

**THE DANIAN IN THE MAASTRICHTIAN TYPE AREA (SE NETHERLANDS,
NE BELGIUM): PAST, PRESENT AND FUTURE RESEARCH**

by

J.W.M. Jagt
Venlo, The Netherlands

and

A.W. Janssen
Rijksmuseum van Geologie en Mineralogie, Leiden, The Netherlands

Jagt, J.W.M., & A.W. Janssen. The Danian in the Maastrichtian type area (SE Netherlands, NE Belgium): past, present and future research.—Meded. Werkgr. Tert. Kwart. Geol., 25(2-3): 213-223, 1 tab. Leiden, October 1988.

A brief historical account of the stratigraphic-palaeontological research into the Early Palaeocene (Danian) of the Maastrichtian type area is presented. In addition, current investigations of several aspects of the Dutch-Belgian Danian are commented upon, with the aim of presenting an up-to-date picture of the biostratigraphy and palaeontology of this stage in this area. Data presented in the papers of the present issue are discussed and suggestions are offered for future research, which should preferably concentrate on fossil groups of special biostratigraphic potential. It is suggested that in the near future a section exposing the Maastrichtian-Danian boundary sequence in the Maastrichtian type area should be chosen as reference section and thus be protected by government bodies responsible for nature conservation.

J.W.M. Jagt, 2de Maasveldstraat 47, 5921 JN Venlo, The Netherlands; A.W. Janssen, Rijksmuseum van Geologie en Mineralogie, Hooglandse Kerkgracht 17, 2312 HS Leiden, The Netherlands.

CONTENTS	Samenvatting, p. 214
	Introduction, p. 214
	Past research, p. 214
	Present and future research, p. 216
	Conclusions, p. 220
	References, p. 220.

SAMENVATTING

Het Danien in het type-gebied van het Maastrichtien (ZO Nederland, NO België): vroeger, tegenwoordig en toekomstig onderzoek.

Een kort historisch overzicht van het stratigrafisch-paleontologische onderzoek in het Vroeg Paleoceen (Danien) in het type gebied van het Maastrichtien wordt gepresenteerd. Daarnaast worden actuele onderzoeksprojecten betreffende verschillende aspecten van het Nederlands-Belgische Danien besproken met het doel een beeld te schetsen van de huidige kennis van de stratigrafie en paleontologie van deze tijd in dit gebied. Resultaten uit de bijdragen in deze aflevering van de Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie worden kort besproken en voorstellen voor toekomstig onderzoek worden gedaan. Dit toekomstig onderzoek zou bij voorkeur toegespitst moeten worden op fossielgroepen met grote biostratigrafische waarde. Het wordt aanbevolen in de nabije toekomst een profiel dat de Maastrichtien-Danien grens ontsluit in het typegebied van het Maastrichtien, bij voorkeur dat van de groeve Curfs te Geulhem, aan te wijzen als referentiesectie, welke dan ook onder het beheer zal vallen van overheidsinstanties op het gebied van natuurbeheer.

INTRODUCTION

In the present contribution a state-of-affairs report of the stratigraphy and palaeontology of the Danian (Geulhem Member of the Houthem Formation) in the Maastrichtian type area is presented. A brief historical account is given and suggestions are offered for future, multidisciplinary research, which should concentrate on the section as exposed in the former Curfs quarry at Geulhem and add to our knowledge of particular fossil groups of special biostratigraphic-correlative value. In view of the importance of a good understanding of the upper limit of the Maastrichtian stage in its type area, and of having a clear picture of the K-T boundary in this area, it is recommended that a section exposing this boundary be preserved for future generations.

PAST RESEARCH

Binkhorst van den Binkhorst (1859, p. 29-30, pl. 3) mentioned for his 'coupe du Heunsberg près de Fauquemont' as highest unit of what he considered the 'craie tuffeau, système maastrichtien (*sic*) de Dumont', a layer of 'craie tuffeau, friable, sablonneuse avec quelques rares fossiles de la couche qu'elle couvre'. The underlying unit is stated to have yielded large numbers of the hemiasterid echinoid *Hemiaster (Bolbaster) prunella* (Lamarck, 1816) in addition to other typically Late Cretaceous macrofossils, such as the gastropod *Nerita rugosa* Hoeninghaus, 1830 and the belemnite *Belemnitella junior* Nowak, 1913.

A year later, Binkhorst van den Binkhorst (1860, p. 61, 62, 65; see also 1863) reported having discovered 'nouvelles couches intéressantes, par la faune spéciale que l'une d'elle renferme', which he described in his 'coupe générale' as follows:

'5. Presque immédiatement sous le sable tertiaire, à Genchen (read: Geulhem), près Meerssen, où la craie supérieure est de plusieurs mètres

plus puissante qu'à Saint-Pierre et Fauquemont, une première couche fossilifère la traverse; elle est formée de petites cailloux entremêlés de débris de bryozoaires, fragments de *Cidaris Faujasi*, etc.

