

Proposal for the recognition of boundaries between Cretaceous stages by means of planktonic foraminiferal biostratigraphy

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Planktonic foraminifera are a much used biostratigraphic tool for the subdivision of the Cretaceous System from the Albian upwards. A proposal is given for the recognition of Cretaceous stages, using major biostratigraphic events to mark their boundaries. Thus, the extinction of *Globotruncanita calcarata* marks the Maastrichtian – Campanian boundary; the extinction of *Dicarinella asymetrica* the Campanian – Santonian boundary; the entry of *D. asymetrica* the Santonian – Coniacian boundary; the entry of *Dicarinella primitiva* with *Marginotruncana ex gr. renzi – sinuosa* the Coniacian – Turonian boundary; the extinction of *Rotalipora cushmani* the Turonian – Cenomanian boundary; the extinction of *Planomalina buxtorfi* the Cenomanian – Albian boundary.

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As stages are units in an artificial subdivision of what is essentially a time – space – rock continuum, their recognizability can only be defined by agreement on their contents of biostratigraphical events, and *ipso facto*, on their differences.

The original definitions are generally based on rather imprecise statements, on *prima facie* conclusions and on lithological correlations, and it is surprising how well the system proves to work in practice. The lithological type-sequences on which the successive stages were based are often in widely separated geographical regions; the recognition of the stages outside the type-areas are based on a large spectrum of fossil groups: the boundaries are frequently based on particularly striking bio-events, which, more often than not, coincide with lithostratigraphical events such as unconformities. The clearer the bio-event, the more suspicious one becomes that a sedimentary or ecological “event” is the underlying cause.

Bio-events, formalized to delimit various types of “bio-zones”, again correspond to artificial moments of a time – space – life continuum. Zones are generally established in widely separated geographical areas, using identical events. The laboriously constructed “standard biozonations” are not necessarily recognizable in the “standard” lithological sequences on which the stages

were originally based. These considerations may well be regarded as storming an open barn-door, but the consequence is just as generally disregarded. Our designating a so-called “boundary-stratotype” by which we pretend to define a precise level for the “boundary” between two stages in one section with “continuous sedimentation”, is an illusion. The best we can attain is a probability value that the sequence under consideration is within a particular stage, or, for that matter, that it can be recognized as falling within a particular biozone or within a number of successive biozones. An attempt to express such a probability numerically was recently made by Spaak (1983) on closely sampled sections of the Mediterranean Neogene.

The sequence of events in associations of tropical – subtropical planktonic foraminifera during the Cretaceous.

Mainly based on the early work by Bolli (1966), Douglas (1969), Pessagno (1967), Herm (1965) and Van Hinte (1963, 1969), an all but generally accepted sequence of well-recognizable entries and exits of taxa among the planktonic foraminifera has by now been established (fig. 1). Most of these events have been recognized in the

Mediterranean, Near Eastern, Carribean and southwest North American regions; several of them may be traced into higher latitudes, the so-called Boreal province.

Major events, from the Albian upwards, are the repeated appearances of keeled forms, such as *Rotalipora*, *Planomalina* and *Praeglobotruncana*; the extinction of the *Rotalipora* – group; the appearances of the double-keeled forms *Dicarinella* and *Marginotruncana*; the extinction of the *Dicarinella* – group; the appearance and radiation of the *Globotruncana* – *Rosita* group with intra-umbilical primary aperture; the entry and exit of strongly spinose forms of *Globotruncana calcarata*; the extinction of the *Globotruncanidae*.

Even though restricted to open marine, outer shelf or deeper facies, planktonic foraminifera have the advantage of large horizontal distribution; they are easily recognizable and require relatively simple optical instruments; many have been well-figured and (re-) described by international teams of students (Robaszynski and Caron, 1979).

The sequence of events as outlined above has been firmly established in a large number of recent papers (Carter & Hart, 1977; Van Hinte, 1972, 1976; Linares Rodriguez, 1977; Peryt, 1980; Wonders, 1980; Weiss, 1982; Bellier, 1983).

