

An overview of Late Cretaceous and Early Palaeogene echinoderm faunas from Liège-Limburg (Belgium, The Netherlands)

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Abstract

With the exception of echinoids, echinoderm faunas from the type area of the Maastrichtian Stage still are more or less *terra incognita*. Material collected recently in the area by a group of professional and amateur palaeontologists comprises numerous new records, which have the added advantage of being well documented stratigraphically. Museum collections, and those pre-dating 1975 in particular, generally suffer from a lack of detail where stratigraphic provenance is concerned. Not only do these new collections considerably increase our knowledge of Late Cretaceous (Campanian-Maastrichtian) and Early Palaeogene (Danian) echinoderm faunas in the area, they also allow conclusions on diversification and extinction patterns prior to and across the K/T boundary to be drawn. In the present paper a brief overview is given of these echinoderm faunas, with emphasis on echinoids and asteroids.

Key words: Late Cretaceous, Early Palaeogene, echinoderms, taxonomy, stratigraphy, taphonomy.

Résumé

À l'exception des échinides, les faunes d'échinodermes de la région-type de l'étage Maastrichtien sont encore plus ou moins *terra incognita*. Du matériel récemment récolté dans cette région par un groupe de paléontologues professionnels et amateurs comprend de nombreuses et nouvelles pièces qui ont l'avantage supplémentaire d'être bien documentées stratigraphiquement. Les collections des musées, et en particulier celles antérieures à 1975, souffrent généralement du manque de précision en ce qui concerne la position stratigraphique. Ces nouvelles collections non seulement élargissent notre connaissance des faunes d'échinodermes du Crétacé supérieur (Campanien-Maastrichtien) et Paléogène inférieur (Danien) dans la région, mais permettent également de tirer des conclusions sur les modèles de diversification et d'extinction de part et d'autre de la limite K/T. Dans cette note, ces faunes d'échinodermes sont brièvement passées en revue en mettant l'accent sur les échinides et les astéries.

Mots-clefs: Crétacé supérieur, Paléogène inférieur, échinodermes, taxinomie, stratigraphie, taphonomie.

Резюме

За исключением морских ежей, фауны иглокожих типичного района Мaaстрихтского яруса остаются в большей или меньшей степени *terra incognita*. Недавно представленные группой палеонтологов, профессионалов и любителей, образцы этого района стали объектом многочисленных новых наблюдений, дополнительным преимуществом которых является их стратиграфическая документированность.

Музейным коллекциям, и в особенности созданным до 1975 года, не хватает, в частности, подробной информации о стратиграфическом происхождении. Новая коллекция не только значительно углубляет наши знания о фаунах иглокожих Позднего Мела (Кампанско-Мaaстрихтский ярус) и Раннего Палеогена (Датский ярус) в данной области, но и позволяет подвести итоги по структуре разнообразия и вымирания, предшествовавшей границе К/Т и вкост границе К/Т. Краткое обозрение фаун иглокожих представлено в данном очерке, особое внимание уделено морским ежам и астероидам.

Ключевые слова: Поздний Мел, Ранний Палеоген, иглокожие, таксономия, стратиграфия, тафономия.

Introduction

The calcareous, multi-element echinoderm skeleton is almost predestined to become fossilised (DONOVAN, 1991). The often gregarious occurrence of echinoderms in many types of marine strata, and the fact that, even in the case of dissociated ossicles, material is readily assigned to family, genus or species, makes them an ideal subject for palaeobiological and palaeoecological studies. All species of echinoid, asteroid, ophiuroid and crinoid from Campanian, Maastrichtian and Danian deposits in southern Limburg (The Netherlands) and contiguous areas in Belgium and Germany are currently being studied (Fig. 1). This is done within the framework of a K/T boundary diversification/ extinction project (JAGT, 1998, 1999a-d; KUTSCHER & JAGT, 1999). This has resulted in numerous new records. These include not only taxa previously described from elsewhere in northwest Europe, but also quite a lot of new genera and species, especially amongst crinoids, asteroids and ophiuroids.

The material consists mostly of dissociated ossicles or portions of skeletons at best (echinoids excepted), but rare finds of well-preserved goniasterid and astropectinid asteroids, ophiurid and ophiolepidid ophiuroids, and bourgueticrinid crinoids are also known. To date, well over 200 species are recorded from the area. The present paper provides a brief outline of studies under way as well as a selection of new records from the area. Crinoids are

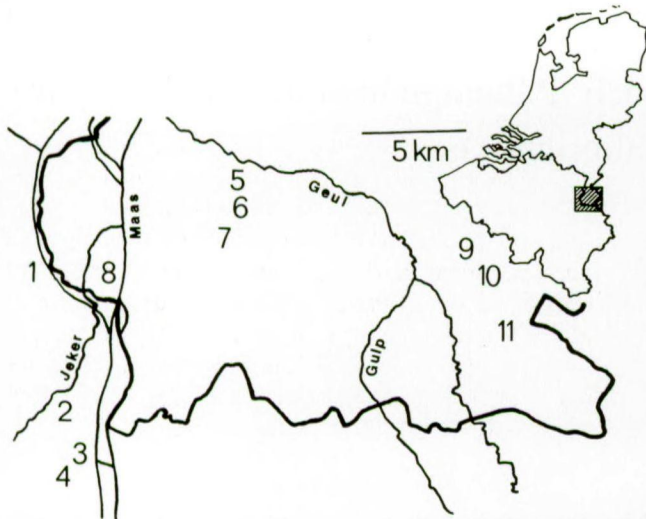


Fig. 1 — Southern Limburg (The Netherlands) and contiguous areas, showing location of outcrops and quarries referred to in the text:

