*) — Smiser, p. 21, fig. 6a-d.

Type — The present whereabouts of Lamarck's original material is unknown.

Material — IRScNB 9004 (IG 6453), NHMM: K 133, 134, and MM 804.

Discussion — Typical representatives and intermediates between *gibba* and *marginata* are typical of the middle Lower Campanian in northern Germany (Ernst, 1975a; Ernst & Koch, 1975), and in France and southern England (Lambert, 1903). Lambert's (1903) material from the 'Craie d'Obourg' of the Mons Basin (southern Belgium) is of comparable age to specimens from Liège.

Occurrence — Known from the Zeven Wegen Member (Gulpen Formation) at Heure-le-Romain and at comparable levels in the CPL SA and CBR-Lixhe quarries (Fig. 11).

Echinocorys gr. *humilis* sensu germanico
Pl. 20, figs. 10-11.

compare
1903 *Echinocorys ovatus* Leske, 1778 Variété *porosa* Lambert, p. 75, pl. 5, fig. 7.
non1903 *Echinocorys ovatus* Leske, 1778 Variété *humilis* Lambert, p. 74, pl. 3, figs. 10-11.
1970a *Echinocorys humilis* Lambert — Ernst, pl. 5, fig. 5.
1994 *Echinocorys* ex gr. *brevis* Lambert-*humilis* Lambert — Hauschke, pl. 22, figs. 5-8; pl. 23, figs. 1-6.

Type — Lambert (1903) did not select a type specimen of his var. *porosa*; the present whereabouts of his original material is unknown.

Material — A number of specimens, including NHMM HB 736.

Discussion — In test morphology, as well as in adapical ambulacral structure, material from the Vaals Formation as exposed at the CPL SA quarry, is close to 'populations' of *Echinocorys* from the Lower Campanian of the Münster Basin (Germany). In fact, Lambert's (1903) var. *porosa* came from that area; the occurrence of close-set pore pairs in the adapical portions of the ambulacra is undoubtedly an adaptation to lithofacies.

Forms more closely comparable to *E. humilis*, of the type Lambert (1903, p. 75) mentioned from the Campanian of Harmignies and Heure-le-Romain, occur in the Zeven Wegen Member in the Haccourt-Lixhe area. A form close to the type occurring in the Beeston Chalk of Norfolk is illustrated in Pl. 21, fig. 8.

Occurrence — Restricted to the Vaals Formation at the CPL SA quarry (Figs. 11, 16).

Echinocorys gr. *limburgica* Lambert, 1903
Pl. 20, fig. 9; Pl. 21, figs. 1-4.

*1903 *Echinocorys limburgicus* (*n. var.*) Lambert, p. 75, pl. 6, figs. 7-9.
*1903 *Echinocorys duponti* Lambert, p. 81, pl. 6, figs. 3-6.
1935a *Echinocorys limburgicus* Lambert — Smiser, p. 24, fig. 8a-c.
1935a *Echinocorys limburgicus* var. *duponti* Lambert — Smiser, p. 26, fig. 9a-b.
?1935a *Echinocorys ciplyensis* Lambert — Smiser, p. 45, fig. 24a-c.
?1935a *Echinocorys ciplyensis* var. *arnaudi* Seunes — Smiser, p. 46, fig. 25a-c.
1994 *Echinocorys* gr. *limburgica* Lambert, 1903 — Jagt & Michels, p. 719, pl. 1, figs. 1-2.

Types — Holotype of *E. limburgica* is IRScNB 9032 (IG 4285; Lambert, 1903, pl. 6, figs. 7-9); holotype of *E. duponti* is IRScNB 9043 (IG 4285; Lambert, 1903, pl. 6, figs. 3, 6); holotype of *E. ciplyensis* is IRScNB 9034 (IG 5496) (Lambert, 1898, pl. 5, figs. 15-16).

Material — Numerous well-preserved specimens in various collections, including IRScNB 9039; NHMM: JJ 835, K 785, 831, MD 1901, GK 121, 488 (W.M. Felder Colln), and Vijlen Groep Colln, nos. A6, A23.

Discussion — For the time being, the oldest available name is applied to representatives of this widely distributed group. Lambert (1903, p. 75) erected his *E. limburgica* on the basis of abundant material from 'la Craie à *Magas pumilus* du Limbourg, à Galoppe et Slenaken', and coeval strata at Aachen-Schneeberg (= Vijlen Member). His var. *duponti* clearly belongs here as well, having been collected from the same strata. As Jagt et al. (1995, p. 13) noted, *E. ciplyensis* Lambert, 1898 and *E. arnaudi* Seunes, 1888, considered to be conspecific by some authors, could well prove to belong to the same group. The latter is known from Lower Maastrichtian strata at Tercis (Dax, SW France) and comparable forms occur commonly in the *sumensis* Zone at Trimingham (Norfolk), which means that the *limburgica* group could well characterise the upper Lower Maastrichtian across western Europe. A direct comparison of 'populations' from the various levels is needed to confirm this.

Of note amongst the present specimens is NHMM MD 1901, a slightly distorted, juvenile test, 21 mm in length, and peristome width of 2.8 mm. Juvenile or subadult specimens of *Echinocorys* are rare, which is no doubt (in part) due to the extreme fragility of their tests.

Occurrence — Highly typical of the Vijlen Member, but possibly extending into the overlying Lixhe 1 Member, at the CPL SA, CBR-Lixhe, and ENCI-Maastricht BV quarries, as well as from Mesch, Snouwenberg, Altembroeck (Voer), the Vijlen-Mamelis area, and Aachen-Schneeberg (Figs. 11, 16-17).

Echinocorys gr. *orbis* Arnaud, 1883
Pl. 21, fig. 10.

*1883 *Echinocorys orbis* Arnaud, in Cotteau, p. 142, pl. 8, figs. 1-4.
1903 *Echinocorys orbis*, Arnaud, 1883 — Lambert, p. 68, pl. 1, figs. 18-20.

Type — The whereabouts of Arnaud's originals is unknown.

Material — NHMM: K 134, 604, and MM 0805-2.

Discussion — Although differing from material from the Campanian of Charentes (France), the present specimens are close to material from the 'Craie d'Obourg' (Upper Campanian), as illustrated by Lambert (1903).

Occurrence — Known only from the Zeven Wegen Member in the Haccourt area (Fig. 11).

Echinocorys gr. *ovata* (Leske, 1778)
Pl. 21, fig. 5.

*1778 *Echinocorytes ovatus* Leske, p. 178, pl. 53, fig. 3.
1903 *Echinocorys ovatus*, Leske, 1778. — Lambert, p. 69, pl. 4, figs. 6-7; pl. 5, figs. 1-2.
1935a *Echinocorys ovatus* Leske (*Echinorytes* [sic]) — Smiser, p. 19, fig. 5a-c.

Type — The present whereabouts of Leske's original material is unknown.

Material — Numerous well-preserved specimens in various collections, including IRScNB 9023 (IG 6312); NHMM: GK 1867, 1999, 2001, and 2607 (W.M. Felder Colln).

Discussion — This group comprises the largest representatives of *Echinocorys*, being particularly common in the lowermost Zeven Wegen Member, but extending to the top of that unit, of early Late Campanian age.

Occurrence — Known only from the Zeven Wegen Member at Heure-le-Romain and at the CPL SA quarry (Figs. 11, 16).

Echinocorys gr. *pyramidata* (Portlock, 1843)
Pl. 21, figs. 6-7.

*1843 *Ananchytes pyramidatus* Portlock, p. 355.
1903 *Echinocorys pyramidatus* Portlock (*Ananchytes*), 1843. — Lambert, p. 71, pl. 4, figs. 4-5.
1935a *Echinocorys pyramidalis* [sic] Portlock (*Ananchytes*) — Smiser, p. 39, fig. 20.
?1972 *Echinocorys pyramidalis* Smiser (non *E. pyramidata* [Portlock]) — Ernst, p. 172, pl. 6, fig. 5.

Type — The present whereabouts of Portlock's original material is unknown.

Material — NHMM MM 1073, and Vijlen Groep Colln, no. A9.

Discussion — Referred to this group are tests which typically are almost symmetrically conical, and which characterise the latest Late Campanian and Early (? earliest)

Maastrichtian in NW Europe. Lambert (1903) documented a comparable stratigraphic range for material from southern Belgium (Mons Basin).

Occurrence — Known to date from the Zeven Wegen and Vijlen members of Haccourt (CPL SA quarry) and Altembroeck (Voer) (Figs. 11, 16).

Echinocorys gr. *subglobosa* (Goldfuss, 1829)
Pl. 21, fig. 9.

*1829 *Ananchytes striatus* (specimen) *subglobosum* Goldfuss, p. 146, pl. 44, fig. 3.
1903 *Echinocorys subglobosus*, Goldfuss, 1826. — Lambert, p. 62, pl. 2, figs. 7-8.
1935a *Echinocorys subglobosus* Goldfuss (*Ananchytes*) — Smiser, p. 15, fig. 3a-e.
1994 *Echinocorys subglobosus* (Goldfuss) — Hauschke, pl. 22, fig. 3.

Type — Holotype, by monotypy, is RFWUIP Goldfuss Colln, no. 344A (Goldfuss, 1829, pl. 44, fig. 3a-c).

Material — IRScNB 9011-9013 (IG 6312), NHMM: GK 2437, 2660, 2661, and 2672 (W.M. Felder Colln), and MM 1130/1-2.

Discussion — A recent re-examination of the type specimen has shown that this could well have come from the Zeven Wegen in the Haccourt area. At the CPL SA quarry, comparable test morphologies are common in the basal Zeven Wegen Member, co-occurring with *E.* gr. *conica*, which is even commoner at this level. In northern Germany, the *subglobosa* group is particularly common in and typical of the lower Upper Campanian (Ernst, 1970b, 1975a; Ernst & Koch, 1975; Hauschke, 1994).

Occurrence — Known only from the lower Zeven Wegen Member at Heure-le-Romain and the CPL SA quarry (Figs. 11, 16).

Genus *Galeola* Quenstedt, 1874

Type species — *Echinocorytes minor*, var. *papillosa* Leske, 1778, by monotypy.

Galeola papillosa basiplana Ernst, 1971
Pl. 21, figs. 12-14.

*1971 *Galeola papillosa basiplana* Ernst, p. 219, figs. 20a, 21, 23/2-6.
1971 *Galeola* m.f. *papillosa/basiplana* Ernst, p. 222, fig. 23/8-9.
1975a *G. papillosa basiplana* — Ernst, p. 87, fig. 11.

Type — Holotype is Ksm2.65 (G. Ernst Colln, Freie Universität Berlin).

Material — NHMM: BL 1068, GK 1465e-g, 1631, 1897, 1898 (W.M. Felder Colln), JJ 728, 768, 6900, K 2993, MA 0321-1, MM 816, 945-946.

Description — Test medium-sized (up to 35 mm in length), generally with well-rounded apex; margins angular, base mostly flat, lacking a raised plastron; peristome in shallow depression; anal angle obtuse; periproct inframarginal; (extremely) thin plated. Tuberculation scattered, numerous miliaries; no fascioles; ambulacra non petaloid, flush, with small, subequal pores; apical system elongate.

Discussion — In addition to forms closely comparable to the type material from the lower Upper Campanian of the Hannover area (Germany), 'populations' from the

basal Zeven Wegen Member also comprise specimens that are closer to what Ernst (1971, fig. 23/8) named *G.* m.f. *papillosa/basiplana* from the 'Craie d'Obourg' of Harmignies (Mons Basin). Next in line to coleoid and ammonoid cephalopods, this echinoid is of particular biostratigraphic importance, as it has been shown to be confined to the lower Upper Campanian, in northern Germany (Ernst, 1963, 1970a, 1971; Schulz, 1985), eastern England (Norfolk; see Brighton, 1939; Schulz, 1985), southern Belgium, and in the extended Maastrichtian type area.

Occurrence — Restricted to the lower Zeven Wegen Member, the highest occurrence between 6 and 7.5 m above the base of that unit, at the CPL SA and CBR-Lixhe quarries, as well as at the Zeven Wegen/Vijlenerbosch and Kosberg (Figs. 11, 16).

Family Cardiasteridae Lambert, 1917
Genus *Cardiaster* Forbes, 1850

Type species — *Spatangus granulosus* Goldfuss, 1829, by original designation.

Cardiaster granulosus (Goldfuss, 1829)
Pl. 22, figs. 1-5.

*1829 *Spatangus granulosus* Goldfuss, p. 148, pl. 45, fig. 3.
1992 *Cardiaster granulosus* (Goldfuss, 1829) — van der Ham & van Birgelen, p. 150, pl. 4, fig. 5.
1994 *Cardiaster granulosus* (Goldfuss, 1829) — Jagt & Michels, p. 719, pl. 1, figs. 3-4.
in press *Cardiaster granulosus* (Goldfuss, 1829) — Smith & Jeffery, fig. 166 (partim).

Type — Holotype, by monotypy, is RFWUIP Goldfuss Colln, no. 347 (Goldfuss, 1829, pl. 45, fig. 3).

Material — Numerous specimens in various collections, including NHMM: JJ 753, 6416, K 774, 2479, MD 3732, and RH 81.

Description — Test medium-sized to large (up to c. 70 mm in length), cordiform, with well-defined frontal sulcus, with raised adjoining interambulacra; adoral surface with sternal zigzag keel; adapical surface low domal, highest at apical system. Adapically, large interambulacral tubercles occur (alternately) along the edges of the anterior sulcus, as well as on both sides of the apical system, and along the suture in interambulacrum 5. Paired ambulacra are flush with test, consist of comma-shaped pore pairs; columns unequally developed, pairs in anterior one smaller and less well developed. Pore pairs in unpaired ambulacrum much smaller, simpler, and oblique. Apical system elongate, four gonopores. Plastron meridosternous with series of alternating plates following first pair of sternal plates. Peristome relatively small, faintly labiate, sunken anteriorly, surrounded by enlarged pores. Periproct relatively large, (sub)circular, in centre of truncated posterior. Marginal fasciole runs below periproct, is best developed posteriorly and becomes diffuse anteriorly. Tuberculation dense, uniform, many miliaries.

Discussion — Goldfuss (1829) originally described this species from Maastricht. In view of the fact that *C. granulosus* is long-ranging and occurs in various facies types in that area, it was decided to re-examine Goldfuss's original (RFWUIP collections). Unfortunately, at the time of my visit (August 1994), the type was not available for

study. There can be no doubt, however, on the species' identity, but it would certainly have helped to have known from which level the type had come. The best preserved material, as far as details of test morphology are concerned, comes from Interval 6 of the Vijlen Member in the Haccourt-Lixhe area (CPL SA and CBR-Lixhe quarries). Numerous specimens, of various size classes, show the typical features to be quite constant; some preserve parts of adapical and adoral spine canopies, and a single specimen with six ambulacra is known as well.

Jagt & Michels (1986) presented a preliminary analysis of *C. granulosus* from various levels in the Liège-Limburg Upper Cretaceous, and noted slight differences in the development of enlarged interambulacral tubercles on the adapical test surface. In material from the Maastricht Formation, including the Kunrade Limestone facies which has produced many well-preserved, generally small specimens, these tubercles were less prominent. This was considered to be directly linked to the nature of the sediment into which these echinoids ploughed. From the Kunrade area, a single specimen preserving both peristomial plating and adoral spines is known (Pl. 22, figs. 3-4). Unfortunately, material from the upper Gulpen Formation (Lixhe and Lanaye members) and lower Maastricht Formation (Valkenburg, Gronsveld, and Emael members) was then very limited, so that no developmental trend through time could be discerned. Even today, there are but very few specimens from this interval, and most of these are poorly preserved. Material from residual flint deposits, although having yielded 'good' specimens of both *C. granulosus* and *C. rutoti* (see below), is of no real help, since it also comprises many intermediate morphologies. Too few of these are currently known from the biocalcarenitic strata themselves to be of much use in unravelling relationships in this group. In addition, representatives of *Cardiaster* are also known from the Lower Campanian (Vaals Formation), as exposed in the Haccourt and Vaals-Eschberg areas (see below). These have to be included in the discussion as well.

For the time being, and based solely on material collected in situ (e.g. ignoring specimens from residual flint deposits), *C. granulosus* and *C. rutoti* are considered to be distinct species, as is the Early Campanian form.

Occurrence — As here understood, *C. granulosus* is currently known from the Vijlen, Lixhe, and Lanaye members (Gulpen Formation), the Valkenburg, Gronsveld, Emael, Nekum, and Meerssen members as well as the Kunrade Limestone facies (all Maastricht Formation), with records from the CPL SA, CBR-Lixhe, CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Nederland BV, Ankerpoort-'t Rooth quarries, as well as from Altembroeck, Mesch, Snouwenberg, Aachen-Schneeberg, Mamelis-Selzerbeek, and the Kunrade-Benzenrade area (Figs. 11, 16-20).

Cardiaster aff. *granulosus* (Goldfuss, 1829)
Pl. 22, figs. 6-7.

Material — NHMM: JJ 174, VG 3055 (W.M. Felder Colln), and 1999009.

Description and discussion — Similar to the previous form, but generally smaller (up to c. 40 mm in length), with frontal sulcus less deep, and interambulacra bordering the unpaired ambulacrum less raised. The most important difference, however, lies in the structure of the plastron, which is similar to the one seen in *C. cordiformis*

(Woodward, 1833) (p. 50), from the upper Upper Campanian of England and northern Germany, and possible precursor of *C. granulosus*. Ernst (1972, fig. 20) illustrated the plastron of a specimen from the *polyplocum* Zone at Ilten-Ahlten (Hannover area) and referred to it as *C.* aff. *granulosus*. Subsequent authors (e.g. Wood, 1988; Niebuhr et al., 1997) have pointed out that this form cannot possibly be synonymised with *C. granulosus*, and that it is widespread and confined to certain horizons in the upper Upper Campanian (*polyplocum* Zone and equivalents).

Whether or not the present material can be referred to *C. cordiformis* remains to be determined; the stratigraphic gap between the specimens from the Vaals Formation (*lingua/quadrata* Zone, early Early Campanian) and typical *C. cordiformis* is probably too great. The Vaals Formation material possibly represents another, stratigraphically older member of the *cordiformis-granulosus* lineage, suggesting it to be an offshoot of *C. jugatus* Schlüter, 1869 of Santonian age (see below).

Occurrence — Apparently confined to the Vaals Formation, with records from the CPL SA quarry, the Cottessen area (southern Limburg) and Vaals-Eschberg (Figs. 11, 16).

Cardiaster rutoti (Lambert, 1911)
Pl. 22, figs. 12-14; Pl. 24, fig. 1.

*1911 *Heteropneustes Rutoti* Lambert, p. 38, pl. 2, fig. 12.
1935b *Toxopatagus rutoti* Lambert (*Heteropneustes*) — Smiser, p. 73, pl. 9, fig. 1.
1981 *Toxopatagus rutoti* (Lambert) — Meijer, p. 192, fig.
1985a *Cardiaster rutoti* (Lambert) — van der Ham, p. 112.

Type — Holotype is IRScNB 9202 (IG 4949; Lambert, 1911, pl. 2, fig. 12; refigured by Smiser, 1935b, pl. 9, fig. 1e).

Material — IRScNB 9203 (IG 6521); NHMM: JJ 7478, 10819, MK 889 (W.M. Felder Colln), RD 72, and 1981148.

Description — Test medium-sized to large (up to 120 mm in length, but mostly smaller), fragile, with well-rounded margins, widest just posterior of apical system, highest well anterior of or at apical system, sloping gradually to truncated posterior; anterior notch shallow and wide, in cross section broadly rounded V-shaped, adjoining interambulacra raised, but not keeled; pores in unpaired ambulacrum small and oblique; paired ambulacra more or less straight, slightly curved, the posterior pair bowed, almost flush with test, the posterior column being wider and better developed; marginal fasciole, best developed posteriorly; plastronal sutures oblique (Smiser, 1935b, pl. 9, fig. 1b). Adoral surface convex across slightly keeled (zigzag) plastron; peristome large, reniform, distinctly labiate; periproct large, (sub)circular to longitudinally elongate, on obliquely truncated posterior. Adapical tuberculation small, uniform, close cover of miliaries; adoral tubercles larger, especially on plastron and towards ambitus in anterior half.

Discussion — Lambert (1911) based this species on an internal flint mould (L: 97 mm; W: 88 mm; H: 45 mm), collected at Looz (= Borgloon, northwest of Tongeren/Tongres), from deposits first correlated with the 'craie de Spiennes', but later with the 'craie de Nouvelles', a view held by Rutot. In both cases, this would

mean a Campanian age for the type. Smiser (1935b) could not have been more right when he observed that the Looz specimen was hardly a sound enough basis for the erection of a new species, and redefined Lambert's taxon. Smiser's material is much better, and includes a well-preserved test from Kanne (Limburg, Belgium; L: 113 mm; W: 105 mm; H: 55 mm). Smiser (p. 75) also expressed his doubts over the Campanian age of Lambert's material, noting that the specimen could well have been collected from strata of Maastrichtian age. Our current knowledge of the Tongeren area, and the fact that Lambert's specimen is preserved as an internal flint mould, underscores Smiser's views.

Although, as outlined above, residual flint deposits in the Haccourt-Lixhe area have yielded tests which are morphologically intermediate between *C. granulosus* and *C. rutoti*, test material of both taxa available for the present study show them to be distinct. Differences are striking and relate to test shape, depth of the anterior sulcus, ambulacral pore size and structure, size of peristome (peristome width 1/4th of test width in *C. rutoti*; 1/8th in *C. granulosus*), width of plastron, and, plastronal sutures.

As briefly commented upon above, the lineage leading to *C. granulosus*, including the Early Campanian *C.* aff. *granulosus* (see above) and the Late Campanian *C. cordiformis*, may represent an offshoot of *C. jugatus*. This species, originally described from the Upper Santonian or lowermost Campanian of Westphalia (Germany; see Schlüter, 1869, p. 247, pl. 3, fig. 3a-d; 1897b, pl. 33, fig. 1), has subsequently been reinterpreted by Ernst (1973, p. 96, fig. 5a-c). Notable is the close resemblance between this species and *C. rutoti* in profile. The structure of the plastron shows closer similarities to that of *C. rutoti* than of *C. granulosus*, and shows beyond doubt that the specimens from the Vaals Formation (see above) cannot be assigned to *C. jugatus*, despite the fact that they of comparable age.

It thus seems as if *Cardiaster* experienced a similar developmental trend as the micrasterid genus *Micraster*, in that at various points in time, offshoots of the main lineage were typical of marginal facies settings.

Occurrence — To date, there are definite records of *C. rutoti* from the Lanaye Member (Gulpen Formation), the Gronsveld, and Nekum members (Maastricht Formation) at the CBR-Romontbos, Ankerpoort-'t Rooth and at the temporary Albertkanaal sections (Kanne) (Figs. 11, 19).

Genus *Cardiotaxis* Lambert, 1917

Type species — *Cardiaster peroni* Lambert, in Peron, 1887, by original designation.

Cardiotaxis heberti (Cotteau, in Cotteau & Triger, 1860)
Pl. 22, figs. 8-11.

*1860 *Cardiaster heberti* Cotteau, in Cotteau & Triger, p. 240.
1869 *Cardiaster maximus* Schlüter, p. 59, pl. 7, fig. 1, 1a-b.
1975a *Cardiotaxis heberti* — Ernst, p. 87, fig. 11.
1978a *Cardiotaxis heberti* (Cotteau, 1856) — Kutscher, p. 627, pl. 1.
1997b *Cardiotaxis heberti* (Cotteau, in Cotteau and Triger, 1860) — Jeffery, p. 688, pl. 7, figs. 9-11; text-fig. 11a-b.
in press *Cardiotaxis heberti* (Cotteau in Cotteau & Triger, 1860) — Smith & Jeffery, fig. 167.

Type — The present whereabouts of Cotteau's original material is unknown.

Material — IRScNB 9192 (IG 6312); NHMM: GK 1870, 1871, 2724 (W.M. Felder Colln), JJ 720, K 901, and MM 572-1, 572-2.

Description — Test large (up to 85 mm in length), fragile, weakly cordate in outline, greatest width just anterior of apical system; rounded inflated in profile with convex base, highest posterior of apical system, and obliquely truncated posterior. Apical disc anterior, elongate, four gonopores. Frontal notch narrowly U-shaped, fairly deep at ambitus, but flush anterior of apical disc; adjoining anterior interambulacra slightly raised, but not keeled. Paired ambulacra flush, with comma-shaped pore pairs, columns more or less equally developed; pores in unpaired ambulacrum minute and poorly developed. Peristome small, close to anterior border, opening into frontal notch; no enlarged phyllode pores around it. Periproct elongate, small, high on truncated posterior surface. Plastron metasternous, consisting of single plates. Marginal fasciole, best developed posteriorly. Tuberculation fine, sparse.

Discussion — Easily recognised on account of plastronal structure, and lack of enlarged interambulacral tubercles adapically. Jeffery's (1997b) records of *C. heberti* from the Lower Maastrichtian of Belgium and The Netherlands are incorrect (see below).

Occurrence — Restricted to the Zeven Wegen Member (Gulpen Formation), especially to its basal metre, with records from the CPL SA and CBR-Lixhe quarries (Figs. 11, 16-17).

Genus *Hagenowia* Duncan, 1889

Type species — *Cardiaster rostratus* Forbes, 1852, by original designation.

Hagenowia sp. ?nov.
Pl. 23, figs. 1-4.

1999c *Hagenowia* sp. (?nov.) — Jagt, pl. 1, figs. 11-12.

Material — NHMM: JJ 9594, and MB 808-2.

Description and discussion — A detailed description of this species will be published elsewhere. So far, only isolated rostra have been collected, many of which show signs of abrasion. Our current interpretation suggests the material from the upper Lower Campanian (Zeven Wegen Member) of the CPL SA quarry (Haccourt) to be of a taxon intermediate between *H. blackmorei* Wright & Wright, 1949 and *H. elongata* (Brünnich Nielsen, 1942), which Ernst et al. (1971, fig. 2) referred to as *Hagenowia rostrata* ssp., based on material from the Beeston Chalk of Norfolk (see also Schmid, 1972, p. 177, pls 1-4; Kutscher, 1978a, p. 629, pl. 2; Gale & Smith, 1982; Wood, 1988). Whittlesea (1996a) stated that *H. elongata* occurred regularly throughout much of the upper Upper Campanian of Norfolk, and was the commonest echinoid at some horizons, e.g. in the middle Weybourne Chalk. The latter occurrence would correspond well with the Haccourt material. In view of this, it was decided to include the English material, and complement the description with a discussion on the stratigraphic range of this form.

Occurrence — Known exclusively from the lower Zeven Wegen Member at the CPL SA quarry (Figs. 11, 16).

Family Labrotaxidae Smith & Jeffery, in press
Genus *Hemipneustes* L. Agassiz, 1836
[= *Enallopneustes* Pomel, 1883; see Jeffery, 1997a]

Type species — *Spatangus radiatus* Lamarck, 1816 = *S. striato-radiatus* Leske, 1778, by original designation.

Hemipneustes oculatus Cotteau, 1890
Pl. 24, figs. 2-3.

*1890 *Hemipneustes oculatus* Cotteau, p. 4, pl. 1, figs. 1-3.
1982 *Hemipneustes oculatus* Cotteau, 1890 — van der Ham, p. 181, figs. 1-4.

Type — The present whereabouts of Cotteau's original is unknown; the IRScNB collections contain a plaster cast of this specimen.

Material — IRScNB 9045; NHMM: JJ 6186, 8863, 8864, 10311, 10297, MK 1347 (W.M. Felder Colln), and 1983011. The RGM collections contain two topotypes on a single slab (RGM 12 467).

Description — Test of large size (up to c. 150 mm in length), fragile, with well-rounded margins, widest posterior of apical system, highest anterior of apical system, sloping gradually to low, truncated posterior; anterior notch very deep and U-shaped in cross section, occasionally constricted distally; adjoining interambulacra raised, and distinctly keeled; pores in unpaired ambulacrum minute and oblique; paired ambulacra strongly flexuous, the posterior column much wider and shallowly sunken, anterior one flush, interporiferous zones wide; no fascioles; plastronal sutures oblique, closely comparable to those in *C. rutoti*. Adoral surface flat, plastron faintly keeled; peristome large, crescentic, but almost entirely obscured by prominent labral plate, surrounded by large pores; periproct large, circular to transversely oval, obscured from plan view under obliquely truncated posterior. Adapical tuberculation very dense, uniform, tubercles hardly distinguishable from miliaries, except for enlarged tubercles along anterior notch; adoral tubercles larger, especially on plastron, where they are often aligned, and towards ambitus in anterior half. NHMM JJ 6186 preserves peristomial and periproctal plating.

Discussion — This is the largest echinoid species known to date from the study area. Smith (1995, p. 223) was certainly wrong when he considered van der Ham et al.'s (1987) record of *H. oculatus* to be based on rather tall and posteriorly inclined *H. striatoradiatus*. Differences between these species are striking, and even fragments can be assigned without any difficulty. Jagt's (1985) record of *H. oculatus* from the Nekum Member is based on a posterior test fragment, which might be better placed in *Cardiaster rutoti*. This means, that the stratigraphic range of *H. oculatus* in the Maastrichtian type area is reduced to the Lanaye and Valkenburg members, the stratigraphically oldest, and largest, specimen on record to date being no. 2331 in the Deckers Colln, which is from the Lanaye Member (flint beds 12-14) at the CBR-Romontbos quarry, Eben Emael (L: c. 150 mm; W: 137 mm).

The type material is from the 'Craie grise' in the Mons Basin (= Craie phosphatée de Ciply), and is thus of Early Maastrichtian (*obtusa* Zone) age. The present material is considerably younger (Late Maastrichtian).

Occurrence — Restricted to the Lanaye and Valkenburg members, with an unsubstantiated record from the upper Gronsveld/lower Schiepersberg Member, with records from the CBR-Romontbos, ENCI-Maastricht BV, Ankerpoort-Marnebel, and Ankerpoort-'t Rooth quarries (Figs. 11, 18-21).

Hemipneustes striatoradiatus (Leske, 1778)
Pl. 23, figs. 5-7; Pl. 24, figs. 4-9.

*1778 *Spatangus striato-radiatus* Leske, p. 234, pl. 25.
*1935b *Spatagoides striatoradiatus* var. *elevatus* Smiser, p. 71, pl. 8, fig. 1e.
*1935b *Spatagoides striatoradiatus* var. *conicus* Smiser, p. 71, pl. 8, fig. 1g.
*1935b *Spatagoides striatoradiatus* var. *depressus* Smiser, p. 71, pl. 8, fig. 1h.
1985 *Hemipneustes striatoradiatus* (Leske) — Smith, p. 223, pl. 30, figs. 7-8; text-fig. 78c.
1999c *Hemipneustes striatoradiatus* juv. — Jagt, pl. 1, figs. 5-7.

Types — The present whereabouts of Leske's original material is unknown; holotype of var. *conicus* is IRScNB 9197 (IG 4285), holotype of var. *depressus* is IRScNB 9198 (IG 6521) and holotype and paratype of var. *elevatus* are IRScNB 9195 (IG 4285), and IRScNB 9196 (IG 5496).

Material — Hundreds of well-preserved specimens in various collections, including NHMM: JJ 469, 1148, K 1762, 1763, 2412, 2727, MK 653, 755, 860, 890, 1585 (W.M. Felder Colln), and 1999010 (ex Indeherberge Colln, no. 998).

Description — Test medium-sized to large (up to 115 mm in length, mostly smaller), in outline narrowly to broadly rounded anteriorly, truncated posteriorly, widest posterior of apical system, with narrow, shallow, but sharply defined frontal notch; variable in profile, from depressed, flat-topped to distinctly raised anterior of apical system, and sloping strongly to posterior end; sides rather vertical resulting in a quadrate, lateral cross section. Lower surface broadly convex, with faint sternal keel; plastron of cuneiform, alternating plates. Apical system elongate, 4 gonopores, hydropores often extending over genital plates 2 and 3 and oculars II, III and IV. Paired ambulacra flexuous, with markedly unequal pores in two columns; anterior series consisting of small, round pores, posterior series of elongate ones. Pore pairs in frontal ambulacrum small, poorly developed. Peristome large, surrounded by large pores, and posteriorly bounded by hardly protruding labral plate; periproct longitudinally oval, widest above, low on posterior face, with distinct subanal depression indenting the ambitus; portions of subanal fasciole in well-preserved material (e.g. NHMM JJ 469).

Discussion — This is possibly the best known echinoid in the area, and certainly the most sought after. More than thirty years ago, W.M. Felder (1963) remarked that he had never found juveniles of *H. striatoradiatus*, let alone fragments of such tests, and this apparent absence of juveniles has puzzled authors ever since. Here (Pl. 23, figs. 5-7), the first putative juveniles of this species are illustrated. Two samples (NHMM K 1762-1763) from the Meerssen Member (Maastricht Formation) at Blom

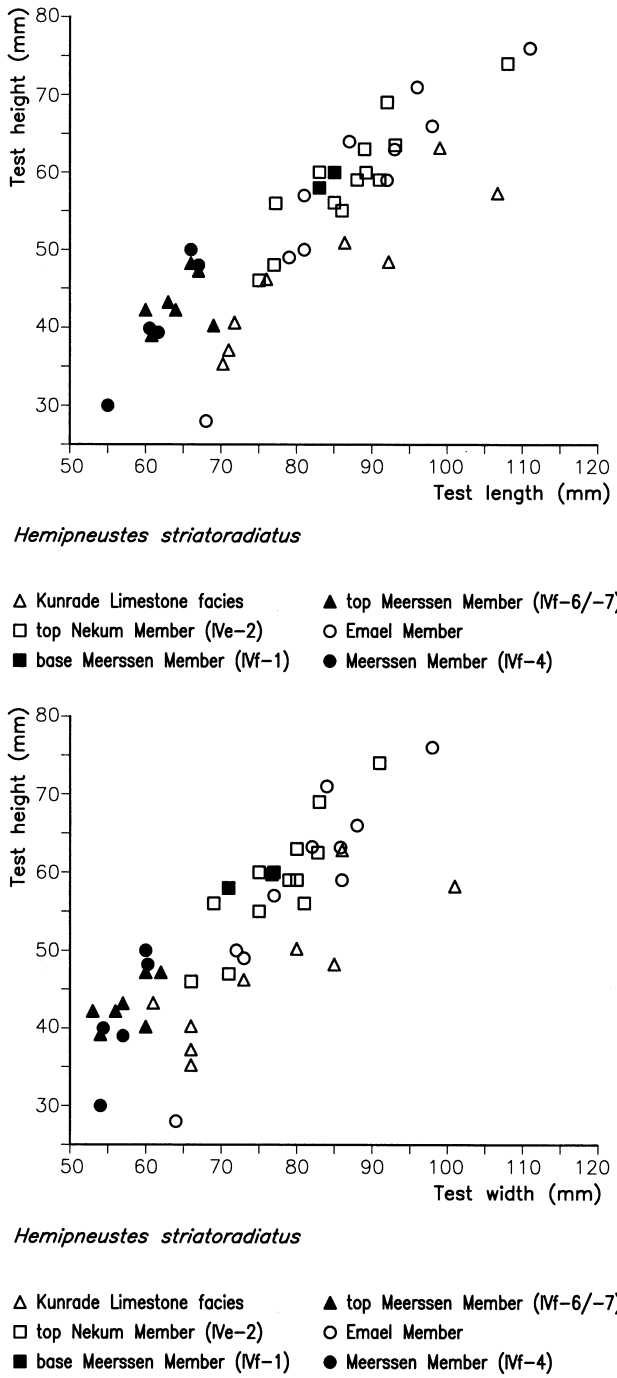


Fig. 12A-B. Relationship between test height, length and width in *Hemipneustes striatoradiatus* (Leske, 1778).

quarry (Berg en Terblijt), yielded these specimens, in several size ranges. Although recrystallisation has obscured details of test plating and ambulacral structure, what can be seen (plastron structure, position of peristome and periproct, frontal sulcus, test outline and profile), strongly suggests these to represent juveniles of *H. striatoradiatus*. At this level in the Meerssen Member, the only other holasteroid echinoid is *Cardiaster granulosus*, but in view of test outline and profile and plastron structure of the present specimens, it is highly unlikely that they are juveniles of that species. Of note also in this respect is the recent discovery in the upper Nekum Member at the CBR-Romontbos quarry by Robert Pieters of death assemblages of *C. granulosus*, comprising various size classes. These substantiate the above conclusion, in demonstrating juvenile *C. granulosus* to have more depressed, wider tests with a flatter base, and more pronounced frontal notch.

