Late Cretaceous-Early Palaeogene echinoderms and the K/T boundary in the southeast Netherlands and northeast Belgium — Part 5: Asteroids

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 5: Asteroids. — Scripta Geol., 121: 377-503, 9 figs., 27 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, Asteroidea, Late Cretaceous, Early Palaeogene, taxonomy, stratigraphy.
All Campanian, Maastrichtian and Danian asteroids known to date from the extended type area of the Maastrichtian Stage, are described and illustrated. The geographic and stratigraphic distribution are documented. Eighteen genera (one of them new) and at least sixty-four species (eight of them new) are listed: *Astropecten*? sp. nov., astropectinid sp. nov., *Coulonia*? sp. nov., *Lophidiaster*? gr. *punctatus/postornatus*, *L. pygmaeus* Spencer, 1913, *Aldebarania* sp. nov., Astropectinidae indet., ctenodiscid? indet., benthopectinid sp. 1 (? spp.), benthopectinid sp. 2, *Metopaster alexiae* sp. nov., *M.* aff. *carinatus* Brünnich Nielsen, 1943, *M. continuus* sp. nov., *M. decipiens* Spencer, 1913, *M. kagstrupensis* Brünnich Nielsen, 1943, *M. lisannae* sp. nov., *M. miriamae* sp. nov., *M.* aff. *planus* (Brünnich Nielsen, 1943), *M. praetumidus* Schulz & Weitschat, 1975, *M. spencerii* Brünnich Nielsen, 1943, *M.* gr. *tumidus* Spencer, 1913, *M. uncatus* (Forbes, 1848), *M. undulatus* Spencer, 1913, *M.* sp. 1, *M.* sp. 2, *M.* sp. 3, *M.* sp. 4 (aff. *elegans* Gale, 1987a), *Parametopaster*? sp., *Haccourtaster aemstelensis* gen. et sp. nov., *Recurvaster antemammillatus* sp. nov., *R. mammillatus* (Gabb, 1876), *R.* gr. *radiatus* (Spencer, 1913), *R. spiniger* sp. nov., *Nymphaster alseni* (Schulz & Weitschat, 1971), *N. spenceri* (Rasmussen, 1950), *N. studlandensis* (Schulz & Weitschat, 1975), *N.* sp., *Chomataster acules* Spencer, 1913, *Ophryaster*? *maastrichtensis* Umbgrove, 1925, *O. magnus* Spencer, 1913, *O. oligoplax* (Sladen, 1891), *Comptoniaster peetersorum* sp. nov., *Crateraster anchylus* (Brünnich Nielsen, 1943), *C. favosus* (Spencer, 1913), *C. reticulatus* (Schulz & Weitschat, 1981), *Caletaster*? sp., goniasterid sp. 1, goniasterid sp. 2, goniasterid sp. 3, goniasterid? sp. 4, goniasterid sp. 5, goniasterid sp. 6, goniasterid sp. 7, goniasterid sp. 8, *Valettaster* gr. *ocellatus* (Forbes, 1848), *Stauranderaster*? *miliaris* Brünnich Nielsen, 1943, *S.*? sp. (? spp.), *Aspidaster*? aff. *senonensis* (Valette, 1902), *A.*? sp. 1, *A.*? sp. 2 (aff. *pistilliferus* Forbes, 1848), *Pycinaster* aff. *cornutus* Rasmussen, 1945, *P. magnificus* Spencer, 1913, *P.*? aff. *rosenkrantzi* (Brünnich Nielsen, 1943), *P.* sp. 1, *P.* sp. 2, and asteriid sp. (? spp.). Quite a number of these must remain in open nomenclature for the time being, being based mainly on limited material. A few of the new taxa will be described elsewhere.

Contents

Introduction

What has been stated for crinoids (Jagt, 1999b) and ophiuroids (Kutscher & Jagt, 2000) also goes for asteroid taxa from the Maastrichtian type area. With the exception

of a handful of species these echinoderms have virtually been neglected.

In the present paper, at least sixty-four species in eighteen genera are listed and illustrated. Descriptions are brief, except for the new genus and new species, and lists of synonyms generally include only references to papers which provide (more) detailed accounts.

Most of the material was collected during the past six to 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 (see Jagt, 1999a for details). Included also are museum collections, although it is realised that these, and those made prior to 1975 in particular, often suffer from a lack of stratigraphic detail. Private collections, notably those of M.J. van Birgelen, M.J.M. Deckers, R.W. Dortangs, L. Indeherberge, and M.M.M. Kuypers have been considered, since these comprise stratigraphically well-documented material. Specimens from these collections illustrated herein have been transferred to the collections of the Natuurhistorisch Museum Maastricht and have the prefix NHMM.

The present paper is the fifth in a series of contributions documenting echinoderm faunas of Late Cretaceous and Early Palaeogene age from the extended Maastrichtian type area. For a discussion of the geographic-stratigraphic setting and general references see Jagt (1999a), and for a brief outline of the project see Jagt (1999b). The present contribution is taxonomic in nature; a palaeobiological/palaeoecological analysis of these asteroid faunas will be presented in Part 6.

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

Material and methods

Like crinoids and ophiuroids, asteroid skeletons disintegrate rapidly upon death into jumbles of many thousands of small to diminutive ossicles (Blake, 1989, 1996). Most of the asteroid material from the extended Maastrichtian type area comes from the same samples which yielded the crinoids and ophiuroids. Asteroids occur generally as dissociated ossicles only, or skeletal concentrations which may either contain ossicles of the same type, implying that these come from an individual which decomposed at that particular site, or yield various types of ossicles of more than one species. The latter are considered to represent coprolites (Gale, 1987a; Breton, 1992a); they occur commonly in white chalk facies types. Ossicles are often etched, fragmentary, and at times show traces of predation (see Neumann, in press), as well as postmortem traces such as *Asteriastoma cretaceum* Breton, 1992a. At a number of localities, rapid burial smothered live populations of benthic organisms. Specimens of astropectinid and goniasterid asteroids preserving marginal armature, and with discs relatively undisturbed, may be mentioned in this respect. More or less articulated specimens are extremely rare, and may be considered the result of sudden burial (obrution) by storm activity or submarine sediment displacement. Occurrences of such well-preserved material in the Zeven Wegen and Vijlen members recall specimens from Santonian-Maastrichtian white chalk strata in southeast England, northern Germany and Denmark. The Nekum and Meerssen members have yielded well-preserved astropec-

tinids, in part preserved in flint. A new specimen of *Nymphaster studlandensis*, preserved in a flint boulder, has recently been found reworked in fluvial deposits at Brunssumerheide.

In view of the generally small size of asteroid ossicles, it was decided in many cases to have photomicrographs 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.

It should be stressed here that, unlike the crinoid, ophiuroid and echinoid faunas, asteroid diversity cannot be fully assessed at this moment. Of a substantial number of taxa, the available material is simply too limited to allow conclusions about range of variation and ontogenetic changes to be drawn. In addition, the study of fossil asteroids relies heavily on a direct comparison with extant taxa. To illustrate this: a few small samples were sent to Dr Daniel B. Blake (University of Illinois, Urbana), who informed me (letter of December 1997) that amongst astropectinids some ossicles recall those of *Plutonaster* Sladen, 1885, while some of the goniasterids resemble those of *Pseudarchaster* Sladen, 1889, both extant genera. Of particular note, however, is material representing the Pterasteridae, a family almost restricted to deep-water settings at the present day. Comparable, if not conspecific, specimens are now known to occur in the upper Lower Maastrichtian of Rügen (M. Kutscher Collection). It is highly likely that work under way (Blake & Jagt, in prep.) will yield still new data on the taxonomy and stratigraphic distribution of Late Cretaceous asteroids.

Quite a number of forms recorded in the present paper must remain indeterminate for now. These include such puzzling specimens as the ones illustrated in Pl. 20, figs. 21-22, which are asymmetric, with a concave inner face, regularly arched outer face with three subequal, crater-like spine bases, and two flattened areas that appear to have served articulation with adjacent ossicles.

Previous work

The earliest reference to fossil asteroids from the Maastrichtian type area may be found in Faujas Saint Fond (1799, pl. 37, fig. 6 = Pasteur, 1802), who illustrated a fragmentary, but well-preserved astropectinid. The present whereabouts of this specimen, which shows a close resemblance to *Coulonia* sp. nov. (Blake & Jagt, in prep.) illustrated herein (Pl. 5, figs. 1-2), is unknown. Faujas's record of an articulated asteroid is remarkable, since such finds are now extremely rare in the area, most asteroid species being known exclusively from dissociated ossicles.

J. Müller (1847, p. 5) recorded *Asterias quinqueloba* Goldfuss, 1829, noting that that author had illustrated (pl. 63, fig. 5a-u) fragments and isolated ossicles of this asteroid from Northfleet, Maastricht, and Rinkerode near Münster. Müller had 'etwa 20 solcher Täfelchen', from the 'Kreidemergel' (= Gulpen Formation, Vijlen Member in current terminology) of Aachen-Schneeberg, as well as from the 'eigentlichen Grünsand' (= Vaals Formation), to the southeast of that locality. That author distinguished at least two varieties, one of which was compared with *Asterias quinqueloba* (= *Crateraster quinqueloba*), the other with *Asterias dunkeri* Roemer. Müller's original material must be presumed lost, which means that his records cannot be substantiated. However,

material from the Vijlen Member collected at the nearby locality of Mamelis-Selzerbeek, includes representatives of the genera *Crateraster*, *Metopaster*, *Ophryaster*, and *Nymphaster*, which makes it more than likely that Müller's specimens were assignable to either of these.

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

from the 'Coupe du Heunsberg près de Fauquemont' (pp. 30-31, = Valkenburg aan de Geul): *Asterias quinqueloba*, Goldf.,

from the 'Craie de Schaasberg' (p. 54): *Asterias quinqueloba*, Goldf.,

from the 'Marne de Kunraad' (p. 59): the same species,

from the 'Craie blanche à silex noirs et marne sans silex' (p. 148): *Asterias (Pentetagonaster) dunkeri*, Mill. and *A. (P.) quinqueloba*, Goldf.,

from the 'craie blanche à silex noirs et marnes sans silex près d'Aix-la-Chapelle' (p. 152): *Asterias dunkeri* Mull., and from the 'sables verts à *Belemnitella quadrata*' (p. 163): *Asterias (Pentetagonaster) quinqueloba*, Goldf. and *A. (P.) dunkeri*, Müll.

The fact that only two asteroid species are mentioned reflects both the rarity of such fossils at the localities mentioned as well as the limited contemporary knowledge of asteroids. In another paper published in the same year, Binkhorst (1859b, p. 421) again recorded these two forms, now from the ?base of the Vijlen Member as exposed southwest of Aachen-Schneeberg.

Other local workers, and Bosquet (in Staring, 1860, p. 408) in particular, listed for 'Nederlandsch en Belgisch Limburg' the following asteroids (in original nomenclature):

859 *Pentagonaster quinqueloba* Goldf. sp.	m 4-8	
860 *P. polygonatus* Forb. sp.	m 15-18'	g 20
861 *P. punctatus* v. Hag.	m 4-17	g 20-23
862 *P. Dunkeri*? Roem.	m 4-12	g 23

Abbreviations are as follows: 'm - Maastrichtsch, g - Gulpensch, h - Herfsch', corresponding (roughly) to the Maastricht, Gulpen, and Vaals formations in current terminology, respectively. Of note is the fact that Bosquet did not list any asteroids from the Vaals Formation.

Later, Bosquet (in Dewalque, 1868) recorded the same species:

Pentagonaster quinqueloba, d'Orb., 1847, (*Asterias quinqueloba*, Goldf., 1830)		m
Pentagonaster polygonatus, Forb.	s	m
Pentagonaster punctatus, Bosq., 1865 (*Asterias punctata*, Hag., 1851)	s	m
Pentagonaster Dunkeri?, Ad. Roem.	s	m

Of interest is the fact that Bosquet considered most asteroid species to be long ranging; without having seen his original material (if still extant) it is impossible to relate his records to any of the species described in the present paper.

With the publication of Ubaghs's (1879) paper, not much progress was booked.

For the 'partie supérieure du tuffeau de Maastricht', he listed (p. 65) *Pentagonaster quinquelobus* d'Orb. For the 'Calcaire de Kunraad' (p. 112) the same species, but with Goldfuss as author,

for the 'Craie marneuse sans silex' (p. 141), *Pentagonaster quinquelobus* Goldf. sp., *P. polygonatus* Forb., and *P. punctatus* Bosq. sp. His list on p. 229, shows the first named to be confined to the 'M.S.', or Maastrichtien supérieur, which would correspond to the upper Maastricht Formation. This clearly shows that it cannot be referred to *Crateraster quinqueloba*, a species unknown from the study area, but instead should be assigned to any of the goniasterids listed herein.

The fact that there is no mention of any asteroids in a catalogue of Ubaghs's collection (Ubaghs, 1885), and that there are only few specimens amongst his surviving collections at the Institut royal des Sciences naturelles de Belgique (Brussels), indicates that he ranked asteroids amongst the least important faunal elements from the units he had studied and collected from personally.

Ubaghs (1888, p. 4), in a listing of fossils in the collections of Ignaz Beissel, under the heading 'Crinoïden und Asterioidea' recorded the following species from the 'Kreidemergel' of the Aachen area (probably Vijlen Member, in original nomenclature): *Pentagonaster dunkeri*, *P. quinquelobus*, and *P. punctatus*, and, on p. 10 of the same paper, *P. quinquelobus* and *P. dunkeri* from the 'Grünsand von Vaals' (= Vaals Formation).

Spencer (1907, pp. 107-110) commented on a number of previously erected asteroid species, mainly from mainland European localities. Amongst these is *Asterias*? *dunkeri* Roemer, 1841 (p. 27); Spencer was unable to refer these isolated ossicles to any of the species known to him.

Things definitely changed for the better with the publication of Spencer's (1913) paper on the evolution of Cretaceous asteroids. On p. 150 he comments on the 'Maestrichtian of Belgium', noting that, '*Metopaster tumidus*, the typical Upper Senonian Asteroid, is present in some abundance. It is, however, a form somewhat distinct from that in the more northern area (see p. 114). At the same time, a few ossicles of *Metopaster mammillatus*, the typical Danian form, are found.' Of note is his remark (p. 150) that, '*Teichaster favosus* and *Chomataster acules* are so rarely found in Belgium that this theory of isolation receives considerable support.' In his 'table of zonal records' he listed from the "Upper" Mucronata, Maastrichtien [sic] of Belgium the following species: *Hadranderaster simplex* Geinitz, *Lophidiaster pygmaeus* Spencer, *Metopaster tumidus* Spencer, *M. mammillatus* Gabb, *Pycinaster crassus* Spencer, *Stauranderaster bulbiferus* Forbes, *S. senonensis* Valette, and *Teichaster favosus*. Most of these records are in need of revision; unfortunately, Spencer did not mention on which collections he based his records.

In the only systematic paper on asteroids from the Maastrichtian type area to have appeared so far, Umbgrove (1925) recorded five species, based on material contained in the collections of the Rijks Geologisch-Mineralogisch Museum at Leiden (= Nationaal Natuurhistorisch Museum, Naturalis). He noted that there could be no doubt that more asteroid species occurred in the Maastrichtian tuffaceous chalk, but that he had been unable to acquire material well enough preserved to be identified to species. Recorded are the following:

Metopaster tumidus (Spencer): Umbgrove noted that the ultimate superomarginals

assigned to this form showed many peculiar varieties in form, thickness and abactinal ornament, and pointed out that Spencer (1913) had already hinted at differences between material from Maastricht and elsewhere, and had shown comparable forms to occur only in the *Marsupites* Zone (= Upper Santonian) of Vendôme (France). Umbgrove also recorded two types of ultimate superomarginals, one swollen, with 1 or 2 spine-like protuberances and very faint granulation/pitting or none at all, and another cap-shaped, with well-developed pitting.

Metopaster mammillatus (Gabb), of which but a single superomarginal was available to Umbgrove. The genuine *Recurvaster mammillatus* does not occur in the Maastricht Formation, being restricted to strata of Palaeocene age. Umbgrove's record may well refer to a new Late Maastrichtian species, described below (*R. antemammillatus* sp. nov.), which could represent its ancestor.

Ophryaster maastrichtensis Umbgrove, based on a well-preserved individual from the upper Maastricht Formation (possibly lower third of Meerssen Member). A recent re-examination of the type has shown that it cannot be assigned to the genus *Ophryaster*; a revision is under way.

Tholaster sp., based on a number of isolated ossicles of irregular shape. Neither of the two specimens illustrated can be referred to *Tholaster* (= *Valettaster*); Umbgrove's fig. 29 appears to be an inferomarginal of an indeterminate goniasterid, while his fig. 30 is undoubtedly a primary radial plate assignable to the Stauranderasteridae. A closely similar ossicle from the basal Meerssen Member at Kanne (Belgium) is here illustrated in Pl. 22, figs. 8-9.

Lophidiaster pygmaeus Spencer, based on Spencer's (1913) original record of this species from St Pieter.

Umbgrove's *Ophryaster maastrichtensis* appears not to have been mentioned or commented upon by subsequent authors.

Rasmussen (1965) listed the following asteroid species for southern Limburg:
for the 'Lower Gulpen Chalk of Vijlenerbos': *Ophryaster magnus*,
for the 'Gulpen Chalk Cr4 in Limbourg' [sic]: *Lophidiaster pygmaeus*,
for the 'Tuffeau de Maastricht Md': *Metopaster* n. sp.,
for the 'Tuffeau de Maastricht, horizon unknown': *Teichaster favosus*,
for the 'Tuffeau de Maastricht Mb-Mc': *Chomataster acules*,
for the "Post-Maastrichtian" of Geulhem, Canal Albert and Zolder: *C. acules*, *Metopaster carinatus*, *M. kagstrupensis*, *M. spenceri*, *M.* n. sp., *Stauranderaster miliaris*, *S.* sp. 1, *S.* sp. 2, *Valettaster granulatus*, and *Archastropecten* n. sp.

The last-named taxon is puzzling; it could well be that Rasmussen meant here what he illustrated in his pl. 8, fig. 13, under the name *Astropecten* n. sp. aff. *cotteswoldia* [sic], but those specimens are from the 'Tuffeau de Ciply' of southern Belgium, and not from the 'Post-Maastrichtian' of the Maastricht area. This matter will be addressed further below (under Systematic palaeontology).

Based on a near-complete individual from the Zeven Wegen Member as exposed at the CPL SA quarry (Haccourt), Gale (1987b) recorded *Nymphaster studlandensis* (Schulz & Weitschat, 1975) from the study area.

Jagt & Collins (1988) confirmed Rasmussen's (1965) records from the Geulhem Member (Houthem Formation) of the typically Early Danian species, *Metopaster*

spencerii and *M. kagstrupensis*, and noted that the asteroid fauna of that unit was more diverse than previously assumed.

Jagt et al. (1994) recorded a near-complete specimen of *Chomataster acules* from the Geulhem Member, noting that Gale's (1987b) deduction that the interradii would have been broad and evenly rounded and the arms long and slender was correct.

From the Vijlen Member in the Aachen area, as well as at the Bovenste Bos/Vijlenerbosch and the Haccourt area, Keutgen (1996, p. 195) recorded *Chomataster acules*, *Coulonia* sp., *Crateraster* sp., *Lophidiaster pygmaeus*, and *Ophryaster* sp.

Finally, Jagt (1999c) illustrated a number of examples of recent additions to the Cretaceous-Palaeocene asteroid faunas of the study area, which are described in detail in the present paper.

Systematic palaeontology

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

BGS Yd	British Geological Survey, Keyworth;
BMNH	Natural History Museum, London (formerly British Museum of Natural History);
GSM	Geological Survey Museum, London;
IRScNB	Institut royal des Sciences naturelles de Belgique, Brussels;
MGUH, GM	Geological Museum of Copenhagen University, type and reference collections, respectively;
NHMM	Natuurhistorisch Museum Maastricht, with individual collections bearing the following prefixes: MB - M.J. van Birgelen Colln BL - L. Blezer Colln MD - M.J.M. Deckers Colln RD - R.W. Dortangs Colln RH - R.W.J.M. van der Ham Colln JJ - J.W.M. Jagt Colln K - M.M.M. Kuypers Colln MM - M. Meijer Colln;
RGM	Nationaal Natuurhistorisch Museum, Leiden (formerly Rijksmuseum van Geologie en Mineralogie);
SGPIH	Geologisch-paläontologisches Institut der Universität Hamburg;
SM	Sedgwick Museum, Cambridge University, Cambridge;
USNM	United States National Museum, Washington DC.

Terminology — This follows Gale (1987a-b), Gale in Smith et al. (1988), and Breton (1992a). Suprageneric classification follows Gale (1987c; see also Simms et al., 1993). Lafay et al. (1995) have recently stressed that Blake's (1987) and Gale's (1987c) proposed asteroid phylogenies conflict in several respects.

Taxonomic procedure — Working with dissociated ossicles invariably means that particular features of the organism needed for a proper classification cannot be evalu-

ated. However, previous studies of Late Cretaceous and Early Palaeogene asteroids have amply shown the taxonomic value of isolated marginal ossicles. In many instances, particularly when goniasterids are considered, it is possible to reconstruct the animal from isolated ossicles, as subsequent discoveries of (near-)complete specimens have shown (see e.g. Breton, 1992a, 1995a). However, there is always the risk of oversplitting (see e.g. Mercier, 1935), if no due attention is paid to intraspecific variation, ontogenetic changes, and preservational peculiarities.

As noted above, asteroid diversity is expected to increase in future as fieldwork continues. Data presented below should be considered preliminary, being based as they are mainly on isolated marginals. A limited number of more or less completely preserved individuals or portions of discs are available, making specific assignment more reliable in these cases. Like most previous studies of Cretaceous asteroids from NW Europe, the taxonomic framework here is based on marginal ossicles only, and is, to some extent, artificial. In a way, this is practical, as it would allow for a preliminary identification in the field. On the other hand, such a method largely ignores the classificatory value of other ossicles such as ambulacrals and adambulacrals. Blake (1996, p. 232) was certainly right when he noted that Late Cretaceous asteroids were primarily known from isolated, robust marginal ossicles, on which taxonomic assignment is based, and that these ossicles were generally rather simple and block like, and subject to a good deal of evolutionary convergence. However, previous studies have demonstrated that it is possible to get a fair idea of asteroid diversity in fossil assemblages, using only these marginal ossicles. The present paper may serve as an example as well.

Class Asteroidea de Blainville, 1830
Subclass Neoasteroidea Gale, 1987c
Order Paxillosida Perrier, 1884
Family Astropectinidae Gray, 1840

Remarks — In contrast to Jurassic forms which have been the subject of detailed studies by, among others, Hess (1955, 1960a, 1960b), Meyer (1988), and Breton (1997a), Late Cretaceous astropectinids are still poorly known. Gale (in Smith et al., 1988, p. 208) intended to revise Cretaceous Astropectinidae from northwest Europe, but this has not yet been completed. Blake & Sturgeon (1995, p. 376) observed that the Astropectinidae has a limited fossil record, although they are environmentally broad ranging and numerically important in recent settings.

A few recent papers have contributed substantially to our knowledge of Cretaceous astropectinids, documenting such new taxa as *Astrocratis acutispina* Blake & Sprinkle, 1996 (p. 1312, figs. 1-3; Lower Campanian, central Texas), *Coulonia platyspina* (see below), *Tethyaster guerangeri* Breton, 1995b (p. 19, figs. 1-6; pls 1-3; Middle Cenomanian, Sarthe, France), *T.*? *albertensis* Hall & Moore, 1990, and others (see below).

In the extended Maastrichtian type area, astropectinids are fairly common at certain levels and are represented in various collections. Mostly these comprise dissociated marginals only; articulated remains are extremely rare, and may be expected only in storm-generated beds.

Genus *Astropecten* Gray, 1840

Type species — *Asterias auranciaca* Linné, 1758, by subsequent designation of Fisher (1908).

Remarks — In view of its similarity to other post-Cretaceous species, such as the ones described by e.g. Rasmussen (1950, 1972), Kaczmarska (1987), and Nosowska (1997), one of the astropectinid taxa occurring in the Early Palaeocene Geulhem Member (Houthem Formation) is here assigned to *Astropecten* s. lat. In doing so, the species below becomes one of the earliest representatives of *Astropecten*, the range of which is occasionally indicated as Late Miocene to Recent (see e.g. Spencer & Wright, in Moore, 1966). However, Rasmussen (1972) recorded a species of Eocene age, while Blake's (1973) *Astropecten* sp. from Oregon (USA) is of Early Oligocene age.

Astropecten? sp. nov.
Pl. 1, figs. 1-2, 8-9, 12; Pl. 2, figs. 7-8.

1965 *Asteropecten* [sic] n. sp. aff. *cotteswoldia* — Rasmussen, pl. 8, fig. 13.
1972 *Astropecten postornatus* (Rasmussen, 1945) — Rasmussen, p. 37, pl. 3, figs. 3-4 (?1-2).

Material — Numerous dissociated marginals in various collections, including NHMM K 1701/a, 4026-2, and MB 493-4/a-c.

Description — Of the present species, only dissociated marginal ossicles are easily recognised. So far, no articulated remains have been found, and although some isolated ambulacrals, adambulacrals and paxillae of astropectinid affinity have been found in the same samples, these cannot be assigned to the present taxon without doubt.

Superomarginals are massive, high (in proximal/interbrachial ossicles, e.g. Pl. 2, figs. 7-8), narrow, and rectangular in outline in proximal disc areas, and squarish more distally. The outer face is asymmetrical, lacks spine bases, and shows a dense cover of granule pits only (Pl. 2, fig. 7), which are largest adorally, and one or two of which may be enlarged (thus resembling spine bases). Articulation surface large, flat, rounded, ridges well developed, fasciolar surface with dense cover of spinelet bases; intermarginal facet concave. Inferomarginals massive, low, and fairly wide. Outer face asymmetrical, flat to slightly convex, with row of between 5 and 8 enlarged, close-set spine bases, of subequal size, occasionally with a second row of between 2 and 5 smaller bases; remainder covered by moderately densely spaced spine bases; articulation surface large, slightly concave, and ridges well developed, fasciolar surface with dense cover of spinelet bases; intermarginal facet concave.

Discussion — In the Geulhem Member, two types of astropectinid are represented, one of which is undoubtedly assignable to *Lophidiaster*? gr. *punctatus/postornatus* (see below). The other type, the present form, has high, narrow superomarginals which lack spine bases and show only adense cover of granule pits, and inferomarginals with a well-developed row of horseshoe-shaped spine bases, occasionally with a second row. In displaying these features, it seems advisable to place these marginal ossicles in the genus *Astropecten* s. lat., at least for the time being.

It was Rasmussen (1965) who first recognised the present form; in his tables 1 and 2 (pp. 37-38) he recorded '*Archastropecten* n. sp.' from the "Post-Maastrichtian" of Geulhem, Canal Albert and Zolder (= Geulhem Member in current terminology). In

his pl. 8, fig. 13, however, he illustrated a few inferomarginals, stated to have come from the Tuffeau de Ciply (Lower Palaeocene, Mons Basin, southern Belgium), under the name *Astropecten* n. sp. aff. *cotteswoldia* [sic]. These records are here taken to refer to the same species. Placement in the Jurassic astropectinid taxon *Archastropecten* Hess, 1995 (p. 27), now considered a subgenus of *Pentasteria* Valette, 1929 (see Hess, 1960a), cannot be upheld.

As far as the specific status of the present form is concerned, Rasmussen (1965) appears to have been right in considering this to be an undescribed form, with close similarities to the Jurassic group of *Archastropecten cotteswoldiae* (Buckman, 1845). Hess's (1955, p. 106, fig. 61) illustration of *A. cotteswoldiae* shows this well, and amongst the primitive characters shared by the present form are the spine base arrangement, and flat to slightly concave articulation surfaces.

Rasmussen (1972, p. 37, pl. 3, figs. 1-4) recorded similar astropectinid ossicles under the name *Astropecten postornatus*. The marginals from the Sonja Member (Agatdal Formation, Upper Danian, western Greenland) illustrated in his pl. 3, figs. 3-4 (MGUH 12777-12778) are much closer to the present form, and are here considered to be conspecific. In the original description (Rasmussen, 1945, p. 424, pl. 9, fig. 16), *Lophidiaster postornatus* from the Upper Danian of Svanemøllen (Copenhagen, Denmark), was described as having 'large rather deep spine pits' on the superomarginals, and 'a rather pronounced granulation' on the inferomarginals. Rasmussen (1972) more or less copied his earlier description (1950, p. 91, pl. 10, fig. 21, as *Astropecten postornatus*), but his illustration of the marginal ossicles does not show the proper arrangement, as he later realised (Rasmussen, 1972, p. 37). In his description, which undoubtedly relies heavily on the material collected from Greenland, he mentioned 'Larger granules or tubercles, horseshoe-shaped or incompletely divided by a furrow, form from one to three oblique rows on the ridge of each inferomarginal near the edge against the superomarginal. This, however, is generally obscured by wear of the surface.'

The present material from the Geulhem Member also comprises many worn and abraded inferomarginals, but invariably the oblique row(s) of spine bases remain visible as such. Therefore, it would seem that Rasmussen (1972) lumped under the name *Astropecten postornatus*, at least two astropectinids. In profile, the ossicles illustrated by him (pl. 3, figs. 1-4) differ considerably as well.

Astropecten? sp. nov. cannot be confused with other Cenozoic species from Europe, such as *Astropecten anglicus* Nosowska, 1997 (p. 239 = *Astropecten granulatus* Rasmussen, 1972, p. 38, pl. 3, figs. 5-8, non Müller & Troschel, 1842) from the Lower Eocene of Barton, England (holotype is BMNH E 53627), and *A. navodicensis* Nosowska, 1997, p. 229, pls 1-5; pl. 6, figs. 1-12), both of which show better developed, horseshoe-shaped spine bases, and much smaller and concave articulation surfaces.

Of note finally is that Maryańska & Popiel-Barczyk (1969, p. 132) recorded from the uppermost Maastrichtian-Lower Danian of central Poland isolated remains referred to *Astropecten*, but unfortunately these were not figured.

Occurrence — In the study area, exclusively known from the Lower Palaeocene Geulhem Member (Houthem Formation), but very common in places, with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt), and the Ankerpoort-Curfs quarry (Geulhem) (Figs. 1A, 9).

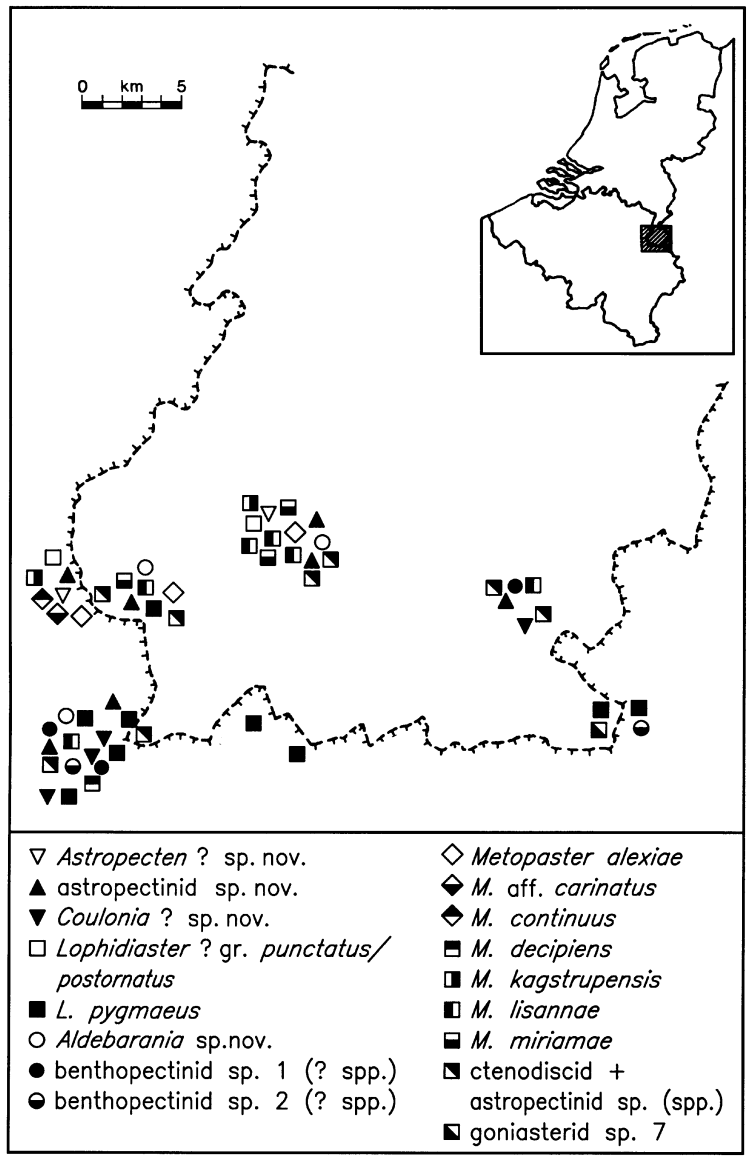


Fig. 1A. Geographic distribution of Late Cretaceous-Early Palaeogene asteroids in the type area of the Maastrichtian Stage.

astropectinid sp. nov.

Pl. 2, figs. 13-14; Pl. 3, figs. 10-12; Pl. 4, figs. 11-12; Pl. 5, figs. 1-5; Pl. 7, figs. 7-8.

?1802 zee-ster of Asteriet — Faujas Saint Fond (Pasteur's translation), p. 264, pl. 37, fig. 6.

Material — Numerous isolated marginals in various collections, including NHMM

JJ 3769, 9591/j, 9993/c, RGM 428 071, as well as a fragmentary, but well-preserved individual (NHMM K 3364a-d).

Description — This appears to be an undescribed species, which will be discussed fully by Blake & Jagt (in prep.).

Discussion — The present form is close to representatives of the genus *Coulonia*, to which a number of Cretaceous and Cenozoic taxa have been referred.

The type species, *Coulonia neocomiensis* de Loriol, 1874 (p. 14, pl. 2, fig. 1) was based on a single, near-complete specimen from the Neocomian 'Pierre jaune' of Rochette near Neuchâtel (Switzerland). Hess (1970, p. 1078, figs. 7-8; pl. 3; pl. 4, figs. 1-2) demonstrated that *Cuneaster hauteriviensis* Hess, 1955 (p. 61, figs. 16-22) was conspecific with *C. neocomiensis*, and illustrated two specimens from the Upper Hauterivian of St Blaise near Neuchâtel. Later, Hess (1975, p. 34, pl. 8, figs. 15-16) figured a pair of supero- and inferomarginals of this species, albeit in an erroneous arrangement.

From the Cenomanian of Dorset (England), Gale (in Smith et al., 1988, p. 207, pl. 43, fig. 7) recorded *Coulonia* sp., and noted a close similarity between his material and astropectinid ossicles from the Upper Albian of Devon and west Dorset.

Coulonia platyspina Hess & Blake, 1995 (p. 785, figs. 1-6) from the Barremian of Morocco, shows inferomarginals which are quite similar to those of the present species, but on the disc inferomarginals appear very much wider, and also shorter, and have a fringe of flattened spines (Hess & Blake, 1995, fig. 6). In both species, the inferomarginals strongly protrude (see e.g. Pl. 7, fig. 3), and fasciolar grooves (intermarginal channels) are deep.

The Eocene (London Clay) *Coulonia colei* (Forbes, 1852) (p. 30, pl. 4, fig. 3) (see also Rasmussen, 1972, p. 41, pl. 3, figs. 9-15; pl. 11, figs. 2-3; pl. 12, figs. 1-2) cannot be confused with the present species, on account of the structure of the marginal ossicles.

The specimen illustrated by Faujas Saint Fond (Pasteur's 1802 translation, pl. 37, fig. 6), the present whereabouts of which is unknown, appears to be conspecific with the present form, in that it shows the same concave interradii, close ventral cover of imbricated actinals, and numerous, narrow marginal ossicles.

Another species bearing a superficial resemblance to the present form is *Dipsacaster jadeti* Breton in Breton et al., 1995 (p. 39, figs. 2-3), from the lower Upper Maastrichtian of Haute-Garonne (France). However, preservation is such that the lateral profile of the marginals cannot be seen, so that a detailed comparison is impossible.

A detailed discussion of the present form's affinities will be provided by Blake & Jagt (in prep.).

Occurrence — Known to date from Lanaye Member (Gulpen Formation), and the Valkenburg, Gronsveld, Emael, Nekum and Meerssen members (Maastricht Formation), with records from the ENCI-Maastricht BV, Ankerpoort-Marnebel, Ankerpoort-'t Rooth, Blom, and CBR-Romontbos quarries and from the temporary Albertkanaal sections (Vroenhoven-Riemst) (Figs. 1A, 4-8).

Material from the Vijlen Member (e.g. Pl. 2, figs. 11-12, as *Coulonia*? sp.) is close, but does not appear to be conspecific. However, material available is too limited to allow a detailed comparison.

Genus *Coulonia* de Loriol, 1874
[= *Cuneaster* Hess, 1955]

Type species — *Coulonia neocomiensis* de Loriol, 1874, by monotypy (= *Cuneaster hauteriviensis* Hess, 1955).

Coulonia? sp. nov.
Pl. 3, figs. 1-9; Pl. 20, fig. 15.

Material — NHMM: JJ 4869, 4921, 5144, 5484, 8266-67, 8780, 9520a, MB 94, 619-28e, and RGM 428 059, 428 061, 428 070.

Description — Of this new species a partial disc and the associated remains of at least two additional individuals are currently known. The disc (Pl. 3, figs. 1-2) appears to have been quite large, with weakly concave margins, and imbricated actinals arranged in distinct rows and with short, pointed spines. A few ambulacrals and adambulacrals preserved in this specimen show the former to be typically astropectinid with prominent head and elongated abradial extension (e.g., Pl. 3, figs. 4, 9). Adambulacra are displaced, but their ventral faces bear tubercles, and these too must have borne pointed spines.

Superomarginals are comparable in length to the inferomarginals, but are markedly less wide (Pl. 3, figs. 7-8). Outer face gently curved and with close-set, rather shallow, rounded spine pits. The proximal and distal facets show two articulation elements, one round to elliptical, with a central depression, close to the intermarginal facet, the other much larger and crescentic, occupying almost the entire height of the aboral facet, with a low articulation ridge connecting both elements (Pl. 3, fig. 7). Articulation facet flat to weakly concave. Inferomarginals are wider than superomarginals and protrude at the disc margin; outer face gently curved in proximal ossicles (Pl. 3, fig. 3) to arched in distal ones (Pl. 3, fig. 5), with ornament consisting of close-set tubercles of varying size, with a crescentic shallow depression in front of the larger tubercles, and two irregular rows of up to 6 tubercles lining the margin/lateral surface. Articulation ridge well developed, extending to more than two thirds of articulation facet, with vertical conspicuous element (Pl. 3, figs. 3, 5), and one or two elliptical articulation bosses, which vary in position according to original position in disc and/or arms. Articulation surface flat, to weakly concave, and intermarginal facet weakly concave.

Discussion — The present material is referred to *Coulonia*, albeit with a query, on account of the similarity to marginal ossicle structure in *C. platyspina* Hess & Blake, 1995. None of the astropectinids recorded previously from the Cretaceous of Europe are likely to be confused, although *Lophidiaster*? *mirabilis* Valette, 1915 (p. 63, fig. 22) from the Campanian of Yonne (France), which Hess (1955, p. 63) referred with a query to *Cuneaster* (= *Coulonia*, see above), seems to be closely related. Brünnich Nielsen (1943, fig. 16) illustrated a single median inferomarginal (MGUH 4198) from the Campanian of Båstad (Skåne, southern Sweden), under the name *Lophidiaster ornatus* Spencer, which appears to be closely related to, if not conspecific with, the present species, but more material is needed to confirm this.

A detailed description is under way (Blake & Jagt, in prep.).

Occurrence — Known only from the Benzenrade Member (Vaals Formation) and Zeven Wegen Member (Gulpen Formation), with records from Benzenrade ('kapelletje'), Heure-le-Romain, and the CPL SA and CBR-Lixhe quarries (Figs. 1A, 2-3).

Genus *Lophidiaster* Spencer, 1913

Type species — *Lophidiaster ornatus* Spencer, 1913, by subsequent designation of Valette (1915). Spencer & Wright (1966, p. U46) noted that type species, by original designation, was *L. ornatus*, but as Hess (1955, p. 64) noted it was actually Valette (1915), who subsequently designated *L. ornatus* as type. Gale (in Smith et al., 1988, p. 208) noted that the type (SM B17718) of *L. ornatus* came from the Lower Albian of Folkestone, and that preservation was such that the specimen must be considered Astropectinidae incertae sedis.

In the interest of nomenclatorial stability it seems advisable to repress *L. ornatus* in favour of the second species referred to *Lophidiaster* by Spencer (1913), *L. pygmaeus*.

Spencer's (1913, p. 138) original diagnosis is brief, 'Marginal, strongly ridged. Spines on marginalia either minute or absent.' It is Hess's (1955, p. 64) subsequent interpretation of the genus *Lophidiaster* that is followed here.

Lophidiaster? gr. *punctatus/postornatus*
Pl. 2, figs. 1-2, 4-6.

*1943 *Lophidiaster punctatus* Brünnich Nielsen, p. 67, pl. 4, fig. 38.
*1945 *Lophidiaster postornatus* Rasmussen, p. 424, pl. 9, fig. 16.
1950 *Astropecten postornatus* (W. Rasmussen) — Rasmussen, p. 91, pl. 10, fig. 21.
1950 *Astropecten punctatus* Br. Nielsen — Rasmussen, p. 92, pl. 10, fig. 20.
1955 *Lophidiaster postornatus* H.W. Rasmussen, 1945 — Hess, p. 66.
1955 *Lophidiaster punctatus* Br. Nielsen, 1943 — Hess, p. 66.
1972 *Lophidiaster punctatus* Nielsen, 1943 — Rasmussen, p. 44.
?*1972 *Lophidiaster haunsbergensis* Rasmussen, p. 45, pl. 3, figs. 16-17.

Types — Holotype of *L. punctatus* is MGUH 4182; holotype of *L. postornatus* is the specimen figured by Rasmussen (1950, pl. 10, fig. 21, MGUH collections), and holotype of *L. haunsbergensis* is MGUH 12779.

Material — Numerous dissociated marginal ossicles in various collections, including NHMM JJ 2939, K 1701/b-c, 4026-2, and MB 432-74a/c.

Description — Superomarginals are massive, short and narrow, with a conspicuous (a)symmetric ridge, covered by close-set, fairly large but rather shallow granule pits. Articulation ridges run either parallel to aboral surface of ossicle or retreat to roughly halfway this facet, so that fasciolar surface becomes progressively wider towards intermarginal facet (e.g., Pl. 2, figs. 5-6). Fasciolar surface with close-set, small spinelet bases.

Inferomarginals are comparable in structure, and either have a similar ornament of granule pits (*punctatus* type), or bear granules of varying sizes (*postornatus* type).