Several authors have given correlations of the resulting biostratigraphical zonation with various macrofossil zones and/or with type sections and boundaries of stages (e.g., Wonders, 1980; Bellier, 1983; Marks, 1984).

The Globotruncanita calcarata Zone and the Campanian – Maastrichtian boundary

The original definition of the Maastrichtian by Dumont (1849) is based on the Tuffeau de Maestricht, as exposed in the quarries in the St. Pieters Mountain near the town of Maastricht. The original author placed this tuffeau above formations which were named craie Sénonien. Many authors have considered the Maastrichtian Stage as being restricted to the original “type”, the type-section being exposed in the ENCI quarry. Comparison with the type-Campanian, exposed in the section of Aubeterre in Charente, about

1,000 km south of Maastricht, proved the existence of a considerable biostratigraphical gap between both types, (Van Hinte, 1966; Van Gorsel, 1973, 1975; Bellier, 1983) a situation that even led to the proposition by Salaj (1980) to introduce a new stage, the Kefian, to identify this gap. By want of good macrofossil and planktonic microfossil faunas, this stage is illustrated mainly by distinct morphometrical hiatuses between *Orbitoides media* s.l. in Aubeterre and *Orbitoides apiculata* from the top (Md) of the ENCI quarry sequence, and between *Lepidorbitoides campaniensis* in the former and *L. minor* in the latter. It is interesting to note that an even more highly developed *Lepidorbitoides*, *L. socialis* is only known from the Pyrenees, and has not been found in the top part of the type Maastrichtian (van Gorsel, 1975). Since Dumont (1849) the “Senonian” has been subdivided into a large number of formations and members (Albers & Felder, 1979), part of which are now generally included in an “extended” Maastrichtian, which corresponds more closely to the proposed biostratigraphic definitions of belemnite and ammonite specialists, and which is now generally accepted as useful for the definition of the boundary between both stages (Jeletzky, 1951; Schmid, 1955, 1959; Birkelund, 1957; Christensen, 1975). *Belemnitella langei* and *Bostrychoceras polyplacum* are considered to define the uppermost Campanian; *Belemnella lanceolata* and *Pachydiscus neubergicus* to define the basal part of the Maastrichtian.

It must be noted that Blaskiewicz (1980), in the section along the Vistula River, Poland, identifies two zones above the *B. polyplacum* (range) Zone i.e. the *Didymoceras donezianum* Zone and the *Nostoceras pozaryskii* Zone, which together cover his *B. langei* Zone.

In the type area Southern Limburg *B. langei* and *B. mucronata minor* have been identified from the Zeven Wegen Member, whereas the base of the Vijlen Member already contains *B. occidentalis*, *B. lanceolata* being absent (Van der Tuuk & Bor, 1980). The hardgrounds separating the members very probably represent considerable time-gaps, which may become rather more pronounced towards the West, where in the Hallembaye Quarry the Beutenaken Member is possibly absent (see also Robaszynski, 1983).

Neither the Vistula section (Peryt, 1980), nor

the sections in the Netherlands and adjacent Belgium and Germany have yielded planktonic foraminiferal faunas comparable to those known from the Tethys areas. Almost without discussion the total range zone of the very marked *Globotruncanita calcarata* is universally accepted as representing the top part of the Campanian, the extinction level of this taxon the stage boundary. Authors thus follow the propositions of Bartenstein (1948), Sigal (1952), Dalbiez (1956) and Herm (1962). Sigal reports that *G. calcarata* ranges to just above the lowest occurrence of *B. pyplocum* in North Africa.

There is, however, no published first-order correlation between ammonite or belemnite zonations and the *calcarata* Zone; second order correlations via calcareous nannofossils (as an intermediary and a means of comparison) in the type-sections (Verbeek, 1983, Abstracts of this Symposium) tend to confirm the general usage.

– It is therefore proposed to equate the base of the Maastrichtian Stage with the extinction level of *Globotruncanita calcarata* (Cushman, 1927) (= top of the *B. langei* Zone and top of the *Nostoceras pozaryskii* Zone).

