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THE POSITION OF THE MONTIAN STAGE AND RELATED FACIES WITHIN THE STRATIGRAPHIC-PALAEOGEOGRAPHIC FRAMEWORK OF NW EUROPE DURING THE DANIAN

GÉRARD BIGNOT
Université Pierre et Marie Curie
Paris, France

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A revision of the status of the Danian and Montian Stages based on available biostratigraphic data for their stratotypes, shows that the Montian is the age-equivalent of part of the Danian and should consequently not appear on the standard global stratigraphic chart. The Early Palaeocene of the Paris Basin is characterised by two diachronous units, viz. the Mont Aimé-Vertus Formation of Early Danian age, and outcrops exposing the 'Calcaire pisolithique', at *e.g.* Vigny, Laversines, Meudon, which are coeval with the stratotypical Montian, and of Middle Danian age. Two successive Danian transgressions are distinguished in the Paris Basin. The biohermal and bioclastic sediments were deposited in marine environments of shallow (a few metres, 30 m at the most) and warm (+18 to +20°C for the coolest month) water and distributed along the pattern of a carbonate ramp.

Key words — Palaeocene, Danian, Montian, North Sea Basin, Paris Basin, Channel area, bioherms, carbonate ramp.

Dr G. Bignot, Université Pierre et Marie Curie, U.F.R. Sciences de la Terre, Département de Géologie sédimentaire, Laboratoire de Micropaléontologie, 4 place Jussieu, T 15-25, E 4, F-75252 Paris Cedex 05, France.

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INTRODUCTION

The stratigraphy of the Montian (or Dano-Montian) deposits of the Paris Basin has been the subject of controversial interpretations for more than a century and a half now. In general, differences of opinion were kept in existence mainly by the poor knowledge of the Danian and Montian stratotypes and of the exact relationship between these stages. Recent comprehensive studies of their microfaunas have provided answers to many questions, but not to all. This may be explained as follows:

- there is variation in the number of planktonic microfossils present in the stratotypes, this number being very low in the Montian, but higher in the Danian, in which stage, however, several marker species are missing;
- occasionally taxa are incompletely identified or even misidentified, which is inevitable in view of the generally poor state of preservation, and of their occasional atypical morphology.

The poor quality of some reference data and their contradictory nature may explain the difficulties one experiences when drawing up synthetic charts. Several attempts however have been made during recent years (Curry *et al.*, 1978; Kockel, 1980; Aubry, 1985; Bignot, 1987; Gallagher, 1990), but none of these is entirely satisfactory.

BIOSTRATIGRAPHY OF THE DANIAN STRATOTYPE

The Danian Stage, first proposed by Desor (1847) at Fakse quarry and at Stevns Klint (Sjaelland, Den-

mark), as well as at Laversines and Vigny (France), a fact which often seems to be forgotten, has been thoroughly studied in the stratotype, the Danian limestone, and in its lateral extension, the Ekofisk Formation (North Sea area).

The position of the Danian in the standard biozonations (Fig. 1) is as follows:

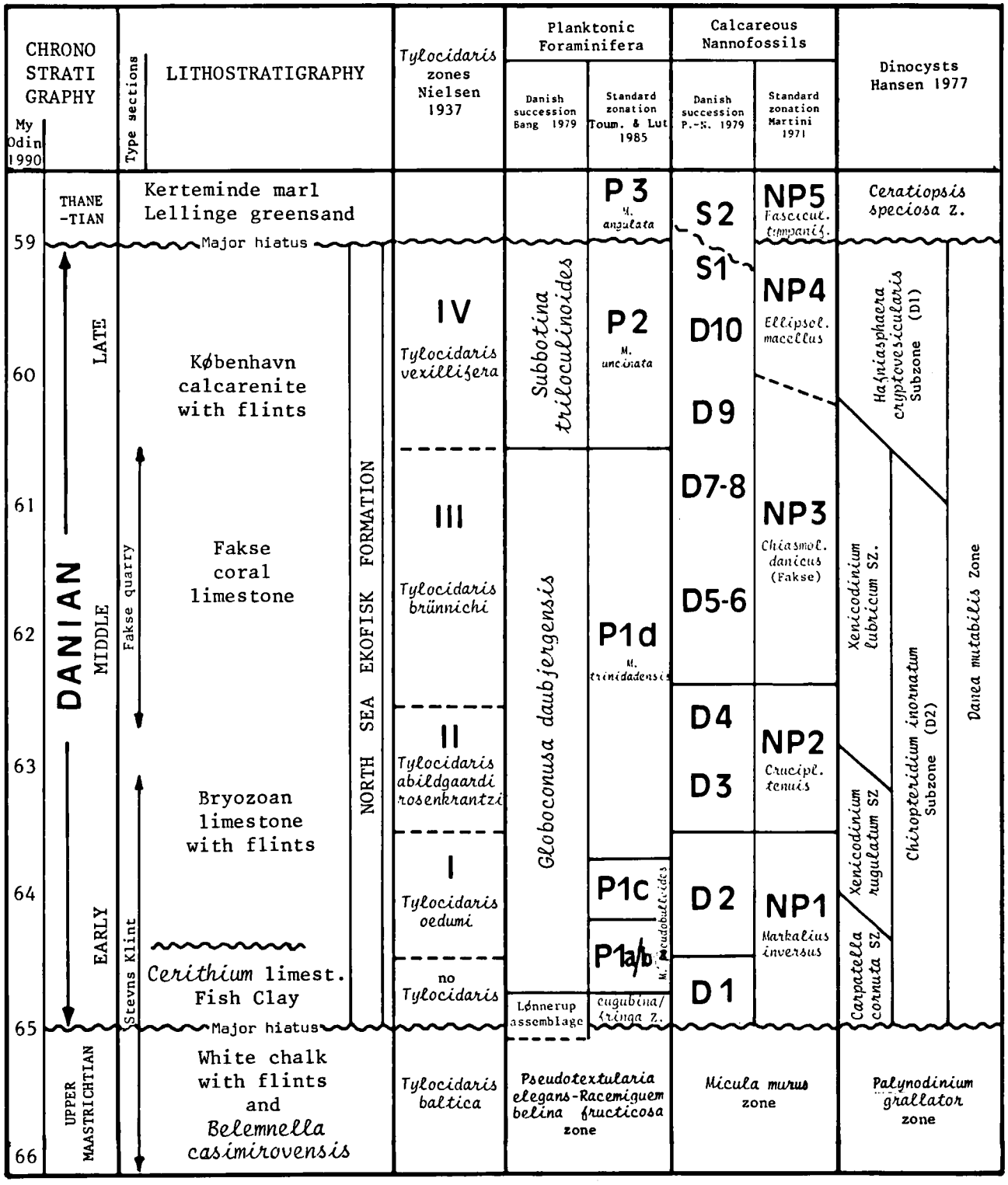

Fig. 1. Tentative correlation between lithostratigraphy and biozonations of the Danian Stage in its type area. This highly schematic representation shows the succession of biozones rather than their exact limits. Compiled from Bang (1974, 1978, 1980, 1990), Gallagher (1990), Hansen (1977), Heilmann-Clausen (1985), Hultberg (1986), Martini (1971), Perch-Nielsen (1979), Romein (1979), Surlyk (1980), Thomsen (1981), Thomsen & Heilmann-Clausen (1985), van Heck & Prins (1987) and including author's interpretations.

1 - planktonic Foraminifera: zones P1-P2. The successive first occurrences of *Globoconusa daubjergensis* (Brönnimann, 1953), *Morozovella compressa* (Plummer, 1926) and *M. trinidadensis* (Bolli, 1957), described in detail by Bang (1990), characterise the various subzones of zone P1. The first appearance of *M. uncinata* (Bolli, 1957) defines the base of zone P2.

2 - calcareous nannofossils: zones NP1-NP4. The presence of zones NP1, NP2 and NP3 has been established following the publication of Martini's (1971) paper. Zone NP4, indicated with a query by Perch-Nielsen (1979), was demonstrated to be present by Heilmann-Clausen (1985), and later by van Heck & Prins (1987). Thomsen & Heilmann-Clausen (1985) assumed that the top of the Danian reached the lower part of zone NP5.