6. Trois mètres plus bas, une seconde couche fossilifère traverse d'une manière irrégulière la craie jaune. Elle est épaisse de 3 à 4 pouces, et est facile à reconnaître par ses taches vertes de glauconie. Elle forme une agglomération de baguettes de *Cidaris Hardouini*, Desor, par milliers d'individus, de dents de Requin, *Corax*, *Lama (sic)*, *Otodus virgulina*, *Notidanus*, et de petites dents de *Sphaerodus* rappelant l'espèce tertiaire *Sphaerodus parvus*, Ag. Tous ces fossiles, à peu exceptions près, ont beaucoup souffert par le transport. Elle contient aussi des bryozoaires, et une espèce d'*Isis* nouvelle pour notre craie.'

The underlying 'couche 7' is reported to have yielded large numbers of the echinoids *H. (B.) prunella*, *Hemipneustes striatoradiatus* (Leske, 1778) and *Faujasia apicalis* (Desor, 1847); it represents the uppermost part of the Meerssen Member (Maastricht Formation) in current lithostratigraphic terminology (W.M. Felder, 1975). Binkhorst's units 5 and 6 are now known as the Geulhem Member of the Houthem Formation: W.M. Felder (1973) described a comparable section for the Curfs quarry at Geulhem.

Triger (1860), in a letter to the Société géologique de France, reacted quite strongly to Binkhorst's (1860) claim of having discovered strata not previously recognized for the 'système maestrichtien'. He explicitly stated that 'couche 6' of Binkhorst

'.... n'est pas plus nouvelle que la première, puisque je l'ai signalé depuis un an à la Société géologique, comme terminant la série des dépôts créacés des environs de Maestricht, n'attachant pas, du reste, à cette couche, une autre importance que celle d'être un fait de plus, entre mille, constatant la parfaite identité qui existe entre la craie supérieure de Maestricht et la craie de Ciplly, où les mêmes radioles de *Cidaris* abondent à la partie supérieure.'

Triger thus seems to have been the first to correlate the Geulhem Member with the 'Tuffeau de Ciplly', although he still referred these strata to the 'Upper' Cretaceous.

Ubaghs (1879, p. 89-92) described for his 'coupe de Geulhem' the following units:

'c. Craie tuffeau, immédiatement sous le sable tertiaire, laquelle, principalement là où elle est en contact avec le sable superposé, est à demi décomposée, et contient de l'oxyde de fer. (...) Dans les couches plus dures se trouvent en grande partie des fossiles à l'état de moules et des empreintes creuses, comme *Cardita*, *Arca*, *Tellina*, *Nucula*, *Pectunculus*, *Venus*, *Pholadomya*, *Turritella*, *Rostellaria*, *Aporrhais Limburgensis*, etc. Le tuffeau entre les parties dures est friable et d'un blanc grisâtre; l'*Hemaster prunella* s'y trouve en abondance. Puissance: 4 mètres.

d. Couche à *Cidaris Hardouini*, Desor. Celle-ci a une puissance de 10-15 centimètres, est friable, de structure oolithique et renferme beaucoup de concrétions calcaires; les aiguillons de *Cidaris Hardouini* sont surtout en grande abondance dans cette mince couche; on en trouve par milliers. Ces aiguillons sont très rares dans la partie plus profonde du tuffeau. Nous y trouvâmes en outre des aiguillons de *Cidaris Faujasii*, *Pentetagonaster (sic) quinqueloba*, *Trochomilia Faujasii*, *Molkia (sic) Isis*, *Crania Hagenowi*, *Mitella lithothryodes (sic)* Bosquet, et une quantité de dents de requins.'

(italics by the present authors)

Collections made from Ubaghs's 'couche e' are stated to include ammonites such as *Baculites vertebralis* Lamarck, 1801, *Sphenodiscus binckhorsti* J. Böhm, 1898 and *Hoploscaphites constrictus* (J. Sowerby, 1817) and echinoids such as *Hemiaster prunella*, *Hemipneustes striatoradiatus* and *Procassidulus lapiscancris* (Leske, 1778), all typical of the Late Maastrichtian in the area (see e.g. W.M. Felder, 1973). What is puzzling in this section is the fact that Ubaghs mentioned *H. prunella* to occur above the unit characterized by large numbers of primary spines of the species now known as *Tylocidaris hardouini* (Desor, 1855) !

Three quarters of a century later Hofker (1955) reported having found in the Curfs quarry near Geulhem a unit yet undescribed and characterized by a foraminifer fauna totally different from the one of the underlying Maastrichtian (Md *sensu* Uhlenbroek, 1912). This unit is the same as the one referred to by the authors quoted above, being characterized by *T. hardouini*. So, the unit had already been described, but indeed Hofker was the first to realize that this unit represented boreal, marine deposits of Palaeocene age, and he compared it to the 'Tuffeau de Cibly', just as Triger had done almost a century earlier !