The Santonian – Campanian boundary

As was pointed out by Van Hinte (1979), Wonders (1980) and Bellier (1983), the stratotypes of these stages do not contain sufficient biostratigraphic information to designate a boundary event with great accuracy. In planktonic foraminiferal biostratigraphy a combination of events, widely recognized, occurs very close to this boundary:

Dicarinella concavata – *D. asymetrica* (= *Marginotruncana carinata* auct.) becomes extinct, *Globotruncanita elevata* s.l. appears. The concurrent range zone of these two species would fit into the gap between the type-sections (Wonders 1980). This zone, named the *Globotruncana manauensis* Zone by Bellier (1983), was shown by this author to contain an ammonite fauna generally regarded as being Late Santonian in age.

– It is therefore proposed to place the base of the Campanian Stage at the extinction level of *Dicarinella asymetrica* (Sigal, 1952), while the top

of the Santonian coincides with the *D. asymetrica* – *G. elevata* concurrent range Zone.

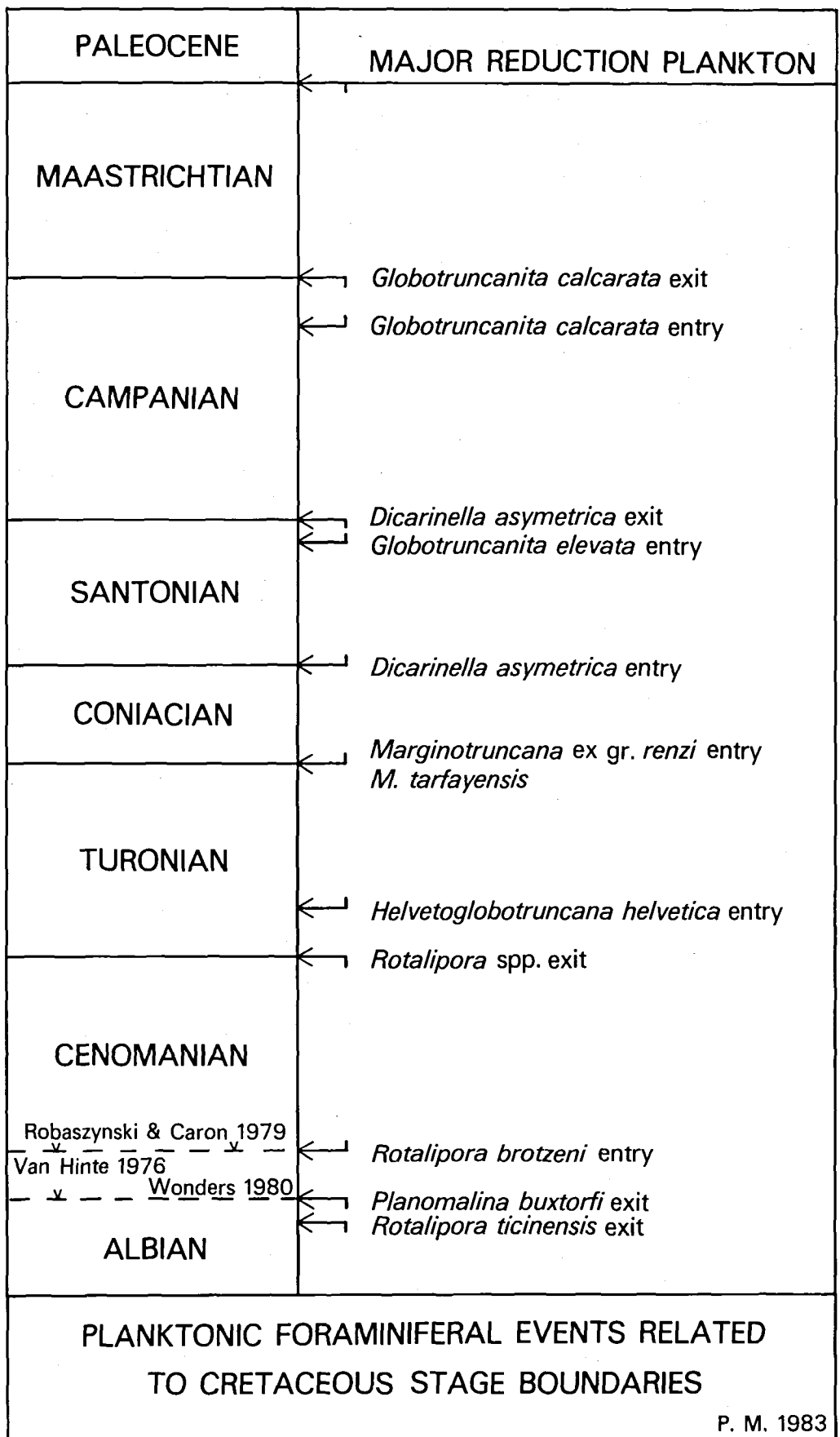
The Coniacian – Santonian boundary

So far no first-order correlations of planktonic foraminiferal events have been found, neither with ammonite distribution, nor with stratotype sections. The stratotype of the Coniacian is notoriously poor in macrofossils and in microfossils (Séronie Vivien, 1972; Van Hinte, 1979) and continuous sections containing diagnostic fossils are absent in the type area. Second order correlations with calcareous nannofossils strongly suggests that the Coniacian is the time during which the rapid development of the *Dicarinella primitiva* – *D. concavata* group of planktonic foraminifera took place. For practical purposes assemblages characterized by *Marginotruncana* species of the *M. renzi* – *M. sigali* group, *Whiteinella* spp. and the *Marginotruncana coronata* – *M. pseudolinneana* group, together with *Dicarinella primitiva* and *Dicarinella concavata*, are generally assigned to the Coniacian by planktonic foraminiferal biostratigraphers, the entry level of *Dicarinella asymetrica* generally being taken as the boundary with the Santonian. Bellier (1983) has published convincing arguments for the usefulness of this correlation. It is, however, impossible to propose this entry to be used as a boundary marker because it does not necessarily fit into a linear evolution and it may well be a time-transgressive morphotype dependent on water-depth, temperature or other ecological parameters.