Many authors have commented on the extreme range of variation of the present species (see e.g. Smiser, 1935b; Engel, 1945; W.M. Felder, 1963, 1973; Defour et al., 1994). Of these, W.M. Felder (1973) noted that in units Mb and Mc (= Emael and Nekum members in current terminology) tests of *H. striatoradiatus* grew to test lengths of 12 cm, the smallest individuals measuring 70 mm. In unit Md (= Meerssen Member), on the other hand, the largest tests measure 80 mm, the smallest 50 mm. This dramatic size decrease was reported to occur at the transition Mc-Md; in units Md and post-Md (!) (= IVf-7 in current terminology, compare Jagt & Fraaye, 1995) a depressed variety, which Smiser (1935b) had described as var. *depressus*, was common. Later, W.M. Felder (1973, fig. 4) slightly adjusted these data, illustrating typical representatives of *H. striatoradiatus* from units Mc, basal Md and uppermost Md. Figure 12A-B confirms that specimens from the uppermost Meerssen Member plot differently from those of the lower Meerssen and Nekum members, which are close. Of note is the wide scatter of material from the Kunrade Limestone facies.

What caused this size decrease in *H. striatoradiatus* remains to be determined. This phenomenon may well be comparable to what Whittlesea (1996b, p. 36) suggested for small species of the genus *Echinocorys*, noting that 'populations [.....] were responding to an environment liable to frequent, major sedimentary influxes by maturing at a small size.' This could thus be an expression of accelerated maturity; the matter will be addressed in greater detail in Part 6 of the current series.

Details of peristomial and periproctal plating (see Pl. 24, figs. 8-9) of this, and other species for which this is known, will be described elsewhere.

Occurrence — Widely distributed and long-ranging, and only in the Lanaye and Valkenburg members overlapping in range with *H. oculatus*. Current records include the Lanaye Member (Gulpen Formation), Valkenburg, Gronsveld, Schiepersberg, Emael, Nekum, and Meerssen members, as well as the Kunrade Limestone facies of the Maastricht Formation, at the CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Blom, Ankerpoort-Curfs, and Ankerpoort-'t Rooth quarries, and the temporary Albertkanaal sections (Vroenhoven-Riemst, Kanne) and the Kunrade-Benzenrade area (Figs. 11, 18-23).

Order Spatangoida Claus, 1876
Suborder Micrasterina Fischer, in Moore, 1966
Family Micrasteridae Lambert, 1920
Genus *Micraster* L. Agassiz, 1836
[= *Gibbaster* Gauthier, 1887; *Isomicraster* Lambert, in de Grossouvre, 1901; *Paramicraster* M□czyńska, 1968]

Type species — *Spatangus Cor Anguinum* Var. a *Anglicum* Leske, 1778, by subsequent designation of Pomel (1883).

Micraster gr. *schroederi/glyphus*
Pl. 25, figs. 1-6.

*1869 *Micraster glyphus* Schlüter, p. 235, pl. 1, fig. 2.
*1892 *Micraster Schröderi* Stolley, p. 259, pl. 8, fig. 5; pl. 9, fig. 1.
1970c *Micraster (Micraster) glyphus* Schlüter 1869 — Ernst, pl. 17, fig. 4.
1972 *Micraster* m.f. *schroederi/glyphus* — Ernst, p. 170, pl. 5, fig. 3.
1975a *Micraster (M.) glyphus* — Ernst, p. 87, fig. 11.
1975 *Micraster glyphus* Schlüter 1869 — Stokes, p. 70, text-fig. 29l (cum syn.).
1975 *Micraster schroederi* Stolley 1891 — Stokes, p. 78, pl. 9, figs. 5-7; pl. 10, figs. 1-2; text-fig. 30c (cum syn.).

Types — The type of *M. schroederi*, figured by Stolley (1892), was destroyed during air raids in World War II on the city of Hamburg (Stokes, 1975, p. 78); a neotype has not yet been designated. The holotype, by monotypy, of *M. glyphus* is RFWUIP Schlüter Colln, no. 11a (Schlüter, 1869, pl. 1, fig. 2). Schlüter (1869) had 27 specimens at his disposal, all from the Upper Campanian of Coesfeld and Darup (Germany). A re-examination of the material contained in the Schlüter Colln (RFWUIP) has shown that no. 11a from Coesfeld (Harlo) closely resembles Schlüter's pl. 1, fig. 2, but lacks the oral test surface. Schlüter's pl. 1, fig. 2a may be based on specimen 11b, in which the frontal notch is inconspicuous. The curvature of the posterior petals in Schlüter's pl. 1, fig. 2 is exaggerated; adnate juvenile oysters on this specimen are not shown in that illustration.

Material — NHMM: JJ 7988, 9503, K 2519, MM 569, 825, 841, 952-1, and 952-2.

Description — Test medium- to large-sized (up to 84 mm in length), cordate, with distinct frontal notch, highest centrally with truncate posterior which is undercut to varying degrees (Pl. 25, figs. 3, 5), ambitus rounded to polygonal. Paired petals sunken, anterior ones c. 1.5 longer than posterior; pores round in inner series, elongate in outer; anterior ambulacrum sunken from apex to peristome, with small non-conjugate pore pairs. Apical system ethmophract, four gonopores. Peristome close to anterior border, with strong labral projection, labral plate generally long and narrow, periproct inframarginal. Subanal fasciole always present, broad. Long, narrow labral plate.

Discussion — Material from the lower Zeven Wegen Member at the CPL SA quarry comprises specimens of typical *schroederi* morphology (Pl. 25, figs. 1-3) as well as those of typical *glyphus* morphology (Pl. 25, figs. 4-5). In the Hannover area (northern Germany), *M. schroederi* is generally held to be confined to the Lower Campanian, *M.*

glyphus to the lower Upper Campanian. Since most authors (see e.g. Ernst, 1970b, 1972; Stokes, 1975) agree that these forms are part of the same lineage, such a distinction is of course arbitrary. A few specimens are close to *M. (M.) schroederi planus* M□czyńska, 1968 (p. 116, pl. 5, fig. 2; pl. 6, figs. 1-2; pl. 7, fig. 1; text-pl. 5, figs. 1-3; text-pl. 6, figs. 1-3), from the Campanian of southern Poland.

Occurrence — Currently known from the entire Zeven Wegen Member at Heure-le-Romain, Haccourt and Lixhe (CPL SA, CBR-Lixhe quarries), and the Zeven Wegen/Vijlenerbosch area (southern Limburg) (Figs. 13, 16-17).

A deformed specimen (NHMM 3323, W.M. Felder Colln) from the Beutenaken Member at Slenaken (southern Limburg), on which van der Ham et al.'s (1987, p. 33) record of *M. schroederi* from that member is partially based, may belong to the present *schroederi/glyphus* group, but preservation is such that a more definite assignment is impossible.

Micraster stolleyi (Lambert, in de Grossouvre, 1901)
Pl. 25, figs. 7-11.

1869 *Epiaster gibbus* — Schlüter, p. 237, pl. 2, fig. 1.
*1901 *Isomicraster Stolleyi* Lambert, in de Grossouvre, p. 959.
1970a *Micraster (Isomicraster) stolleyi* Lambert — Ernst, pl. 5, figs. 7-8.
1970c *Micraster (Isomicraster) stolleyi* Lambert 1901 — Ernst, pl. 18, figs. 6-7.
1972 *Micraster (Isomicraster) stolleyi* Lambert — Ernst, pp. 164, 168, pl. 2, fig. 8; pl. 4, fig. 6.
1975a *Micraster (Isomicraster) stolleyi* — Ernst, p. 87, fig. 11.
1975 *Micraster stolleyi* Lambert 1901 — Stokes, p. 79, text-fig. 30f.

Type — Holotype, by monotypy, is RFWUIP Schlüter Colln, no. 12 (Schlüter, 1869, pl. 2, fig. 1).

Material — NHMM: GM 786, JJ 4821, 7494, 10316; Appeldoorn Colln, no. 44.

Description — Test tall, small to medium-sized (up to 63 mm in length), cordate, with distinct, but shallow frontal notch, highest centrally, with steep anterior and low, truncate posterior, ambitus rounded. Paired petals slightly sunken, anterior ones c. 1.5 longer than posterior; pores round in inner series, elongate in outer; anterior ambulacrum almost flush with test to slightly sunken close to apex, adorally sunken to peristome, with pore pairs comparable to those of paired petals. Apical system ethmophract, four gonopores. Subanal fasciole absent, periproct very low on test posterior (Pl. 25, figs. 8, 11); peristome close to anterior border, labral plate and plastron wide.

Discussion — This is a rare species, first described from the upper Zeven Wegen Member of the CPL SA quarry by Michels & Jagt (1985). In that part of the unit, *M. stolleyi* co-occurs with *M.* gr. *schroederi/glyphus*, but is much rarer. However, it is easily recognised, even in fragments, from representatives of that group, in having the pore pairs of the anterior ambulacrum similar to those of the paired petals, the absence of the subanal fasciole, the low position of the periproct, and the width of the plastron and labral plate.

Occurrence — Apparently confined to the upper Zeven Wegen Member, with records from the CPL SA and CBR-Lixhe quarries (Figs. 13, 16-17).

Genus *Cyclaster* Cotteau, in Leymerie & Cotteau, 1856
[= *Brissopneustes* Cotteau, 1887]

Type species — *Cyclaster declivus* Cotteau, in Leymerie & Cotteau, 1856, by monotypy.

Cyclaster platornatus Kutscher, 1978b
Pl. 24, figs. 10-12.

*1978b *Cyclaster platornatus* Kutscher, p. 1028, pl. 3, figs. 1-5.
1987 *Cyclaster platornatus* Kutscher, 1978 — Jagt & Michels, p. 58, figs. 1-3, 4b, 5-6.
1990 *Cyclaster platornatus* Kutscher, 1978 — Jagt & Michels, p. 179, figs. 1-6.
1994 *Cyclaster platornatus* Kutscher, 1978 — Jagt & Michels, p. 719, pl. 2, figs. 5-6.

Type — Holotype is SGWG 60/2 (Kutscher, 1978b, pl. 3, figs. 1-3).

Material — NHMM: JJ 3439, 3605, 3711, 3717, 3822, 6144, 11108, K 739, and 811.

Description — Test depressed, length up to 43 mm, rounded ovate in outline. Apical system ethmophract, three large gonopores, madreporite lacking gonopore. Paired ambulacra petaloid, short and slightly sunken, anterior pair slightly longer than posterior. Pores round to transversely elongate. Anterior ambulacrum with enlarged pore pairs adapically, only weakly depressed. Peristome large, with prominent rim. Plastron with elongate labral plate; sternal plates subequal. Subanal and peripetalous fascioles present; the latter is complete but not sharply defined. Expression of sexual dimorphism in gonopore size.

Discussion — Easily distinguished from co-occurring species of *Diplodetus* (see below), by the short, slightly sunken paired petals, well-developed peripetalous fasciole and rather sparse adoral tuberculation, and in having but three gonopores.

Jeffery (1997b, p. 699) noted that, since all representatives of *Cyclaster* she had studied had consistently mesamphisternous plastronal plating and ethmophract apical systems, the genus was best placed in the Micrasteridae. In addition, she synonymised *Brissopneustes danicus* Schlüter, 1897a (p. 18, pl. 1, figs. 1-4), and *Cyclaster bruennichi* Ravn, 1927 (p. 345, pl. 5, fig. 5), with *C. integer* (Seunes, 1888) (p. 798, pl. 28, fig. 1), and accepted *Brissopneustes suecicus* Schlüter, 1987a, p. 34, pl. 1, figs. 5-8, *B. ruegensis* Kutscher, 1978b (p. 1027, pl. 2, figs. 1-5) and *C. galei* Jeffery, 1997b (p. 704, pl. 10, figs. 5-8; text-figs. 16, 18a-c) as valid species. In the upper Lower Maastrichtian of Rügen, *C. platornatus* and *C. ruegensis* co-occur (Kutscher, 1978b); only the former is known from the Maastrichtian type area, while the Lower Palaeocene (Geulhem Member) has not yielded any representatives of this genus. Of note in this respect is the record of two Early Palaeogene species described by Smiser (1935b, pp. 84, 85, pl. 7, figs. 7, 8) from the 'Calcaire grossier' ('Montian' = ? middle Danian) at Eysden (colliery, pit 2). Smiser's *Isopneustes eysdenensis* (holo- and paratype: IRScNB 9211 and 9212, respectively) and *I. montensis* (holotype: IRScNB 9213 (IG 8591) are synonymised with *Diplodetus coloniae* (Cotteau, 1877), from the Palaeocene of the French Pyrenees, by Smith & Jeffery (in press).

Occurrence — Apparently confined to Interval 6 of the Vijlen Member in the Haccourt area (CPL SA quarry) (Figs. 13, 16).

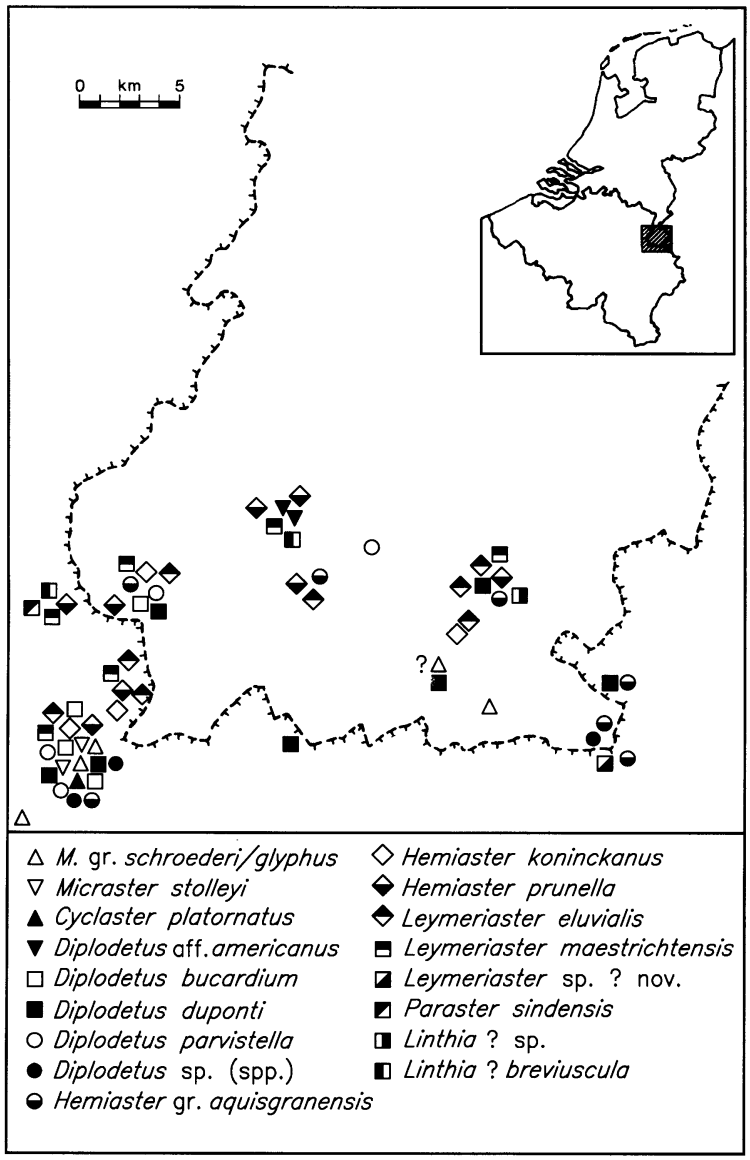


Fig. 13. Geographic distribution of Late Cretaceous-Early Palaeogene spatangoid echinoids in the type area of the Maastrichtian Stage.

Genus *Diplodetus* Schlüter, 1900

Type species — *Diplodetus schlueteri* Lambert, in Lambert & Thiéry, 1924 = *Diplodetus brevistella* Schlüter, 1870 (see Schlüter, 1900, p. 364), by subsequent designation of Lambert & Thiéry (1924).

Remarks — Smith & McGugan (1997) are followed in considering *Plesiaster*, in

which formerly all European brissids now assigned to *Diplodetus* were placed, as a distinct genus.

Indeherberge et al. (1998) have recently pointed out that the type material of two species currently placed in the genus *Diplodetus*, viz. *D. bucardium*, and *D. parvistella*, consists of internal flint moulds, and that, although these species are definitely distinct from *D. duponti* (based on test material), the study into these echinoids has only just started. The use of silicone rubber in the production of artificial casts of internal and external moulds has been shown to be very enlightening. Only in this way can internal flint moulds, which are locally very common in residual flint deposits, be linked with test material from the upper Gulpen (Vijlen, Lixhe, and Lanaye members) and lower Maastricht (Valkenburg, and Gronsveld members) formations.

In addition to the three species mentioned above, the Vaals Formation at a number of localities in southern Limburg and the province of Liège has yielded internal moulds assignable to *Diplodetus*, while at least three distinct test morphologies are known from the Zeven Wegen Member (Gulpen Formation, pers. comm. R. van der Ham). However, this material is generally poorly preserved and distorted, so that real diversity, geographic and stratigraphic distribution cannot be assessed fully at this time.

Diplodetus aff. *americanus* (Stephenson, 1941)
Pl. 26, figs. 1-3.

compare
*1941 *Micaster (Plesiaster) americanus* Stephenson, p. 69, pl. 7, figs. 1-4.
1953 *Micraster americanus* Stephenson — Cooke, p. 38, pl. 15, figs. 10-13.
1995 *Diplodetus* sp. — Jagt & Fraaye, p. 53.
1996 *Micraster (Plesiaster) americanus* Stephenson 1941 — Jagt, p. 158.

Type — Holotype of *D. americanus* is USNM 76285.

Material — NHMM: RD 70, 75, JJ 9933, and 9934a/b.

Description — Test medium-sized (up to c. 57 mm in length), highest across the posterior petals, sloping posterior; anterior ambulacrum virtually flush with test. Paired ambulacra deeply sunken, the anterior pair diverging at c. 120°, and 1.5 times longer than posterior pair (diverging at 55°). Peristome small, positioned almost a quarter of test length from anterior margin; labral plate short and wide. Periproct high on sloping posterior; subanal fasciole present, peripetalous fasciole best developed posteriorly. Adapical surface evenly tuberculate; largest tubercles occurring adorally (plastron, near peristome).

Discussion — Apparently close to *D. americanus* from the Maastrichtian Saratoga Chalk, Ripley Formation, Corsicana Marl and Prairie Bluff Chalk of Texas, Arkansas, and Mississippi, but also quite similar to some specimens here referred to *D. parvistella* (see e.g. Pl. 26, figs. 4-5). The present form differs from the former in having (virtually) no frontal notch, shorter paired petals, the anterior of which diverge at 120°, rather than at 105-110° (see Smith & Jeffery, in press), and apparently shorter labral plate. Unfortunately, all specimens available at this time are distorted to varying degrees, and preserved in a fine-grained, biocalcarenitic matrix which tends to obscure details of ambulacral plating.

The occurrence in the uppermost Maastrichtian of a species of *Diplodetus* is of special note, since representatives of this genus are generally restricted to the lower portion of the Maastrichtian Formation.

Occurrence — To date, the present species is known only from section IVf-7 of the Meerssen Member at the Ankerpoort-Curfs quarry and in the Geulhemmerberg underground workings (Figs. 13, 23).

Diplodetus bucardium (Goldfuss, 1829)
Pl. 26, figs. 6-7.

*1829 *Spatangus bucardium* Goldfuss, p. 157, pl. 49, fig. 1a-c.
1899 *Plesiaster bucardium* Goldf. sp. — Schlüter, p. 119, pl. 9, figs. 1-4.
1979 *Diplodetus bucardium* (Goldfuss 1826) — Stokes, p. 625.
1998 *Diplodetus bucardium* (Goldfuss, 1829) — Indeherberge et al., p. 687, fig. 3.

Type — Holotype, by monotypy, is RFWUIP Goldfuss Colln, no. 367 (Goldfuss, 1829, pl. 49, fig. 1).

Material — Many specimens in various collections, mostly interal flint moulds, including NHMM: JJ 2228, 2229, and 1997093/1-2.

Description — Test only slightly longer than wide (up to c. 55 mm in length), thin, highest posterior of apical system, vertically truncate posterior; frontal notch distinct. Paired ambulacra petaloid, deeply sunken, anterior pair diverging at c. 100°, 1.4-1.5 times longer than posterior pair, with elongate pores. Labrum wide, peristome c. one quarter of test length from anterior margin. Subanal fasciole well developed, traces of peripetalous fasciole bordering posterior petals only. Adapical tuberculation dense, and heterogeneous.

Occurrence — Especially well known from residual flint deposits, representing (part of) the Lanaye Member at the CPL SA and CBR-Lixhe quarries, and from the same member at the CBR-Romontbos and ENCI-Maastricht BV quarries (Figs. 13, 16, 19-20).

Diplodetus duponti (Lambert, 1911)
Pl. 27, figs. 1-2.

?*1902 *Micraster maestrichtensis* Lambert, p. 121, pl. 6.
*1911 *Micraster duponti* Lambert, p. 50, pl. 2, fig. 21; pl. 3, figs. 1-2.
1979 *Diplodetus duponti* (Lambert 1911) — Stokes, p. 626.
1992 *Diplodetus duponti* (Lambert, 1911) — van der Ham & van Birgelen, p. 150, pl. 4, figs. 7-8.
1994 *Diplodetus duponti* (Lambert, 1911) — Jagt & Michels, p. 719, pl. 2, figs. 1-2.
1995 *Diplodetus duponti* (Lambert, 1911) — Jagt et al., p. 12.
1998 *Diplodetus duponti* (Lambert, 1911) — Indeherberge et al., p. 688, fig. 5.
in press *Diplodetus duponti* (Lambert, 1911) — Smith & Jeffery, fig. 175.

Type — Holotype is IRScNB 9200 (IG 4285, Bosquet Colln) (Lambert, 1911, pl. 2, fig. 2), paratype IRScNB 9201 (IG 4285). The present whereabouts of Lambert's (1902) original is unknown.

Material — Many specimens in various collections, including NHMM: JJ 11031, MM 1005, and 1997092/1-2.

Description — Test longer than wide (up to 60 mm in length), with distinct, but shallow frontal notch and undercut truncate posterior. Paired ambulacra moderately sunken, apparently less deep than in *D. bucardium* and *D. parvistella*, and morphologically closer to *Micraster*; anterior petals diverging at c. 105°, c. 1.5 times longer than posterior, with roundish-elongate pores. Labral plate wide, peristome at c. one quarter test length from anterior margin, strongly labiate with prominent rim. Subanal fasciole well developed, broad; peripetalous fasciole patchy, best developed bordering posterior petals. Adapical tuberculation dense, but finer than in *D. bucardium*.

Discussion — Lambert (1911, p. 51) noted that the type of his *Micraster duponti* came from the 'craie marneuse' of Slenaken, while other specimens had been collected from the 'Sénonien supérieur' at Kunrade. The Slenaken material could thus have come from the Vijlen Member, but the preservation of the type (IRScNB 9200) suggests otherwise. Typical *duponti*, i.e. corresponding to Lambert's (1911, pl. 3, figs. 1-2), are known from the Kunrade Limestone facies. The Vijlen Member at various localities in southern Limburg and Liège has yielded specimens displaying *duponti* morphologies, which means that this form could well have been long-ranging. However, additional material is needed to establish whether material from the Vijlen Member and the Kunrade Limestone facies is conspecific or not.

Lambert's (1902) *Micraster maestrichtensis* might well turn out to be conspecific, in which case that name has priority. Unfortunately, the present whereabouts of the type is unknown, so that, for the time being, *D. duponti* is here accepted as valid.

Occurrence — Apparently widely distributed, with records from the Vijlen Member at the CPL SA and CBR-Lixhe quarries, Altembroeck (Voer) and Mamelis/Schneeberg, from residual flint deposits representing the upper Gulpen and lower Maastricht formations in the Haccourt-Lixhe area, and from the Kunrade Limestone facies in the Kunrade-Benzenrade area (Figs. 13, 16-17).

Diplodetus parvistella (Schlüter, 1899)
Pl. 26, figs. 4-5; Pl. 27, figs. 3-4.

*1899 *Plesiaster parvistella* Schlüter, p. 121, pl. 9, fig. 5.
1979 *Plesiaster parvistella* Schlüter 1899 — Stokes, p. 627.
1998 *Diplodetus parvistella* (Schlüter, 1899) — Indeherberge et al., p. 687, fig. 4.

Type — Holotype, by monotypy, is RFWUIP Schlüter Colln, no. 278 (Schlüter, 1899, pl. 9, fig. 5).

Material — NHMM: JJ 2463, 3425, 6414, 6830, 6831, 9710, 11031, K 1446, RD 71, and 1997091/1-2.

Description — Test depressed, thin, with ovate outline, longer than wide (up to 60 mm in length), sloping posterior, highest posterior of apical system. Paired ambulacra deeply sunken, and appearing truncated; anterior petals diverging at c. 105°, and 1.4 times longer than posterior. Peristome at c. one quarter test length from anterior margin. Labral plate wide, peristome with distinct rim. Subanal fasciole well developed, peripetalous fasciole diffuse. Adapical tuberculation dense, and fine, with scattered miliaries.

Discussion — Easily distinguished from congeners by its relatively short, deeply

sunken, and truncated paired petals. Originally based (Schlüter, 1899) on an internal flint mould which formed part of Goldfuss's type series of *D. bucardium*, recently collected material has allowed this form to be characterised more fully. Like *D. duponti*, it appears to be long-ranging and widely distributed.

Occurrence — Known to date from the Vijlen Member at the CPL SA and CBR-Lixhe quarries, and from the residual flint deposits at those localities, from the Valkenburg and Gronsveld members (Maastricht Formation) at the ENCI-Maastricht quarry. Van der Ham et al. (1987) also recorded the species from the Lanaye and Emael members (Figs. 13, 16-17, 20).

Diplodetus spp.
Pl. 25, figs. 12-13.

Material — A few, generally poorly preserved tests in various collections, including NHMM: HB 719, 731, JJ 8681, K 2520, and MM 130.

Discussion — This is a heterogeneous lot, comprising mostly poorly preserved and fragmentary material from the Vaals Formation and Zeven Wegen Member (Gulpen Formation) of southern Limburg (Vaals-Eschberg) and Liège (Haccourt, Lixhe).

Lambert (1911, p. 37, pl. 1, fig. 15) was the first to record a species of *Diplodetus* from the 'craie blanche' (= Zeven Wegen Member) at Hallembaye (= Haccourt), as *Plesiaster* cf. *bucardium* (IRScNB 9208, IG 4285, Bosquet Colln). Recently collected material allows three distinct morphologies to be recognised (pers. comm. R. van der Ham), but it is often difficult to distinguish these from co-occurring *Hemiaster* gr. *aquisgranensis*. Jagt & Michels (1994, p. 719, pl. 2, figs. 3-4) described *Diplodetus* sp., erroneously recorded from the Vijlen Member, but actually coming from the underlying Zeven Wegen Member. This specimen is here refigured in Pl. 25, figs. 12-13.

Although clearly distinguished from species occurring in Maastrichtian strata (see above), these cannot be assigned to species at this time, but may be assumed to be related to the various species erected by Schlüter (1900), who described quite a number of species, based mainly on poorly preserved material, as follows:

D. brevistella (Schlüter, 1870) from the 'untere Mucronaten-Schichten' at Coesfeld-Sükerhoek and Darup;

D. cretaceus (Schlüter, 1870) from the 'obere Mucronaten-Kreide, Zone des *Heteroceras polyplocum*' at Haldem. Niebuhr et al. (1997, pl. 4, figs. 5-6) recorded this species from the upper *bipunctatum/roemeri* Zone of Ahlten, near Haldem. However, note that their pl. 4, fig. 6 cannot be referred to *Diplodetus*, but is actually a hemiasterid, as can be seen from the tall interambulacral plates and the short, petaloid posterior petals. This specimen could well belong to the *H. aquisgranensis* group, as earlier recorded from the Hannover area by Jagt & van Knippenberg (1995) and from Coesfeld by van der Ham (1988b);

D.? *recklinghausenensis* Schlüter, 1900 from the Upper Santonian of Recklinghausen;

Plesiaster minor (Schlüter, 1870) from the upper Lower Campanian of Lette, Coesfeld and Holtwick;

Plesiaster(?) *cavifer* Schlüter, 1900 from the upper Lower Campanian of Lette and Coesfeld; and,

Plesiaster(?) *cordiformis* Schlüter, 1900, from the 'untere Mucronaten-Schichten' near Coesfeld.

These species are in need of a modern revision; surely, too much splitting has occurred in this group.

Suborder Hemiasterina Fischer, in Moore, 1966
Family Hemiasteridae H.L. Clark, 1917
Genus *Hemiaster* L. Agassiz, in L. Agassiz & Desor, 1847

Type species — *Spatangus bufo* Brongniart, 1822, by subsequent designation of Savin (1903).

Hemiaster gr. *aquisgranensis* Schlüter, 1899
Pl. 28, figs. 1-6.

*1899 *Hemiaster (?) aquisgranensis* Schlüter, p. 123, pl. 10, figs. 1-2.
*1911 *Hemiaster rutoti* Lambert, p. 52, pl. 3, figs. 3-5.
1985b *Hemiaster aquisgranensis* Schlüter, 1899 — van der Ham, p. 147, figs. 1-4, 6.
1992 *Hemiaster aquisgranensis* Schlüter, 1899 — van der Ham & van Birgelen, p. 150, pl. 4, fig. 6.
1998 *Hemiaster (Bolbaster) aquisgranensis* — van der Ham & Jagt, p. 857, fig. 1a.
in press *Hemiaster stella* (Morton, 1830) — Smith & Jeffery, fig. 183a-c (partim).

Types — Holotype of *H. aquisgranensis* is RFWUIP Schlüter Colln, no. 279a. Schlüter's pl. 10, fig. 2 is based on a second specimen, no. 279b, in the same collection, and not on the holotype as stated in the caption. Holotype of *H. rutoti* is IRScNB 9215 (IG 4285, Bosquet Colln; Lambert, 1911, pl. 3, figs. 3-5).

Material — NHMM: JJ 3775, 3910, 5698, 6603, 7287, 8585, 9977, K 581, 3831, KK 87 (W.M. Felder Colln), MM 935, and VG 1337 (W.M. Felder Colln).

Description — Test medium- to large-sized (up to 75 mm in length), ovate, with truncate posterior, highest posterior of apical system; anterior ambulacrum long, narrow; paired ambulacra form moderately sunken petals, the curvature and width of which vary considerably (e.g. Pl. 28, figs. 1, 3, 6). Anterior petals flexuous distally and c. twice the length of posterior ones, anterior pair diverging at c. 90°, posterior at c. 80°. Peristome labiate, thickened rim. Well-developed peripetalous fasciole. Periproct high on truncate posterior. Tubercles non scrobiculate.

Discussion — Easily distinguished from similarly globular (*Bolbaster*) congeners, on account of well-developed petals, large size and non-scrobiculate tuberculation.

Occurrence — As here understood, representatives of the '*aquisgranensis*' group occur in various types of lithofacies and are long-ranging, with records from the Vaals Formation (Vaals and Haccourt-Lixhe areas), the Zeven Wegen, Vijlen, Lixhe 1-3, and Lanaye members (Gulpen Formation) and the Valkenburg and Gronsveld members (Maastricht Formation) of the CPL SA, CBR-Lixhe, CBR-Romontbos, Ankerpoort-'t Rooth and ENCI-Maastricht BV quarries, the Kunrade Limestone facies of the Kunrade-Benzenrade area (Figs. 13, 16-17, 19-21).

Hemiaster koninckanus d'Orbigny, 1855
Pl. 28, figs. 10-11; Pl. 30, figs. 1-3.

*1855 *Hemiaster koninckanus* d'Orbigny, p. 250, pl. 885.
1984 *Hemiaster koninckanus* d'Orbigny, 1855 — van der Ham, p. 169, figs. 1, 4a.
1998 *Hemiaster (Bolbaster) koninckanus* d'Orbigny, 1855 — van der Ham & Jagt, p. 857, fig. 1c.

Type — Holotype, by monotypy, is the specimen illustrated by d'Orbigny (1855, pl. 885); its present whereabouts is unknown.

Material — NHMM: BL 0247, GK 1428 (W.M. Felder Colln), JJ 9941, K 1496, 1859, 2069, 3699, MK 599-601, 608, 634, 3413 (W.M. Felder Colln), and MM 51, 547, 557.

Description — Test small to medium-sized (up to 30 mm in length), elongate and globular, width 85-90% of length, highest towards posterior, keeled between apical system and posterior (Pl. 28, fig. 11); posterior truncate with small overhang above periproct, positioned high on posterior. Paired ambulacra narrow, parallel-sided and distinctly sunken; anterior pair c. 1.3 times longer than posterior. Well-developed peripetalous fasciole; tuberculation dense, scrobiculate. Peristome small, with distinct rim.

Discussion — Although juvenile and/or poorly preserved material may be difficult to distinguish from *H. prunella*, the present species has longer, and more deeply sunken paired ambulacra, a posteriorly keeled test, and a less densely tuberculate labral plate (see Van der Ham, 1984, fig. 4a).

Occurrence — This species is widely distributed and ranges from the upper Lanaye Member (Gulpen Formation) to basal Valkenburg Member (Maastricht Formation), and from the basal Nekum Member to the uppermost Meerssen Member (Maastricht Formation) with records from the CBR-Romontbos, Ankerpoort-Marnebel, and ENCI-Maastricht BV quarries, at Fromberg as well as from residual flint deposits in the Haccourt-Lixhe area (Figs. 13, 18-20).

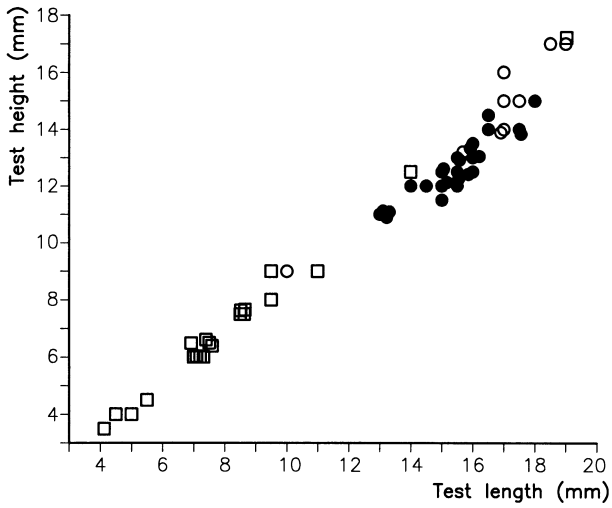
Hemiaster prunella (Lamarck, 1816)
Pl. 29.

*1816 *Spatangus prunella* Lamarck, p. 33.
1984 *Hemiaster prunella* (Lamarck) — van der Ham, p. 172, figs. 3, 4b.
1998 *Hemiaster (Bolbaster) prunella* (Lamarck, 1816) — van der Ham & Jagt, p. 857, fig. 1d.
in press *Hemiaster prunella* (Lamarck, 1816) — Smith & Jeffery, fig. 182a-b.

Type — Holotype, by monotypy, is the specimen referred to in Lamarck's (1816) original description; its present whereabouts is unknown.

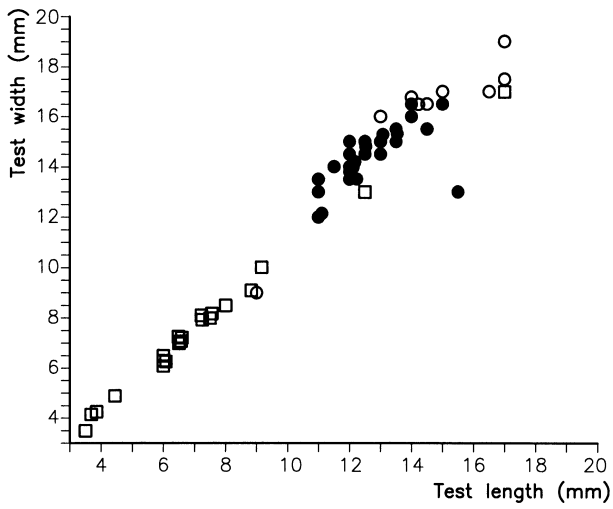
Material — IRScNB 9216 (IG 6521), NHMM: BL 0127, 0131, JJ 6735, K 947, 1423, 4150(3), and VN 611-612.

Description — Test small (up to 22 mm in length; Fig. 14), ovate and globular, highest centrally or just posterior of apical system, truncate posterior. Paired ambulacra form narrow, parallel-sided, (very) shallowly sunken petals; anterior petals about twice as long as posterior, anterior pair diverging at 110-135°, posterior at 95-105°. Well-developed peripetalous fasciole; tuberculation dense, scrobiculate. Peristome small, with distinct rim.



Hemiaster prunella

● Meerssen Member (IVf–6)
○ Lanaye Member (level 11)
□ Lanaye Member (levels 19–20)



Hemiaster prunella

● Meerssen Member (IVf–6)
○ Lanaye Member (level 11)
□ Lanaye Member (levels 19–20)

Fig. 14A-B. Relationship between test height, length, and width in *Hemiaster prunella* (Lamarck, 1816).