- 1 - temporary Albertkanaal sections;
- 2 - CBR-Romontbos quarry;
- 3 - CBR-Lixhe quarry;
- 4 - CPL SA quarry;
- 5 - Ankerpoort-Curfs quarry;
- 6 - Blom quarry;
- 7 - Ankerpoort-'t Rooth quarry;
- 8 - ENCI-Maastricht BV quarry;
- 9 - Kunrade;
- 10 - Benzenrade;
- 11 - Vijlen.

The inset map of The Netherlands and Belgium shows the area of the main map (shaded).

not illustrated here, and only few figures of ophiuroids are included, since the chapters describing these echinoderms have either just come out or are about to be published (JAGT, 1999b and KUTSCHER & JAGT, 1999, respectively). Holothurians are not considered any further; with the exception of dissociated elements of the peristomial ring, ossicles of these echinoderms are extremely rare in the area (compare ZELEZNIK, 1985).

Crinoids

Known to date from the area are 36 species, in 20 genera, with all articulate (sub)orders represented. Of these, 3 genera and 6 species are new (JAGT, 1999b).

Isocrinids (genera *Austinocrinus*, *Isocrinus*?, *Isselocrinus*, *Praeisselocrinus*? and *Nielsenocrinus*) are particularly well represented in the Late Campanian (CPL SA and CBR-Lixhe quarries) and Early Maastrichtian (Vijlen/Aachen area), but do extend into the latest Maastrichtian. At least one species (possibly two) occur in the shallow-water settings represented by the Nekum and Meerssen members (Maastricht Formation; Fig. 2), where they are associated with much commoner comatulids. Of

note is the absence of isocrinids in the Geulhem Member (Early Palaeocene).

Comatulids are represented by atelecrinids, pterocoids, conometrids, notocrinids and antedonids, and occur throughout the entire Late Cretaceous section. However, in the Campanian and Early Maastrichtian they are comparatively rare. Their acme is in the Nekum and Meerssen members, where *Jaekelometra* gr. *belgica* (JAEKEL, 1902), *J.* gr. *concava* (SCHLÜTER, 1878), *Semiometra lenticularis* (SCHLÜTER, 1878) and *S. saskiae* JAGT, 1999b are very common locally (CBR-Romontbos, ENCI-Maastricht BV and Blom quarries). In addition to centrodorsals representing various ontogenetic stages, such occurrences have also yielded (proximal) brachials, cirrals and pinnules. Brachials with syzygial articulations are fairly common, suggesting these crinoids to have been able to shed arms easily, which in turn would indicate stressful conditions (?increased predation pressure; compare MESSING, 1997) in shallow-water, subtropical settings. At times, species distinction is difficult, particularly of *Jaekelometra*, *Amphorometra* and *Hertha*. In this respect, they resemble extant forms (MESSING, 1997).

In comparison with the underlying Meerssen Member, comatulid diversity decreases noticeably in the Geulhem Member, with only two forms represented, *Hertha* gr. *mystica* VON HAGENOW, 1840 (?) and *Atuatucametra an-nae* JAGT, 1999b.

Bourgueticrinids range through the entire section, being commonest in the Late Campanian, early Late Maastrichtian and Early Palaeocene. Of special note is the crinoid/ophiuroid lagerstätte at the base of the Gronsveld Member (ENCI-Maastricht BV quarry; see JAGT *et al.*, 1998). Newly collected slabs which preserve up to ten crinoids, as well as ophiuroids and rare asteroids, demonstrate the impact of storm activity on these crinoid "meadows". Not only do these allow the density and spatial distribution of "populations" (see BAUMILLER & ROME, 1998) to be determined, but also the nature of the substrate to be analysed in detail. Quite a few crowns have penetrated the substrate to depths of almost 10 cm, with arms outspread.

Bourgueticrinids disappear from the section above the base of the Emael Member, only to reappear in the Geulhem Member (Albertkanaal sections and Ankerpoort-Curfs quarry), with species that are well known from Danian strata in Denmark and southern Sweden, namely *Bourgueticrinus danicus* BRÜNNICH NIELSEN, 1913 and *Democrinus?* *maximus* BRÜNNICH NIELSEN, 1915. HÅKANSSON *et al.* (1996) have recently suggested that an important evolutionary phase in the Bourgueticrinina took place during the earliest Palaeocene, and that numerous new dorsal cup morphologies arose through neoteny/paedomorphosis.

Of the infraorder Holopodinia only a single representative is known, *Cyathidium vliexi* JAGT, 1986, which is now known from the base of the Vijlen Member, the Meerssen Member and the Kunrade limestone facies (Kunrade area). There are no Danian records of this genus in the study area.