3 - dinocysts: Danea mutabilis Zone (Hansen, 1977; Kjellström & Hansen, 1981), or the equivalent zone with *Danea californica* Drugg, 1970 (Hultberg, 1986).

The Danian as currently defined is situated between 65 and 59 Ma according to Odin (1990).
Fossils from beds underlying the Danian stratotype are indicative of the Late Maastrichtian: the zone of the coleoid cephalopod *Belemnella (Neobelemnella) casimirovensis* (Skolozdrówna, 1932) (see Schulz & Schmid, 1983), the planktonic foraminifer Pseudotextularia elegans-Racemiguembelina fructicosa Zone (Hultberg & Malmgren, 1987), the calcareous nannofossil Micula prinsii Zone (Perch-Nielsen, 1979), and the dinoflagellate Chiropteridium inornatum-Palynodinium grallator Concurrent Range Zone (Hansen, 1977, 1979), but in many areas the uppermost Maastrichtian is represented by a hiatus (Kjellström & Hansen, 1981; Hultberg & Malmgren, 1987; Mortimer, 1987).

Where it comprises the Lønnerup assemblage (= 'Globigerina' eugubina/fringa Zone), the Danian is complete at its base (Bang, 1979a, b, 1980). However, almost everywhere in the Danish Trough, in Denmark as well as in the North Sea, the stage starts with black shales or with a strongly disturbed argillaceous chalk yielding reworked material. These argillaceous levels are the result of resuspension and subsequent transportation of a previously deposited sediment, and coincide with halokinetic or tectonic instability along the margin of the trough (Kennedy, 1987; Hultberg, 1987; D'Heur, 1990).

The upper part of the Danian is cut by an erosion surface (probably submarine) situated in zones P2 and NP4, and capped by the transgressive Selandian deposits which are approximately age-equivalent at all localities. The time represented by the hiatus, underlined by the change in lithology, is about 1 Ma, but may be longer in the North Sea at the base of the Maureen Formation, the precise age of which is unknown.

Biostratigraphy of the Montian stratotype

Following Marlière (1954, 1957) the Montian stratotype or 'Calcaire grossier de Mons' (Dewalque, 1868) has been associated with related formations, especially the 'Tuffeau de Ciply', which yields rare planktonic microfossils. These rare occurrences allow to assign the Montian to the following biozones (Fig. 2):

a - planktonic Foraminifera: P1(c)d

Zone P1d is characterised by the co-occurrence of *Globoconusa daubjergensis*, *Morozovella pseudobulloides* (Plummer, 1926), *M. compressa* (Plummer, 1926) and *Subbotina triloculinoides* (Plummer, 1926) (see Moorkens, 1971). *Morozovella compressa* is absent from the lower part of the 'Tuffeau de Ciply' (Meijer, 1969). Should its late appearance be significant, then it determines the limit between zones P1c and P1d. Some authors have indicated that the top of the Montian stratotype is of zone P2 age, their arguments relying on the succession of *G. daubjergensis* by *G. kozlowskii* Brotzen & Pożaryska, 1961, a species unknown from the type Danian, but reported to co-occur in some Tethyan deposits with *Morozovella uncinata* (Hofker, 1976; Salaj *et al.*, 1976). Note that the distinction between these two subspecies (or ecomorphs ?) is exclusively based on size: < 185 µm = *G. daubjergensis*, > 185 µm = *G. kozlowskii* (Moorkens, 1982). It is doubtful if *G. kozlowskii* reaches beyond zone P1; the species was not retained in Toumarkine & Luterbacher's (1985) standard biozonation chart. As far as the occurrence of 4 or 5 specimens of *Globorotalia* aff. *varianta* (Subbotina, 1953) and of only a single individual of *Globorotalia* cf. *imitata* Subbotina, 1953 in the 'Calcaire d'Obourg' (Moorkens, 1982) is concerned, this appears to be stratigraphically insignificant in view of the range of these species (almost matching that of *Morozovella pseudobulloides*) and of their identification with a query. Whether or not zone P2 is present in the Montian stratotype cannot be determined with certainty.

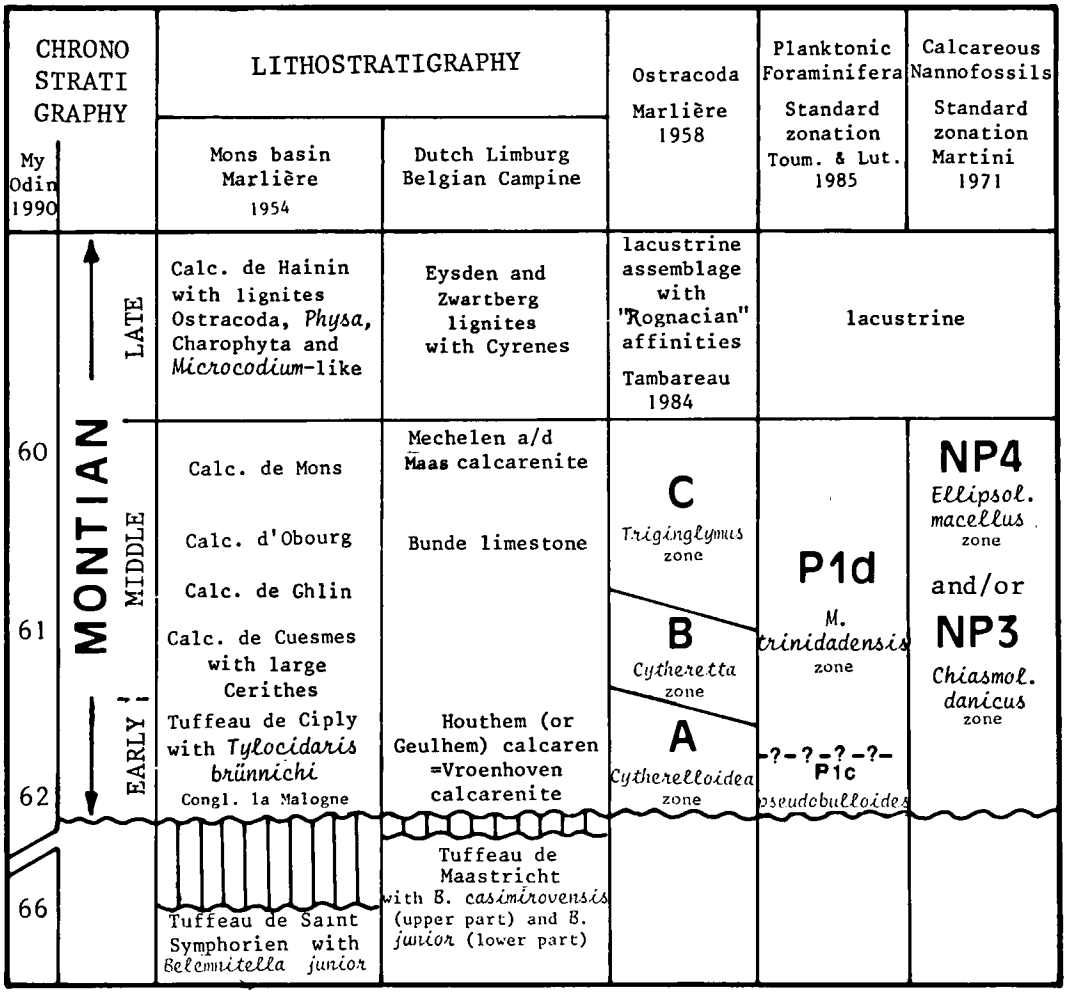

Fig. 2. Tentative correlation between lithostratigraphy and biozonations of the Montian in the type area. Compiled from Marlière (1954, 1957), Meijer (1969), Moorkens (1982), Robaszynski (1979), Robaszynski & Christensen (1989) and Vinken (1988).

b - calcareous nannofossils: NP3-lower NP4.