The following year, Hofker (1956) presented a number of additional localities from where this unit had become known and referred to it as 'Onder-Palaeocene' ('Lower Palaeocene'). Again a year later, Hofker (1957) described in some detail sections along the Albert Canal, in which the same unit had been recognized. He proposed to subdivide it into two units: the Me (= the uppermost part of Uhlenbroek's 1912 Md) with mixed assemblages of Maastrichtian and Palaeocene faunas and the 'Lower Palaeocene' proper with at its base an indurated chalk layer yielding molluscan faunas.

Meijer (1959, 1965) rejected Hofker's chronostratigraphic subdivision and demonstrated on the basis of planktonic foraminifers and echinoids that the entire unit between the Maastrichtian Md (Meerssen Member *sensu* W.M. Felder, 1975) and the Early Oligocene was of Danian age. It should be noted that Meijer retained Hofker's Me and referred to Hofker's 'Lower Palaeocene' as Pa. In the meantime, Rasmussen (1964, 1965) had pointed out the strong faunal relationships between the Tuffeau de Cibly, the 'Post-Maastrichtian' and the Danish type Danian, paying particular attention to echinoderms.

In Hofker (1966) the reader will find additional data presented by Hofker in the late fifties and early sixties based on the study of foram faunas. A formal lithostratigraphy for the Maastrichtian type area (including strata of Santonian to Montian age) was proposed by W.M. Felder (1975). In this scheme Hofker's Me + Pa are referred to as Geulhem Member of the Houthem Formation.

After the publication of Rasmussen's 1965 paper there seems to have been a general consensus in the subsequent literature that this 'Post-Maastrichtian', or Geulhem Member in modern terms, is of Danian age, although this unit is still often referred to as 'Dano-Montian'.

The reader is referred to the paper by Jagt & Collins (1988, in the present issue), and to the section below, for a discussion of the results obtained by studies over the past decade.

PRESENT AND FUTURE RESEARCH

In the papers by Bless (1988), van der Ham (1988) and Jagt & Collins (1988), all in the present thematic issue, arguments have been put forward in support of a Danian age of the Geulhem Member. Yet, exact correlations with the Danish-Swedish Danian have still to be established, if at

all possible. The results from analyses of several groups of fossils of biostratigraphic value are often conflicting to such an extent that the overall picture becomes blurred.

Multidisciplinary research is needed, and a coordination of all projects is essential in this respect. The way in which the research is now conducted is far from ideal: attention is only paid to isolated aspects of the Danian in the Maastrichtian type area (see *e.g.* Jaarverslag Rijks Geologische Dienst, 1987, p. 34) and one cannot help but feeling that the research is of limited scope. A good example for this is the mollusc fauna: no professional palaeontologist seems to have been interested in these faunas for a very long period indeed and no collections of any importance are present in Dutch public collections. Regrettably, this also means that all information potentially included in this fossil group, *e.g.* in the fields of palaeoecology and biostratigraphy, inclusive of possibilities for regional and extra-regional correlations, is not available now. For some further notes on the mollusc faunas the reader is referred to Jagt & Janssen (1988, in the present issue).

The temporary sections along the Albert Canal between Vroenhoven and Veldwezelt (Belgium, province of Limburg) have been extensively sampled, mainly (or almost exclusively) by non-professional collectors, who have amassed enormous amounts of extremely interesting macrofossil material. In this respect, it is very unfortunate that this material has become dispersed over a large number of collections that are usually inaccessible to professional palaeontologists. What is even worse, though, is the fact that most of the private collectors were not aware of the prime demands with regard to palaeontological specimens, that is, accurate documentation of geographical and stratigraphical provenance of the material. Admittedly, it was extremely difficult, at certain times, to determine the precise position of isolated sections along this canal in the total section of the Geulhem Member. Meijer's (1959) section was only applicable to a small stretch along this canal. Large-scale excavations revealed sections previously unknown (see *e.g.* van der Ham, 1988, in this issue), which were often removed with remarkable speed by the excavators, thus preventing detailed sections to be constructed. Such detailed sections would have been extremely interesting, considering the observed lateral variability of the deposits [see also, for the occurrence of so-called 'lenticular sediment bodies', P.J. Felder (1988, the present issue)]. In addition, the rather disorderly method of excavation and the eventually far from steep tali were certainly not favourable to scientists who wished to acquire some sort of overall picture of the Geulhem Member in all its aspects, whether lithologic, facial or faunal.

Detailed studies of the abundant material collected along the Albert Canal are intended for the near future. The echinoid fauna in particular has already received, and will receive, much attention, and deservedly so. A thorough discussion of this fauna, together with comparisons of the echinoid assemblages of the Early Palaeocene in the Mons Basin (southern Belgium) and the type Danian of Denmark, is in preparation. The echinoid fauna is definitely Danian in nature, and species from the uppermost Geulhem Member display affinities with taxa of Montian age described from other parts of NW Europe (van der Ham, 1988). From a detailed study of the *Tylocidaris* populations in the Geulhem Member it may prove to be possible to introduce two total range zones, the lower one characterized by *T. hardouini* (Desor, 1855) and the upper one by *T. bruennichi* Ravn, 1928.