Finally, roveacrinids have been shown to range to right below the K/T boundary, with *Birgelenocrinus degraafi* JAGT, 1999b and *Applinocrinus cretaceus* (BATHER, 1924) occurring in the middle/higher Meerssen Member. Of the other species, *Veugellersia diana* JAGT, 1999b, two stratigraphically highly disjunct occurrences are known; one in the early Late Campanian (Benzenrade area) and one in the Late Maastrichtian (Ankerpoort-'t Rooth quarry).

Echinoids

To date, over 100 species are on record, but diversity is still increasing. Notable recent additions and discoveries include the following:

- the Zeven Wegen Member (CPL SA quarry) has yielded the highly specialised, bizarre holasteroid *Hagenowia* (Pl. 1, Figs. 11, 12), which may prove conspecific with material from Norfolk and northwest Germany, and represent a still undescribed member of the *blackmorei/elongata* lineage.
- the Benzenrade Member near Benzenrade has yielded the zeuglopleurid *Zeuglopleurus rowei* GREGORY, 1900 (Pl. 1, Fig. 4), which extends the range of this rare species, recorded mostly from white chalk settings (see SMITH & WRIGHT, 1996), to the early Late Campanian.
- from the Meerssen Member (ENCI-Maastricht BV quarry) additional spines of the psychocidarid *Tylocidaris inexpectata* JAGT & VANDERHAM, 1995 have been collected, showing it to range to the top of that unit. This species may be a sister taxon of the Early Palaeocene *T. oedumi* BRÜNNICH-NIELSEN, 1938, which in turn may prove to be a junior synonym of *T. hardouini* (DESOR, 1855).
- A small phymosomatid from the Nekum Member (ENCI-Maastricht BV quarry) preserves spines and the lantern, and shows the type of spine referred to as *Phymosoma rutoti* LAMBERT, 1898 in the literature, to belong to a genus close to *Trochalosoma* LAMBERT, 1897.
- of the locally very common Danian saleniid *Hyposalenia heliophora* (AGASSIZ & DESOR, 1846), a number of specimens with well-preserved lanterns have been collected, one of which is illustrated here in Pl. 1, Figs. 1-3.
- the Meerssen Member (ENCI-Maastricht BV quarry) has yielded the second, well-preserved specimen of an apparently new species of the plagiochasmid genus *Plagiochasma*. MEIJER (1965) noted that it appeared to differ consistently from the Palaeocene *P. cruciferum* (MORTON, 1830) [= *P. analis* (DESOR, 1857)].
- from the Zeven Wegen Member (CPL SA quarry), juveniles of the diadematid *Centrostephanus?* sp. (Pl. 1, Figs. 9, 10) are now known.
- new well-preserved material of the stomopneustid *Winkleria maastrichtensis* ENGEL, 1964 (Pl. 1,

Fig. 8) allows the ambulacral structure to be described in detail, and a direct comparison with the genus *Plistophyma* (see SMITH, 1995; SMITH & JEFFERY, in press) to be carried out.

- the Meerssen Member has yielded diminutive holasteroids (Pl. 1, Figs. 5-7). These appear to be juveniles of the common holasteroid *Hemipneustes striatoradiatus* (LESKE, 1778), of which literally thousands of adult specimens have been collected in the area. The apparent absence in the area of juveniles of this species has always been a mystery; it may be that the fragile tests stood virtually no chance of being preserved in the shallow-water settings represented by the Nekum and Meerssen members.

JAGT (1998) noted that echinoid faunal composition across the K/T boundary varied considerably. Suffering heavy losses are infaunal selective deposit feeders (hemiassterids), shallow infaunal/semi-infaunal selective deposit feeders (holasteroids), infaunal bulk sediment swallowers (cassidulids), infaunal selective deposit feeders (faujasiids) and the epifaunal browser *Orthopsis*. Epifaunal diversity (cidaroids) is comparable across the boundary, with psychocidarids occurring especially in the Danian. Epifaunal generalists (saleniids) increase in diversity across the boundary, and within the Geulhem Member nearshore hardground grazers (arcopeltids, arbaciids) are confined to the upper part. That part has also yielded the highest diversity in shallow-water, more protected firm bottom species (phymosomatids, cidaroids).

Ophiuroids

Previous studies of ophiuroids from the study area (e.g., BERRY, 1938) were based almost exclusively on dissociated ossicles, which generally were poorly preserved. In recent years, especially storm-dominated deposits (Meerssen Member) have yielded many specimens with discs and (portions of) arms preserved, allowing species to be better defined. Thus, the pitfalls of combining various unrelated types of dissociated ossicles into species (see discussion in RASMUSSEN, 1950, 1952) can be evaded. In addition, preliminary observations on predation pressure, based on the number of regenerating arms (see ARONSON, 1987) are possible.

In view of the fact that most ophiuroid species, particularly those of the Late Campanian and early Late Maastrichtian, are also known from the Early Maastrichtian of Rügen (NE Germany), KUTSCHER & JAGT (1999) decided to base their descriptions mainly on material from that locality. Numerous new species, amongst the (sub)families Ophiobyrsinae, Asteronychidae, Euryaliidae, Ophiomyxidae, Ophiacanthidae, Ophiuridae, Amphiuroidae, Ophiothricidae, Ophiocomidae, Ophiodermatidae and Ophiolepididae. Material from the Benzenrade, Nekum, Meerssen and Geulhem members in the study area is complementary.