Discussion — Grouped here are all (Early) Palaeocene astropectinids of *Lophidiaster* type, whose interrelationships still need to be determined, and in which superomarginals have an ornament consisting of close-set granule pits, and inferomarginals either a comparable ornament of granule pits, or a dense cover of granules. Excep-

tions would be the Late Palaeocene '*Lophidiaster*' *inversus* Rasmussen, 1972 (p. 46, pl. 3, figs. 18-19) and *L.* sp. aff. *pygmaeus* sensu Rasmussen, 1972 (p. 48, pl. 3, figs. 26-27), both from Kroisbach (Austria).

Brünnich Nielsen (1943, p. 67) erected *L. punctatus* for astropectinid ossicles of Early and Late Danian age, which had a rather narrow ridge with typical ornament, consisting of scattered, rather deep spine pits, in common. In the meantime, at least two more or less complete discs (NHMM K 2086, GM 1992.255) have been collected from the Lower Danian (*oedumi* and *abildgaardi* zones) of Stevns Klint (Denmark), which allow this species to be redescribed. Later, Rasmussen (1945) erected *L. postornatus*, which differed from *L. punctatus* in having an inferomarginal ornament of pronounced granules. According to Rasmussen (1950, table 1), these two forms co-occur in the Upper Danian of Denmark, while the Lower and Middle Danian had only yielded *L. punctatus*. Rasmussen's (1972) record of *L. haunsbergensis*, which has an ornament of granule pits on both the supero- and inferomarginals, shows that this group continues at least into the Upper Palaeocene.

Awaiting the detailed description of the two discs of *L. punctatus* mentioned above, this suite of astropectinids is here referred to as *L.*? gr. *punctatus/postornatus*. Marginal ornament as well as ossicular profile suffice to distinguish this group from co-occurring *Astropecten*? sp. nov. (see above).

Occurrence — Confined to the Geulhem Member (Houthem Formation), with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 1A, 9).

Lophidiaster pygmaeus Spencer, 1913
Pl. 4, figs. 1-7.

*1913 *Lophidiaster pygmaeus* Spencer, pp. 139, 150, pl. 11, fig. 20 (non 21); pl. 16, figs. 17-19.
1950 *Astropecten*? *pygmæus* (Spencer) — Rasmussen, p. 92, pl. 10, fig. 19.
1955 *Lophidiaster pygmaeus* (von Hagenow M.S.) Spencer, 1913 — Hess, p. 66.
1956 *Lophidiaster pygmaeus* Spencer — Müller, p. 642, pls 1-2.
1999c *Lophidiaster pygmaeus* — Jagt, pl. 2, fig. 9.

Type — Syntypes of *L. pygmaeus* are BMNH E 13263-E 13264 (Lewis, 1993).

Material — Numerous isolated marginals, as well as associated remains of a few individuals, including NHMM JJ 3169, 3211, 3570, 3713a-g, 4980, 6889, 10600/4, K 1836, MB 591-4a, and RGM 428 062.

Description — Associated remains from the Vijlen Member of the CPL SA quarry include ambulacrals (Pl. 4, fig. 1), circumorals (Pl. 4, fig. 6), paxillae (Pl. 4, fig. 2), and terminals (Pl. 4, fig. 7), and marginal ossicles (Pl. 4, figs. 4-5), which all correspond closely to the material described by Müller (1956) from the upper Lower Maastrichtian of Rügen. There is little new information to add to Müller's description. In the present material superomarginals invariably have well-developed granules, while most inferomarginals appear smooth, but some may actually have the same coarse granulation. Material from the Zeven Wegen Member differs in being generally longer and in having a wider ridge with smaller, but more closely spaced granules. For the time being, these are lumped with 'typical' *L. pygmaeus*, which is fairly common in the Vijlen and Lanaye members (Gulpen Formation).

Discussion — This is the only astropectinid species of the '*Lophidiaster*' type to occur in the Gulpen and Maastricht formations, and to have well-developed marginal granulation, either on the superomarginals or on both supero- and inferomarginals.

Remarks — Rasmussen's (1972, p. 48, pl. 3, figs. 26-27) *Lophidiaster* sp. aff. *pygmaeus* from the Upper Palaeocene of Austria differs markedly and appears unrelated.

Occurrence — Known to date from the Zeven Wegen, Vijlen, and Lanaye members (Gulpen Formation), the Valkenburg, Gronsveld, and Emael members (Maastricht Formation (and possibly even higher?), with records from Heure-le-Romain, and the CPL SA, CBR-Lixhe, CBR-Romontbos, Ankerpoort-Marnebel, and ENCI-Maastricht BV quarries, as well as from Snouwenberg, Mamelis-Selzerbeek, the Aachen area and Altembroeck (Figs. 1A, 2-7).

Genus *Aldebarania* Blake & Sturgeon, 1995

Type species — *Aldebarania arenitea* Blake & Sturgeon, by monotypy.

Aldebarania sp. nov.
Pl. 4, figs. 8-10; Pl. 5, figs. 6-12; Pl. 7, figs. 5-6?.

Material — NHMM 1999015/1-3, JJ 2787, and RGM 428 072, and numerous isolated marginals in various collections.

Description and discussion — This material represents the first European record of the otherwise exclusively North American Maastrichtian (Rocky Point Member, Peedee Formation of North Carolina) genus *Aldebarania*. For a detailed description reference is made to Blake & Jagt (in prep.).

In inferomarginal armature and details of marginal ossicle structure and of ventral and dorsal disc plating, this species may be distinguished from astropectinid sp. nov. (see above).

Occurrence — Known to date from the Nekum Member (Maastricht Formation), with records from the CBR-Romontbos and ENCI-Maastricht BV quarries, and possibly from the Meerssen Member (IVf-3) of Blom quarry (Figs. 1A, 5-6, 8).

Astropectinidae indet.
Pl. 1, fig. 11; Pl. 2, fig. 3.

Material — Numerous isolated marginals in various collections, including NHMM JJ 9591/a, and MB 590-4.

Description and discussion — This material may include more than one species, but in the absence of articulated remains and/or marginals associated with ambulacrals, adambulacrals and aboral ossicles, the proper placement of these ossicles cannot be determined.

Occurrence — Ossicles of this type are known to date from the Benzenrade Member (Vaals Formation), the Lanaye Member (Gulpen Formation), and the Gronsveld, Emael, Nekum, and Meerssen members and Kunrade Limestone facies (Maastricht Formation), with records from the Blom, ENCI-Maastricht BV, Ankerpoort-Marnebel, Ankerpoort-'t Rooth and CBR-Romontbos quarries, and from the temporary

Albertkanaal sections (Vroenhoven-Riemst), the Kunrade area and at Welterberg/Benzenrade (Figs. 1A, 4-8).

Family Ctenodiscidae Sladen, 1889
ctenodiscid? indet.
Pl. 1, figs. 3-4, 10.

Material — A number of isolated marginal ossicles, including RGM 428 060, as well as an arm fragment, NHMM MB 680.

Description and discussion — Although superficially similar to some asteropectinid material (see Astropectinidae indet., above), the present specimens, and the arm fragment in particular, may be compared to ctenodiscids (D.B. Blake, pers. comm.). To date, only a single fossil ctenodiscid is known, *Paleoctenodiscus campaniurnis* Blake, 1988 (p. 630, figs. 1.1-1.8) from the Campanian of Baja California (Mexico). More material is needed to assess the status of the present form.

Occurrence — Ossicles of this type are known from the Lanaye Member (Gulpen Formation) and Emael Member (Maastricht Formation), with records from the CBR-Romontbos quarry (Eben Emael) (Fig. 1A, 5).

Order Notomyotida Ludwig, 1910
Family Benthopectinidae Verrill, 1894
benthopectinid sp. 1 (? spp.)
Pl. 6, figs. 1-4.

1999c benthopectinid indet. — Jagt, pl. 1, fig. 18.

Material — Only a handful of isolated marginal ossicles, including NHMM JJ 9591/h-i, MB 507-19, and 867-6.

Description — Marginal ossicles referred here have a polygonal, asymmetric outline, with a subspherical outer face, and 1-3 subequal spine bases in an oblique row, the remainder of the outer face covered by rather coarse, close-set granules (e.g., Pl. 6, figs. 1-2); lateral faces subtriangular, concave, and bordered by low articulation ridge. Ossicles here illustrated appear to be inferomarginals; superomarginals have not been recognised so far in the available material.

Discussion — These ossicles appear attributable to the Benthopectinidae, in that there is a certain similarity to material of the Recent *Cheiraster gazellae* Studer, 1883 and *Pectinaster hylacanthus* Fisher, 1913, and the Early Oligocene *Mistia spinosa* Blake, 1973, as illustrated by Blake (1973, pl. 16, figs. 1-44; pl. 17, figs. 1-21, 35-36). The few ossicles available are closely comparable, suggesting they belong to a single taxon.

Fossil benthopectinids are poorly known, with only few forms having been based on more or less completely preserved discs, e.g. the Jurassic *Plesiastropecten hallovenis* Peyer, 1944, and *Xandarosaster hessi* Blake, 1984 from Germany (see Blake, 1984), and the Albian *Alkaidia sumralli* Blake & Reid, 1998.

Occurrence — Currently known from the Vijlen Member (Gulpen Formation), the Emael Member and the Kunrade Limestone facies (Maastricht Formation) of the CPL SA and CBR-Romontbos quarries and the Kunrade-Kunderberg area (Figs. 1A, 2, 5).

benthopectinid sp. 2
Pl. 6, figs. 5-6, 8, 10-12; Pl. 7, figs. 1-2.

1953 Zwischenplatten QA, RA — Müller, p. 45, pl. 10, figs. QA, RA.
1999c indeterminate 'cryptozonid' — Jagt, pl. 2, figs. 1-2, 4.

Material — NHMM JJ 5488, 6921, 6996, 10600/8, MB 808-7/a-b, e-i, and 808-9a.

Description — Grouped here are rod-like to irregularly shaped, rather thin ossicles which have one or more conspicuously elevated spine bases, of varying size, and an additional granulation, and highly typical, radiating stereom structure, with almost flat to markedly concave or partially 'excavated' interossicular facets. A single terminal ossicle (Pl. 6, figs. 11-12) shows the same ornament and three terminal as well as two lateral spines, directed both downwards and upwards. A few specimens (Pl. 6, fig. 8) represent portions of disc and/or arms, and are associated with sturdy ambulacrals. The variety in ossicle outline may be ascribed to the original position within the skeleton; it seems unlikely that more than one taxon is represented.

Discussion — The assignment of these ossicles has presented problems. A similar type is known to occur quite commonly in the upper Lower Maastrichtian of Rügen (see Müller, 1953). A full description of the present form is under way (Blake & Jagt, in prep.).

Occurrence — Known to date from the Zeven Wegen and Vijlen members (Gulpen Formation) at the CPL SA quarry (Haccourt) and of temporary outcrops at Aachen (Hans Böckler Allee) (Figs. 1A, 2).

Superorder Surculifera Gale, 1987c
Order Valvatida Perrier, 1884
Family Goniasteridae Forbes, 1841
Genus *Metopaster* Sladen, 1893
[= *Mitraster* Sladen, 1893; *Spenceria* Fourtau, 1914; *Dictydaster* Mercier, 1935; *Ravniaster* Brünnich Nielsen, 1943]

Type species — *Goniaster (Goniodiscus) parkinsoni* Forbes, 1848, by subsequent designation of Rasmussen (1950) (ICZN Opinion 331).

Remarks — Of the present genus a long-ranging main lineage (*Metopaster parkinsoni*), and many short-lived (in part endemic) taxa have so far been described in the literature (see e.g. Cottreau, 1937; Breton, 1979, 1981, 1992a, 1997b; Gale, 1987a, 1989; Villier, 1996; Villier et al., 1997). Gale (1989, p. 287) noted that, 'Each region and facies has a small endemic suite of *Metopaster* species, accompanied by ubiquitous *M. parkinsoni*.'. The same holds true for the Maastrichtian type area, with the exception that representatives of *M. parkinsoni* have not yet been recognised.

Metopaster alexiae sp. nov.
Pl. 9, figs. 8-11; Pl. 26, figs. 3, 15-16.

1999c *Metopaster* sp. nov. — Jagt, pl. 2, fig. 18.

Types — Holotype is NHMM MB 377-23/e (Pl. 9, figs. 10-11); paratypes are MB

377-23/c-d.

Type locality and horizon — Blom quarry, Berg en Terblijt; Maastricht Formation, Meerssen Member (base IVf-3).

Derivation of name — Named after my sister-in-law, Alexia Jagt-van Beers.

Diagnosis — Marginals with narrow depressed border, and central area with large, circular granule pits; fully-grown ultimate superomarginals have two, (sub)equal wart-like protuberances, the position of which varies slightly, and correspond to six inferomarginals.

Material — In addition to the types, NHMM K 1656 and MM 1270.

Description — This new taxon is based on isolated marginals only, which means that disc outline and number of marginals on each side of the arm cannot be determined. Marginals have a well-defined, slightly depressed narrow border (Pl. 9, figs. 8-11; Pl. 26, fig. 15) with fine granule pits (mostly obliterated by recrystallisation), and a central area with evenly spaced, fairly large granule pits. Median superomarginals have a steep lateral surface, are evenly rounded, and a tumid aboral surface (Pl. 26, figs. 15-16), and well-developed articular ridge, and width equalling length. Ultimate superomarginals are longer than wide, with a steep lateral margin, a more or less straight, evenly rounded aboral surface, and aboral swelling with two (sub)equal, wart-like protuberances, the position of which varies (compare Pl. 9, figs. 8, 10), and which appear to be absent in juvenile and/or subadult ossicles (see Pl. 26, fig. 3). The intermarginal facet shows that up to 6 inferomarginals corresponded to a superomarginal. Inferomarginals have not been recognised yet.

Discussion — On account of the occurrence of these two distal wart-like protuberances, the present species is easily recognised amongst species of *Metopaster* from the type Maastrichtian. There is a superficial resemblance to *M. bromleyi* Gale, 1987a (p. 22, pl. 2, figs. 14-16; pl. 3, figs. 1-5; text-fig. 10/5, holotype is BMNH E 13304; paratypes are BMNH E 54341-54346, 54192-54194) from the uppermost Lower Campanian of southern Sweden, to *M. thoracifer* (Geinitz, 1871) (see Spencer, 1913, p. 110, pl. 10, figs. 1-3; Gale, 1987a, p. 37, pl. 1, fig. 5; text-fig. 12; Wright & Smith, 1987, p. 213, pl. 47, fig. 8) from the Cenomanian to Coniacian of England, Germany and Denmark, and to *M. calcar* Spencer, 1913 (lectotype is BMNH E 13305, designated by Gale, 1987a, p. 24; = *M. cristagalli* Spencer, 1913, p. 120, pl. 15, fig. 18) from the Santonian and Lower Campanian of southern Sweden. However, all of these are easily distinguished on the position of protuberances, nature of granule pits and superomarginal profile.

Occurrence — Apparently confined to the Meerssen Member (Maastricht Formation), with records from the temporary Albertkanaal sections (Vroenhoven-Riemst), and the ENCI-Maastricht BV and Blom quarries (Figs. 1A, 6, 8).

Metopaster aff. *carinatus* (Brünnich Nielsen, 1943)
Pl. 7, figs. 9-10?; Pl. 9, figs. 1-3; Pl. 26, fig. 11?.

compare

*1943 *Ravniaster carinatus* Brünnich Nielsen, p. 52, pl. 4, fig. 34.

1950 *Metopaster carinatus* (Br. Nielsen) — Rasmussen, p. 50, pl. 5, figs. 12-13.

1965 *Metopaster carinatus* — Rasmussen, pl. 8, fig. 2.

Type — Holotype of *M. carinatus* is MGUH 4178.

Material — Two pairs of ultimate supero- and inferomarginals (NHMM RH 285/a-b); MB 432-74/d may also belong here, but is atypical in being more or less smooth, while MB 432-74/u, a median superomarginal, may also be conspecific.

Description — The present specimens closely resemble material referred to as *M.* aff. *planus* (see below), but are even smaller, and ultimate infero- and superomarginals are in contact over their entire length, except for a very small, distal inferomarginal, rather than a combination of one larger and one smaller distal inferomarginal. The narrow, depressed border is well developed, with close-set granule pits, whereas the central area shows an exsculptate type of ornament. Recrystallisation appears to have obliterated details of ornament on the aboral surface. The lateral and aboral surfaces are evenly rounded, and are not tumid, nor do they show a curvature. The articulation facet is well developed, concave, and bordered by a strong ridge.

Discussion — In comparison with material illustrated by Rasmussen (1950) from the Upper Danian of Denmark, the present specimens differ slightly in not showing the even curvature of the aboral surface, and in showing an exsculptate type of ornament, so that assignment is tentative.

Occurrence — Known exclusively from the upper Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Kesselt) (Fig. 1A).

Metopaster continuus sp. nov.
Pl. 24, figs. 8-16, 22-27.

Types — Holotype is NHMM JJ 11142/h (Pl. 24, figs. 23, 27); paratypes are JJ 11142a-g, i-j and RGM 428 076.

Type locality and horizon — Temporary Albertkanaal sections at Vroenhoven-Riemst/Kesselt, lower Geulhem Member (Houthem Formation).

Derivation of name — Lat. *continuus*, meaning 'connected to' or 'following upon', in reference to its apparent continuation into the Early Palaeocene of the lineage of the Late Cretaceous *Metopaster stainsforthi* Wright & Wright, 1941 (see below).

Diagnosis — Medium-sized species, apparently with arms produced, curved aborally at the tips, with at least 6-7 superomarginals (estimated) present in each side of arm, and decreasing evenly in size distally; ornament on marginals restricted to slightly tumid central area, especially in distal ossicles, but very variable.

Material — In addition to the types, numerous isolated marginals in the van Birgelen, Jagt, and Kuypers collections.

Description — Of this species, only dissociated marginal ossicles are known, but both proximal and distal supero- and inferomarginals are available, allowing a reasonably accurate reconstruction.

Median superomarginals (Pl. 24, figs. 22-27) are wider than long, with the outer surface evenly curved, and gently swollen from the lateral to the aboral surface, and bearing very closely set, evenly sized granule pits; no depressed narrow border. Proximal and distal facets are concave, and border by a distinct articulation ridge (Pl. 24, figs. 26-27). In some proximal ossicles (Pl. 24, fig. 24) ornament is irregular, in showing raised, denser stereom patches, which are either smooth or bear coarse, scattered granule pits. This type of ornament is prominent on distal superomarginals (Pl. 24,

figs. 10-12). Median inferomarginals (Pl. 24, figs. 8-9, 13-14) are also wider than long, with the outer face almost flat to slightly tumid (e.g., Pl. 24, figs. 15-16), and with close-set, evenly sized granule pits, and in some with a raised central area of smooth, denser stereom patches (Pl. 24, figs. 8-9).

Discussion — In having recurved arms, and a larger number of superomarginal ossicles which decrease in size distally, the present form resembles species of *Recurvaster*, but differs from those in lacking a sharply delimited, raised central area. Amongst species of *Metopaster*, the closest resemblance is to *Metopaster stainforthi* Wright & Wright, 1941 (p. 231, pl. 13, figs. 1-4, 11-12; pl. 17, figs. 1-2) from the Middle Santonian to Lower Campanian of England and Germany (see also Gale, 1987a, p. 35, pl. 9, figs. 11-14, cum syn.). The type of ornament in *M. stainforthi* resembles that seen in *M. decipiens* (see below) and *M. undulatus* (see below). Gale (1987a) assumed *M. stainforthi* to have evolved from individuals of *M. parkinsoni* of Santonian age which have the central areas of marginal ossicles reduced and diffuse (see e.g. Gale, 1987a, pl. 2, figs. 11, 13), with permanent acquisition of this type of ornament, as well as longer, aborally curved arms. The present species appears to continue this lineage into the Lower Palaeocene; it differs from *M. stainsforthi* (see also Schulz & Weitschat, 1975, p. 269, pl. 27, figs. 6-8) in having a smaller ossicular angle, and slightly shorter marginals, but is otherwise closely similar.

Amongst Early Palaeocene species from Denmark (see Brünnich Nielsen, 1943; Rasmussen, 1950), there is none that could be confused with *M. continuus*, except for *Recurvaster communis* Brünnich Nielsen, 1943 (p. 45, pl. 4, fig. 33). Rasmussen (1950, p. 68) rightly noted that the specimens figured by Brünnich Nielsen were both inferomarginals, and that their ornament did not differ from that of co-occurring species of *Metopaster* and *Recurvaster*, i.e. with narrow, depressed border, and raised central area with large granule pits. More material is needed, preferably articulated, to determine the status of Brünnich Nielsen's form.

Occurrence — Confined to the lower Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Vroenhoven-Riemst) (Fig. 1A).

Metopaster decipiens Spencer, 1913
Pl. 8, figs. 1-4, 6, 7?, 8?

*1913 *Metopaster decipiens* Spencer, p. 118, pl. 10, fig. 18.
1941 *Metopaster undulatus* Spencer — Wright & Wright, p. 238, pl. 14, figs. 5-6.
1975 "*Metopaster*" cf. *decipiens* Spencer, 1913 — Schulz & Weitschat, p. 266.
1975 "*Metopaster*" cf. *undulatus* Spencer, 1913 — Schulz & Weitschat, p. 268.
1987a *Metopaster decipiens* Spencer 1913 — Gale, p. 26, pl. 4, figs. 13-16; pl. 5, figs. 2-4.
1987 *Metopaster undulatus* Spencer — Wright & Smith, p. 214, pl. 47, fig. 9.
?1992 *Parametopaster* aff. *decipiens* (Spencer, 1913) — Breton, p. 193, pl. 19, figs. 8-9.
1999c *Metopaster decipiens* — Jagt, pl. 2, fig. 3.

Type — Holotype is BMNH E 20306.

Material — Numerous isolated marginals, and associated remains of a few individuals, including NHMM JJ 3463bis/1-2, 3464bis, 4741, 6478, 7188, 8725a, 10600/7, MB 639-2a, and RGM 428 066.

Description — In this small species, with three superomarginals in each side of the

arm (Gale, 1987a), median supero- and inferomarginals are square, with the outer face gently and evenly rounded (Pl. 8, fig. 4), and the ultimate superomarginal (SM3) is triangular, distinctly longer than wide (Pl. 8, fig. 1), with the lateral margin straight or weakly convex, and the distal end slightly swollen aborally. Large, deep granule pits cover the central area, and decrease towards the margins, often irregularly distributed, and many specimens have rugosities interspersed between granule pits (Pl. 8, figs. 3, 6).

Discussion — Gale (1987a, p. 27) noted that *M. decipiens* differed from its descendant *M. undulatus* (see below) in that the latter has a distinctive marginal profile (see Pl. 24, figs. 1-7) characterised by a swelling near the margin of the lateral surface, and short ultimate superomarginals with strongly curved outer faces. He also recorded morphological intermediates between *M. decipiens* and *M. undulatus* from the upper Upper Campanian (Beeston Chalk) of Norfolk. Similarly short forms, but with much coarser ornament (see Pl. 8, figs. 7-8), are known from the Zeven Wegen Member in the Haccourt-Lixhe area, where they co-occur with typical *M. decipiens*.

Gale (1987a) recorded material from the Lower Campanian (*Offaster pilula* Zone) in southern England, up to the Weybourne Chalk (Upper Campanian) of Norfolk, and from correlative strata in France.

Occurrence — Exclusively known from the Zeven Wegen Member (Gulpen Formation) at the CPL SA quarry (Figs. 1A, 2).

Metopaster kagstrupensis Brünnich Nielsen, 1943
Pl. 8, figs. 9-12; Pl. 9, figs. 4-7; Pl. 12, figs. 17?, 21?

*1943 *Metopaster kagstrupensis* Brünnich Nielsen, p. 33, pl. 1, figs. 13-15.
1950 *Metopaster kagstrupensis* Br. Nielsen — Rasmussen, p. 43, pl. 5, figs. 1-4; text-fig. 4i.

Type — Lectotype, by subsequent designation of Rasmussen (1950), is MGUH 4105.

Material — Numerous isolated marginals in various collections, including NHMM JJ 11139, MM 1266, and RGM 428 065; NHMM JJ 11147/b, d may also belong here.

Description — The present material, although generally of smaller size (?representing juvenile and/or subadult individuals), corresponds closely to specimens from the type locality, Stevns Klint, and type stratum, the Lower Danian Bryozoan Limestone (see Pl. 9, figs. 5-6). According to Rasmussen (1950) this species has three strongly tumid superomarginals in each side of the arm, with median inferomarginals taller than corresponding superomarginals, and a large ossicular angle. There is some variation in the length/height relationship of ultimate superomarginals, with some ossicles closely comparable to material from Denmark (e.g. Rasmussen, 1950, pl. 5, fig. 3), while others appear longer. The same holds true for the tumidity of the aboral surface of the superomarginals. On account of their height, inferomarginals of the present species are easily distinguished from those of the co-occurring *M. spencerii* (see below).

Discussion — There is little to add to Rasmussen's (1950) account of the species.

Occurrence — Known to date only from the lower Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Vroenhoven-Riemst) and the Ankerpoort-Curfs quarry (Figs. 1A, 9).

Metopaster lisannae sp. nov.
Pl. 10, figs. 3?, 8-12, 13?

1925 *Metopaster tumidus* (Spencer) — Umbgrove, p. 207 (partim), figs. 1-12 (?partim).

Types — Holotype is NHMM K 1162 (Pl. 17, figs. 1-2); paratypes are NHMM JJ 9973, K 744, and 1075a.

Type locality and horizon — ENCI-Maastricht BV quarry, Maastricht; Maastricht Formation, Meerssen Member (IVf-4).

Derivation of name — Named after my niece, Lisanne Jagt.

Diagnosis — A medium-sized species with tall, rather short ultimate superomarginals, generally lacking a well-defined narrow border as well as granule pits, but with coarse granules especially on junction between lateral and aboral surface, one or more of which may grow into blunt spines; lateral surface steep and markedly concave centrally; up to six inferomarginals correspond to ultimate superomarginal. Proximal articulation facet concave aborally, occasionally with granules lined along the distinct articulation ridge, which is especially prominent aborally. Inferomarginals have the same ornament on the central area, but narrow border may be better developed.

Material — In addition to the types, fairly many isolated ultimate superomarginals, mostly poorly preserved, including NHMM BL 0351, JJ 7103, 9223-9224, 11100, K 2592, 4238, MB 104a, and 234-23, as well as unregistered material in the H. Vlieks Collection (Simpelveld-Molsberg).

Description — Of this taxon, two discrete forms are distinguished, at least for the time being, with var. A corresponding to *M. lisannae* 's. str.' (e.g., Pl. 10, figs. 8-12), and var. B (e.g., Pl. 10, figs. 3, 13) to a form with comparatively well-developed aborodistal spines. Material currently assigned to var. B, and from the Kunrade Limestone facies (Maastricht Formation) of the Kunrade-Benzenrade area, is characterised by being consistently longer than tall, and in having one or two spines. Distal inferomarginals with a prominent spine-like protuberance of the type illustrated in Pl. 10, fig. 13, are known from this unit, as well as from the Nekum Member (Maastricht Formation).

Ultimate superomarginals are short, with width almost equalling height, and lack a well-defined narrow border, except along the aboral plate margins, and show a total absence of granule pits. Instead, coarse blunt and elongate granules, in particular on the tumid junction between lateral and aboral surfaces, occur and one or more of which may grow into blunt spines. With size increase the lateral surface becomes steeper and markedly concave between the tumid aboral face and the distal margin. Up to six inferomarginals correspond to an ultimate superomarginal. The proximal articulation facet is concave aborally, occasionally with granules lined along the distinct articulation ridge, which is especially prominent aborally. Inferomarginals have the same granular ornament on the central area (Pl. 10, fig. 9), with a tendency for granules to coalesce, and the depressed border is better developed. Other marginals have not yet been recognised, but are assumed to show the same lack of granule pits.

Discussion — The combination of absence of granule pits, poorly defined central area and occurrence of conspicuous granules and blunt spines, distinguishes this

species from other NW European species of *Metopaster*. Some ultimate superomarginals which lack well-developed spines are close to *M.* aff. *loirensis* Gale, 1987a (p. 32, pl. 3, fig. 20) from the Upper Santonian of Touraine (France), which also completely lack granule pits on the central areas, and have a tall tumidity on the ultimate superomarginal.

The present species probably represents a (?short-lived) offshoot of the *tumidus* 'lineage', representatives of which occur in coeval, white chalk facies types (Denmark, northern Germany), and with which it shares the tall, short ultimate superomarginals and prominent aboral swelling. However, the poorly delimited central area, which lacks granule pits, distinguishes *M. lisannae* immediately.

Occurrence — *M. lisannae* var. A is apparently confined to the (middle/upper) Meerssen Member (Maastricht Formation), with records from the ENCI-Maastricht BV, and Blom quarries (Figs. 1A, 6, 8), while var. B is known from the Nekum and Meerssen members and Kunrade Limestone facies (Maastricht Formation), from the CBR-Romontbos, ENCI-Maastricht BV, Ankerpoort-'t Rooth, and Blom quarries, and the Kunrade Limestone facies (Maastricht Formation) of the Kunrade-Benzenrade area (Figs. 1A, 5-8).

Metopaster miriamae sp. nov.
Pl. 26, figs. 8-10, 12-14, 17.

1925 *Metopaster tumidus* (Spencer) — Umbgrove, p. 207 (partim), figs. 13-21 (?partim).

Types — Holotype is NHMM JJ 10535/h (Pl. 26, figs. 10, 12); paratypes are JJ 10535/g, and K 2688-7.

Type locality and horizon — ENCI-Maastricht BV quarry, Maastricht; Maastricht Formation, Meerssen Member (IVf-5/-6).

Derivation of name — Named after my niece, Miriam Jagt.

Diagnosis — A small species, in which ultimate superomarginals are longer than wide, low, with a fairly well-delimited, narrow depressed border, and raised central area, which on the lateral surface bears close-set granule pits, and on the aboral surface conspicuous granulation interspersed with granule pits; ultimate superomarginal corresponding with one large (occupying more than two thirds the length) and one much smaller inferomarginals. Proximal articulation facet low, concave especially adradially, and bordered by a prominent ridge. Median superomarginals show close-set, rather small granule pits on the central area. Other ossicles have not yet been recognised.

Material — Fairly many isolated (supero)marginals in the van Birgelen, Kuypers and Jagt collections.

Description — Ultimate superomarginals are relatively small, longer than wide, low, with a fairly well-delimited, narrow depressed border, and raised central area, which shows close-set granule pits on the lateral surface (Pl. 26, fig. 12), and on the aboral surface conspicuous granulation interspersed with granule pits (Pl. 26, figs. 12, 14). The ultimate superomarginal corresponds to one large (occupying more than two thirds the length) and one much smaller inferomarginal ossicle (Pl. 26, figs. 9-10). Proximal articulation facet low, concave especially adradially, and bordered by a prominent ridge. Median superomarginals show close-set, rather small granule pits

on the central area, and a similar, low, gently curved profile (Pl. 26, figs. 13, 17). Other ossicles have not yet been recognised.

Discussion — In its low, coarsely granulate ultimate superomarginals, in which the central area is generally well delimited, and to which but 1-2 inferomarginals correspond, this species is reminiscent of *Metopaster hunteri* (Forbes, 1848) (see Sladen, 1893, pl. 12, fig. 3; pl. 15, figs. 3-5; Spencer, 1907, fig. 18; Breton, 1992a, p. 138, pl. 8, figs. 8-11; pls. 9-10; text-figs. 56-60; Gale, 1987a, p. 29, pl. 6, figs. 18-23; pl. 8, figs. 1-9), which is restricted to the Coniacian-Lower Campanian of the Wessex-Paris Basin.

Another superficially similar species, *Metopaster schulzi* Breton, 1992a (p. 145, pl. 11; text-figs. 61-63), has recently been recorded from the uppermost Coniacian/lowermost Santonian of Seine-Maritime (France). This species lacks granulation, but instead has close-set granule pits, and was assumed to have descended from *M. thoracifer*.

Co-occurring with the present species are closely comparable forms, which at similar lengths, have 3-4 inferomarginals corresponding to an ultimate superomarginal, and show close-set granule pits, with or without granulation (see *Metopaster* sp. 1 below).

Occurrence — Apparently restricted to the Meerssen Member (Maastricht Formation), with records from the ENCI-Maastricht BV, Ankerpoort-'t Rooth, and Blom quarries (Figs. 1A, 6-8).

Metopaster aff. *planus* (Brünnich Nielsen, 1943)
Pl. 7, figs. 13-16.

compare
*1943 *Ravniaster planus* Brünnich Nielsen, p. 51, pl. 3, figs. 10-13.
1950 *Metopaster planus* (Br. Nielsen) — Rasmussen, p. 48, pl. 5, fig. 11 (cum syn.).

Type — Lectotype, designated by Rasmussen (1950), is MGUH 4134.

Material — A number of isolated superomarginals, including NHMM JJ 11148/a-c.

Description — Of this small species, marginals have a rather indistinct depressed narrow border (Pl. 7, fig. 15), and a central area with fairly large granule pits. Lateral surface steep, rather abruptly rounded into aboral surface with slight swelling over its entire length. Proximal articulation facet is particularly small and inconspicuous, with a prominent articulation ridge. An enlarged inferomarginal corresponded to the ultimate superomarginal, and distally, one (or two) very much smaller inferomarginal ossicles (see Rasmussen, 1950, pl. 5, fig. 11c, e). Median supero- and inferomarginals have not been recognised in the present material, but are presumed to be very low and diminutive.

Discussion — Rasmussen (1950, p. 49) noted that this was a small and poorly known species, of which no articulated remains had yet been found. The present material appears to differ slightly from the Danish specimens in that the ultimate supero- and/or inferomarginals appear to be consistently longer and more rounded in outline, and with an even smaller proximal articulation facet. For this reason, assignment to *M. planus* is tentative.

Occurrence — Apparently confined to the lower Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 1B).

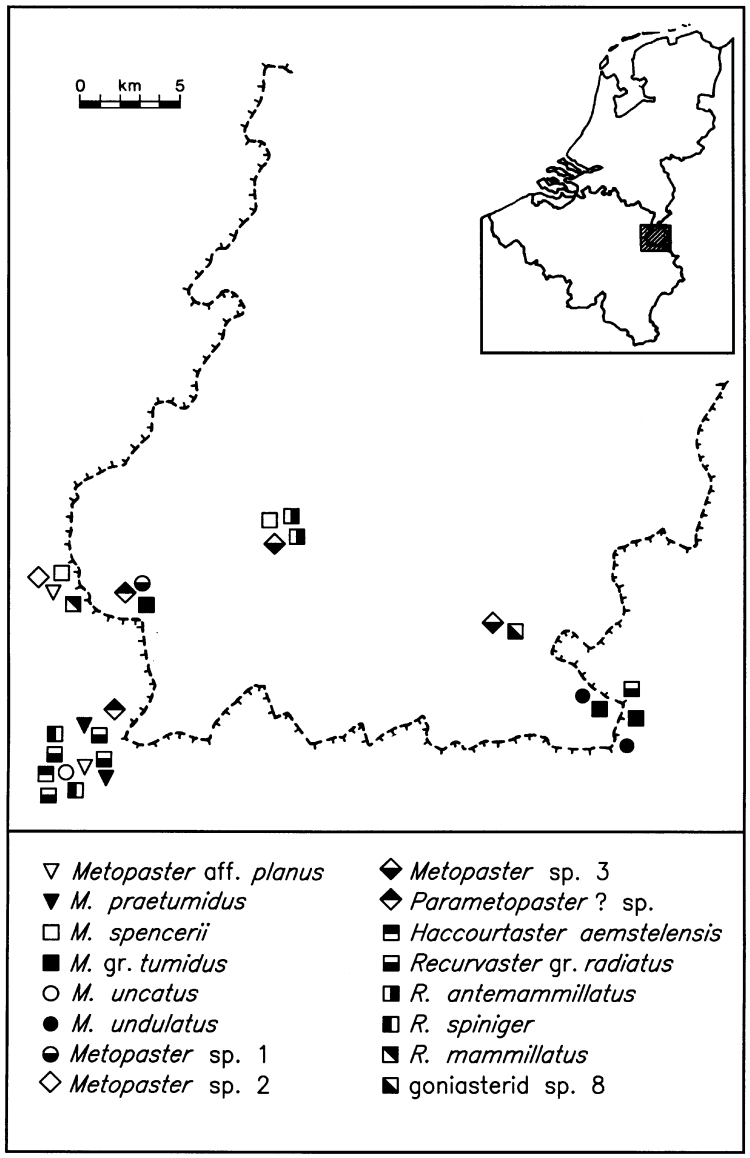


Fig. 1B. Geographic distribution of Late Cretaceous-Early Palaeogene asteroids in the type area of the Maastrichtian Stage.

Metopaster praetumidus Schulz & Weitschat, 1975
Pl. 7, figs. 11-12?; Pl. 11, figs. 3, 5-9, 18-19.

1941 *Metopaster tumidus* Spencer — Wright & Wright, p. 233, pl. 13, fig. 13; pl. 16, fig. 6, non text-fig. 6.
*1975 *Metopaster praetumidus* Schulz & Weitschat, p. 257, pl. 24, figs. 2-3.
1987a *Meteopaster* [sic] *tumidus* Spencer 1913 — Gale, p. 37 (partim), pl. 4, figs. 5-12.
1987 *Metopaster tumidus* Spencer — Wright & Smith, p. 213, pl. 47, fig. 3.

Type — Holotype is SGPIH 1761.

Material — A number of isolated (ultimate supero)marginals, including NHMM JJ 5125, 7782, K 1364, MB 233/a, 776/a, 868-5/a, and RGM 428 067. RGM 428 073 may also belong here.

Description — Small to medium-sized species, of which ultimate superomarginals are comparatively low and short, with an aboral swelling, and scattered granule pits which may lack from the lateral and aboral margins of the central area. Median superomarginals (Pl. 11, fig. 3; Pl. 11, figs. 18-19) show the same aboral swelling, and gently curved lateral margin. Here granule pits are largest on the aboral swelling, and tend to disappear near the aboral margin (Pl. 11, fig. 18).

Discussion — Although some specimens (e.g. Pl. 11, fig. 9) are closely similar to *M. tumidus* (Pl. 11, figs. 16-17), most have a considerably smaller ossicular angle, and are assigned to *M. praetumidus*. This species was originally recorded from the lower Upper Campanian (*stobaei/basiplana* Zone) of Lägerdorf (NW Germany), and subsequent records are from the *stobaei/basiplana* or *vulgaris* zones of the Hannover area (Germany; see Frerichs, 1997). Despite the fact that Gale (1987a, p. 38) remarked that in the Campanian, *M. tumidus* (including *M. praetumidus* as here understood; see synonymy above) did not attain the large size of Maastrichtian specimens, and that the smaller size and less well-developed aboral tumidity on superomarginals were size dependent. Consequently, that author thought that, on this basis, there was no justification for retaining *M. praetumidus* as a separate species.

However, in the absence of material of latest Campanian and earliest Maastrichtian age from the Maastrichtian type area, *M. praetumidus* and *M. tumidus* are considered to be distinct species, at least for the time being.

Isolated superomarginals may be distinguished from those of the co-occurring *Recurvaster* gr. *radiatus* (see below; Pl. 11, fig. 4) by their steeper lateral surface and more pronounced aboral swelling.

Occurrence — Apparently restricted to the Zeven Wegen Member (Gulpen Formation) with records from the CPL SA and CBR-Lixhe quarries (Figs. 1B, 2-3).

Metopaster spencerii Brünnich Nielsen, 1943
Pl. 25, figs. 1-9.

*1943 *Metopaster spencerii* Brünnich Nielsen, p. 35, pl. 1, figs. 16-17; pl. 2, fig. 1.
1950 *Metopaster spencerii* Br. Nielsen — Rasmussen, p. 46, pl. 5, figs. 5-8; text-fig. 4j.
1987a *Metopaster spencerii* Nielsen 1943 — Gale, p. 26, pl. 4, fig. 4.
1999c *Metopaster spencerii* — Jagt, pl. 2, fig. 17.

Type — Lectotype, by subsequent designation of Rasmussen (1950), is MGUH 4108.

Material — Numerous isolated (ultimate supero-)marginals in various collections, including NHMM JJ 2926, 4432, 4743, 5648, MM 1212, and RGM 428 064.

Description — Of the present species, so far only dissociated ossicles have been collected, and no articulated remains. However, from associated ossicles it is possible to reconstruct (Pl. 25, figs. 1-2) the species, and show it to have had slightly concave sides and conspicuously recurved ultimate superomarginals. The number of superomarginals in each side of the arm cannot be determined, but is likely to have been

either three or four. Ultimate superomarginals from the Geulhem Member are surprisingly uniform, given the wide range of variation that characterises 'populations' from the Lower Danian Bryozoan Limestone of Stevns Klint (Denmark; see e.g. Gale, 1987a, pl. 4, fig. 4, and Pl. 11, figs. 5-6 here). Most specimens conform to the ones illustrated by Rasmussen (1950, pl. 5, figs. 7-8). Ornament consists of scattered granule pits, which may be lacking on the lateral surface, near the lower margin, which is steep; a depressed border is rarely developed. The aboral swelling is conspicuous. The proximal articulation facet is deeply concave, small, triangular, and bordered by a prominent ridge. Median superomarginals either have parallel sides (Pl. 25, fig. 8) or are asymmetric (Pl. 25, fig. 4), have a conspicuous central swelling which may extend from the lower lateral surface to the aboral margin, with large granule pits especially aborally. The length of these ossicles exceeds the width and height (Pl. 25, figs. 4, 9). The same holds true for the inferomarginals (Pl. 25, fig. 3) which are as long as the corresponding superomarginals, and show a flat, even concave outer face with granule pits occupying the central area only.

Discussion — Although this is a variable species, the unique structure of the marginal ossicles precludes confusion with co-occurring species of the genus.

Occurrence — Restricted to the lower Geulhem Member (Houthem Formation), with records from the temporary Albertkanaal sections (Vroenhoven-Riemst), and the Ankerpoort-Curfs quarry (Figs. 1B, 9).

Metopaster gr. *tumidus* Spencer, 1913
Pl. 10, figs. 4-7; Pl. 11, figs. 15-17.

*1913 *Metopaster tumidus* Spencer, p. 113, pl. 10, fig. 8; pl. 14, figs. 1-2; pl. 15, fig. 1.
1950 *Metopaster tumidus* Spencer — Rasmussen, p. 33, pl. 4, figs. 1-5; text-fig. 4c-d.
1971 *Metopaster tumidus* Spencer 1913 — Schulz & Weitschat, p. 113 (partim), pl. 24, figs. 1-6.
1975 *Metopaster tumidus* Spencer, 1913 — Schulz & Weitschat, p. 258, pl. 24, fig. 4.
1987a *Meteopaster* [sic] *tumidus* Spencer 1913 — Gale, p. 37 (partim).
1999c *Metopaster tumidus* — Jagt, pl. 2, fig. 21.

Type — Holotype is BMNH E 13266; paratypes are BMNH E 13265, 13267-13273.

Material — A number of isolated marginals, including NHMM JJ 3992, 9465a, 9552, 11120/a-b, K 2200, and MB 1239-22/a-b.