Discussion — A few specimens (Pl. 29, fig. 6) have a depression across the adapical face, similar to those described by Asgaard (1976, figs 2-3, 7-10) for the micrasterid *Cyclaster danicus* (Schlüter, 1897a) (= *C. integer* (Seunes, 1888) according to Jeffery, 1997b, p. 699), from the Lower Palaeocene of Denmark, and interpreted to be a function of adverse environmental conditions or parasite attack. Others (Pl. 29, fig. 4) show a curious pitting in the anterior test half, possibly the result of parasitic infection.

Occurrence — This is a widely distributed, and long-ranging species, with records from the middle Lanaye Member (Gulpen Formation) to the uppermost Meerssen Member (Maastricht Formation), with considerable hiatuses and a distributional acme in latter unit, at the CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Ankerpoort-Curfs, Ankerpoort-'t Rooth, Blom, and Ankerpoort-Curfs quarries, as well as from the temporary Albertkanaal outcrops at Vroenhoven-Riemst, and from the Kunrade Limestone facies in the Kunrade-Benzenrade area (Figs. 13, 18-23).

The Vijlen Member (Gc1 level, *sumensis* Zone) at Altembroeck has yielded a single specimen of a paedomorphic hemiasterid, closely related to the *prunella/koninckanus* group (Jagt et al., 1995; van der Ham & Jagt, 1998, p. 857, fig. 1e), representing the oldest record of that group, which markedly predates the earliest *H. prunella* and *H. koninckanus*, which first occur in the (middle/upper) Lanaye Member.

Genus *Leymeriaster* Lambert, in Lambert & Thiéry, 1924

Type species — *Hemiaster leymeriei* L. Agassiz, in L. Agassiz & Desor, 1847, by original designation.

Leymeriaster eluvialis (van der Ham, 1995)
Pl. 28, figs. 7-8.

*1995 *Hemiaster (Leymeriaster) eluvialis* van der Ham, p. 156, pls 1-2, pl. 3, figs. 1-5; text-figs. 3, 4a.
1998 *Hemiaster (Leymeriaster) eluvialis* van der Ham, 1995 — van der Ham & Jagt, p. 857, fig. 1f.

Type — Holotype is NHMM 1993050 (van der Ham, 1995, pl. 1; pl. 2, 1-2, 4, 6).

Material — NHMM: MM 855, 936, and RD 124 (paratype).

Description — Test medium-sized (up to 50 mm in length), slightly broader than long, bulging anteriorly and tapering posteriorly, highest anterior of apical system. Anterior ambulacrum with short, narrow groove, bordered by sharply keeled interambulacra. Pore pairs in groove separated by small ridges extending to interambulacral margins; anterior petals strongly depressed and flexed. Well-developed peripetalous fasciole, closely following anterior petals, and crossing unpaired ambulacrum in narrow convexity. Tuberculation dense and scrobiculate.

Discussion — Easily distinguished from *L. maestrichtensis* (see below), whose range partially overlaps, by the very short, narrow groove in the anterior ambulacrum and by the raised interambulacral margins surrounding the petals. Another, undescribed species (see *Leymeriaster* sp. ?nov., below) appears to be more closely related.

Occurrence — Known to date to range from the middle Lanaye Member (Gulpen Formation) to the upper Nekum Member (Maastricht Formation), with records from the Blankenberg (Cadier en Keer), CBR-Romontbos, Ankerpoort-Marnebel, and

ENCI-Maastricht BV quarries, from residual flint deposits in the Haccourt-Lixhe and Eben Emael areas, and from the Kunrade Limestone facies of Fromberg and Winthagen (Figs. 13, 18-20).

Leymeriaster maestrichtensis (Schlüter, 1897a)
Pl. 28, fig. 9.

*1897a *Hemiaster maestrichtensis* Schlüter, p. 32, pl. 2, figs. 3-4.
1935b *Brissopneustes maestrichtensis* Lambert (*Micraster*) — Smiser, p. 85, pl. 8, fig. 2.
1955 *Hemiaster (Leymeriaster) maestrichtensis* Schlueter — Meijer, p. 74, plate.
1995 *Hemiaster (Leymeriaster) maestrichtensis* Schlüter, 1897 — van der Ham, p. 158, pl. 3, figs. 6-10.
1998 *Hemiaster (Leymeriaster) maestrichtensis* Schlüter, 1897 — van der Ham & Jagt, p. 857, fig. 1g.
in press *Leymeriaster maestrichtensis* (Schlüter, 1897) — Smith & Jeffery, fig. 186.

Type — Holotype, by monotypy, is the original of Schlüter's (1897a, pp. 30, 32, pl. 2, figs. 3-4). This was reported to be in the collections of Liège University, but Meijer (1955, p. 74) was unable to locate it there.

Material — IRScNB 9214 (IG 6521); NHMM: BL 0559(261), JJ 1125, 5965, MM 0066, 0500, 0508, 0538, 0587, 0931-0934, 1148, and 1196.

Description — Test medium-sized (up to 47 mm in length), width equalling length, highest directly behind apical system; petals deeply sunken, anterior ones 4-5 times longer than the short posterior; groove of anterior ambulacrum reaching ambitus; broad peripetalous fasciole, straight across anterior of test; tuberculation dense, and scrobiculate.

Occurrence — Known to range from the basal Gronsveld to the uppermost Meerssen members (Maastricht Formation), with records from the CBR-Romontbos, and ENCI-Maastricht BV quarries, the temporary Albertkanaal sections (Vroenhoven-Riemst), as well as Kunrade Limestone facies of the Kunrade-Benzenrade area, and residual flint deposits in Eben Emael area (Figs. 13, 19-20).

Leymeriaster sp. ?nov.
Fig. 15.

1998 *Hemiaster (Leymeriaster)* sp. — van der Ham & Jagt, p. 857, fig. 1b.

Material — NHMM: VG 3047, 1996001, W.M. Felder Colln, unregistered (1 specimen), and H.J. Janssens Colln, unregistered (3 specimens).

Description — A detailed description of this form, which appears to be closely related to the Turonian *L. leymeriei* (Desor, in L. Agassiz & Desor, 1847), is under way (van der Ham, in prep.).

Occurrence — The present record is based on six slightly distorted, silicified tests from the Vaals Formation at Vaals-Eschberg (Fig. 13).

Family Schizasteridae Lambert, in Doncieux, 1905

Remarks — With very few exceptions, schizasterid echinoids in the Maastrichtian type area are of Early Palaeocene age (Geulhem Member, Houthem Formation).

Fig. 15. *Leymeriaster* sp. ?nov.; A-C: NHMM 1996001, D-E: W.M. Felder Colln (unregistered), Vaals Formation, Vaals-Eschberg (southern Limburg, NL). Scale bar equals 5 mm.

However, material is often fragmentary and poorly preserved, making definite assignment to genus and species difficult, if not impossible. Test fragments preserving both peripetalous and latero-anal fascioles are easily identified as belonging to this family, but have to remain in open nomenclature. Van der Ham (1988a, p. 155) pointed out that material from the upper Geulhem Member was very heterogeneous, and that *Linthia houzeaui* Cotteau, 1879, recorded from the 'Calcaire grossier de Mons' (= middle/late Danian) of southern Belgium and of the Campine mining district (Belgium; see Smiser, 1935b, p. 87, pl. 8, fig. 3) had not yet been recognised amongst this material.

Smith & Jeffery (in press) noted that *Linthia* was most similar to *Paraster*, differing from that genus in having long, straight petals, the anterior pair of which is at least 1.5 times longer than the posterior.

Genus *Linthia* Desor, 1853

Type species — *Linthia insignis* Desor, 1853, by original designation.

Linthia? sp.
Pl. 30, figs. 7-8.

?1987 *Linthia* sp. 1 — van der Ham et al., p. 33.
1988a *Linthia* sp. (spp.) — van der Ham, p. 155, pl. 9, figs. 1-5 (partim).

Material — NHMM: MB 432-I, and RH 285-10.

Description — Only fragments known; tests fragile, of medium to large size (41 mm and more in length), with ethmolytic apical system, four gonopores; anterior ambulacrum strongly sunken, distinct frontal notch. Paired ambulacra moderately to deeply sunken, posterior pair 1/3 to 1/2 the length of anterior one; well-developed peripetalous and latero-anal fascioles; tuberculation non-scrobiculate.

Discussion — This material probably comprises more than one species, but in view of generally poor preservation, it must remain generically and specifically indeterminate.

Occurrence — Geulhem Member, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 13, 23). Material from the Nekum Member and the Kunrade Limestone facies (Maastricht Formation) of southern Limburg in the Meijer (NHMM; Meijer, 1965b) and Vlieks collections may belong here as well.

Linthia? *breviuscula* (d'Orbigny, 1855) sensu van der Ham, 1988a
Pl. 30, figs. 9-10.

*1855 *Hemiaster breviusculus* d'Orbigny, pl. 888.
1988a ?*Linthia breviuscula* (d'Orbigny, 1855) — van der Ham, p. 155, pl. 9, figs. 6-8.

Material — NHMM MM 862.

Description — Test small (up to 8 mm in length), apical system ethmolytic, ?four gonopores. Anterior and paired ambulacra shallowly depressed, posterior pair about half the length of anterior pair; interporiferous zone narrow. Fascioles and tuberculation not preserved due to recrystallisation.

Discussion — This is undoubtedly a schizasterid, but since tuberculation and fascioles are not visible and gonopores have not opened, Smith & Jeffery (in press) listed it as 'Indeterminate schizasterids'.

Occurrence — Known only from the lower Geulhem Member (Houthem Formation) of the Geulhem area (Fig. 13).

Genus *Paraster* Pomel, 1869

Type species — *Schizaster gibberulus* Agassiz, in L. Agassiz & Desor, 1847, by original designation.

Paraster sindensis (Duncan & Sladen, 1882)
Pl. 30, figs. 4-6.

*1882 *Linthia sindensis* Duncan & Sladen, p. 18, pl. 4.
1988a *Linthia* sp. (spp.) — van der Ham, p. 155, pl. 9, figs. 1-5 (partim).

Type — Holotype, by monotypy, is the original of Duncan & Sladen's (1882) pl. 4; its present whereabouts is unknown.

Material — NHMM MB 345.

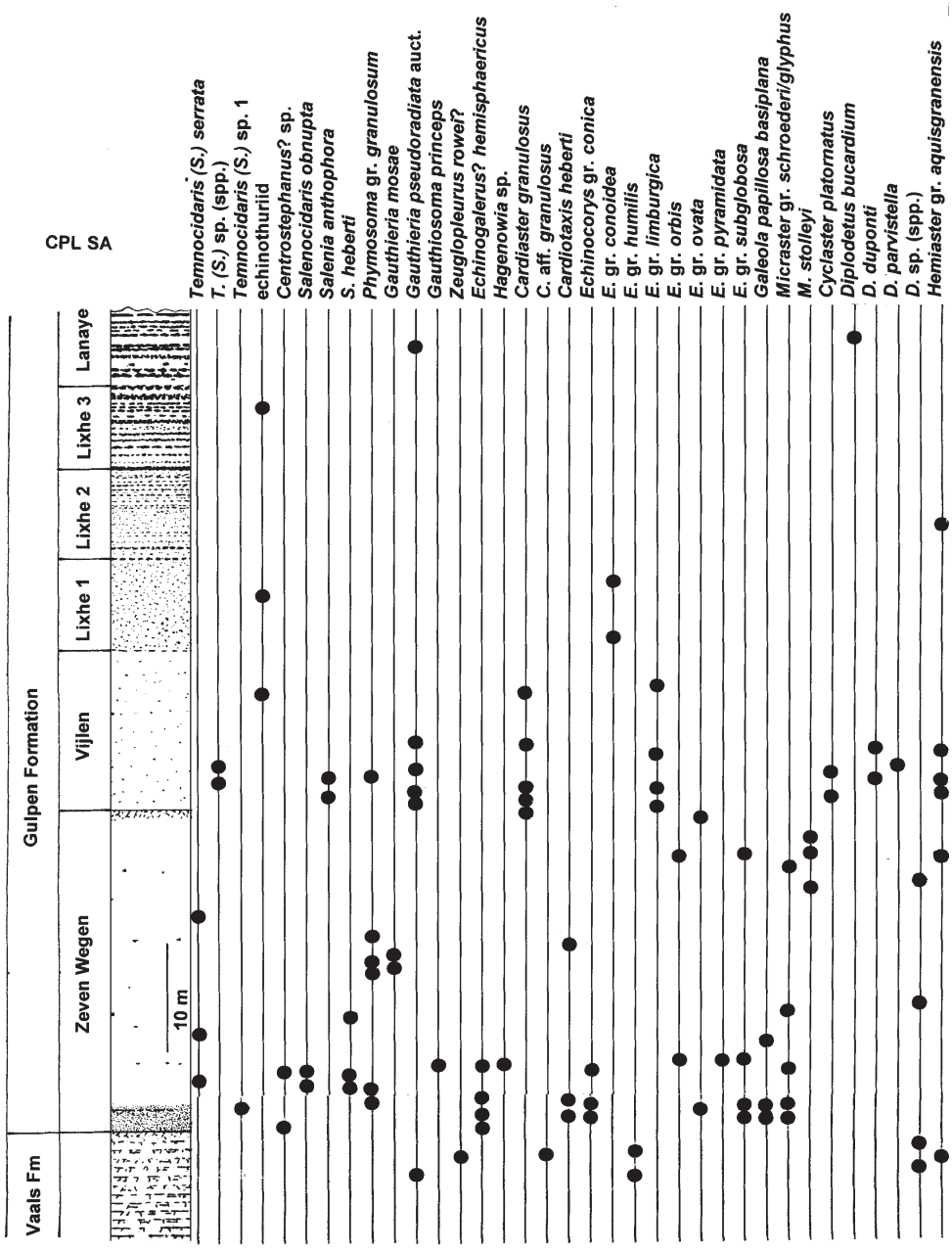


Fig. 16. Lithostratigraphy of section exposed at Ciments Portland Liégeois SA quarry (Haccourt, Liège) and stratigraphic provenance of echinoid material studied herein.

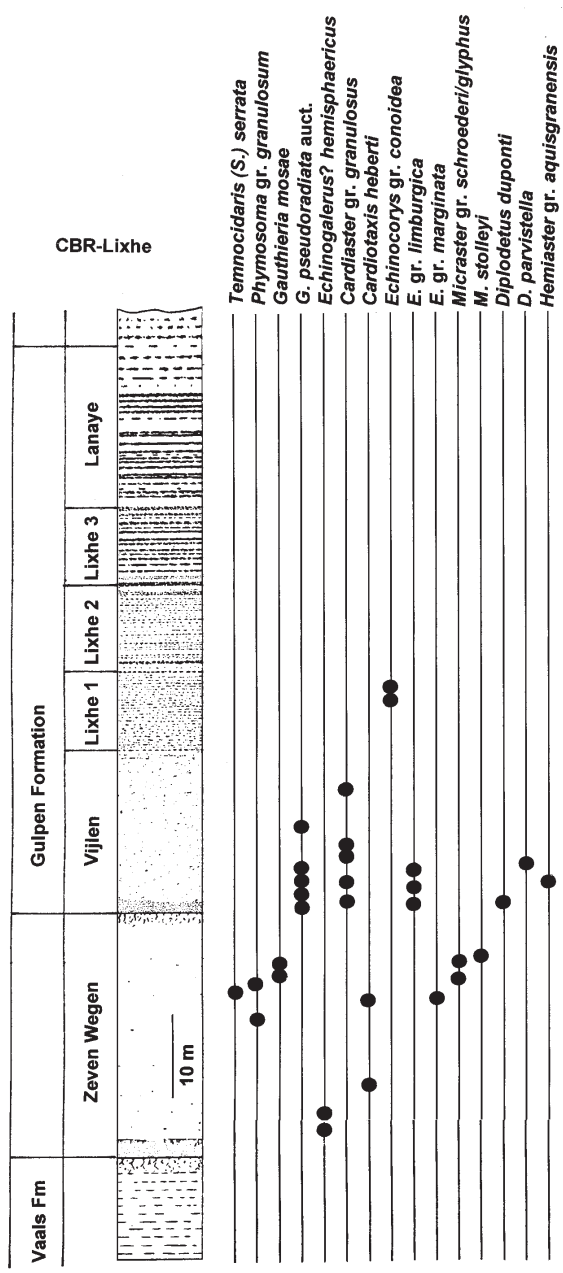


Fig. 17. Lithostratigraphy of section exposed at Cimenterie Briqueterie Réunie-Lixhe quarry (Lixhe, Liège) and stratigraphic provenance of echinoid material studied herein.

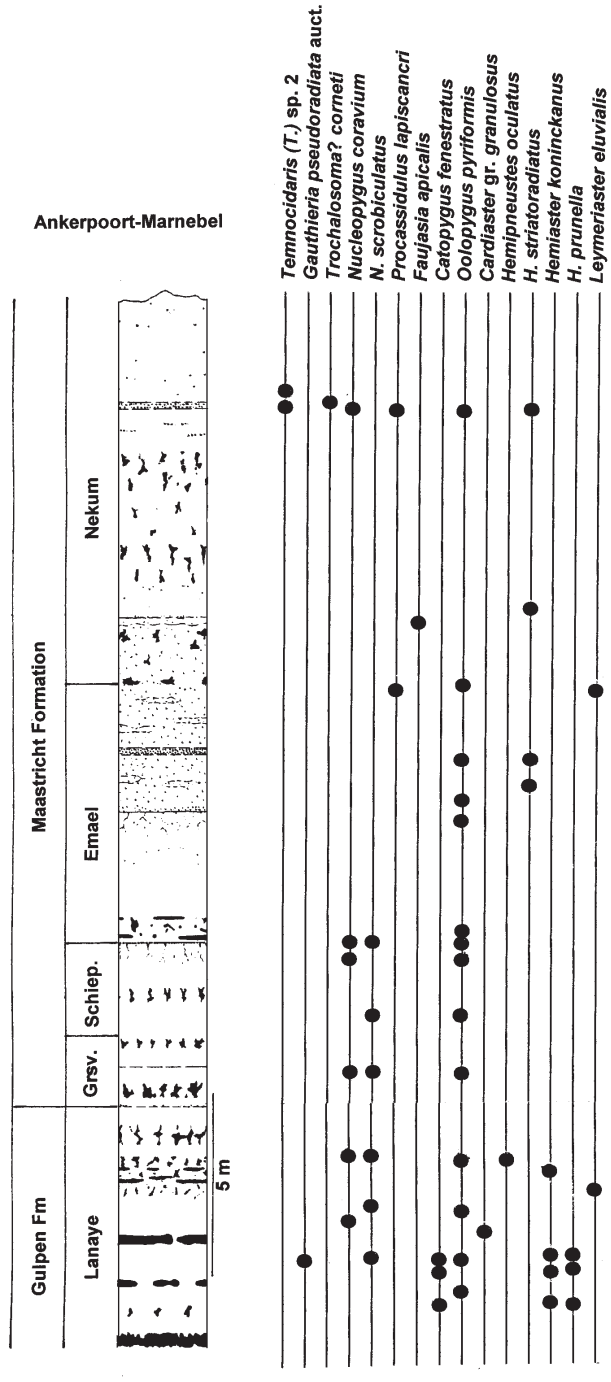


Fig. 18. Lithostratigraphy of section exposed at Ankerpoort-Marnebel (Eben Emael, Liège) and stratigraphic provenance of echinoid material studied herein.

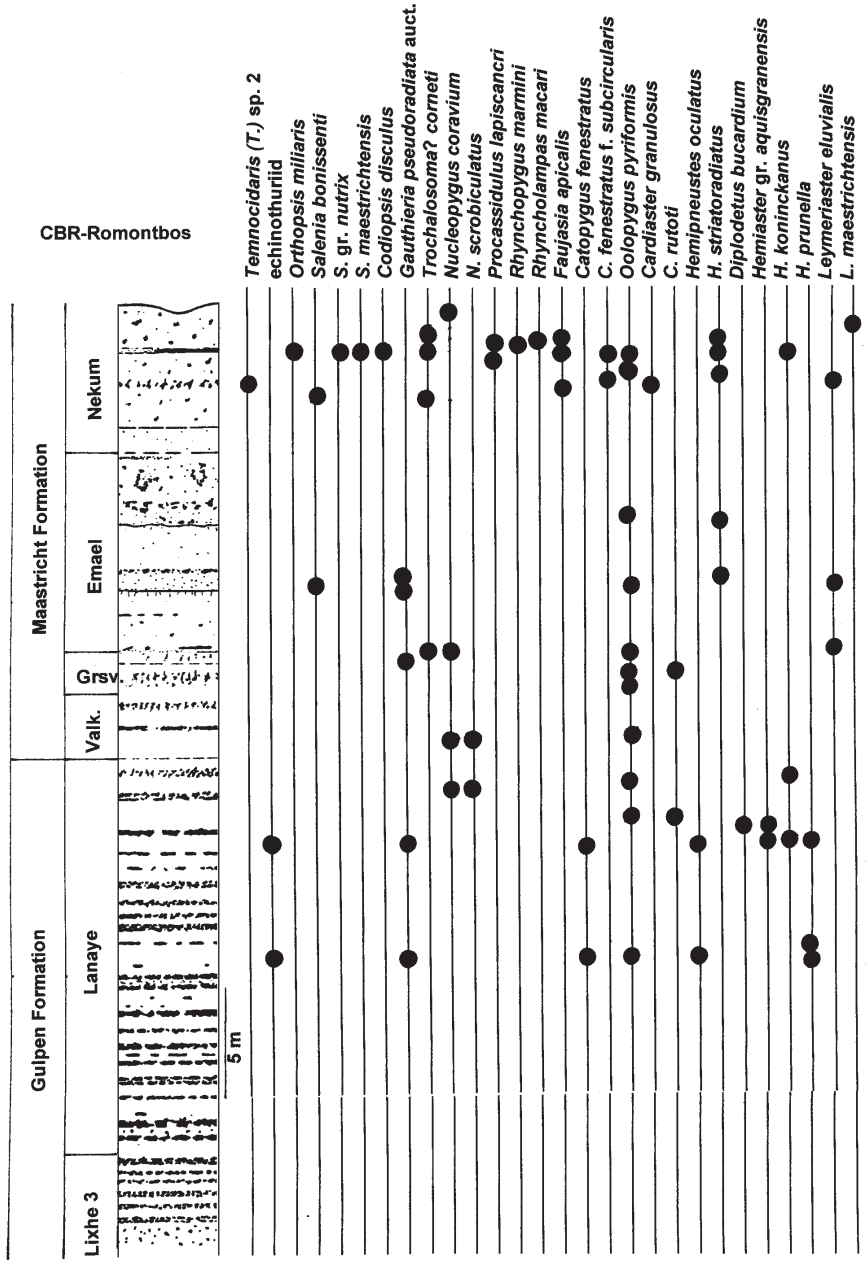


Fig. 19. Lithostratigraphy of section exposed at Cimenterie Briqueterie Réunie-Romontbos quarry (Eben Emael, Liège) and stratigraphic provenance of echinoid material studied herein.

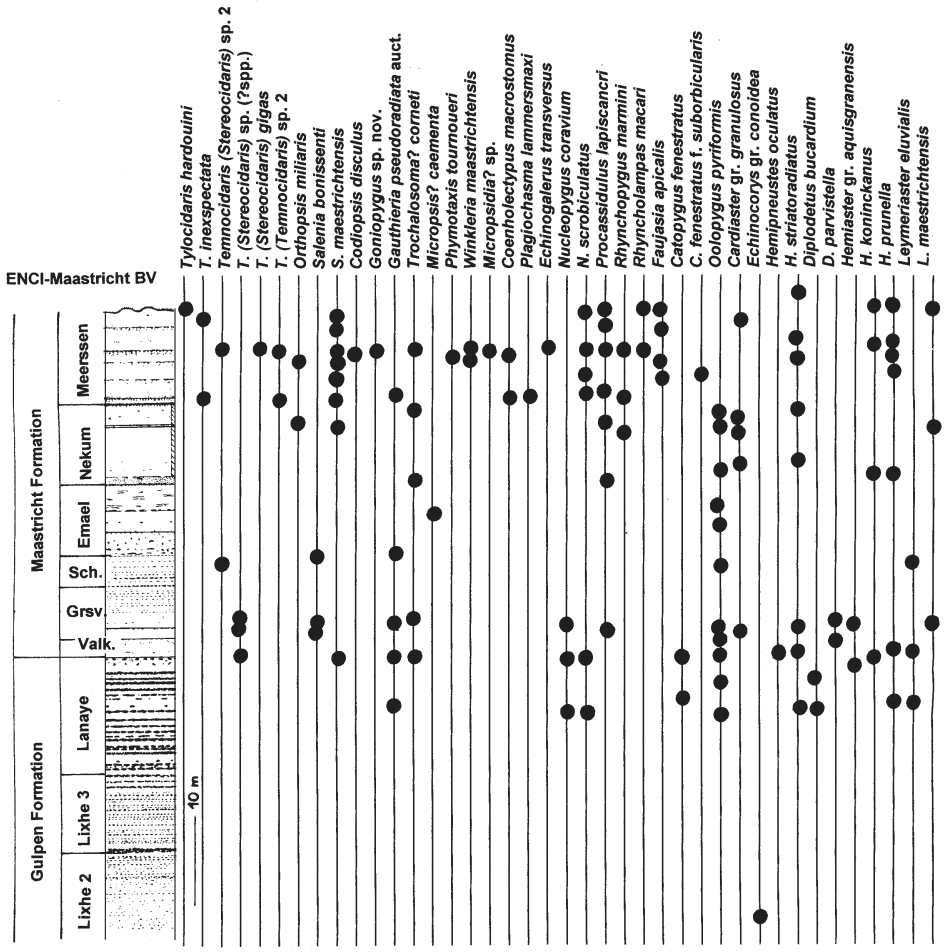


Fig. 20. Lithostratigraphy of section exposed at ENCI-Maastricht BV quarry (Maastricht) and stratigraphic provenance of echinoid material studied herein.

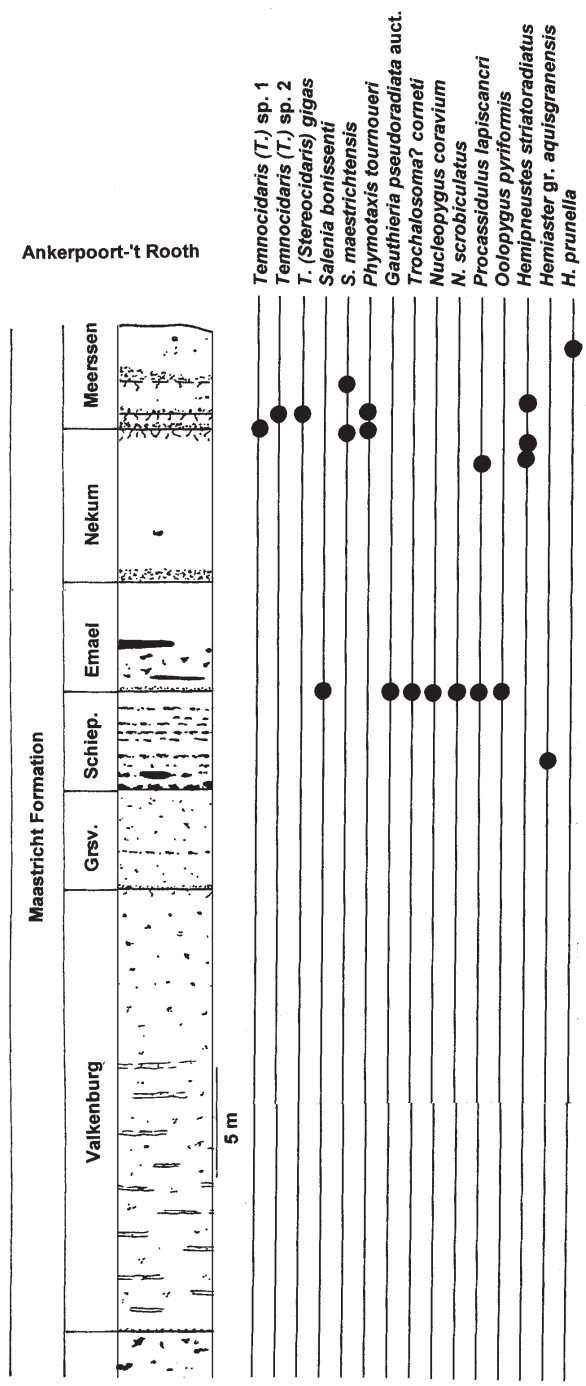


Fig. 21. Lithostratigraphy of section exposed at Ankerpoort-'t Rooth quarry (Bemelen) and stratigraphic provenance of echinoid material studied herein.

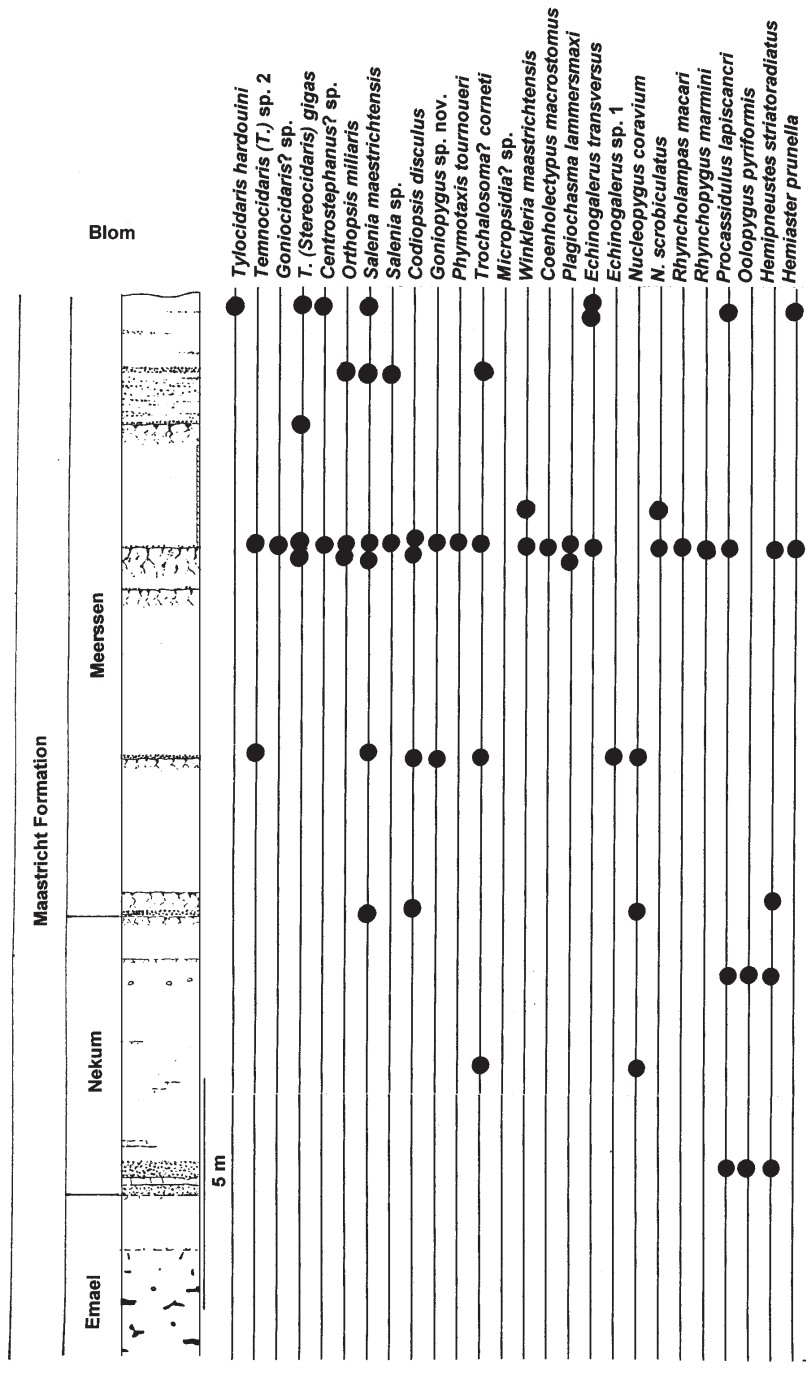


Fig. 22. Lithostratigraphy of section exposed at former Blom quarry (Berg en Terblijt, Limburg) and stratigraphic provenance of echinoid material studied herein.

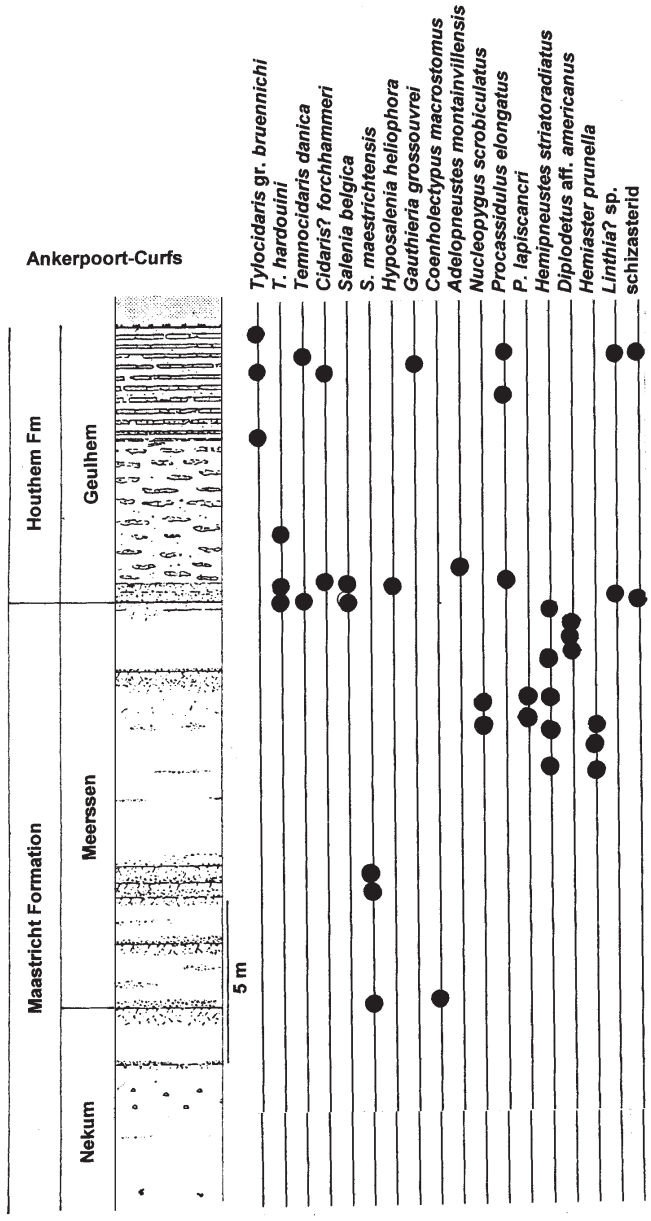


Fig. 23. Lithostratigraphy of section exposed at Ankerpoort-Curfs quarry (Geulhem, Limburg) and stratigraphic provenance of echinoid material studied herein.

Description — Test medium-sized (31 mm in length), of subcircular outline, flat base, and smoothly rounded upper surface, highest just posterior of apical system, no keel; paired ambulacra forming straight, moderately sunken petals, with posterior pair considerably shorter than anterior. Ethmolytic apical system with 4 gonopores; well-developed peripetalous and latero-anal fascioles. Labral plate short and wide.

Discussion — Smith & Jeffery (in press) considered this to be the only specifically determinate schizasterid in the echinoid faunas from the Geulhem Member. The species was first described from the Lower Danian (*Cardita beaumonti* beds) of Sind (Pakistan).

Occurrence — Known only from the lower Geulhem Member of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 13).

Acknowledgements

For full Acknowledgements see the final (sixth) part of this series at the end of this volume.

This research was supported (in part) by the Geosciences Foundation (GOA) with financial aid from the Netherlands Organisation for Scientific Research (NWO). This is contribution No. 10 of the 'Vijlen Werkgroep'.

References

[For additional references see also Parts 1-3 of the current series (Jagt, 1999a, b, 2000a).]

Agassiz, L. & E. Desor, 1846. Catalogue raisonné des familles, des genres et des espèces de la classe des Échinodermes, précédé d'une introduction sur l'organisation, la classification et le développement progressif des types dans la série des terrains par M. L. Agassiz. — Ann. Soc. nat., 3, 6: 305-374, pls 15-16.

Agassiz, L. & E. Desor, 1847. Catalogue raisonné des espèces, des genres, et des familles d'échinides. — Ann. Soc. nat., 3, 7: 129-168; 3, 8: 5-35, 355-380.

Archiac, A. d', 1835. Mémoire sur la formation crétacée du sud-ouest de la France. — Mém. Soc. géol. Fr., 2, 2: 157-193, pls 11-13.