In general, the more robust forms such as *Ophiomusium granulosum* (Pl. 1, Figs. 16, 17), are overrepresented in ophiuroid samples. Comparatively more articulated remains, such as discs and portions of arms, are known of these forms. The Geulhem Member has yielded only few species; the most interesting amongst these is a new ophiolepidid (Pl. 1, Fig. 13).

Asteroids

Starfishes are the most neglected group amongst the echinoderms of the study area, which may be explained by the fact that these animals disintegrated rather rapidly upon death and only a jumble of dissociated ossicles remained (BLAKE, 1989, 1996). However, although more or less complete specimens are extremely rare (see e.g., FAUJAS SAINT FOND, 1799; UMBGROVE, 1925), asteroids undoubtedly deserve better. At least 50 species have now been recognised in strata of Campanian, Maastrichtian and Danian age. More than half of these have been described previously from elsewhere in Europe, in particular from white chalk facies types. These include the following:

- representatives of the *studlandensis-alseni-peakei* lineage of *Nymphaster*, which have been shown to constitute good index fossils (GALE, 1987b, 1989; BRETON, 1992) in the early and late Late Campanian (Pl. 2, Figs. 8, 19, 20).
- *Nymphaster spenceri* (RASMUSSEN, 1950) and *N. wrighti* (RASMUSSEN, 1950), well known from the Maastrichtian of northern Germany and Denmark.
- *Lophidiaster pygmaeus* SPENCER, 1913 (Pl. 2, Fig. 9), which first occurs in the Zeven Wegen Member, and is a minor constituent of asteroid faunas in the remainder of the Gulpen Formation and the lower part of the Maastricht Formation. A find of associated ossicles of a single individual suggests that MÜLLER's (1956) description of this taxon is in need of a revision.
- the sphaerasterid *Valettaster* (Pl. 2, Fig. 15), of which at least two species occur, one of them possibly new (Zeven Wegen Member), the other assignable to *V. ocellatus* (FORBES, 1848), a long-ranging taxon (see BRETON, 1985).
- *Metopaster tumidus* SPENCER, 1913, of which typical examples are known only from the Early Maastrichtian portion of the Vijlen Member (Pl. 2, Fig. 21); forms assignable to SCHULZ & WEITSCHAT's (1975) *M. praetumidus* occur in the Zeven Wegen Member.
- Late Cretaceous species of *Crateraster* are common (Pl. 2, Fig. 22), *C. favosus* (SPENCER, 1913) occurring in the Zeven Wegen Member and *C. reticulatus* (SCHULZ & WEITSCHAT, 1981) in the Vijlen Member. Typically Early Palaeocene representatives such as *C. anchylus* (BRÜNNICH NIELSEN, 1943) and *C. retiformis* (SPENCER, 1913) are known from the Geulhem Member, but neither is particularly common.
- "cryptozonid" (? echinasterid) forms such as the one illustrated by MÜLLER (1953, pl. 10, fig. RA1-2) have been found associated with ambulacrals and terminal plates in the Zeven Wegen Member (Pl. 2, Figs. 1, 2, 4).
- of *Metopaster decipiens* SPENCER, 1913 (Pl. 2, Fig. 3) quite a few associated remains of individuals have been collected from the Zeven Wegen Member.
- *Metopaster undulatus* SPENCER, 1913 (Pl. 2, Fig. 7), which BRETON (1992) placed in his new genus *Parametopaster*, is known exclusively from the Early Maastrichtian portion of the Vijlen Member; a comparable (new?) form, with a pronounced ornament of pits of varying size (Pl. 2, Fig. 10), occurs in the Zeven Wegen Member.
- the enigmatic goniasterid *Chomataster acules* SPENCER, 1913, ranging from the early Late Campanian to the Middle Danian (Late Danian in Denmark; RASMUSSEN, 1945), of which a fairly well-preserved individual is known from the Geulhem Member of the temporary Albertkanaal sections (Vroenhoven-Riemst).
- *Ophryaster oligoplax* (SLADEN, 1891) (Pl. 2, Figs. 5, 6), of which several well-preserved arm fragments and numerous dissociated marginals, some preserving granules, have been collected from the Zeven Wegen Member; in the Vijlen Member, *O. magnus* SPENCER, 1913 occurs in places.

Typically Early Palaeocene species such as *Metopaster spencerii* BRÜNNICH NIELSEN, 1943 (Pl. 2, Fig. 17), *M. kagstrupensis* BRÜNNICH NIELSEN, 1943 and *Astropecten punctatus* (BRÜNNICH NIELSEN, 1943) (Pl. 2, Fig. 16) are known from the Geulhem Member, and it is in part on these forms that RASMUSSEN (1965) based his correlation of that unit with the lower part of the Danish Bryozoakalk (Stevens Klint).