Description — Grouped under this heading are specimens such as the ones from the Vijlen Member (Pl. 11, figs. 15-17), which shows the species to have been medium to large sized, with tall superomarginals, and a prominent aboral swelling, and short ultimate superomarginals. Material from the basal Valkenburg Member (Pl. 10, figs. 4-7) differs in being still shorter, less tall, with a gently curved (i.e. less steep) lateral surface, a less conspicuous aboral swelling, but otherwise similar ornament of scattered granule pits, and a well-developed narrow border. Four to five inferomarginal ossicles correspond to an ultimate superomarginal. Except for the lateral profile, these ossicles closely resemble the one illustrated by Rasmussen (1950, pl. 4, fig. 3b). Some specimens of *Metopaster poulsenii* Brünnich Nielsen, 1943 (see e.g. Rasmussen, 1950, pl. 1, fig. 9, holotype MGUH 4095), originally described from the upper Upper Maastrichtian of Stevns Klint (Denmark), are similar as well. *Metopaster tumidus* and *M. poulsenii* are very similar, with the former probably having evolved from *M. hunteri*

(see Gale, 1987a, p. 34). The main difference lies in the fact that *M. tumidus* has four superomarginals in each side of the arm, and *M. poulsenii* three. As long as no articulated specimens are known from the Maastrichtian type area, specimens of Late Maastrichtian age are here grouped under *M. tumidus* as well.

Discussion — The short, tall ultimate superomarginals with well-delimited central area and scattered granule pits, as well as the aboral swelling, distinguish this species (group) from congeners.

Occurrence — Present records of *M.* gr. *tumidus* include the (lower) Vijlen Member (Gulpen Formation) of Mamelis-Selzerbeek and the Aachen city area, and the basal Valkenburg Member (Maastricht Formation) at the ENCI-Maastricht BV quarry only (Figs. 1B, 6).

Metopaster uncatus (Forbes, 1848)
Pl. 11, fig. 12-14.

*1848 *Goniaster (Goniodiscus) uncatus* Forbes, p. 472.
1975 *Metopaster uncatus* (Forbes, 1848) — Schulz & Weitschat, p. 259, pl. 25, figs. 1-5 (cum syn.).
1987a *Metopaster uncatus* (Forbes 1848) — Gale, p. 39, pl. 5, figs. 5-20; pl. 6, figs. 1-7; text-figs. 13-14 (cum syn.).
1987 *Metopaster uncatus* (Forbes) — Wright & Smith, p. 213, pl. 47, fig. 7.
1992a *Metopaster uncatus* (Forbes, 1848) — Breton, p. 128, pls. 6-7; pl. 8, figs. 1-7; text-figs. 19, 24, 30, 48-55 (cum syn.).

Type — BMNH unknown (Gale, 1987a, p. 40).

Material — Two isolated marginals, NHMM MB 776/b and 868-5/a.

Description — From the (lower) Zeven Wegen Member at the CPL SA quarry (Haccourt), a single ultimate superomarginal (Pl. 11, fig. 14) and a median superomarginal (Pl. 11, figs. 12-13) are available. These show a moderately well-defined central area which lacks granule pits, an aboral swelling and rugosities (Pl. 11, fig. 12). The sides in the median superomarginal are straight, the width exceeding the length. Rugosities on the aboral central surface vary considerably in definition and density, as remarked by Gale (1987a, p. 40). The shape of the ultimate superomarginal in *M. uncatus* appears to vary considerably as well. The present specimen compares well with material figured by Gale (1987a, pl. 6, fig. 17), also of Late Campanian age.

Discussion — The absence of granule pits, and the occurrence of rugosities, distinguish this form from co-occurring congeners.

Occurrence — Exclusively known from the (lower) Zeven Wegen Member (Gulpen Formation) of the CPL SA quarry (Figs. 1B, 2).

Metopaster undulatus Spencer, 1913
Pl. 8, fig. 5; Pl. 24, figs. 1-7.

*1913 *Metopaster undulatus* Spencer, p. 118, pl. 10, figs. 19-20; pl. 15, figs. 20-24.
*1943 *Metopaster granulatus* Brünnich Nielsen, p. 32, pl. 1, fig. 12.
1950 *Metopaster undulatus* Spencer — Rasmussen, p. 40, pl. 3, figs. 15-16; text-fig. 4h.
1953 *Metopaster undulatus* W.K. Spencer — Müller, p. 55, pl. 8, figs. TT-WW.
1975 "*Metopaster*" *undulatus* Spencer, 1913 — Schulz & Weitschat, p. 267, pl. 27, figs. 4-5 (cum syn.).
1975 *Metopaster rugatus* (Forbes, 1848) — Schulz & Weitschat, p. 260, pl. 25, figs. 8-9 (cum syn.).

1987a *Metopaster undulatus* Spencer 1913 — Gale, p. 39, pl. 5, fig. 1 (cum syn.).
1999c *Metopaster undulatus* — Jagt, pl. 2, fig. 7.

Types — Holotype of *M. undulatus* is BMNH E 13274; paratypes are BMNH E 13275-13278; holotype of *M. granulatus* is MGUH 4104.

Material — A number of isolated marginals, including NHMM JJ 9466, MB 1239-22/x-z, and 1239-22/aa-bb.

Description — A small species, with broad median marginals with a swelling on the lateral margin (Pl. 24, figs. 3-5), and a short ultimate superomarginal (Pl. 24, figs. 1-2, 6-7), with a strongly curved lateral margin (Pl. 24, fig. 2), and an outer surface with granule pits of subequal size (Pl. 24, fig. 1). The lateral swelling shows large, deep granule pits, which decrease in size towards the margins of the flattened to slightly convex outer face, and there are interspersed with rugosities of varying size (Pl. 24, fig. 1).

Discussion — Gale (1987, p. 39) noted that this was a well-characterised species which displayed little variation in marginal shape and ornament. Material illustrated here compares well with specimens from the upper Lower Maastrichtian of Rügen (NHMM JJ 5430).

Occurrence — Known only from the Vijlen Member (Gulpen Formation), with records from Mamelis-Selzerbeek and the Aachen city area (Hans Böckler Allee) (Fig. 1B).

Metopaster sp. 1
Pl. 24, figs. 18-19?; Pl. 26, figs. 2, 6-7.

Material — NHMM JJ 10534/a-b; K 745 may belong here as well.

Description and discussion — Co-occurring with *M. miriamae* sp. nov. (see above) are superficially similar ultimate superomarginals. In specimens of comparable size, the latter have 3-4 inferomarginals corresponding to an ultimate superomarginal, and these decrease in size distally, rather than one large and a much smaller ossicle as in *M. miriamae* sp. nov. These ossicles have a steep lateral surface and a well-developed narrow border, especially proximally and along the inner aboral margin, and show close-set granule pits. The possibility that these could represent juvenile specimens of *M. alexiae* (see above, and Pl. 26, fig. 3) can be refuted, on the basis of the height and width of the proximal articulation facet.

Occurrence — Currently known from the Meerssen Member (Maastricht Formation) of the ENCI-Maastricht BV quarry (Figs. 1B, 6). NHMM K 745 is from the Meerssen Member (IVf-4) of the Blom quarry.

Metopaster sp. 2
Pl. 24, fig. 17.

Material — A single ultimate superomarginal, NHMM MB 432-74/t.

Description and discussion — Although apparently close to material referred above to as *M.* aff. *planus*, in showing a poorly delimited central area, comparatively large and widely scattered granule pits, and one large (reaching halfway the length) and a

smaller inferomarginal ossicle corresponding to it, this specimen has six, subequal, blunt protuberances on an aboral swelling. This may be individual variation, but as long as but a single specimen is available, it is best left in open nomenclature.

Occurrence — Upper Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Kesselt) (Fig. 1B).

Metopaster sp. 3
Pl. 10, figs. 14-15; Pl. 12, figs. 18-19.

Material — Two ultimate superomarginals, NHMM MB 784-21/b, and 865-9/a.

Description and discussion — These specimens are longer than wide, low, with an evenly curved outer face, a fairly well-delimited central area, covered by close-set, small granule pits, and a slight swelling along the junction of the lateral and adoral surface. Three inferomarginals, decreasing evenly in size distally, correspond to these ultimate superomarginals.

Amongst Campanian-Maastrichtian congeners, I could find no match, so that the specimens will have to remain in open nomenclature.

Occurrence — Known from the Benzenrade Member (Vaals Formation) of de Wingerd quarry, and from the Meerssen Member (Maastricht Formation, IVf-4) of Blom quarry (Berg en Terblijt) (Figs. 1B, 8).

Metopaster sp. 4 (aff. *elegans* Gale, 1987a)
Pl. 10, figs. 16-17.

compare
*1987a *Metopaster elegans* Gale, p. 28, pl. 8, fig. 24; pl. 9, figs. 1-3; text-fig. 10/3.

Material — A single ultimate superomarginal, NHMM MB 724-21/c.

Description and discussion — Comparable to *M. elegans*, a species recorded from the upper Lower Campanian of southern Sweden, is the even cover with closely spaced fine granule pits on the outer face. However, rather than being long and narrow, with a decrease in height to a rounded distal termination, the present ultimate superomarginal is almost as long as wide. Moreover, there is a central area in the present form, the border being comparatively narrow but well developed. Four inferomarginals, rapidly decreasing in size distally, correspond to this ultimate superomarginal.

The nature of the close-set, fine granule pits immediately distinguishes this form from congeners, but with only a single specimen available, it will have to remain in open nomenclature.

Occurrence — Known from the Meerssen Member (Maastricht Formation, IVf-4) of Blom quarry (Berg en Terblijt) (Figs. 1D, 8).

Indeterminate goniasterine species

Illustrated here are also a number of isolated marginals representing the typical *Metopaster/Recurvaster* morphology, which cannot at present be assigned to species. They are added to illustrate goniasterine diversity; more material is needed to be cer-

tain about their proper assignment. Such ossicles include NHMM JJ 11147/a (Pl. 12, fig. 13), JJ 3992 (Pl. 12, figs. 14-15), MB 432-74/i-k (Pl. 19, figs. 12-14), JJ 10536 (Pl. 24, figs. 20-21), and MB 339-8/b (Pl. 25, figs. 10-11). The ossicle in Pl. 18, figs. 18-19 (K 1343) may belong to a small-sized goniasterine, of unknown affinity.

Genus *Parametopaster* Breton, 1992a

Type species — Parametopaster fournieri Breton, 1992a, by original designation.

Parametopaster? sp.
Pl. 10, figs. 1-2.

Material — Two ultimate superomarginals, NHMM K 2762 and MB 385-6/a.

Description — The larger specimen is markedly longer than wide, has an indistinct narrow border; prominent aboral swelling, and steep lateral face which is concave between the tumid aboral face and the distal margin. Up to six inferomarginals correspond to this ultimate superomarginal, and decrease gradually in size distally. The proximal articulation facet is concave aborally, and has a distinct ridge. Ornament consists of very close-set, shallow granule pits, which show a tendency to coalesce into undulose patterns. The smaller ossicle is comparable in structure, has a similar ornament, but also has a fairly large, spine-like protuberance near the distal margin.

Discussion — For the time being, these specimens are distinguished from co-occurring *M. lisannae* (see above), in that they have close-set granule pits, which in places coalesce, and lack the typical coarse granulation of the latter. This type of ornament recalls that of the type species of *Parametopaster*, *P. fournieri* (see Breton, 1992a, fig. 81, pl. 19, figs. 1-7; text-figs. 81-84), but in the absence of the typical elongate pedicellariae of that genus, assignment is tentative at best.

Occurrence — Known only from the upper Nekum Member (Maastricht Formation) at Ankerpoort-Marnebel quarry (Eben Emael), and the basal Meerssen Member of the St Pietersberg-Zonneberg, Maastricht (Figs. 1B, 4).

Genus *Haccourtaster* gen. nov.

Type species — Haccourtaster aemstelensis sp. nov., by monotypy.

Derivation of name — After the village of Haccourt (Liège, Belgium), near the CPL SA quarry.

Diagnosis — A small, short-lived offshoot of *Metopaster* characterised by arched median marginals and short, enlarged ultimate superomarginals, all with a well-delimited central area bearing an ornament of highly subequal spine pits, and circular, irregularly distributed deep pits (?pedicellariae); distal and proximal articulation facets reduced, the internal face showing deep depressions on both sides of reduced intermarginal facet.

Haccourtaster aemstelensis sp. nov.
Pl. 27, figs. 1-6.

1999c '*Parametopaster*' (sp. nov.?) — Jagt, pl. 2, fig. 10.

Types — Holotype is NHMM MB 1044-6/c (Pl. 27, figs. 1, 6); paratypes are 1044-6/d-f.

Type locality and horizon — CPL SA quarry, Haccourt (Liège, Belgium), basal Zeven Wegen Member (Gulpen Formation).

Derivation of name — In honour of Professor Gijsbert J. Boekschoten (Vrije Universiteit, Amsterdam), with reference to Dutch poet and playwright Joost van den Vondel's (1587-1679) famous work, *Gijsbreght van Aemstel* (1637).

Diagnosis — As for genus.

Material — In addition to the types, a number of isolated marginals in sample NHMM MB 1044-6.

Description — Only isolated supero- and inferomarginal ossicles are known. Ultimate superomarginals (Pl. 27, figs. 1, 4, 6) are slightly longer than wide, broadly triangular in outline, and with more or less straight lateral margin and evenly convex aboral face. Central area not well delimited, an extremely narrow zone lines the margin. Rugosities occur near the inner aboral margin; distal aboral swelling moderate. Ornament consists of close-set granule pits, (near)equal in size on the lateral surface, but much larger and more or less crater shaped on the lateral/aboral junction as well as distally (Pl. 27, figs. 1, 4, 6), occasionally arranged in a row. Interspersed are deep, subcircular to elliptical pits (?pedicellariae), scattered over the ossicle. The proximal articulation facet is weakly concave, and bordered by two ridges which run (near)parallel to the outer face. Of note, is the indentation on this articulation surface, which reduces the area of intermarginal facet. Three or four inferomarginal ossicles correspond to a single superomarginal.

Median infero- and superomarginals have near-parallel sides and an evenly curved, flat outer face, which bears the same ornament, but apparently with more numerous deep (?pedicellarial) pits than the ultimate superomarginals (see e.g., Pl. 27, fig. 2). The flat intermarginal facet is much reduced, with only a triangular 'portion' remaining, bordered on either side by deep excavations (Pl. 27, figs. 3, 5). Inferomarginal have a larger ossicular angle than superomarginals, but are otherwise closely comparable.

Discussion — From co-occurring *Metopaster decipiens* (see above), the present form is easily distinguished. Ornament and pedicellariae in the former are different. Amongst other goniasterine asteroids, there is none which could be confused with the present form. Despite the fact that only isolated ossicles are known, it appears warranted to erect a new genus and species for it, in view of its distinctive ornament and marginal structure. Like *Parametopaster* Breton, 1992a, this genus appears to be a (?short-lived) offshoot of the main *Metopaster* lineage.

Occurrence — Confined to the basal Zeven Wegen Member (Gulpen Formation), and known only from the CPL SA quarry (Haccourt) (Figs. 1B, 2).

Genus *Recurvaster* Brünnich Nielsen, 1943

Type species — *Recurvaster stevenensis* Brünnich Nielsen, 1943, by original designation = *Metopaster tumidus radiatus* Spencer, 1913.

Recurvaster antemammillatus sp. nov.
Pl. 25, figs. 12-23; Pl. 26, figs. 1, 4-5.

1999c *Recurvaster* sp. nov. — Jagt, pl. 2, figs. 23-24.

Types — Holotype is NHMM K 1424/d (Pl. 25, figs. 18-19); paratypes are 1424/a-c, e-i.

Type locality and horizon — Blom quarry, Berg en Terblijt; Meerssen Member, Maastricht Formation (IVf-6).

Derivation of name — Latin *ante*, meaning before, to denote the relationship with its possible descendant, *R. mammillatus* (Gabb, 1876) (see below).

Diagnosis — Medium-sized species with tall, asymmetric median superomarginals, with well-delimited central area covered by close-set granule pits, an aboral swelling, and rather low, squat inferomarginals with the same ornament.

Material — In addition to the types, NHMM MB 108-8, 377-23/f, and ?1299-8/a.

Description — Sample NHMM K 1424 from the upper Meerssen Member of Blom quarry contains some twenty marginal ossicles, both median and distal, which apparently stem from a single individual. A median superomarginal (SM2 ?) is selected as the type of this new form, which seems to be the direct precursor of *R. mammillatus*. It differs from that species in having even taller superomarginals, markedly asymmetric in median ossicles, but with parallel sides in distal ossicles, a less conspicuous aboral swelling, and in lower inferomarginals, with a more acute ossicular angle. Ornament consists of a well-delimited, raised central area, with close-set granule pits, on all ossicles available. More distal supero- and inferomarginals are asymmetric, have a narrow lateral surface and show the arms to have been recurved, the height of adjacent marginals decreasing evenly in size distally. Distal and proximal facets are concave, with the articulation ridge stout, and particularly wide in median ossicles.

Discussion — The closest relative of the present species appears to be *Goniaster mammillatus* Gabb, 1876 (p. 178, pl. 5, fig. 2, 2b, non 2a), originally described from the Vincentown Sands of New Jersey (USA). Rasmussen (1950, p. 66, pl. 8, figs. 3-13; pl. 9, fig. 4) followed Brünnich Nielsen (1943) in assigning it to *Recurvaster*. Material illustrated by Spencer (1913, p. 114, pl. 10, fig. 16; pl. 15, figs. 8-10) illustrates the abovementioned differences between *R. antemammillatus* and *R. mammillatus* well. The latter species ranges through the Danian of Denmark, and extends into the Thanetian (Late Palaeocene) of New Jersey.

Occurrence — Apparently confined to the middle/upper Meerssen Member (IVf-3 to IVf-6, Maastricht Formation), with records from the Blom quarry and possibly from the Geulhemmerberg section (Figs. 1B, 8).

Recurvaster mammillatus (Gabb, 1876)
Pl. 11, figs. 20-21; Pl. 12, fig. 20?.

*1876 *Goniaster mammillatus* Gabb, p. 178, fig. 2, 2b (non 2a).
1943 *Recurvaster mammillatus*. (Gabb.) — Brünnich Nielsen, p. 43, pl. 2, figs. 10-14.
1950 *Recurvaster mammillatus* (Gabb) — Rasmussen, p. 66, pl. 8, figs. 3-13; pl. 9, fig. 4.

Type — Rasmussen (1950, p. 66) considered the inferomarginal illustrated by Gabb (1876) to be the holotype; its present whereabouts is unknown.

Material — A few marginals, including NHMM MB 339-8/a; JJ 11147/c may also belong here.

Description — Although comparatively small, the median superomarginal illustrated here (Pl. 11, figs. 20-21) matches material illustrated by Rasmussen (1950) in being relatively tall and with a conspicuous aboral tumidity. However, the granule pits are apparently coarser than in the Danish material. Whether or not this can be ascribed to variation remains to be determined on the basis of additional material from the Geulhem Member.

Discussion — There is little to add to Rasmussen's (1950) detailed description of this species, and it is his interpretation that is followed here.

Occurrence — Isolated inferomarginals from the lower Geulhem Member (Houthem Formation) such as the one illustrated in Pl. 12, fig. 20, could prove to belong to *R. mammillatus* as well. Currently, it is known only from the temporary Albertkanaal sections at Vroenhoven-Riemst (Fig. 1B).

Recurvaster gr. *radiatus* (Spencer, 1913)
Pl. 11, figs. 1-2, 4; Pl. 12, figs. 5-6.

*1913 *Metopaster tumidus* var. *radiatus* Spencer, p. 113, pl. 14, fig. 3; pl. 15, figs. 3-5.
1950 *Recurvaster radiatus* (Spencer) — Rasmussen, p. 57, pl. 7; pl. 8, figs. 1-2; pl. 9, figs. 1-3; text-figs. 1-2.
?1971 *Metopaster* sp. — Schulz & Weitschat, p. 115, pl. 24, figs. 7-8.
1975 *Recurvaster* cf. *radiatus* (Spencer, 1913) — Schulz & Weitschat, p. 263, pl. 26, fig. 5.
1987a *Recurvaster radiatus* (Spencer 1913) — Gale, p. 44, pl. 9, figs. 7-10 (with additional synonymy).

Type — Holotype is SM B48513.

Material — A limited number of isolated marginals, including NHMM JJ 4754, 4907, 4920, 5124, 6810, 8769, MB 639-2/b, 1239-22/c-d, and RGM 428 068.

Description — This large species of *Recurvaster*, the type of the genus, typically has strongly tumid superomarginals which have numerous, deep granule pits, and differs from its precursor *R. blackmorei* Rasmussen, 1950 (p. 64, pl. 6, figs. 1-7; Lower Campanian, holotype is BMNH E 13933), in its consistently larger size. Gale (1987a, p. 44) pointed out that most of the morphological differences between fully-grown individuals of *R. radiatus* and *R. blackmorei* were allometric consequences of this size difference. However, *R. radiatus* does seem to have slightly more tumid proximal superomarginals with deeper, more numerous granule pits on markedly reduced central areas. Material illustrated here from the Zeven Wegen (Pl. 11, figs. 1-2, 4) and Vijlen (Pl. 12, figs. 5-6) members shows proximal superomarginals to be tumid aborally, with well-delimited central area, but with granule pits more or less restricted to the tumid portion of the ossicle. Inferomarginals either have a dense cover of granule pits, or appear virtually smooth.

Discussion — *Recurvaster radiatus* was erected for material of Early Maastrichtian age. As noted by Gale (1987a, p. 45), isolated *Recurvaster* ossicles are common in the mucronata Zone chalk of Norfolk, particularly in the Weybourne Chalk, and in correlative strata in Germany (see Schulz & Weitschat, 1975). According to those authors,

the Late Campanian material would be transitional between *R. blackmorei* Rasmussen, 1950, and *R. radiatus* (see also Gale, 1987a, p. 45, pl. 9, figs. 4-6).

Material from the Zeven Wegen and Vijlen members is almost identical, which is why it is here referred to as a group.

Occurrence — Known with certainty only from the Zeven Wegen and (lower) Vijlen members (Gulpen Formation) with records from Heure-le-Romain, the CPL SA (Haccourt) and CBR-Lixhe quarries, and from Mamelis-Selzerbeek (Figs. 1B, 2-3).

Recurvaster spiniger sp. nov.
Pl. 12, figs. 1-4, 7-12, 16.

Types — Holotype is NHMM K 769 (Pl. 12, figs. 1-2); paratypes are MB 284-1/a-d, and 867-7/a-b.

Type locality and horizon — CPL SA quarry, Haccourt (Liège), Vijlen Member (Gulpen Formation), base + c. 4 m.

Derivation of name — Lat. *spiniger*, meaning thorny or spiny, in reference to the large spine bases on proximal superomarginals and proximal and distal inferomarginals.

Diagnosis — Medium- to large-sized species, based on isolated marginals only, with proximal superomarginals having a sloping lateral profile, gently curved outer face with two large spine bases, one on an aboral tumidity, directed obliquely upwards, the other near the intermarginal margin, and directed outwards. Ornament consisting of close-set granule pits on well-demarcated central area. Distal superomarginals with almost flat lateral/aboral surfaces, lacking spines, and with granule pits either covering entire central area, or leaving out portions of it. Proximal and distal inferomarginals short, square or wedge-shaped, with a single large crater-shaped spine pit (directed downwards) placed centrally or slightly towards inner margin.

Material — In addition to the types, a few isolated marginals, including JJ 2644, 3621, and MB 1221-3.

Description — A medium- to large-sized species, with proximal superomarginals (Pl. 12, figs. 1-2) having a strongly sloping lateral profile, gently curved outer face with two large spine bases, one on an aboral tumidity, directed obliquely upwards, the other near the intermarginal margin, and directed outwards. The ornament consists of close-set granule pits on well-demarcated central area. Distal superomarginals have almost flat lateral/aboral surfaces, lack spines, and show granule pits to cover either the entire central area, or just portions of it. Proximal and distal inferomarginals are short, squat or wedge-shaped, with a single large crater-shaped spine pit (directed outwards/downwards), either placed centrally or closer to the intermarginal margin. Other ossicle types have not been recognised yet.

Discussion — So far, only a single spine-bearing species of *Recurvaster* has been described in the literature. From the upper Lower Maastrichtian of Hemmoor (NW Germany), Schulz & Weitschat (1971, p. 116, pl. 24, figs. 10-17) described their new species, *R. gibber*, noting that median superomarginals were strongly tumid aborally, with numerous large granule pits, and a large inferomarginal ossicular angle of c. 75°. In this form, median and dorsal inferomarginals do not bear spines. Additional material of *R. gibber* of late Early and early Late Maastrichtian age, described and illustrat-

ed by Schulz & Weitschat (1975, p. 264, pl. 26, figs. 6-7), allowed the species to be characterised more fully. The new specimens are all smaller than the holotype (SGPIH 1355), and according to those authors, a good differential feature would be the presence of large spine pits on the distal inferomarginals, from IM 9 or 10 onwards. In a few specimens, such spine pits are also found on distal superomarginals.

Recurvaster spiniger differs from *R. gibber* in having smaller supero- and inferomarginal ossicular angles, lower inferomarginals, and large spine pits developed on proximal superomarginals (SM1-2 ?) as well as on proximal and distal inferomarginals. Moreover, distal inferomarginals are distinctly wedge shaped, suggesting the arms to have been short, but strongly recurved.

Like *R. gibber*, the new species could represent a short-lived offshoot of the main *R. blackmorei-radiatus* lineage, by ?reduction of the number of marginals and extension of spine pits onto the proximal disc portion.

Gale (1987a, p. 45) opined that *R. gibber*, since it co-occurred with typical *R. radiatus*, and could thus not be separated either stratigraphically or geographically, did not warrant specific status.

Occurrence — Currently known only from the Vijlen (Interval 6) and Lixhe 1 members (Gulpen Formation) of the CPL SA (Haccourt) and CBR-Lixhe quarries (Figs. 1B, 2-3).

Genus *Nymphaster* Sladen, 1885

Type species — *Nymphaster protentus* Sladen, 1889, by subsequent designation of Fisher (1919).

Nymphaster alseni (Schulz & Weitschat, 1971)
Pl. 13, figs. 1-4.

*1971 *Chomataster alseni* Schulz & Weitschat, p. 119, pl. 25, figs. 20-29.
1975 *Chomataster alseni* Schulz & Weitschat, 1971 — Schulz & Weitschat, p. 279, pl. 31, fig. 7.
1987b *Nymphaster alseni* (Schulz and Weitschat 1971) — Gale, p. 165, pl. 5, figs. 2-9; text-fig. 3.3 (cum syn.).
1989 *Nymphaster alseni* — Gale, p. 286, figs. 2, 5-6.
1992a *Nymphaster alseni* (Schulz & Weitschat, 1971) — Breton, p. 287, pl. 35, figs. 1-6.
1999c *Nymphaster alseni* — Jagt, pl. 2, figs. 19-20.

Type — Holotype is the unregistered specimen in the Weitschat Colln (SGPIH collections), illustrated by Schulz & Weitschat (1971, pl. 25, figs. 20-29).

Material — NHMM MB 806-9, and JJ 8725/1-2.

Description — Only few ossicles which can be referred to this species without doubt have been recognised in the collections at hand. The interradial marginals in this species formed a vertical wall (see Schulz & Weitschat, 1971, pl. 25, fig. 21), consisting of six pairs of ossicles. Superomarginals are tall, narrow and tumid aborally. Swollen aborally are the large, wedge-shaped angle plates (SM3) (Pl. 13, figs. 1-2). The ornament consists of a dense cover of granule pits, which are largest on the aboral swelling of SM3 (Pl. 13, fig. 1). More distal omarginals have a single, (near-)centrally

placed spine pit at the junction of aboral and lateral faces.

Only the interradial and angle ossicles are easily distinguished from those of its congener, *N. studlandensis* (see below). Material illustrated here compares closely with specimens figured by Gale (1987b, pl. 5, figs. 4a-b, 7), and represents subadult and adult individuals.

Discussion — Gale (1987b, p. 165) diagnosed this species as follows, 'Large, arms sharply demarcated from disc, interradius straight or slightly curved, forming vertical wall; six tall, narrow interradial marginals present, strongly tumid aborally; wedge plates large, swollen; radial superomargionals each bear single crater-shaped spine pit.' That author (p. 165, fig. 3) also illustrated the ontogenetic variation, with smaller individuals having long, proportionately broad marginal ossicles; with increasing size, superomarginals become progressively steeper, taller and more tumid. *Nymphaster alseni* differs from its precursor, *N. studlandensis* (see below), in its greater size, and in the presence of large, crater-shaped pits on distal superomarginals, and from its descendant *N. peakei* Gale, 1987b (p. 166, pl. 5, figs. 9-12, 14; text-fig. 3.4; holotype BGS Yd 3985) in the absence of crater-shaped pits on proximal superomarginals. The latter species was first recorded from the Catton Sponge Beds (Upper Campanian) of Sheringham (Norfolk, England), and was based on dissociated ossicles only. Correlative strata ('Craie de Spiennes', upper Upper Campanian) in the Mons basin (southern Belgium) have recently yielded a portion of an articulated individual of *N. peakei* (L. Indeherberge Colln), a detailed description of which is under way (Jagt et al., in prep.).

Occurrence — *Nymphaster alseni* is apparently confined to the middle and upper portion of the Zeven Wegen Member (Gulpen Formation), with records from the CPL SA and CBR-Lixhe quarries (Figs. 1C, 2-3). Gale (1987b, p. 166) noted that this species occurred in the Weybourne Chalk (*mucronata* Zone, Upper Campanian) of Norfolk, while at Lägerdorf (Germany), it was recorded in the *vulgaris* and *minor-polyplocum* zones. *Nymphaster alseni* is the second member in the *studlandensis-alseni-peakei* lineage which characterises the upper Lower to upper Upper Campanian of NW Europe (Gale, 1989). As Gale (1989, fig. 2) showed, there is overlap in the proportional growth (height/width for interradial marginals) of *N. studlandensis* and *N. alseni*. This means that the present records of *N. studlandensis* from the middle/upper Zeven Wegen Member at the CPL SA and CBR-Lixhe quarries (see Figs. 2-3) could also refer to juvenile or subadult individuals of *N. alseni*.

Nymphaster spenceri (Rasmussen, 1950)
Pl. 13, figs. 9-15.

*1950 *Chomataster spenceri* Rasmussen, p. 81, pl. 10, figs. 13-14; text-fig. 6c.
1975 *Chomataster spenceri* H.W. Rasmussen, 1950 — Schulz & Weitschat, p. 281.

Type — Holotype is MGUH 7531.

Material — NHMM MB 1239-22/e-h.

Description and discussion — Of this species, a limited number of isolated marginals are available, and, although they are easily recognised, these ossicles do not contribute substantially to our knowledge of this still poorly known species. Rasmussen

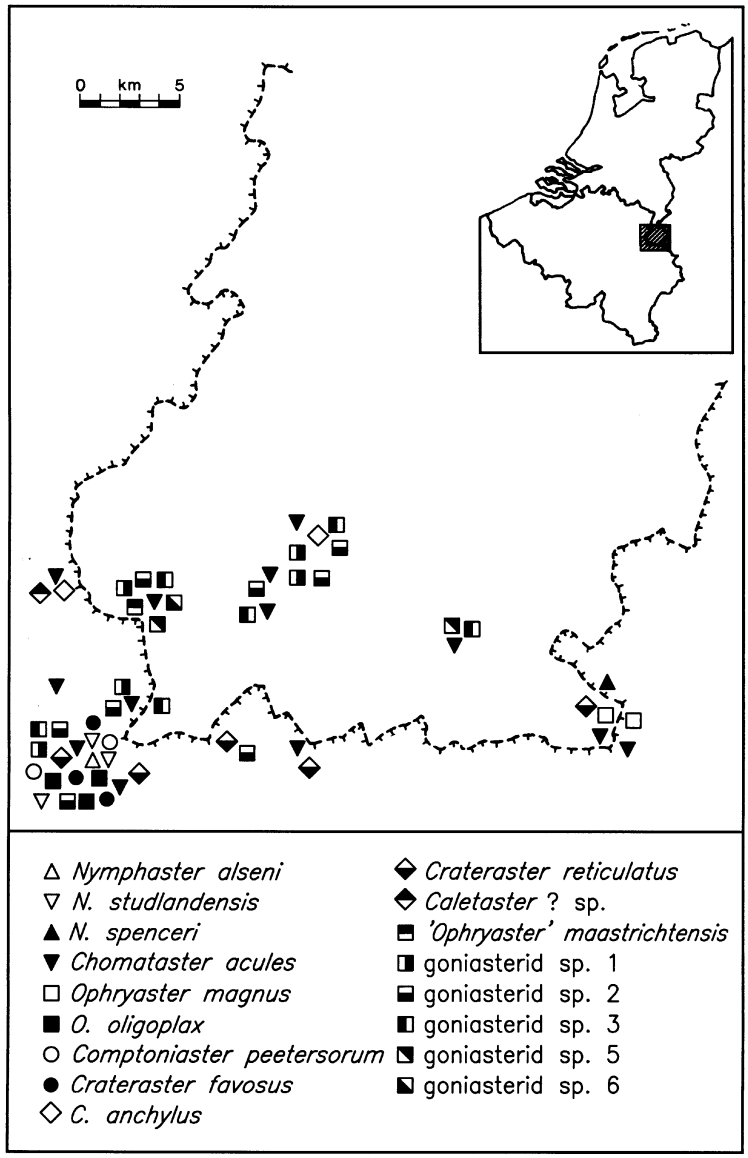


Fig. 1C. Geographic distribution of Late Cretaceous-Early Palaeogene asteroids in the type area of the Maastrichtian Stage.

(1950) noted that superomarginals have a low, but steep lateral surface (see Pl. 13, figs. 13-15) which passes sharply into the slightly tumid aboral surface, which bears an ornament of closely spaced granule pits. Schulz & Weitschat (1975, p. 281) interpreted the holotype of *N. spenceri* to be a proximal radial superomarginal, and noted that, with the exception of four articulated superomarginals from a distal arm portion, only isolated marginals had been found, so that neither body form nor the num-

ber of median (= interradial) superomarginals were known. They referred a single angle plate with a query to *N. spenceri*, noting that this was hardly wedge shaped, barely tumid, and had contacted the adjacent ossicle of the neighbouring interradius over nearly its entire length.

Schulz & Weitschat (1981, p. 281) are here followed in considering *N. spenceri*, which is close to the late Early to late Late Maastrichtian *N. wrighti* (Rasmussen, 1950) (p. 82, pl. 11, figs. 1-2; text-fig. 6d) of Denmark and northern Germany, and to *N. studlandensis* (see below), to be a descendant of *N. rectus* (Schulz & Weitschat, 1975) (p. 277, pl. 31, figs. 1-3), rather than of *N. studlandensis*. These authors (see also their fig. 4) noted isolated superomarginals from the upper Upper Campanian (Beeston Chalk) of Norfolk to be much closer to *N. spenceri* than to *N. studlandensis*. It should be noted that Gale (1987b, p. 161, pl. 2, figs. 3-5; text-fig. 3.1) synonymised *N. rectus* with *N. humilis* (Schulz & Weitschat, 1975) (p. 275, pl. 29, figs. 3-4) of Early Santonian to Early Campanian age.

Occurrence — Known exclusively from the lower Vijlen Member (Gulpen Formation) of Mamelis-Selzerbeek (Fig. 1C).

Nymphaster studlandensis (Schulz & Weitschat, 1975)
Pl. 13, figs. 7-8, 16-20.

*1975 *Chomataster studlandensis* Schulz & Weitschat, p. 278, pl. 31, figs. 4-6.
1987b *Nymphaster studlandensis* (Schulz and Weitschat 1975) — Gale, p. 163, pl. 4, figs. 11-15; pl. 5, fig. 1; text-fig. 3.2 (cum syn.).
1989 *Nymphaster studlandensis* — Gale, p. 286, figs. 2, 5-6.
1992a *Nymphaster studlandensis* (Schulz & Weitschat, 1975) — Breton, p. 286, text-fig. 120.
1999c *Nymphaster studlandensis* — Jagt, pl. 2, fig. 8.

Type — Holotype is BMNH Wright Colln, no. 9533.

Material — BMNH E 54300, NHMM 1994640, NHMM JJ 4882, 5123, 5960, 6159, 6370, 6581, and 7555a.

Description — In addition to a fragmentary, but well-preserved individual preserved in an erratic flint boulder (Pl. 13, figs. 18-20), the present collections include associated remains of at least three individuals from the lower Zeven Wegen Member at the CPL SA quarry. SM3 are wedge shaped and occupy the angles of the arms (see Pl. 13, fig. 19). Interradial superomarginals (e.g., Pl. 13, figs. 16-17) are as tall as broad in profile, with steeply inclined, evenly curved outer faces, and discrete lateral and aboral surfaces. Ornament on both supero- and inferomarginals consists of an even cover of closely spaced granule pits, largest in size on the aboral swelling of SM3, and NHMM 1994640 preserves quite a number of these granules. Distal superomarginals (e.g., Pl. 13, figs. 7-8) have a single, small crater-shaped pit, placed (near-)centrally on the aboral-lateral margin.

Discussion — Gale (1987b, p. 163) diagnosed this species as follows, 'Arms well demarcated from disc, interradius straight, made up of six pairs of marginals; interradial marginals short, tall, with steeply inclined outer face, slight aboral tumidity; angle plates wedge shaped.' Of a new specimen preserved as an external mould in flint (Pl. 13, figs. 18-20), which shows this typical features well, a silicone rubber mould was prepared. The use of silicone rubber in the study of fossil asteroids has

proved to be very productive (see e.g. Breton, 1992b). *Nymphaster studlandensis* is ancestral to *N. alseni* (Gale, 1987b, 1989), from which it differs in being smaller, and in lacking tall, tumid SM3. Gale (1987b, fig. 3; see also 1989, fig. 2) noted that during ontogeny, the interradial marginal ossicles increased in proportional height. For this reason, and assuming that there was no overlap in the stratigraphic ranges of *N. studlandensis* and *N. alseni* (compare Gale, 1989, fig. 6), material recorded from the middle Zeven Wegen Member at the CPL SA and CBR-Lixhe quarries (see Figs. 2-3) and here referred to *N. studlandensis* could equally well belong to juvenile and/or subadult individuals of *N. alseni*. In that case, *N. studlandensis* would be restricted to the lower 5-6 m of the Zeven Wegen Member, with *N. alseni* ranging throughout the remainder of that unit. This then would correspond well to the biozonation as based on coleoid cephalopods (see Jagt, 1999a, and Keutgen & Jagt, 1999, for details). Gale (1987b, p. 165) noted that *N. studlandensis* occurred in the upper Lower/lower Upper Campanian (*senior/gracilis* to *stobaei/basiplana* Zones) at Lägerdorf, and in the *mucronata* Zone of Studland Bay (Dorset, England), where it ranged up to 25 m beneath the top of the succession.

Occurrence — Confined to the lower Zeven Wegen Member (Gulpen Formation), with records from Heure-le-Romain, and the CPL SA and CBR-Lixhe quarries (Figs. 1C, 2-3).

Nymphaster sp.
Pl. 13, figs. 5-6.

Material — NHMM JJ 7045.

Description and discussion — A single (?third) superomarginal from the lower Zeven Wegen Member (base + 4.5-5.5 m) at the CPL SA quarry (Haccourt) differs from those of co-occurring *N. studlandensis* is being considerably longer, and in having three crater-shaped spine pits, the central one of which is the largest. As this specimen falls well within the stratigraphic range of *N. studlandensis* it may be nothing more than an atypical example of that species. Angle ossicles of *N. peakei* are very much taller, and have just one spine pit.

Occurrence — Recorded from the lower Zeven Wegen Member at the CPL SA quarry, and incorporated in the range of *N. studlandensis* (see Figs. 1C, 2).

Genus *Chomataster* Spencer, 1913

Type species — *Chomataster acules* Spencer, 1913, by monotypy.

Remarks — Gale (1987b, p. 172) noted that *Chomataster* was a very poorly known genus, based exclusively on isolated marginal ossicles. From these, Gale assumed the interradius to have been broad and evenly rounded, arms long and slender, and with the large, crater-shaped spine pits probably bearing spherical spines. Jagt et al. (1994) have subsequently shown this assumption to be correct, with possible exception of spine structure (see below).

The ancestry of *Chomataster* is unknown; Gale (1987b, 1989) suggested it probably evolved outside NW Europe, and migrated into this area during the (early) Late Campanian. Material of this age was recorded by Gale (1987b) from the *mucronata*

Zone of Studland Bay (Dorset) and Hanaskog (southern Sweden). Material from the lower Zeven Wegen Member recorded here is of comparable age.

Chomataster acules Spencer, 1913
Pl. 14.

*1913 *Chomataster acules* Spencer, p. 128, pl. 12, figs. 28, 31; pl. 16, figs. 8-13.
*1945 *Chomataster brünnichi* Rasmussen, p. 59, text-fig. 12.
1950 *Chomataster acules* Spencer — Rasmussen, p. 79, pl. 10, fig. 12; text-fig. 6e.
1953 *Chomataster acules* Spencer — Müller, p. 59, pl. 7, fig. QQ1-3.
1965 *Chomataster acules* — Rasmussen, pl. 8, fig. 1.
1969 *Chomataster* sp. — Maryańska & Popiel-Barczyk, p. 132, pl. 2, fig. 6.
1971 *Chomataster acules* Spencer 1913 — Schulz & Weitschat, p. 119, pl. 25, fig. 19.
1975 *Chomataster acules* Spencer, 1913 — Schulz & Weitschat, p. 279, pl. 31, fig. 10.
1975 *Chomataster* n. sp. aff. *acules* — Schulz & Weitschat, p. 280, pl. 31, figs. 8-9.
1987b *Chomataster acules* Spencer 1913 — Gale, p. 174, pl. 5, figs. 15-16 (cum syn.).

Type — Holotype is BMNH E 13255; paratypes are BMNH E 13256-13262.

Material — NHMM JJ 2680, 2729, 3907, 6580, 7266, 9673-74, 10836, 11126a, K 1836, 4152(9), MD 3443, 3498, MM 1287, 1289, and RGM 428 069.

Description — Median superomarginals (e.g., Pl. 14, figs. 1-2, 5, 7-8, 10) are tall, narrow, with a vertical lateral face, and a single, large, crater-shaped spine pit at the summit of the lateral face, either placed centrally or distally. Inferomarginals (e.g., Pl. 14, figs. 3-4, 9, 11-12) have a broad, rounded oral surface, and a narrow intermarginal facet, and up to 5 crater-shaped pits on the oral face. In profile, marginals differ in structure to a certain extent, but this undoubtedly reflects their original position along the disc and arm margins. The Late Campanian material (e.g., Pl. 14, figs. 5-6, 12, 14-15) represents the remains of a single individual with ambulacrals, adambulacrals and circumorals associated. The marginals in this find show less deeply excavated proximal and distal facets, and less well-developed facet margins than material of Maastrichtian and Early Palaeocene age. Proximal and distal facets occasionally show granules (e.g., Pl. 14, fig. 9). Spines possibly referable to this species (Pl. 14, fig. 13) are stout, flat-based and pointed.