Arnaud, H., 1897. Quelques observations sur les Salenia crétacées du Sud-Ouest. — Actes Soc. linn. Bordeaux, 52: 1-35, pls 1-3.

Asgaard, U., 1976. *Cyclaster danicus*, a shallow burrowing non-marsupiate echinoid. — Lethaia, 9: 363-375.

Birgelen, M. van & R. van der Ham, 1999. *Echinogalerus*-soorten uit het Gulpens Krijt (Maastrichtien) van Zuid-Limburg, de Voerstreek en de Schneeberg. — Natuurhist. Maandbl., 88: 215-218.

Brighton, A.G., 1939. The Chalk Echinoid *Galeola* in England. — Geol. Mag., 76: 497-501.

Brotzen, F., 1959. On Tylocidaris species (Echinoidea) and the stratigraphy of the Danian of Sweden. With a bibliography of the Danian and the Paleocene. — Sver. geol. Unders., C 571: 1-81, pls 1-3.

Brünnich Nielsen, K., 1925. Nogle Echiniderester fra Danmarks Senon og Danien. — Meddr dansk geol. Foren., 6: 2-10, pl. 1.

Brünnich Nielsen, K., 1938. Faunaen i Ældre Danium ved Korporalskroen. — Meddr dansk geol. Foren., 9 (1937): 118-126.

Brünnich Nielsen, K., 1942. *Martinosigra elongata* n.g. et n. sp. a New Echinoid from the White Chalk of Denmark. — Meddr dansk geol. Foren., 10: 159-166, 2 pls.

Cooke, C.W., 1941. Cenozoic regular echinoids of eastern United States. — J. Paleont., 15, 1: 1-20, pls 1-4.

Cooke, C.W., 1953. American Upper Cretaceous Echinoidea. — Prof. Paper U.S. geol. Surv., 254-A: i-iv + 1-44, pls 1-16.

Cooke, C.W., 1959. Cenozoic Echinoids of Eastern United States. — Prof. Paper U.S. geol. Surv., 321: i-iii + 1-106, pls 1-43.

Cotteau, G., 1861-1867. Paléontologie Française. Description des animaux invertébrés commencée par Alcide d'Orbigny continuée sous la direction d'un comité spécial. Terrain crétacé, 7. Échinides. — Masson, Paris: 1-894, pls 1007-1204, 1087bis, 1204bis.

Cotteau, G., 1866. Échinides nouveaux ou peu connus. — Rev. Mag. Zool., 2, 18: 201-209, 262-268, pls 14, 19.

Cotteau, G. & J. Triger, 1855-1869. Échinides du Département de la Sarthe, considerés au point du vue zoologique et stratigraphique. — J.-B. Baillière, Paris: i-xv + 1-455, 66 pls.

Cotteau, G., 1875. Note sur les Échinides crétacés de la province du Hainaut. — Bull. Soc. géol. Fr., 3, 2, 8: 638-660, pls 19-20.

Cotteau, G., 1890. Notice sur l'*Hemipneustes oculatus* (Drapiez), Cotteau de la craie de Ciply et les autres espèces du genre *Hemipneustes*. — Ann. Soc. r. malacol. Belg., 4: 3-10.

Cotteau, G., A. Peron & V. Gauthier, 1881. Échinides fossiles de l'Algérie, 7. Étage Sénonien. — Masson, Paris: 1-197, pls 1-20.

Defour, E., T. Geussens, L. Indeherberge & V. Strijbos, 1994. Vormvariaties van *Hemipneustes striatoradiatus* en *Hemiaster prunella* uit het Boven-Krijt van Limburg. — Likona Jaarboek '93: 7-14.

Desmoulins, C., 1837. Troisième mémoire sur les Échinides. Synonymie générale. — Actes Soc. linn. Bordeaux, 9: 45-364.

Desor, E., 1842. Des Galérites. In: L. Agassiz. Monographies d'Échinodermes vivans et fossiles. — Petitpierre, Neuchâtel: i-iv + 1-94, 13 pls.

Desor, E., 1855-1858. Synopsis des échinides fossiles. — Ch. Reinwald, Paris/Kriedel & Niedner, Wiesbaden: i-lxviii + 1-490, 44 pls.

Dortangs, R., 1990. Mond- en anusplaatjes van irregulaire zeeëgels. Onderzoek naar het voorkomen van mond- en anusplaatjes bij irregulaire zeeëgels in het Zuidlimburgse Krijt. — Grondb. Hamer, 44: 42-43.

Duncan, P.M. & W.P. Sladen, 1882. The fossil Echinoidea from the strata beneath the trap (*Cardita beaumonti* beds). — Palaeont. Indica, 14, 1, 3: 1-20, pls 1-4.

Engel, H., 1945. Over de variatie van Hemipneustes striatoradiatus (Leske). — Verh. geol.-mijnbouwk. Gen. Ned. Kol., Geol., 14 [Gedenkboek Dr. Ir. P. Tesch m.i.]: 173-182.

Engel, H., 1964a. On *Winkleria maastrichtensis* nov. gen. et nov. spec. (Echinoidea, Regularia, Stirodonta, Phymosomina, ?Phymosomatidae) from the Upper-Cretaceous (Md) of Maastricht (Limburg, Netherlands). — Beaufortia, 126: 207-210, 1 pl.

Engel, H., 1964b. On two new species of Holectypus Desor from the Senonian of South-Limburg near Maastricht, Netherlands. — Zool. Meded., 39: 235-239, pl. 14.

Engel, H., 1972. *Phymosoma maastrichtensis* spec. nov., a fossil echinoid from the Cretaceous of Maastricht (Echinacea, Phymosomatoida, Phymosomatidae). — Zool. Meded., 47: 540-544, pl. 1.

Engel, H. & M. Meijer, 1957. Notes sur les Échinides du Tuffeau de Maastricht (Maestrichtien Dumont, 1849). II. *Lychnidius scrobiculatus* (Goldfuss, 1829). — Natuurhist. Maandbl., 46: 88-94, 1 pl.

Ernst, G., 1963. Stratigraphische und gesteinschemische Untersuchungen im Santon und Campan von Lägerdorf (SW-Holstein). — Mitt. geol. Staatsinst. Hamburg, 32: 71-127, pls 13-14.

Ernst, G., 1970a. Faziesgebundenheit und Ökomorphologie bei irregulären Echiniden der nordwestdeutschen Oberkreide. — Paläont. Z., 44: 41-62, pl. 5.

Ernst, G., 1970b. The Stratigraphical Value of the Echinoids in the Boreal Upper Cretaceous. — Newsl. Stratigr., 1: 19-34.

Ernst, G., 1970c. Zur Stammesgeschichte und stratigraphischen Bedeutung der Echiniden-Gattung *Micraster* in der nordwestdeutschen Oberkreide. — Mitt. geol.-paläont. Inst. Univ. Hamburg, 39: 117-135, pls 17-18.

Ernst, G., 1971. Biometrische Untersuchungen über die Ontogenie und Phylogenie der *Offaster/Galeola*-Stammesreihe (Echin.) aus der nordwesteuropäischen Oberkreide. — N. Jb. Geol. Paläont. Abh., 139: 169-225.

Ernst, G., 1972. Grundfragen der Stammesgeschichte bei irregulären Echiniden der nordwesteuropäischen Oberkreide. — Geol. Jb., A4: 63-175, 7 pls.

Ernst, G., 1973. Die Echiniden-Fauna des Santon der Gehrdener Berge. — Ber. naturhist. Ges. Hannover, 117: 79-102.

Ernst, G., 1975a. Stratigraphie, Fauna und Sedimentologie der Oberkreide von Misburg und Höver bei Hannover (Exkursionsführer). — Mitt. geol.-paläont. Inst. Univ. Hamburg, 44: 69-97.

Ernst, G., 1975b. Die Santon-Transgression im Raume Misburg bei Hannover (Stratigraphie, Fauna und Sedimentologie). — Ber. naturhist. Ges. Hannover, 119: 361-377, 1 pl.

Ernst, G. & W. Koch, 1975. Stratigraphie und Fauna der Oberkreide von Misburg, Höver und Wunstorf (Niedersachsen). — Exkursion E, 45. Jahresvers. Paläont. Ges., Hannover: E1-E44.

Ernst, G., F. Schmid & G. Klischies, 1979. Multistratigraphische Untersuchungen in der Oberkreide des Raumes Braunschweig-Hannover. In: J. Wiedmann (ed.). Aspekte der Kreide Europas. — Int. Union geol. Sci., A6: 11-46.

Ernst, G., M.-G. Schulz & F. Schmid, 1971. Die Entwicklungsgeschichte der hochspezialisierten Echiniden-Reihe *Infulaster-Hagenowia* in der borealen Oberkreide. — Paläont. Z., 45: 120-143, pls 13-14.

Felder, P.J., 1963. Een vindplaats van de zeeëgel *Catopygus subcircularis* Smiser 1935. — Sprekende Bodem, 7: 33-36.

Felder, W.M., 1963. [Over *Hemipneustes striatoradiatus* (Leske)]. — Natuurhist. Maandbl., 52: 119.

Felder, W.M., 1973. Kalksteengroeven in het boven-krijt [sic] van Zuid Limburg. De groeve Curfs te Geulhem. — Sprekende Bodem, 17, 3: 2-9.

Fell, H.B., 1996a-b. Cidaroids. Diadematacea. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata 3, 2. — Geol. Soc. Am., Boulder/Univ. Kansas Press, Lawrence: U312-U339, U340-U366a.

Fischer, A.G., 1966. Spatangoids. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata 3, 2. — Geol. Soc. Am., Boulder/Univ. Kansas Press, Lawrence: U543-U628.

Fletcher, T.P., 1977. Lithostratigraphy of the Chalk (Ulster White Limestone Formation) in Northern Ireland. — Rep. Inst. Geol. Sci., 77, 24: i-iv + 1-33.

Geys, J.F., 1979. Salenioid Echinoids from the Maastrichtian (Upper Cretaceous) of Belgium and The Netherlands. — Paläont. Z., 53: 296-322.

Geys, J.F., 1980. Phymosomatoid echinoids from the Campanian and the Maastrichtian of Belgium and the Netherlands. — Paläont. Z., 54: 199-224.

Geys, J.F., 1981. Arbacioid Echinoids from the Maastrichtian (Upper Cretaceous) of Belgium and the Netherlands. — Paläont. Z., 55: 257-270.

Geys, J.F., 1982. Two salenioid echinoids in the Danian of the Maastricht area. — Palaeontology, 25: 265-276, pl. 29.

Geys, J.F., 1983. *Rachiosoma gigasei* nov. spec. an addition to the echinoderm fauna of the Maastrichtian (Upper Cretaceous) of Belgium. — Bull. Soc. belge Géol., 92: 255-259, 1 pl.

Geys, J.F., 1987. The genus *Typocidaris* (Cidaroida; Echinoidea) in the Upper Cretaceous of the Maastricht area (Belgium and the Netherlands). — Bull. Inst. r. Sci. nat. Belg., Sci. Terre, 57: 201-215, 2 pls.

Geys, J.F., 1990. The Genus *Temnocidaris* (Echinoidea, Cidaroida) in the Upper Cretaceous and Lower Tertiary of the Maastricht area (Belgium and The Netherlands). — Bull. Inst. r. Sci. nat. Belg., Sci. Terre, 60: 107-114, 2 pls.

Geys, J.F. & J. Jagt, 1986. Additional regular echinoids from the Upper Cretaceous in the Maastricht area (Belgium). — Paläont. Z., 60: 93-107.

Gravesen, P., 1993. Early Danian species of the echinoid genus *Tylocidaris* (Cidaridae, Psychocidarinae) from eastern Denmark. — Contr. Tert. Quatern. Geol., 30: 41-73, 4 pls.

Gregory, J.W., 1900. Appendix A. *Zeuglopleurus rowei*, n. sp. In: A.W. Rowe. The zones of the White Chalk of the English Coast. I. Kent and Sussex. — Proc. Geol. Ass., 16, 6: 353-354.

Grossouvre, A. de, 1901. Recherches sur la craie supérieure. 1. Stratigraphie générale, avec une monographie du genre *Micraster*, par J. Lambert. — Mém. Serv. Carte géol. dét. Fr., 1901: i-viii + 1-1013, 3 pls.

Ham, R.W.J.M. van der, 1982. De zee-egel *Hemipneustes oculatus* Cotteau, 1890 voor het eerst in Nederland gevonden. — Natuurhist. Maandbl., 71: 181-185.

Ham, R.W.J.M. van der, 1984. De zeeëgel *Hemiaster koninckanus* d'Orbigny, 1855 in het Maastrichtien van Zuid-Limburg en aangrenzende delen van België en Nederland. — Natuurhist. Maandbl., 73: 169-176.

Ham, R.W.J.M. van der, 1985a. *Hemiaster koninckanus* en de zeeëgelfauna van het vuursteeneluvium van Hallembaye: aanvullingen. — Natuurhist. Maandbl., 74: 110-112.

Ham, R.W.J.M. van der, 1985b. De zeeëgel *Hemiaster aquisgranensis* Schlüter, 1899 in het Campaniën en het Maastrichtiën van Zuid-Limburg en aangrenzende delen van België en Duitsland. — Natuurhist. Maandbl., 74: 147-156.

Ham, R.W.J.M. van der, 1987. De zeeëgel *Goniophorus pentagonalis* Müller, 1855: waarschijnlijk de steenkern van *Gauthieria* gr. *radiata*. — Natuurhist. Maandbl., 76: 4-6.

Ham, R.W.J.M. van der, 1988a. Echinoids from the Early Palaeocene (Danian) of the Maastricht area (NE Belgium, SE Netherlands): preliminary results. In: J.W.M. Jagt & A.W. Janssen (eds). Faunal and stratigraphical aspects of the Early Palaeocene (Danian) in the SE Netherlands and NE Belgium. — Meded. Werkgr. Tert. Kwart. Geol., 25: 127-161, 9 pls.

Ham, R.W.J.M., 1988b. De zeeëgel *Hemiaster aquisgranensis* nieuw voor Coesfeld (Nordrhein-Westfalen). — Grondb. Hamer, 42: 106-110.

Ham, R.W.J.M. van der, 1995. *Hemiaster (Leymeriaster) eluvialis*, a new echinoid from the late Maastrichtian of NE Belgium and SE Netherlands. — Bull. Inst. r. Sci. nat. Belg., Sci. Terre, 65: 153-164, pls 1-3.

Ham, R.W.J.M., 1999. Zee-egels uit het oostelijk eluvium. — Sprekende Bodem (Nederl. Geol. Ver., Afd. Limburg speciale uitgave December 1999): 35-45.

Ham, R. van der & M. van Birgelen, 1992. Zeeëgels uit het Maastrichtien van de Schneeberg en omgeving (Aken, Duitsland). — Natuurhist. Maandbl., 81: 139-153, pls 1-4.

Ham, R.W.J.M. van der & J.W.M. Jagt, 1998. Late Cretaceous hemiasterid echinoids from the Maastrichtian type area. In: R. Mooi & M. Telford (eds). Echinoderms: San Francisco. — A.A. Balkema, Rotterdam/Brookfield: 857-862.

Ham, R.W.J.M. van der & W. de Wit, 1998. Zee-egels. In: J.W.M. Jagt, J. Leloux & A.V. Dhondt (eds). Fossielen van de St. Pietersberg [Limburgnummer 9b]. — Grondb. Hamer, 52: 134-137, pls 20-21.

Ham, R. van der, W. de Wit, G. Zuidema & M. van Birgelen, 1987. Zeeëgels uit het Krijt en Tertiair van Maastricht, Luik en Aken. Een atlas van de zeeëgels uit het Campaniën, Maastrichtiën en Daniën van Zuid-Limburg en aangrenzende delen van België en Duitsland. — Publ. natuurhist. Gen. Limburg, 36: 1-92, 24 pls.

Hauschke, N., 1994. Temporäre Aufschlüsse im Campan des nordwestlichen Münsterlandes in den Jahren 1990-1992, unter besonderer Berücksichtigung der Fossilfunde. — Geol. Paläont. Westf., 32: 41-111, 24 pls.

Hawkins, H.L., 1912. Classification, morphology and evolution of the Echinoidea Holectypoida. — Proc. zool. Soc. Lond., 1912: 440-497.

Hucke, K. & E. Voigt, 1967. Einführung in die Geschiebeforschung (Sedimentärgeschiebe). — Nederl. Geol. Ver., Oldenzaal: 1-132, pls 1-50.

Indeherberge, L., V. Strijbos & T. Geussens, 1993. Voorkomen van het vuursteen-eluvium uit het Boven-Krijt in het heuvellandschap tussen Zichen (Riemst) en Sluizen (Tongeren). — Likona Jaarboek '92: 7-14.

Indeherberge, L., D. Bogaerts, T. Geussens & J. Snellings, 1996. Tussen Vechmaal en Kanne: een geologische tocht door het Krijt van zuidoost-Limburg. — Likona Jaarboek '95: 7-15.

Indeherberge, L.J., E.H.O. Defour, R.W.J.M. van der Ham & J.W.M. Jagt, 1998. Artificial casts and species identification of the Cretaceous echinoid *Diplodetus*. In: R. Mooi & M. Telford (eds). Echinoderms: San Francisco. — A.A. Balkema, Rotterdam/Brookfield: 687-692.

Jagt, J.W.M., 1985. Einige Bemerkungen zu dem Seeigel *Hemipneustes striatoradiatus* (Leske, 1778) aus dem Obermaastricht der Lüttich-Limburger Kreide. — Arb. Krs. Paläont. Hannover, 13: 73-80.

Jagt, J.W.M., 1999a. Late Cretaceous-Early Palaeogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium — Part 1: Introduction and stratigraphy. — Scripta

Geol., 116: 1-57.

Jagt, J.W.M., 1999b. Late Cretaceous-Early Palaeogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium — Part 2: Crinoids. — Scripta Geol., 116: 59-255, 46 pls.

Jagt, J.W.M., 1999c. An overview of Late Cretaceous and Early Palaeogene echinoderm faunas from Liège-Limburg (Belgium, The Netherlands). — Bull. Inst. r. Sci. nat. Belg., Sci. Terre, 69 (Suppl. A): 103-118, 2 pls.

Jagt, J.W.M. & H.L. Bongaerts, 1986a. Vondstmelding van het genus *Echinocorys* in het Onder-Campanien van Haccourt, Liège. — Grondb. Hamer, 40: 40-42.

Jagt, J.W.M. & H.L. Bongaerts, 1986b. Opmerkingen over enkele echiniden uit het Onder- en Boven-Campanien in de groeve CPL (Haccourt, B.). — Grondb. Hamer, 40: 45-61.

Jagt, J.W.M. & R.H.B. Fraaye, 1995. Latest Maastrichtian macrofaunas: Ankerpoort-Curfs quarry (Geulhem, The Netherlands). In: J.W.M. Jagt, H. Leereveld & M. Wilpshaar (eds). Annual Assembly of IGCP Project No. 362 Tethyan and Boreal Cretaceous, 17-18 September 1995, Maastricht, Progr. Abstr.: 50-52.

Jagt, J.W.M. & R.W.J.M. van der Ham, 1994. Early Palaeocene marsupiate regular echinoids from NE Belgium. In: B. David, A. Guille, J.-P. Féral & M. Roux (eds). Echinoderms through Time. Proc. Eighth Int. Echinoderm Conf., Dijon/France/6-10 September 1993. — A.A. Balkema, Rotterdam/Brookfield: 725-729, 2 pls.

Jagt, J.W.M. & R.W.J.M. van der Ham, 1995. First record of the echinoid genus *Tylocidaris* Pomel 1883 from the type Maastrichtian of the Netherlands. — Paläont. Z., 69: 233-239.

Jagt, J.W.M., R.W.J.M. van der Ham, L. Indeherberge & R. Meuris, 1999. A note on *Salenia* gr. *nutrix* Peron and Gauthier, 1881 (Echinoidea) from the Maastrichtian type area (southeastern Netherlands, northeastern Belgium). — J. Paleont., 73: 661-664.

Jagt, J.W.M. & P.H.M. van Knippenberg, 1995. A note on a late Campanian hemiasterid echinoid from Hannover-Misburg (N Germany). — N. Jb. Geol. Paläont. Mh., 1995, 2: 111-117.

Jagt, J.W.M. & G.P.H. Michels, 1986. *Cardiotaxis heberti* (Cotteau 1860) en *Cardiaster granulosus* (Goldfuss 1829) uit het onderste deel van de Formatie van Gulpen (Boven-Krijt): paleobiologie, voorkomen en systematiek. — Grondb. Hamer, 40: 185-205.

Jagt, J.W.M. & G.P.H. Michels, 1987. *Cyclaster platornatus* Kutscher, 1978: an addition to the echinoid fauna from the late Maastrichtian of NE Belgium. — Geol. Mijnbouw, 66: 57-63.

Jagt, J.W.M. & G.P.H. Michels, 1990. Additional note on the echinoid genus *Cyclaster* from the Late Maastrichtian of northeastern Belgium. — Geol. Mijnbouw, 69: 179-185.

Jagt, J.W.M. & G.P.H. Michels, 1994. The palaeobiology of a late Maastrichtian echinoid fauna from Haccourt (Liège, NE Belgium). In: B. David, A. Guille, J.-P. Féral & M. Roux (eds). Echinoderms through Time. Proc. Eighth Int. Echinoderm Conf., Dijon/France, 1993. — A.A. Balkema, Rotterdam/Brookfield: 719-724, 2 pls.

Jeffery, C.H., 1997a. Revision of the echinoid *Enallopneustes* from the Upper Cretaceous of North Africa. — Cret. Res., 18: 237-248.

Jeffery, C.H., 1997b. All change at the Cretaceous-Tertiary boundary? Echinoids from the Maastrichtian and Danian of the Mangyshlak Peninsula, Kazakhstan. — Palaeontology, 40: 659-712, 10 pls.

Kennedy, W.J., 1986. The ammonite fauna of the Calcaire à *Baculites* (Upper Maastrichtian) of the Cotentin Peninsula (Manche, France). — Palaeontology, 29: 25-83, pls 1-16.

Kier, P.M., 1962. Revision of the cassiduloid echinoids. — Smiths. misc. Coll., 144: i-iv + 1-262, pls 1-44.

Kier, P.M., 1966. Cassiduloids. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata 3, 2. — Geol. Soc. Am., Boulder/Univ. Kansas Press, Lawrence: U492-U523.

Klein, J.T., 1734. Naturalis dispositio Echinodermatum. Accessit Lucubratincula de aculeis Echinorum marinorum, cum spicilegio de Belemnites. — T.J. Schreiber, Gedani: 1-79, 37 pls.

Kutscher, M., 1978a. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. I. Holasteridae Durham & Melville [sic]. — Z. geol. Wiss., 6: 627-639, 3 pls.

Kutscher, M., 1978b. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. II. Spatangoida Claus, 1876. — Z. geol. Wiss., 6: 1025-1037, 3 pls.

Kutscher, M., 1979. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. III. Vertreter der Gattungen *Echinogalerus* König, 1825 und *Galerites* Lamarck, 1801. — Z. geol. Wiss., 7: 559-569, 2 pls.

Kutscher, M., 1983. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. IV. Saleniidae Agassiz, 1838. — Z. geol. Wiss., 11: 889-903, 4 pls.

Kutscher, M., 1985a. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. Vertreter der Ordnungen Echinothurioida Claus, 1880, Diadematoida Duncan, 1889 und Phymosomatoida Mortensen, 1904. — Z. geol. Wiss., 13: 235-247, 3 pls.

Kutscher, M., 1985b. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. Vertreter der Phymosomatidae Pomel, 1883. — Z. geol. Wiss., 13: 521-532, 2 pls.

Kutscher, M., 1985c. Neue Echiniden aus dem Unter-Maastricht der Insel Rügen. Weitere Vertreter der Phymosomatidae Pomel, 1883. — Z. geol. Wiss., 13: 731-740, 2 pls.

Lamarck, J.P. de, 1816. Histoire naturelle des animaux sans vertèbres, ou tableau général des classes, des ordres, et des genres de ces animaux, 3. Les Échinides. — Déterville & Verdière, Paris: 1-59.

Lambert, J., 1898. Note sur les Échinides de la craie de Ciply. — Bull. Soc. belge Géol., Paléont., Hydrol., 11 (1897): 141-190, pls 2-5.

Lambert, J., 1902. Sur un *Micraster* nouveau de la craie de Maestricht. — Bull. Soc. belge Géol., Paléont., Hydrol., 16: 121-128, pl. 6.

Lambert, J., 1903. Description des Échinides crétacés de la Belgique principalement de ceux conservés au Musée royal de Bruxelles. I. Étude monographique sur le Genre *Echinocorys*. — Mém. Mus. r. Sci. nat. Belg., 2: 1-151, pls 1-6.

Lambert, J., 1909a. Révision de quelques Cidaridae de la Craie. — Bull. Soc. Sci. hist. nat. Yonne, 62 (1908): 113-175, 1 pl.

Lambert, J., 1909b. Liste critique des échinides du Calcaire à *Baculites* du Cotentin. — Bull. Soc. linn. Normandie, 6, 2: 3-30, pl. 1.

Lambert, J., 1911. Description des Échinides crétacés de la Belgique principalement de ceux conservés au Musée royal de Bruxelles. II. Échinides de l'étage Sénonien. — Mém. Mus. r. Hist. nat. Belg., 4: 1-81, pls 1-3.

Lambert, J. & P. Thiéry, 1909-1925. Essai de nomenclature raisonnée des Échinides. — L. Ferrière, Chaumont: i-iii + 1-80, pls 1-2 (1909); 81-160, pls 3-4 (1910); 161-240, pls 5-6 (1911); 241-320, pls 7-8 (1914); 321-384, pl. 9 (1921); 385-512, pls 10-11, 14 (1924); 513-607, pls 12-13, 15 (1925).

Leske, N.G., 1778. Jacobi Theodori Klein Naturalis dispositio Echinodermatum, edita et descriptionibus novisque inventis et synonymis auctorum aucta. — G.E. Beer, Lipsiae: i-xxii + 1-278, 54 pls.

Lewis, D.N., 1986. The Cretaceous echinoid *Boletechinus*, with notes on the phylogeny of the Glyphocyphidae and Temnopleuridae. — Bull. Br. Mus. nat. Hist. (Geol.), 40: 59-90.

Maczyńska, S.S., 1968. Echinoids of the Genus *Micraster* L. Agassiz from the Upper Cretaceous of the Cracow-Miechow area. — Prace Muz. Ziemi, 12: 87-168, pls 1-28.

Meijer, A.W.F., 1981. *Toxopatagus rutoti* (Lambert), een zeldzame irregulaire zee-egel uit de Limburgse Krijtafzettingen. — Natuurhist. Maandbl., 70: 192-193.

Meijer, M., 1955. Sur un échinide peu connu du Maestrichtien du Limbourg hollando-belge. *Hemiaster (Leymeriaster) maestrichtensis* Schlueter. — Natuurhist. Maandbl., 44: 74-77, 1 pl.

Meijer, M., 1956. Notes sur les échinides du tuffeau de Maastricht (Maestrichtien, Dumont, 1849). I. *Echinogalerus (Rostrogalerus) transversus* (Smiser). — Natuurhist. Maandbl., 45: 38-44, 1 pl.

Meijer, M., 1965a. Sur la présence du genre *Plagiochasma* (Enchinoidea) [sic] dans les tuffeaux maastrichtien et dano-montien aux environs de Maastricht (Pays-Bas). — Natuurhist. Maandbl., 54: 96-102, pl. 1.

Meijer, M., 1965b. The stratigraphical distribution of Echinoids in the Chalk and Tuffaceous Chalk in the neighbourhood of Maastricht (Netherlands). — Meded. Geol. Sticht., n.s., 17: 21-25.

Melville, R.V., 1952. On a new species of irregular echinoid (*Plagiochasma coxwellensis* sp. nov.) from the Lower Greensand of Farringdon, Berks. — Bull. geol. Surv. Great Br., 4: 1-7, 1 pl.

Melville, R.V. & J.W. Durham, 1966. Skeletal morphology. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata 3, 1. — Geol. Soc. Am., Boulder/Univ. Kansas Press, Lawrence: U220-U257.

Michels, G. & J. Jagt, 1985. Eerste melding van de zeeëgel *Micraster stolleyi* J. Lambert in A. de

Grossouvre, 1901 (Spatangoida) in het Luiks-Limburgse Boven-Krijt (Campanien). — Grondb. Hamer, 39: 50-56.
Mortensen, T., 1928. A monograph of the Echinoidea, 1. Cidaroidea. — C.A. Reitzel, Copenhagen: i-v + 1-551, 88 pls.
Morton, S.G., 1829-1830. Synopsis of the organic remains of the ferruginous sand formation of the United States; with geological remarks. — Am. J. Sci., 1, 17: 274-295; 1, 18: 243-250, pls 1-3.
Moskvin, M.M. & N.V. Shumanskaia, 1993. Rod *Echinocorys* (morskie ezhi) v otlozeniiakh datskogo jarusa vostochnoi chasti evropeiskoi paleobiogeograficheskoi oblasti. Stat'ia 2. — Byull. Mosk. o-ba. ispyt. prir., Otd. geol., 67: 44-59, pls 3-5.
Nestler, H., 1972. Die Cidariden (Echinoidea) der Kreide (Unteres Maastricht) Rügens. — Wiss. Z. Ernst-Moritz-Arndt Univ. Greifswald, math.-naturwiss. Reihe, 2: 171-190, pls 1-6.
Nietsch, H., 1921. Die irregulären Echiniden der pommerschen Kreide. — Abh. geol.-paläont. Inst. Univ. Greifswald, 2: 1-47, 11 pls.
Ødum, H., 1926. Studier over Daniet i Jylland og paa Fyn. — Danm. geol. Unders., 2, 45: 1-280, 6 pls.
Orbigny, A.D. d', 1854-1860. Paléontologie Française. Description des animaux invertébrés. Terrain crétacé, 6. Échinides irréguliers. — Masson, Paris: 1-596, pls 801-1006.
Philip, G.M. & R.J. Foster, 1971. Marsupiate Tertiary echinoids from southeastern Australia and their zoogeographic significance. — Palaeontology, 14: 666-695, pls 124-134.
Pomel, A., 1883. Classification méthodique et genera des échinides, vivants et fossiles. — A. Jourdan, Alger: 1-131, 1 pl.
Portlock, J.E., 1843. Report on the geology of the County of Londonderry, and of parts of Tyrone and Fermanagh, examined and described under the authority of the Master General and Board of Ordnance. — A. Milliken, Dublin: i-xxxii + 1-784, pls 1-38, A-I.
Quenstedt, F.A., 1852. Handbuch der Petrefactenkunde. — H. Laupp, Tübingen: i-iv + 1-792, pls 1-61.
Quenstedt, F.A., 1873-1875. Petrefactenkunde Deutschlands, 3. Echinodermata. 1. Echiniden. — Fuess, Leipzig: i-viii + 1-720, pls 62-89.
Ravn, J.P.J., 1927. De irregulære Echinider i Danmarks Kridtaflejringer. — Kgl. danske Vidensk. Selsk. Skr., naturv.-math. Afd., 11: 307-354, pls 1-5.
Ravn, J.P.J., 1928. De regulære Echinider i Danmarks Kridtaflejringer. — Kgl. danske Vidensk. Selsk. Skr., naturv.-math. Afd., 1: 1-63, pls 1-6.
Rosenkrantz, A., 1970. Marine Upper Cretaceous and lowermost Tertiary deposits in West Greenland. Investigations before and since 1938. — Bull. geol. Soc. Denmark, 19: 406-453.
Salah, A.A., 1982. Die Temnocidariden (reg. Echiniden) der Maastricht-Stufe von NW-Deutschland. — Geol. Jb., A61: 207-223, 3 pls.
Salah, A.A. & F. Schmid, 1982. Die Tylocidariden (reg. Echiniden) der Ober-Maastricht-Stufe von Dänemark und NW-Deutschland. — Geol. Jb., A61: 177-205, 7 pls.
Savin, L., 1903. Catalogue raisonnée des Échinides fossiles de la Savoie. — Bull. Soc. Hist. nat. Savoie, 2, 8: 1-195, 3 pls.
Schlüter, C., 1869. Fossile Echinodermen des nördlichen Deutschlands. — Verh. naturhist. Ver. preuß. Rheinl. Westph., 26: 225-253, 3 pls.
Schlüter, C., 1881. Ueber die Vertikalverbreitung der fossilen Diadematiden und Echiniden im nördlichen Deutschland. — Sitz.Ber. niederrh. Ges. Natur- u. Heilkde, 1881: 213-218.
Schlüter, C., 1883. Die Regulären Echiniden der norddeutschen Kreide. I. Glyphostoma (Latistellata). — Abh. k. preuß. geol. Landesanst., 4: i-vi + 1-72, pls 1-7.
Schlüter, C., 1892. Die regulären Echiniden der norddeutschen Kreide. II. Cidaridae, Salenidae [sic]. — Abh. königl. preuß. geol. Landesanst., 5: i-ix + 1-243, pls 8-21.
Schlüter, C., 1897a. Ueber einige exocyclische Echiniden der baltischen Kreide und deren Bett. — Z. dt. geol. Ges., 49: 18-50, pls 1-2.
Schlüter, C., 1897b. Ueber einige baltische Kreide-Echiniden. I. Ueber einen angeblichen *Hemipneustes* im Trümmerkalke Schwedens, II. *Cidaris Forchhammeri* im Faxekalk ?. — Z. dt. geol. Ges., 49: 889-905, pls 32-33.
Schlüter, C., 1899. Ueber einige von Goldfuss beschriebene Spatangiden. II. Stück. — Z. dt. geol. Ges., 51: 104-124, pls 9-10.

Schlüter, C., 1900. Ueber einige Kreide-Echiniden. — Z. dt. geol. Ges., 52: 360-379, pls 15-18.
Schlüter, C., 1902. Zur Gattung *Caratomus*. — Z. dt. geol. Ges., 54: 302-335, pls 11-12.
Schmid, F., 1972. *Hagenowia elongata* (Nielsen), ein hochspezialisierter Echinide aus dem höheren Untermaastricht NW-Deutschlands. — Geol. Jb., A4: 177-195, 4 pls.
Schulz, M.-G., 1985. Die Evolution der Echiniden-Gattung *Galerites* im Campan und Maastricht Norddeutschlands. — Geol. Jb., A80: 3-93, 15 pls.
Seunes, J., 1888. Echinides crétacés des Pyrénées occidentales. — Bull. Soc. géol. Fr., 16: 791-815, pls 28-31.
Smiser, J.S., 1935a. A revision of the Echinoid genus *Echinocorys* in the Senonian of Belgium. — Mém. Mus. r. Hist. nat. Belg., 67: 1-52, pls 1-2.
Smiser, J.S., 1935b. A monograph of the Belgian Cretaceous echinoids. — Mém. Mus. r. Hist. nat. Belg., 68: 1-98, pls 1-9.
Smith, A.B., 1984. Echinoid Palaeobiology. — George Allen & Unwin, London: i-x + 1-190.
Smith, A.B., 1995. Late Campanian-Maastrichtian echinoids from the United Arab Emirates-Oman border region. — Bull. nat. Hist. Mus. Lond. (Geol.), 51: 121-240, 34 pls.
Smith, A.B. & C.H. Jeffery, in press. Maastrichtian and Palaeocene echinoids: An illustrated key. — Spec. Pap. Palaeont.
Smith, A.B. & A. McGugan, 1997. A new deep-water spatangoid echinoid from the Cretaceous of British Columbia, Canada. — Bull. nat. Hist. Mus. Lond. (Geol.), 52: 103-107.
Smith, A.B. & C.W. Wright, 1989. British Cretaceous echinoids. Part 1, General Introduction and Cidaroida. — Monogr. Palaeontogr. Soc. Lond., 141 (578): 1-101 + i-vi, 32 pls.
Smith, A.B. & C.W. Wright, 1990. British Cretaceous echinoids. Part 2. Echinothurioida, Diadematoida and Stirodonta (1, Calycina). — Monogr. Palaeontogr. Soc. Lond., 143 (583): 101-198 + i-iv, pls 33-72.
Smith, A.B. & C.W. Wright, 1993. British Cretaceous echinoids. Part 3, Stirodonta 2 (Hemicidaroida, Arbacioida and Phymosomatoida, Part 1). — Monogr. Palaeontogr. Soc. Lond., 147 (593): 199-267 + i-ii, pls 73-92.
Smith, A.B. & C.W. Wright, 1996. British Cretaceous echinoids. Part 4, Stirodonta 3 (Phymosomatidae, Pseudodiadematidae) and Camarodonta. — Monogr. Palaeontogr. Soc. Lond., 150 (602): 268-341, pls 93-114.
Sorignet, L., 1850. Oursins fossiles de deux arrondissements du Département de l'Eure (Louviers et Andelys). — Barbaret, Vernon: i-iv + 1-83.
Stephenson, L.W., 1941. The larger invertebrate fossils of the Navarro Group of Texas (exclusive of corals and crustaceans and exclusive of the fauna of the Escondido Formation). — Texas Univ. Bull., 4101: 1-641, pls 1-95.
Stokes, R.B., 1975. Royaumes et provinces fauniques du Crétacé établis sur la base d'une étude systématique du genre *Micraster*. — Mém. Mus. natl Hist. nat., n.s., C31: 1-94, pls 1-12.
Stokes, R.B., 1979. The echinoid genus *Diplodetus* from the Santonian to Danian of Northern Europe. — N. Jb. Geol. Paläont. Mh., 1979(10): 619-630.
Wagner, C.D. & J.W. Durham, 1966. Holasteroids. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata 3, 2. — Geol. Soc. Am., Boulder/Univ. Kansas Press, Lawrence: U523-U543.
Weber, G.F., 1934. Yurskie i melovye morskie yezhi Kryma [Jurassic and Cretaceous echinoids from Crimea]. — Trans. United geol. prospect. Serv. USSR, 312: 1-99, 12 pls.
Wind, J., 1954. *Tylocidaris* Piggene som ledeforsteninger i vort øvre Senon og Danien. — Meddr dansk geol. Foren., 12: 481-486, pls. 12-13.
Woodward, S., 1833. An outline of the geology of Norfolk. — Longman & Co., London: 1-55, pls 1-6.
Wright, C.W., 1967. Notes on Cretaceous Saleniidae. — Proc. Geol. Ass., 78: 9-25, pls 1-2.
Wright, C.W. & E.V. Wright, 1949. The Cretaceous echinoid genera *Infulaster* Desor and *Hagenowia* Duncan. — Ann. Mag. nat. Hist., 12, 2: 454-474.