In addition to the above-mentioned taxa, which allow interregional correlations with localities elsewhere in northwest Europe, the asteroid faunas in the study area also contain what appear to be endemic elements, although use of the term "endemic" should in fact be avoided. It may well be that the "typical Maastricht tuffaceous chalk" facies was distributed much more extensively over northwest Europe, but that these strata were eroded completely by subsequent transgressive phases. This, in fact, goes for all echinoderm groups, not only for starfish. New finds include:

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Fig. 2 — Lithostratigraphy and biozonation of Campanian-Maastrichtian strata in the type area of the Maastrichtian Stage (from JAGT, 1999a).

	VF	ZW	B	Vij	Li	L	Va	Gr	S	E	N	M	Ge
<i>Diplodetus</i> spp.	x	x											
<i>D. cf. americanus</i>												x	
<i>D. parvistella</i>				x			x	x					
<i>D. duponti</i>						x	x						
<i>D. bucardium</i>						x	x						
<i>Hemiaster</i> gr. <i>aquisgranensis</i>	x	x		x	x	x	x	x					
<i>H. prunella</i>						x	x			x		x	
<i>H. koninckanus</i>						x	x				x	x	
<i>Leymeriaster eluvialis</i>						x		x		x			
<i>L. maestrichtensis</i>											x	x	
<i>L. sp. nov.</i>	x												
<i>Linthia?</i> <i>breviuscula</i>													x
<i>Li.?</i> sp.													x
<i>Paraster sindensis</i>													x
Ophiuroids													
<i>Ophiosmilax?</i> sp. nov.		x		x									
<i>Asteronyx?</i> sp. nov.				x									
<i>Trichaster?</i> <i>ornatus</i>		x		x		x	x	x		x	x	x	
<i>T.?</i> sp.		x		x		x						x	
<i>Ophiomyxa?</i> sp. nov.				x								x	
<i>Ophiomyxa?</i> <i>jekerica</i>		x									x	x	
<i>Ophioscolex?</i> sp. nov. 1		x											
<i>Ophioscolex?</i> sp. nov. 2		x		x									
<i>Ophiacantha?</i> <i>danica</i>		x		x		x		x				x	
<i>Ophiacantha?</i> sp. nov. 1		x											
<i>Ophiacantha?</i> sp. nov. 2				x									x
<i>Stegophiura?</i> <i>hagenowi</i>		x		x				x					
<i>S.?</i> sp. nov.		x											
<i>Ophiecten?</i> sp. nov.												x	
<i>Felderophiura vanderhami</i>										x	x	x	
<i>Ophioplinthaca?</i> <i>fuerstenbergii</i>	x											x	
<i>Amphiura?</i> sp. nov.		x		x									
amphiurid gen. et sp. nov. 1												x	
amphiurid gen. et sp. nov. 2	x												
<i>Ophiothrix?</i> sp. nov. 1	x	x		x				x					
<i>Ophiothrix?</i> sp. nov. 2				x									x
<i>Ophiactis?</i> sp. nov.		x											
<i>Ophiocoma?</i> <i>senonensis</i>		x		x								x	x
<i>Ophioderma?</i> sp. nov.		x				x							
<i>Ophioderma?</i> <i>substriatum</i>		x		x		x							
<i>Ophiarachna?</i> sp. nov.												x	
<i>Ophiotitanos serrata</i>	x	x		x		x		x			x	x	x
<i>Ophiolepis?</i> sp. nov. 1		x											
<i>Ophiolepis?</i> sp. nov. 2		x		x									
<i>Ophiolepis?</i> sp. nov. 3													
<i>Ophiomusium</i> sp. nov. 1		x											
<i>Ophiomusium granulosum</i>		x		x	x	x	x	x		x			x

	VF	ZW	B	Vij	Li	L	Va	Gr	S	E	N	M	Ge
<i>Ophiomusium</i> sp. nov. 2												x	
<i>Ophiomusium</i> sp. nov. 3				x									
ophiolepidid gen. et sp. nov.													x
Crinoids													
<i>Austinocrinus bicoronatus</i>				x									
<i>Isocrinus?</i> sp.												x	
<i>I.?</i> lanceolatus				x									
<i>Isselocrinus buchii</i>				x									
<i>Praeisselocrinus?</i> limburgicus				x									
<i>Nielsenocrinus carinatus</i>		x											
<i>N. agassizii</i>				x									
<i>N. ewaldi</i>											x	x	
<i>Jaekelometra</i> gr. belgica											x	x	
<i>J. gr. concava</i>											x	x	
<i>J.?</i> defectiva								x		x			
<i>Placometra</i> gr. laticirra	x	x				x		x					
<i>Atuatucametra annae</i>													x
<i>Amphorometra</i> gr. conoidea		x									x	x	
<i>Semiometra impressa</i>		x											
<i>S. lenticularis</i>											x	x	
<i>S. saskiae</i>											x	x	
<i>Loriolometra retzii</i>	x												
<i>Hertha</i> gr. plana				x	x								
<i>H. gr. pygmea</i>				x									
<i>H. gr. mystica</i>													x
<i>Dunnocrinus aequalis</i>						x	x	x		x			
<i>Bourgueticrinus</i> aff. baculatus		x											
<i>B. sp.</i>		x	x										
<i>B. bruennichielseni</i>													x
<i>B. aff. brydonei</i>				x	x								
<i>B. constrictus</i>				x	x								
<i>B. danicus</i>													x
<i>B. hureae</i>		x											
<i>B.?</i> suedicus		x											
<i>Democrinus?</i> maximus													x
“ <i>Monachocrinus gallicus</i> ”		x											
<i>Cyathidium vlieksi</i>				x								x	
<i>Applinocrinus cretaceus</i>	x	x		x	x	x				x		x	
<i>Birgelenocrinus degraafi</i>												x	
<i>Veugelersia diana</i>	x									x			
Asteroids													
astropectinid sp.												x	
<i>Astropecten?</i> punctatus													x
<i>A.?</i> sp. nov.													x
<i>Aldebarania</i> sp. nov.											x		
<i>Lophidiaster pygmaeus</i>		x		x	x	x	x	x		x			
<i>Coulonia</i> sp. nov.											x	x	