The occurrence of *Chiasmolithus danicus* (Brotzen, 1959) van Heck & Perch-Nielsen, 1987 in the 'Calcaire de Mons' (Mons Basin) and in the Geulhem Member of the Houthem Formation (Maastricht area) makes it impossible to refer the Montian to zones NP1 and NP2. In addition, the discovery of *Biantholithus* cf. *sparsus* Bramlette & Martini, 1964 in the Geulhem Member indicates that this unit should be assigned to zone NP3 and/or the lower part of zone NP4 (Čepek & Moorkens, 1979; Verbeek *et al.*, 1988).

c - dinocysts: Danea mutabilis Zone

Key index dinocyst species are rare and scattered (Wilson, 1971). It seems that the Montian stratotype can be approximately referred to the time interval between 62 and 60 Ma.

The sedimentary gap at the contact between the 'Poudingue de la Malogne' and the 'Tuffeau de Saint Symphorien' with the index coleoid cephalopod *Belemnitella junior* Nowak, 1913 is extensive, and might be of a magnitude of 3 my. Its extent is smaller in the Maastricht area (southern Limburg), where the Geulhem Member overlies the Meerssen Member (Maastricht Formation, 'Tuffeau de Maestricht') with *Belemnella casimirovensis*.

Towards the top, the Montian progressively becomes more lacustrine in nature. The Hainin Formation yields ostracod faunas resembling those found in the Rognacian of the Provence (France; see Tambareau, 1984), and mammalian teeth similar to those from the 'Middle Palaeocene' of North America (Godfriaux & Thaler, 1974).

It is uncertain whether the 'Calcaire de Mons' and the 'Tuffeau de Ciply' are either coeval lateral equivalents or whether they are superimposed as

has been suggested on the basis of an analysis of the distribution of ostracods (Marlière, 1957, 1958; Godfriaux & Marlière, 1971) and foraminifers (Moorkens, 1982). However, this is a problem of regional interest only, since both units are roughly time-equivalent.

The above analysis shows that the type Montian is in part correlatable with the Danian, and, more precisely, corresponds with its middle part. The assumption that the 'Calcaire de Mons' would be stratigraphically younger than the type Danian, and that the Montian would represent an intermediate stage between the Danian and the Thanetian is no longer valid. The Montian has no place on the chronostratigraphic scale; however, the term may be preserved as an adjective indicating the coralgal or bioclastic facies of Middle Danian age in the shallow seas of the Paris Basin, the Mons Basin and elsewhere (Gruas *et al.*, 1992). The term 'Dano-Montian' should be rejected.

Paris Basin: Montian facies and Mont Aimé-Vertus Formation

In the Paris Basin, the Montian deposits (erroneously named 'Calcaire pisolithique' in the past) do not yield any planktonic microfossils, which is the reason why correlations with other formations are approximate at best.

The assemblages of benthic Foraminifera and ostracods of the Montian strata of the Paris Basin are very similar to those of the Montian stratotype (Marie, 1937, 1947; Damotte & Feugueur, 1963; Damotte, 1964, 1973). There are a few differences, but these seem to be of an ecological rather than a chronological nature (Bignot, 1990b, 1992). The Montian strata of the Paris Basin — with the exception of those of the Mont Aimé and Vertus — are all of Middle Danian age (probably zones Pld and NP3).

At all localities, Montian strata rest on Late Cretaceous (Campanian) chalks with the coleoid cephalopod *Belemnitella mucronata* (von Schlottheim, 1813), a corroded and perforated hardground marking the contact. It has recently been suggested that this surface with its large sharp-edged depressions ('polje'-like) is probably of subaerial karstic origin (Bignot, 1990a).

Montian sedimentation ends with brackish or lacustrine marls ('Marnes de Meudon'), imperceptibly grading upwards into Thaneto-Sparnacian alterites with the enigmatic rock-destroyer *Microcodium elegans* Glück, 1912.

Similar to other Montian outcrops in the Paris Basin, those of the Mont Aimé-Vertus Formation have for a long time been considered to represent the 'Calcaire pisolithique'. However, these strata have a number of peculiarities which were first indicated by Soyer (1944): they occur in isolated patches, 50 km away from the nearest (eastern) Montian outcrops and consist of shelly limestones with varying percentages of quartz (mean 10-20%, but up to 50%), with abundant detritic terrigenous material, which occurs in limited amounts in or is absent from typical Montian facies.

In addition, palaeontological data stress the special position taken by the Mont Aimé and Vertus strata. Chavan (1948, p. 571), who studied the molluscan faunas, concluded that 'Les premiers dépôts témoignent de l'existence d'un Crétacé vraisemblablement plus élevé que celui de Meudon, en place ou remanié dans le Danien'. Later, Margerie *et al.* (1966, p. 1551) thought that the microfossils, foraminifers and ostracods, of the base of the Mont Aimé-Vertus Formation, were indicative of 'Un âge thanétien pour ce niveau ... avec remaniement de matériaux maestrichtiens.' A number of authors have accepted this formation to be younger than other Montian outcrops and to be of Thanetian (Guillevin, 1977) or 'late Dano-Montian' age (Villalard *et al.*, 1977; Mégnien & Wyns, 1980).

The micropalaeontological content of the Mont Aimé-Vertus Formation shows the following characteristic features:

- a lack of planktonic microfossils, with the exception of foraminifers and calcareous nannofossils that have been reworked from underlying chalks, and of dinocysts without stratigraphic value (Foucher, 1987);
- a lack of characteristic Thanetian foraminifers;
- a lack of a number of benthic foraminifer species characteristic of Montian facies [*e.g. Pararotalia globigeriniformis* (van Bellen, 1946), *Boldia vertebralis* (Marie, 1946) and *Scarificatina reinholdi* Marie, 1964];
- the occurrence of about twenty Palaeogene benthic foraminifer species [*Valvulina limbata* Terquem, 1882, *Reussella referata* (Jennings, 1936), *Uvigerinella europaea* (Cushman & Edwards, 1937), *Nonion graniferum* (Terquem, 1882), *N. thalmanni* van Bellen, 1946, *Pararotalia pontica* (Glaessner, 1937)] not known to occur before the Danian everywhere;
- the occurrence of incertae sedis [*Bonetocardiella maastrichtiensis* (Visser, 1951)] and of large benthic foraminifers [*Omphalocyclus macroporus* (Lamarck, 1816), *Hellenocyclina beotica* Reichel, 1949] which are

common in the Maastrichtian stratotype (Blanc & Guillevin, 1974);
- the occurrence of the foraminifers, *Laffitteina mengaudi* (Astre, 1923) [= *L. bibensis* Marie, 1945] and *Fallotia* cf. *colomi* (Silvestri, 1940) [= *Fascispira* cf. *dordonica* Ciry, 1967], which, in Europe and Africa, seem to disappear at the end of the Cretaceous (Blanc, 1975; Bignot, 1985); *L. mengaudi* has not been recorded from the Maastrichtian stratotype. In addition, the good state of preservation and the abundance of these faunas throughout the Mont Aimé-Vertus Formation do not permit to consider them as reworked fossils.

To reconcile all these data, an Early Danian age was proposed for the Mont Aimé-Vertus Formation by Bignot (1987), which implied that the genera *Laffitteina* Marie, 1945 and *Fallotia* Douvillé, 1902 crossed the K-T boundary. In the Middle East, additional species of *Laffitteina* have been recorded from the Palaeocene (Rahaghi, 1976); representatives of this genus are absent from all European localities exposing strata of Palaeocene age. The fragmented and abraded foraminifers recorded by Villain (1988) from the 'Tuffeau de Ciply' under the name *L.* cf. *mengaudi* are doubtful, and may have been reworked.

The Mont Aimé-Vertus Formation, which is slightly older than the Montian facies, represents the oldest Early Danian deposits in the Paris Basin, which are closest to the K-T boundary. However, an iridium peak has so far not been found (M. Renard, pers. comm.).