Manuscript received 14 May 1999.

Plate 1

Figs. 1-15. *Tylocidaris (T.)* gr. *bruennichi* Ravn, 1928
1-7: NHMM PK 759, primary spines, Ankerpoort-Curfs quarry, Geulhem, Houthem Formation, upper Geulhem Member.
8-10: NHMM RH 285/1, oral, aboral and lateral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.
11-14: NHMM RH 285/2-5, primary spines, same locality and stratigraphy.
15: NHMM RH 285/6, test segment, same locality and stratigraphy.

Figs. 16-31. *Tylocidaris (T.) hardouini* (Desor, 1855)
16-21, 23-30: NHMM K 1732, primary spines, Ankerpoort-Curfs quarry, Geulhem, Houthem Formation, lower Geulhem Member.
22, 31: NHMM RH 436/1-2, test segments, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, lower Geulhem Member.

Fig. 32. *Tylocidaris (T.) oedumi* Brünnich Nielsen, 1938; NHMM JJ 10708, primary spines of the type comparable to Gravesen's (1993) oldest *oedumi* populations, virtually indistinguishable from *T. hardouini* (see figs. 16-21, 23-30), Stevns Klint, south of Højerup, Sjælland (Denmark), lowermost Danian Bryozoan Limestone.

Figs. 33-35. *Tylocidaris (T.) inexspectata* Jagt & van der Ham, 1995
33-34: NHMM 1994139 (**holotype**), ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Meerssen Member.
35: NHMM DE 050, same locality, Maastricht Formation, Meerssen Member (IVf-6).

Fig. 36. *Ctenocidaris*? *distincta* (Sorignet, 1850); NHMM MB 432VV-1, test fragment, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Fig. 37. *Cidaris*? sp.; NHMM MB 432VV-2, test fragment, same locality and stratigraphy.

Scale bars equal 1 mm.

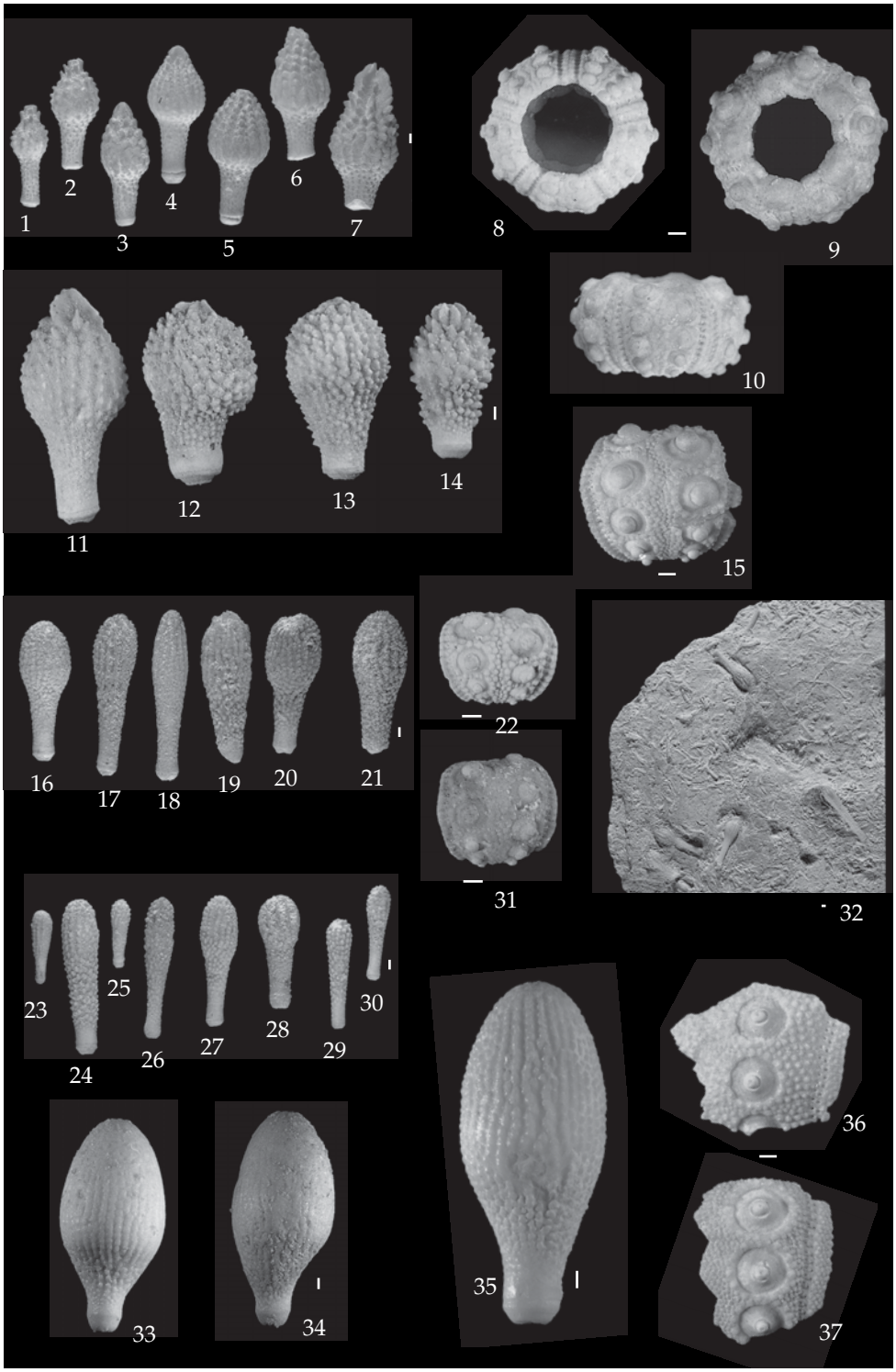

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37

Plate 2

Fig. 1. *Temnocidaris (T.)* sp. 1; NHMM 1982153, complete test preserving scrobicular spines, Ankerpoort-'t Rooth quarry, Bemelen, Maastricht Formation, base Meerssen Member.

Fig. 2. *Temnocidaris (T.)* sp. 2; NHMM K 2944, test fragment, Ankerpoort-Marnebel quarry, Eben Emael, Maastricht Formation, Nekum Member (Kanne Horizon).

Fig. 3. *Temnocidaris (T.) danica* (Desor, 1855); NHMM MB 681-1, interambulacral plates, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, lower Geulhem Member.

Figs. 4-5. *Temnocidaris (Stereocidaris) serrata* (Desor, 1858)
4: NHMM JJ 6390, test segment, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, sponge level - 6.10 m.
5: NHMM JJ 7288, complete test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, top - 9.7/11.6 m.

Fig. 6. *Temnocidaris (Stereocidaris*) sp. 1; NHMM JJ 5953, test segment, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 1.90 m.

Fig. 7. *Cidaris*? *rosenkrantzi* Ravn, 1928; NHMM RH 285-7, test segment, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Fig. 8: Indeterminate cidaroid adapical interambulacral plate; NHMM JJ 6602, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 0-4 m.

Fig. 9. *Cidaris*? *forchhammeri* Desor, in L. Agassiz & Desor, 1846; NHMM RH 285-8, test fragment, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 10-12. Indeterminate cidaroid spines; temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.
10, 12: NHMM MB 432FF-1/2, note colour banding.
11: NHMM RH 285-9.

Figs. 13-15. *Temnocidaris (Stereocidaris) gigas* (Schlüter, 1892)
13: NHMM K 1402, adapical interambulacral plate, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-6).
14-15: NHMM BL 0163a-b, interambulacral plates, same locality, Maastricht Formation, Meerssen Member (IVf-4).

Scale bars equal 5 mm.

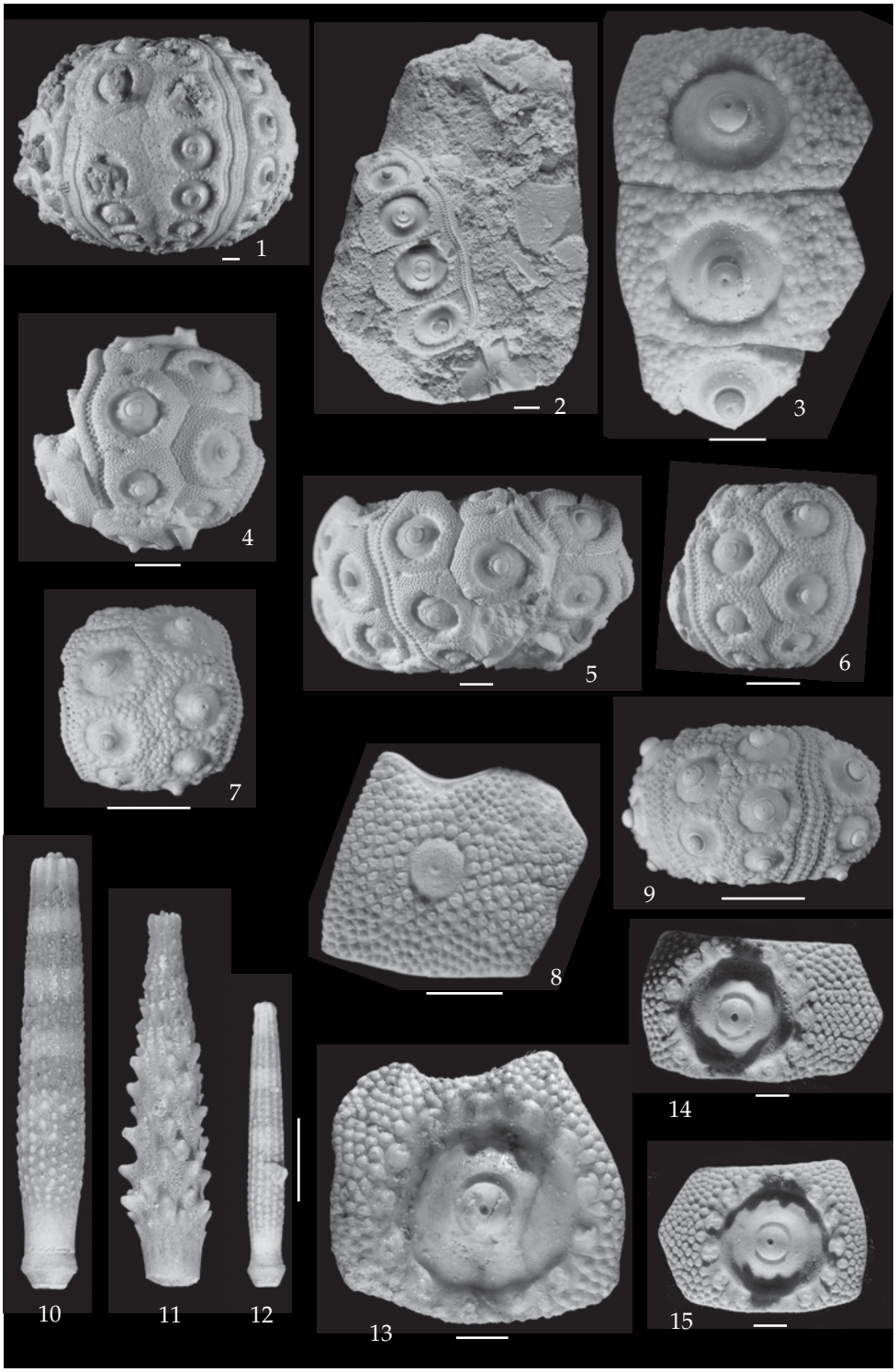

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Plate 3

Fig. 1. *Temnocidaris (Stereocidaris) gigas* (Schlüter, 1892); NHMM K 752, interambulacral plate preserving some ambulacral plates, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Fig. 2. Indeterminate cidarid interambulacral plate; NHMM JJ 6794, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 4.5 m.

Figs. 3-6, 8-9. *Centrostephanus*? sp. (spp. ?)
3-4: NHMM MB 808-9, lateral and apical views of juvenile test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6/7 m.
5-6: NHMM K 1408, primary spines, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-6).
8: NHMM JJ 10600/11a, ambulacral plate, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member.
9: NHMM JJ 10600/11b, genital plate, same locality and stratigraphy.

Fig. 7. *Echinothuria*? sp.; NHMM JJ 11436 (sample Vij/I), hoofed primary spine, Aachen-Hans Böckler Allee, Gulpen Formation, Vijlen Member.

Scale bars equal 5 mm, except in figs 3-4, 7-9, where it represents 1 mm.

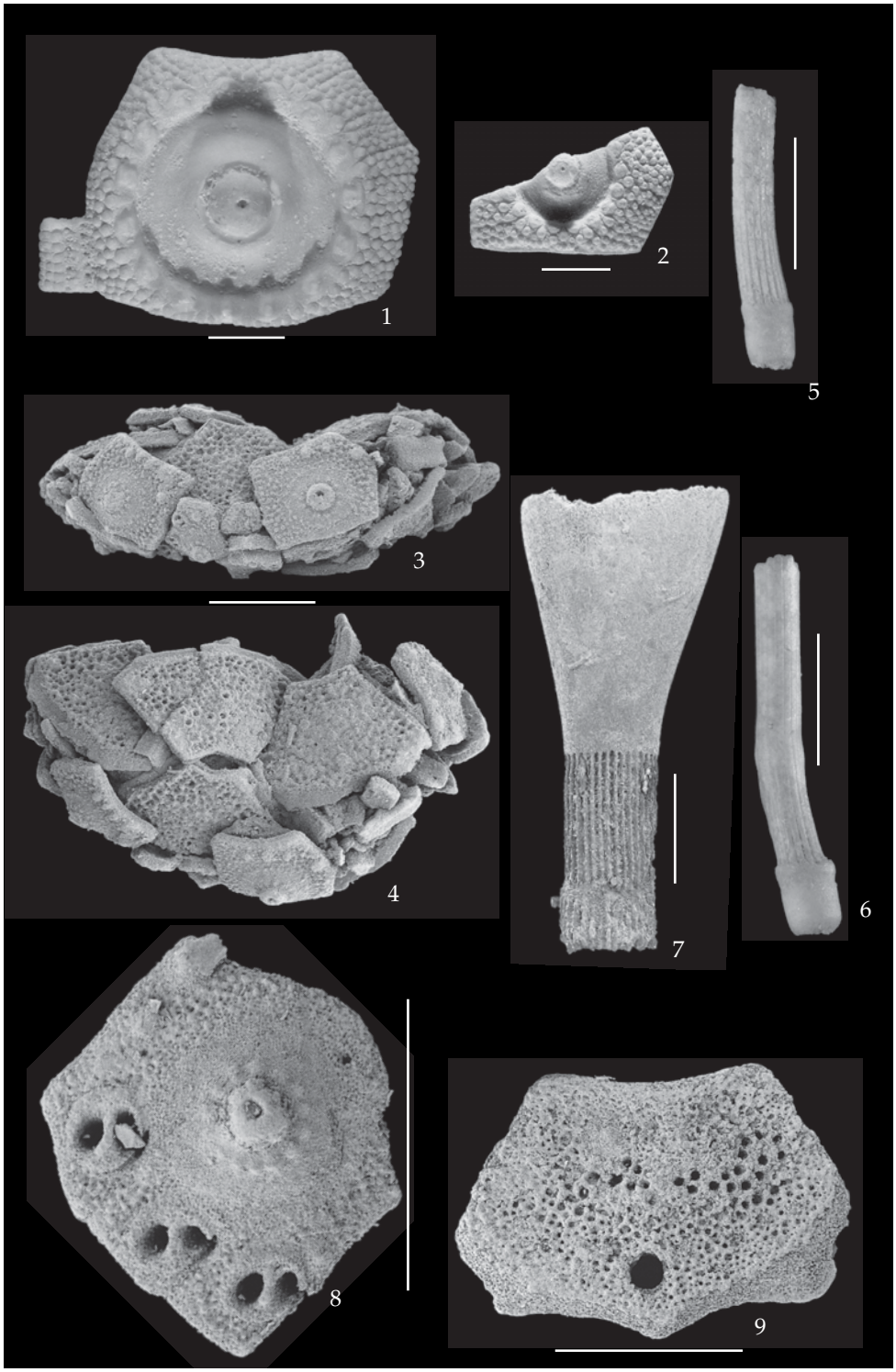

1
2
5
3
4
7
6
8
9

Plate 4

Fig. 1. *Centrostephanus*? sp.; NHMM BL 0054, ambital interambulacral plate, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Fig. 2. Diadematid primary spine; NHMM MB 1239-13, Mamelis-Selzerbeek, Gulpen Formation, lower Vijlen Member.

Figs. 3-4. *Salenia (S.) desori* Lambert, 1911 ?; IRScNB 10162 (illustrated by Geys, 1979, fig. 11/3-6, as *S. belgica*), apical and lateral views of test, Ciply (southern Belgium), Craie phosphatée de Ciply (Lower Maastrichtian, *obtusa* Zone), or Tuffeau de Ciply (Early Palaeocene; see text).

Figs. 5-6, 9. *Salenia (S.) belgica* Lambert, 1898
5-6: NHMM MM 895, apical and lateral views of test, Vroenhoven-Riemst, Houthem Formation, lower Geulhem Member (illustrated as *Salenia minima* by Geys, 1982, pl. 29, figs. 1-4).
9: NHMM MB 491, Ankerpoort-Curfs quarry, Geulhem, Houthem Formation, lower Geulhem Member.

Figs. 7-8. *Salenia (S.) sigillata* Schlüter, 1892; IRScNB 9104 (**holotype** of *Salenia rutoti* Lambert, 1911), oblique apical and lateral views of test, Slenaken, Gulpen Formation, Beutenaken Member inferred (? or lower Vijlen Member).

Figs. 10-11. *Orthopsis miliaris* (d'Archiac, 1835); NHMM BL 0154, oral and lateral views of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Scale bars equal 5 mm, except in fig. 2, where it represents 1 mm.

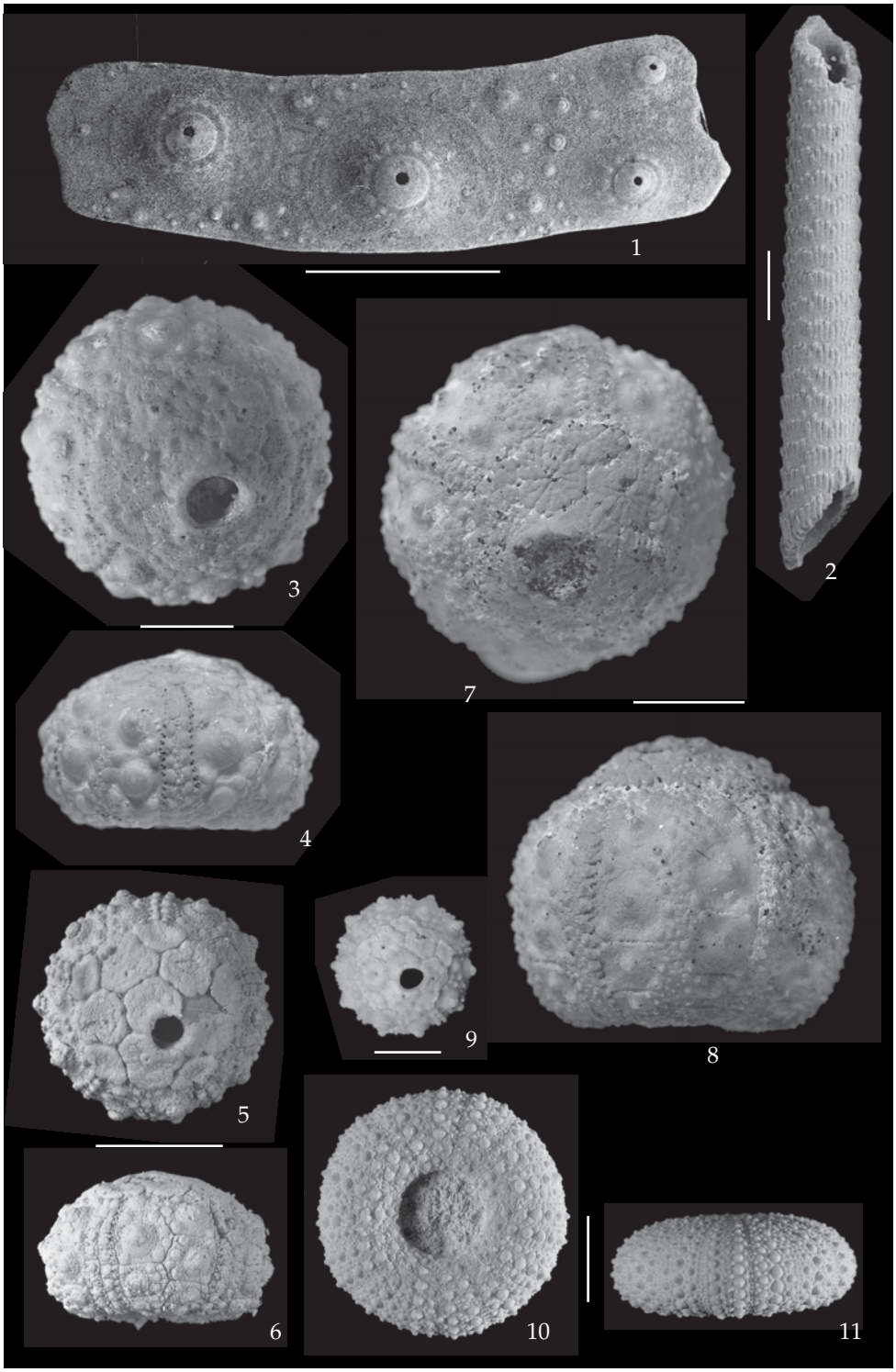

1
2
3
7
4
8
9
5
6
10
11

Plate 5

Figs. 1-5, 8-11. *Salenia (Pleurosalenia) anthophora* (J. Müller, 1847)
1-2: NHMM JJ 6459, aboral and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 1.7 m.
3: IRScNB 9103, lateral view of test, Slenaken, Gulpen Formation, Vijlen Member inferred.
4-5: IRScNB 10161, aboral and lateral views of test, Gulpen, Gulpen Formation, Vijlen Member inferred.
8, 10: NHMM MB 1773-1 (ex 453-1), lateral and aboral views of test, Oud Lemiers (southern Limburg), Gulpen Formation, Vijlen Member.
9: NHMM MB 1773-2 (ex 453-1), lateral view of test, same locality and stratigraphy.
11: RFWUIP unregistered (Schlüter Colln, **neotype**), lateral view of test, Schneeberg-Aachen, Gulpen Formation, Vijlen Member.

Figs. 6-7, 12-13, ?14. *Salenia (Pleurosalenia) bonissenti* (Cotteau, 1866) sensu Lambert, 1898
6-7: IRScNB 9107, apical and lateral views of test, Ciply (southern Belgium), 'Poudingue de Malogne' (base of Tuffeau de Ciply).
12-13: NHMM K 3873, lateral and oral view of fragmentary test, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, Emael Member (Lava Horizon).
14: primary spine probably belonging to *S. (P.) bonissenti*; NHMM MD 2924a, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.

Scale bars equal 5 mm.

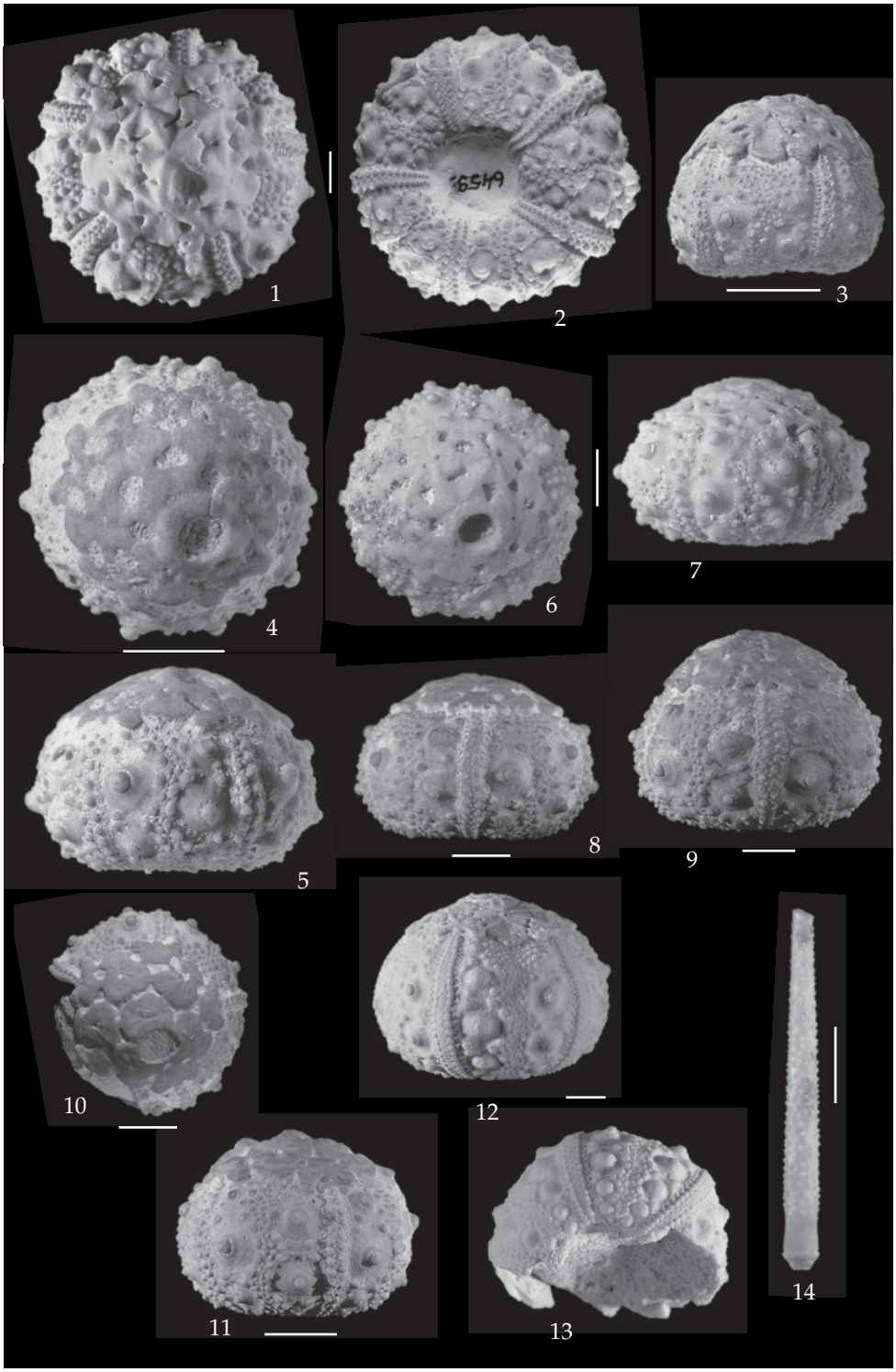

1
2
3
4
6
7
5
8
9
10
12
14
11
13

Plate 6

Fig. 1. *Salenia (Pleurosalenia) bonissenti* (Cotteau, 1866) sensu Lambert, 1898; NHMM HS 0001, aboral view of test, Ankerpoort-Marnebel quarry, Eben Emael, Maastricht Formation, Emael Member.

Figs. 2, 9-11. *Salenia (Pleurosalenia)* sp.
2: NHMM K 1069, aboral view of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member, Berg en Terblijt Horizon - 2 m.
9-11: NHMM K 1183/1-3, same locality, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 3-5. *Salenia (Pleurosalenia)* sp. nov.; NHMM MB 432-J (**holotype**), aboral and lateral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 6-7. *Salenia (Pleurosalenia) heberti* (Cotteau, 1865)
6: NHMM JJ 7783, oblique lateral view of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 2.5-3 m.
7: NHMM MD 2850, apical view of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 3-4 m.

Fig. 8. *Salenia (Pleurosalenia) maestrichtensis* Schlüter, 1892; IRScNB 10158, aboral view of test, St Pietersberg, Maastricht, Maastricht Formation, Meerssen Member inferred.

Figs. 12-13. *Salenidia (? Platysalenia) sanctipetri* Geys, 1979; IRScNB 10160 (**holotype**), lateral and aboral views of test, St Pietersberg, Maastricht Formation, Meerssen Member inferred.

Scale bars equal 1 mm.

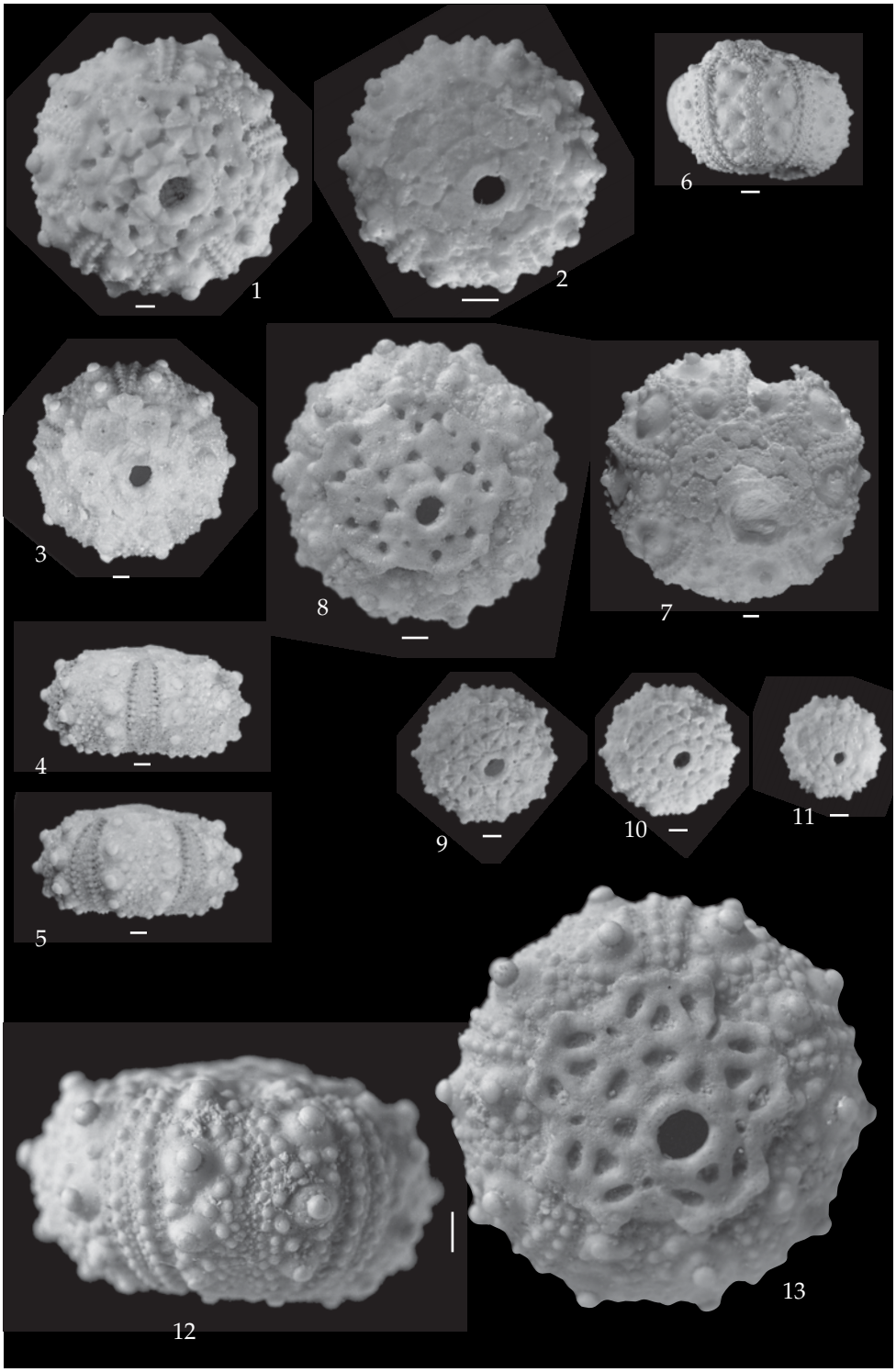

1
2
6
3
8
7
4
9
10
11
5
12
13

Plate 7

Figs. 1-2. *Salenocidaris minima* (Desor, in L. Agassiz & Desor, 1846); NHMM MB 339, apical and lateral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, lower Geulhem Member.

Fig. 3. *Salenocidaris obnupta* (Schlüter, 1892); NHMM JJ 2986, lateral view of test, with associated demipyramid, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 3-4 m.

Figs. 4-10. *Hyposalenia heliophora* (Desor, in L. Agassiz & Desor, 1846)
4, 8: NHMM MM 899, lateral and apical views of test, Geulhem, Houthem Formation, lower Geulhem Member.
5-7, 9-10: NHMM JS V50, lateral and apical view of test, associated lantern and detail of ambulacral plating, Vroenhoven-Riemst, Houthem Formation, lower Geulhem Member.

Scale bars equal 1 mm.

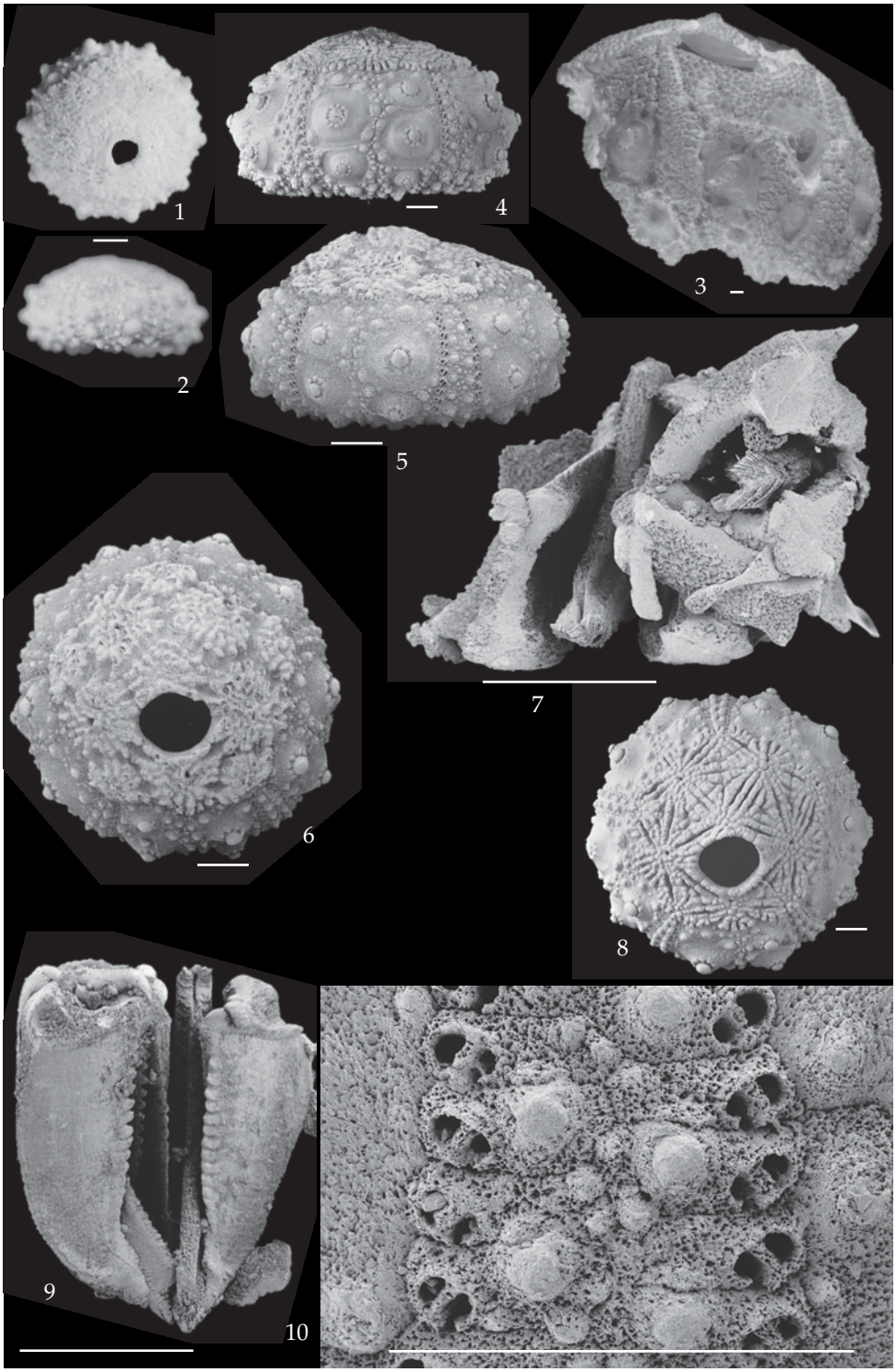

1
4
3
2
5
7
6
8
9
10

Plate 8

Figs. 1-5. *Codiopsis disculus* Peron & Gauthier, 1881
1-2: NHMM BL 0111, aboral and oral views of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).
3: IRScNB 9122 (**holotype** of *Codiopsis pierrensis* Smiser, 1935b), oblique oral view of test, St Pietersberg, Maastricht, Maastricht Formation, Meerssen Member inferred.
4-5: NHMM 1999008, aboral and lateral views of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member.