- apparently juvenile goniasterids, closely related to *Crateraster* (Pl. 1, Fig. 14), from the Meerssen Member (Blom quarry).
- many paxillosidans, such as possible radiasterids (Pl. 2, Fig. 13) and astropectinids, e.g. the form illustrated in Pl. 2, Fig. 12, which RASMUSSEN (1965, pl. 8, fig. 13) referred to as *Astropecten* n. sp. aff. *cotteswoldia* [sic]. Cainozoic astropectinids (see e.g., RASMUSSEN, 1972; KACZMARSKA, 1987) are in need of a modern revision; only rarely have species been based on such well-preserved remains as those recently described by NOSOWSKA (1997). Forms closely related to or assignable to the genera *Tethyaster* (see e.g., HALL & MOORE, 1990; BRETON, 1995), *Dipsacaster* (see BRETON *et al.*, 1995), *Coulonia* (= *Cuneaster*; see HESS & BLAKE, 1995) and the otherwise exclusively North American *Aldebarania* (see BLAKE & STURGEON, 1995) are known from the Zeven Wegen Member and the higher Maastricht Formation (Emael, Nekum and Meerssen members; Pl. 2, Fig. 11), in particular. From flint nodules in the upper Nekum Member (CBR-Romontbos quarry), three well-preserved individuals are known of an astropectinid referable to *Aldebarania* (D.B. Blake, pers. comm.).
- stauranderasterids, especially from the Geulhem Member, appear close to *Stauranderaster miliaris* BRÜNNICH-NIELSEN, 1943 (Pl. 2, Fig. 14); the Meerssen Member has yielded another form (Pl. 2, Fig. 25).
- rare benthopectinids (Pl. 1, Fig. 18), comparable to material illustrated by BLAKE (1973, 1984).
- various new species of the goniasterid *Metopaster*; this genus in particular appears to have been very successful in establishing local species, as offshoots of the *parkinsoni* lineage. GALE (1987a) erected a number of such short-lived offshoots, which are particularly typical of marginal settings, e.g., coarse-grained biocalcarenites in southern Sweden. Comparable forms have been discussed by BRETON (1992,

- 1997), VILLIER (1996) and VILLIER *et al.* (1997). One of the new species, *Metopaster* sp. nov. (Pl. 2, Fig. 18) is reminiscent of *M. calcar* SPENCER, 1913, from the Santonian-Early Campanian of southern Sweden (see GALE, 1987a, pl. 8, figs. 12-21) and of *M. bromleyi* GALE, 1987a (pl. 2, figs. 14-16; pl. 3, figs. 1-5) from the late Early Campanian of the same area.
- remains of at least two individuals of what appears to be a new species of *Recurvaster*, seemingly closely related to and a possible precursor of the Early Palaeocene *R. mammillatus* (GABB, 1876), are known from the uppermost Meerssen Member (Pl. 2, Figs. 23, 24) of Blom quarry.
- dissociated ossicles of asteriids (Pl. 1, Figs. 15, 19), closely comparable to material from the Cenomanian-Coniacian of France as illustrated by BRETON & FERRÉ (1995). Asteriids have rarely been recorded as fossils, and for that reason it comes as no surprise that new finds almost invariably represent new genera and/or species (see e.g., BLAKE, 1990a; BLAKE & PETERSON, 1993; BLAKE *et al.*, 1996; BLAKE & ARONSON, 1998).

Reference is made to JAGT (1999d) for more details and for a discussion of functional morphology and palaeoecology of these asteroid faunas, based on literature data (BLAKE, 1989, 1990b).

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PLATE 1

Note — Data on provenance of material in Plates 1 and 2, as well as repository and registration numbers of specimens illustrated, are supplied by JAGT (1999b-d) and KUTSCHER & JAGT (1999), to which reference is made.