The Danian of the western Channel

Some chalks of Danian age, described by Curry, Hensey, Martini & Whittard (1965), Curry, Murray & Whittard (1965) and Curry, Hamilton and Smith (1970), are found in a large area of 120 x 50 km, between 49° and 49°40 N, and 3°30 and 5° W. The chalk series reaches a maximum thickness of 120 metres. From studies of planktonic foraminifers (Andreieff, Bouysse, Curry, Fletcher, Hamilton, Monciardini & Smith, 1975; Andreieff, Bouysse & Monciardini, 1975) it appears that two levels may be distinguished:
- a lower level, of zone P1 age;
- and an upper level, with a few '*Globorotalia* gr. *inconstans-praecursoria* (tendant vers *uncinata*)' (Andreieff, Bouysse & Monciardini, 1975, p. 6), which should be assigned to zone P2.

These chalks apparently rest conformably on Late Maastrichtian chalks (with the calcareous nannofossil *Micula murus* (Martini, 1961) Bukry, 1973); at the top they are cut by an erosion surface capped with Thanetian, Ypresian or, more frequently, Lutetian deposits.

These still poorly known beds are highly important palaeogeographically, since they show that at the time of their deposition the Paris Basin was an extension of the Atlantic Ocean as well as of the North Sea.

Danian palaeogeography of the Paris Basin

The palaeogeographic reconstructions (Fig. 3) of the Montian sea were speculative for a long time. A first attempt which took into account the peculiarities of the Mont Aimé-Vertus Formation was made by Pomerol (1982, p. 378, fig. 8), who showed two age-equivalent embayments. Another attempt (Bignot, 1987, p. 163, fig. 7) shows two successive marine advances. The first, of an Early Danian age, is limited to a narrow eastern gulf. The second, of Middle Danian (= Montian) age, is in line with the 'Norman Trough', extending towards the north, and merging with the Mons Basin and Maastricht area.

Kockel's (1988) map, which shows a connection between the Paris Basin and the North Sea and Danish-Polish Trough, presents a general and suggestive picture, but is incomplete in its western part where the submarine outcrops of the Channel as well as the Montian outcrops of the Mons Basin (!) are missing. Equally interesting is Curry's (1992, p. 394, fig. 13.2b) map which shows the location of possible source areas of Danian microfossils that have been found reworked in Thanetian deposits.

During the Middle Danian, the (Anglo)Paris-Belgian Basin is flooded by the Montian sea, which joins the North Sea through the Channel. This shallow sea (depth a few metres, 30 m at the most) permits zooxanthellate coralgal patch reefs to develop. In the Danish Trough the water depth (exceeding 100 m, and possibly between 200 and 300 m: see review in Bernecker & Weidlich, 1990) allows azooxanthellate bioherms to develop. Each of these bioherms is surrounded by a bioclastic ring, and calcarenites (= 'tuffeau') or chalks with flint. Near the shore, shales generated by the subaerial weathering of the Cretaceous chalks are deposited in lagoons and lakes. This picture agrees well with the pattern of a carbonate ramp (Bignot, 1992), the facies distribution of which is depicted in Fig. 4.

Except where they pass upwards into Sparnacian alterites (southern part of Paris Basin), the Montian

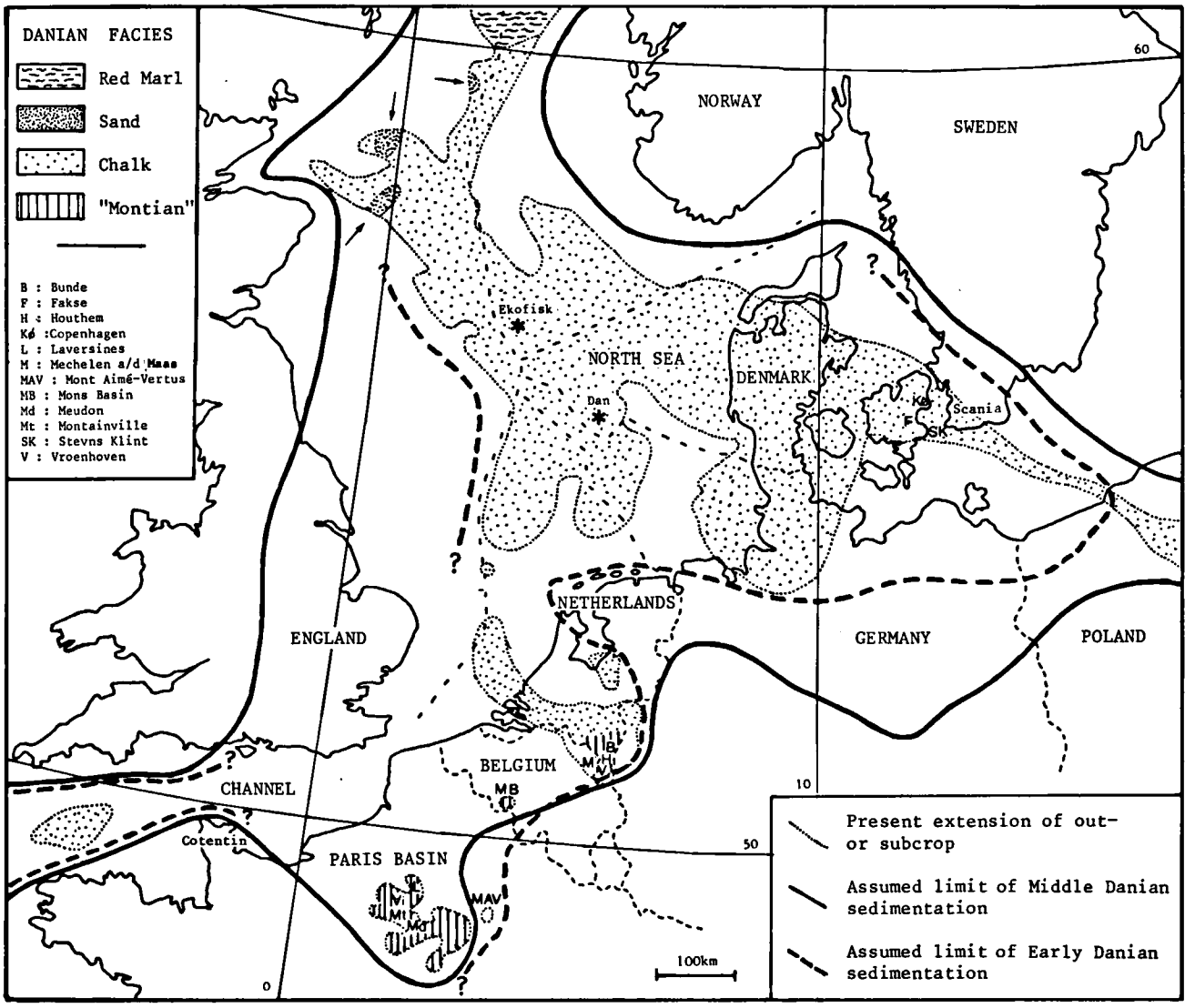

Fig. 3. Palaeogeography of NW Europe during the Danian Stage. Mostly according to Kockel (1988), with some additions.

strata are capped at the top by an erosion surface which was fossilised by overlying Thanetian transgressive sediments. There is an abrupt change in sedimentation: limestones are overlain by glauconitic, occasionally conglomeratic sands, which are proof of a general renewal of subaerial erosion. This erosion is connected with the Alpine uplift and/or the opening of the ocean between Europe and Greenland. Following a regression of unknown extent and magnitude, there was another transgression which abraded a peneplain. The Montian deposits were preserved only in structural (Mons Basin) or topographical traps ('poljes' of Laversines, Vigny and other localities).

Two palaeogeographic events took place prior to the Montian transgression:

- the end-Cretaceous regression: the sea retreated to a few areas with continued subsidence, *e.g.* North Sea and the western Channel;
- the temporary transgressive episode during which the Mont Aimé-Vertus Formation was laid down in mid- and supralittoral environments with a hypohaline trend.