Occurrence — A long-ranging form, which is common at certain levels (e.g. basal Gronsveld Member at ENCI-Maastricht BV quarry; basal Emael Member at CBR-Romontbos and Ankerpoort-Marnebel quarries), with records from the Zeven Wegen, Vijlen, and Lanaye members (Gulpen Formation), and the Valkenburg, Gronsveld, Emael, and Nekum members (Maastricht Formation) of the CPL SA, CBR-Lixhe, CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, and Ankerpoort-'t Rooth quarries, as well as from temporary outcrops at Aachen (Hans Böckler Allee), at Altembroeck, Mamelis-Selzerbeek, and Wahlwiller (Figs. 1C, 2-7).

Genus *Ophryaster* Spencer, 1913

Type species — *Nymphaster oligoplax* Sladen, 1893, by original designation.

Ophryaster? *maastrichtensis* Umbgrove, 1925
Pl. 19, figs. 1-5?; Pl. 27, fig. 7.

*1925 *Ophryaster maastrichtensis* Umbgrove, p. 209, fig. 28.

Type — Holotype is RGM 14209.

Discussion — The present specimen (Pl. 27, fig. 7) is of particular note in being one of the very few, more or less complete asteroids from the Maastrichtian type area known to date. Umbgrove provided a brief description, but failed to present detailed comparisons of his new species with other Late Cretaceous, NW European goniasterids. Umbgrove noted that the marginals were smooth, but a recent re-examination has revealed close-set, shallow granule pits. The superomarginals, and in particular the aboral surface of these, are not visible, but a preliminary comparison with marginal ossicles of *O. magnus* and *O. oligoplax* (see below) has shown that the present form cannot be assigned to *Ophryaster*. A revision is in preparation and will be published elsewhere. At this moment, it cannot be excluded that one of the indeterminate goniasterid taxa listed below, could in fact be conspecific with *O.*? *maastrichtensis*.

A few, more or less complete specimens, representing various size classes, of a goniasterid are known from the Meerssen Member (base IVf-3; Maastricht Formation) of Blom quarry (Berg en Terblijt; see Pl. 19, figs. 1-5). Unfortunately, recrystallisation has obscured all details of marginal ornament, which is especially frustrating since several individuals even preserve ambulacral and aboral spinelets. These juveniles might well be assignable to the present species, or alternatively, to goniasterid sp. 1 (see below).

Occurrence — Judging from the matrix type, the type specimen is from the lower/middle Meerssen Member of the Maastricht area (? St Pietersberg) (Fig. 1C).

Ophryaster magnus Spencer, 1913
Pl. 15, figs. 8-13.

*1913 *Ophryaster magnus* Spencer, p. 130, pl. 16, figs. 25-26, ?non 20-24, 27.
1950 *Ophryaster magnus* Spencer — Rasmussen, p. 85, pl. 11, fig. 3.
1981 *Ophryaster magnus* Spencer, 1913 — Schulz & Weitschat, p. 37, pl. 7, figs. 3-5.

Type — Holotype is BMNH E 13280; paratypes are BMNH E 13281-13285.

Material — A handful of isolated marginals, including NHMM MB 1239-22/l-o.

Description and discussion — Rasmussen (1950) and Schulz & Weitschat (1981) both described finds of associated ossicles of various individuals, and noted that the present form differed from its possible precursor *O. oligoplax*, in having a coarser ornament and a narrower, smooth aboral zone on the superomarginals. The present material from Mamelis-Selzerbeek shows that although the granule pits are closely spaced, there is some variation (see Pl. 15, figs. 8-11); the same holds for the width of the smooth aboral zone. Rasmussen (1950) also noted that abactinals were smooth in *O. magnus*, while those of *O. oligoplax* showed a central granulation, but in the present material this ossicle type is not represented.

For the time being, *O. magnus* is accepted as a distinct species, but in future, it

may well turn out to be advisable to lump this with *O. oligoplax*. Stratigraphically well-documented material, preferably articulated, is needed to substantiate this claim. Schulz & Weitschat (1981, p. 36) noted that, from the Lower Campanian upwards, in the Lägerdorf-Kronsmoor-Hemmoor sections, forms with relatively wide smooth zones in the superomarginals and those with narrow zones co-occurred. Those authors assumed these to possibly represent distinct lineages, which between the Lower Campanian and Maastrichtian, showed but few phylogenetic changes (e.g., *O. oligoplax-O. magnus* vs *O. dorsolevis-O.* n. sp. aff. *dorsolevis*). Only in ornament are distinctions present between later forms (i.e. of Maastrichtian age) and those from the Lower Campanian. The introduction of *Ophryaster dorsolevis* by Schulz & Weitschat (1981, p. 38, pl. 6, fig. 1; pl. 7, fig. 6; holotype is BMNH E 13945), for an Early Campanian form from Wiltshire (England) and the Hannover area (Germany), has to a certain extent clouded matters. Even more problematic is the occurrence in the Lower and lower Upper Maastrichtian of marginals referred to as *O.* n. sp. aff. *dorsolevis* by Schulz & Weitschat (1981), which are said to differ from co-occurring *O. magnus* in having a wider aboral smooth zone in superomarginals.

Occurrence — As here interpreted, *O. magnus* is known exclusively from the Vijlen Member (Gulpen Formation) of Mamelis-Selzerbeek and the Aachen city area (Fig. 1C).

Ophryaster oligoplax (Sladen, 1891)
Pl. 15, figs. 1-7, 14-16; Pl. 16, figs. 7-9.

*1891 *Nymphaster oligoplax* Sladen, p. 19, pl. 8, fig. 3.
1913 *Ophryaster oligoplax*, Sladen, sp. — Spencer, p. 130.
1981 *Ophryaster oligoplax* (Sladen, 1891) — Schulz & Weitschat, p. 37, pl. 6, figs. 2-4; pl. 7, figs. 1-2.
1992a *Ophryaster oligoplax* (Sladen, 1891) — Breton, p. 246, pl. 27; pl. 28, figs. 1-10; text-figs. 107-108.
1999c *Ophryaster oligoplax* — Jagt, pl. 2, figs. 5-6.

Type — Holotype is BMNH OR 40178.

Material — Material available for the present study includes a fairly well-preserved juvenile (NHMM MB 761-32), a number of distal arm portions, and associated remains of at least four individuals (with adambulacrals and ambulacrals), including NHMM JJ 6233, 6531, 7649/a-b, 7991, and MM 1286.

Description and discussion — Specimens illustrated here correspond closely to material illustrated by Schulz & Weitschat (1981), and it is their interpretation of the species that is followed here. However, as pointed out above, it seems that the distinction between the various species is less clear cut than claimed by previous authors. Added to this is the long stratigraphic range of the present form: the type was described from the upper Middle Santonian of Kent (England), while Schulz & Weitschat (1981) extended it down to the Middle Coniacian and up to the Upper Campanian. Breton (1992a) added material from the Lower Coniacian (or even Upper Turonian) of Normandy (France).

Occurrence — As here understood, *O. oligoplax* is apparently confined to the Zeven Wegen Member (Gulpen Formation) with records from Heure-le-Romain and the CPL SA and CBR-Lixhe quarries (Figs. 1C, 2-3).

Genus *Comptoniaster* Breton, 1984

Type species — *Goniaster (Stellaster) comptoni* Forbes, 1848, by original designation.

Comptoniaster peetersorum sp. nov.
Pl. 16, figs. 1-6.

Type — Holotype is NHMM JJ 11438, consisting of two arm fragments, supero- and inferomarginals, isolated adambulacrals, ambulacrals and abactinals (Pl. 16, figs. 2-6); paratype is RGM 428 074.

Type locality and horizon — CPL SA quarry, Haccourt (Liège), Zeven Wegen Member (Gulpen Formation).

Derivation of name — In honour of the Peeters family (Reuver, the Netherlands).

Diagnosis — Medium- to large-sized species, with straight to weakly concave interbrachial disc margin; marginals numerous, short and tall, with outer face of superomarginals gently curved and slightly swollen aborally, and with markedly sloping inner margin (covered by adjoining abactinals). Ornament of close-set, fine granule pits, more numerous on inferomarginals; pedicellariae large, elongate and numerous on both supero- and inferomarginals.

Material — In addition to the types, NHMM JJ 7487.

Description — A medium- to large-sized species; interbrachial disc margin straight to weakly concave; marginals numerous, short and tall, with (near-)parallel sides, and with outer face of superomarginals gently curved and slightly swollen aborally, and with slanting inner margin (covered by adjoining actinals). The ornament consists of close-set, fine granule pits, more closely spaced on the inferomarginals; pedicellariae large (equalling the length of the marginal ossicle or nearly so), elongate (rod-like) and numerous on both supero- and inferomarginals. In profile, inferomarginals taller than superomarginals, with outer face gently curved, and rounded ventrally. Intermarginal facet large, weakly concave, articulation ridges strong.

Discussion — The present species is assigned to *Comptoniaster* Breton, 1984 (emend. Breton, 1992a), despite the fact that this is not known to range higher than the Santonian. The material differs markedly from co-occurring *Ophryaster oligoplax* (see above) in that the marginals are much taller, have an even finer granule pit ornament, and have much larger pedicellariae. In addition, the conspicuous pit-free band near the inner margin of the superomarginals as seen in *O. oligoplax* is missing in the present species. Finally, ambulacral structure differs (compare e.g. Pl. 15, fig. 6 and Pl. 16, fig. 6).

In the Upper Cretaceous of Europe, only a single species of *Comptoniaster* has so far been recorded (see Breton, 1992a), viz. *C. weitschati* Breton, 1988 (p. 14, figs. 6-8) of Late Turonian-earliest Coniacian age. This differs from *C. peetersorum* sp. nov. in having lower and wider marginals.

Occurrence — Known to date only from the Zeven Wegen Member (Gulpen Formation) at Heure-le-Romain, and of the CPL SA and CBR-Lixhe quarries (Figs. 1C, 2-3).

Genus *Crateraster* Spencer, 1913
[= *Teichaster* Spencer, 1913; *Austinaster* Adkins, 1928]

Type species — *Asterias quinqueloba* Goldfuss, 1831, by the subsequent designation of Spencer (1913).

Remarks — Gale (1987b) is followed in considering *Teichaster* to be a junior synonym of *Crateraster*, and to accept four European Cretaceous species as valid, viz. *C. quinqueloba* (Goldfuss, 1831) (Late Albian-Upper Campanian), *C. rotundus* Schulz & Weitschat, 1981 (Late Santonian), *C. favosus* (Spencer, 1913) (Upper Campanian-?Lower Maastrichtian), and *C. reticulatus* (Schulz & Weitschat, 1981) (Maastrichtian).

Crateraster anchylus (Brünnich Nielsen, 1943)
Pl. 17, figs. 5-6; Pl. 19, fig. 16.

*1943 *Teichaster anchylus* Brünnich Nielsen, p. 54, pl. 3, figs. 14-15, 17; text-fig. 9.
1950 *Teichaster anchylus* Br. Nielsen — Rasmussen, p. 70, pl. 10, figs. 3-4.

Type — Lectotype, by subsequent designation of Rasmussen (1950), is the original of Brünnich Nielsen's (1943, pl. 3, fig. 14) (MGUH collections).

Material — A limited number of dissociated marginals, including NHMM JJ 11141, and MB 681-16/a.

Description and discussion — The present material conforms to Rasmussen's (1950, p. 79) diagnosis, in displaying tall superomarginals with steep lateral faces, and large ossicular angle. Both supero- and inferomarginals are narrow and rather short, and have an ornament of closely spaced, fairly large granule pits, the size of which increases towards and on the aboral tumidity. Sides are parallel or asymmetric. Inferomarginals less tall, abruptly rounded in profile (Pl. 17, fig. 5), and with large, circular, shallow granule pits, in particular on the lateral surface. Distal and proximal articulation facets concave, and ridges well developed.

A direct comparison with material from the Lower Danian Bryozoan Limestone of Stevns Klint (Denmark), with the present specimens shows these to be assignable to *C. anchylus*, but to comprise juvenile and/or subadult individuals only.

Occurrence — Known exclusively from the lower Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Vroenhoven-Riemst) and the Ankerpoort-Curfs quarry (Figs. 1C, 9).

Crateraster favosus (Spencer, 1913)
Pl. 16, figs. 10-11.

*1913 *Teichaster favosus* Spencer, p. 122, pl. 12, figs. 14-16, 18; pl. 16, figs. 14-16.
1941 *Teichaster favosus* Spencer — Wright & Wright, p. 240, pl. 14, figs. 12-13.
1981 *Teichaster favosus* Spencer, 1913 — Schulz & Weitschat, p. 34, pl. 5, figs. 5-6.
1987b *Crateraster favosus* (Spencer 1913) — Gale, p. 181, pl. 7, figs. 7-19; text-fig. 6a (cum syn.).

Type — Holotype is BMNH E 13238.

Material — Associated remains of a few individuals and numerous isolated marginals and other ossicles, including NHMM JJ 2987, and 5122.

Description — The present material adds little to the detailed description of this species presented by Gale (1987b). Median marginals (e.g., Pl. 16, figs. 10-11) are as long as wide. In profile, median superomarginals show steeply inclined aboral surfaces with a distinct tumidity, and short vertical lateral surfaces. Inferomarginals have lateral surfaces equal in length to oral surfaces, and are evenly curved. Ornament consists of rather fine, closely spaced granule pits on the aboral and oral surfaces. Lateral surfaces bear crater-like pits (Pl. 16, fig. 10), most strongly developed on distal marginals.

Discussion — Gale (1987b, p. 181) noted that in this species the arms curved aborally, and marginals decreased in size evenly towards arm tips. In fully-grown individuals there were no rugosities, only (crater-shaped) spine pits. In having consistently recurved arms, and in a (general) absence of rugosities on marginal ossicles, *C. favosus* differs from *C. quinqueloba* (Goldfuss, 1831). In comparison to the Maastrichtian *C. reticulatus* (see below), *C. favosus* was shown to be of consistently smaller size, to have 'lipped' crater-like pits on distal marginals, and shallower, smaller granule pits on marginals.

Occurrence — Apparently confined to the Zeven Wegen Member (Gulpen Formation) of Heure-le-Romain and the CPL SA and CBR-Lixhe quarries (Figs. 1C, 2-3).

Crateraster reticulatus (Schulz & Weitschat, 1981)
Pl. 16, figs. 12-14; Pl. 17, figs. 1-4, 7-12.

*1981 *Teichaster reticulatus* Schulz & Weitschat, p. 35, pl. 5, figs. 7-9.
1987b *Crateraster reticulatus* (Schulz and Weitschat 1981) — Gale, p. 184, pl. 7, fig. 10; text-fig. 6b.
1999c *Crateraster reticulatus* — Jagt, pl. 2, fig. 22.

Type — Holotype is SGPIH 2532a.

Material — In addition to the three (possibly four) fragmentary individuals (NHMM JJ 2650, 2651/1-3), the associated remains of at least four specimens, and numerous isolated ossicles, including JJ 3109/a-d, and MB 1239-22/o-q.

Description and discussion — Grouped here is all material from the Vijlen Member of the CPL SA and CBR-Lixhe quarries, Snouwenberg, Mamelis-Selzerbeek, and the Aachen city area, despite the fact that this would then become a seemingly heterogeneous lot. Judging from the fragmentary individuals in Pl. 16, figs. 12-14 and Pl. 17, figs. 1-4, this was a small species (R/r: 2.6), with long arms, not recurved aborally, and an ornament of close-set, fairly large granule pits and rugosities aborally; terminal ossicle elongate, distally slightly constricted and with a single, large spine base, as in *C. favosus* (BMNH E 20280). However, *C. reticulatus* is normally (see Schulz & Weitschat, 1981; Gale, 1987b) stated to be a large species, with arms recurved aborally in distal region as in *C. favosus*, with proximal marginals nearly twice as tall as broad (compare Pl. 17, fig. 9), and lateral surface of outer face vertical, aboral surface narrow and curved. The outer face of marginals has a narrow rim on which granule pits are not present (see e.g., Pl. 17, fig. 10). Granule pits rather large, evenly sized, and deeply impressed (Pl. 17, fig. 10); pits on distal marginals are as large as or larger than those on proximal ossicles.

In view of the fact that most specimens from the Haccourt-Lixhe area are compar-

atively small, and often retain rugosities on the aboral face, these could well represent juvenile and/or subadult individuals. However, it cannot be ruled out that in fact they do represent a distinct species, characterised by long, depressed arms, and a large terminal ossicle with a single spine. A re-examination of the type lot of *C. reticulatus* (SGPIH 3532a-c) has shown that the terminal in individuals of that size had three spines. Material representing intermediate growth stages is needed to determine the relationships between the Haccourt-Lixhe 'population' and *C. reticulatus*. For the time being, they are lumped here.

Crateraster reticulatus differs from *C. favosus* in being larger, in having a different marginal ornament with more deeply impressed granule pits. Proportionately, the greater marginal height would be a consequence of allometry.

Occurrence — As here understood, representatives of this 'group' are now known from the Vijlen Member (and extending into the overlying Lixhe 1 Member?, Gulpen Formation), with records from Snouwenberg, the CPL SA and CBR-Lixhe quarries, from Mamelis-Selzerbeek and Altembroeck (Figs. 1C, 2-3).

Genus *Caletaster* Breton, 1979

Type species — *Caletaster girardi* Breton, 1979, by monotypy.

Caletaster? sp.
Pl. 19, fig. 11.

Material — A single superomarginal, NHMM MB 432-74/h.

Description and discussion — In marginal profile and ornament, this specimen is surprisingly close to material of *Caletaster decombei* Breton, 1992a (p. 326, pl. 40, figs. 10-11; text-figs. 132-133) from the Upper Turonian of NW France. That species is characterised by convex, medium-sized marginals, with outer face fairly tumid, and intermarginal and lateral facets concave; and fairly large, deep, equal-sized granule pits. In these features, it differs considerably from the type species, *C. girardi* Breton, 1979 (p. 48, pl. 8, figs. 40-42; text-figs. 27-28; Coniacian-Campanian), as well as from *C. romani* Breton, 1988a (p. 34, figs. 25-29; Cenomanian-Turonian).

The stratigraphic and geographic range of *Caletaster*, according to Breton (1979, 1992a; but see also Gale, in Smith et al., 1988), is Cenomanian to Campanian of the Paris Basin, Vendée and Aude (France). In view of this huge stratigraphic gap, the present material is referred to *Caletaster* with a query.

Occurrence — Known exclusively from the upper Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Kesselt) (Fig. 1C).

goniasterid sp. 1
Pl. 17, figs. 13-15; Pl. 18, figs. 5-6, 10-12?; Pl. 19, fig. 15; Pl. 20, fig. 17.

Material — Numerous isolated marginals, including NHMM JJ 10443, MB 649-9/a-b, and MD 2918.1/a, d.

Description — Medium-sized species, with well-rounded, moderately tall marginals; in inferomarginals distal and proximal facets are concave, bordered by well-developed articulation ridge, running parallel to ossicle curvature, and bordered

itself by shallow groove (Pl. 17, fig. 13; Pl. 18, fig. 5); occasionally tubercles of varying sizes on facets (Pl. 18, fig. 5); ornament consisting of medium- to large-sized, close-set granule pits, leaving zone smooth low on the lateral surface. Superomarginals with tumid aboral surface; ornament of lateral and aboral surface and distal and proximal facets similar to that of inferomarginals.

Discussion — This form is very close to representatives of *Crateraster* (see e.g. Pl. 17, figs. 2, 11), but has finer granule pits, and generally also granules on distal and proximal facets. Closely related, if not conspecific, are the ossicles in Pl. 18, figs. 10-12, which are shorter, and have a larger ossicular angle, but are otherwise comparable in the ornament of outer face and distal and proximal facets.

Superficially similar forms occur in the Lower Palaeocene Geulhem Member (see Pl. 19, figs. 17-18), but the ornament appears to be coarser, and both these ossicles have pedicellariae which are atypical of the genus *Crateraster*. These must remain indeterminate as well.

Occurrence — Material of this type is now known from the Gronsveld, Emael, Nekum and Meerssen members (Maastricht Formation) at the CBR-Romontbos, Ankerpoort-Marnebel, ENCI-Maastricht BV, Ankerpoort-'t Rooth and Blom quarries (Figs. 1C, 4-8).

goniasterid sp. 2
Pl. 18, figs. 7-9.

Material — Numerous isolated marginals, as well as associated remains of a few individuals, including NHMM JJ 2917, 3083, 6786, 10450, K 1100, 1425, 4161, MB 108-8/a, and MD 2918.1.

Discussion — Only dissociated ossicles are known; these are robust, with both supero- and inferomarginals considerably wider than long (median), less so in distal ossicles. Proximal and distal facets deeply concave, articulation ridge prominent; outer face evenly arched, lateral surface almost straight; in some median ossicles occurs a large, centrally placed spine base on the lateral/aboral junction (Pl. 18, fig. 8); otherwise spine bases appear confined to distal ossicles. No other ornament. Intermarginal facet concave.

This species might be comparable in structure to other robust goniasterids such as the Oxfordian *Noviaster hostettleri* Hess, 1991 (p. 882, figs. 7-11) from Switzerland, but in the absence of articulated remains it must remain in open nomenclature.

Occurrence — Material available is from the Vijlen Member (Interval 6) of the CPL SA quarry, the Lanaye Member (Gulpen Formation) and the Valkenburg, Gronsveld, Nekum and Meerssen members (Maastricht Formation) of the ENCI-Maastricht BV, Ankerpoort-Marnebel, CBR-Romontbos, Ankerpoort-'t Rooth, and Blom quarries (Figs. 1C, 2, 4-8).

goniasterid sp. 3
Pl. 18, figs. 1-4.

Material — Numerous isolated marginals, including NHMM JJ 9591/k-m, 11119h, K 3565, 4140(14), and MD 2918.

Description and discussion — Small parallel-sided to slightly wedge-shaped marginals, rather thin and depressed, with ornament consisting of closely spaced granule pits on both supero- and inferomarginals. Outer face evenly arched, inner margin of ?superomarginals sloping (Pl. 18, fig. 2). Highly typical of this form is that the proximal facet is markedly concave in ?inferomarginals, while the distal facet is oblique and expanded laterally (Pl. 18, fig. 1); in ?superomarginals these differences are less clearly expressed.

Occurrence — Currently known from the Lanaye Member (Gulpen Formation), the Gronsveld, Emael, Nekum, and Meerssen members and Kunrade Limestone facies (Maastricht Formation) at the CBR-Romontbos, ENCI-Maastricht BV, Ankerpoort-Marnebel and Blom quarries, and in the Kunrade area (Figs. 1C, 4-6, 8).

goniasterid? sp. 4
Pl. 1, figs. 5-7; Pl. 2, figs. 9-10.

Material — Numerous isolated marginals in various collections, including NHMM JJ 3873, and 9591/b-d.

Description and discussion — This material has presented quite some problems, and it is feared that actually more than one species may be represented in this lot. Blake & Reid (1998, p. 514) erected the genus *Capellia* (type species *C. mauricei*) for a *Pseudarchaster*-like goniasterid from the Albian of Texas. In common with the present material, *Capellia mauricei* (see Blake & Reid, 1998, fig. 3) shows tall, robust marginals with broad, deep fascioles with sharply defined edges (see e.g., Pl. 1, figs. 5-7), supero- and inferomarginals aligned, interbrachial superomarginals cuneate in transverse section, and marginal ossicles parallel sided and outer faces weakly arched. Moreover, inferomarginals show spine bases (Pl. 1, fig. 6), while superomarginals lack these.

More material, preferably articulated and/or associated with ambulacrals, adambulacrals and aboral ossicles, would do much to elucidate matters.

Occurrence — Ossicles of this type are known to date from the Benzenrade Member (Vaals Formation), the Lanaye Member (Gulpen Formation), and the Gronsveld, Emael, Nekum, and Meerssen members and Kunrade Limestone facies (Maastricht Formation), with records from the Blom, ENCI-Maastricht BV, Ankerpoort-Marnebel, Ankerpoort-'t Rooth and CBR-Romontbos quarries, and from the temporary Albertkanaal sections (Vroenhoven-Riemst), the Kunrade area and at Welterberg/Benzenrade (Figs. 1A, 4-8).

goniasterid sp. 5
Pl. 18, figs. 14-17; Pl. 19, fig. 19; Pl. 20, fig. 16.

Material — Numerous isolated marginals, including NHMM K 1153, MB 487-6, and MD 2918.1/b-c.

Description and discussion — Grouped here are small, asymmetric marginal ossicles, all of which show fairly large, closely spaced granule pits, which are largest on an aboral swelling, reaching the size of spine bases (Pl. 20, fig. 16). Outer face evenly arched, distal and proximal facets similar, concave, articulation ridges prominent.

A distal inferomarginal with a prominent spine base (Pl. 18, figs. 14-15) is here

placed as well, mainly on account of a similar ornament. Contrary to the (?median) marginals this ossicle is parallel sided.

There is some resemblance to marginals of *Nymphaster rectus* (see Schulz & Weitschat, 1971, pl. 25, figs. 14-18, as *Calliderma smithiae*).

Occurrence — Known from the Gronsveld and Emael members (Maastricht Formation) of Ransdaal-Karstraat and of the ENCI-Maastricht BV quarry (Figs. 1C, 6).

goniasterid sp. 6
Pl. 18, fig. 13; Pl. 19, figs. 6-7.

Material — A limited number of isolated marginals, including NHMM JJ 10535/a-b.

Description and discussion — There is a resemblance to marginals referred here to as goniasterid sp. 3, but the present form is considerably larger, with distal and proximal facets similar, and concave. Outer face almost straight, flattened, with ornament of closely spaced, small granule pits. Grouped here are ?superomarginals (Pl. 18, fig. 13) and ?inferomarginals (Pl. 19, figs. 6-7), on account of a general similarity in structure, but this association cannot be substantiated at this moment. More material is needed to determine its status.

Occurrence — The present material comes from the Meerssen Member (Maastricht Formation) at the ENCI-Maastricht BV quarry (Figs. 1C, 6).

goniasterid sp. 7
Pl. 20, figs. 1-10.

Material — A handful of isolated marginals, NHMM MB 661-49/a-f.

Description and discussion — In marginal profile, these silicified ossicles from the temporary Vaals-Eschberg outcrops resemble those of some species of *Comptoniaster*; however, both supero- and inferomarginals have well-developed, crater-like spine bases (Pl. 20, figs. 7-10), while the remainder of the outer face is covered by closely spaced granule pits. The problem is that the intermarginal facet of what are here considered to be superomarginals (Pl. 20, figs. 4-5) is much wider than that of the possible inferomarginals (Pl. 20, figs. 1-3), but these could represent distal arm regions. More material is needed for a more reliable assignment.

Occurrence — Known exclusively from the Vaals Formation at Vaals-Eschberg (Fig. 1A).

goniasterid sp. 8
Pl. 20, figs. 11-14, 18.

Material — A handful of isolated marginals, NHMM MB 619-28/a-d.

Description and discussion — Like the previous form, the present material appears to be close to *Comptoniaster* and *Ophryaster*, in having a comparable ornament of closely spaced granule pits and elongate pedicellariae (Pl. 20, fig. 18) that occupy almost the entire length of the marginal.

From coeval strata (Zeven Wegen Member) in the Heure-le-Romain and Haccourt-Lixhe areas, *Ophryaster oligoplax* (Sladen, 1891) and *Comptoniaster peetersorum* sp.

nov. are known, but the present material cannot be assigned with confidence to either of these.

Occurrence — Known only from the Benzenrade Member (Vaals Formation) in the Benzenrade area (Fig. 1B).

Family Sphaerasteridae Schöndorf, 1906
Genus *Valettaster* Lambert, 1914
[= *Tholaster* Spencer, 1913, non Seunes, 1890; *Tholasterina* Valette, 1915]

Type species — *Oreaster ocellatus* Forbes, 1848, by subsequent designation of Rasmussen (1950).

Valettaster gr. *ocellatus* (Forbes, 1848)
Pl. 20, figs. 23-29; Pl. 21, figs. 1-7.

*1848 *Oreaster ocellatus* Forbes, p. 468.
1905 *Pentaceros ocellatus*, Forbes, sp. — Spencer, p. 85, pl. 25, fig. 4.
1913 *Tholaster ocellatus* (Forbes) — Spencer, p. 138, pl. 13, fig. 24.
1950 *Valettaster ocellatus* (Forbes) — Rasmussen, p. 94, pl. 10, figs. 22-23.
1988 *Valettaster ocellatus* (Forbes 1848) — Gale in Smith et al., p. 194, pl. 41, fig. 1.
1985a *Valettaster ocellatus* (Forbes, 1848) — Breton, p. 91, figs. 2-5.
1999c *Valettaster* sp. (?nov.) — Jagt, pl. 2, fig. 15.

Type — Holotype is BMNH E 2571.

Material — Numerous isolated aboral ossicles, occasionally found associated, including NHMM JJ 761a/1-4, 3054, 3699, 4441, 4740, 10517, 11145, MB 339-8/c, 681-16/b, 1044-6/a-b, 1239-22/cc, r-s, and RGM 428 063.

Description — Only the large aboral ossicles have been recognised in the collections studied, but these form an admittedly heterogeneous lot. On features of ornament, it has proved virtually impossible to make clear-cut subdivisions, the ornament being extremely variable.

Ossicles resemble low, truncated cones, equidimensional or elongate in aboral view, in outline markedly polygonal. Interior face flat, weakly convex, or occasionally concave in part; sloping sides with irregularly placed, discontinuous radiating ridges separated by grooves. Outer face flat, mostly comparatively small (e.g. Pl. 20, figs. 23, 24; Pl. 21, fig. 2), but occasionally large (Pl. 20, figs. 25-29), and parallel to inner face. In well-preserved ossicles, the outer face shows an intricate pattern of fine ridges, or discrete granules, most commonly radiating from a central point, but sometimes parallel to one of the sides.

Discussion — I follow Gale (in Smith et al., 1988) in considering *V. ocellatus* to be a long-ranging species (or species complex) with records from the Cenomanian-Palaeocene of NW Europe. The fact that only a handful of specimens preserve ossicles in place does not really help matters, i.e. in determining the range of variation.

Material from the Zeven Wegen Member (Pl. 20, figs. 25-28; all ossicles originating in the same individual) may prove to be distinct. Typical features include large, flat to concave outer face with closely spaced granules, arranged in rows, but with no tendency to coalesce, or form undulose ridges, and irregularly shaped inner faces.

Different also is NHMM JJ 4441 (Pl. 21, fig. 3) in showing an outer face with thin, elongate granules arranged in indistinct rows, but widely separated, and not radiating from a central point. Discrete, but small, tubercles are shown by MB 1044-6/a-b (Pl. 20, fig. 23; Pl. 21, fig. 2), which have very small outer faces, and which represent the stoutest ossicles seen in the present collections.

Valettaster argus (Spencer, 1907) (p. 99, pl. 25, fig. 6; pl. 29, figs. 8-9; holotype is BMNH E 5019) shows high domed ossicles, which do not appear to have discrete outer faces, but only ocellate facets. *Valettaster ocellatus* and *V. argus* are occasionally reported to co-occur (see e.g. Breton, 1986). Whether or not the distinction can be upheld remains to be determined; Spencer (1913, p. 138) noted that, 'It is probable that they are not two divergent offshoots from a parent stock, ...'.

Valettaster granulatus Brünnich Nielsen, 1943 (p. 65, pl. 4, fig. 37) (see also Rasmussen, 1950 p. 94, pl. 10, fig. 24), from the Upper Danian of Saltholm (Denmark) shows comparatively large granules on the outer face. Rasmussen (1965, pl. 8, fig. 4) recorded this form, but his illustration is such that that record cannot be substantiated. In the collections from the Geulhem Member I have seen this form was not represented.

In view of all these uncertainties on the specific status of the various 'morphotypes', I prefer to lump this material and use the oldest name available for it.

Occurrence — Currently known from the Zeven Wegen, Vijlen and Lanaye members (Gulpen Formation), the Valkenburg, Emael, Nekum, and Meerssen members (Maastricht Formation), and the Geulhem Member (Houthem Formation), with records from the CPL SA, CBR-Romontbos, ENCI-Maastricht BV, and Blom quarries, the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt), and Mamelis-Selzerbeek (Figs. 1D, 2, 5-6, 8).

Family Stauranderasteridae Spencer, 1913

Remarks — From the Upper Cretaceous, three stauranderasterid genera are known, viz. *Stauranderaster*, *Aspidaster*, and *Hadranderaster* Spencer, 1907 (type species: *Pentaceros abbreviatus* Spencer, 1905 = *Oreaster simplex* Geinitz, 1871). The difference between the two first-named is that the arms in *Aspidaster* are club shaped with large carinals, while in *Stauranderaster* arms are long, narrow, and straight sided, and carinals are weak or absent (see Spencer & Wright in Moore, 1966, p. U55). In view of the fact that from the Maastrichtian type area only dissociated ossicles are known, it is usually impossible to determine whether these are best placed in *Stauranderaster* or in *Aspidaster*. It appears that both genera are represented. Below a first attempt to assign the material to species is made.

Genus *Stauranderaster* Spencer, 1907

Type species — *Oreaster boysii* Forbes, 1848, by original designation.

Remarks — In the Upper Maastrichtian and Lower Palaeocene of the Maastrichtian type area, at least two types appear to be represented, which differ fundamentally in ornament.

Stauranderaster? *miliaris* Brünnich Nielsen, 1943
Pl. 21, figs. 10-11; Pl. 22, figs. 1-4.

*1943 *Stauranderaster miliaris* Brünnich Nielsen, p. 63, pl. 4, fig. 35.
1950 *Stauranderaster miliaris* Br. Nielsen — Rasmussen, p. 88, pl. 10, fig. 17.
1965 *Stauranderaster miliaris* — Rasmussen, pl. 8, fig. 3.

Type — Holotype is MGUH 7533.

Material — Numerous isolated marginal ossicles, including NHMM JJ 2928, 11146/a-d, and K 1701/d.

Description and discussion — Marginal ossicles of this form are easily recognised in showing a narrow depressed margin (Pl. 21, figs. 10-11) bordering a raised area with close-set, rather delicate granules. Articulation ridges are pronounced (Pl. 21, fig. 10). Other ossicles have not yet been recognised.

Occurrence — Known only from the lower Geulhem Member (Houthem Formation), with records from the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) and the Ankerpoort-Curfs quarry (Figs. 1D, 9).

Stauranderaster? sp. (? spp.)
Pl. 21, figs. 8-9, 12-13; Pl. 22, figs. 5-6.

Material — Numerous isolated ossicles, including NHMM JJ 10535/c-d, 11024/a-b, and MB 432-74/o-p.

Description — Ossicles grouped here differ from the preceding species in showing an ornament consisting of more widely spaced, deep, circular granule pits (Pl. 21, figs. 9, 12-13); mostly the depressed margin is well developed (Pl. 21, fig. 13; Pl. 22, fig. 6). The articulation ridges appear less prominent (Pl. 21, fig. 8), but this could be a preservational matter.

Discussion — With only dissociated ossicles available, it cannot be determined with certainty whether one or more taxa are involved. This type of stauranderasterid is of special note in probably being the only asteroid to cross the K/T boundary; in its coarse ornament it differs from species recorded by Rasmussen (1950) from the Upper Maastrichtian and Lower Palaeocene of Denmark.

Occurrence — Known from the Valkenburg and Meerssen members (Maastricht Formation), the Geulhem Member (Houthem Formation), with records from the ENCI-Maastricht BV and Blom quarries, and the temporary Albertkanaal sections (Vroenhoven-Riemst) (Figs. 1D, 6, 8).

Genus *Aspidaster* de Loriol, 1884

Type species — *Aspidaster delgadoi* de Loriol, 1884, by original designation.

Aspidaster? aff. *senonensis* (Valette, 1902)
Pl. 22, fig. 10.

compare
*1902 *Pentaceros senonensis* Valette, p. 17, figs. 1-2 (?non 3-7).

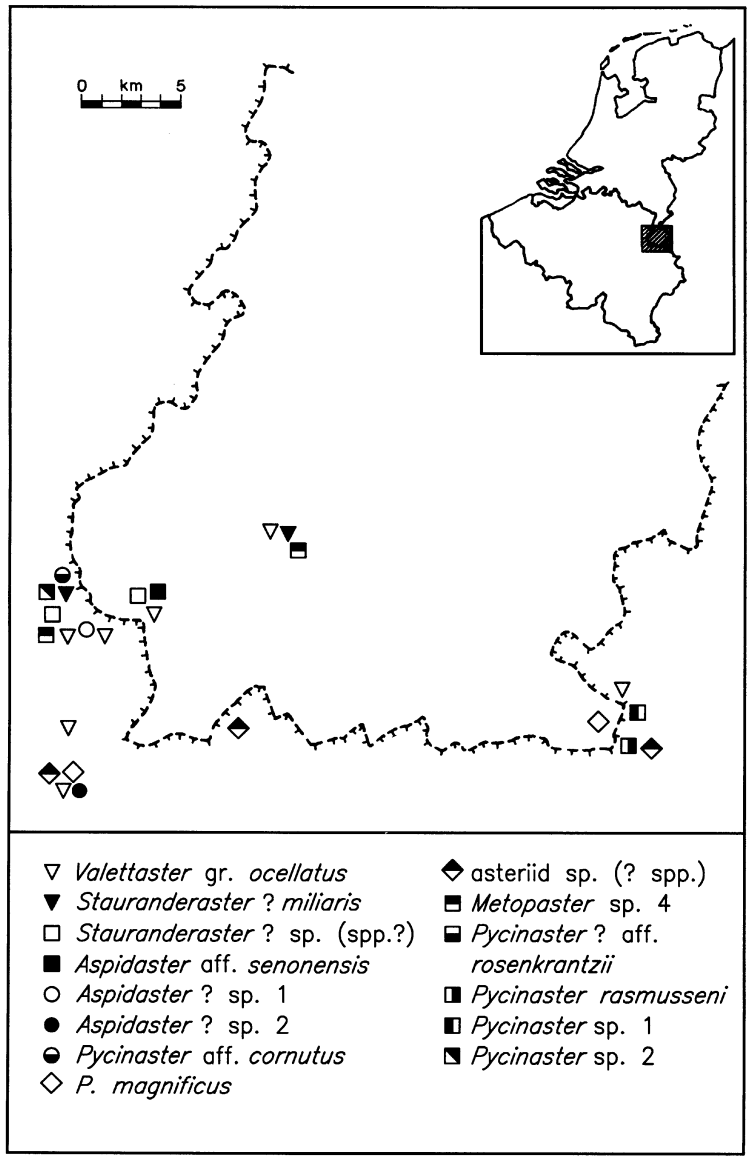


Fig. 1D. Geographic distribution of Late Cretaceous-Early Palaeogene asteroids in the type area of the Maastrichtian Stage.

1907 *Pycinaster senonensis*, Valette, sp. — Spencer, p. 95 (partim), pl. 29, fig. 6.
1913 *Stauranderaster senonensis* — Spencer, p. 134, pl. 13, figs. 14-15.
1915 *Stauranderaster senonensis* — Valette, p. 52, fig. 18/1-3.
1971 *Stauranderaster*? *senonensis* (Valette 1902) — Schulz & Weitschat, p. 127, pl. 26, figs. 20-22.

Material — A handful of aboral ossicles, probably primary interradials, including NHMM JJ 10537.

Description and discussion — In aboral aspect, these ossicles are subcircular, with more or less irregular outline, with tumid, smooth outer face. The inner surface is irregular, the sides slope and appear excavated (scalloped).

Illustrations of comparable primary aboral ossicles of stauranderasterids may be found in Sieverts-Doreck (1958, fig. 1, as *Stauranderaster* cf. *senonensis* Valette = *S.*? *dorecki* Schulz & Weitschat, 1971, p. 128, pl. 26, figs. 23-24), and Schulz & Weitschat (1971, pl. 26, figs. 20-22, as *Stauranderaster*? *senonensis* (Valette, 1902). Although closest to the latter form, the present material is referred to it with a query.

Occurrence — Material available is from the basal Valkenburg Member (Maastricht Formation) at the ENCI-Maastricht BV quarry (Figs. 1D, 6).

Aspidaster? sp. 1
Pl. 22, figs. 8-9.

?1925 *Tholaster* sp. (c.f. *argus* Spencer) — Umbgrove, p. 211, fig. 30 (?non 29).

Material — A single aboral ossicle (?primary interradial), NHMM JJ 2284.

Description and discussion — In aboral aspect, the specimen is irregularly teardrop shaped, and longer than wide. The outer face is tumid (Pl. 22, fig. 8), and evenly covered with fine, closely spaced granule pits, and lacks a depressed border. The margin is weakly notched (Pl. 22, fig. 8), the inner surface being irregular, bulbous centrally.

The specimen illustrated in Umbgrove's (1925) fig. 30 appears to be conspecific, but with only these ossicles at hand, generic and specific assignment are impossible.

Occurrence — Known only from the basal Meerssen Member (Maastricht Formation) at the temporary Albertkanaal sections near Kanne (Limburg, Belgium) (Fig. 1D).

Aspidaster? sp. 2 (aff. *pistilliferus* Forbes, 1848)
Pl. 22, fig. 12.

compare
*1848 *Oreaster pistilliferus* Forbes, p. 467.
1905 *Pentaceros pistilliferus*, Forbes sp. — Spencer, p. 88, pl. 25, fig. 5.

Material — A single aboral ossicle (?primary interradial), NHMM JJ 2658.

Description and discussion — In aboral aspect, the specimen has an irregular, elongate outline; the outer face is drawn out into into a blunt upper end, with four subequal, blunt protuberances, and scattered granule pits; the sides either straight or slightly convex. The inner face is irregular (?preservational matter), bulbous at the centre. Except for the scattered granule pits, this ossicle appears smooth.

There is a superficial resemblance to what Spencer (1905, p. 88, pl. 25, fig. 5) described and figured as *Pentaceros pistilliferus*. Otherwise, nothing comparable appears to have been described in the literature.

Occurrence — Known exclusively from the lower Zeven Wegen Member (Gulpen Formation) of the CPL SA quarry (Haccourt) (Figs. 1D, 2).

Family Pycinasteridae Spencer & Wright, in Moore, 1966

Remarks — Pycinasterids occur throughout the entire Campanian to Palaeocene succession in the extended type Maastrichtian, but diversity appears to be highest during the Palaeocene. Similar in age to *P. magnificus* (see below) are possible pycinasterid ossicles (Pl. 20, figs. 19-20) from the Benzenrade Member (Vaals Formation), but these have prominent spine bases, and are skewed.

Genus *Pycinaster* Spencer, 1907
[= *Pycnaster* Sladen, 1891, non Pomel, 1883]

Type species — *Goniaster (Goniodiscus) angustatus* Forbes, 1848, by original designation.

Pycinaster aff. *cornutus* Rasmussen, 1945
Pl. 22, figs. 15-16.

*1945 *Pycinaster cornutus* Rasmussen, p. 423, pl. 9, figs. 12-14.
1950 *Pycinaster cornutus* W. Rasmussen — Rasmussen, p. 76, pl. 10, fig. 9.

Type — Lectotype, by subsequent designation of Rasmussen (1950), is the specimen illustrated by Rasmussen (1945, pl. 9, fig. 12) (MGUH collections).

Material — A single proximal superomarginal, NHMM MB 432-74/r.