Fig. 6. *Goniopygus heberti* Cotteau, 1866; NHMM MB 432-C, adoral view of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 7-8. *Goniopygus minor* Sorignet, 1850; temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member; 7: NHMM MB 432-A/1, oblique lateroapical view of female (brood pouches); 8: NHMM MB 432-A/2, oblique lateroapical view of male.

Fig. 9. *Goniopygus* sp. nov.; NHMM K 2284, aboral view of test, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (top IVf-3).

Scale bars equal 1 mm.

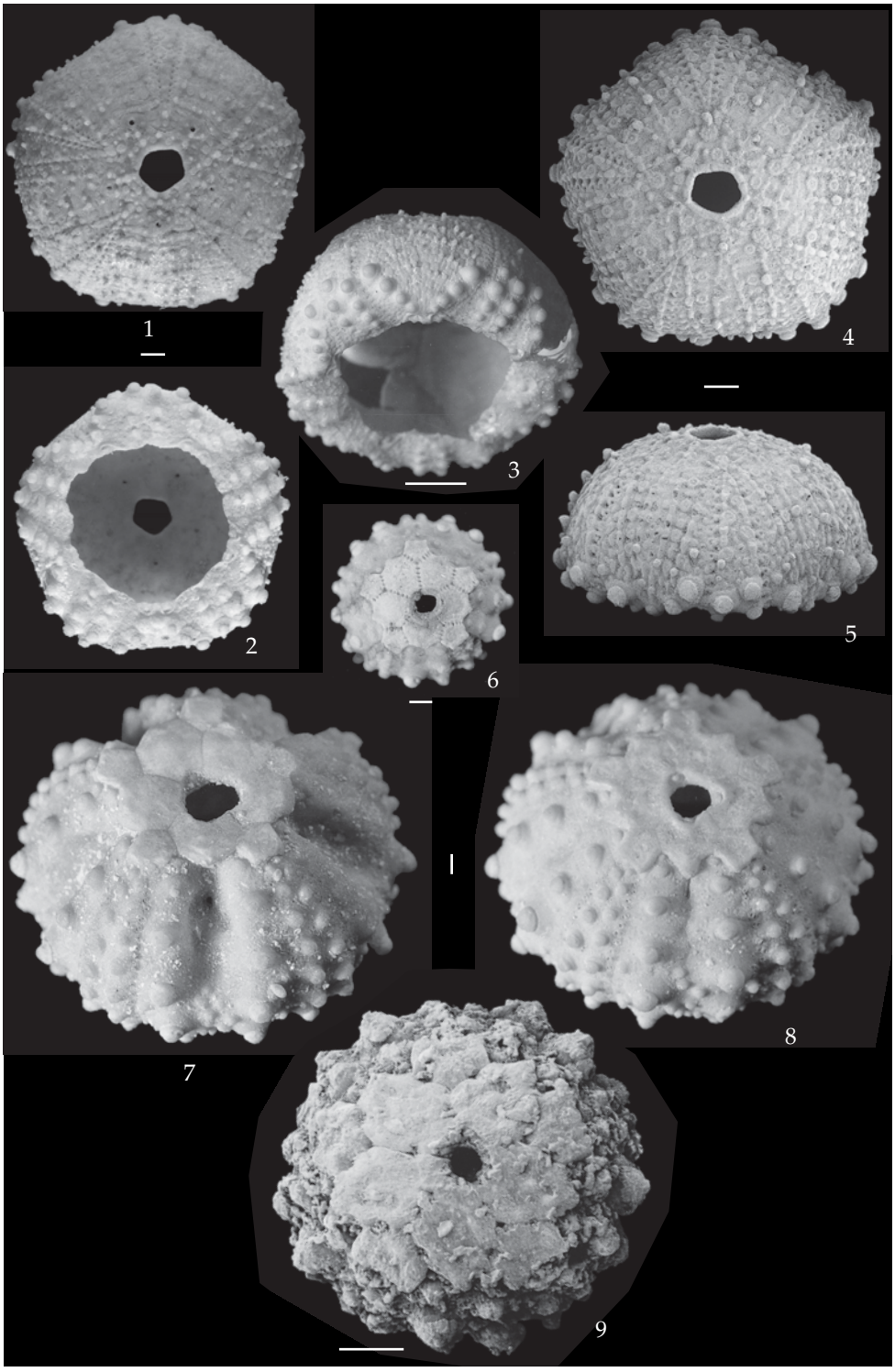

1
2
3
4
5
6
7
8
9

Plate 9

Figs. 1-6. *Phymosoma* gr. *granulosum* (Goldfuss, 1829)
1-3: NHMM GK 4565 (W.M. Felder Colln), aboral, lateral and oral views of test, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member.
4-6: NHMM MB 432-U, aboral, lateral and oral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Figs. 7-8, 11, 14. *Gauthieria grossouvrei* (Lambert, 1898); temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member; 7-8: NHMM MB 432-P/1, lateral and oral views of test; 11: NHMM MB 432-P/2, adoral view of test; 14: NHMM MB 432-P/3, adoral view of test.

Figs. 9-10. *Circopeltis maastrichtensis* (Engel, 1972); temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member; 9: NHMM MB 432-R/1, lateral view of test; 10: NHMM MB 432-R/2, test fragment.

Figs. 12-13, 15. *Micropsidia salis* (Cooke, 1941); NHMM MB 432-N, lateral, aboral and oral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Scale bars equal 10 mm.

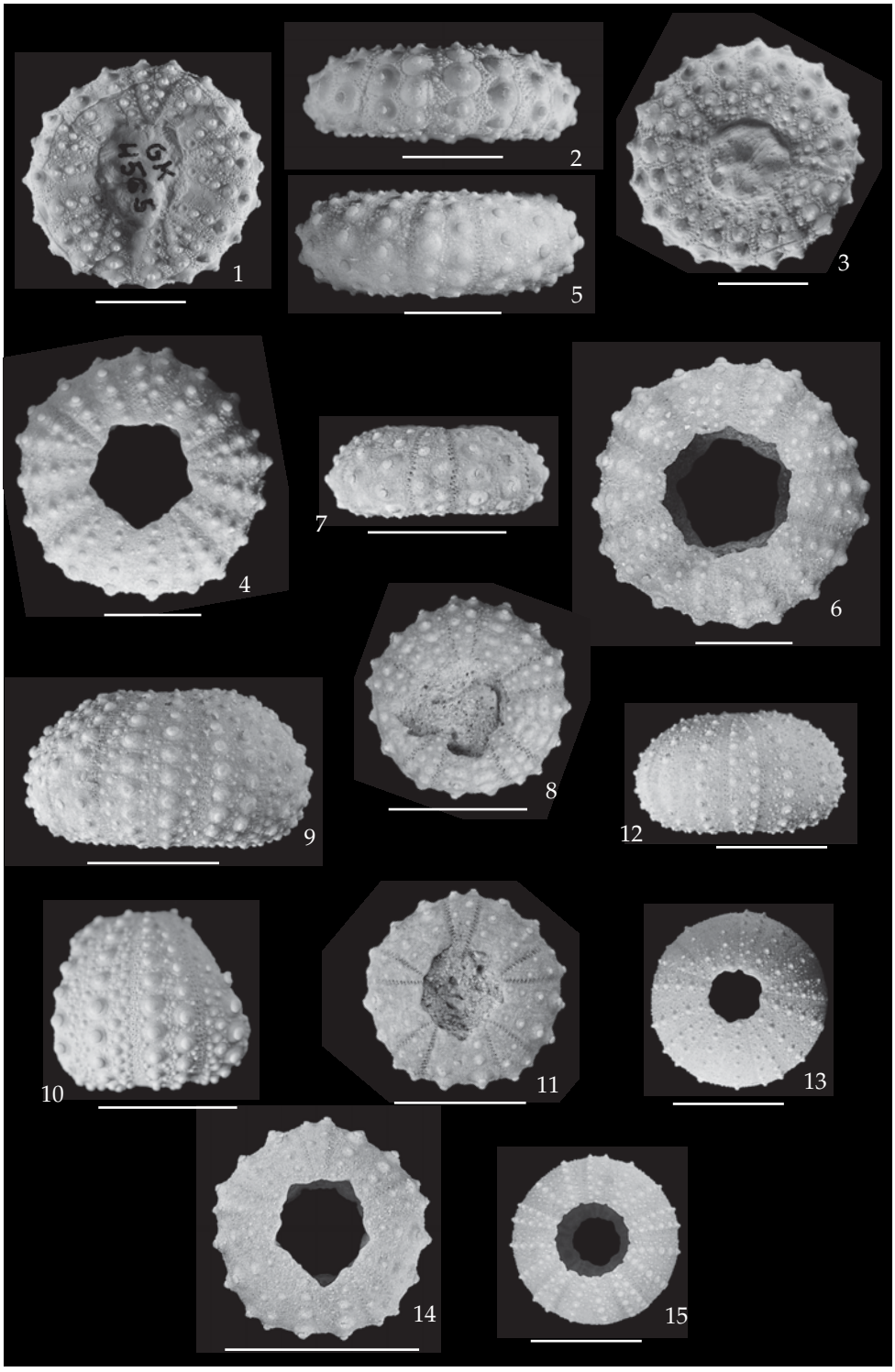

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Plate 10

Figs. 1, 4-7. *Gauthiosoma princeps* (von Hagenow, 1840)
1: NHMM GK 1264 (W.M. Felder Colln), lateral view of test, Vijlenerbosch (southern Limburg), Gulpen Formation, Vijlen Member.
4-7: NHMM DE 051, aboral, lateral and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member.

Figs. 2-3: *Gauthiosoma krimica* (Weber, 1934) ?; IRScNB 10204 (**holotype** of *Rachiosoma gigasei* Geys, 1983), lateral and aboral views of test, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member(?).

Figs. 8-11. *Gauthieria mosae* Geys, 1980
8-9: IRScNB 10178 (**holotype**), oral and oblique lateral views of test, Heure-le-Romain (Liège), Gulpen Formation, Zeven Wegen Member.
10-11: NHMM JJ 7643, oral and aboral views of test fragment, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member, crinoid level - 0.5 m.

Fig. 12. *Trochalosoma*? *corneti* (Cotteau, 1875); NHMM MD 3816, oral view of test, Ankerpoort-Marnebel (N), Eben Emael, Maastricht Formation, top Emael Member.

Figs. 13-14. *Phymosoma* gr. *granulosum* (Goldfuss, 1829); NHMM BL 0560, aboral and lateral views of test, Welten-de Dael (Kunrade area), Maastricht Formation, Kunrade Limestone facies.

Scale bars equal 10 mm.

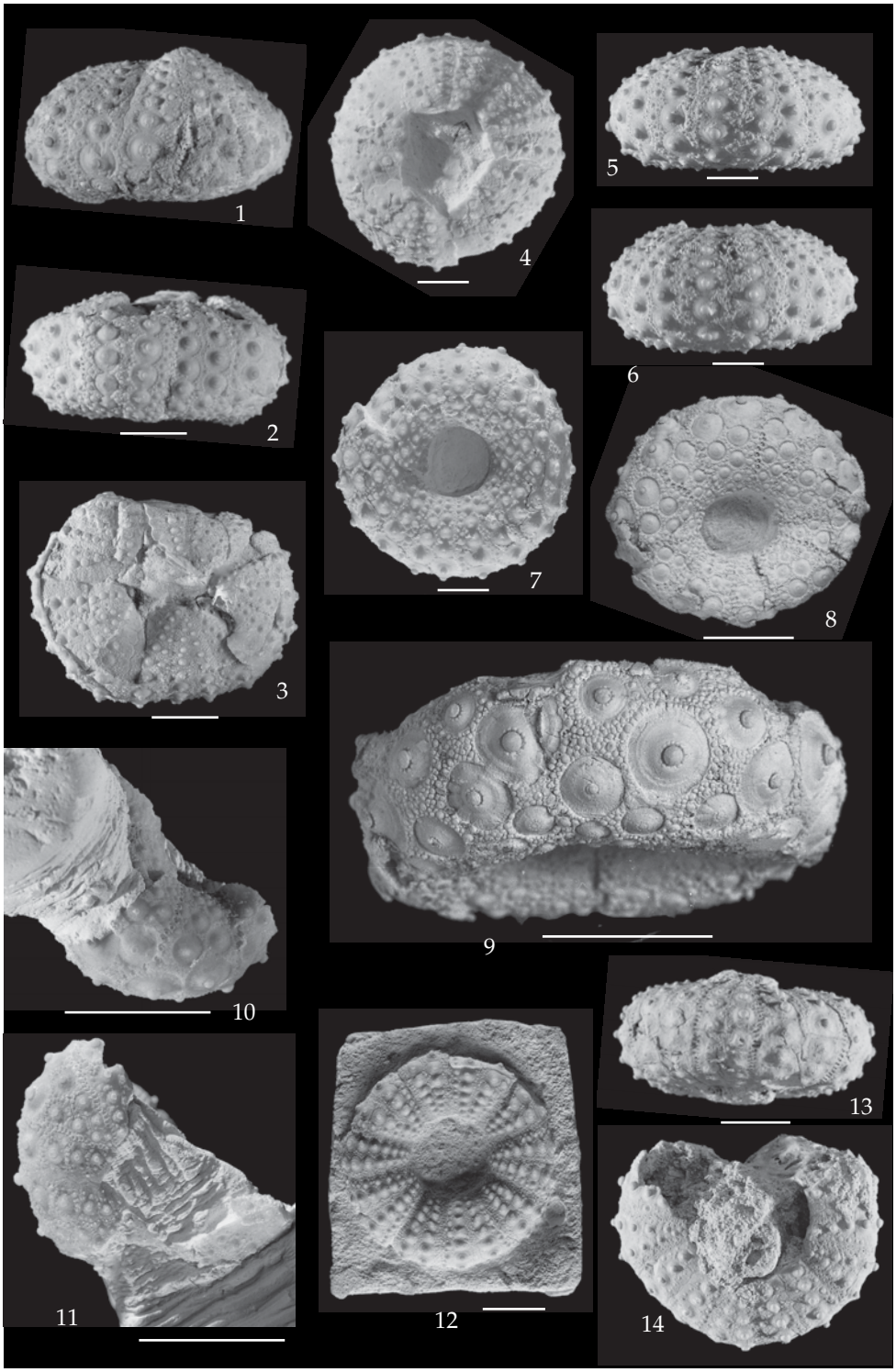

1
2
3
4
5
6
7
8
9
10
11
12
13
14

Plate 11

Figs. 1-2. *Gauthieria maeandrina* (Schlüter, 1883); IRScNB 9118 (**holotype**), detail of aboral ambulacral plating and aboral view of test, Kunrade area, Maastricht Formation, Kunrade Limestone facies.

Figs. 3-8. *Phymotaxis tournoueri* (Cotteau, 1866)
3: Falize Colln (NHMM, unregistered), Ankerpoort-'t Rooth quarry, Bemelen, Maastricht Formation, base Meerssen Member.
4, 7-8: NHMM MM 164, aboral, lateral and oral views of test, St Pietersberg, Maastricht, Maastricht Formation, Meerssen Member.
5-6: NHMM K 615, lateral and aboral views of test fragment, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (top IVf-4).

Scale bars equal 10 mm.

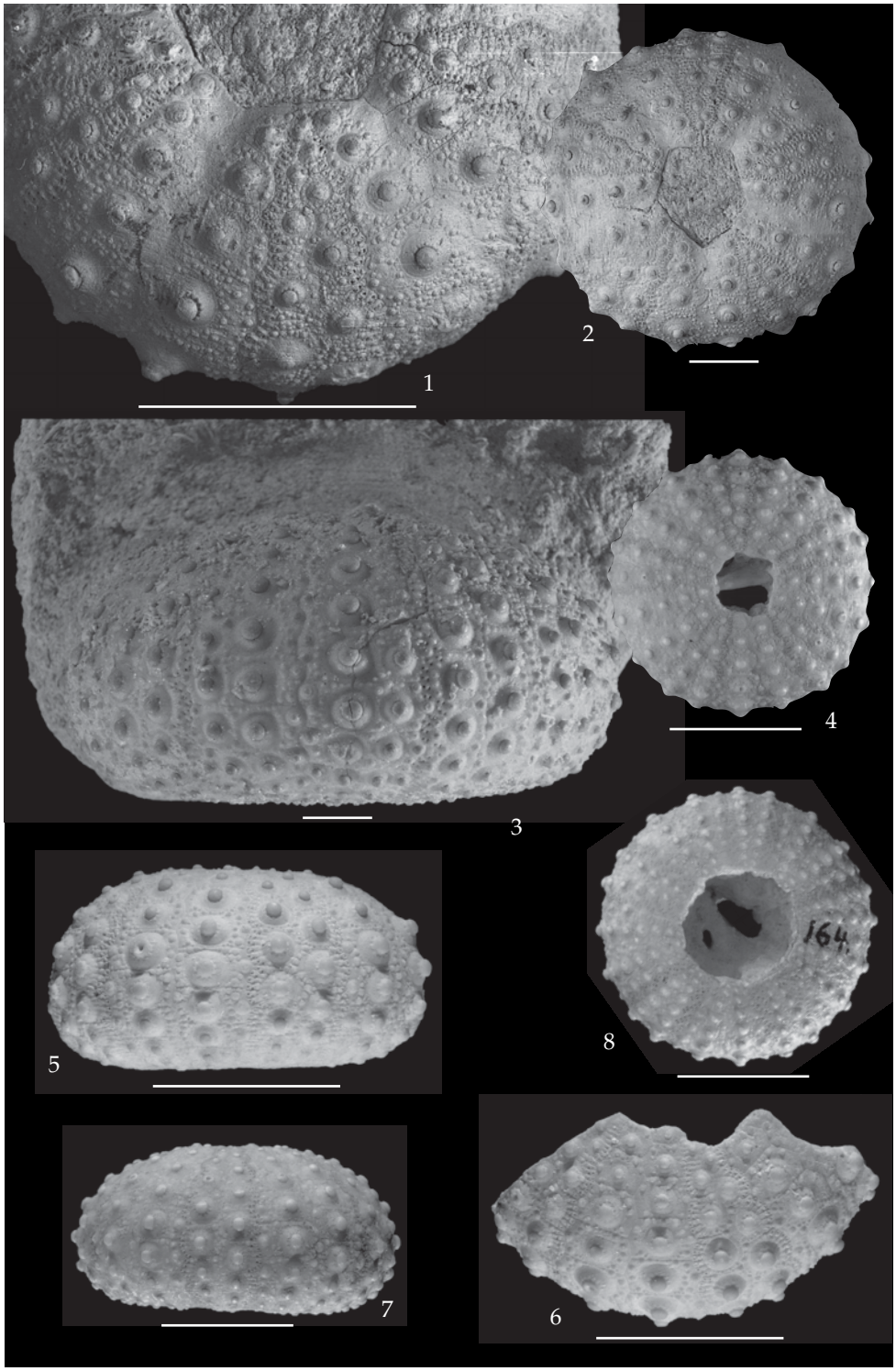

1
2
3
4
5
6
7
8
164.

Plate 12

Figs. 1-11. *Gauthieria pseudoradiata* auctt., non Schlüter, 1883 ?
1: NHMM K 1882, lateral view of test, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, Emael Member (Lava Horizon).
2: NHMM JJ 8885, lateral view of test, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 0.75 m.
3: NHMM K 4276(1), test preserving spines, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.
4-6: NHMM MM 1008, aboral, lateral and oral views of test, Kunrade area, Maastricht Formation, Kunrade Limestone facies.
7-8: NHMM JJ 3390, aboral and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 0-4 m.
9-11: NHMM JJ 1105, aboral, oral and lateral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member.

Figs. 12-13. *Micropsis*? *caementum* Jagt & van der Ham, sp. nov.; NHMM K 2681 (**holotype**), test fragment with detail of ambulacral plating, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Emael Member.

Scale bars equal 5 mm.

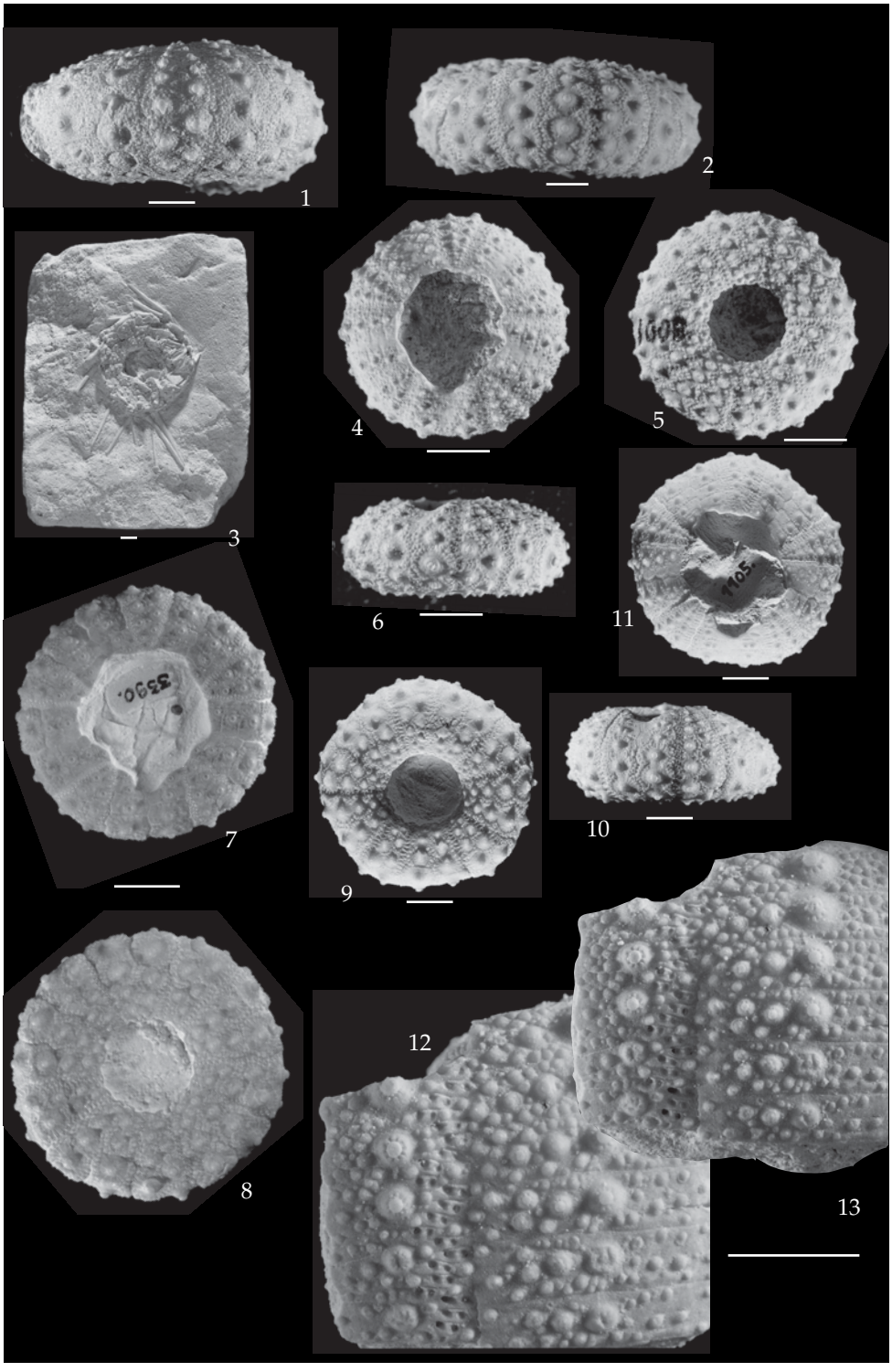

1
2
3
4
5
6
7
8
9
10
11
12
13

Plate 13

Figs. 1-2. Phymosomatid primary spines, probably assignable to *Gauthieria pseudoradiata* auctt.; NHMM JJ 9395-11, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.

Figs. 3-16. *Trochalosoma*? *corneti* (Cotteau, 1875)
3-7: NHMM MD 2924b, primary spines of *inops* morphology, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.
8: NHMM JJ 9370-19, primary spine of *inops* type, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.
9: NHMM K 4152(6), primary spine of *rutoti* type, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, Nekum Member, Kanne Horizon + 2 m.
10-15: NHMM BL 0123, primary spines of *rutoti* type, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).
16: NHMM AC M-100, oral view of test with associated spines and lantern, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, top Nekum Member.

Scale bars equal 1 mm.

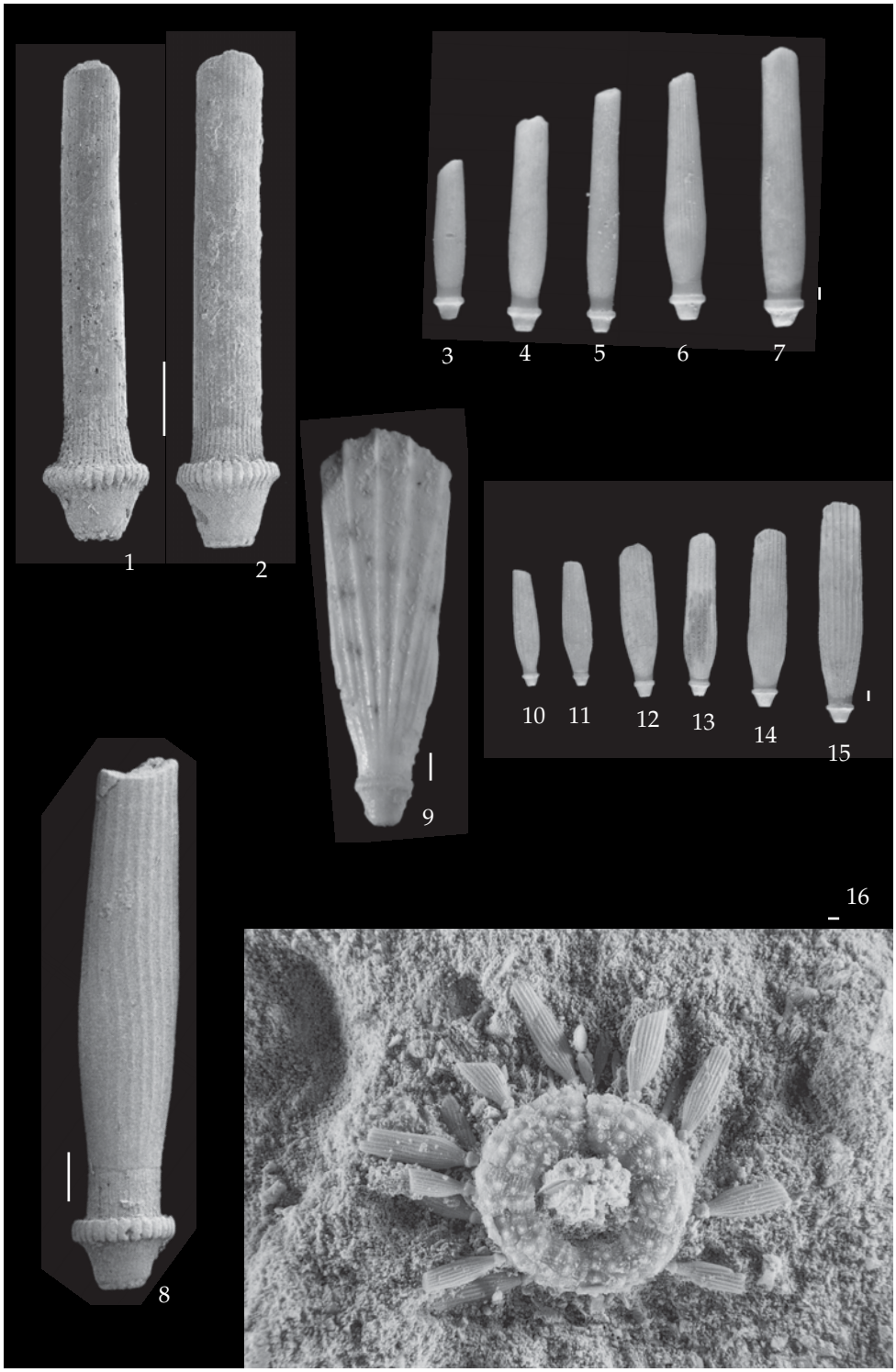

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Plate 14

Figs. 1-4. *Micropsidia*? sp.; NHMM RF 1998-1, aboral, oblique lateral and oral views of female test, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member.

Figs. 5-7. *Thylechinus* sp. nov.; temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member; 5-6: NHMM MB 432-M/1 (**holotype**), aboral and lateral views of male test; 7: NHMM MB 432-M/2, aboral view of female test (brood pouches).

Figs. 8-10. *Winkleria maastrichtensis* Engel, 1964a; NHMM K 1180, oral, oblique lateral and lateral views of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 11-12. *Zeuglopleurus rowei* Gregory, 1900; NHMM MB 865-3/1, oblique lateral and aboral view of test, de Wingerd quarry, Benzenrade, Vaals Formation, Benzenrade Member.

Scale bars equal 1 mm.

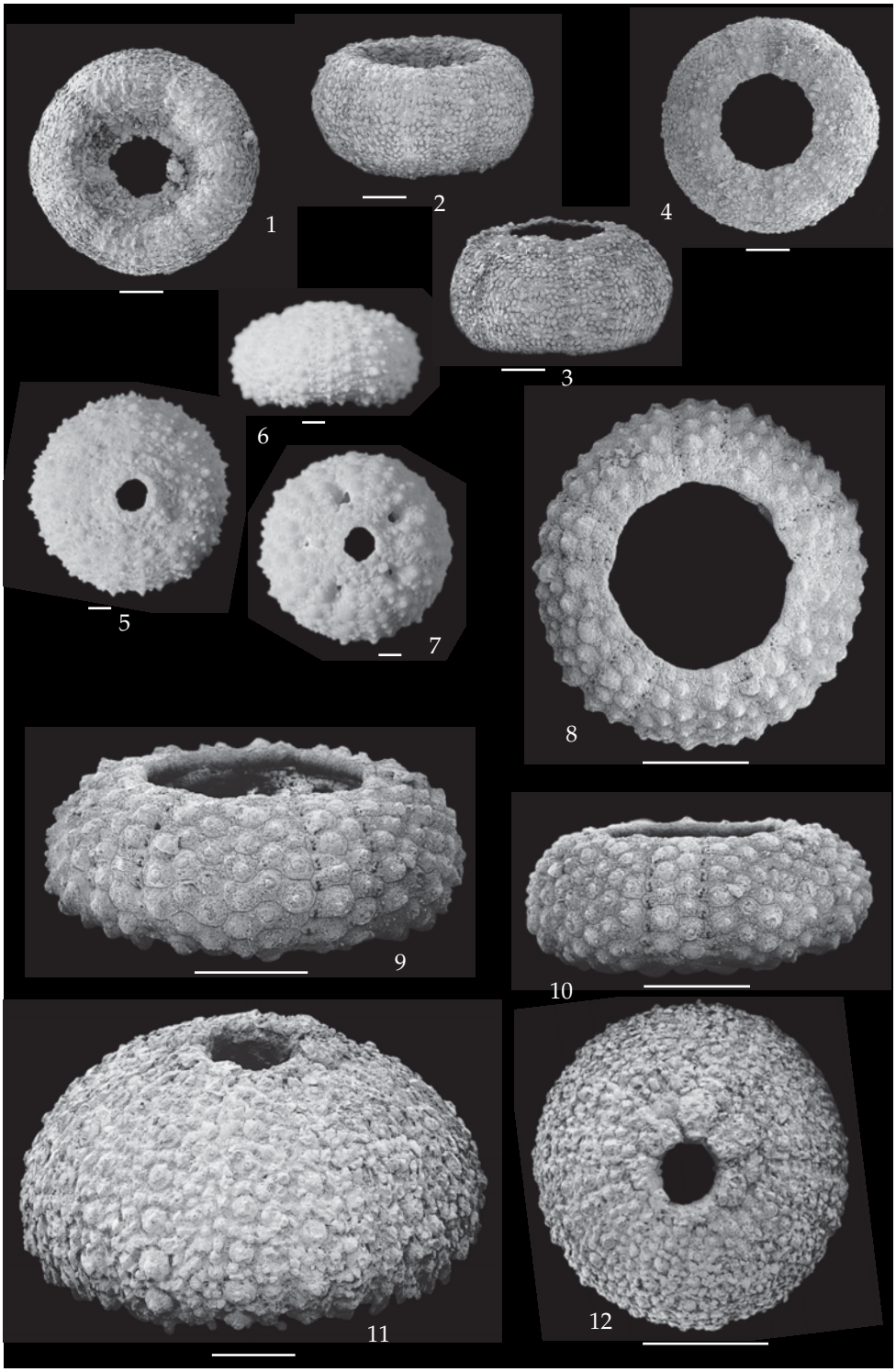

1
2
3
4
5
6
7
8
9
10
11
12

Plate 15

Figs. 1-2. *Coenholectypus macrostomus* (Engel, 1964b); NHMM MB 347, aboral and lateral views of test, Ankerpoort-Curfs quarry, Geulhem, Maastricht Formation, base Meerssen Member.

Figs. 3-6. *Adelopneustes montainvillensis* (Sorignet, 1850); NHMM MK 770 (W.M. Felder Colln), aboral, oral, lateral and posterior views of test, Ankerpoort-Curfs quarry, Geulhem, Houthem Formation, lower Geulhem Membner.

Figs. 7-10. *Adelopneustes boehmi* (Nietsch, 1921); NHMM MB 432-D, aboral, oral, posterior and lateral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 11-13. *Galerites stadensis* Lambert, 1911; NHMM Vijlen Groep Colln, no. 513, aboral, lateral and oral views of test, Altembroeck section, Voer (Limburg), Gulpen Formation, Vijlen Member.

Scale bars equal 1 mm.