In addition to echinoids, asteroids may turn out to be stratigraphically significant. This is certainly the case for a number of distinctive species of the genus *Metopaster* Sladen, 1893, but taxa of the genera *Valettaster* Lambert, 1914, *Aspidaster* de Loriol, 1884, *Pycinaster* Spencer, 1907, *Chomataster* Spencer, 1913 and *Crateraster* Spencer, 1913 (incl. *Teichaster* Spencer, 1913; see Gale, 1987) may also prove to have stratigraphic potential. The asteroid fauna of the type Danian is comparatively well-

known and it will therefore prove to be fairly easy to establish correlations by means of these echinoderms.

The crinoid and ophiuroid fauna of the Geulhem Member will be treated in a similar fashion: a detailed study of these groups should not only be taxonomic in nature, but also include a thorough review of their correlative value.

Bless (1988, this issue) studied the changes in ostracod assemblages across the K-T boundary and put this event, together with Late Cretaceous ones, in a larger perspective. The ostracod fauna of the Geulhem Member is completely different from the underlying latest Maastrichtian one, and represents returning boreal influences in the Maastricht area during the Danian. Bless accepted Deroo's (1966) age determination (*i.e.* Late Danian) for the Geulhem Member; from the other contributions in this issue, however, it has become clear that this will have to be adjusted: strata of Early and Middle Danian age are present as well.

From a preliminary study of several samples taken in the sections along the Albert Canal it is concluded that brachiopods may be stratigraphically important as well. A thorough systematic framework is needed before a detailed picture of their ranges and palaeoecologic significance can be presented (see *e.g.* Asgaard, 1968).

A multidisciplinary study of the faunas and flora of the Geulhem Member should absolutely include an analysis of the dinoflagellate content of this unit, since these fossils have proved to be extremely valuable tools in extra-regional correlations. Dinoflagellate cysts have received much attention over the past few years, especially in the study of K-T boundary sequences over the entire world (see *e.g.* Askin, 1987; Brinkhuis & Leereveld, 1988; Heilmann-Clausen, 1985; Hultberg, 1986, 1987). The dinoflagellate zonation for the Danian is constantly refined and it would be very interesting to know how the Danian deposits in the Maastricht area fit in this zonation. The same holds for palynomorph assemblages.

Another group of microfossils that has been extensively dealt with by palaeontologists over the last decade are the planktonic foraminifers (see *e.g.* D'Hondt & Keller, 1987; Kuhn & Weidich, 1987; Spiegler *et al.*, 1988). Zonations by means of these fossils have been proposed for a number of key K-T boundary sections, for instance, for El Haria (Tunisia) (see Brinkhuis & Zachariasse, 1988). These authors described the so far most detailed picture of Early Danian planktonic foraminiferal assemblages and zonation. They introduced an up-dated zonation and referred key index taxa to other genera. An interesting point these authors raised concerns the development of the earliest Danian planktonic foraminifers: they suggested that benthic species of the genus *Caucasina* Khalilov, 1951 gave rise to *Parvularugoglobigerina fringa* (Subbotina, 1953) and *G. minutula* Luterbacher &

Table 1. Chrono- and lithostratigraphy and ranges of index fossils in the Geulhem Member of the Houthem Formation in the Maastricht area. Data are partly of a preliminary nature and are taken from:

- 1 - W.M. Felder (1975), Kuyl (1980);
- 2 - Meijer (1959), Čepek & Moorkens (1979), Cavelier & Pomerol (1986);
- 3 - Hofker (1966), Doppert & Neele (1983), Letsch & Sissingh (1983);
- 4 - Čepek & Moorkens (1979), Vangerow & Schloemer (1967), Verbeek (1986);
- 5 - Deroo (1966);
- 6 - Meijer (1965), van der Ham (1988), Jagt (unpubl.);
- 7 - Jagt & Collins (1988), Jagt (1986).