Description — Highly asymmetric, tall, with steep lateral surface, and with rounded, tumid, long aboral face; internal facet steep as well. Proximal articulation facet tall, ridge prominent; distal facet deeply concave. Aboral face shows a single, large central spine pit, lacking a rim, and occupying slightly less than half the length of the ossicle. Remainder of plate with ornament of closely spaced, small granule pits.

Discussion — The present specimen is close to *P. cornutus* from the uppermost Danian of Svanemøllen (Copenhagen), but more material is needed to determine whether it falls within the range of variation of that species or not.

Occurrence — Apparently confined to the upper Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 1D).

Pycinaster magnificus Spencer, 1913
Pl. 22, figs. 13?, 14?, 17-21; Pl. 23, fig. 3.

*1913 *Pycinaster magnificus* Spencer, p. 125, pl. 11, figs. 14-15.
1971 *Pycinaster magnificus* Spencer 1913 — Schulz & Weitschat, p. 123, pl. 26, figs. 8-19.
1987 *Pycinaster magnificus* Spencer — Wright & Smith, p. 216, pl. 47, figs. 1-2.
1988 *Pycinaster magnificus* Spencer, 1913 — Breton, p. 125.

Type — Spencer (1913) failed to designate a type specimen.

Material — Numerous isolated marginals, and associated remains of at least two individuals, including NHMM JJ 4716, 5958-59, 8160/a-b, K 4167(2), and MB 1239-22/v-w.

Description — This is the largest amongst the Late Cretaceous-Palaeogene asteroids of the study area, and indeed, worldwide. Median superomarginals (Pl. 22, figs. 17-21) are tall, more than twice as high as wide, clearly cuneate and aborally strongly tumid; lateral surface concave, inner face concave aborally, and with bulbous inner extension in lower portion. Median inferomarginals (Pl. 23, fig. 3) tall, slightly curved. Ornament on marginals either lacking or in the form of large, circular granule pits on aboral swelling (Pl. 22, fig. 19).

In view of their size, a few isolated aboral ossicles (Pl. 22, figs. 13-14) appear to belong here as well.

Discussion — Although these differ in details, a few supero- and inferomarginals from the Lower Maastrichtian Vijlen Member at Mamelis-Selzerbeek are referred here as well (see also *Pycinaster* sp. 1 below). *Pycinaster magnificus* ranges throughout the Campanian of England, Germany, and Belgium (the present records).

Occurrence — Known from the Zeven Wegen Member at the CPL SA quarry (Haccourt), and apparently extending into the lower Vijlen Member (Gulpen Formation), at Mamelis-Selzerbeek (Figs. 1D, 2).

Pycinaster? aff. *rosenkrantzii* Brünnich Nielsen, 1943
Pl. 23, figs. 1-2.

compare
*1943 *Pycinaster rosenkrantzii* Brünnich Nielsen, p. 58, pl. 4, figs. 6-9.
1950 *Pycinaster*? *rosenkrantzii* (Br. Nielsen) — Rasmussen, p. 77, pl. 10, fig. 11; text-fig. 6f.

Type — Lectotype, by subsequent designation of Rasmussen (1950), is MGUH 4146.

Material — A few marginals, including NHMM MB 432-74/s.

Description — The specimen illustrated is tall, evenly tumid, wedge shaped (Pl. 23, fig. 1) and with aboral swelling; ornament of closely spaced granule pits, which increase markedly in size aborally; no spine pit developed. Internal face curved (Pl. 23, fig. 2), proximal and distal articulation facets similar, concave over entire height; ridges prominent.

Discussion — The present specimen is comparable to material from Denmark to such an extent that it could well be considered conspecific. However, more material is needed, preferably representing arm ossicles, to determine this beyond doubt. Rasmussen (1950) noted that marginals of *P. rosenkrantzii* closely resembled those of the genus *Chomataster* (= *Nymphaster* in current terminology); I concur. Both the wedge shape of the interradial ossicle and presence of spine bases suggest a parallel with the Late Campanian *Nymphaster studlandensis-alseni-peakei* lineage.

A few smaller, more or less wedge-shaped marginals (Pl. 19, figs. 8-10) are comparable in profile, but the ornament differs considerably, while one of the specimens has a large spine base aborally. These must remain indeterminate for now.

Occurrence — Apparently confined to the upper Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Vroenhoven-Riemst/Kesselt) (Fig. 1D).

Pycinaster sp. 1
Pl. 21, figs. 14-15; Pl. 22, fig. 7.

compare
1950 *Pycinaster crassus* Spencer — Rasmussen, p. 73 (partim), pl. 10, figs. 6-7.

Material — A few isolated marginals, including NHMM MB 1239-22/t-u.

Description and discussion — In showing an ornament of coarse, scattered granule pits, a few ossicles in the lot that also yielded the marginals of *P. magnificus* referred to above (see also Pl. 21, fig. 15; Pl. 22, fig. 7) cannot be referred to that species. Ossicles of similar size of that species are smooth, and show only occasional pedicellariae. Rasmussen (1950, p. 74) recorded material from the Upper Maastrichtian of Stevns Klint, which he referred to *P. crassus*, an otherwise Santonian-(? Early) Campanian species.

The present lot (NHMM MB 1239) includes also a few marginals (not illustrated), which are undoubtedly conspecific with Rasmussen's (1950, p. 76) *Pycinaster* aff. *cornutus* from the Lower Maastrichtian of Møn. Müller (1953, p. 49, pl. 1, fig. A; pl. 2, fig. G; pl. 3, fig. L; pl. 4, fig. U; pl. 6, figs. DD-HH; pl. 9, figs. EA-GA; pl. 10, figs. ZA-BC) erected *P. rasmusseni* for this form.

Occurrence — Apparently confined to the lower Vijlen Member (Gulpen Formation) at Mamelis-Selzerbeek (Fig. 1D).

Pycinaster sp. 2
Pl. 22, fig. 11.

compare
*1943 *Pycinaster danicus* Brünnich Nielsen, p. 57, pl. 4, figs. 1-5.
1950 *Pycinaster danicus* Br. Nielsen — Rasmussen, p. 75, pl. 10, fig. 8.

Material — A single distal inferomarginal, NHMM MB 432-74/q.

Description and discussion — A distal inferomarginal with very fine, close-set granule pits and two subequal, centrally placed spine bases, appears to match material from the Danian of Fakse (Denmark), described and figured by Brünnich Nielsen (1943) and Rasmussen (1950). More material is needed to confirm this assignment.

Occurrence — Apparently confined to the upper Geulhem Member (Houthem Formation) of the temporary Albertkanaal sections (Kesselt) (Fig. 1D).

Order Forcipulatida Perrier, 1884
Family Asteriidae Gray, 1840
asteriid sp. (? spp.)
Pl. 6, figs. 7?, 9?; Pl. 7, figs. 3?, 4?; Pl. 23, figs. 4-10.

1999c asteriid indet. — Jagt, pl. 1, figs. 15, 19.

Material — NHMM JJ 2944, 9469, MB 808-7/c-d, j, o-r, 808-9b, and 1175-4a.

Description — With the exception of a few fragmentary remains (van Birgelen Colln) of arms and/or discs (see e.g. Pl. 23, fig. 8), preserving various types of dorsal

ossicles and ambulacrals, from the Zeven Wegen Member (Gulpen Formation) of the CPL SA quarry (Haccourt), only small (up to c. 2.5 mm in length), dissociated, cruciform dorsal ossicles are known, with a comparatively coarse stereom structure. At least two basic types are represented, with circular spine bases, having a much finer stereom mesh (e.g. Pl. 23, figs. 4, 6), and of variable diameter, and shallow depressions near plate margins for overlapping adjacent ossicles (e.g. Pl. 23, figs. 5, 7).

Another type is referred here with a query; these ossicles (see Pl. 6, figs. 7, 9?; Pl. 7, figs. 3?, 4?) have an irregular, lobate outline, are asymmetric, and have a large circular to elliptical spine base, with a distinct 'crenulate' ring and a fairly deep central pit, and marginal depressions for overlap as well (see Pl. 7, fig. 4). Their stereom meshwork appears to be more intricate with more variation in density and structure than that of the cruciform ossicles. One of the specimens (Pl. 7, fig. 3) has associated ambulacrals and (?)adambulacrals, the structure of which would contradict assignment to the Asteriidae.

Discussion — Although several ossicular types are represented, and a few fragmentary discs and/or arms are available, it seems premature to attempt specific assignment of these remains. Detailed comparisons with fossil and extant asteriids are needed for a proper placement.

Asteriids have a very limited fossil record. Müller (1953, p. 45, pl. 10, fig. SA1-2) illustrated a single asteriid ossicle from the upper Lower Maastrichtian of Rügen, which is closely comparable to material figured here. Material contained in the M. Kutscher Collection (Sassnitz, Rügen), to be described in the near future, shows that such ossicles are fairly common at Rügen. From Hettangian (Lower Jurassic) strata in southern Germany, Blake (1990) described two new genera and species of asteriid, *Germanasterias amplipapularia* and *Hystrixasterias hettangiurnus*, and showed the carinal series to consist of cruciform ossicles with stout spines. Blake & Peterson (1993, p. 586, figs. 1.1-1.6) described a new genus and species of neomorphasterid asteriid, *Pegaster stichos*, from the Ten Mile Member (Chico Formation) of northern California, of Campanian age. This is characterised by stout ossicles, and relatively short, blunt arms; the ossicular type separates this form easily from the material described here. Much closer are the specimens discussed and illustrated by Breton & Ferré (1995), who documented asteriid ossicles from the Upper Cenomanian to Coniacian of Eure, Seine-Maritime, Sarthe, Loir-et-Cher, and Somme (France), and the new pedicellasterine genus and species from the Coniacian of Angola described by Blake et al. (1996), *Afraster scalariformis*.

Blake & Aronson (1998) noted that genera and species of extant asteriids are based mainly on ossicular arrangement and the nature and arrangement of pedicellariae. In fossil representatives, ossicular arrangement is mostly severly disrupted and pedicellariae are generally lacking. Those authors (p. 347, figs. 4.6-4.13) described from the Eocene of Seymour Island (Antarctica), the new species *Sclerasterias zinsmeisteri*.

Occurrence — Asteriid ossicles have so far been collected only from the Zeven Wegen and Vijlen members (Gulpen Formation) at the CPL SA quarry (Haccourt), Snouwenberg, and Aachen (Hans Böckler Allee) (Figs. 1D, 2).

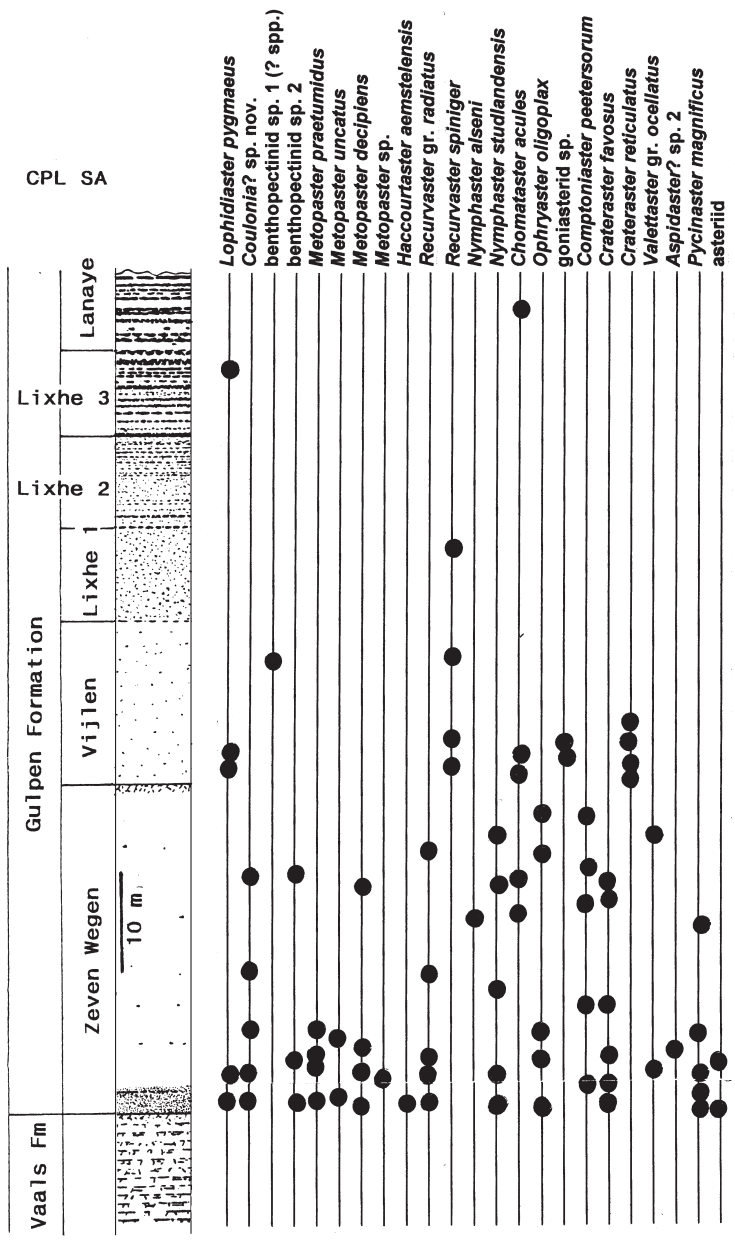


Fig. 2. Lithostratigraphy of section exposed at Ciments Portland Liégeois SA quarry (Haccourt, Liège) and stratigraphic provenance of asteroid material studied herein.

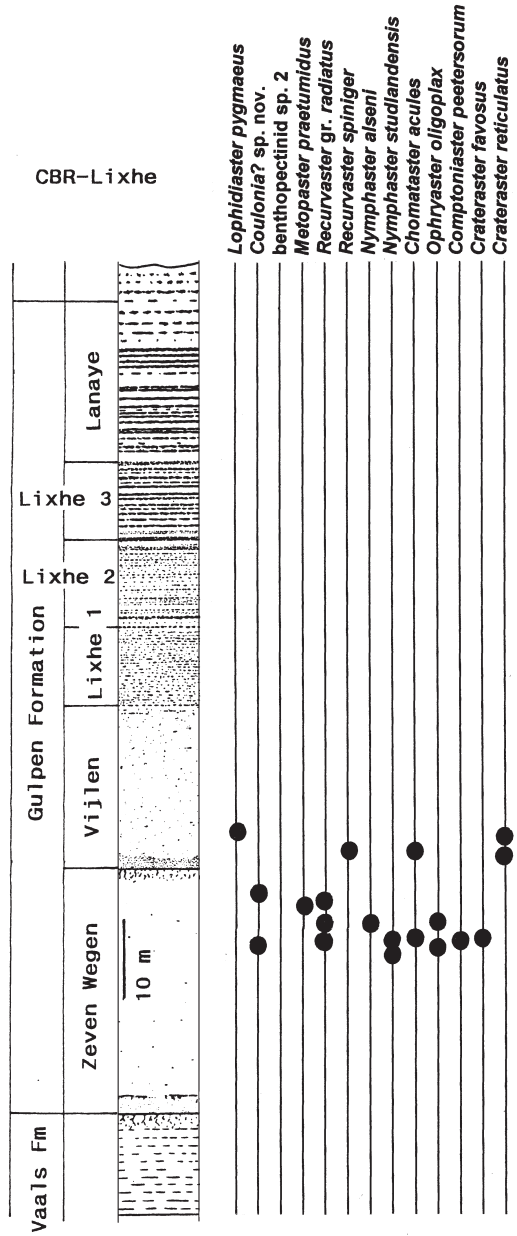


Fig. 3. Lithostratigraphy of section exposed at Cimenterie Briqueterie Réunie-Lixhe quarry (Lixhe, Liège) and stratigraphic provenance of asteroid material studied herein.

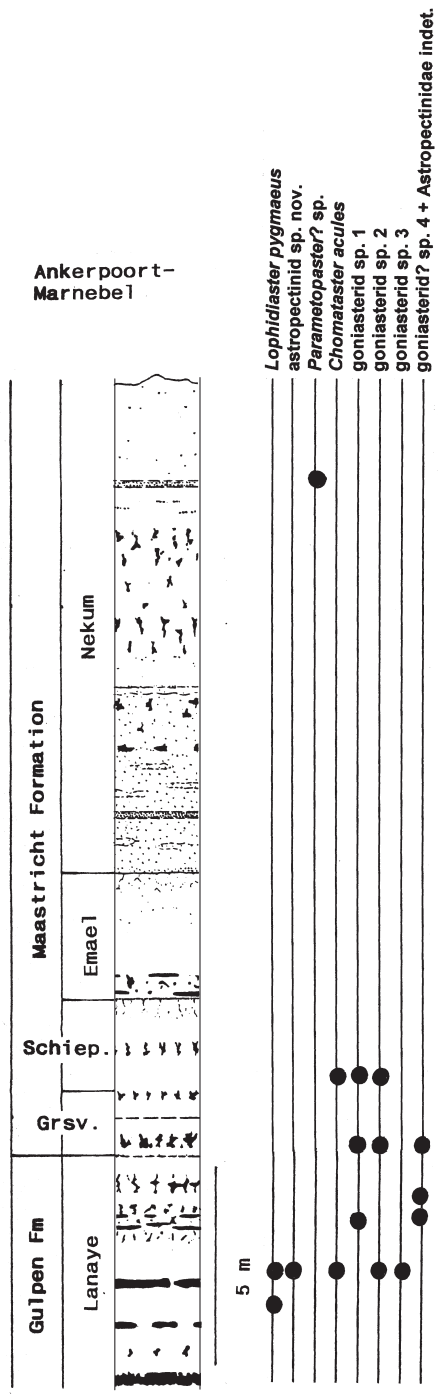


Fig. 4. Lithostratigraphy of section exposed at Ankerpoort-Marnebel quarry (Eben Emael, Liège) and stratigraphic provenance of asteroid material studied herein.

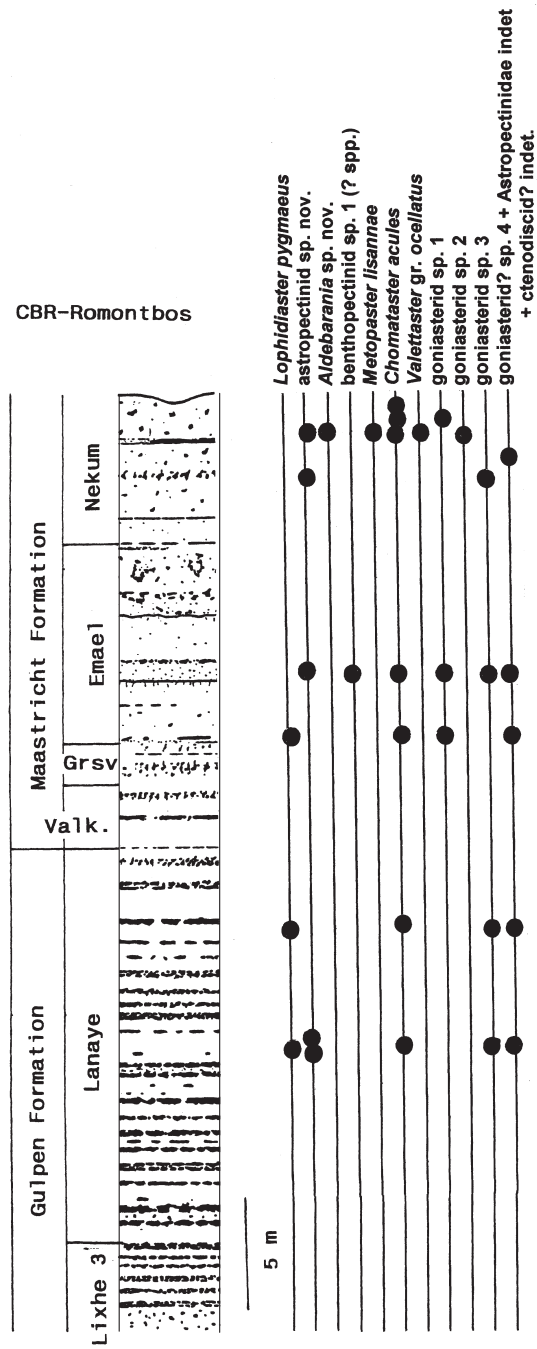


Fig. 5. Lithostratigraphy of section exposed at Cimenterie Briqueterie Réunie-Romontbos quarry (Eben Emael, Liège) and stratigraphic provenance of asteroid material studied herein.

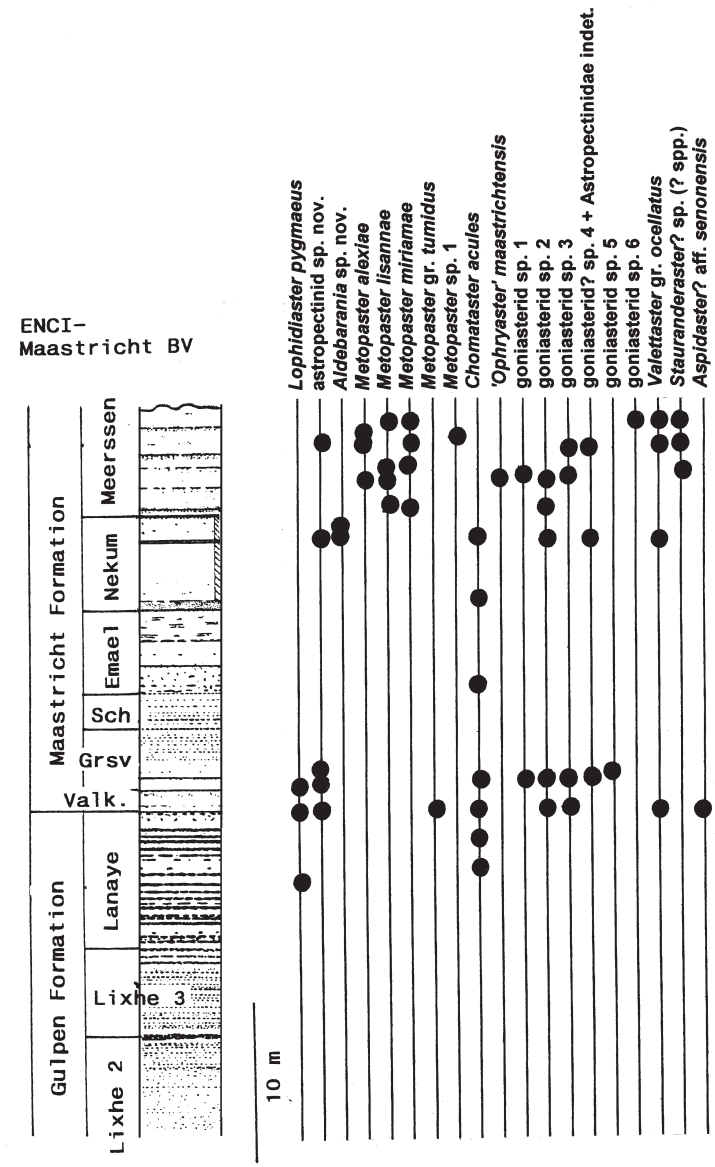


Fig. 6. Lithostratigraphy of section exposed at ENCI-Maastricht BV quarry (Maastricht) and stratigraphic provenance of asteroid material studied herein.

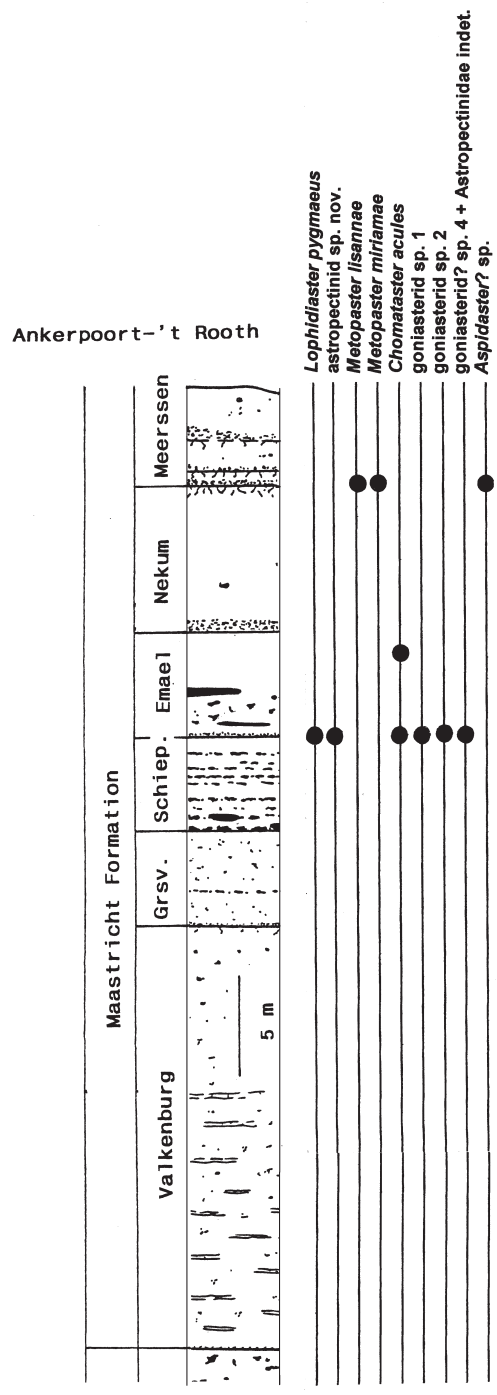


Fig. 7. Lithostratigraphy of section exposed at Ankerpoort-'t Rooth quarry (Bemelen) and stratigraphic provenance of asteroid material studied herein.

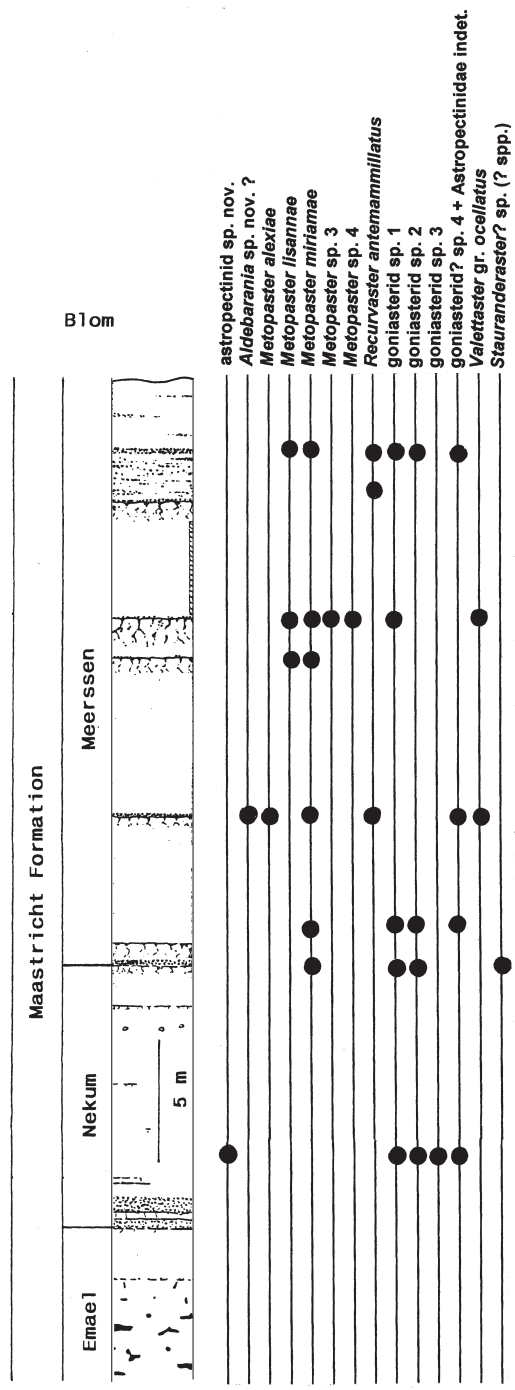


Fig. 8. Lithostratigraphy of section exposed at Blom quarry (Berg en Terblijt) and stratigraphic provenance of asteroid material studied herein.

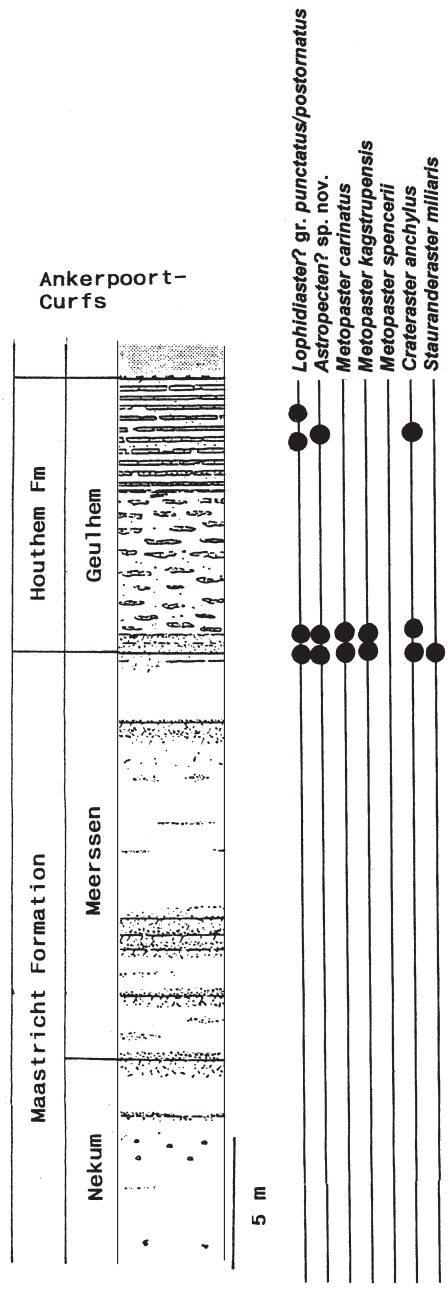


Fig. 9. Lithostratigraphy of section exposed at Ankerpoort-Curfs quarry (Geulhem) and stratigraphic provenance of asteroid material studied herein.

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. 11 of the 'Vijlen Werkgroep'.

References

[For additional references see also Parts 1-4 of the current series (Jagt, 1999a, b, 2000a, b).]

Blake D.B., 1973. Ossicle morphology of some Recent asteroids and description of some West American fossil asteroids. — Univ. Calif. Publ. geol. Sci., 104: 1-59, 19 pls.

Blake, D.B., 1984. The Benthopectinidae (Asteroidea: Echinodermata) of the Jurassic of Switzerland. — Eclogae geol. Helv., 77: 631-647.

Blake, D.B., 1987. A classification and phylogeny of post-Palaeozoic sea stars (Asteroidea: Echinodermata). — J. nat. Hist. Lond., 21: 481-528.

Blake, D.B., 1988. A first fossil member of the Ctenodiscidae (Asteroidea, Echinodermata). — J. Paleont., 62: 626-631.

Blake, D.B., 1989. Asteroidea: functional morphology, classification, and phylogeny. In: M. Jangoux & J.M. Lawrence (eds). Echinoderm Studies 3. — A.A. Balkema, Rotterdam/Brookfield: 179-223, pls 1-3.

Blake, D.B., 1990a. Hettangian Asteriidae (Echinodermata: Asteroidea) from southern Germany: taxonomy, phylogeny and life habits. — Paläont. Z., 64: 103-123.

Blake, D.B., 1990b. Adaptive zones of the class Asteroidea (Echinodermata). — Bull. mar. Sci., 46: 701-718.

Blake, D.B., 1996. Fossils explained 18: Starfishes. — Geology Today, Nov.-Dec. 1996: 230-235.

Blake, D.B. & R.B. Aronson, 1998. Eocene stelleroids (Echinodermata) at Seymour Island, Antarctic Peninsula. — J. Paleont., 72: 339-353.

Blake, D.B., G. Breton & S. Gofas, 1996. A new genus and species of Asteriidae (Asteroidea; Echinodermata) from the Upper Cretaceous (Coniacian) of Angola, Africa. — Paläont. Z., 70: 181-187.

Blake, D.B. & D.O. Peterson, 1993. An unusual new asteriid (Echinodermata: Asteroidea) from the Cretaceous of California. — J. Paleont., 67: 586-589.

Blake, D.B. & R. Reid III, 1998. Some Albian (Cretaceous) asteroids (Echinodermata) from Texas and their paleobiological implications. — J. Paleont., 72: 512-532.

Blake, D.B. & J. Sprinkle, 1996. *Astrocratis acutispina*, new genus and species, a new asteroid from the Late Cretaceous of Texas. — Eclogae geol. Helv., 89: 1311-1320.

Blake, D.B. & K. Sturgeon, 1995. *Aldebarania arenitea*, a new genus and species of Astropectinidae (Asteroidea; Echinodermata) from the Maastrichtian (Upper Cretaceous) Peedee Formation of North Carolina. — J. Paleont., 69: 376-380.

Breton, G., 1979. Les Astéries du Crétacé de Normandie. — Bull. Soc. géol. Norm. Amis Mus. Havre, 65 (1978): 5-87, pls 1-8.

Breton, G., 1981. *Metopaster meudonensis* Cottreau, 1937, astérie du Campanien terminal du Bassin de Paris. — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 67 (1980): 21-30, 2 pls.

Breton, G., 1984. *Comptoniaster*, gen. nov. de Goniasteridae du Mésozoique. — Symbioses, 15 (1983): 244-245.

Breton, G., 1985. *Valettaster* ? Sphaerasteridae mésozoique. — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 72: 91-99.

Breton, G., 1986. Découverte d'un juvenile de ? *Crateraster quinqueloba* (Goniasteridae, Stelleroidea)

dans la craie campanienne du Bassin de Paris. — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 73: 29-32.

Breton, G., 1988a. Description d'espèces nouvelles de Goniasteridae (Asteroidea, Echinodermata) du Crétacé de France. — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 75: 9-40.

Breton, G., 1988b. *Pycinaster magnificus* Spencer, 1913 (Echinodermata, Asteroidea): conservation proposée pour le nom spécifique [Case 2564]. — Bull. zool. Nomencl., 45: 125-126.

Breton, G., 1992a. Les Goniasteridae (Asteroidea, Echinodermata) Jurassiques et crétacés de France. Taphonomie, systématique, biostratigraphie, paléobiogéographie, évolution. — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, h.s. Suppl., 78: 1-590, pls 1-48.

Breton, G., 1992b. Réexamen de l'holotype de *Pentaceros dilatatus* Meunier, 1906 [= *Nymphaster obtusus* (Forbes, 1848)], Goniasteridae (Asteroidea) Echinodermata, Crétacé supérieur du Bassin de Paris. — Bull. Mus. natn Hist. nat. Paris, 14: 267-273, pl. 1.

Breton, G., 1995a. La forme du corps de *Crateraster debrisi* Breton, 1992 (Asteroidea, Goniasteridae). — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 82: 51-53.

Breton, G., 1995b. *Tethyaster guerangeri* sp. nov. (Astropectinidae, Asteroidea, Echinodermata): deux spécimens d'astérides d'une conservation exceptionelle du Cénomanien du Mans (Sarthe, France). — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 82: 17-29, pls 1-3.

Breton, G., 1997a. Deux étoiles de mer du Bajocien du nord-est du Bassin de Paris (France): leurs alliés actuels sont des fossiles vivants. — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 84: 23-34.

Breton, G., 1997b. Patterns and processes of heterochrony in Mesozoic goniasterid sea-stars. — Lethaia, 30: 135-144.

Breton, G., M. Bilotte & G. Sigro, 1995. *Dipsacaster jadeti* sp. nov., Astropectinidae (Asteroidea, Echinodermata) du Maastrichtien des Petites Pyrénées (France). — Bull. trim. Soc. géol. Norm. Amis Mus. Havre, 82: 35-42.

Breton, G. & B. Ferré, 1995. Première observation d'éléments squelettiques d'Asteriidae (Asteroidea, Echinodermata) dans les craies du Cénomanien au Coniacien du Bassin de Paris. — Rev. Micropaléont., 38: 299-309, 2 pls.

Brünnich Nielsen, K., 1943. The asteroids of the Senonian and Danian deposits of Denmark. — Biol. Skr. danske Vidensk. Selsk., 2, 5: 3-68, pls 1-4.

Cottreau, J., 1937. Un Stelléride de la craie de Meudon (S.-et-O.). — C.R. somm. Séances Soc. géol. Fr., 1937, 7: 78-79.

Fisher, W.K., 1908. Some necessary changes in the generic names of starfishes. — Zool. Anz., 33: 356-359.

Fisher, W.K., 1911. Asteroidea of the North Pacific and adjacent waters. Part 1. Phanerozonia and Spinulosa. — Bull. U.S. natl Mus., 76: i-xiii + 1-420, 122 pls.

Fisher, W.K., 1919. Starfishes of the Philippine Seas and adjacent waters. — Bull. U.S. natl Mus., 100: i-xii + 1-712, 156 pls.

Forbes, E., 1848. On the Asteriadae found fossil in British strata. — Mem. geol. Surv. Gr. Br., 2, 2: 457-482.

Forbes, E., 1852. A monograph of the Echinodermata of the British Tertiaries. — Monogr. Palaeontogr. Soc. London, 1852: i-vii + 1-36, pls 1-4.

Frerichs, U., 1997. *Metopaster praetumidus* Schulz & Weitschat, ein Seesternfund aus dem Obercampan von Misburg. — Arb.Krs Paläont. Hannover, 25: 120-124.

Gabb, W.M., 1876. Note on the discovery of representatives of three orders of fossils new to the Cretaceous formation of North America. — Proc. Acad. nat. Sci. Philad., 1876: 178-179, pl. 5.

Gale, A.S., 1987a. Goniasteridae (Asteroidea, Echinodermata) from the Late Cretaceous of north-west Europe. 1. Introduction. The genera *Metopaster* and *Recurvaster*. — Mesozoic Res., 1 (1986): 1-69, pls 1-9.

Gale, A.S., 1987b. Goniasteridae (Asteroidea, Echinodermata) from the Late Cretaceous of north-west Europe. 2. The Genera *Calliderma*, *Crateraster*, *Nymphaster* and *Chomataster*. — Mesozoic Res., 1: 151-186, pls 1-7.

Gale, A.S., 1987c. Phylogeny and classification of the Asteroidea (Echinodermata). — Zool. J. linn. Soc. Lond., 89: 107-132.

Gale, A.S., 1988. Asteroids. In: A.B. Smith, C.R.C. Paul, A.S. Gale & S.K. Donovan. Cenomanian and Lower Turonian echinoderms from Wilmington, south-east Devon, England. — Bull. Br. Mus. nat. Hist. (Geol.), 42: 189-208, pls 41-43.

Gale, A.S., 1989. Migration and evolution in Late Cretaceous Goniasteridae (Asteroidea, Echinodermata) from north-west Europe. — Proc. Geol. Ass., 100: 281-291.

Hall, R.L. & S. Moore, 1990. ?*Tethyaster albertensis*, a Late Cretaceous (Turonian) sea star from the Cardium Formation, Alberta, Canada. — J. Paleont., 64: 1045-1049.

Hess, H., 1955. Die fossilen Astropectiniden (Asteroidea). Neue Beobachtungen und Übersicht über die bekannten Arten. — Schweiz. paläont. Abh., 71: 1-114, pls 1-4.

Hess, H., 1960a. Über die Abgrenzung der Astropectiniden-Gattungen *Pentasteria* Valette und *Archastropecten* Hess. — Eclogae geol. Helv., 53: 329-331.

Hess, H., 1960b. *Pentasteria (Archastropecten) procera* n. sp. (Asteroidea, Astropectinidae) aus dem Bajocien von Cheltenham, England. — Eclogae geol. Helv., 53: 331-334, pl. 1.

Hess, H., 1970. Schlangensterne und Seesterne aus dem oberen Hauterivien «Pierre jaune» von St-Blaise bei Neuchâtel. — Eclogae geol. Helv., 63: 1069-1091, pls 1-4.

Hess, H., 1974. Neue Funde des Seesterns *Terminaster cancriformis* (Quenstedt) aus Callovien und Oxford von England, Frankreich und der Schweiz. — Eclogae geol. Helv., 67: 647-659, 3 pls.

Hess, H., 1991. Neue Seesterne (Goniasteridae) aus dem mittleren Oxford von Reuchenette (Berner Jura). — Eclogae geol. Helv., 84: 873-891.

Hess, H. & D.B. Blake, 1995. *Coulonia platyspina* n. sp., a new astropectinid sea star from the Lower Cretaceous of Morocco. — Eclogae geol. Helv., 88: 777-788.

Jagt, J.W.M., A.V. Dhondt, L. Indeherberge, E. Defour, R. Meuris, C. Neumann & R. van der Ham, in prep. Notes on echinoderms and bivalves from the Craie de Spiennes (Late Campanian, Mons Basin, southern Belgium).

Jagt, J.W.M., J. Savelsbergh & A.S. Gale, 1994. Presentation of a near-complete early Palaeocene specimen of *Chomataster acules* Spencer, 1913 (Asteroidea) from NE Belgium. In: B. David, A. Guille, J.-P. Féral & M. Roux (eds). Echinoderms through Time. — A.A. Balkema, Rotterdam/Brookfield: 318.

Kaczmarska, G., 1987. Asteroids from the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland). — Acta geol. pol., 37: 131-144, pls 1-8.

Lafay, B., A.B. Smith & R. Christen, 1995. A combined morphological and molecular approach to the phylogeny of asteroids (Asteroidea: Echinodermata). — Syst. Biol., 44: 190-208.

Loriol, P. de, 1874. Description de quelques astérides du terrain néocomien des environs de Neuchâtel. — Mém. Soc. Sci. nat. Neuchâtel, 5: 5-19, pls 1-2.

Mercier, J., 1935. Les Stellérides Mésozoïques du Bassin de Paris (Bordure Occidentale). — Mém. Soc. linn. Normandie, n.s., 3: 1-66, pls 1-3.

Meyer, C.A., 1988. Ein neuer Seestern aus den Solothurner Schildkrötenkalken (Oberes Kimmeridgien, Kt. Solothurn). — Eclogae geol. Helv., 81: 843-856.

Müller, A.H., 1953. Die isolierten Skelettelemente der Asteroidea (Asterozoa) aus der obersenonen Schreibkreide von Rügen. — Geologie, Beih. 8: 3-66, pls 1-10.

Müller, A.H., 1956. Zur genaueren Kenntnis von *Lophidiaster pygmaeus* (Asterozoa) aus der Schreibkreide (Maastricht) von Rügen. — Geologie, 5: 642-651, 2 pls.

Nosowska, E., 1997. Asteroids from the Nawodzice Sands (Middle Miocene; Holy Cross Mountains, Central Poland). — Acta geol. pol., 47: 225-241, pls 1-12.

Neumann, C., in press. Evidence of predation on Cretaceous sea stars from north-west Germany. — Lethaia.

Rasmussen, H.W., 1945. Observations on the Asteroid Fauna of the Danian. — Meddr dansk geol. Foren., 10(1944): 417-426, pl. 9.

Schulz, M.-G. & W. Weitschat, 1971. Asteroideen aus der Schreibkreide von Lägerdorf (Holstein) und Hemmoor (N.Niedersachsen). — Mitt. geol.-paläont. Inst. Univ. Hamburg, 40: 107-130, pls 23-26.