- Figs. 1-3 — *Hyosalenia heliophora*, apical and lateral views of test (x 6), and associated lantern (x 23).
 Fig. 4 — *Zeuglopleurus rowei*, apical view, x 9.
 Figs. 5-7 — *Hemipneustes striatoradiatus* juv., apical, oral and lateral views, x 9.
 Fig. 8 — *Winkleria maastrichtensis*, oblique lateral view, x 17.5.
 Figs. 9, 10 — *Centrostephanus?* sp. juv., lateral and oblique apical views, x 15.
 Figs. 11, 12 — *Hagenowia* sp. (?nov.), rostra, x 15 and x 12, respectively.
 Fig. 13 — Ophiolopidae n. sp., lateral arm plate, x 30.
 Fig. 14 — Goniasteridae indet. juv., x 6.5.
 Figs. 15, 19 — asteriid indet., x 20 and x 26, respectively.
 Figs. 16, 17 — *Ophiomusium granulosum*, proximal arm portions, x 16 and x 5, respectively.
 Fig. 18 — benthoplectinid indet., x 21.

PLATE 2

- Figs. 1, 2, 4 — indeterminate "cryptozoid" (? echinasterid), marginals, ambulacrals and terminal plate; x 13 (1), x 19 (2) and x 25 (4).
 Fig. 3 — *Metopaster decipiens*, ultimate superomarginal, x 9.
 Figs. 5, 6 — *Ophryaster oligoplax*, marginals preserving granules, x 10.
 Fig. 7 — *Metopaster undulatus*, ultimate superomarginal, x 7.5.
 Fig. 8 — *Nymphaster studlandensis*, distal marginal, x 17.
 Fig. 9 — *Lophidiaster pygmaeus*, superomarginal, lateral view, x 20.
 Fig. 10 — "Parametopaster" (sp. nov.), oblique view of ultimate superomarginal, x 8.
 Fig. 11 — astropectinid indet., superomarginal, x 18.
 Fig. 12 — astropectinid (sp. nov.), inferomarginal, x 18.
 Fig. 13 — radiasterid(?) indet., superomarginal, x 20.
 Fig. 14 — stauranderasterid, x 11.
 Fig. 15 — *Valettaster* sp. (nov.), x 7.
 Fig. 16 — *Astropecten punctatus*, interradial superomarginal, x 18.
 Fig. 17 — *Metopaster spencerii*, median superomarginal, x 4.5.
 Fig. 18 — *Metopaster* sp. nov., ultimate superomarginal, x 4.
 Figs. 19, 20 — *Nymphaster alseni*, interradial superomarginal, x 3.
 Fig. 21 — *Metopaster tumidus*, ultimate superomarginal, x 3.
 Fig. 22 — *Crateraster reticulatus*, median supero- and inferomarginal, x 3.
 Figs. 23, 24 — *Recurvaster* sp. nov., median superomarginal, x 3.
 Fig. 25 — stauranderasterid, x 3.5.