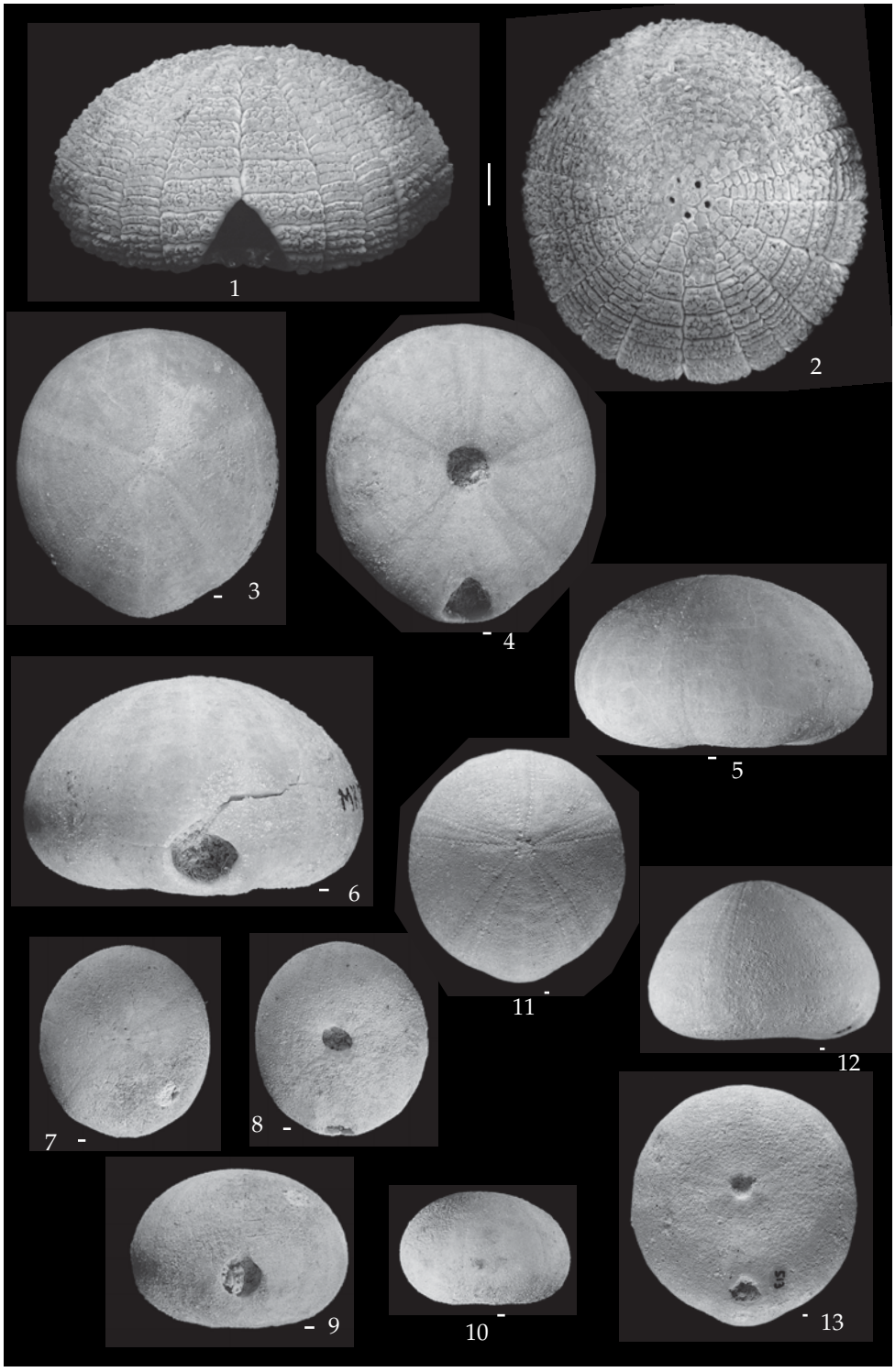

1
2
3
4
5
6
7
8
9
10
11
12
13

Plate 16

Fig. 1. *Galerites stadensis* Lambert, 1911; NHMM Vijlen Groep Colln, no. K2496, lateral view of test, Altembroeck section, Voer (Limburg), Gulpen Formation, Vijlen Member.

Figs. 2-4. *Echinogalerus*? *hemisphaericus* (Desor, 1842) sensu Schulz, 1985; NHMM JJ 816, oral, aboral and lateral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member.

Fig. 5. *Echinogalerus transversus* (Smiser, 1935b); NHMM K 750, aboral view of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 6-7. *Echinogalerus muelleri* (Schlüter, 1902)
6: NHMM BL 0822, aboral view of test.
7: NHMM BL 0811, oral view of test, both Kunrade area, Maastricht Formation, Kunrade Limestone facies.

Figs. 8-10. *Faujasia* (*F.*) *apicalis* (Desor, 1847); NHMM JJ 8818, aboral, oral and lateral views of test, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-3).

Scale bars equal 1 mm.

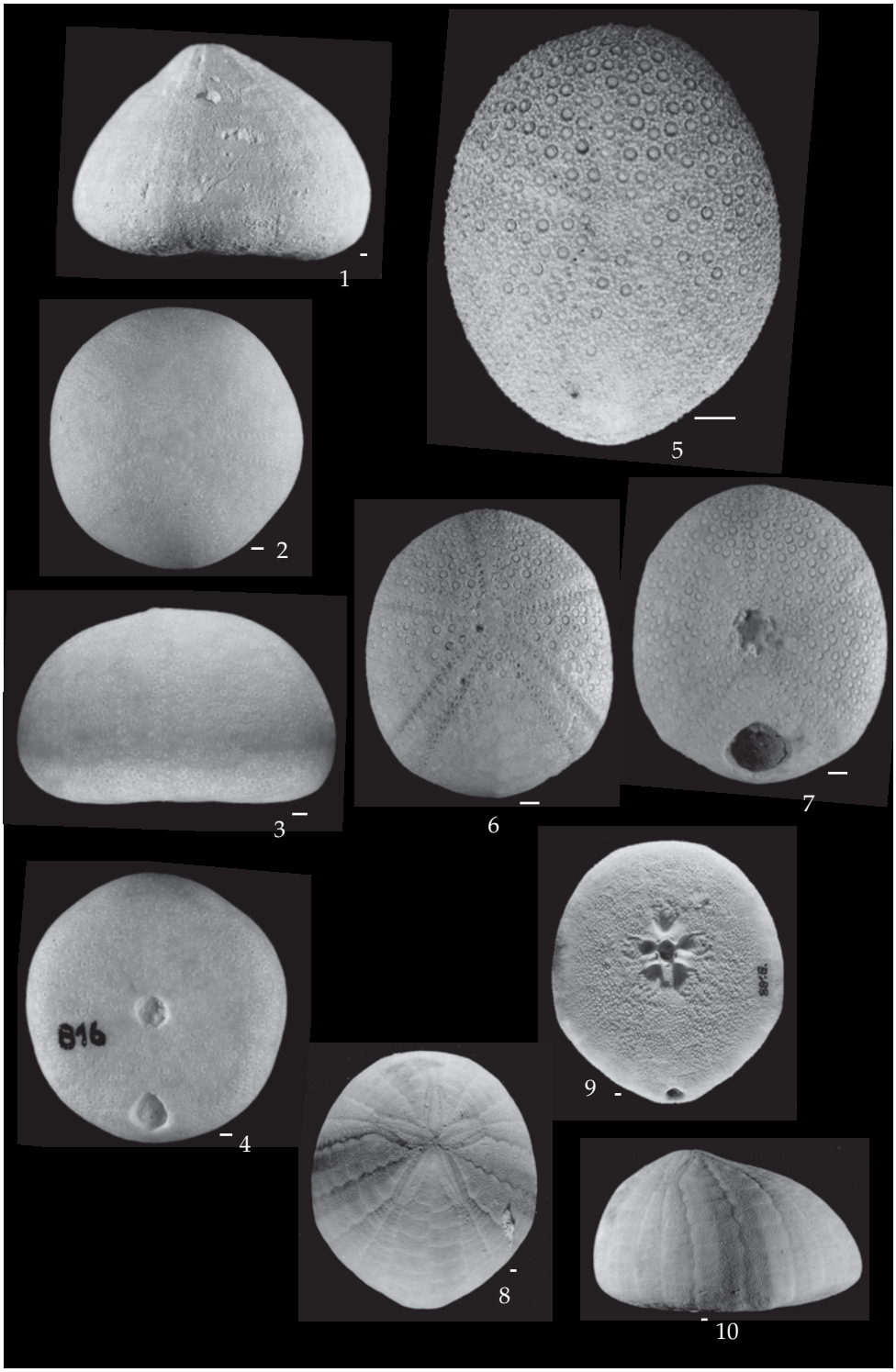

1
2
3
4
5
6
7
8
9
10
816

Plate 17

Figs. 1-3, 10. *Plagiochasma lammersmaxi* Jagt & van der Ham, sp. nov.
1-3: NHMM TL 1985/1 (**holotype**), aboral, oral and posterior views of test, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Meerssen Member.
10: NHMM BL 0645, oral view of test fragment, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 4-6. *Plagiochasma cruciferum* (Morton, 1830); NHMM MB 432-E, aboral, lateral and oral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 7-9. *Oolopygus* gr. *pyriformis* (Leske, 1778)
7: NHMM JJ 565, aboral view of test, ENCI-Nederland BV quarry, Maastricht, Gulpen Formation, Lanaye Member.
8-9: NHMM K 1216, oral and posterior views of test, Ankerpoort-Marnebel quarry, Eben Emael, Maastricht Formation, Emael Member (? Lava Horizon).

Scale bars equal 10 mm.

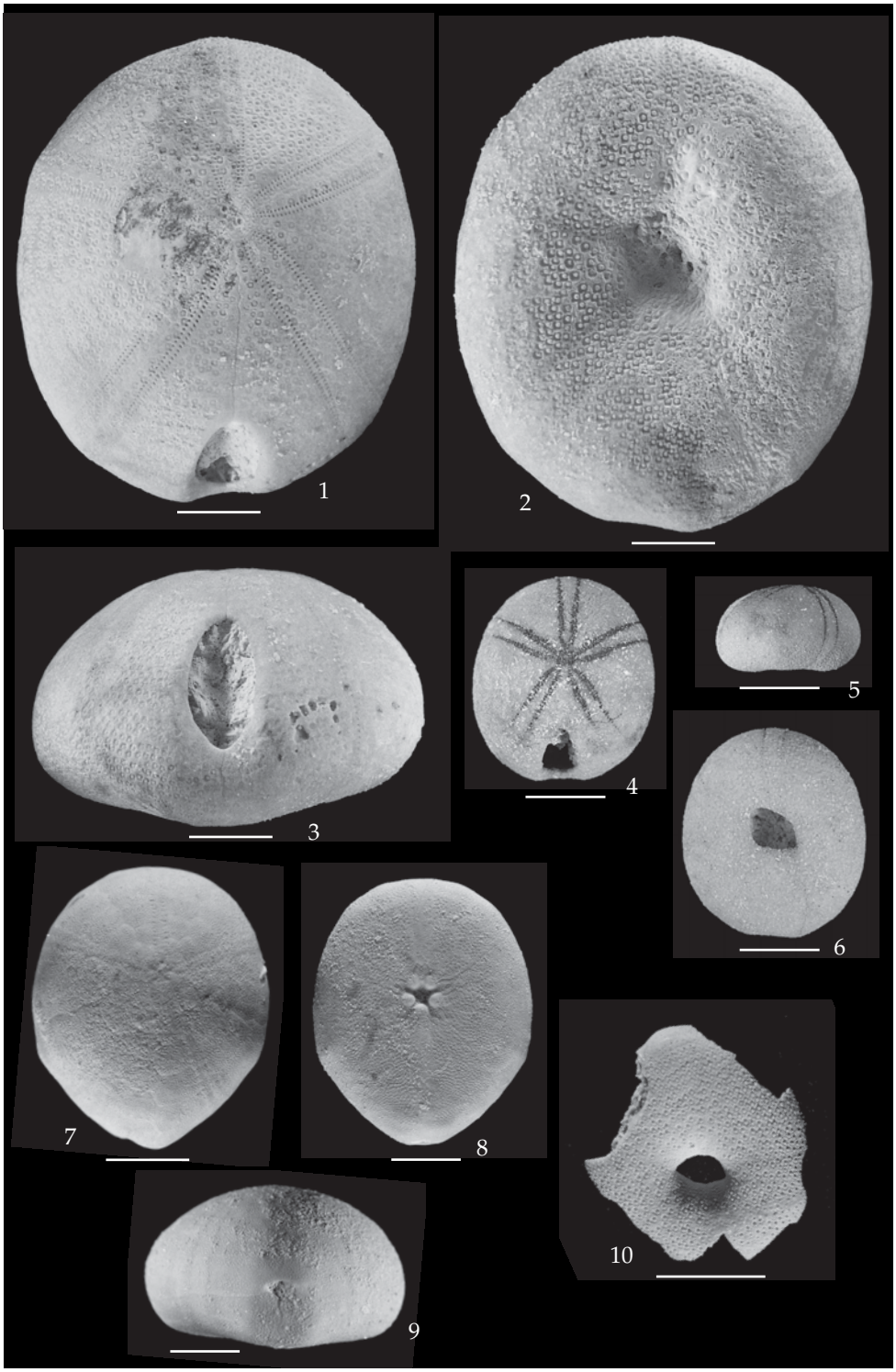

1
2
3
4
5
6
7
8
9
10

Plate 18

Figs. 1-3. *Catopygus fenestratus* forma *subcircularis* Smiser, 1935b; NHMM K 3563, aboral, oral and lateral views of test, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, Nekum Member, Kanne Horizon - c. 2.5 m.

Figs. 4-6. *Catopygus fenestratus* Agassiz, 1847; NHMM K 4150(1), aboral (note borings), oral and lateral views of test, Ankerpoort-Marnebel quarry, Eben Emael, Gulpen Formation, Lanaye Member (20-21).

Figs. 7-10. *Rhynchopygus marmini* (Desmoulins, 1837); St Pietersberg W, Maastricht, Maastricht Formation, Meerssen Member; 7: NHMM MM 114/1, oral view of test; 8-10: NHMM MM 114/2-4, aboral view of tests (note variable size of gonopores as an expression of sexual dimorphism).

Figs. 11-16. *Procassidulus elongatus* (d'Orbigny, 1856); temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member; 11-13: NHMM MB 432-G/1, aboral, oral and lateral views of test; 14-16: NHMM MB 432-G/2, aboral, oral and lateral views of test.

Scale bars equal 1 mm.

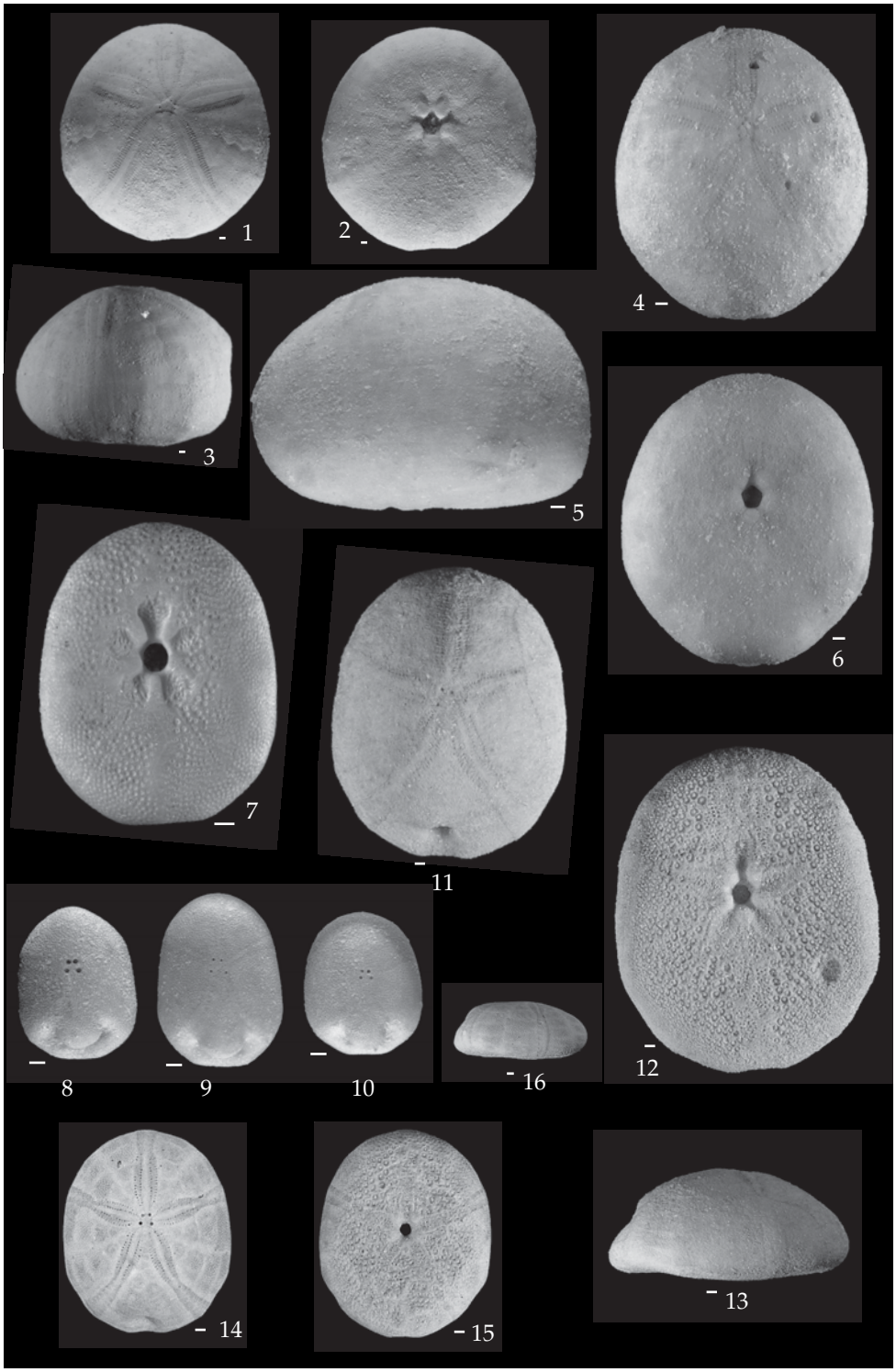

1
2
4
3
5
6
7
11
12
8
9
10
16
14
15
13

Plate 19

Fig. 1. *Procassidulus lapiscancri* (Leske, 1778); NHMM VN 543, aboral view of pathologic test, lacking AI, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member.

Figs. 2-4. *Rhyncholampas macari* (Smiser, 1935b)
2, 4: NHMM MM 115, aboral and posterior views of test, temporary Albertkanaal sections, Vroenhoven-Riemst, Maastricht Formation, upper Meerssen Member (IVf-5/-6 ?).
3: NHMM BL 0643, oral view of test, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 5-8. *Gitolampas oblongus* (Smiser, 1935b); temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member; 5: NHMM MB 432-F/1, aboral view of test; 6-8: NHMM MB 432-F/2, aboral, oral and lateral views of test.

Figs. 9-11. *Nucleopygus scrobiculatus* (Goldfuss, 1829); NHMM MM 070/1, aboral, oral and lateral views of test, St Pietersberg W, Maastricht, Maastricht Formation, Meerssen Member.

Scale bars equal 1 mm.

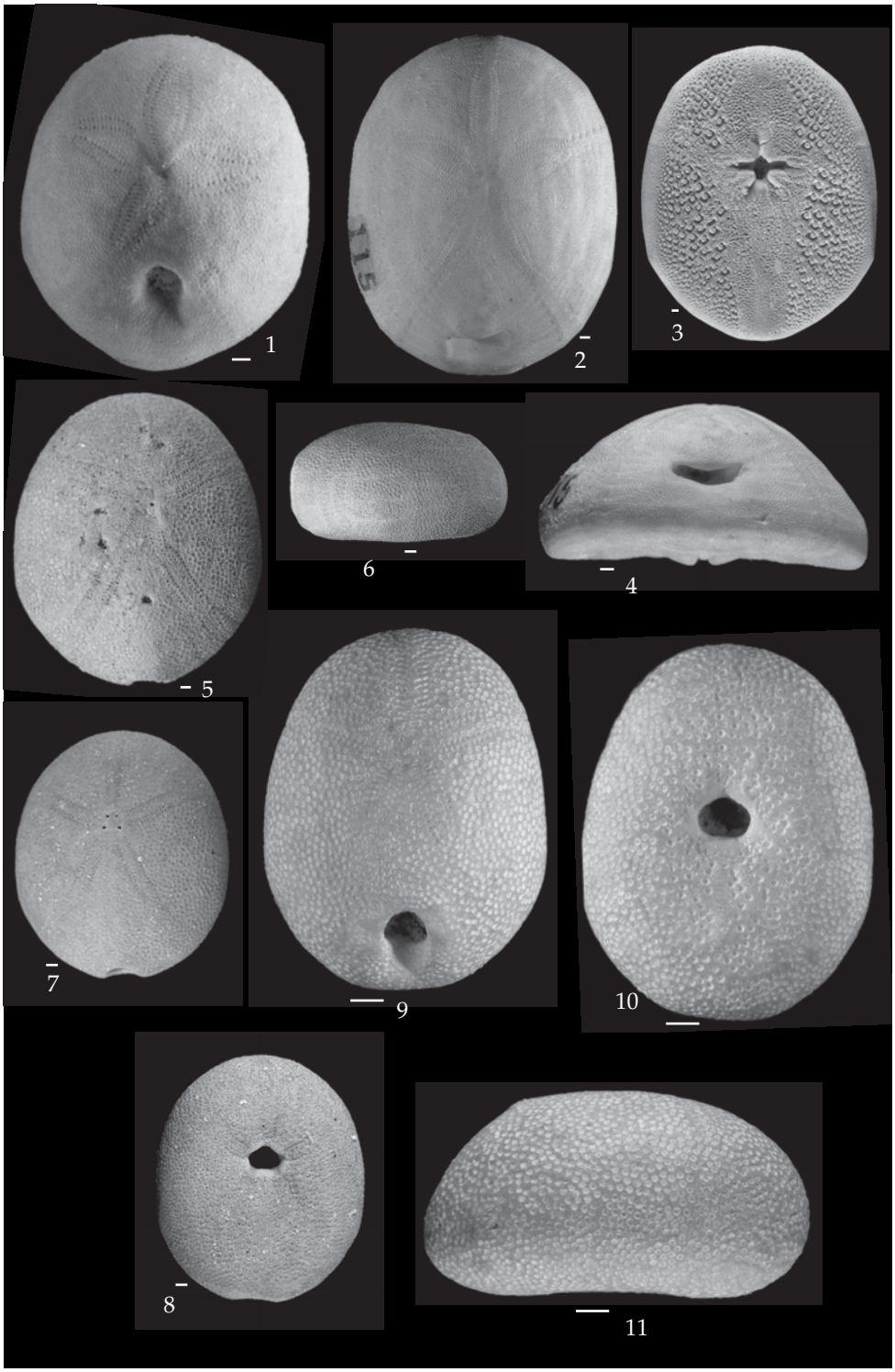

1
2
3
4
5
6
7
8
9
10
11

Plate 20

Figs. 1-2. *Nucleopygus coravium* Defrance, in L. Agassiz & Desor, 1847; NHMM K 3343, aboral and lateral views of test, Ankerpoort-Marnebel quarry, Eben Emael, Maastricht Formation, Emael Member (Lava Horizon).

Fig. 3. *Nucleopygus scrobiculatus* (Goldfuss, 1829); NHMM MM 070/2, aboral view of test, St Pietersberg W, Maastricht, Maastricht Formation, Meerssen Member.

Figs. 4-5. *Echinocorys* gr. *conica* (Agassiz, 1847)
4: NHMM GK 6606 (W.M. Felder Colln), lateral view of test, CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.
5: NHMM GK 2655 (W.M. Felder Colln), posterior view of test, same locality and stratigraphy.

Figs. 6-7: *Echinocorys* gr. *conoidea* (Goldfuss, 1829); NHMM MD 1607, lateral and aboral views of test, CPL SA quarry, Haccourt, Gulpen Formation, upper Lixhe 1 Member.

Fig. 8. *Echinocorys* gr. *gibba* (Lamarck, 1816); NHMM MM 0804, lateral view of test, Heure-le-Romain, Gulpen Formation, middle Zeven Wegen Member.

Fig. 9. *Echinocorys* gr. *limburgica* Lambert, 1903; NHMM K 831, oral view of test, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Vijlen Member, base + 0-6 m.

Figs. 10-11. *Echinocorys* gr. *humilis* sensu germanico (non Lambert, 1903); NHMM HB 736, aboral and oral views of test, CPL SA quarry, Haccourt, upper Vaals Formation.

Scale bars equal 5 mm.

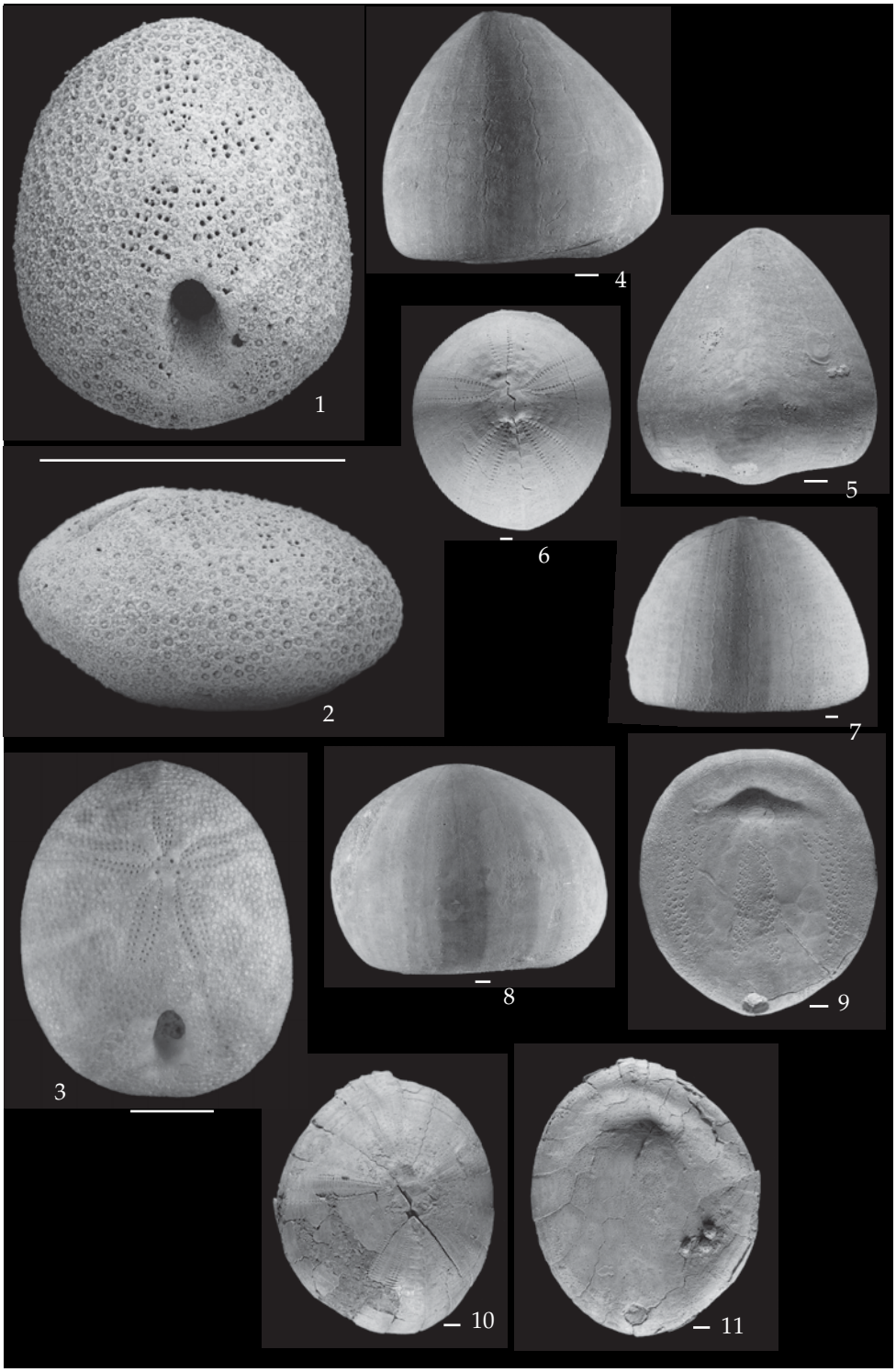

1
2
3
4
5
6
7
8
9
10
11

Plate 21

Figs. 1-4. *Echinocorys* gr. *limburgica* Lambert, 1903
1: NHMM Vijlen Groep Colln, no. A23, lateral view of test, Altembroeck, Voer (Limburg), Gulpen Formation, Vijlen Member.
2: NHMM JJ 835, oral view of test preserving plastronal spines, CPL SA quarry, Haccourt, Gulpen Formation, lower Vijlen Member.
3: NHMM K 785, oral view of test, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Vijlen Member, base + 0-2 m.
4: NHMM Vijlen Groep Colln, no. A6, lateral view of test, Altembroeck, Voer (Limburg), Gulpen Formation, Vijlen Member.

Fig. 5. *Echinocorys* gr. *ovata* (Leske, 1778); NHMM GK 1999 (W.M. Felder Colln), lateral view of test, CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.

Figs. 6-7. *Echinocorys* gr. *pyramidata* (Portlock, 1843)
6: NHMM MM 1073, lateral view of test, Bonne Espérance, Loën (Lixhe), Gulpen Formation, Zeven Wegen Member, base + c. 5 m.
7: NHMM Vijlen Groep Colln, no. A9, lateral view of test, Altembroeck, Voer (Limburg), Gulpen Formation, Vijlen Member.

Fig. 8. *Echinocorys* gr. *humilis* Lambert, 1903; NHMM MM 1096, lateral view of test, Bonne Espérance, Loën (Lixhe), Gulpen Formation, Zeven Wegen Member.

Fig. 9. *Echinocorys* gr. *subglobosa* (Goldfuss, 1829); NHMM GK 2437 (W.M. Felder Colln), lateral view of test, CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.

Fig. 10. *Echinocorys* gr. *orbis* Arnaud, 1883; NHMM K 133, lateral view of test, CPL SA quarry, Haccourt, Gulpen Formation, lower Zeven Wegen Member.

Fig. 11. *Echinocorys* sp.; NHMM RH 184d, internal flint mould preserving peristomial plating, residual flint deposits, southern Limburg, probably Gulpen Formation, Lixhe Member.

Figs. 12-14. *Galeola papillosa basiplana* Ernst, 1971
12: NHMM BL 1068(297), lateral view of test, 'De Molt', southeast of Kosberg (southern Limburg), Gulpen Formation, Zeven Wegen Member.
13-14: NHMM K 2993, lateral and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + c. 1 m.

Scale bars equal 5 mm.

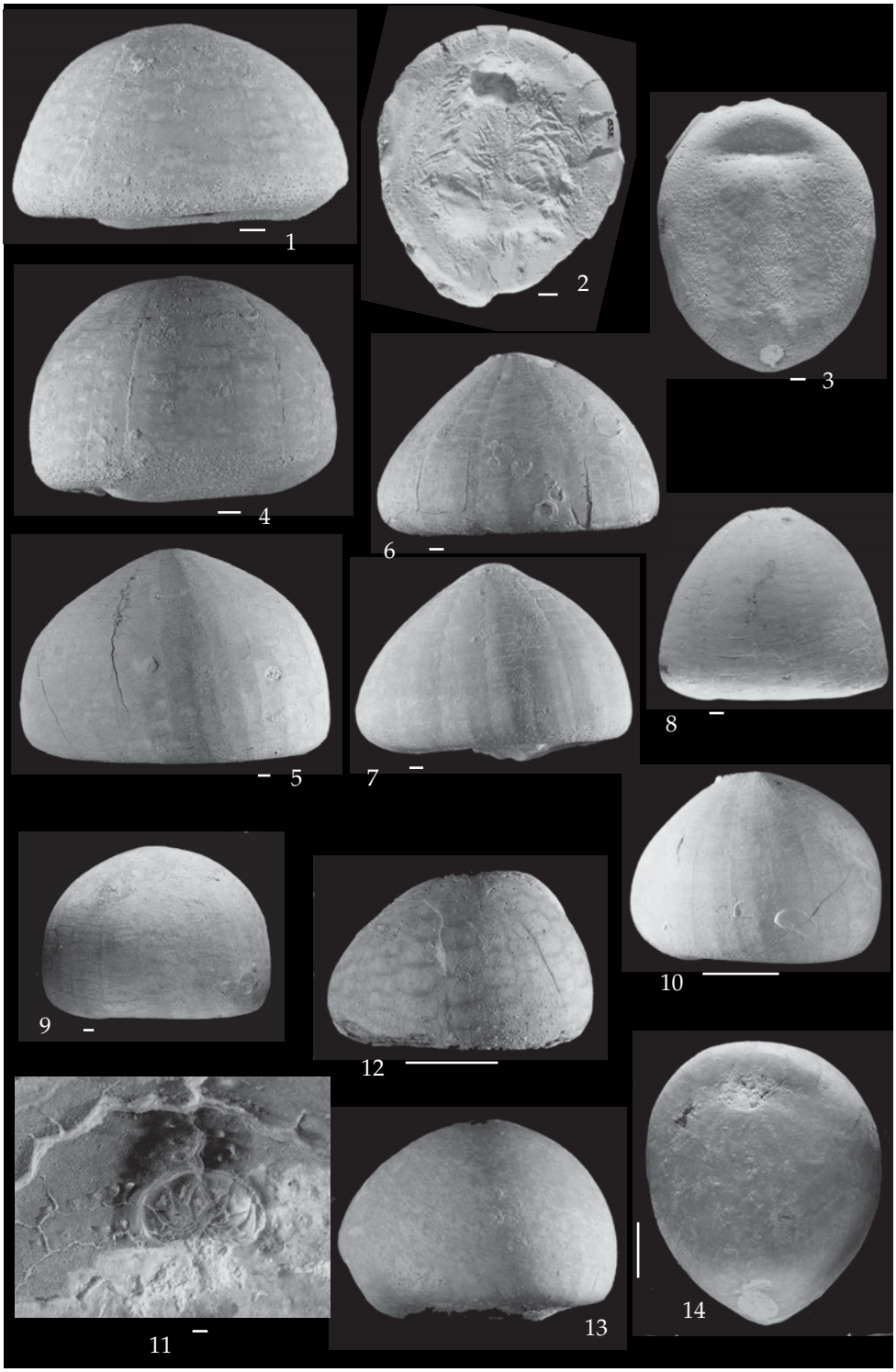

1
2
3
4
6
5
7
8
9
12
10
11
13
14

Plate 22

Figs. 1-5. *Cardiaster granulosus* (Goldfuss, 1829)
1: NHMM MD 3732, aboral view of test, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Vijlen Member, base + c. 7 m.
2: NHMM JJ 6416, aboral view of pathological test (six ambulacra), CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + c. 5 m.
3-4: NHMM RH 81, oral view of test preserving spines and peristomial plating, Kunrade/Benzenrade area, Maastricht Formation, Kunrade Limestone facies.
5: NHMM JJ 753, oral view of test, CPL SA quarry, Haccourt, Gulpen Formation, lower Vijlen Member.

Figs. 6-7. *Cardiaster* aff. *granulosus* (Goldfuss, 1829); NHMM VG 3055 (W.M. Felder Colln), oral and aboral views of silicified test, temporary outcrops Vaals-Eschberg, Vaals Formation.

Figs. 8-11. *Cardiotaxis heberti* (Cotteau, in Cotteau & Triger, 1860)
8: NHMM GK 2724 (W.M. Felder Colln), oral view of test, CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.
9: NHMM K 901, oral view of fragmentary test preserving spine canopy, same locality, Haccourt, Gulpen Formation, Zeven Wegen Member, top - c. 15 m.
10-11: NHMM JJ 720, aboral and lateral views of test, same locality, Gulpen Formation, base Zeven Wegen Member.

Figs. 12-14. *Cardiaster rutoti* (Lambert, 1911); NHMM MK 889 (W.M. Felder Colln), aboral, oral and lateral views of test, Ankerpoort-'t Rooth quarry, Maastricht Formation, member unknown.

Scale bars equal 5 mm.