Schulz, M.-G. & W. Weitschat, 1975. Phylogenie und Stratigraphie der Asteroiden der nordwestdeutschen Schreibkreide. Teil I: *Metopaster/Recurvaster*- und *Calliderma/Chomataster*-Gruppe. — Mitt. geol.-paläont. Inst. Univ. Hamburg, 44: 249-284, pls 24-31.

Schulz, M.-G. & W. Weitschat, 1981. Phylogenie und Stratigraphie der Asteroiden der nordwestdeutschen Schreibkreide. Teil II: *Crateraster/Teichaster*-Gruppe und Gattung *Ophryaster*. — Mitt. geol.-paläont. Inst. Univ. Hamburg, 51: 27-42, pls 2-7.

Sieverts-Doreck, H., 1958. Über eine bemerkenswerte Seesternplatte aus dem Campan von Lägerdorf (Holstein). — Mitt. geol. Staatsinst. Hamburg, 27: 74-76.

Sladen, W.P., 1891-1893. A monograph on the British fossil Echinodermata from the Cretaceous Formations, 2. The Asteroidea and Ophiuroidea. — Monogr. Palaeontogr. Soc. Lond., 1891: 1-28, pls 1-8; 1893: 29-66, pls 9-16.

Spencer, W.K., 1913. The Evolution of the Cretaceous Asteroidea. — Phil. Trans. r. Soc. Lond., B204: 99-177, pls 10-16.

Spencer, W.K. & C.W. Wright, 1966. Asterozoans. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata, 3, 1. — Geol. Soc. America, Boulder/Univ. Kansas Press, Lawrence: U4-U107.

Umbgrove, J.H.F., 1925. Asteroidea uit het Maastrichtsche Tufkrijt. — Verh. geol.-mijnb. Gen. Nederl. Kol., geol. serie, 7: 207-212, 1 pl.

Valette, A., 1902. Note sur quelques stellérides de la craie sénonienne de Département de l'Yonne. — Bull. Soc. Sci. hist. nat. Yonne, 56: 3-26.

Valette, A., 1915. Nouvelle note sur les stellérides de la craie blanche du Département de l'Yonne. — Bull. Soc. Sci. hist. nat. Yonne, 1915: 1-72.

Villier, L., 1996. Les Goniasteridae (Asteroidea, Echinodermata) du Campanien d'Aquitaine; ontogenèse, évolution et paléoécologie. — Univ. de Bourgogne, Dijon: 1-50 (unpubl. master's thesis).

Villier, L., G. Breton & D. Néraudeau, 1997. Contexte paléoécologique, biodiversité et signification biostratigraphique des astérides dans le Campanien stratotypique. — Ann. Soc. géol. Nord, 5: 181-188.

Wright, C.W. & E.V. Wright, 1941. Notes on Cretaceous Asteroidea. — Q. Jl geol. Soc. Lond., 96 (1940): 231-248, pls 13-17.

Manuscript received 27 January 2000.

Plate 1

Figs. 1-2, 8-9, 12. *Astropecten*? sp. nov.
1: NHMM MB 493-4/a, distal inferomarginal, Ankerpoort-Curfs quarry, Geulhem, Houthem Formation, Geulhem Member, base + 0-1 m.
2, 12: NHMM MB 493-4/b, distal inferomarginal, same locality and stratigraphy.
8-9: NHMM MB 493-4/c, proximal inferomarginal, same locality and stratigraphy.

Figs. 3-4, 10. Ctenodiscid? indet.
3-4: NHMM MB 680, arm fragment, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, base Emael Member.
10: RGM 428 060 (ex Jagt Colln, no. 2794), ?inferomarginal, same locality, Gulpen Formation, Lanaye Member (12-13).

Figs. 5-7. Goniasterid? sp. 4; NHMM JJ 9591/b-d, respectively, ?inferomarginal (5) and ?superomarginals (6-7), same locality, Maastricht Formation, Emael Member (Lava Horizon).

Fig. 11. Astropectinidae indet.; NHMM JJ 9591/a, proximal ?inferomarginal, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, Emael Member (Lava Horizon).

Scale bars equal 1 mm, except in figs. 7 and 10, where they represent 100 µm.

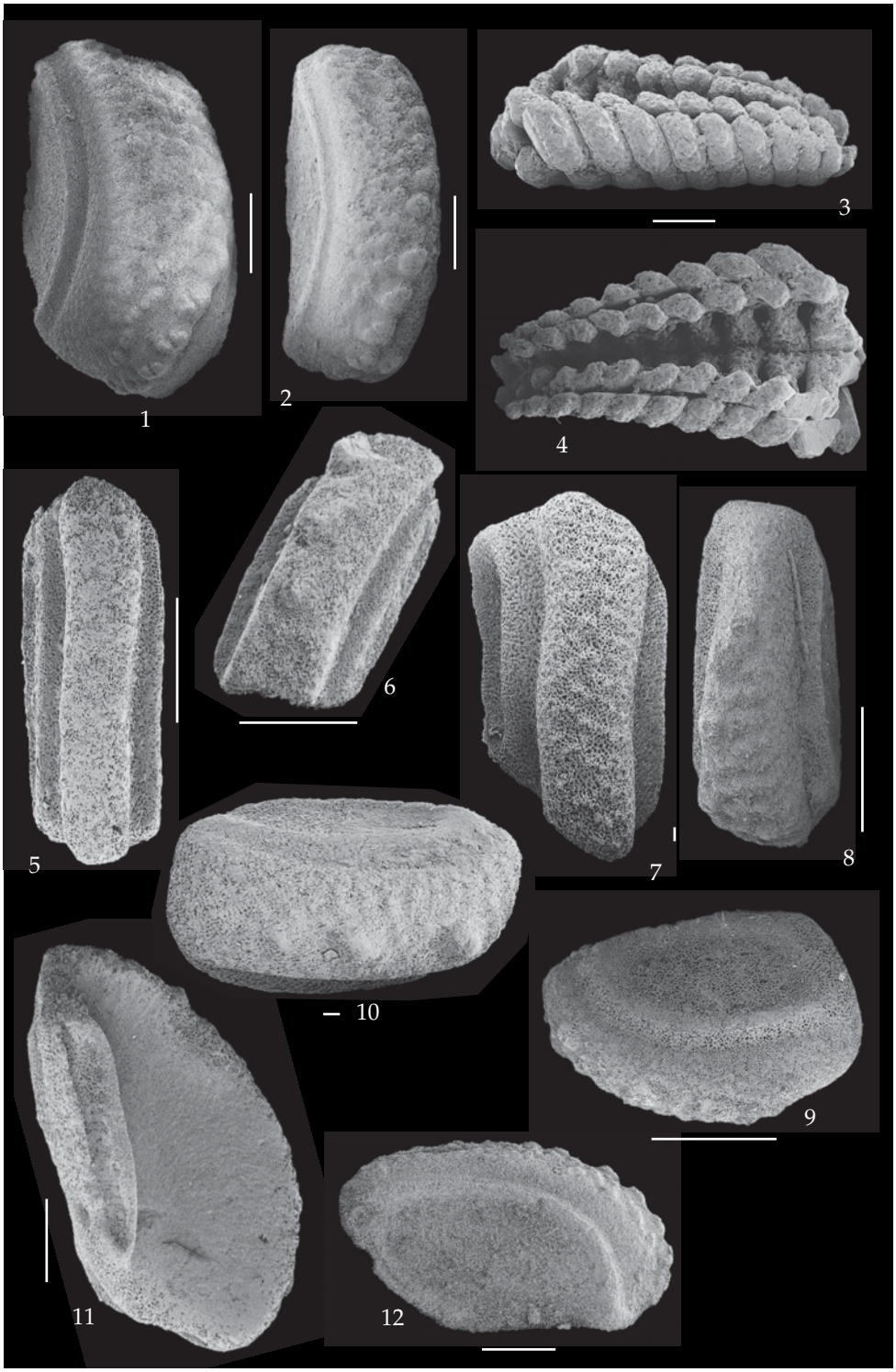

1
2
3
4
5
6
7
8
9
10
11
12

Plate 2

Figs. 1-2, 4-6. *Lophidiaster*? gr. *punctatus/postornatus*
1-2: NHMM K 1701/b-c, supero- and inferomarginal, respectively, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.
4-6: NHMM 432-74/a-c, inferomarginal (4) and superomarginals (5-6), temporary Albertkanaal sections, Kesselt, Houthem Formation, upper Geulhem Member.

Fig. 3. Astropectinidae indet.; NHMM MB 590-4, proximal ?superomarginal, CBR-Romontbos quarry, Eben Emael, Gulpen Formation, Lanaye Member (21-22).

Figs. 7-8. *Astropecten*? sp. nov.; NHMM K 1701/a, interbrachial superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Figs. 9-10. Goniasterid? sp. 4; NHMM JJ 3873, ?inferomarginal, same locality, Maastricht Formation, Meerssen Member (?IVf-6).

Figs. 11-12. *Coulonia*? sp.
11: NHMM MB 785-2/a, inferomarginal, Heure-le-Romain, Gulpen Formation, base Vijlen Member.
12: NHMM MB 387-7/a, inferomarginal, Hans Böckler Allee, Aachen, Gulpen Formation, Vijlen Member.

Figs. 13-14. Astropectinid sp. nov.; NHMM JJ 9993/c, inferomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.

Scale bars equal 1 mm, except in figs. 2, 7-10 where they represent 100 µm.

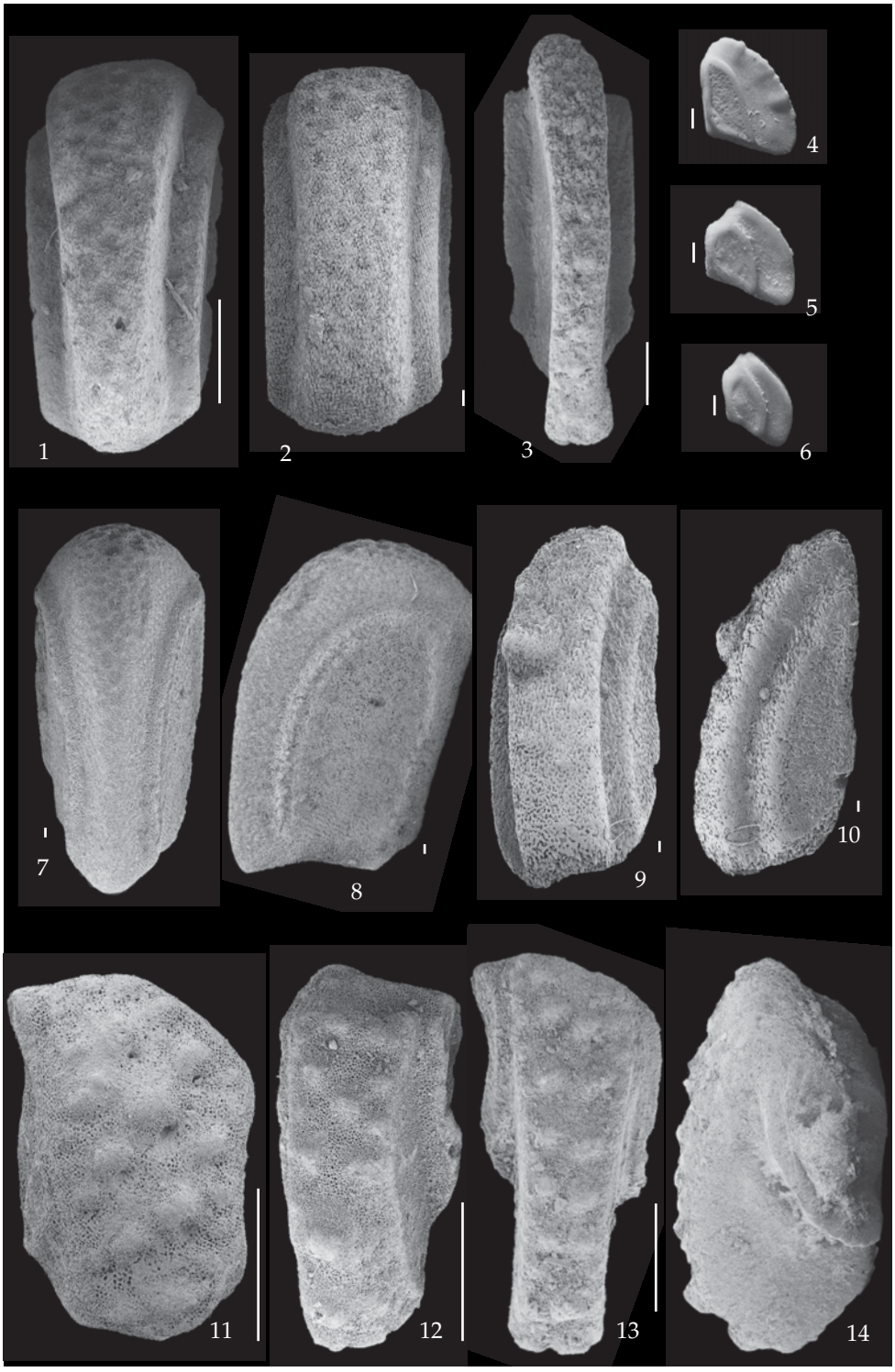

1
2
3
4
5
6
7
8
9
10
11
12
13
14

Plate 3

Figs. 1-9. *Coulonia*? sp. nov.
1-2: NHMM MB 94, portion of disc, Heure-le-Romain, Gulpen Formation, Zeven Wegen Member, top - 9-12 m.
3, 6: RGM 428 059 (ex Jagt Colln, no. 8780/a); median inferomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, crinoid level.
4: NHMM JJ 8780/d, ambulacral, same locality and stratigraphy.
5: RGM 428 061 (ex Jagt Colln, no. 8780/b), distal inferomarginal, same locality and stratigraphy.
7-8: RGM 428 070 (ex Jagt Colln, no. 8780/e), median superomarginal, same locality and stratigraphy.
9: NHMM JJ 8780/c, ambulacral, same locality and stratigraphy.

Figs. 10-12. Astropectinid sp. nov.; CBR-Romontbos quarry, Eben Emael; Maastricht Formation, Emael Member (Lava Horizon).
10: NHMM JJ 9591/e, superomarginal.
11: NHMM JJ 9591/f, superomarginal.
12: RGM 428 071 (ex Jagt Colln, no. 9591/e), inferomarginal.

Scale bars equal 1 mm.

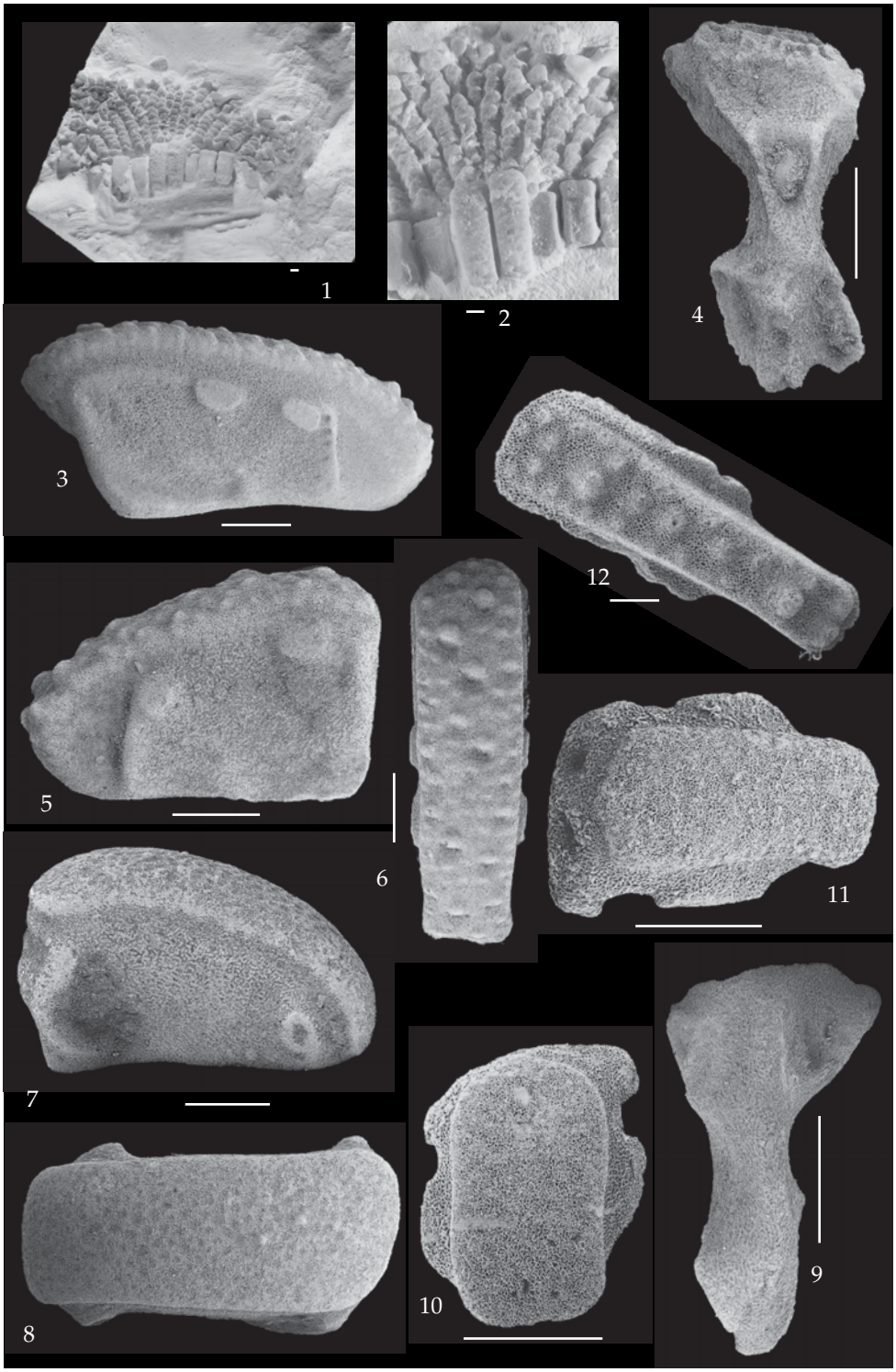

1
2
3
4
5
6
7
8
9
10
11
12

Plate 4

Figs. 1-7. *Lophidiaster pygmaeus* Spencer, 1913; CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 0-3 m (1-6), and base + 2.15 m (7).
1: NHMM JJ 3713/a, ambulacral.
2: NHMM JJ 3713/b, paxilla.
3: NHMM JJ 3713/c, oral.
4-5: RGM 428 062 (ex Jagt Colln, no. 3713/d), median superomarginal.
6: NHMM JJ 3713/e, circumoral.
7: NHMM JJ 3169, terminal.

Figs. 8-10. *Aldebarania* sp. nov.
8: NHMM JJ 2787, distal superomarginal, CBR-Romontbos quarry, Eben Emael, Maastricht Formation, upper Nekum Member.
9-10: RGM 428 072 (ex Jagt Colln, no. 3770), median superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, upper Nekum Member.

Figs. 11-12. Astropectinid sp. nov.; NHMM JJ 3769, median inferomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, upper Nekum Member.

Scale bars equal 100 µm, except in figs. 3, 9-12, where they represent 1 mm.


1
2
3
4
5
6
7
8
9
10
11
12

Plate 5

Figs. 1-5. Astropectinid sp. nov.; ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-5/-6).
1-2: NHMM K 3364/a.
3: NHMM K 3364/b, lateral view of supero- and inferomarginals.
4-5: NHMM K 3364/c, ambulacral, adambulacral and inferomarginal details.

Figs. 6-12. *Aldebarania* sp. nov.; CBR-Romontbos quarry, Eben Emael (Liège); Maastricht Formation, upper Nekum Member.
6-7: NHMM 1999015-1.
8: NHMM 1999015-2.
9-12: NHMM 1999015-3.

Scale bars equal 1 mm, except in fig. 3, where it represents 100 µm.

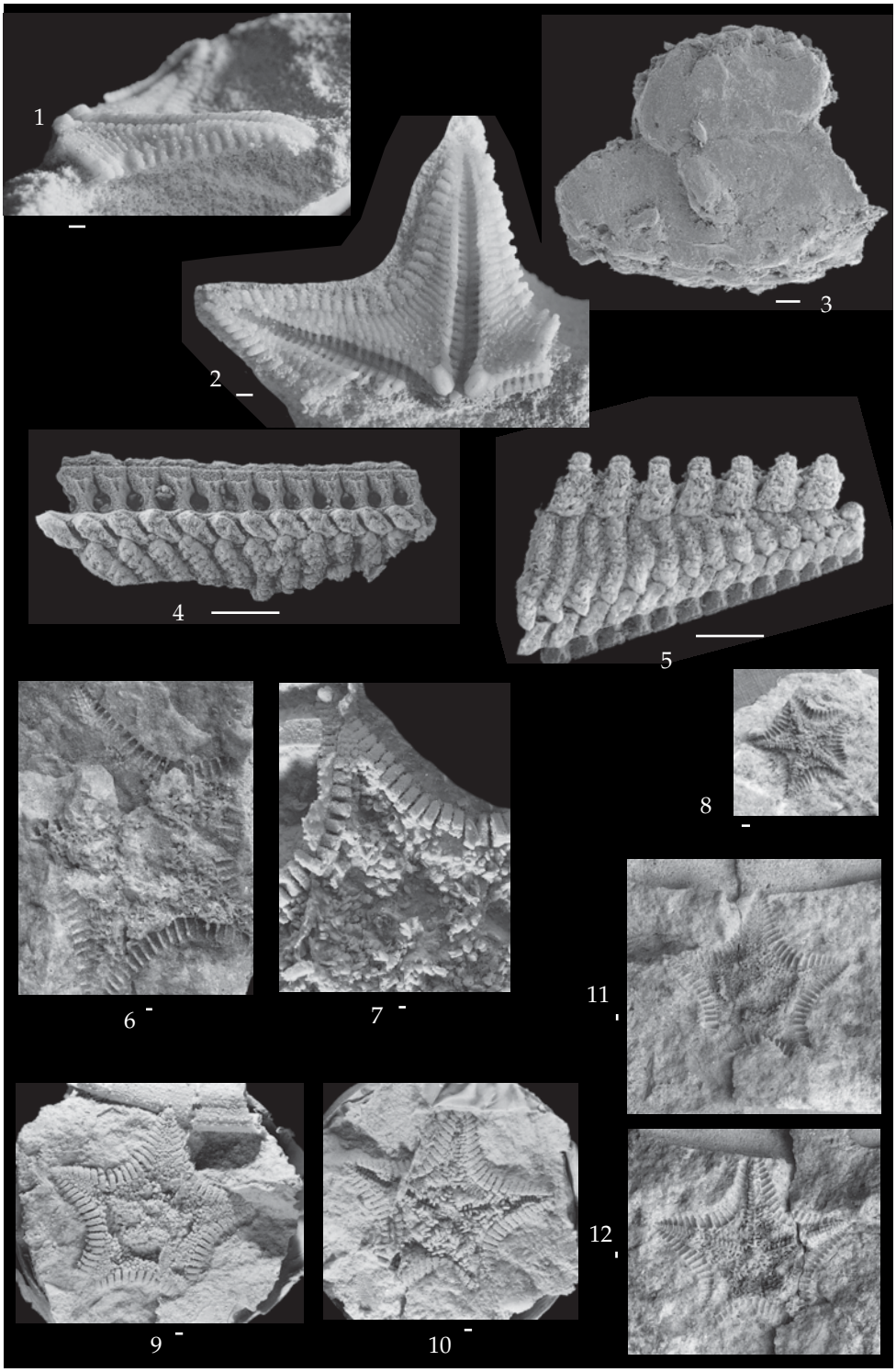

1
2
3
4
5
6
7
8
9
10
11
12

Plate 6

Figs. 1-4. Benthopectinid sp. 1 (? spp.)
1-2: NHMM JJ 9591/h-i, inferomarginals, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon).
3: NHMM MB 867-6, ?inferomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, top - c. 4 m.
4: NHMM MB 507-19, inferomarginal, Kunrade area, Maastricht Formation, Kunrade Limestone facies.

Figs. 5-6, 8, 10-12. Benthopectinid sp. 2; CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
5: NHMM MB 808-7/a.
6: NHMM MB 808-7/b.
8: NHMM MB 808-9/a, note preservation of ambulacrals.
10: NHMM MB 808-7/e.
11-12: NHMM MB 808-7/f, terminal.

Figs. 7, 9. Asteriid sp. (? spp.) ?; CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
7: NHMM MB 808-7/c.
9: NHMM MB 808-7/d.

Scale bars equal 100 µm, except in figs. 1, 6, 8, where they represent 1 mm.

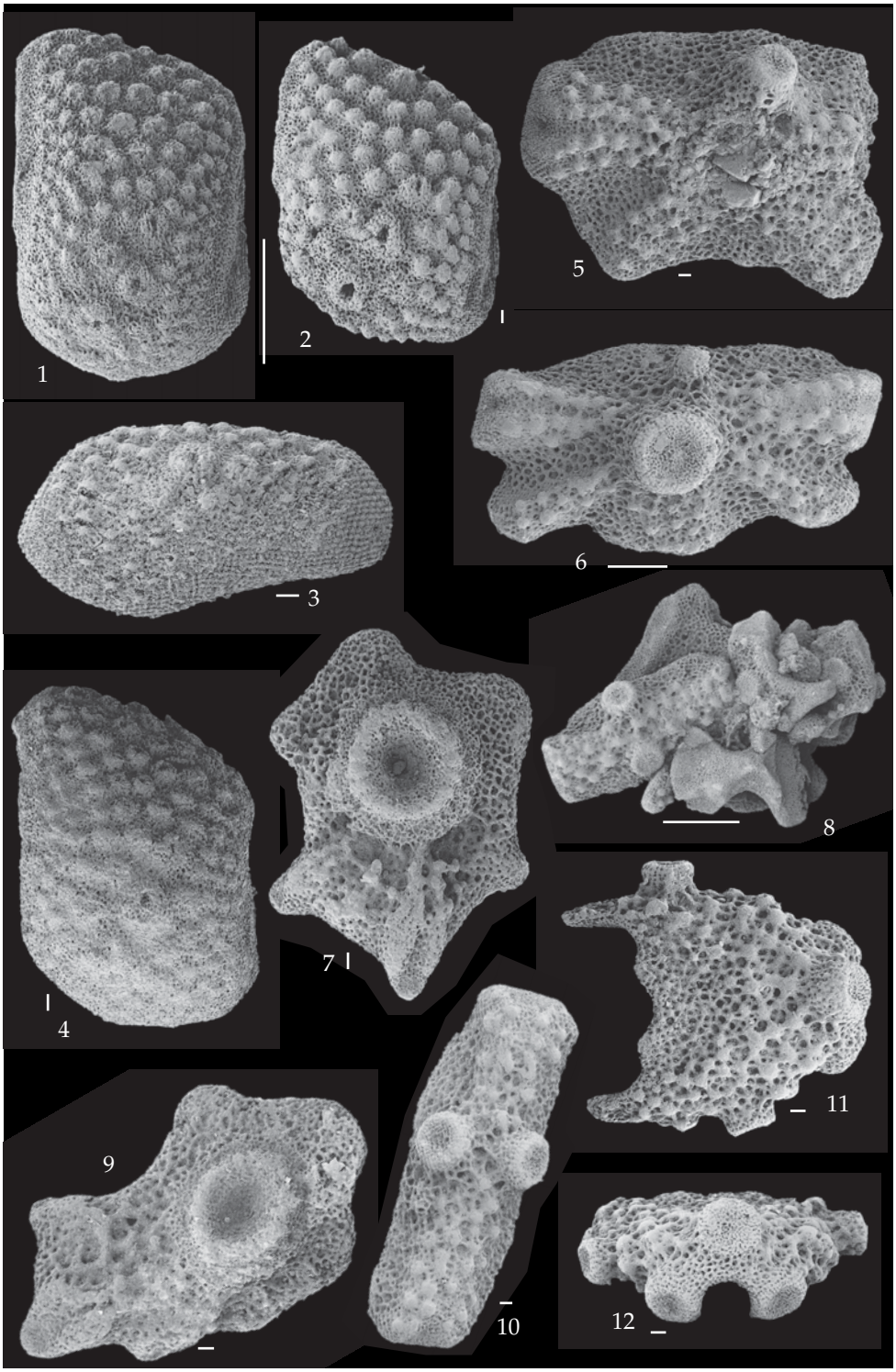

1
2
3
4
5
6
7
8
9
10
11
12

Plate 7

Figs. 1-2. Benthopectinid sp. 2; CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
1: NHMM MB 808-7/g.
2: NHMM MB 808-7/h.

Figs. 3-4. Asteriid sp. (? spp.) ?; CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
3: NHMM MB 808-7/i, ambulacrals and marginals associated.
4: NHMM MB 808-7/j.

Figs. 5-6. *Aldebarania* sp. nov. ?; NHMM MB 377-23/a-b, portions of disc, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (base IVf-3).

Figs. 7-8. Astropectinid sp. nov.; NHMM JJ 9591/j, median inferomarginal, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon).

Figs. 9-10. *Metopaster* aff. *carinatus* (Brünnich Nielsen, 1943)?; NHMM MB 432-74/d, ultimate superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Figs. 11-12. *Metopaster praetumidus* Schulz & Weitschat, 1975?; RGM 428 073 (ex Jagt Colln, no. 2459), median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, lower Zeven Wegen Member.

Figs. 13-16. *Metopaster* aff. *planus* (Brünnich Nielsen, 1943); NHMM JJ 11148/a-c, ultimate superomarginals, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Scale bars equal 1 mm, except in figs. 1-2, and 4, where they represent 100 µm.

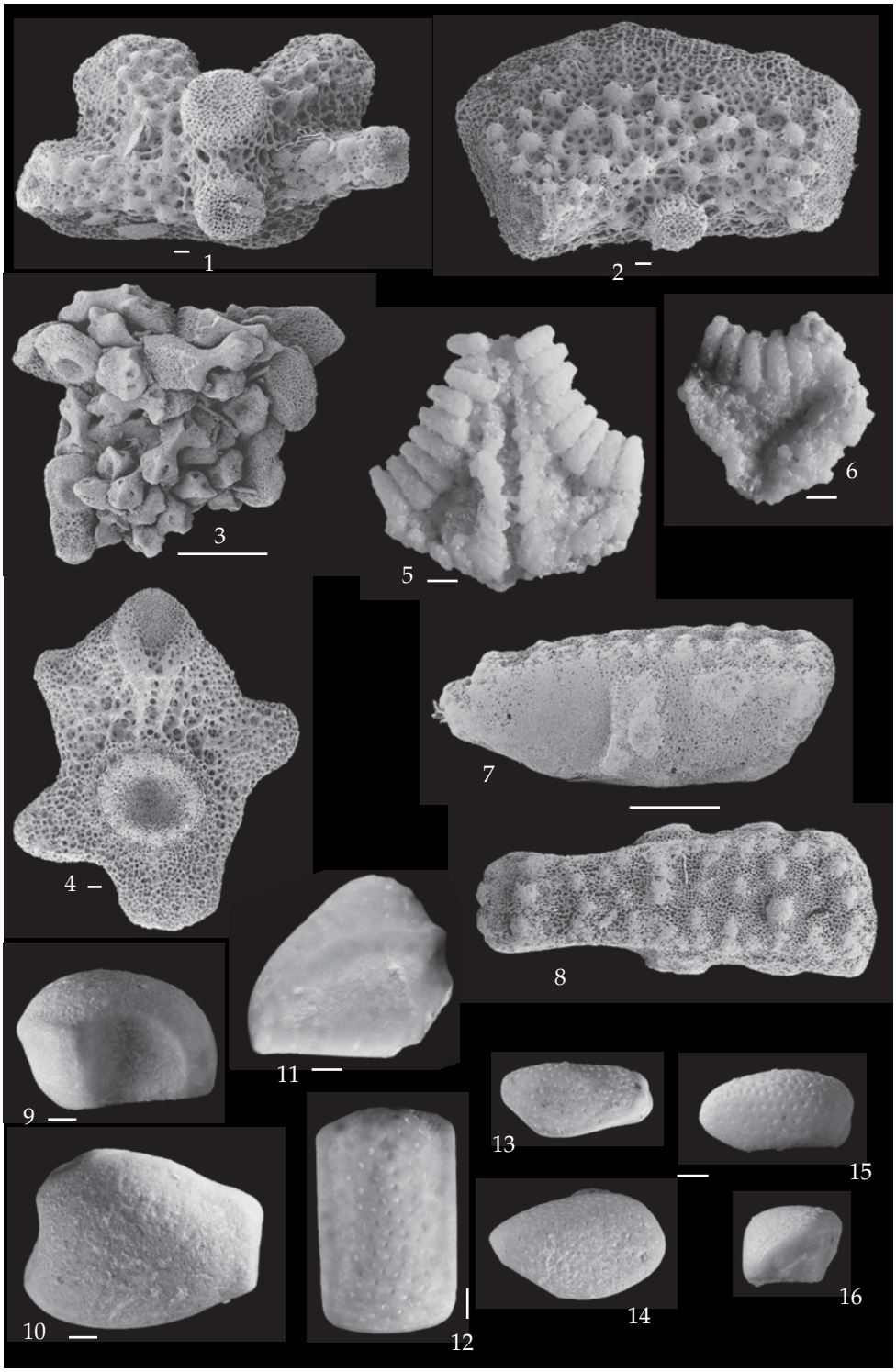

1
2
3
5
6
4
7
8
11
9
13
15
10
12
14
16

Plate 8

Figs. 1-4, 6, 7?, 8?. *Metopaster decipiens* Spencer, 1913
1-2: RGM 428 066 (ex Jagt Colln, no. 3201), ultimate superomarginal, and detail of pedicellaria, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 1.5/2 m.
3: NHMM MB 639-2/a, median inferomarginal, same locality, Gulpen Formation, Zeven Wegen Member, base + 1.5 m.
4: NHMM JJ 7188, median inferomarginal, same locality, Gulpen Formation, Zeven Wegen Member, top - 9.7-11.6 m.
6: NHMM MB 808-7/k, median inferomarginal, same locality, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
7: NHMM JJ 3463bis/1, ultimate superomarginal, same locality, Gulpen Formation, lower Zeven Wegen Member.
8: NHMM JJ 3463bis/2, ultimate superomarginal, same locality and stratigraphy.

Fig. 5. *Metopaster undulatus* Spencer, 1913; NHMM MB 387-7/b, median inferomarginal, Hans Böckler Allee, Aachen-Vaalserquartier, Gulpen Formation, Vijlen Member.

Figs. 9-12. *Metopaster kagstrupensis* Brünnich Nielsen, 1943
9-10: NHMM JJ 11139, ultimate superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.
11-12: RGM 428 065 (ex Jagt Colln, no. 4433), ultimate superomarginal, same locality and stratigraphy.

Scale bars equal 1 mm, except in fig. 2, where it represents 100 µm.

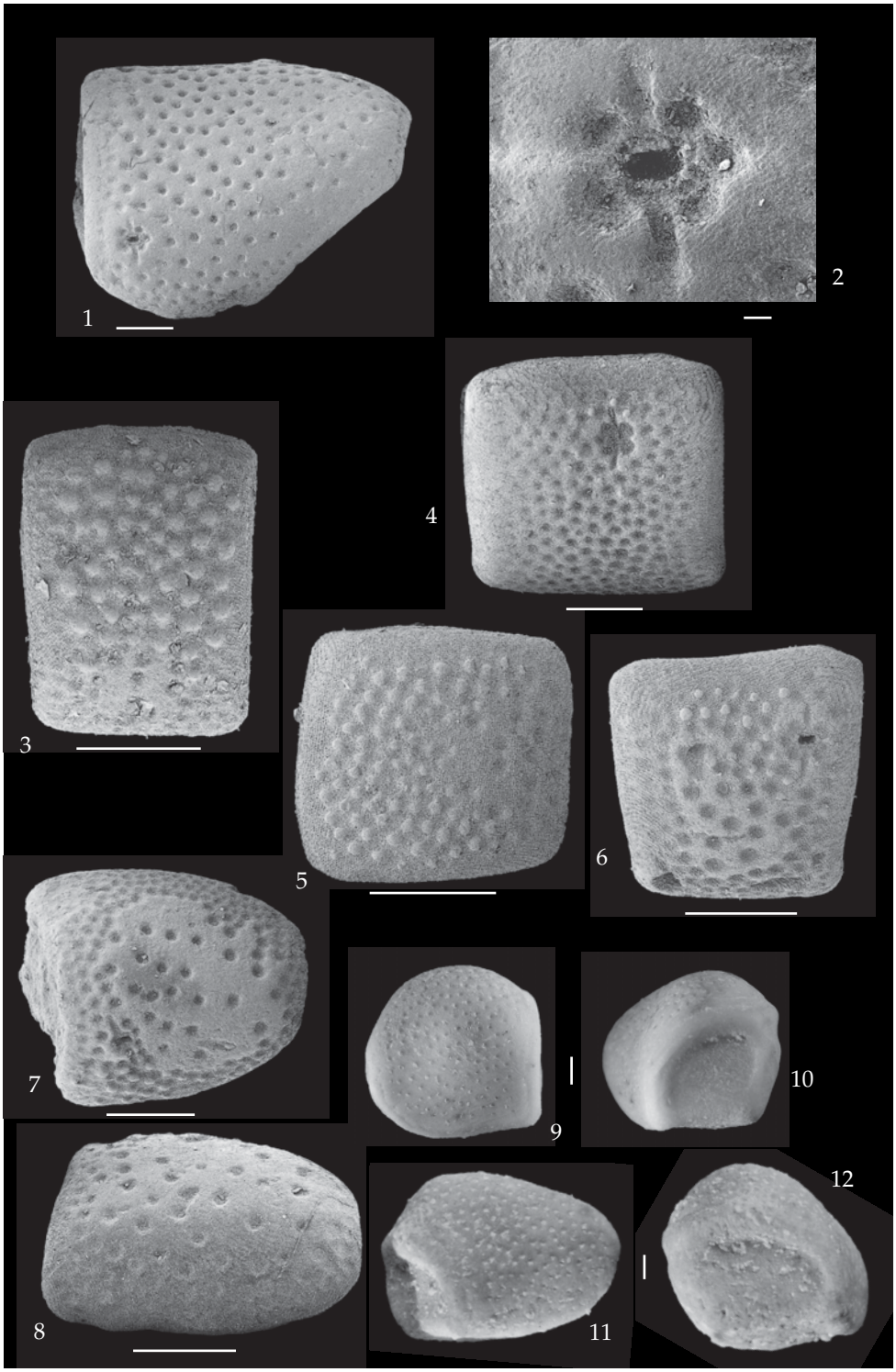

1
2
3
4
5
6
7
8
9
10
11
12

Plate 9

Figs. 1-3. *Metopaster* aff. *carinatus* (Brünnich Nielsen, 1943); NHMM RH 285/a-b, ultimate infero- and superomarginals, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 4-7. *Metopaster kagstrupensis* Brünnich Nielsen, 1943
4, 7: NHMM MM 1266, portions of disc, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, lower Geulhem Member.
5-6: NHMM JJ 9519, reconstruction of portion of disc from associated marginals, Stevns Klint (Sjælland, Denmark), south of Højerup Kirke, Lower Danian Bryozoan Limestone.

Figs. 8-11. *Metopaster alexiae* sp. nov.; Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (base IVf-3).
8-9: NHMM MB 377-23/c-d (**paratypes**), ultimate superomarginals.
10-11: NHMM MB 377-23/e (**holotype**), ultimate superomarginal.

Scale bars equal 1 mm.


1
2
3
4
5
6
7
8
9
10
11

Plate 10

Figs. 1-2. *Parametopaster*? sp.; NHMM K 2762, ultimate superomarginal, Ankerpoort-Marnebel quarry, Eben Emael (Liège), Maastricht Formation, upper Nekum Member (Kanne Horizon).

Figs. 3, 13. *Metopaster lisannae* sp. nov. ? (var. B)
3: NHMM MB 784-21/a, ultimate superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).
13: NHMM MB 655-17, ultimate inferomarginal, road cutting near Schunck quarry, Kunrade, Maastricht Formation, Kunrade Limestone facies.

Figs. 4-7. *Metopaster* gr. *tumidus* Spencer, 1913; ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Valkenburg Member.
4-5: NHMM JJ 11120/a-b, ultimate superomarginals.
6-7: NHMM JJ 9552, ultimate superomarginal.

Figs. 8-12. *Metopaster lisannae* sp. nov. (var. A)
8: NHMM K 744 (**paratype**), ultimate superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member, top IVf-4.
9: NHMM JJ 9973 (**paratype**), distal inferomarginal, same locality, Maastricht Formation, Meerssen Member (IVf-4).
10: NHMM K 1075/a (**paratype**), ultimate superomarginal, same locality, Maastricht Formation, Meerssen Member (IVf-6).
11-12: NHMM K 1162 (**holotype**), ultimate superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 14-15. *Metopaster* sp. 3; NHMM MB 784-21/b, ultimate superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 16-17. *Metopaster* sp. 4 (aff. *elegans* Gale, 1987a); NHMM MB 784-21/c, ultimate superomarginal, same locality and stratigraphy.

Scale bars equal 1 mm.

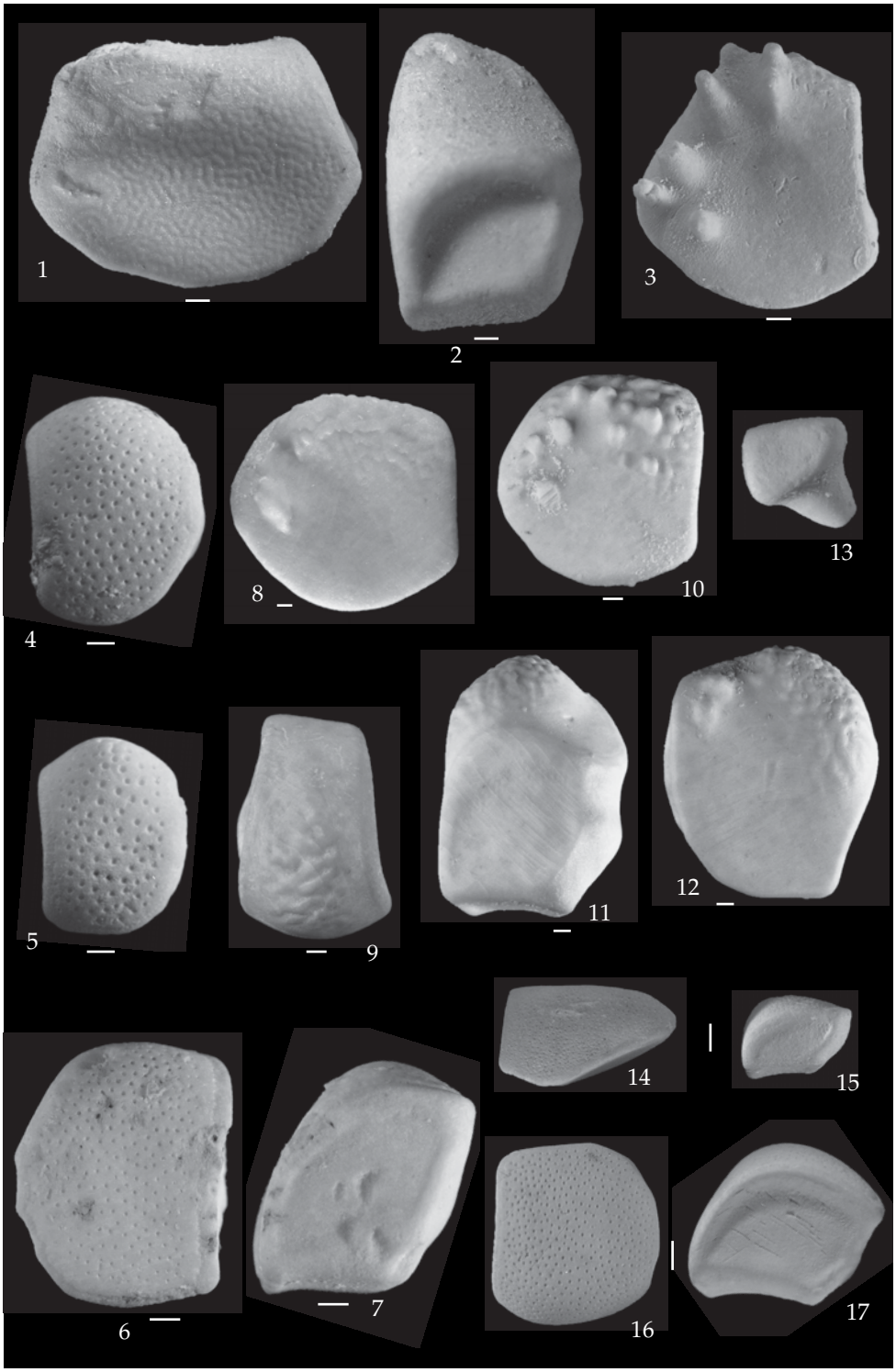

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

Plate 11

Figs. 1-2, 4. *Recurvaster* gr. *radiatus* Spencer, 1913
1-2: RGM 428 068 (ex Jagt Colln, no. 729a), distal inferomarginal, CPL SA quarry, Haccourt, Gulpen Formation, lower Zeven Wegen Member.
4: NHMM MB 233/b, median superomarginal, same locality and stratigraphy.