It is not easy to delimit even approximately the extent of this Early Danian sea. It probably communicated with the Danish Trough towards the north and reached the foothills of the Ardennes which supplied terrigenous material. Towards the west and south, its extension is unknown. The nearest (Maastrichtian) occurrences of *Laffitteina* are in the Aquitaine area (Bignot, 1985, Fleury *et al.*, 1985)

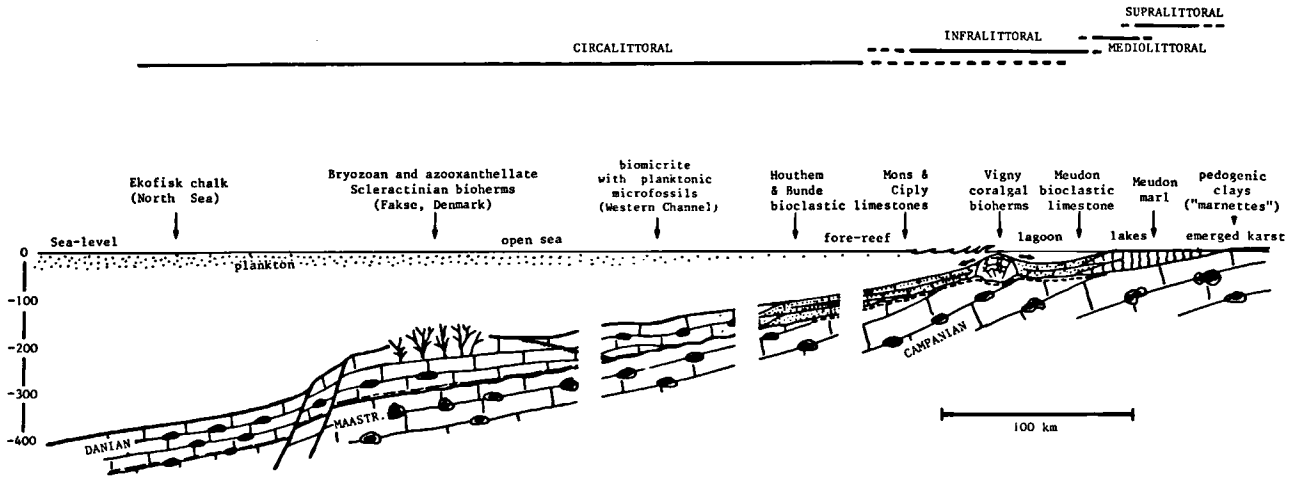

Fig. 4. Successive transgressions in the Paris Basin across the K-T boundary and possible correlation with the eustatic sea level curve of Haq *et al.* (1987). The two Danian transgressions follow the Maastrichtian transgressions, the older one, localised in the western and central Channel and in the Cotentin Peninsula, correlating with the lower part of the Maastricht Formation (type Maastrichtian, Mb), the younger one, covering the eastern part of the Paris Basin, is of latest Maastrichtian age (Meerssen Member of Maastricht Formation, type Maastrichtian, Md) and was eroded during a brief regressive episode at the K-T boundary; it has yielded specimens of the benthic foraminifer *Omphalocyclus macroporus* and other orbitoid foraminifers found reworked in the basal Mont Aimé-Vertus Formation.

and suggest that there may have been a marine communication between the east of the Paris Basin and the Atlantic Ocean during this time.

NW European Danian tropical climate

In spite of their low specific diversity, the zooxanthellate scleractinian faunas of Vigny and Montainville lived in warm waters: on average +18 to +20°C for the coolest month. The abundance of calcareous algae (*Archaeolithothamnium* Rothpletz, 1891, Udoteacea, and Dasycladaceae), of molluscs (the bivalve *Chama* Linné, 1758, and gastropods *Mitra* Lamarck, 1799 and large *Campanile* Bayle, 1884 and of benthic foraminifers with strongly calcified tests, furnishes additional proof of warm water temperatures in the Montian sea.

The climatic conditions were identical at Mons, where the same faunas are found, with the exception of reef-building scleractinians. Their absence is due to the influx of fresh waters (Villatte, 1977). A palynological analysis of the Hainin lacustrine strata has shown that, 'L'élément tempéré est dominé par les éléments chauds et même subtropicaux' (Roche, 1970, p. 114).

Further north, the faunal assemblages differ on account of the sea becoming deeper. According to Floris (1979), however, the azooxanthellate framebuilders of Fakse developed in a subtropical sea with temperatures at the sea floor probably of about +18°C. The planktonic faunas differ slightly from those of lower latitudes. Perch-Nielsen (1979) mentioned the rarity of the calcareous nannofossil *Ellipsolithus macellus* (Bramlette & Sullivan, 1964) Sullivan, 1964. Amongst the foraminifers, a few tropical ecomorphs are absent (*Globoconusa kozlowskii*), while others such as *Globoconusa gigantea* (Bang, 1969) and *Morozovella danica* (Bang, 1971) are restricted to Denmark and the North Sea. These peculiarities could be an indication of the immediate vicinity of the boundary between the tropical and temperate realms.

The conclusions for the Middle Danian agree with what is known in the same areas of the climatic conditions across the K-T boundary. During the Late Cretaceous, Tethyan affinities are evident (Bless *et al.*, 1987), and larger foraminifers characteristic of tropical environments are known very far north: in southern Sweden during the Campanian (van Gorsel, 1973), and in northern Germany during the Maastrichtian (Hagn & Voigt, 1986). Molluscan faunas and several finds of calcareous algae have induced previous authors (Farchad, 1936) to assume that Thanetian sands were tropical deposits. These assumptions have recently been proved correct by the discovery of nummulitid foraminifers on the Rockall Plateau, at a present-day latitude of 57°20 N (van Hinte & Wong, 1975).