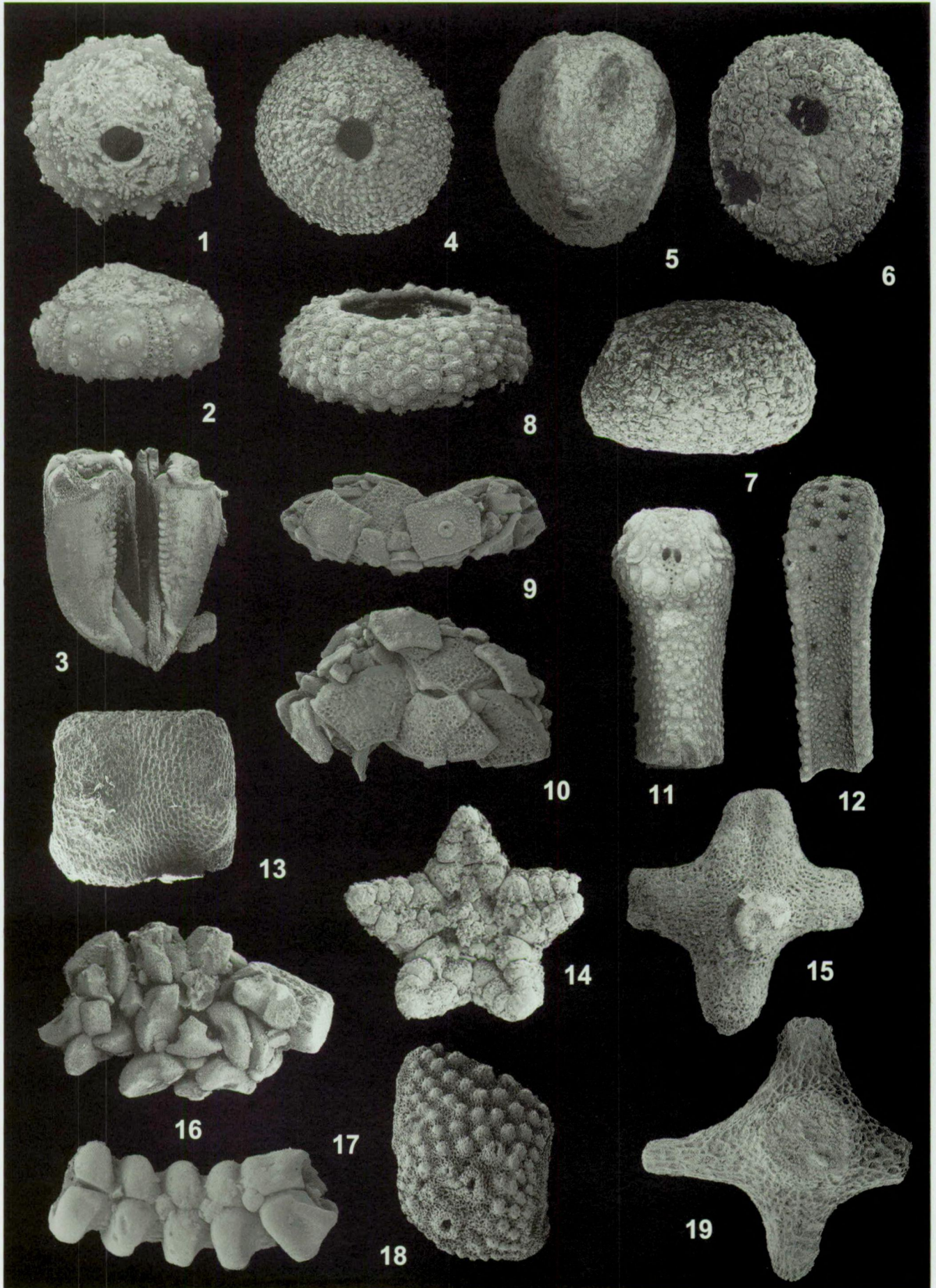


PLATE 1

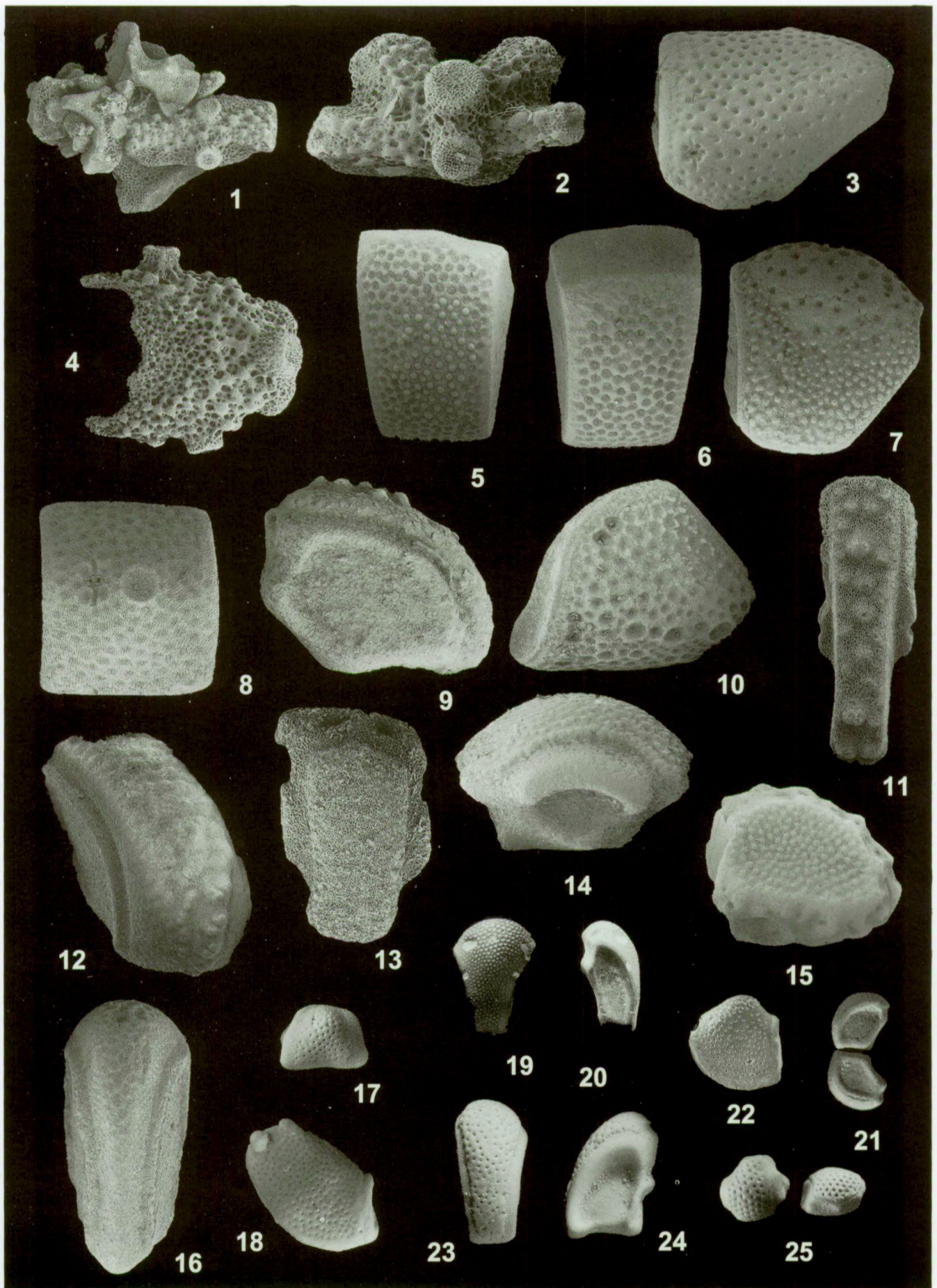


PLATE 2