LATE MAASTRICHTIAN (PARS)	DANIAN mid-EARLY (?) to LATE	OLIGOCENE LATDORFIAN	STRATIGRAPHY CHRONO-
MAASTRICHT Fm MEERSSEN Mbr	HOUTHEM FORMATION GEULHEM MEMBER	TONGEREN Fm KLIMMEN Mbr	LITHO- 1)
<i>Heterohelix striata</i> <i>Guembeliria cretacea</i> <i>Biglobigerinella biforaminate</i> 'dwarfed <i>Globotruncana</i> / <i>Rugoglobigerina</i> assemblage'	<i>Globoconusa daubjergensis</i> <i>Subbotina pseudobulloides</i> Globoconusa daubjergensis Zone Subbotina pseudobulloides Zone (P 1 b)		PLANKTONIC FORAMINIFERS 2)
Foram Zone M (- N ?)	Foram Zone P Anomalinoidea danica Zone (FT 1) (<i>Globoconusa daubjergensis</i> FT 1a + <i>Bulimina trigonalis</i> FT 1b) FK Zone (pars) (<i>Pararotalia globigeriniformis</i> - <i>Rotalia saxorum</i>)		BENTHIC FORAMINIFERS 3)
'post- <i>Nephrolithus frequens</i> Interval'	<i>Markalius inversus</i> --- NP 3 <i>Cruciplacolithus tenuis</i> <i>Braarudosphaera bigelowi</i> , <i>B. discula</i> NP 1 <i>Biantholithus sparsus</i> Zone		CALCAREOUS NANNOPLANKTON 4)
4ème faunizone (pars) (zone à <i>Globobesleria roemeriana</i> , <i>Limburgina ornata</i> et <i>Mosaelesleria interrupta</i>)	5ème faunizone (couches à <i>Cytherelloidea</i>) <i>Alatacythere heerlenensis</i> <i>Curfsina geleensis</i> <i>Ruggieria pustulosa</i>		OSTRACODS 5)
<i>Hemipneustes drunella</i> <i>Faujasia apicalis</i> <i>Hemipneustes striatoradiatus</i>	<i>Metopaster spenceri</i> <i>M. kagstrupensis</i> Astropectinidae <i>Bourgueticrinus danicus</i> <i>Democrinus maximus</i> <i>Tylocidaris hardouini</i> <i>T. bruennichi</i>		ECHINODERMS 6)
<i>Hoploscaphites constrictus</i> <i>Belemnella (Neoblemnella) casimirovensis</i> <i>Tenuipteria argentea</i> <i>Belemnella gr. junior</i>	 <i>Pycnolepas bruennichi</i> <i>Danocrania geulhemensis</i> <i>Ditrupe schlotheimi</i>		OTHER MACROFOSSILS 7)

Premoli-Silva, 1964. The same authors presented a refined dinoflagellate zonation with the *Danea californica* Zone (= *D. mutabilis* Zone *sensu* J.M. Hansen, 1977; see also Hultberg, 1986), the lower limit of which (= entry of *Danea californica* Drugg, 1970 *emend.* Damassa, 1979) defines the base of the Danian.

From P.J. Felder's (1988, in this issue) contribution it is clear that there are no obvious changes in lithology, bioclast assemblages and gamma radiation across the K-T boundary in the former Curfs quarry. Over a larger area, however, lithologically differing sections which are characterized by particular bioclast assemblages, will prove to be difficult to correlate. For such purposes we obviously will have to rely on data obtained by the study of the various planktonic organisms.

CONCLUSION

From the above discussion it is obvious that the K-T boundary and the zonation of the Early Palaeocene (Danian) by means of high resolution fossil groups such as calcareous nannoplankton, dinoflagellate cysts and planktonic foraminifers, as well as on the basis of other methods, still arouses considerable interest among stratigraphers and palaeontologists (see *e.g.* Birkelund & Perch-Nielsen, 1980; Carpenter *et al.*, 1987; Elliot *et al.*, 1987; Hansen *et al.*, 1987; Jiang & Gartner, 1986; Keller, 1987; Lamolda, 1988; Lerbekmo *et al.*, 1987; Lindinger & Keller, 1987; Naidin, 1987; Russell, 1979; Sheehan & Hansen, 1986; Ward *et al.*, 1986; Wolbach *et al.*, 1988 and Zinsmeister *et al.*, 1987).

In this respect, it is certainly regrettable that no such detailed studies have yet been carried out in the Danian of the Maastricht area. It is to be hoped that in the near future as many aspects of sedimentology, biostratigraphy and biota as possible will receive the deserved interest in a multidisciplinary approach, with the sacred purpose to eventually elucidate the precise interrelationships of the various contemporaneous deposits in NW Europe and beyond. Such a diligent project is herewith recommended to, *e.g.* the Regional Committee of Northern Palaeogene Stratigraphy, or other bodies concerned.

Furthermore and finally, it is advised here, following Hofker (1955), to designate the section exposed in the former Curfs quarry at Geulhem (being the stratotype of the Geulhem Member) a reference section for the K-T boundary sequence in the environs of Maastricht. Attention should than be paid to this section by the 'Werkgroep Gea' of the Rijksinstituut voor Natuurbeheer, and other government bodies responsible for nature conservation that could manage and preserve such a site for future generations, as is the case for a number of other localities in The Netherlands (see *e.g.* Gonggrijp, 1986; Gonggrijp & Felder, 1988).

REFERENCES

- Askin, R.A., 1987. The Cretaceous/Tertiary boundary in Antarctica as defined by marine dinoflagellate cysts.—*Geol. Soc. Am., Abstr., Progr.*, 19: 575.
- Asgaard, U., 1968. Brachiopod palaeoecology in Middle Danian limestones at Fakse, Denmark.—*Lethaia*, 1(2): 103-121, 7 figs, 1 tab.
- Binkhorst van den Binkhorst, J.T., 1859. Esquisse géologique et paléontologique des couches crétacées du Limbourg, et plus spécialement de la craie tuffeau, avec carte géologique, coupes, plan horizontal des carrières de St.-Pierre, etc. Maastricht (van Osch-America et Cie.), xviii + 268 pp., 5 pls, 1 map.