The Turonian – Coniacian boundary

Similar difficulties exist for the *Turonian* – *Coniacian* boundary. Again the stratotype sections are geographically rather far apart and they do not contain diagnostic planktonic foraminifera (Van Hinte, 1979).

The case is well stated by Bellier (1983), who suggests that the appearance of *Marginotruncana* of the *sinuosa* group, together with the deployment of the *Dicarinella primitiva* – *concavata* group can provisionally be used as markers to distinguish the Coniacian from the Turonian.



This does not contradict the first-order correlations with the *Marthasterites furcatus* Zone in coccolith biostratigraphy, a zone found by several authors to occur in stratotype Coniacian (Verbeek, 1977; Sissingh, 1977, 1978; Manivit, 1980; Wonders 1980; Perch-Nielsen, 1983).

Although it is tempting to propose the above described events to recognize the Turonian – Coniacian boundary, further research towards first-order correlations with various other groups of taxa (ammonites, inoceramids, echinoids, benthic foraminifera, calcareous nannofossils) is necessary. For an attempt in this direction, based on continuous sections in Romania, see also Ion, 1979.

The Cenomanian – Turonian boundary

As was already put forward by Marks (1977), the acceptance of the stratotype sections for the Cenomanian in Le Mans area as proposed by Juignet (1974, 1980) produces a somewhat embarrassing situation for accurately drawing the boundary by means of planktonic foraminifera.

At, or near this boundary a number of striking events occur:

The *Thalmaninella* – *Rotalipora* group of keeled planktonic taxa, widespread and flourishing during the Cenomanian, disappears abruptly, to be succeeded by a brief interval dominated by globular, unkeeled forms:

Whiteinella and *Hedbergella* (the *Whiteinella aprica* Zone, popularly the “Zone à grosses globigérines”) followed in turn by the entry and exit of the ubiquitous keeled form *Helvetoglobotruncana helvetica* (Bolli).