Figs. 3, 5-9, 18-19. *Metopaster praetumidus* Schulz & Weitschat, 1975
3: NHMM MB 233/a, median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, lower Zeven Wegen Member.
5-6: NHMM MB 868-5/a, ultimate superomarginal, same locality and stratigraphy.
7-8: RGM 428 067 (ex Jagt Colln, no. 4910), median superomarginal, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member, top - 0-6 m.
9: NHMM MB 776/a, ultimate superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 1.5 m.
18-19: NHMM K 1364, median superomarginal, same locality, Gulpen Formation, Zeven Wegen Member, base + c. 8 m.

Figs. 10-11. *Recurvaster spiniger* sp. nov.; NHMM JJ 6621, median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 2.5 m.

Figs. 12-14. *Metopaster uncatus* (Forbes, 1848)
12-13: NHMM MB 868-5/a, median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
14: NHMM MB 776/b, ultimate superomarginal, same locality, Gulpen Formation, Zeven Wegen Member, base + 1.5 m.

Figs. 15-17. *Metopaster* gr. *tumidus* Spencer, 1913
15: NHMM MB 1239-22/a, median superomarginal, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
16-17: NHMM MB 1239-22/b, ultimate superomarginal, same locality and stratigraphy.

Figs. 20-21. *Recurvaster mammillatus* (Gabb, 1876); NHMM MB 339-8/a, median superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Scale bars equal 1 mm.

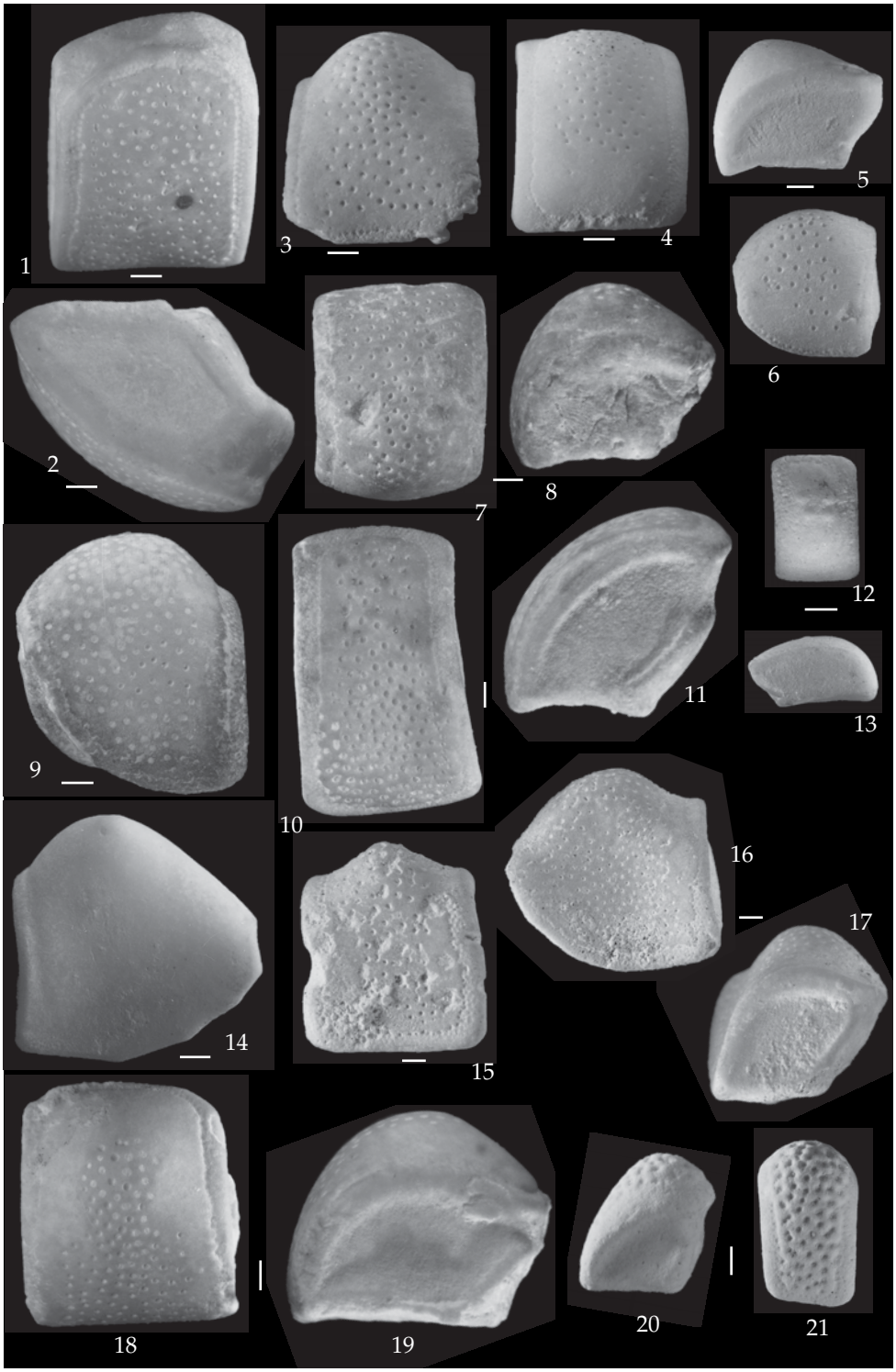

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Plate 12

Figs. 1-4, 7-12, 16. *Recurvaster spiniger* sp. nov.
1-2: NHMM K 769 (**holotype**), median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + c. 4 m.
3-4: NHMM MB 867-7/a (**paratype**), median inferomarginal, same locality, Gulpen Formation, Vijlen Member, top - c. 4 m.
7-9: NHMM MB 284-1/a-c (**paratypes**), inferomarginals, same locality, Gulpen Formation, Lixhe 1 Member, Hallembaye 1 Horizon - 3 m.
10-11: NHMM MB 284-1/d (**paratype**), distal superomarginal, same locality and stratigraphy.
12, 16: NHMM MB 867-7/b (**paratype**), distal superomarginal, same locality, Gulpen Formation, Vijlen Member, top - c. 4 m.

Figs. 5-6. *Recurvaster* gr. *radiatus* Spencer, 1913; Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
5: NHMM MB 1239-22/c, median superomarginal.
6: NHMM MB 1239-22/d, median inferomarginal.

Figs. 13-15. Indeterminate goniasterine
13: NHMM JJ 11147/a, median superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.
14-15: NHMM JJ 3992, median superomarginal, Oud Valkenburg ('de Drie Beeldjes' outcrop), Gulpen Formation, (uppermost?) Lanaye Member.

Figs. 17, 21. *Metopaster kagstrupensis* Brünnich Nielsen, 1943?
17: NHMM JJ 11147/b, median superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.
21: NHMM JJ 11147/d, median inferomarginal, same locality and stratigraphy.

Figs. 18-19: *Metopaster* sp. 3; NHMM MB 865-9/a, ultimate superomarginal, de Wingerd quarry, Vaals Formation, Benzenrade Member, 2 m below contact with Kunrade Limestone facies.

Fig. 20. *Recurvaster mammillatus* (Gabb, 1876) ?; NHMM JJ 11147/c, median inferomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Scale bars equal 1 mm.

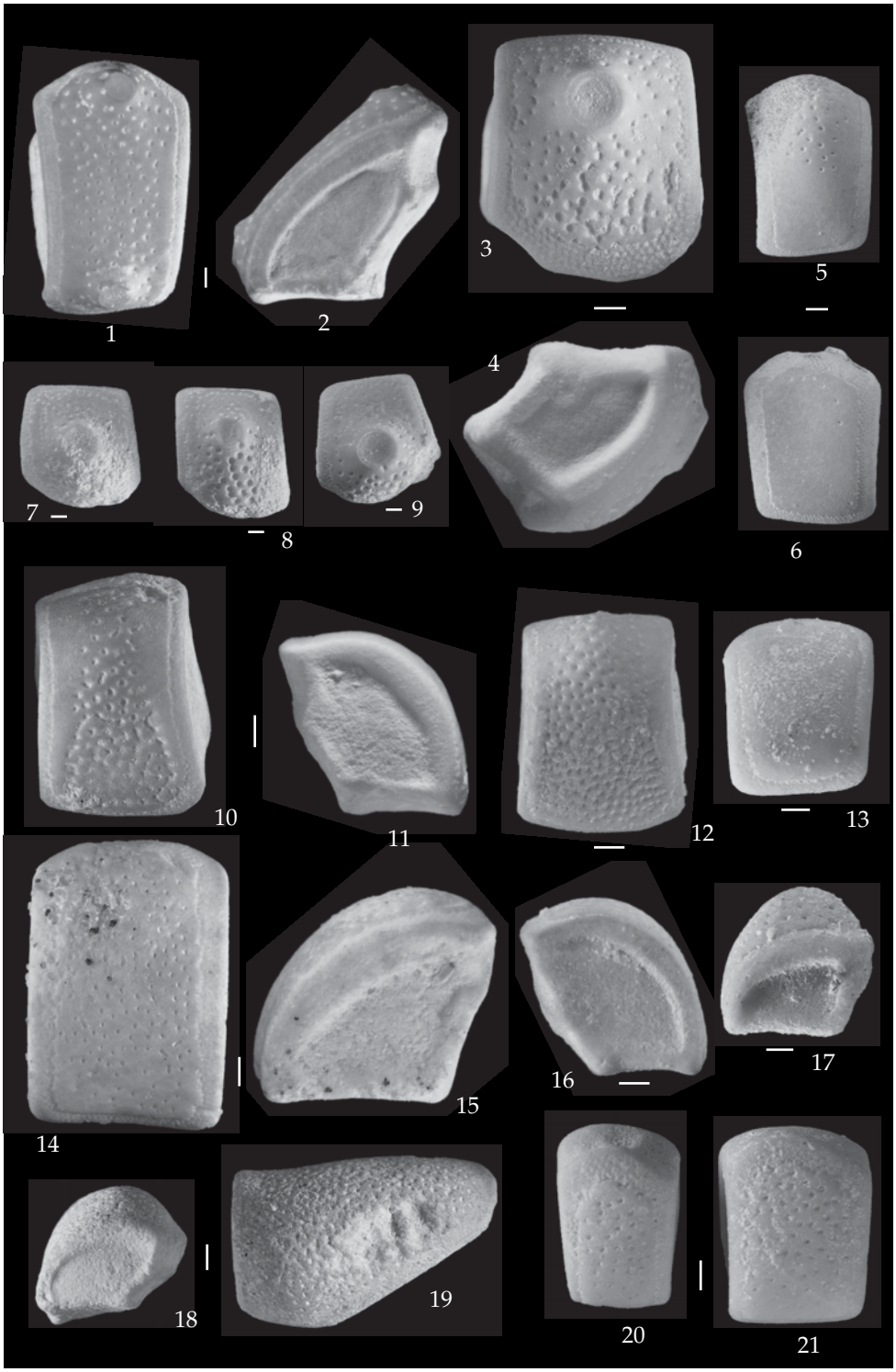

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Plate 13

Figs. 1-4. *Nymphaster alseni* (Schulz & Weitschat, 1971)
1-2: NHMM MB 806-8, large angle ossicle (SM3), CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member, top - c. 8 m.
3-4: NHMM JJ 8725/1-2, interradial superomarginals (SM1), CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base sponge level (= top - c. 15 m).

Figs. 5-6. *Nymphaster* sp.; NHMM JJ 7045, superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 4.5/5.5 m.

Figs. 7-8, 16-20. *Nymphaster studlandensis* (Schulz & Weitschat, 1975)
7-8: NHMM MB 808-7/l, distal superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
16-17: NHMM JJ 5123, interradial superomarginal (SM2 ?), same locality, Gulpen Formation, Zeven Wegen Member, base + 2-3 m.
18-20: NHMM 1994640, individual preserved in flint, showing interradial superomarginals (Fig. 19) and inferomarginals (Fig. 20), Brunsummerheide (Pliocene-Pleistocene gravel deposits, erratic boulder).

Figs. 9-15. *Nymphaster spenceri* (Rasmussen, 1950); Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
9, 15: NHMM MB 1239-22/e, distal superomarginal.
10, 14: NHMM MB 1239-22/f, interradial superomarginal.
11: NHMM MB 1239-22/g, interradial superomarginal.
12-13: NHMM MB 1239-22/h, interradial superomarginal.

Scale bars equal 1 mm.

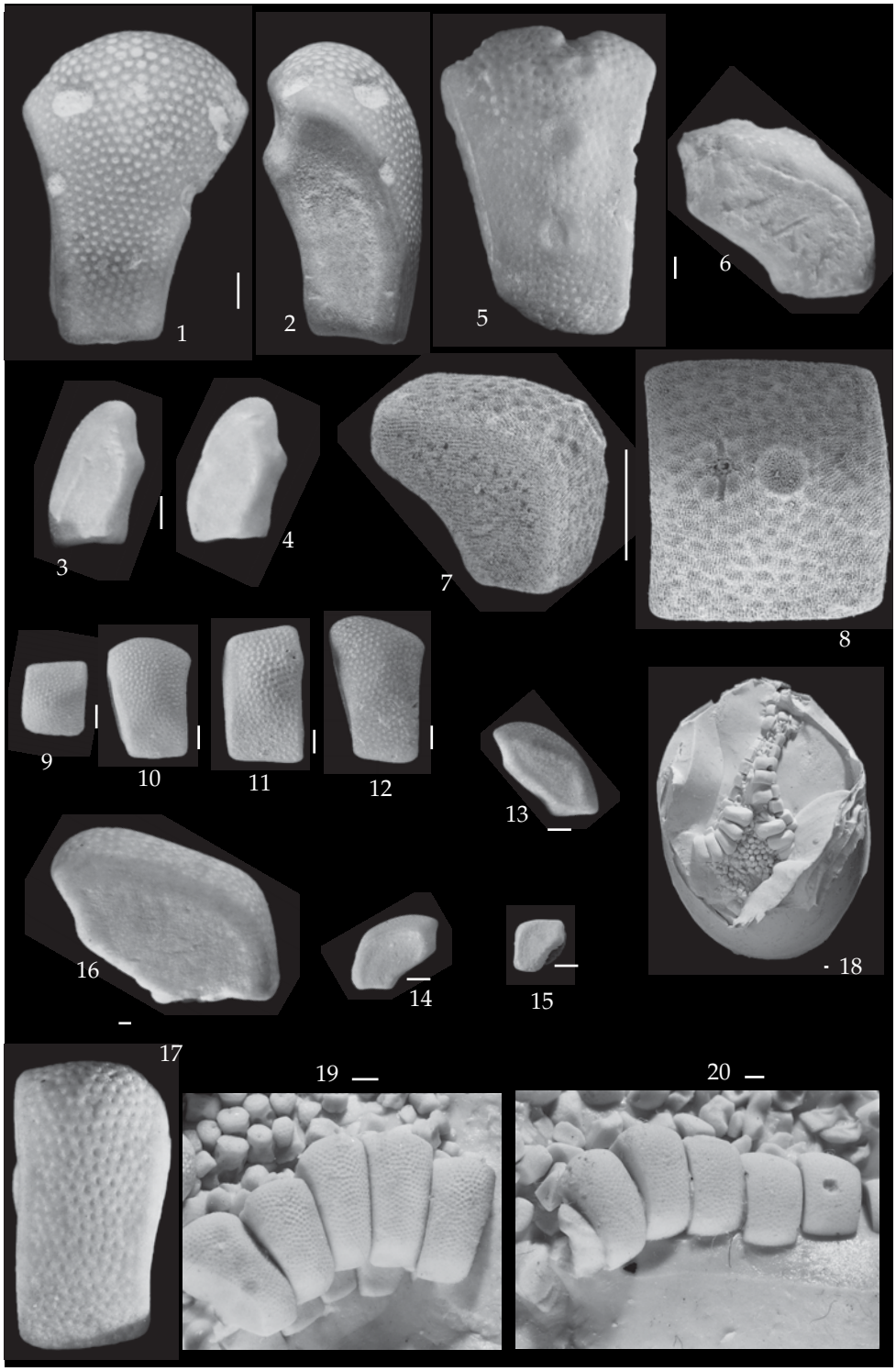

1
2
5
6
3
4
7
8
9
10
11
12
13
16
14
15
18
17
19
20

Plate 14

Figs. 1-15. *Chomataster acules* Spencer, 1913
1-2: RGM 428 069 (ex Jagt Colln, no. 8458), median superomarginal, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon).
3-4: NHMM JJ 7054, median inferomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + c. 5 m.
5: NHMM JJ 8250/a, median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base crinoid level.
6: NHMM JJ 8250/b, circumoral, same locality and stratigraphy.
7: NHMM MB 1239-22/i, median superomarginal, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
8: NHMM MB 432-74/e, median superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.
9, 11: NHMM MB 1239-22/j-k, median inferomarginals, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
10: NHMM K 2969, median superomarginal, Ankerpoort-Marnebel quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon).
12: NHMM JJ 8250/c, median inferomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base crinoid level.
13: NHMM JJ 10442, superomarginal spine, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon).
14: NHMM JJ 8250/d, ambulacral, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base crinoid level.
15: NHMM JJ 8250/e, adambulacral, same locality and stratigraphy.

Scale bars equal 1 mm, except in figs. 13 and 15, where they represent 100 µm.

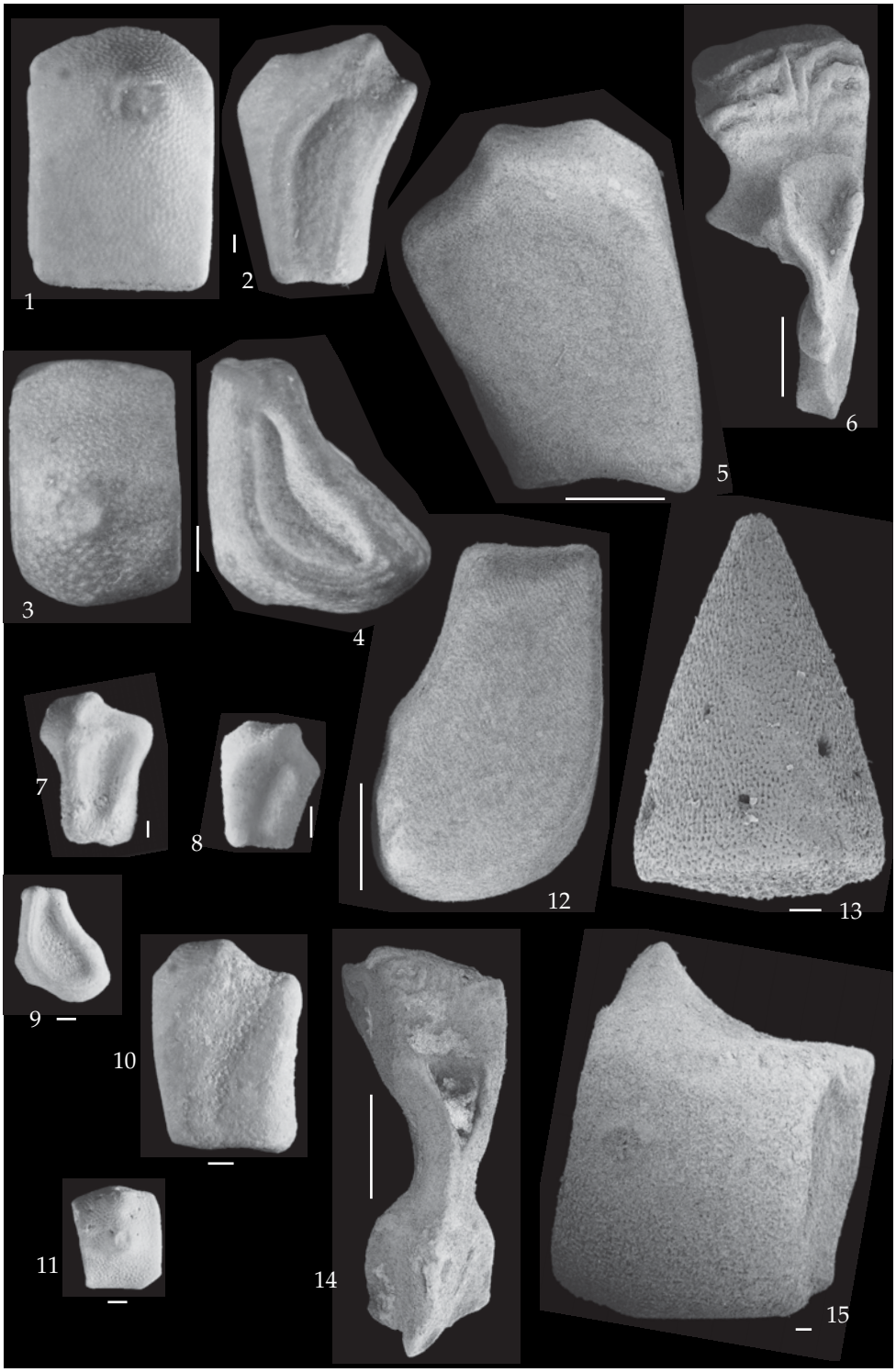

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Plate 15

Figs. 1-7, 14-16. *Ophryaster oligoplax* (Sladen, 1891)
1-2: NHMM JJ 6233/a, median superomarginal, CBR-Lixhe quarry, Lixhe, Gulpen Formation, Zeven Wegen Member, top - c. 7 m.
3-4: NHMM JJ 6233/b, median inferomarginal, same locality and stratigraphy.
5: NHMM JJ 6233/c, adambulacral, same locality and stratigraphy.
6-7: NHMM JJ 6233/d-e, ambulacrals, same locality and stratigraphy.
14: NHMM JJ 7991, arm fragment, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, top - 9.7-11.6 m.
15-16: NHMM JJ 6531, distal arm fragment, Heure-le-Romain, Gulpen Formation, Zeven Wegen Member, crinoid level.

Figs. 8-13. *Ophryaster magnus* Spencer, 1913; Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member; all superomarginals.
8: NHMM MB 1239-22/l.
9, 12: NHMM MB 1239-22/m.
10, 13: NHMM MB 1239-22/n.
11: NHMM MB 1239-22/o.

Scale bars equal 1 mm.

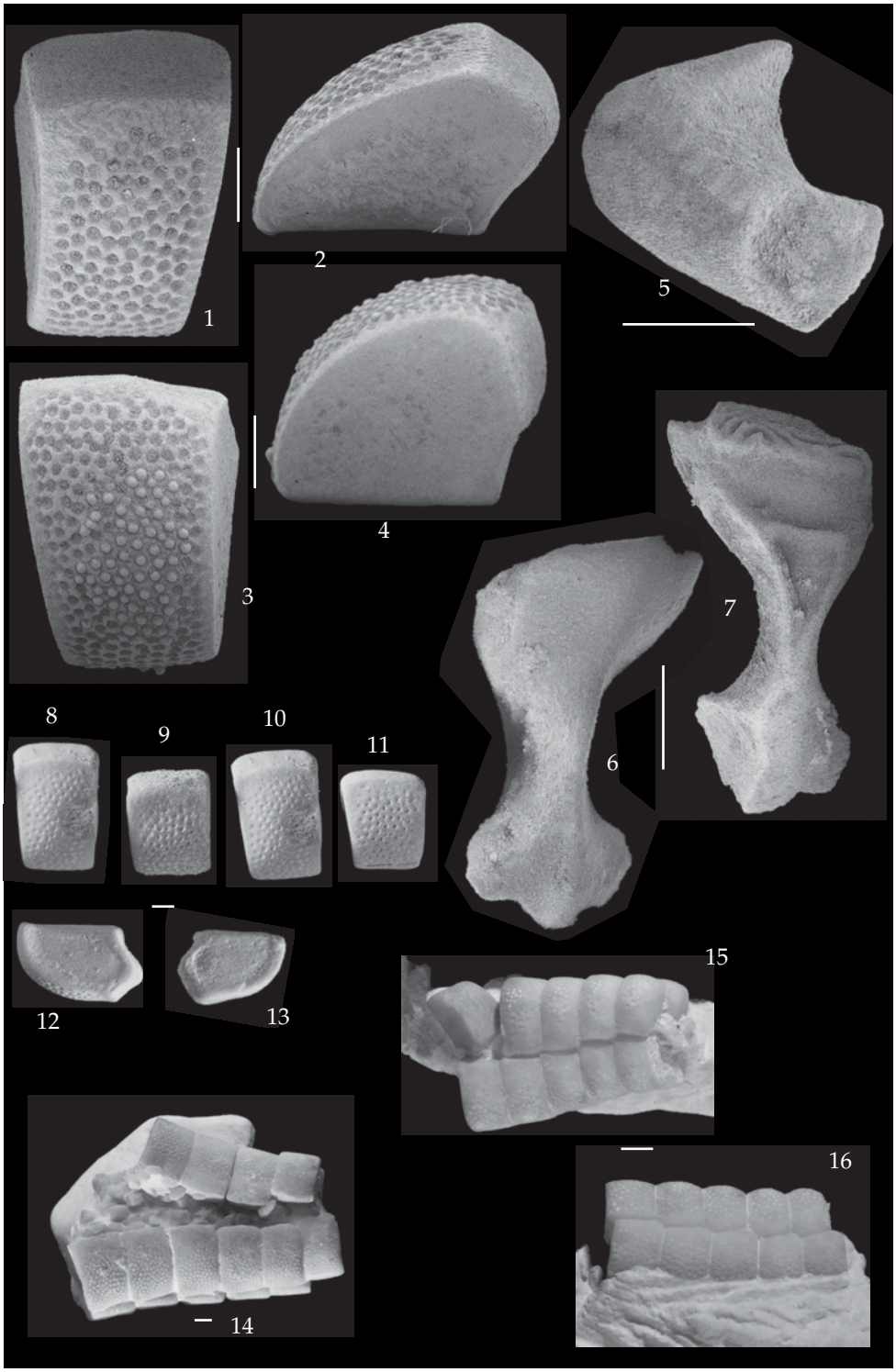

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Plate 16

Figs. 1-6. *Comptoniaster peetersorum* sp. nov.
1: RGM 428 074 (ex Jagt Colln, no. 7487), median infero- and superomarginal, same locality, Gulpen Formation, Zeven Wegen Member, base crinoid level - 0-2 m.
2-6: NHMM JJ 11438 (**holotype**), CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + c. 10 m; portion of disc (3, 5), distal arm fragment, note preservation of adambulacral spines (4), dissociated marginals (2), and ambulacrals (6).

Figs. 7-9. *Ophryaster oligoplax* (Sladen, 1891)
7: NHMM MB 761-32, Heure-le-Romain, Gulpen Formation, Zeven Wegen Member, top - c. 8 m.
8-9: NHMM JJ 7649/a-b, CBR-Lixhe quarry, Lixhe (Liège), Zeven Wegen Member, crinoid level.

Figs. 10-11. *Crateraster favosus* (Spencer, 1913); NHMM JJ 4765, median superomarginal, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 1.75 m.

Figs. 12-14. *Crateraster reticulatus* (Schulz & Weitschat, 1981); NHMM JJ 2650/1, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 3.35 m, portion of disc, showing oral frame.

Scale bars equal 1 mm.

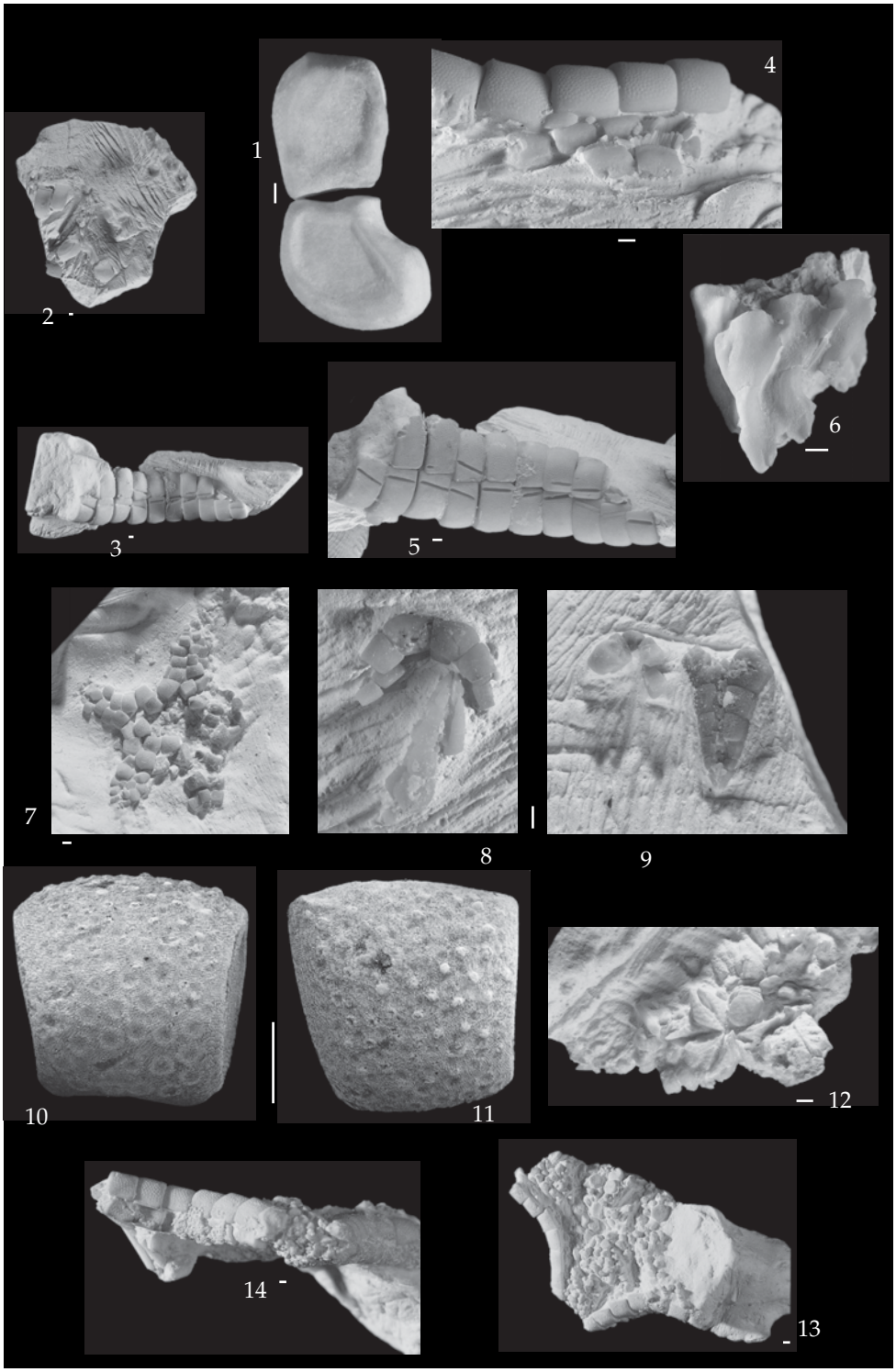

1
2
3
4
5
6
7
8
9
10
11
12
13
14

Plate 17

Figs. 1-4, 7-12. *Crateraster reticulatus* (Schulz & Weitschat, 1981)
1: NHMM JJ 2651/3, distal arm fragment, note preservation of terminal, CPL SA quarry, Haccourt, Gulpen Formation, Vijlen Member, base + 3.35 m.
2: RGM 428 075 (ex Jagt Colln, no. 3109a), median supero- and inferomarginals, same locality, Gulpen Formation, Vijlen Member, base + 3-4 m.
3-4: NHMM JJ 2651/2, portion of disc, same locality, Gulpen Formation, Vijlen Member, base + 3.35 m.
7-8: NHMM JJ 3109/b-c, ambulacrals, same locality, Gulpen Formation, Vijlen Member, base + 3-4 m.
9-10: NHMM MB 1239-22/o, median superomarginal, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
11: NHMM MB 1239-22/p-q, distal supero- and inferomarginals, same locality and stratigraphy.
12: NHMM JJ 3109/d, terminal, same locality, Gulpen Formation, Vijlen Member, base + 3-4 m.

Figs. 5-6. *Crateraster anchylus* (Brünnich Nielsen, 1943); temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.
5: NHMM JJ 11141, median infero- and superomarginals.
6: NHMM MB 681-16/a, median superomarginal.

Figs. 13-15. Goniasterid sp. 1; NHMM JJ 10443, median inferomarginal, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon).

Scale bars equal 1 mm.

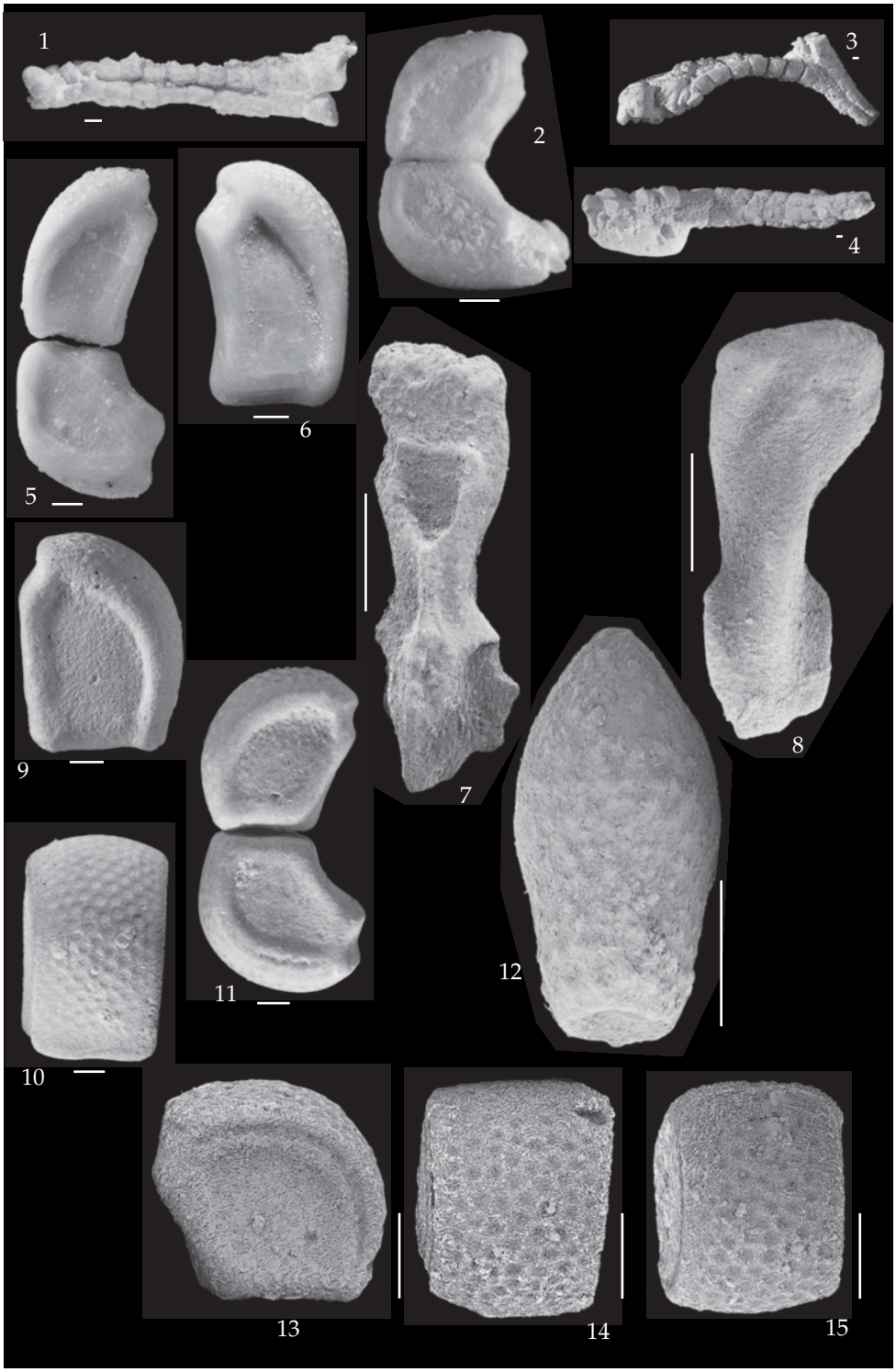

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Plate 18

Figs. 1-4. Goniasterid sp. 3; NHMM JJ 9591/k-m, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, Emael Member (Lava Horizon), ?inferomarginals (1, 3), ?superomarginal (2, 4).

Figs. 5-6. Goniasterid sp. 1; NHMM MB 649-9/a-b, CBR-Romontbos quarry, Eben Emael (Liège), Maastricht Formation, base Emael Member.

Figs. 7-9. Goniasterid sp. 2
7-8: NHMM MB 108-8/a, median superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-6).
9: NHMM K 4161, marginals of a single individual, CBR-Romontbos quarry, Eben Emael (Liège), Gulpen Formation, Lanaye Member.

Figs. 10-12. Goniasterid sp. 1 (?); NHMM MB 108-8/b-c, inferomarginals, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-6).

Fig. 13. Goniasterid sp. 6; NHMM JJ 10535/a, ?superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-5/-6).

Figs. 14-17. Goniasterid sp. 5
14-15: NHMM MB 487-6, distal inferomarginal, disused Ransdaal quarry (Karstraat), Maastricht Formation, Kunrade Limestone facies ('oesterbank van Craubeek').
16-17: NHMM K 1153, distal inferomarginal, ENCI-Maastricht BV, Maastricht, Maastricht Formation, base Gronsveld Member.

Figs. 18-19. Indeterminate goniasterine; NHMM K 1343, median superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-4).

Scale bars equal 1 mm.

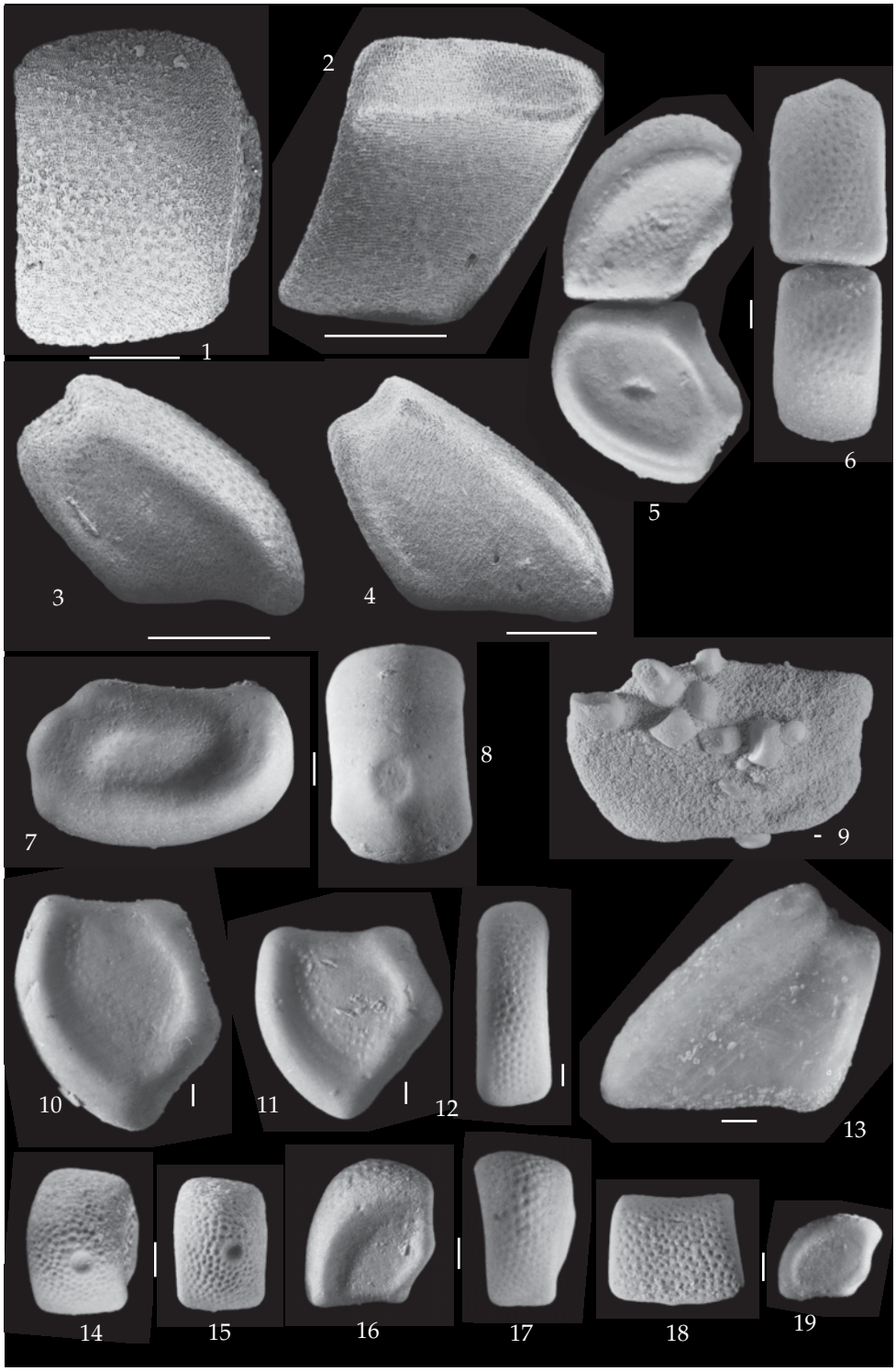

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

Plate 19

Figs. 1-5. Goniasteridae juv. indet. (*Ophryaster*? *maastrichtensis* Umbgrove, 1925 ?); Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (base IVf-3).
1-4: NHMM K 976/a.
5: NHMM K 976/b.