- Binkhorst van den Binkhorst, J.T., 1860. Sur la craie de Maestricht et sur les fossiles de cette localite.—Bull. Soc. géol. France, (2)17: 61-66.
- Binkhorst van den Binkhorst, J.T., 1863. (Course à Geulhem et à Fauquemont, le 2 septembre 1863).—Bull. Soc. géol. France, (2)20: 804-811.
- Birkelund, T., & K. Perch-Nielsen, 1980. Cretaceous-Tertiary boundary events.—*Episodes*, 1980 (2): 35-36, 1 fig.
- Bless, M.J.M., 1988. Possible causes for the change in ostracod assemblages at the Maastrichtian-Palaeocene boundary in southern Limburg, The Netherlands.—*Meded. Werkgr. Tert. Kwart. Geol.*, 25(2-3): 197-211, 6 figs, 1 tab. (this volume).
- Brinkhuis, H., & H. Leereveld, 1988. Dinoflagellate cysts from the Cretaceous/Tertiary boundary sequence of El Kef, northwest Tunisia.—*Rev. Palaeobot. Palynol.*, 56(1-2): 5- 19, 5 figs, 2 pls.
- Brinkhuis, H., & W.J. Zachariasse, 1988. Dinoflagellate cysts, sea level changes and planktonic foraminifers across the Cretaceous-Tertiary boundary at El Haria, northwest Tunisia.—*Mar. Micropaleont.*, 13(2): 153-191, 8 figs, 9 pls.
- Carpenter, M.A., S. D'Hondt, G. Keller, M. Lindinger, C.D. Perry & C. Ryan, 1987. Geochemical analyses (Ca, Cd, Ni, Mn, Sr) of benthic Foraminifera from the Cretaceous/Tertiary boundary, Brazos River, Texas and El Kef, Tunisia.—*Geol. Soc. Am., Abstr., Progr.*, 19: 611.
- Cavelier, C., & C. Pomerol, 1986. Stratigraphy of the Paleogene.—*Bull. Soc. géol. France*, (8)2(2): 255-265, 1 tab.
- Čepek, P., & T. Moorkens, 1979. Cretaceous/Tertiary boundary and Maastrichtian-Danian biostratigraphy (coccoliths and Foraminifera) in the Maastrichtian type area. *In*: W.K. Christensen & T. Birkelund (eds). Cretaceous-Tertiary boundary events symposium, 2. Proceedings. Copenhagen (Univ. Press): 137-142, 2 figs.
- Deroo, G., 1966. Cytheracea (ostracodes) du Maastrichtien de Maestricht (Pays-Bas) et des régions voisines; résultats stratigraphiques et paléontologiques de leur étude.—*Meded. Geol. Sticht.*, (C)V(2)2: 197 + 42 pp., 22 figs, 9 tabs, 27 pls.
- D'Hondt, S., & G. Keller, 1987. Patterns of evolution in some earliest Paleocene lineages of planktic Foraminifera.—*Geol. Soc. Am., Abstr., Progr.*, 19: 639.
- Doppert, J.W.C., & N.G. Neele, 1983. Biostratigraphy of marine Paleogene deposits in The Netherlands and adjacent areas.—*Meded. Rijks Geol. Dienst*, 37(2): 3-79, 5 figs, 32 pls, 1 encl.
- Elliot, D.H., C.E. Macellari & D.E. Rieske, 1987. The physical setting of the Cretaceous-Tertiary boundary on Seymour Island, Antarctic Peninsula.—*Geol. Soc. Am., Abstr., Progr.*, 19: 654.
- Felder, P.J., 1988. Maastrichtian-Early Tertiary strata in the SE Netherlands (Curfs quarry, Rur Valley Graben) and the Campine Mining District (NE Belgium): lithology, gamma radiation and bioclast assemblages.—*Meded. Werkgr. Tert. Kwart. Geol.*, 25(2-3): 115-125, 6 figs (this volume).
- Felder, W.M., 1973. Kalksteengroeven in het Boven-Krijt van Zuid Limburg. De groeve Curfs te Geulhem.—*Sprekende Bodem*, 17(3): 2-9, numerous figs.
- Felder, W.M., 1975. Lithostratigrafie van het Boven-Krijt en het Dano-Montien in Zuid-Limburg en het aangrenzende gebied. *In*: W.H. Zagwijn & C.J. van Staaldunen (eds). Toelichting bij geologische overzichtskaarten van Nederland. Haarlem (Rijks Geol. Dienst): 63-75, numerous figs.
- Gale, A.S., 1987. Goniasteridae (Asteroidea, Echinodermata) from the Late Cretaceous of north-west Europe, 2. The genera *Calliderma*, *Crateraster*, *Nymphaster* and *Chomataster*.—*Mesozoic Res.*, 1(4): 151-186, 6 figs, 7 pls.
- Gonggrijp, G., 1986. Het Gea-project: 'Geografisch- (en geologisch-) karakteristieke plekjes voor algeheele vernietiging en ondergang vrijwaren'.—*Grondboor en Hamer*, 40(5): 114-122, 8 figs,
- Gonggrijp, G.P., & W.M. Felder, 1988. Mergelland, een geologisch 'buitenmuseum'.—*Natuurhist. Maandbl.*, 77(7-8): 129-137, 14 figs.
- Hansen, J.M., 1977. Dinoflagellate stratigraphy and echinoid distribution in Upper Maastrichtian and Danian deposits from Denmark.—*Bull. geol. Soc. Denmark*, 26(1-2): 1-26, 22 figs.
- Hansen, T., R.B. Farrand, H.A. Montgomery, H.G. Billm & G. Blechschmidt, 1987. Sedimentology and extinction patterns across the Cretaceous-Tertiary boundary interval in East Texas.—*Cret. Res.*, 8: 229-252, 10 figs, 2 tabs.
- Ham. R.W.J.M. van der, 1988. Echinoids from the Early Palaeocene (Danian) of the Maestricht area (NE Belgium, SE Netherlands): preliminary results.—*Meded. Werkgr. Tert. Kwart. Geol.*, 25(2-3): 127-161, 1 fig., 1 tab., 9 pls.