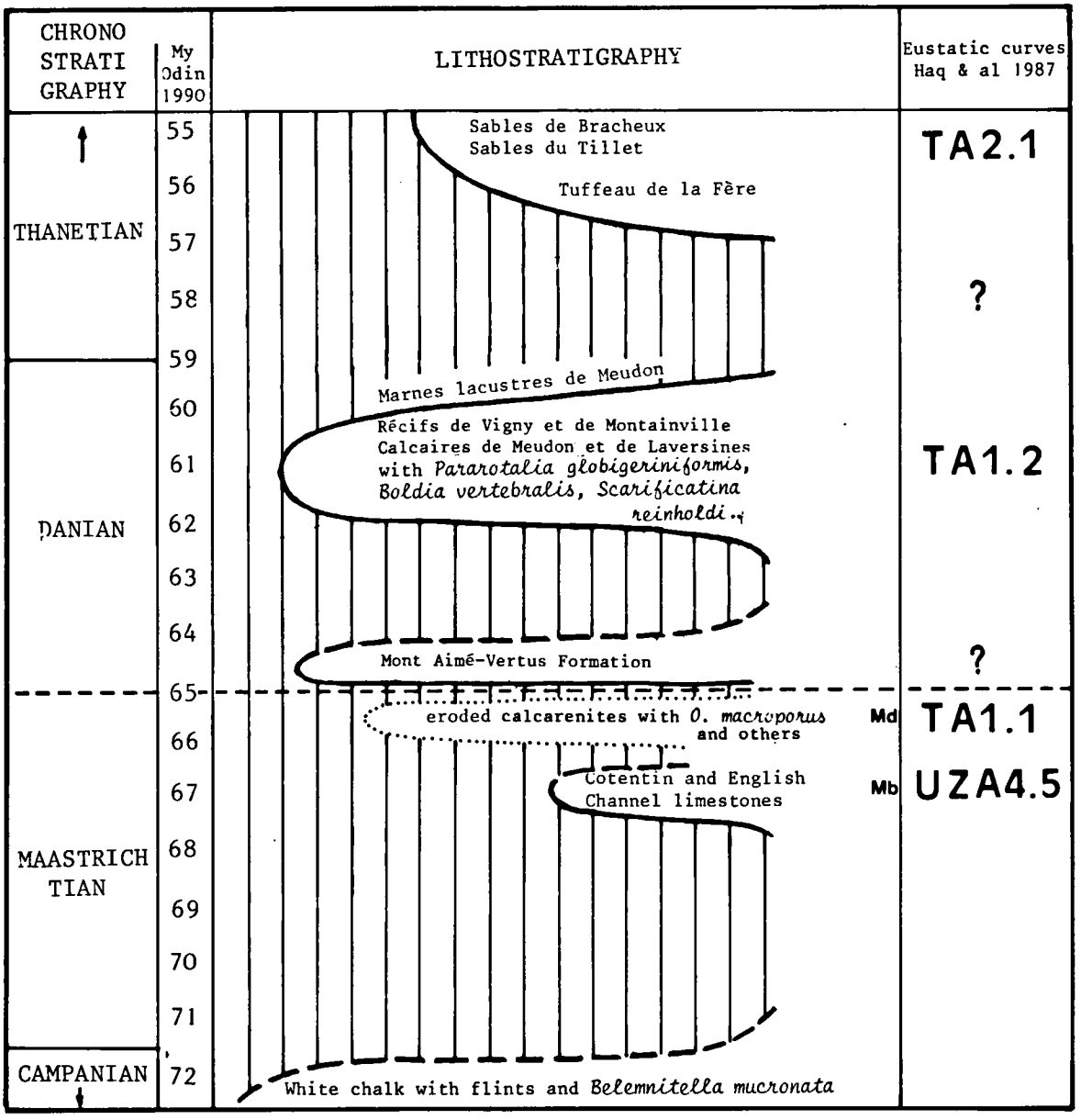

Fig. 5. Relative position of a number of Danian formations in NW Europe in the context of a carbonate ramp, modified from Bignot (1992).

The northward migration of the European continent since the later Palaeocene is about 10°. The northern limit of the tropical climatic belt is estimated to have been at 45 to 48°N (at present at 25°N) during the Late Cretaceous and the Palaeogene.

However, variations of $\delta^{18}O$ indicate a drop of the mean temperature of the sea water of 4 to 8°C across the K-T boundary. This drop is thought to have been very rapid (within a few hundreds of thousands of years) and corresponds with the iridium peak at Stevns Klint (Buchardt & Jørgensen, 1979; Kaminski & Malmgren, 1989). It is not well documented by palynological evidence. The dinocyst assemblages of the Fiskeler (Fish Clay) appear to differ only slightly from those of the latest Maastrichtian (Kjellström & Hansen, 1981). Additional studies of the spores and pollen of this unit are necessary before the palaeoclimatic events at the K-T boundary can be fully understood (Kedves, 1979-1980, and *in litt.*).

Conclusions

The geological history of NW Europe (Fig. 5) across the K-T boundary is very complex and difficult to reconstruct. In the Paris Basin, the very few outcrops that remain today reflect unstable palaeogeographies, with strong weathering of the continental areas that were either drowned or uncovered by low-scale oscillations of sea level.

The succession of transgressions outlined above does not agree well with the global relative changes in eustatic sea level (Haq *et al.*, 1987). The Montian transgression can be compared with cycle TA 1.2, but what about the Mont Aimé-Vertus transgression ?

Danian palaeogeography follows the same pattern as the Cretaceous, which corresponds to the geometry of a neritic ramp with chalky pelagic sedimentation. It is structured in large-scale mounds (Juignet & Kennedy, 1974; Thomsen, 1976; Quine & Bosence, 1991) covering the entire platform to the proximity of the littoral zone. The peculiar chalky sedimentation is very different from actualistic examples. It could in part be linked to the persistence of emerged surrounding continents submitted to a moderate and almost entirely chemical erosion (karst).

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References

Andreieff, P., P. Bouysse, D. Curry, B.N. Fletcher, D. Hamilton, C. Monciardini & A.J. Smith, 1975. The stratigraphy of post-Palaeozoic sequences in part of the Western Channel. — Phil. Trans. r. Soc. London, (A)279: 79-97.

Andreieff, P., P. Bouysse & C. Monciardini, 1975. Résultats stratigraphiques de la campagne Géomanche II (1972) en Manche occidentale. — Bull. Inf. Géol. Bass. Paris, 12(4): 3-13.

Aubry, M.-P., 1985. Northwestern European Paleogene magnetostratigraphy, biostratigraphy, and paleogeography: calcareous nannofossil evidence. — Geology, 13: 198-202.

Bang, I., 1974. Planktonic Foraminifera from the North Sea Basin (abstract). — Third Planktonic Conference, Kiel, 1974, Abstracts of Papers: 53.

Bang, I., 1978. Some comments on the planktonic foraminifera-zonation of the North Sea Danian. — Danm. geol. Unders., (3)44: 70-79.

Bang, I., 1979a. Foraminifera in the lowermost Danian of Denmark. *In*: T. Birkelund & R.G. Bromley (eds). Cretaceous-Tertiary boundary events symposium, 1. The Maastrichtian and Danian of Denmark. Copenhagen (University Press): 108-114, 2 pls.

Bang, I., 1979b. Foraminifera from the type section of the eugubina Zone and Cretaceous/Tertiary boundary localities in Jylland, Denmark. *In*: W.K. Christensen & T. Birkelund (eds). Cretaceous-Tertiary boundary events symposium, 2. Proceedings. Copenhagen (University Press): 127-130, 1 pl.

Bang, I. 1980. Foraminifera from the type section of the eugubina zone compared with those from Cretaceous/Tertiary boundary localities in Jylland, Denmark. — Danm. geol. Unders., Årbog 1979: 139-165, 10 pls.

Bang, I., 1990. Biostratigraphy of the North Sea Danian based on planktonic Foraminifera. — Tert. Res., 11(2-4): 191-193.

Bernecker, M., & O. Weidlich, 1990. The Danian (Paleocene) Coral Limestone of Fakse, Denmark: A Model for Ancient Aphotic, Azooxanthellate Coral Mounds. — Facies, 22: 103-138, pls 26-33.

Bignot, G., 1985. Sur la répartition géographique de quelques Foraminifères benthiques africains et européens du Crétacé terminal. — Géol. Médit., 11(2)(1984): 135-146.

Bignot, G., 1987. Les paléoenvironnements et les paléogéographies du Bassin de Paris au Danien, d'après les Foraminifères du Mont Aimé (Marne, France). — Rev. Micropaléont., 30(3): 150-176, pls 1-5.

Bignot, G., 1990a. Le contact du calcaire montien sur la craie campanienne à Meudon. Controverses anciennes. Perspectives nouvelles. — Bull. Inf. Géol. Bass. Paris, 27(4): 33-36.

Bignot, G., 1990b. La place du calcaire de Meudon dans la paléogéographie montienne du bassin de Paris. Approche micropaléontologique. — Bull. Inf. Géol. Bass. Paris, 27(4): 51-61.

Bignot, G., 1992. Une association de Foraminifères du récif montien de Vigny. Considérations sur la paléogéographie dano-montienne du Nord-Ouest européen. — Rev. Micropaléont., 35(3) [in press]

Blanc, P.L., 1975. Contribution à l'étude du genre Laffitteina, Elphidiidé du Crétacé terminal. — Rev. Micropaléont., 18(2): 61-68.

Blanc, P.L., & Y. Guillevin, 1974. Nouvel indice de Maestrichtien dans l'Est du Bassin de Paris. — C.R. Acad. Sci. Paris, (D)279: 465-467.

Bless, M.J.M., P.J. Felder & J.P.M.T. Meessen, 1987. Late Cretaceous sea level rise and inversion: their influence on the depositional environment between Aachen and Antwerp. — Annls Soc. géol. Belg., 109(2)(1986): 333-355, 3 pls.

Buchardt, B., & N.O. Jørgensen, 1979. Stable isotope variations at the Cretaceous/Tertiary boundary in Denmark. *In*: W.K. Christensen & T. Birkelund (eds). Cretaceous-Tertiary boundary events symposium, 2. Proceedings. Copenhagen (University Press): 54-61.

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 (University Press): 137-142.

Chavan, A., 1948. L'âge des principaux gisements de Calcaire pisolithique. — Bull. Soc. géol. France, (5)18: 565-574.