Figs. 6-7. Goniasterid sp. 6; NHMM JJ 10535/b, ?inferomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-5/-6).

Figs. 8-10. Indeterminate goniasterine; temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Fig. 11. *Caletaster*? sp.; NHMM MB 432-74/h, ?proximal superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 12-14. Indeterminate goniasterine; NHMM MB 432-74/i (median superomarginal), NHMM MB 432-74/j (median superomarginal), and NHMM MB 432-74/k (median superomarginal), respectively, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Fig. 15. Goniasterid sp. 1; NHMM MD 2918.1/a, median superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.

Fig. 16. *Crateraster anchylus* (Brünnich Nielsen, 1943); NHMM MB 432-74/l, median inferomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Figs. 17-18. Indeterminate goniasterine; temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.
17: NHMM MB 432-74/m, distal inferomarginal.
18: NHMM MB 432-74/n, median superomarginal (note pedicellaria).

Fig. 19. Goniasterid sp. 5; NHMM MD 2918.1/b, median superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.

Scale bars equal 1 mm.

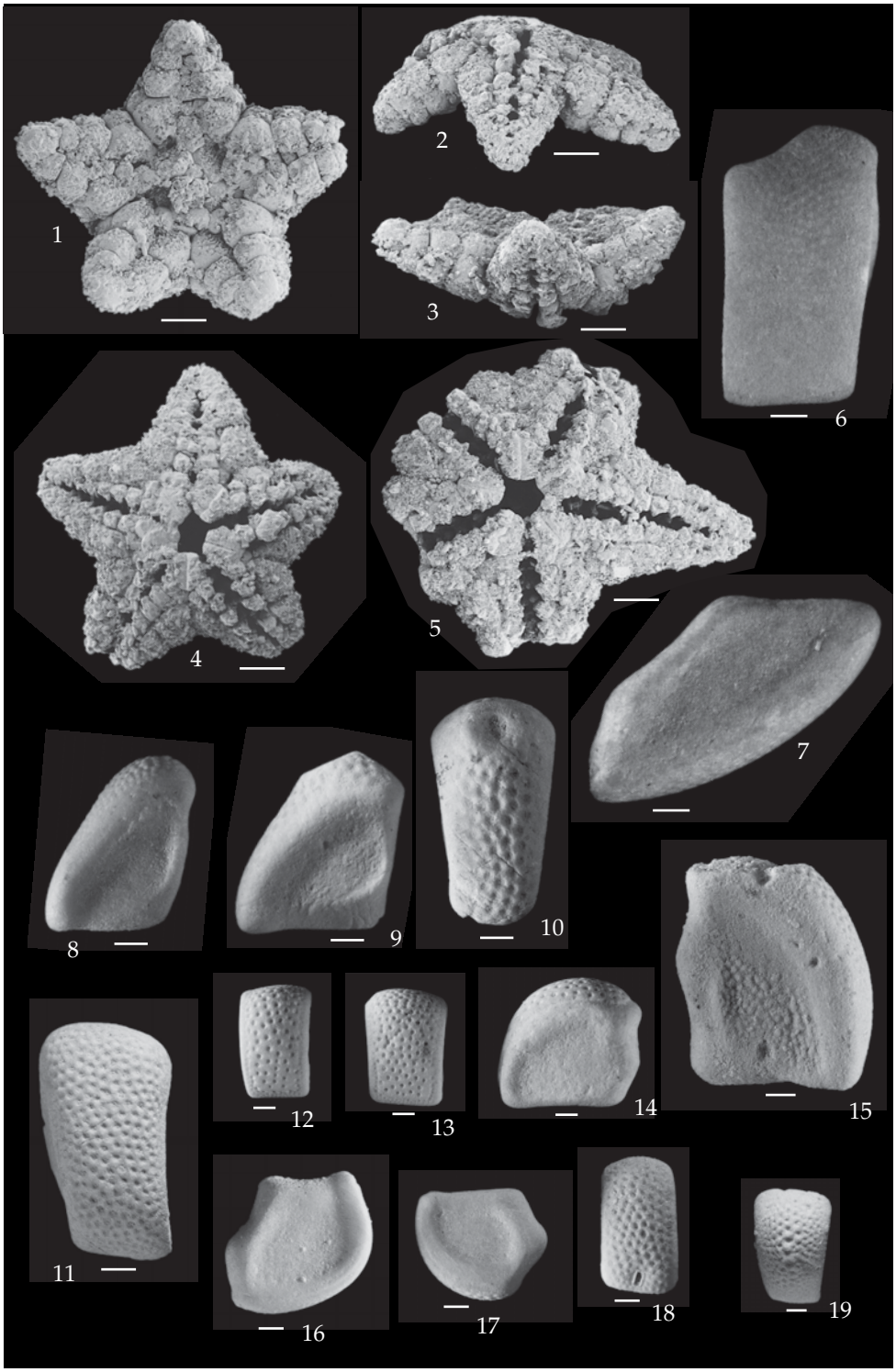

1
2
3
6
4
5
7
8
9
10
11
12
13
14
15
16
17
18
19

Plate 20

Figs. 1-10. Goniasterid sp. 7; Vaals-Eschberg, Vaals Formation.
1, 8, 10: NHMM MB 661-49/a, inferomarginal.
2: NHMM MB 661-49/b, inferomarginal.
3: NHMM MB 661-49/c, inferomarginal.
4: NHMM MB 661-49/d, superomarginal.
5: NHMM MB 661-49/f, superomarginal.
6-7, 9: NHMM MB 661-49/e, superomarginal.

Figs. 11-14, 18. Goniasterid sp. 8; NHMM MB 619-28/a-d, all inferomarginals, note pedicellaria, Benzenrade ('kapelletje'), Vaals Formation, Benzenrade Member.

Fig. 15. *Coulonia*? sp. nov.; NHMM MB 619-28/e; same locality and stratigraphy.

Fig. 16. Goniasterid sp. 5; NHMM MD 2918.1/c, superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Gronsveld Member.

Fig. 17. Goniasterid sp. 1; NHMM MD 2918.1/d, inferomarginal, same locality and stratigraphy.

Figs. 19-20. *Pycinaster*? sp.; NHMM MB 619-28/f-g, Benzenrade ('kapelletje'), Vaals Formation, Benzenrade Member.

Figs. 21-22. Indeterminate ; NHMM MB 865-9/b-c, ?marginals, de Wingerd quarry, Benzenrade, Vaals Formation, Benzenrade Member, 2 m below contact with Kunrade Limestone facies.

Figs. 23-29. *Valettaster* gr. *ocellatus* (Forbes, 1848)
23: NHMM MB 1044-6/a, aboral ossicle, CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.
24: NHMM JJ 11145, aboral ossicle, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2-4 m.
25-28: NHMM JJ 761a/1-4, aboral ossicles, CPL SA quarry, Haccourt, Gulpen Formation, lower Zeven Wegen Member.
29: NHMM MB 681-16/b, aboral ossicle, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Scale bars equal 1 mm.

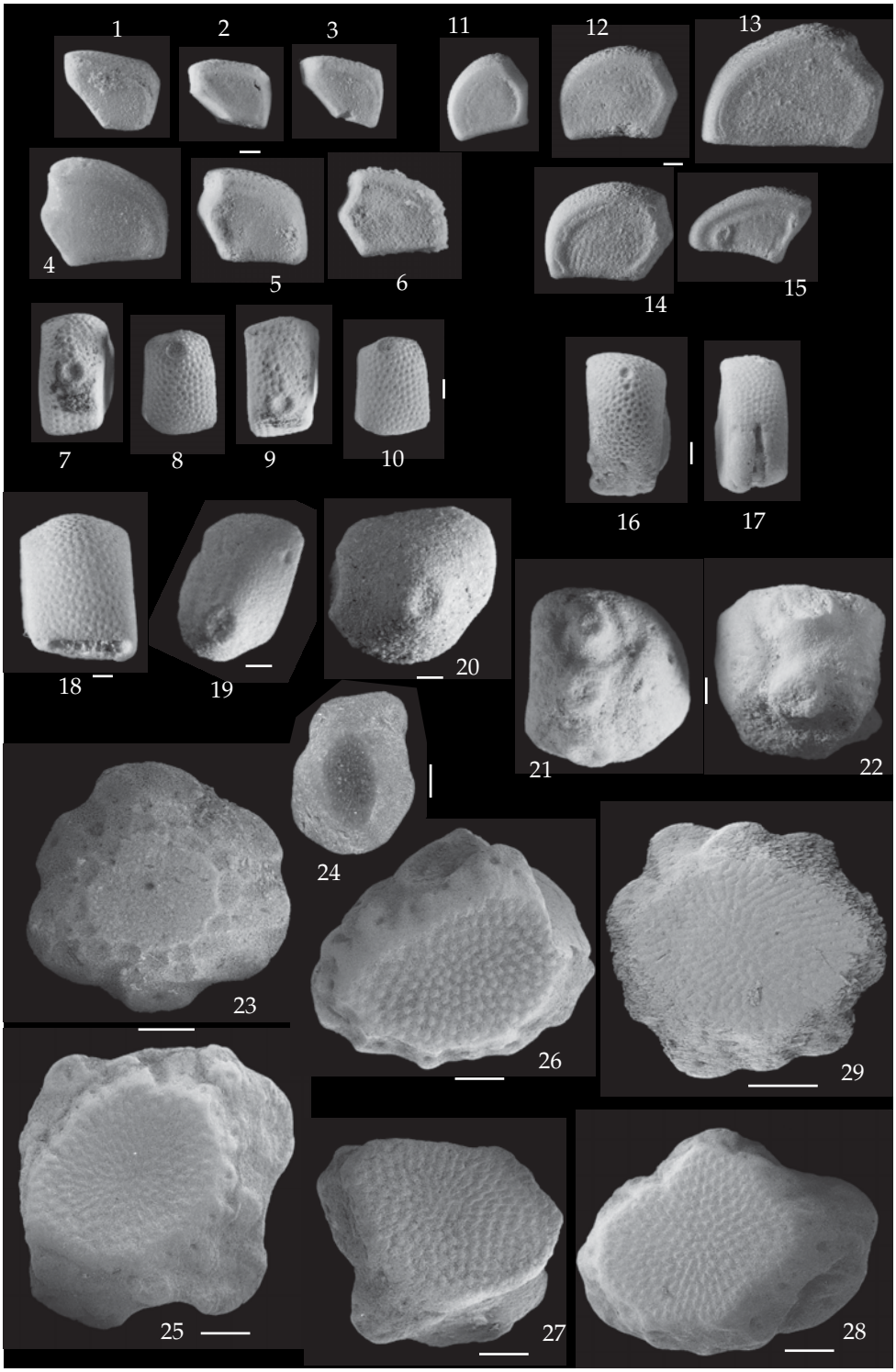

1
2
3
11
12
13
4
5
6
14
15
7
8
9
10
16
17
18
19
20
21
22
24
23
26
29
25
27
28

Plate 21

Figs. 1-7. *Valettaster* gr. *ocellatus* (Forbes, 1848)
1: NHMM JJ 3699, aboral ossicle, ENCI-Maastricht BV quarry, Maastricht; Maastricht Formation, upper Nekum Member.
2: NHMM MB 1044-6/b, aboral ossicle, CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.
3: NHMM JJ 4441, aboral ossicle, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2-4 m.
4: NHMM JJ 4740, aboral ossicle, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 1.25 m.
5-7: NHMM MB 1239-22/r-s, cc, aboral ossicles, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.

Figs. 8-9, 12-13. *Stauranderaster*? sp. (? spp.).
8-9: NHMM JJ 10535/c-d, marginal ossicles, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-5/-6).
12-13: NHMM JJ 11024/a-b, same locality, Maastricht Formation, Meerssen Member (IVf-4).

Figs. 10-11. *Stauranderaster*? *miliaris* Brünnich Nielsen, 1943; NHMM K 1701/d, marginal ossicle, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Figs. 14-15. *Pycinaster* sp. 1; NHMM MB 1239-22/t, distal inferomarginal, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.

Scale bars equal 1 mm.

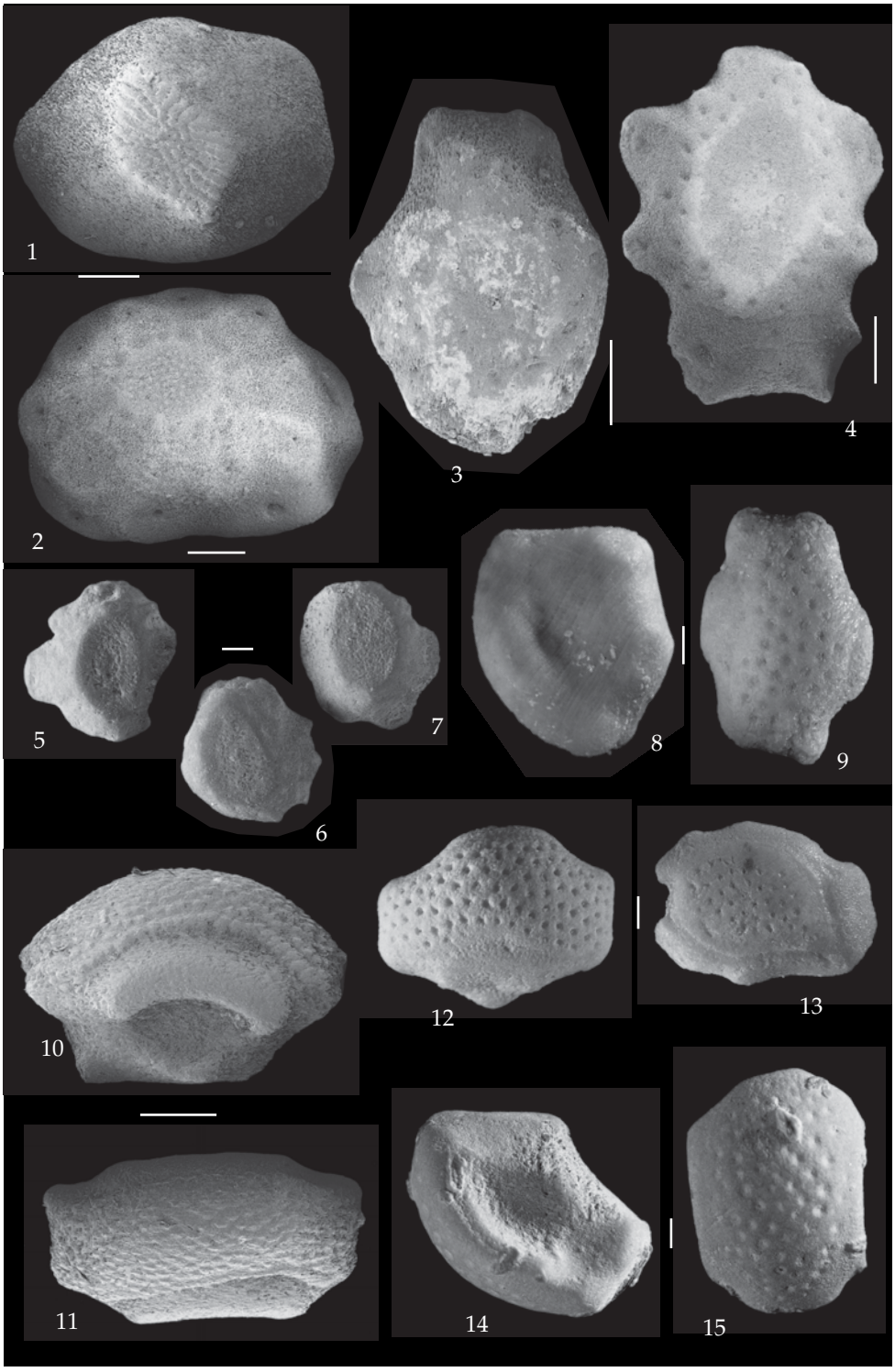

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Plate 22

Figs. 1-4. *Stauranderaster*? *miliaris* Brünnich Nielsen, 1943; NHMM JJ 11146/a-d, marginal ossicles, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2-4 m.

Figs. 5-6. *Stauranderaster*? sp. (spp. ?); NHMM MB 432-74/o-p, marginal ossicles, temporary Albertkanaal sections, Vroenhoven-Riemst/Kesselt, Houthem Formation, upper Geulhem Member.

Fig. 7. *Pycinaster* sp. 1; NHMM MB 1239-22/u, distal inferomarginal, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.

Figs. 8-9. *Aspidaster*? sp. 1; NHMM JJ 2284, marginal ossicle, temporary Albertkanaal sections, Kanne, Maastricht Formation, base Meerssen Member.

Fig. 10. *Aspidaster*? aff. *senonensis* (Valette, 1902); NHMM JJ 10537, ?primary interradial, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Valkenburg Member.

Fig. 11. *Pycinaster* sp. 2; NHMM MB 432-74/q, distal inferomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Fig. 12. *Aspidaster*? sp. 2 (aff. *pistilliferus* Forbes, 1848); NHMM JJ 2658, ?primary interradial, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + c. 4 m.

Figs. 13-14. *Pycinaster magnificus* Spencer, 1913 ?; NHMM MB 808-7/m-n, aboral ossicles, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.

Figs. 15-16. *Pycinaster* aff. *cornutus* Rasmussen, 1945; NHMM MB 432-74/r, superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Figs. 17-21. *Pycinaster magnificus* Spencer, 1913.
17-18: NHMM MB 1239-22/v, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
19-21: NHMM JJ 8160/a-b, superomarginal and lateral view of supero- and inferomarginals, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base sponge level.

Scale bars equal 1 mm.

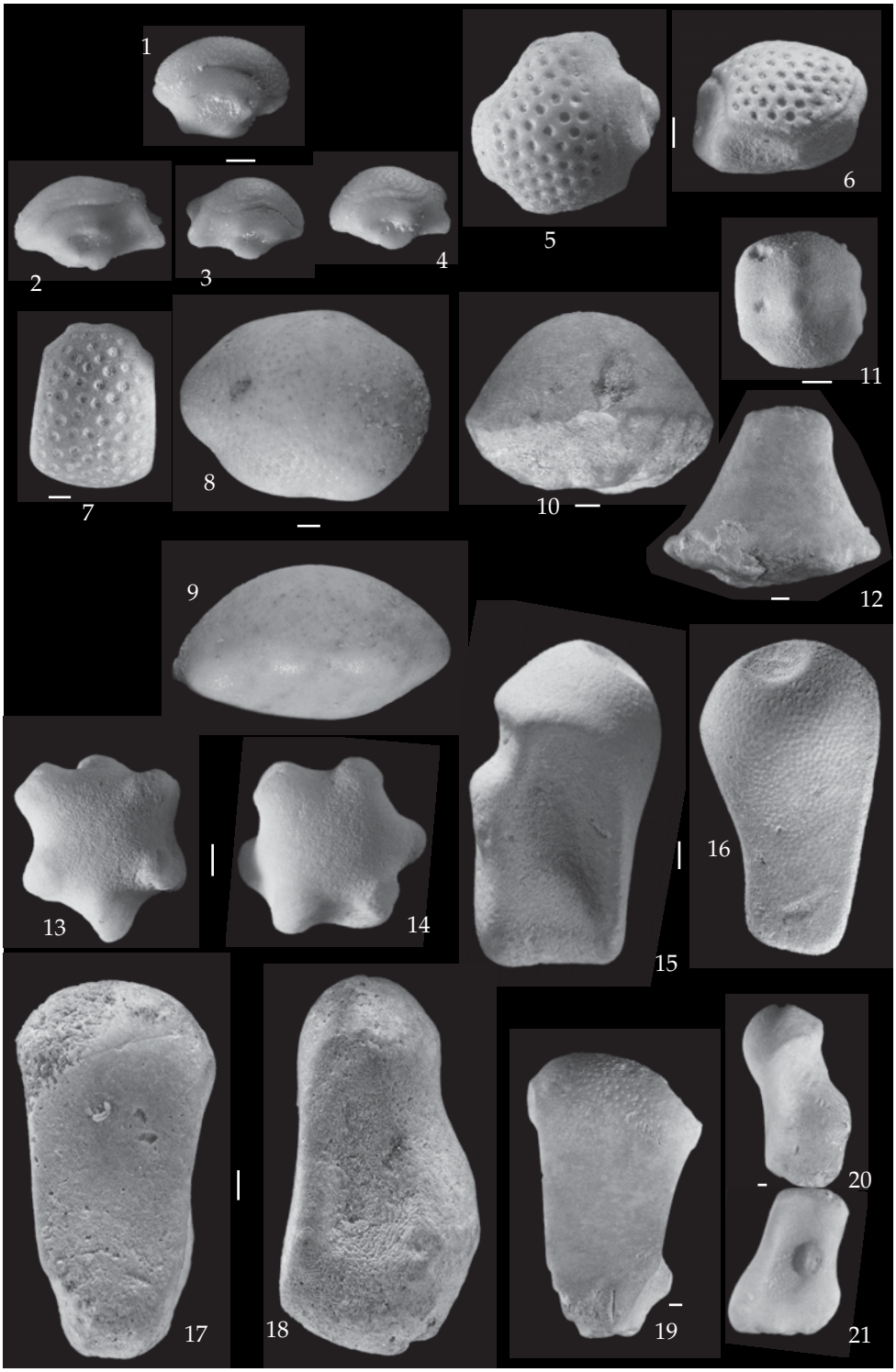

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Plate 23

Figs. 1-2. *Pycinaster*? aff. *rosenkrantzii* Brünnich Nielsen, 1943; NHMM MB 432-74/s, proximal superomarginal (SM1 ?), temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Fig. 3. *Pycinaster magnificus* Spencer, 1913; NHMM MB 1239-22/w, inferomarginal, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.

Figs. 4-10. Asteriid sp. (? spp.)
4: NHMM MB 808-7/o, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
5: NHMM MB 808-7/p, same locality and stratigraphy.
6: NHMM JJ 2944, same locality, Gulpen Formation, Zeven Wegen Member, base + 3-4 m.
7: NHMM MB 808-7/q, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.
8: NHMM MB 808-9/b, portion of disc/arm, same locality and stratigraphy.
9: NHMM JJ 9469, Hans Böckler Allee, Aachen, Gulpen Formation, Vijlen Member.
10: NHMM MB 808-7/r, CPL SA quarry, Haccourt, Gulpen Formation, Zeven Wegen Member, base + 6-7 m.

Scale bars equal 100 µm, except in figs. 1-3, and 8, where they represent 1 mm.

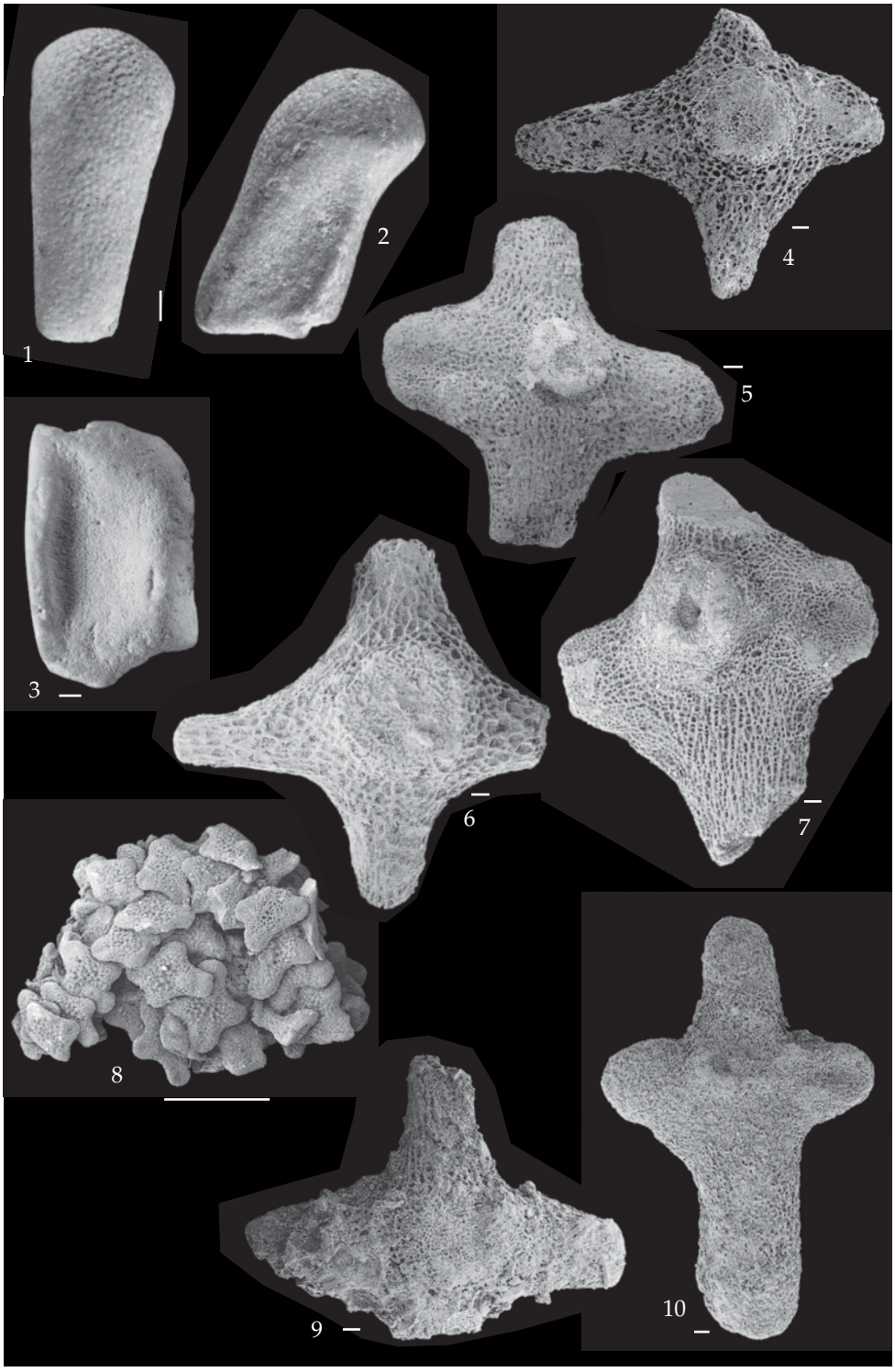

1
2
3
4
5
6
7
8
9
10

Plate 24

Figs. 1-7. *Metopaster undulatus* Spencer, 1913
1-2: NHMM JJ 9466, ultimate superomarginal, Hans Böckler Allee, Aachen, Gulpen Formation, Vijlen Member.
3-5: NHMM MB 1239-22/x-z, inferomarginals, Mamelis-Selzerbeek, Gulpen Formation, Vijlen Member.
6: NHMM MB 1239-22/aa, ultimate superomarginal, same locality and stratigraphy.
7: NHMM MB 1239-22/bb, ultimate superomarginal, same locality and stratigraphy.

Figs. 8-16, 22-27. *Metopaster continuus* sp. nov.; temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2-4 m.
8, 15: NHMM 11142/a (**paratype**), median inferomarginal.
10-12: NHMM 11142/c-e (**paratypes**), distal superomarginals.
9: NHMM 11142/b (**paratype**), median inferomarginal.
13, 16: NHMM 11142/f (**paratype**), median inferomarginal.
14: NHMM 11142/k (**paratype**), median inferomarginal.
22, 26: NHMM JJ 11142/g (**paratype**), median superomarginal.
23, 27: NHMM JJ 11142/h (**holotype**), median superomarginal.
24: NHMM JJ 11142/i (**paratype**), median superomarginal.
25: NHMM JJ 11142/j (**paratype**), median superomarginal.

Fig. 17. *Metopaster* sp. 2; NHMM 432-74/t, ultimate superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Figs. 18-19. *Metopaster* sp. (aff. sp. 1); NHMM K 745, ultimate superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (top IVf-4).

Figs. 20-21. Indeterminate goniasterine; NHMM JJ 10536, median superomarginal, ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, base Valkenburg Member.

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

Plate 25

Figs. 1-9. *Metopaster spencerii* Brünnich Nielsen, 1943
1-2: NHMM JJ 11137, reconstruction of individual from associated superomarginals, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2-4 m.
3: NHMM JJ 11138/a, distal inferomarginal, same locality and stratigraphy.
4, 9: NHMM JJ 11138/b, median superomarginal, same locality and stratigraphy.
5-6: NHMM JJ 8907 and JJ 8196, respectively, ultimate superomarginals, Stevns Klint (Sjælland, Denmark), north of Højerup Kirke, Lower Danian Bryozoan Limestone.
7-8: NHMM JJ 8523, median superomarginal, Rødvig (Korsnæb section, Sjælland, Denmark), Lower Danian Bryozoan Limestone.

Figs. 10-11. Indeterminate goniasterine; NHMM MB 339-8/b, median superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, Geulhem Member, base + 2 m.

Figs. 12-23. *Recurvaster antemammillatus* sp. nov.; Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-6).
12-17: NHMM K 1424/a-c and /o-q (**paratypes**), inferomarginals.
18-19: NHMM K 1424/d (**holotype**), median superomarginal.
20-23: NHMM K 1424/e-h (**paratypes**), median and distal superomarginals.

Scale bars equal 1 mm.

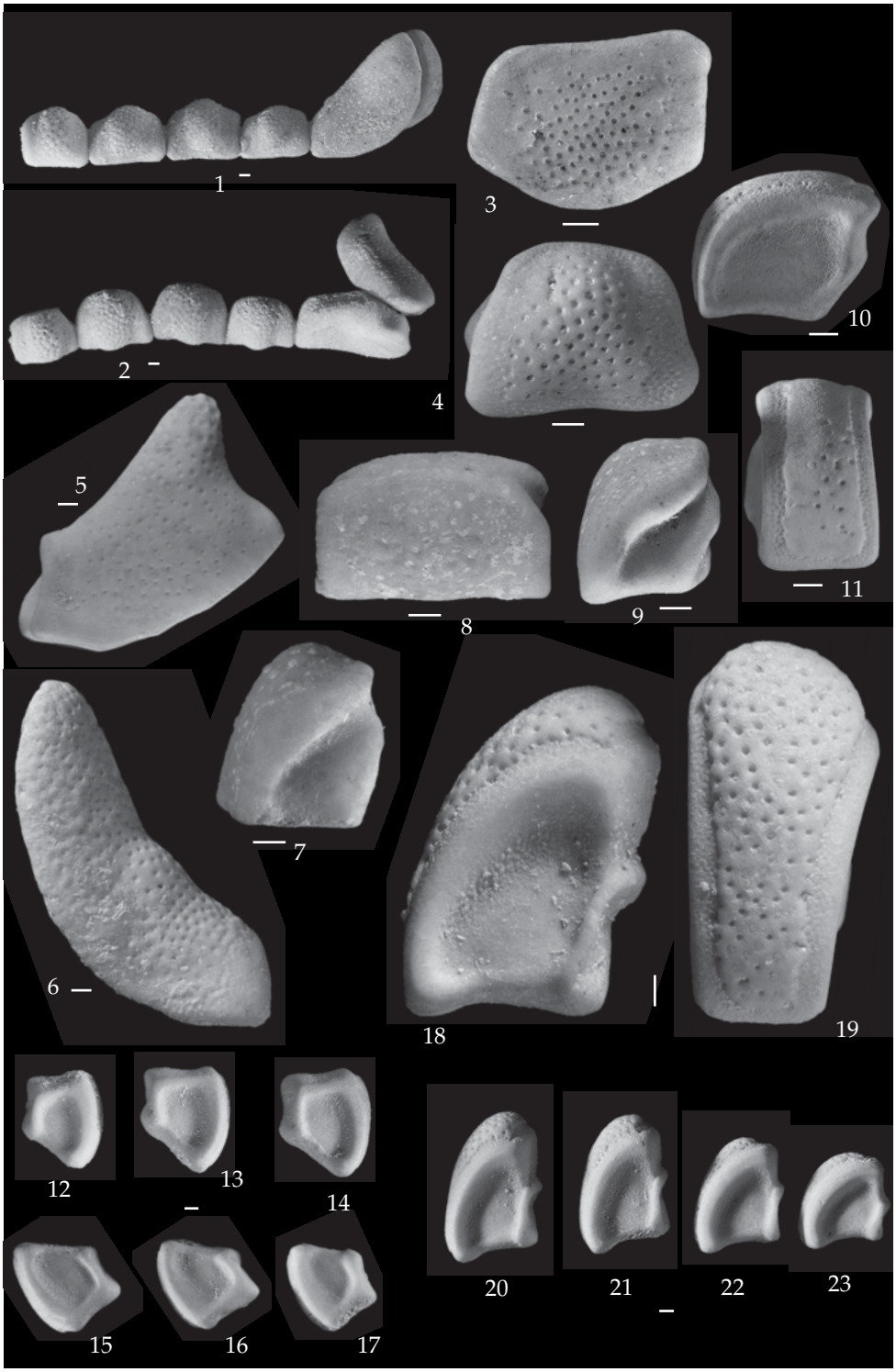

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

Plate 26

Figs. 1, 4-5. *Recurvaster antemammillatus* sp. nov.
1: NHMM K 1424/i (**paratype**), median superomarginal, Blom quarry, Berg en Terblijt, Maastricht Formation, Meerssen Member (IVf-6).
4-5: NHMM MB 377-23/f, median superomarginal, same locality, Maastricht Formation, Meerssen Member (base IVf-3).

Figs. 2, 6-7. *Metopaster* sp. 1; ENCI-Maastricht BV quarry, Maastricht, Maastricht Formation, Meerssen Member (IVf-5/-6).
2: NHMM 10534/a, ultimate superomarginal.
6-7: NHMM 10534/b, ultimate superomarginal.

Figs. 3, 15-16. *Metopaster alexiae* sp. nov.
3: NHMM JJ 10535/e, ultimate superomarginal (juvenile), same locality and stratigraphy.
15-16: NHMM JJ 10535/f, median superomarginal, same locality and stratigraphy.

Figs. 8-10, 12-14, 17. *Metopaster miriamae* sp. nov.
8-9: NHMM JJ 10535/g (**paratype**), ultimate superomarginal, same locality and stratigraphy.
10, 12: NHMM JJ 10535/h (**holotype**), ultimate superomarginal.
13, 17: NHMM JJ 10535/i, median superomarginal.
14: NHMM K 2688-7 (**paratype**), ultimate superomarginal, same locality, Maastricht Formation, Meerssen Member (top IVf-4).

Fig. 11. *Metopaster* aff. *carinatus* (Brünnich Nielsen, 1943) ?; NHMM MB 432-74/u, median superomarginal, temporary Albertkanaal sections, Vroenhoven-Riemst, Houthem Formation, upper Geulhem Member.

Scale bars equal 1 mm.

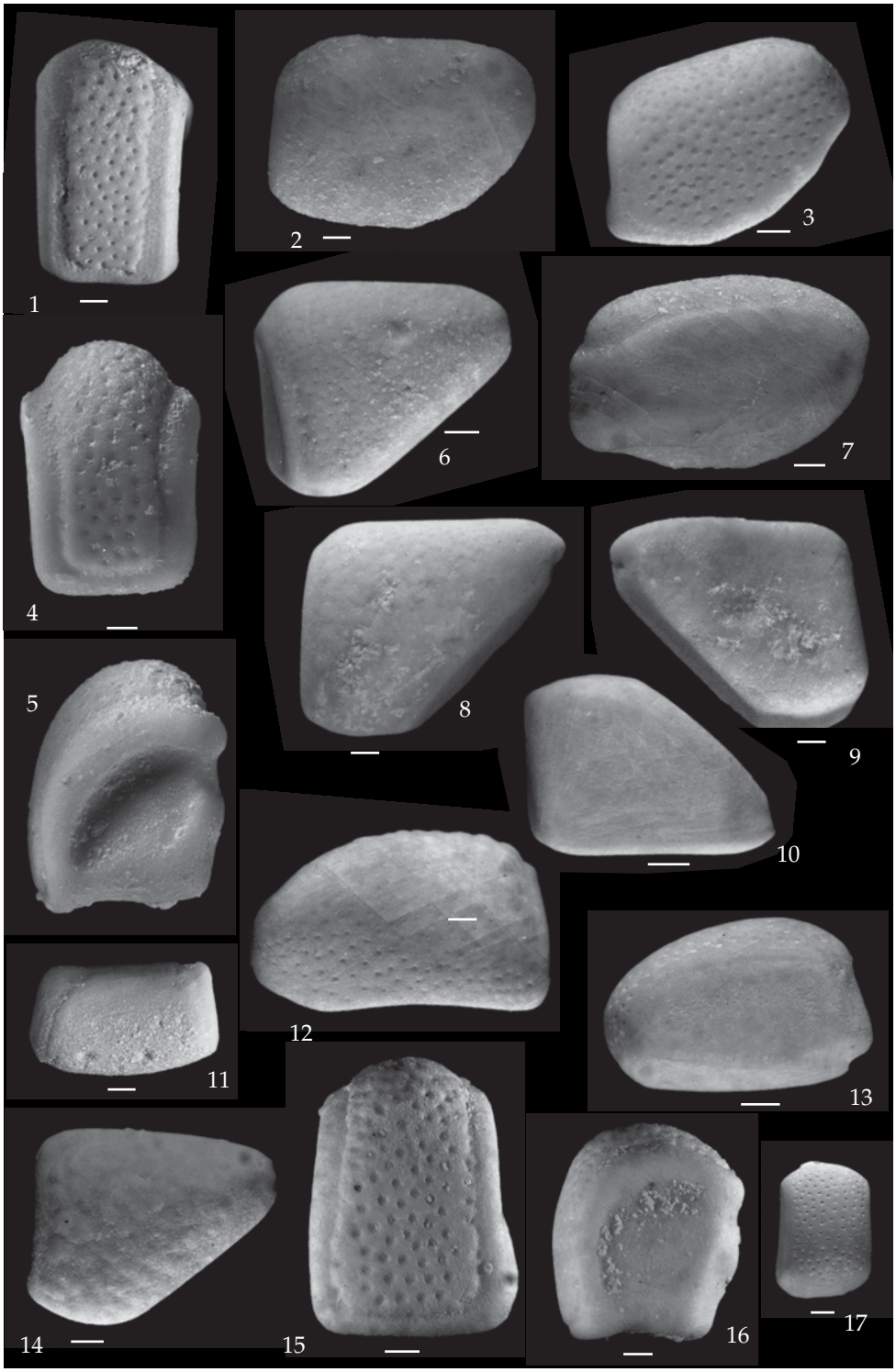
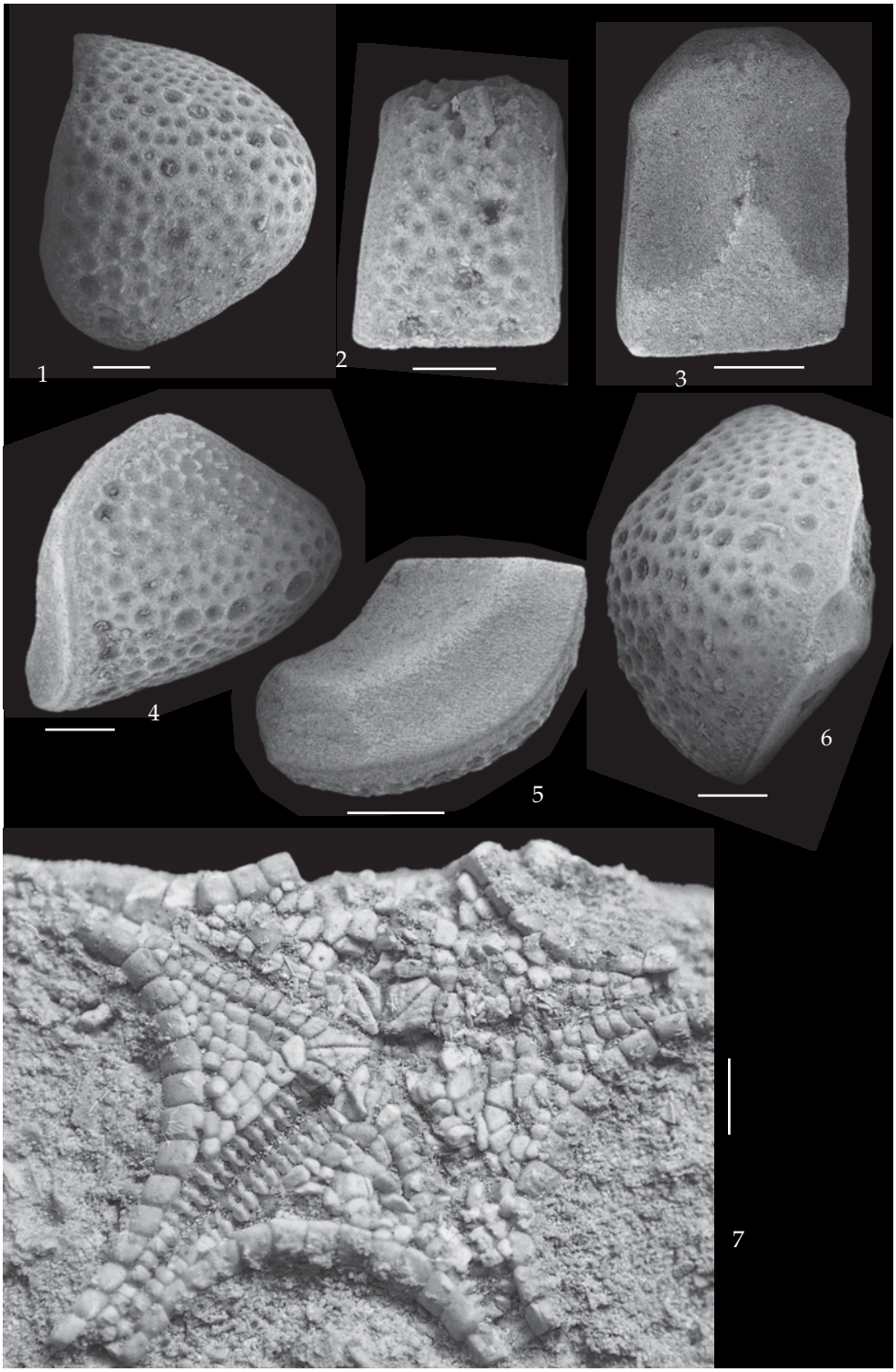

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

Plate 27

Figs. 1-6. *Haccourtaster aemstelensis* gen. et sp. nov.; CPL SA quarry, Haccourt, Gulpen Formation, base Zeven Wegen Member.
1, 6: NHMM MB 1044-6/c (**holotype**), ultimate superomarginal.
2: NHMM MB 1044-6/d (**paratype**), median inferomarginal.
3, 5: NHMM MB 1044-6/e (**paratype**), median superomarginal.
4: NHMM MB 1044-6/f (**paratype**), ultimate superomarginal.

Fig. 7. *Ophryaster*? *maastrichtensis* Umbgrove, 1925; RGM 14209 (**holotype**), lower/middle Meerssen Member (Maastricht Formation) of Maastricht area (? St Pietersberg).

Scale bars equal 1 mm, except in fig. 7, where it represents 5 mm.


1
2
3
4
5
6
7