- Heilmann-Clausen, C., 1985. Dinoflagellate stratigraphy of the uppermost Danian to Ypresian in the Viborg 1 borehole, central Jylland, Denmark.—*Danm. geol. Unders.*, (A)7: 1-69, 13 figs, 15 pls, 1 range chart.
- Hofker, J., 1955. Ontdekking van een nog niet bekende geologische formatie in Zuid-Limburg.—*Natuurhist. Maandbl.*, 44(7-8): 78.
- Hofker, J., 1956. Het Onder-Paleoceen van Zuid-Limburg.—*Natuurhist. Maandbl.*, 45(11-12): 132-133.
- Hofker, J., 1957. Een nieuwe laag in het bovenste Krijt van Zuid-Limburg.—*Natuurhist. Maandbl.*, 46(9-10): 121-123, 2 figs.
- Hofker, J., 1966. Maestrichtian, Danian and Paleocene Foraminifera.—*Palaeontographica*, suppl. (A)10: 376 pp., 178 figs, 69 tabs, 86 pls.
- Hultberg, S.U., 1986. Danian dinoflagellate zonation, the C-T boundary and the stratigraphical position of the fish clay in southern Scandinavia.—*J. Micropalaeont.*, 5(1): 37-47, 8 figs, 2 pls.
- Hultberg, S.U., 1987. Palynological evidence for a diachronous low-salinity event in the C-T boundary clay at Stevns Klint, Denmark.—*J. Micropalaeont.*, 6(2): 35-40, 4 figs.
- Jaarverslag van de Rijks Geologische Dienst 1987. Haarlem (Rijks Geol. Dienst): 103 pp., 21 figs, 4 tabs.
- Jagt, J.W.M., 1986. *Sphenodiscus binckhorsti* J. Böhm 1898 (Ammonoidea) in de Kalksteen van Nekum en de biostratigrafie van de Formatie van Maastricht.—*Grondboor en Hamer*, 40(1): 1-17, 12 figs.
- Jagt, J.W.M., & J.S.H. Collins, 1988. The biostratigraphy of the Geulhem Member (Early Palaeocene), with reference to the occurrence of *Pycnolepas bruennichi* Withers, 1914 (Crustacea, Cirripedia).—*Meded. Werkgr. Tert. Kwart. Geol.*, 25(2-3): 175-196, 2 figs, 1 pl. (this volume).
- Jagt, J.W.M., & A.W. Janssen, 1988. *Jouannetia* (Bivalvia, Pholadidae) and *Neritopsis* (Gastropoda, Neritopsidae), two molluscs from the Danian (Palaeocene) of the Maastricht area (SE Netherlands and NE Belgium).—*Meded. Werkgr. Tert. Kwart. Geol.*, 25(2-3): 163-174, 2 pls (this volume).
- Jiang, M.J., & S. Gartner, 1986. Calcareous nannofossil succession across the Cretaceous/Tertiary boundary in east-central Texas.—*Micropalaeont.*, 32(3): 232-255, 6 figs, 1 pl.
- Keller, G., 1987. Prolonged biotic stress and species survivorship across the Cretaceous-Tertiary boundary.—*Geol. Soc. Am., Abstr., Progr.*, 19: 724.
- Kuhn, W., & K.F. Weidich, 1987. Neue mikropaläontologische Ergebnisse aus dem Paleozän des Haunsberg-Helvetikums (Salzburg, Österreich).—*Paläont. Z.*, 61(3-4): 181-201, 7 figs, 2 tabs.
- Kuyl, O.S., 1980 (ed.). Toelichting bij de geologische kaart van Nederland 1 : 50.000. Heerlen (62W oostelijke helft, 62O westelijke helft). Haarlem (Rijks Geol. Dienst): 206 pp., 75 figs, 7 appendices, 8 maps, 38 photos.
- Lamolda, M.A., 1988. Paleontology and evolution: extinction events.—*Episodes*, 11(2): 142-143, 1 fig.
- Lerbekmo, J.F., A.R. Sweet & R.M. St. Louis, 1987. The relationship between the iridium anomaly and palynological floral events at three Cretaceous-Tertiary boundary localities in western Canada.—*Bull. geol. Soc. Am.*, 99: 325-330, 4 figs.
- Letsch, W.J., & W. Sissingh, 1983. Tertiary stratigraphy of The Netherlands.—*Geol. Mijnbouw*, 62: 305-318, 16 figs.
- Lindinger, M., & G. Keller, 1987. Stable isotope stratigraphy across the Cretaceous/Tertiary boundary in Tunisia: evidence for a multiple extinction mechanism?—*Geol. Soc. Am., Abstr., Progr.*, 19: 747.
- Meijer, M., 1959. Sur la limite supérieure de l'étage Maestrichtien dans la région-type.—*Bull. Acad. roy. Belg., Sci.* (5)45: 316-338, 7 figs.
- Meijer, M., 1965. The stratigraphical distribution of echinoids in the Chalk and Tuffaceous Chalk in the neighbourhood of Maastricht (Netherlands).—*Meded. geol. Sticht.*, (n.s.) 17: 21-25, 1 fig.
- Naidin, D.P., 1987. The Cretaceous-Tertiary boundary in Mangyshlak, U.S.S.R.—*Geol. Mag.*, 124(1): 13-19, 4 figs.
- Rasmussen, H. Wienberg, 1964. Les affinités du Tuffeau de Cibly en Belgique et du Post-Maestrichtien Me des Pays-Bas avec le Danien. *In*: Colloque sur le Paléogène, Bordeaux, Septembre 1962, 2.—*Mém. Bur. Rech. Géol. Min.*, 28: 865- 873, 2 tabs.
- Rasmussen, H. Wienberg, 1965. The Danian affinities of the Tuffeau de Cibly in Belgium and the 'Post-Maastrichtian' in The Netherlands.—*Meded. geol. Sticht.*, (n.s.)21: 33-40, 2 tabs, 2 pls.
- Russell, D.A., 1979. The Cretaceous-Tertiary boundary problem.—*Episodes*, 1979(4): 21-24, 4 figs, 1 tab.
- Sheehan, P.M., & T.A. Hansen, 1986. Detritus feeding as a buffer to extinction at the end of the Cretaceous.—*Geology*, 14: 868-870, 1 fig.