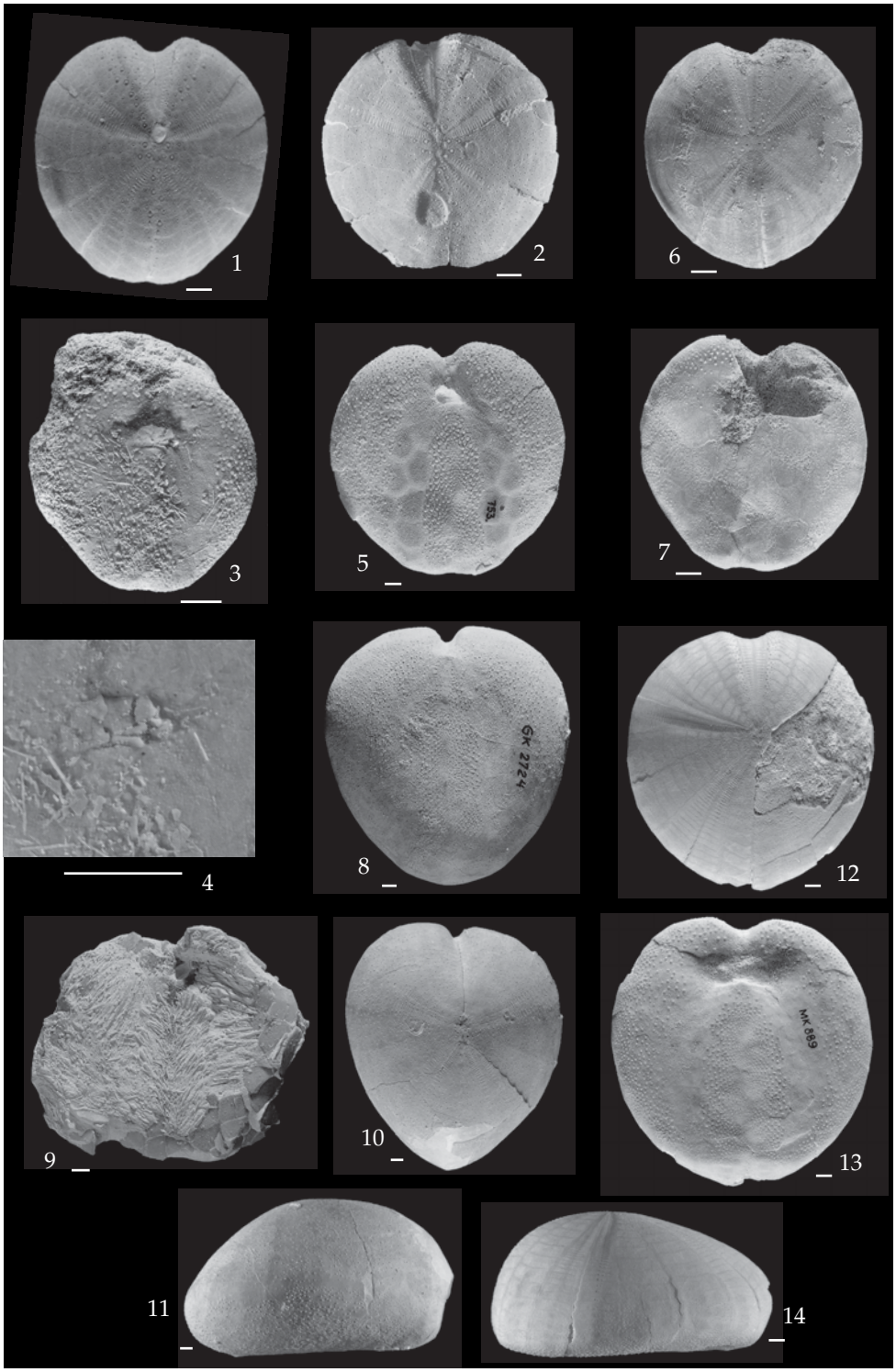

1
2
6
3
5
7
4
8
12
9
10
13
11
14

Plate 23

Figs. 1-4. *Hagenowia* sp. (?nov.); CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6/7 m.
1-2: NHMM MB 808-2/1, anterior and lateral views of rostrum.
3-4: NHMM MB 808-2/2, posterior view of rostrum, and close up of apical system.

Figs. 5-7. *Hemipneustes striatoradiatus* (Leske, 1778) juv.; Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (base IVf-3).
5, 6: NHMM K 1763, lateral and aboral views of test.
7: NHMM K 1762, oral view of test, showing plastronal plating.

Scale bars equal 100 µm, except in figs. 5-7, where they represent 1 mm.


1
2
3
4
5
6
7

Plate 24

Fig. 1. *Cardiaster rutoti* (Lambert, 1911); NHMM RD 72, aboral view of test, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, Gronsveld Member.

Figs. 2-3. *Hemipneustes oculatus* Cotteau, 1890; NHMM JJ 8863, aboral and oral views of test, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Valkenburg Member, base + c. 1.5 m.

Figs. 4-9. *Hemipneustes striatoradiatus* (Leske, 1778)
4-6: NHMM JJ 1148, aboral, lateral and posterior views of test, temporary outcrops Albertkanaal sections, Vroenhoven-Riemst, Maastricht Formation, top Meerssen Member (IVf-5/-6 ?).
7: NHMM K 2727, oral view of test preserving spines and peristomial plating, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-3).
8-9: NHMM 1999010 (ex Indeherberge Colln, no. 998), silicone rubber casts of internal test surfaces preserving periproctal and peristomial plating, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, upper Nekum Member.

Figs. 10-12. *Cyclaster platornatus* Kutscher, 1978b
10-11: NHMM JJ 3439, aboral and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 4-5 m.
12: NHMM JJ 3717, oral view of fragmentary test, same locality, Gulpen Formation, Vijlen Member, base + 0-3 m.

Scale bars equal 5 mm.

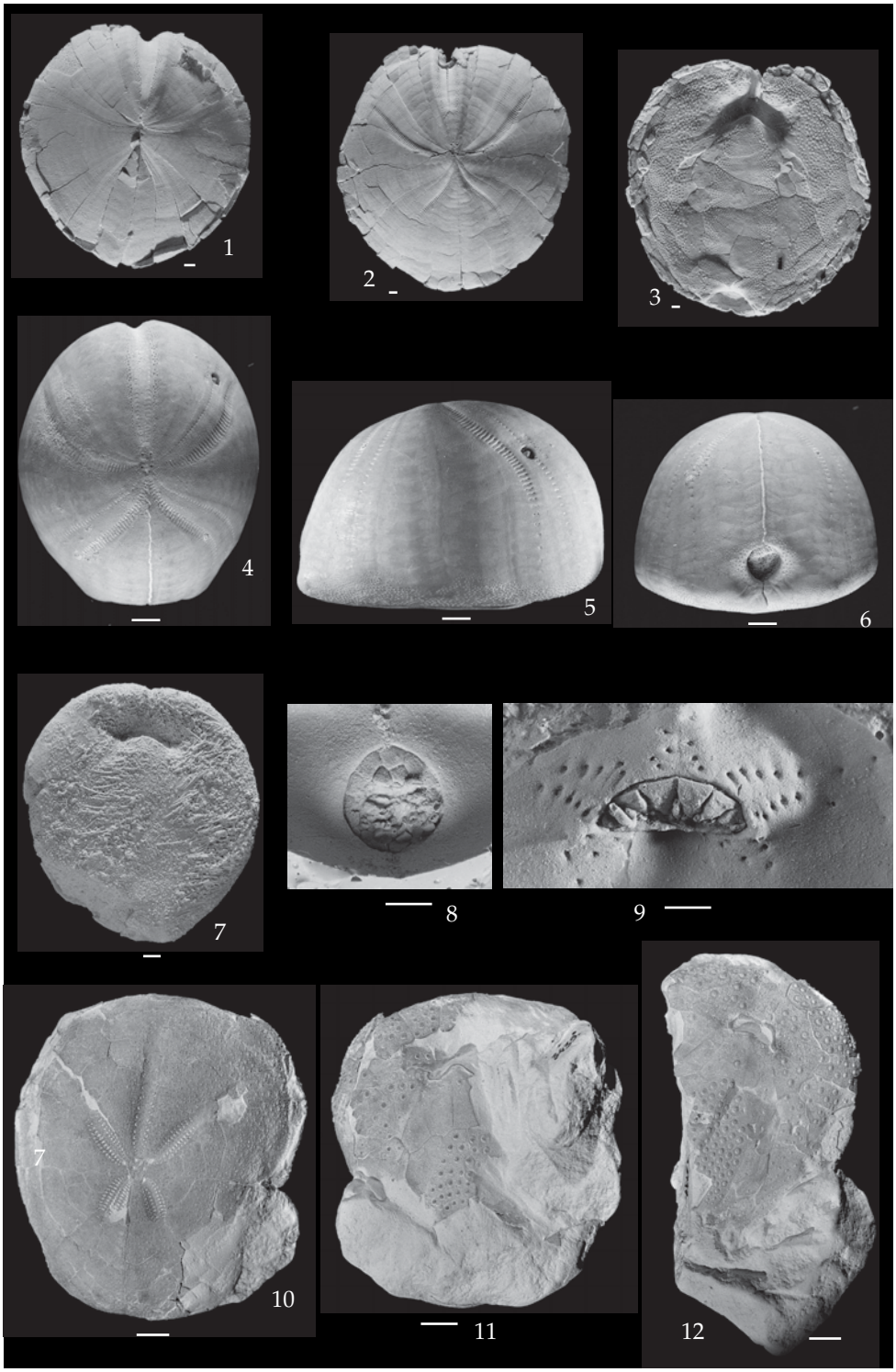

1
2
3
4
5
6
7
8
9
7
10
11
12

Plate 25

Figs. 1-6. *Micraster* gr. *schroederi/glyphus*
1-3: NHMM MM 569, aboral, oral and lateral views of test illustrating typical *schroederi* morphology, Bonne Espérance/Loën, Lixhe, Gulpen Formation, lower Zeven Wegen Member.
4-5: NHMM MM 952-1, aboral and lateral views of test illustrating typical *glyphus* morphology, CPL SA quarry, Haccourt, Gulpen Formation, lower Zeven Wegen Member.
6: NHMM K 2519, oral view of juvenile test, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member, top - 4 m.

Figs. 7-11. *Micraster stolleyi* (Lambert, in de Grossouvre, 1901)
7-9: Appeldoorn Colln, no. 44, lateral, posterior and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member.
10-11: NHMM GM 786, oral and posterior views of test, same locality, Haccourt, Gulpen Formation, Zeven Wegen Member, top - 0-5 m.

Figs. 12-13. *Diplodetus* sp.; NHMM MM 130, aboral and oral views of test, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member.

Scale bars equal 5 mm.

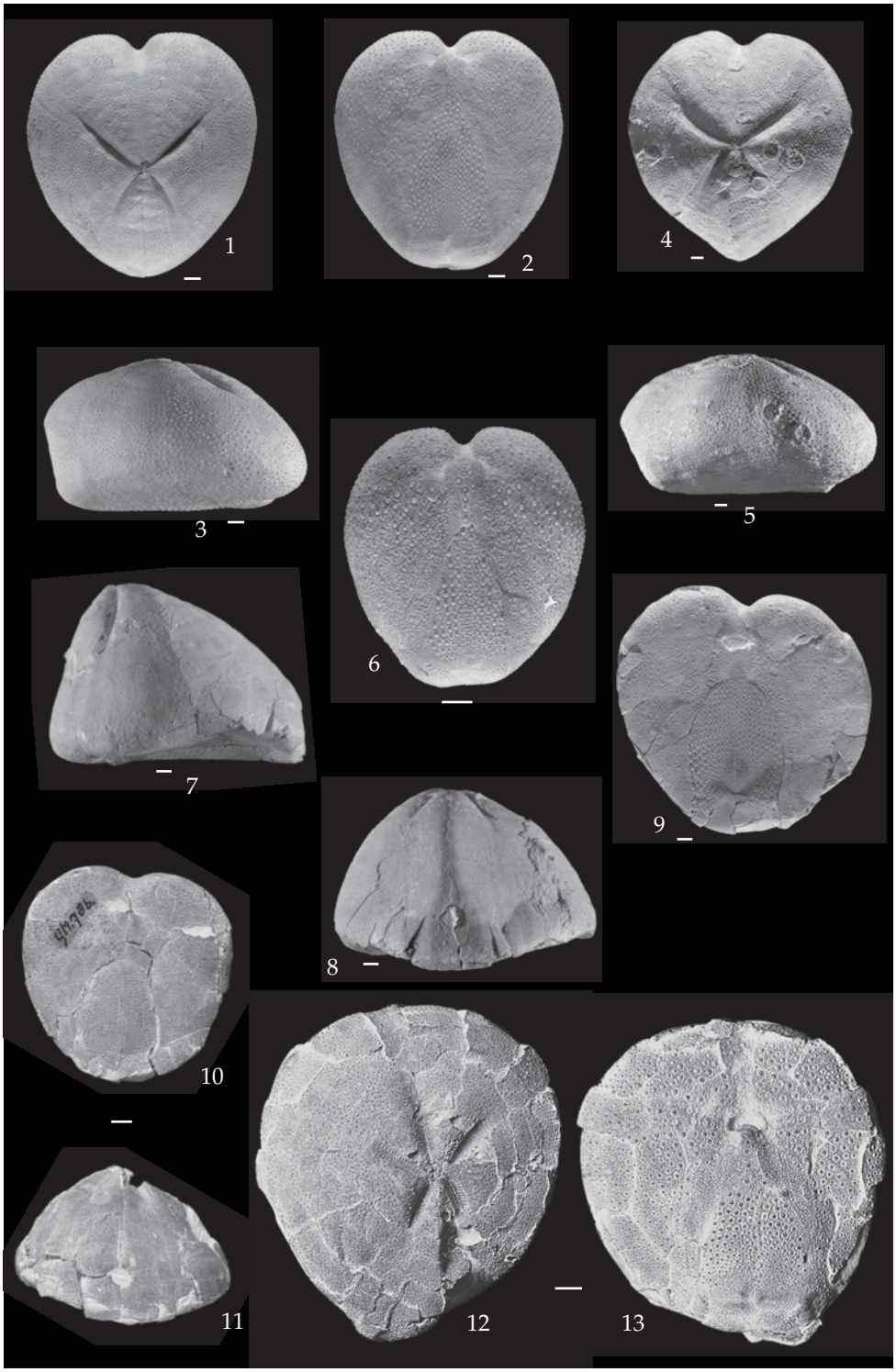

1
2
4
3
5
6
7
9
8
10
11
12
13

Plate 26

Figs. 1-3. *Diplodetus* aff. *americanus* (Stephenson, 1941); NHMM RD 70, aboral, oral and lateral views of test, Ankerpoort-Curfs quarry, Geulhem, Maastricht Formation, Meerssen Member (IVf-7).

Figs. 4-5. *Diplodetus parvistella* (Schlüter, 1899); NHMM RD 71, aboral and oral views of test, between Valkenburg aan de Geul and Oud-Valkenburg, Maastricht Formation, 'Valkenburg' Member.

Figs. 6-7. *Diplodetus bucardium* (Goldfuss, 1829)
6: NHMM 1997093-1, internal flint mould, CPL SA quarry, Haccourt, residual flint deposits.
7: NHMM 1997093-2, silicone cast showing external aboral test morphology, same locality and stratigraphy.

Scale bars equal 10 mm.

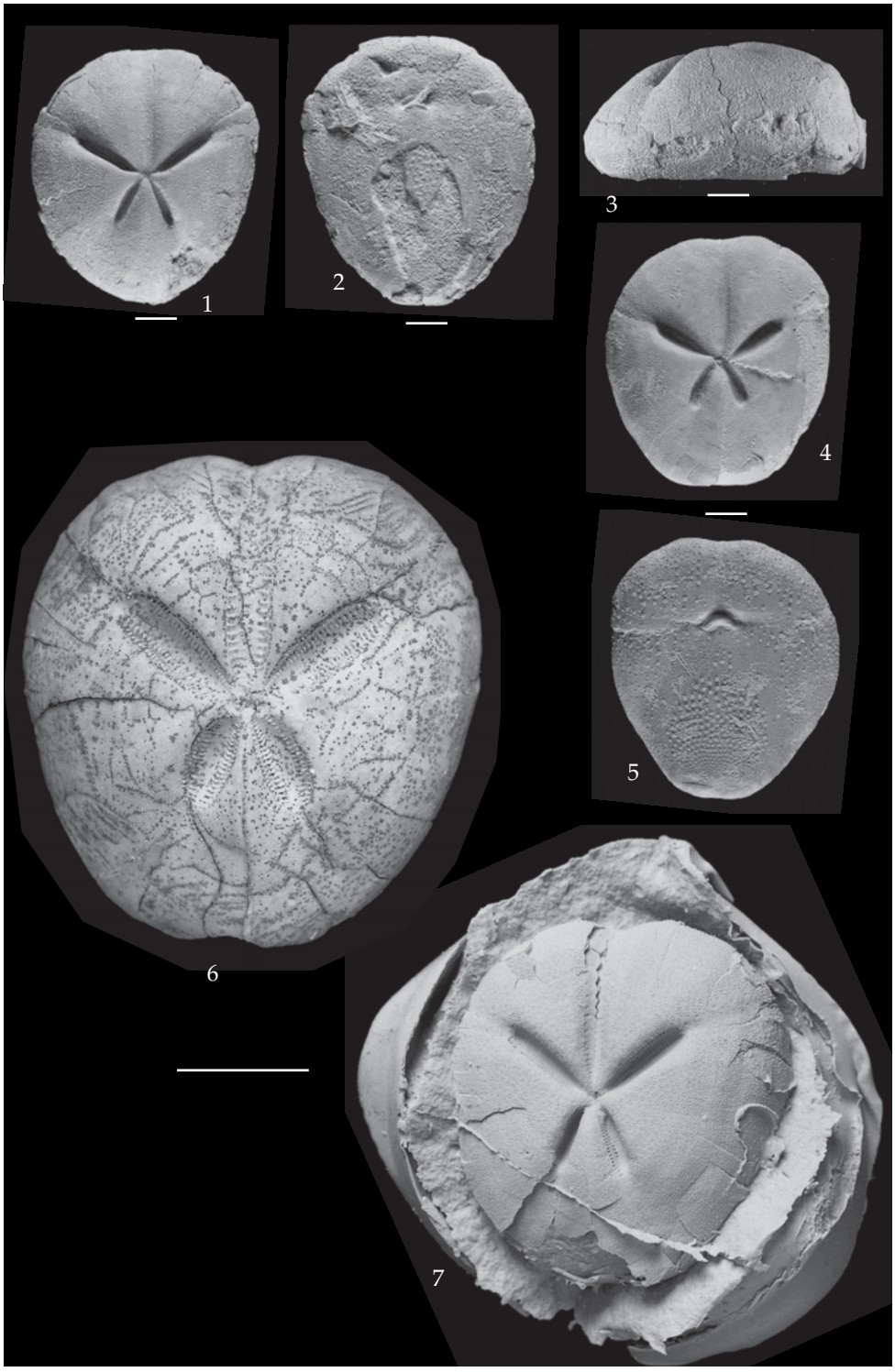

1
2
3
4
5
6
7

Plate 27

Figs. 1-2. *Diplodetus duponti* (Lambert, 1911)
1: NHMM 1997092-1, internal flint mould, CBR-Lixhe quarry, Lixhe, residual flint deposits.
2: NHMM 1997092-2, silicone cast of external aboral test surface of the same specimen.

Figs. 3-4. *Diplodetus parvistella* (Schlüter, 1899)
3: NHMM 1997091-1, CBR-Lixhe quarry, Lixhe, residual flint deposits.
4: NHMM 1997091-2, silicone cast of external aboral test surface of the same specimen.

Scale bars equal 10 mm.

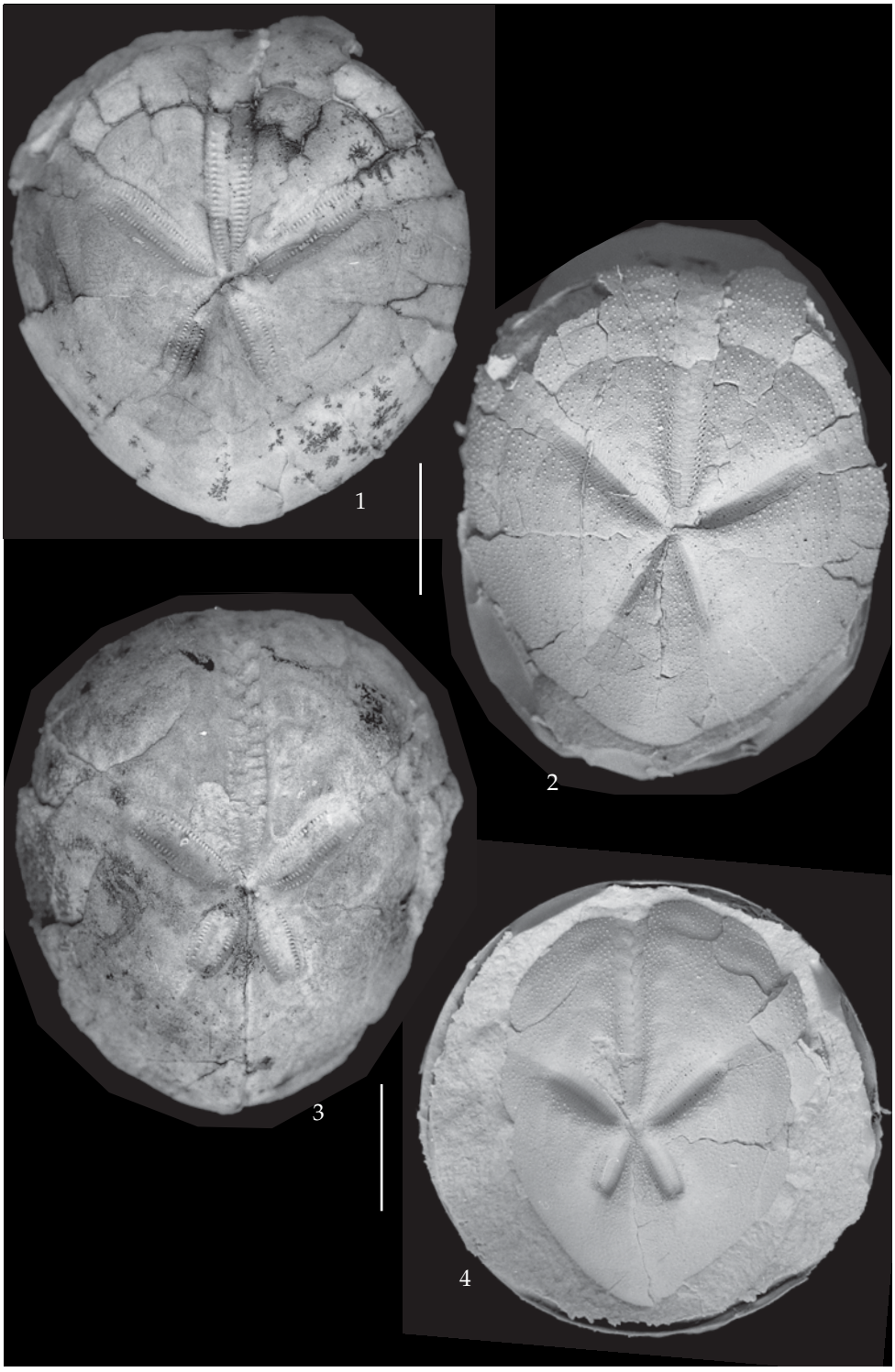

1
2
3
4

Plate 28

Figs. 1-6. *Hemiaster* gr. *aquisgranensis* Schlüter, 1899
1: NHMM JJ 3775, aboral view of test, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 0-3 m.
2: NHMM JJ 6603, oral view of test preserving spines and pedicellariae, same locality, Gulpen Formation, Vijlen Member, base + 5 m.
3: NHMM VG 1337 (W.M. Felder Colln), aboral view of internal mould, Terstraeten, Vaals Formation, base Cottessen Member.
4: NHMM K 581, oral view of test fragment preserving spines and part of peristomial plating, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 0-3 m.
5: NHMM K 3831, aboral view of test fragment, same locality, Gulpen Formation, Zeven Wegen Member, top - 0-8 m.
6: Vlieks Colln (unregistered), aboral view of test, Benzenrade, Maastricht Formation, Kunrade Limestone facies.

Figs. 7-8. *Leymeriaster eluvialis* (van der Ham, 1995)
7: NHMM 1993050 (**holotype**), aboral view of silicone cast, CBR-Lixhe quarry, Lixhe, residual flint deposits.
8: NHMM 1999011 (Indeherberge Colln, no. 518; **paratype**), oral view of silicone cast, same locality and stratigraphy.

Fig. 9. *Leymeriaster maestrichtensis* (Schlüter, 1897a); NHMM RH 543, aboral view of internal flint mould, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, upper Nekum Member.

Figs. 10-11. *Hemiaster koninckanus* d'Orbigny, 1855; NHMM ZE 223 (W.M. Felder Colln), aboral and lateral views of internal flint mould, Pleistocene gravel deposits, southern Limburg.

Scale bars equal 1 mm, except in figs. 1, 2, 4 and 6, where they represent 5 mm.

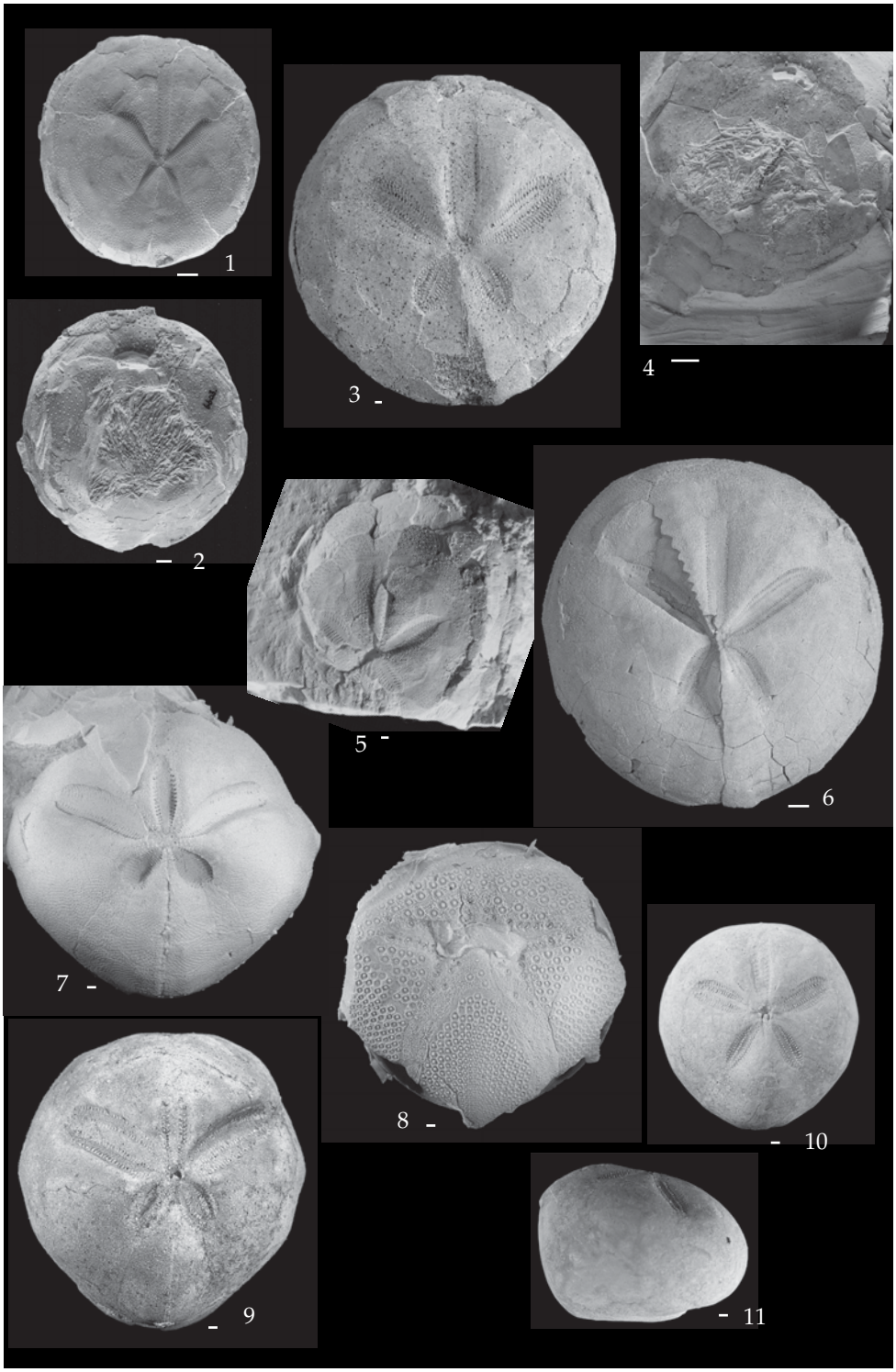

1
2
3
4
5
6
7
8
9
10
11

Plate 29

Figs. 1-8. *Hemiaster prunella* (Lamarck, 1816)
1-3: NHMM K 918, aboral, oral and lateral views of test (note boring), CBR-Romontbos quarry, Eben Emael, Gulpen Formation, Lanaye Member (20-21).
4: NHMM VN 612, aboral view of test with curious depressions encircling anterior portion of apical fasciole, Vroenhoven-Riemst, Maastricht Formation, Meerssen Member.
5, 7-8: NHMM BL 0131a-c, aboral views of juvenile tests, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).
6: NHMM VN 611, aboral view of test with ?parasitic depression, of the type previously recorded for the micrasterid *Cyclaster danicus* by Asgaard (1976), ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member.

Scale bars equal 1 mm.

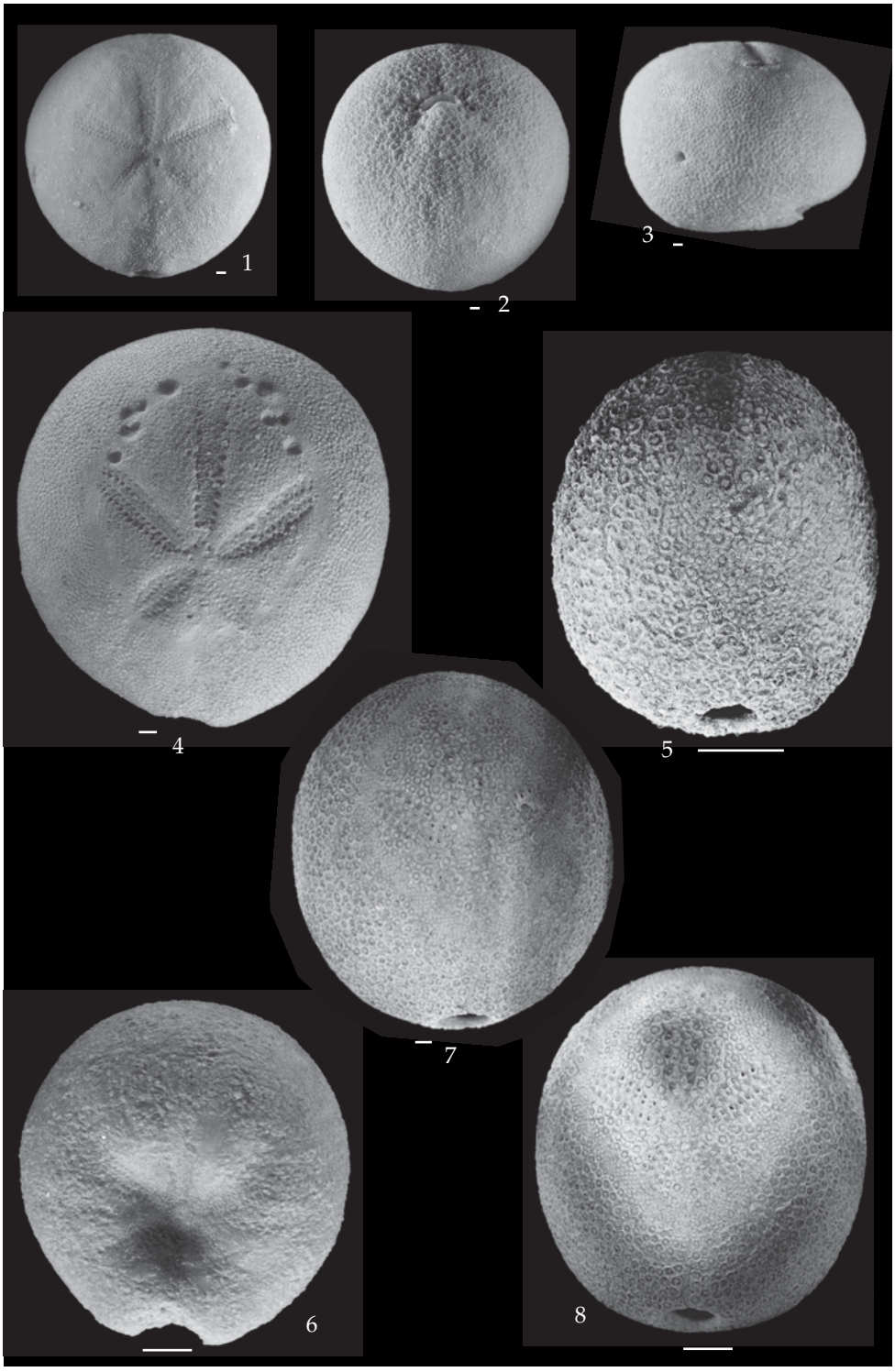

1
2
3
4
5
6
7
8

Plate 30

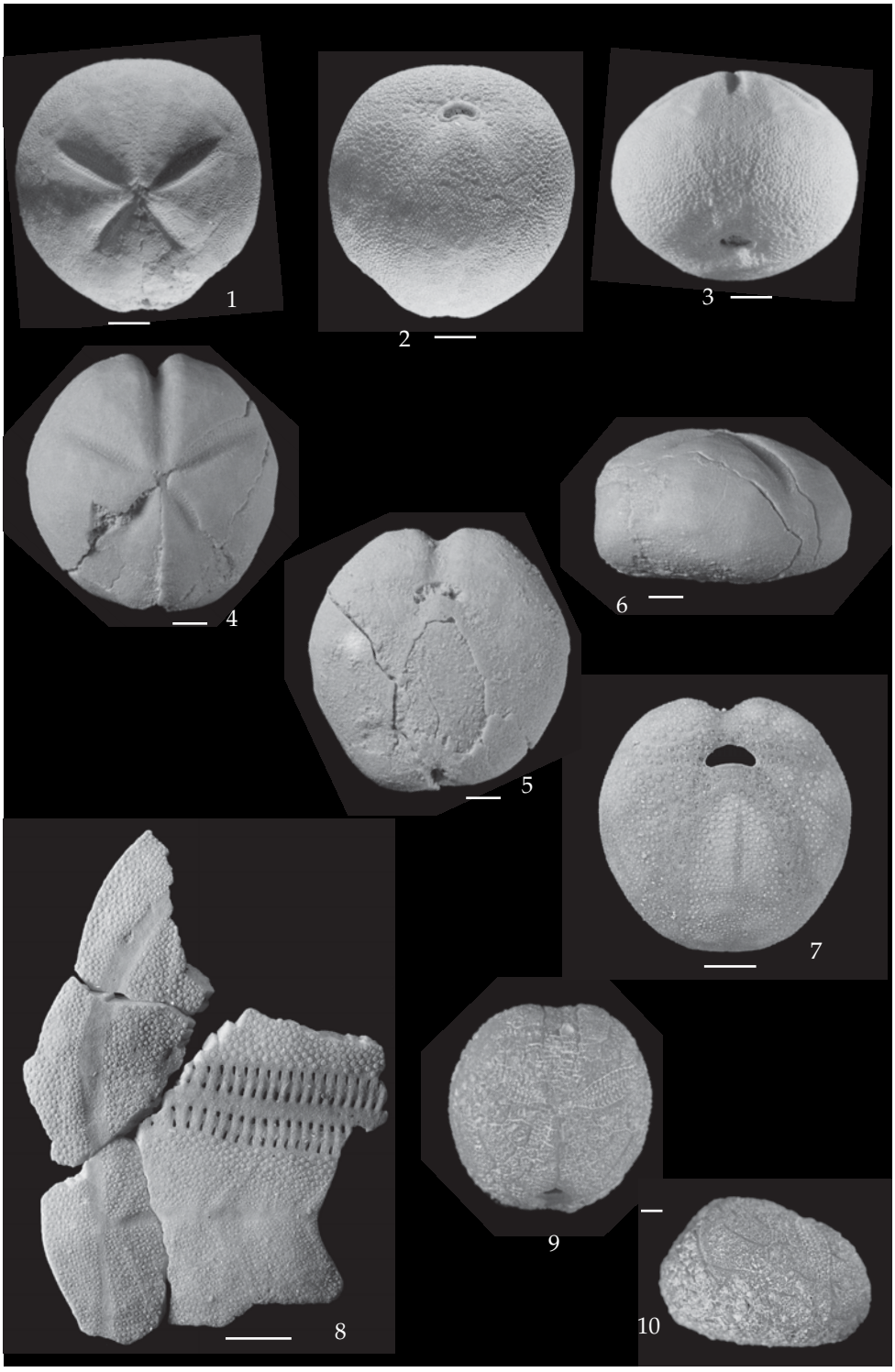
Figs. 1-3. *Hemiaster koninckanus* d'Orbigny, 1855; NHMM K 4090, aboral, oral and anterior views of test, Ankerpoort-Marnebel quarry, Eben Emael, Gulpen Formation, Lanaye Member (20-21).

Figs. 4-6. *Paraster sindensis* (Duncan & Sladen, 1882); NHMM MB 345, aboral, oral and lateral views of test, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, lower Geulhem Member.

Figs. 7-8. *Linthia*? sp.; temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.
7: NHMM MB 432-I, oral test fragment.
8: NHMM RH 285-10, aboral test fragment, showing parts of peripetalous and lateroanal fascioles.

Figs. 9-10: *Linthia*? *breviuscula* (d'Orbigny, 1855) sensu van der Ham, 1988a (= indeterminate schizasterid, Smith & Jeffery, in press); NHMM MM 862, aboral and lateral views of juvenile test, road cutting between Geulhem and Berg en Terblijt, Houthem Formation, base Geulhem Member.

Scale bars equal 5 mm, except in figs. 9-10, where it represents 1 mm.


1
2
3
4
5
6
7
8
9
10