The topmost formation of the “stratotype” Cenomanian: the Craie à *Terebratella carentonensis*, contains an association rather typical for the *Wh. aprica* Zone (Juignet, 1974; Bellier, 1983).

A very similar “grosses globigérines” association is found in beds with *Inoceramus labiatus*, a fossil generally accepted as indicating the base of the Turonian Stage. Several authors (Bellier, 1983; Robaszynski & Caron, 1979; Robaszynski et al. 1980) have therefore proposed to draw the boundary between the Cenomanian and Turonian half way the *Whiteinella aprica* Zone. It must be noted that Van Hinte (1972) in an early paper on this subject already advocated the

Cenomanian – Turonian Boundary half-way his “*Hedbergella lehmanni*” Zone (= *Whiteinella aprica* Zone).

However, it is more convenient to draw boundaries at major biostratigraphic events, in particular where a new pelagic faunal assemblage is found to appear.

The *Rotalipora* extinction, followed in rapid succession by the appearances of single-keeled and doubled-keeled representatives of the *Helvetoglobotruncana*, *Marginotruncana* and *Dicarinella* groups, is such an event. It is, moreover, widely accompanied by remarkable changes in the sedimentary succession (Schlanger & Jenkins, 1976; Hart & Bailey, 1979; Wonders, 1980; Fisher, 1980; Arthur & Premoli Silva, 1982; Peryt, 1983; Bellier, 1983), often taking the shape of relatively thin carbonaceous black shale intercalations, hardgrounds or phosphatic nodule concentrations. It appears that at the Cenomanian – Turonian boundary a virtually world-wide oceanic “crisis” happened (De Boer, 1983) which is most easily recognizable by the extinction of *Rotalipora*.

– For this reason it is strongly advocated that the Cenomanian – Turonian boundary be made to coincide with this level. The possible consequence can be that in ammonite stratigraphy the boundary would fall in, or just below, the *Metoicoceras geslinianum* Zone, as was advocated by Wright 1957 (Hancock, 1983).

The Albian – Cenomanian boundary

The stratotype sections defining the Upper Albian and the Lower Cenomanian again do not provide us with diagnostic planktonic foraminifera. For the sake of convenience, Van Hinte (1972, 1975) suggested to use the extinction level of the marker *Planomalina buxtorfi* as the boundary level between the Albian and the Cenomanian. Recent data provided by Bellier (1983) who found *Mantelliceras* aff. *couloni* and *Sciponoceras baculoides* associated with *Thalmaninella* (= *Rotalipora* auct.) *appenninica* and the last representatives of *Planomalina buxtorfi* indicates that Van Hinte’s proposal is very close to the accepted boundary used in the ammonite zonation. Certainly for purposes of time-stratigraphic correlation of oceanic data and in

sections with abundant planktonic foraminifera, the top of the *appenninica* – *buxtorfi* Zone sensu Wonders 1980 (i.e. slightly above the extinction level of *Thalmaninella* (= *Rotalipora* auct.) *ticinensis* can be used for recognition of this boundary.

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Dansk sammendrag

Kridttidens etagegrænser foreslås defineret ved hjælp af planktoniske foraminiferer. Uddøen af *Globotruncanita calcarata* markerer maastrichtien – campanien grænsen, uddøen af *Dicarinella asymetrica* markerer campanien – santonien grænsen, tilsynekomsten af *D. asymetrica* markerer santonien – coniacien grænsen, tilsynekomsten af *Dicarinella primitiva* og *Marginotruncana* ex. gr. *renzi-sinuosa* markerer coniacien – turonien grænsen, uddøen af *Rotalipora cushmani* markerer turonien – cenomanien grænsen og uddøen af *Planomalina buxtorfi* markerer cenomanien – albien grænsen.

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