Christensen, W.K., 1979. Maastrichtian belemnites from Denmark. *In*: T. Birkelund & R.G. Bromley (eds). Cretaceous-Tertiary boundary events symposium, 1. The Maastrichtian

and Danian of Denmark. Copenhagen (University Press): 42-44.

Curry, D., 1992. Tertiary. *In*: P.McL.D. Duff & A.J. Smith (eds). Geology of England and Wales. London (Geological Society of London): 389-411.

Curry, D., C.G. Adams, M.C. Boulter, F.C. Dilley, F.E. Eames, B.M. Funnell & M.K. Wells, 1978. A correlation of Tertiary rocks in the British Isles. — Geological Society of London, Special Reports, 12: 1-72.

Curry, D., D. Hamilton & A.J. Smith, 1970. Geological and shallow subsurface geophysical investigations in the Western Approaches to the English Channel. — Institute of Geological Sciences, London, Report 70(3): 12 pp.

Curry, D., J.B. Hensey, E. Martini & W.F. Whittard, 1965. The geology of the Western Approaches of the English Channel, 2. Geological interpretation aided by Boomer on Sparker records. — Phil. Trans. r. Soc. London, (B)248: 315-351.

Curry, D., J.W. Murray & W.F. Whittard, 1965. The geology of the Western Approaches of the English Channel, 3. The Globigerina Silts and associated rocks. — Colston Papers, Proc. 17th Symp. Colston Res. Soc., Bristol: 239-264.

Damotte, R., 1964. Contribution à l'étude des "calcaires montiens" du Bassin de Paris, la faune d'ostracodes. — Bull. Soc. géol. France, (7)6: 349-356.

Damotte, R., 1967. La faune d'ostracodes du "calcaire pisolithique" de Meulan (Yvelines). — C. R. somm. Soc. géol. France, 3: 97, 98.

Damotte, R., & L. Feugueur, 1963. L'âge du calcaire de Vigny (S. & O.) à partir de données paléontologiques nouvelles. — C. R. Acad. Sci. Paris, 256: 3864-3866.

Desor, E., 1847. Sur le terrain danien, nouvel étage de la Craie. — Bull. Soc. géol. France, (2)4: 179-182.

Dewalque, G., 1868. Prodrome d'une description géologique de la Belgique. Bruxelles (Decq)/Liège (Carmanne), 442 pp.

D'Heur, M., 1990. Chalk and petroleum in North-West Europe. *In*: J.B. Burland, L.D. Roberts, D.L. Jones, R.N. Mortimore & B.B.O. Corbett (eds). International Chalk Symposium, Brighton Polytechnic, September 1989. London (T. Telford): 631-639.

Farchad, H., 1936. Etude du Thanétien (Landénien marin) du Bassin de Paris. — Mém. Soc. géol. France, n.s., 30: 1-103, 6 pls.

Fleury, J.-J., G. Bignot, A. Blondeau & A. Poignant, 1985. Biogéographie des Foraminifères benthiques téthysiens du Sénonien à l'Eocène supérieur. — Bull. Soc. géol. France, (8)1(5): 757-770.

Floris, S., 1979. Maastrichtian and Danian corals from Denmark. *In*: T. Birkelund & R.G. Bromley (eds). Cretaceous-Tertiary boundary events symposium, 1. The Maastrichtian and Danian of Denmark. Copenhagen (University Press): 92-94.

Foucher, J.-P., 1987. Les dinokystes du Paléocène de la région de Vertus-Mont Aimé (Marne, France). — Trav. Docum. Géogr. trop. Talence, 59: 57.

Gallagher, L.T., 1990. Calcareous nannofossil biozonation of the Tertiary of the North Sea Basin. — Newsl. Stratigr., 22(1): 21-41.

Godfriaux, I., & R. Marlière, 1971. Relations entre Danien et Montien à Mons. — Bull. Soc. géol. France, (7)13(3-4): 239-246.

Godfriaux, I., & L. Thaler, 1974. Note sur la découverte de dents de mammifères dans le Montien continental du Hainaut (Belgique). — Bull. Acad. r. Belg., Cl. Sci., (5)58: 536-541.

Gorsel, J.T. van, 1973. Helicorbitoides from southern Sweden and the origin of the Helicorbitoides-Lepidorbitoides lineage. — Proc. Kon. Ned. Akad. Wet., (B)76(4): 273-286, 4 pls.

Gruas-Cavagnetto, C., Y. Tambareau & J. Villatte, 1992. Découverte de pollens, dinoflagellés et foraminifères dans le Danien des Petites Pyrénées: implications sur la position de la limite Crétacé/Tertiaire. — Géobios [in press]

Guillevin, Y., 1977. Contribution à l'étude des Foraminifères du Montien du Bassin de Paris. — Cah. Micropaléont., 4: 1-79.

Hagn, H., & E. Voigt, 1986. Ein Massenvorkommen von Orbitoides apiculatus Schlumberger in einem Geschiebe eines ockergelben Hornsteins von Segrahn (Holstein). — Mitt. Bayer. Staatsslg. Paläont. hist. Geol., 26: 7-15, 2 pls.

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.

Hansen, J.M., 1979. Dinoflagellate zonation around the boundary. *In*: T. Birkelund & R.G. Bromley (eds). Cretaceous-Tertiary boundary events symposium, 1. The Maastrichtian and Danian of Denmark. Copenhagen (University Press): 136-141.

Haq, B.U., J. Hardenbol & P.R. Vail, 1987. Chronology of fluctuating sea levels since the Triassic. — Science, 235: 1156-1167.

Heck, S. van, & B. Prins, 1987. A refined nannoplankton zonation for the Danian of the Central North Sea. *In*: H. Stradner & K. Perch-Nielsen (eds). International Nannoplankton Association, Vienna Meeting 1985, Proceedings. — Abh. geol. Bundesanst., 39: 285-303, 1 pl.

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, pls 1-15.

Hinte, J.E. van, & T.E. Wong, 1975. Nummulites rockallensis n. sp. from the Upper Paleocene of Rockall Plateau (North Atlantic). — J. foram. Res., 5(2): 90-101.

Hofker, J., 1976. The importance of the Globigerina daubjergensis-kozlowskii gens as a time-marker in the lower Tertiary. — Paläont. Z., 50(1-2): 34-39.

Hultberg, S.U., 1986. Danian dinoflagellate zonation, the C-T boundary and the stratigraphical position of the Fish Clay in southern Scandinavia. — J. Micropalaeontol., 5(1): 37-47.

Hultberg, S.U., 1987. Palynological evidence for a diachronous low-salinity event in the C-T boundary clay at Stevns Klint, Denmark. — J. Micropalaeontol., 6(2): 35-40.

Hultberg, S.U., & B.A. Malmgren, 1987. Quantitative biostratigraphy based on Late Maastrichtian dinoflagellates and planktonic Foraminifera from southern Scandinavia. — Cret. Res., 8(3): 211-218.

Juignet, P., & W.J. Kennedy, 1974. Structures sédimentaires et mode d'accumulation de la craie du Turonien supérieur et du Sénonien des Pays de Caux. — Bull. B.R.G.M., (2)4(1): 19-47.

Kaminski, M.A., & Malmgren, B.A., 1989. Stable isotope and trace element stratigraphy across the Cretaceous/Tertiary boundary in Denmark. — Geol. Fören. Stockh. Förh., 111(4): 305-312.

Kedves, M., 1979-1980. Palynological investigations on sediments of the Lower Danian (Fish Clay, Denmark), 1 and 2. — Acta Min.-Petr. Szeged, 24(1): 167-186; (2): 335-376.

Kennedy, W.J., 1987. Sedimentology of Late Cretaceous-Pal-

aeocene chalk reservoirs, North Sea Central Graben. *In*: J. Brooks & K. Glennis (eds). Petroleum Geology of NW Europe, 1. London (Graham & Trotman): 469-481.

Kjellström, G., & J.M. Hansen, 1981. Dinoflagellate biostratigraphy of the Cretaceous-Tertiary boundary in southern Scandinavia. — Geol. Fören. Stockh. Förh., 103(2): 271-278.