- Spiegler, D., F. Gramann & C.H. von Daniels, 1988. Planktonic Foraminifera. The description of the inter-regional zonation (NPF zones). *In*: R. Vinken *et al.* (eds). The Northwest European Tertiary Basin. Results of the International Geological Correlation Programme Project no. 124.—*Geol. Jb.*, (A) 100: 152-160, fig. 80.
- Triger, J., 1860. (Une lettre relative à une communication faite dans la séance précédente par M. Binkhorst, sur la craie de Maestricht).—*Bull. Soc. géol. France*, (2)17: 103-107.
- Ubaghs, C., 1879. Description géologique et paléontologique du sol du Limbourg avec catalogue général des fossiles du terrain crétacé, coupe de la superposition des couches, et description de quelques grands vertébrés de la craie supérieure de Maastricht. Roermond (Romen & Fils), 275 + ii pp., 2 tabs, 7 pls.
- Uhlenbroek, G.D., 1912. Het Krijt van Zuid-Limburg. Toelichting bij eene geologische kaart van het Krijtgebied van Zuid-Limburg.—*Jaarversl. Rijksopsp. Delfst.* 1911: 48-57.
- Vangerow, E.F., & W. Schloemer, 1967. Vergleich des 'Vetschauer-Kalkes' der Aachener Kreide mit dem Kreide-Profil von Süd-Limburg anhand von Coccolithen.—*Geol. Mijnbouw*, 46: 453-458, 8 figs, 1 tab.
- Verbeek, J.W., 1986. Calcareous nannoplankton at the Cretaceous-Tertiary boundary in the region near Maastricht in the Province of Limburg (The Netherlands).—*Proceed. Koninkl. Akad. Wetensch.*, (B)89(4): 357-365, 3 figs.
- Ward, P., J. Wiedmann & J.F. Mount, 1986. Maastrichtian molluscan biostratigraphy and extinction patterns in a Cretaceous/Tertiary boundary section exposed at Zumaya, Spain.—*Geology*, 14: 899-903, 4 figs.
- Wolbach, W.S., I. Gilmour, E. Anders, C.J. Orth & R.R. Brooks, 1988. Global fire at the Cretaceous-Tertiary boundary.—*Nature*, 334(6184): 665-669, 4 figs, 1 tab.
- Zinsmeister, W.J., R.M. Feldmann, M.O. Woodburne, M.A. Kooser, R.A. Askin & D.E. Elliot, 1987. Faunal transitions across the K/T boundary in Antarctica.—*Geol. Soc. Am., Abstr., Progr.*, 19: 906.

Manuscript received 19 September 1988