Kockel, F., 1980 (comp.). A lithostratigraphic scheme for the NW-European Tertiary basins. — Newsl. Stratigr., 8(3): 236, 237.

Margerie, P., G. Deroo & J. Sigal, 1966. Sur l'âge des couches dites "pisolithiques" du Mont-Aimé (Marne). — C. R. Acad. Sci. Paris, (D)263: 1549-1551.

Marie, P., 1937. Sur la faune des Foraminifères du Calcaire pisolithique du Bassin de Paris. — Bull. Soc. géol. France, (5)7: 289-294.

Marie, P., 1947. Sur l'âge montien du Calcaire de Bunde (Limbourg hollandais). — C.R. somm. Soc. géol. France, 7: 145-147.

Marlière, R., 1955. Définition actuelle et gisement du Montien dans le Bassin de Mons. — Annls Soc. géol. Belg., 78(5-7): B 297-B 316.

Marlière, R., 1957. Sur le "Montien" de Mons et de Ciply. — Bull. Soc. belge Géol., Paléont., Hydrol., 66(1): 153-166.

Marlière, R., 1958. Ostracodes du Montien de Mons et résultats de leur étude. — Mém. Soc. belge Géol., Paléont., Hydrol., 5: 1-53, 6 pls.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In*: A. Farinacci (ed.). Proc. 2nd Plankt. Conf., Roma 1970, 2. Roma (Edizioni Tecnoscienza): 739-785, 4 pls.

Mégnien, F., & R. Wyns, 1980. Dano-Montien. *In*: C. Mégnien (ed.). Synthèse géologique du Bassin de Paris, 1. — Mém. B.R.G.M., 101: 338-342.

Meijer, M., 1969. Les foraminifères planctiques du Tuffeau de Ciply (stratotype): leur signification bio- et chronostratigraphique. *In*: P. Brönnimann & H.H. Renz (eds). Proc. 1st Int. Conf. Plankt. Microfoss., Geneva 1967, 2. Leiden (E.J. Brill): 414-419, 1 pl.

Moorkens, T., 1971. Some late Cretaceous and early Tertiary planktonic Foraminifera from the Maastrichtian type area. *In*: A. Farinacci (ed.). Proc. 2nd Plankt. Conf., Roma 1970, 2. Roma (Edizioni Tecnoscienza): 847-877, 5 pls.

Moorkens, T., 1982. Foraminifera of the Montian stratotype and of subjacent strata in the "Mons well 1969", with a review of Belgian Paleocene stratigraphy. — Mém. Expl. Carte géol. Belg., 17(2): 1-186.

Mortimer, C.P., 1987. Upper Cretaceous calcareous nannofossil biostratigraphy of the southern Norwegian and Danish North Sea area. *In*: H. Stradner & K. Perch-Nielsen (eds). International Nannoplankton Association, Vienna Meeting 1985, Proceedings. — Abh. geol. Bundesanst., 39: 143-175.

Odin, G.S., 1990. Echelle numérique des temps géologiques mise à jour en 1990. — Géochronique, 35: 12-21.

Perch-Nielsen, K., 1979. Calcareous nannofossil zonation at the Cretaceous/Tertiary boundary in Denmark. *In*: T. Birkelund & R.G. Bromley (eds). Cretaceous-Tertiary boundary events symposium, 1. The Maastrichtian and Danian of Denmark. Copenhagen (University Press): 115-135.

Pomerol, C., 1982. Les pulsations du Bassin de Paris, marge, détroit, seuil et aire subsidente. — Mém. Géol. Univ. Dijon, 7 (Livre jubilaire G. Lucas): 373-380.

Quine, M., & Bosence, D., 1991. Stratal geometries, facies and sea-floor erosion in Upper Cretaceous chalk, Normandy, France. — Sedimentology, 38: 1113-1152.

Rahaghi, A., 1976. Contribution à l'étude de quelques grands Foraminifères de l'Iran. — Publ. Nat. Iran Oil Comp., 6: 32-44.

Robaszynski, F., 1979. Paléocène et Eocène inférieur de la région de Mons et du Nord de la France: arguments actuels de corrélation. — Bull. Soc. belge Géol., 87(4)(1978): 239-247.

Robaszynski, F., & W.K. Christensen, 1989. The upper Campanian-Lower Maastrichtian chalks of the Mons basin, Belgium: a preliminary study of belemnites and foraminifera in the Harmignies and Ciply areas. — Geol. Mijnbouw, 68(4): 391-408.

Roche, E., 1970. Flores du Paléocène et de l'Eocène inférieur des bassins sédimentaires anglais, belge et parisien. Intérêt climatique et phytogéographique. — Assoc. nat. prof. Biol. Belg., 16(3): 109-134.

Romein, A.J.T., 1979. Lineages in Early Paleogene calcareous nannoplankton. — Utrecht Micropaleont. Bull., 22: 1-231.

Salaj, J., K. Pożaryska & J. Szczechura, 1976. Foraminiferida zonation and subzonation of the Paleocene of Tunisia. — Acta palaeont. pol., 21(2): 127-190, 27 pls.

Schulz, M.-G., & F. Schmid, 1983. Das Ober-Maastricht von Hemmoor (N-Deutschland); Faunenzonen-Gliederung und Korrelation mit dem Ober-Maastricht von Dänemark und Limburg. — Newsl. Stratigr., 13(1): 21-39.

Soyer, R., 1944. Recherches sur l'extension du Montien dans le Bassin de Paris. — Bull. Serv. Carte géol. dét. France, 213(44)(1943): 1-108.

Surlyk, F., 1980. Denmark. *In*: Com. Nat. Français Géol. (ed.). Geology of the European countries. Paris (Dunod): 5-54.

Tambareau, Y., 1984. Les ostracodes du "Montien continental" de Hainin, Hainaut, Belgique. — Rev. Micropaléont., 27(2): 144-156, 2 pls.

Thomsen, E., 1976. Depositional environment and development of Danian bryozoan biomicrite mounds (Karlby Klint, Denmark). — Sedimentology, 23: 485-509.

Thomsen, E., 1981. Revised definition of the Danian in Paleogene stages. — Bull. Inf. Géol. Bass. Paris, Mém. h.s., 2: 82-89.

Thomsen, E., & C. Heilmann-Clausen, 1985. The Danian-Selandian boundary at Svejstrup with remarks on the biostratigraphy of the boundary in western Denmark. — Bull. geol. Soc. Denmark, 33(3-4): 341-362.

Toumarkine, M., & H.-P. Luterbacher, 1985. Paleocene and Eocene planktic Foraminifera. *In*: H.M. Bolli, J.B. Saunders & K. Perch-Nielsen (eds). Plankton Stratigraphy. Cambridge (Cambridge University Press): 87-154.

Verbeek, J.W., E. Steurbaut & T. Moorkens, 1988. Belgium. *In*: R. Vinken (ed.). The Northwest European Tertiary Basin (I.G.C.P. 124). — Geol. Jb., (A)100: 257-273.

Villalard, P., F. Mégnien *et al.*, 1977. Carte géologique au 1/50.000, no. 188. Vertus, avec notice de 24 pp., Paris (BRGM).

Villain, J.M., 1988. Le Montien du Bassin de Mons, Belgique. Stratigraphie et environnements micropaléontologiques. — Rev. Paléobiol., 7(1): 43-61.

Villatte, J., 1977. Le stratotype du Montien de Mons. Les mollusques du sondage de Mons. — Mém. Expl. Carte géol. Belg., 17(1): 27-218, 11 pls.

Vinken, R., 1988 (ed.). The Northwest European Tertiary Basin (I.G.C.P. 124). — Geol. Jb., (A)100: 1-508.

Wilson, G.J., 1971. Observations on European late Cretaceous dinoflagellate cysts. *In*: A. Farinacci (ed.). Proc. 2nd Plankt. Conf., Roma 1970, 2. Roma (Edizioni Tecnoscienza): 1259-1275, 4 pls.

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