

# Integrated Microfossil Biostratigraphy, Mid-Cretaceous (Albian to Santonian)

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## 1. Introduction

Between 1966 and 1982 a number of papers have been published, in which biozonations based on various groups of fossils were correlated. In 1966, Porthault *et al.* published a paper in which the range of planktic Foraminifera was incorporated within an ammonite and inoceramid zonation from sections measured in the Cenomanian–Turonian of the Alpes-Maritimes, France. Slightly more detailed ranges and correlations were given by Porthault (1969, 1974) and Donze *et al.* (1970). Since then a veritable plethora of papers on the biostratigraphy of the Albian–Turonian interval have been published. Using sections in France, Spain, Tunisia and Italy, Verbeek (1976, 1977*a,b*), Verbeek & Wonders (1977), Wonders & Verbeek (1977), Wonders (1980) and de Vries (1977) have published papers covering much of the Albian–Turonian interval, in which the same samples were used for the study of planktic Foraminifera and coccoliths. In particular, the section of El Kef in Tunisia was used for this purpose, but excellent results were likewise obtained from the section at El Burrueco near Jaén in Spain, while sections from stratotype areas of the Cenomanian and Turonian were included.

Independently, Sissingh (1977, 1978) published a coccolith zonation for the El Kef section. His zonal scheme, which is somewhat different from the one produced by Verbeek, was correlated with a planktic foraminiferal zonation established by Postuma, by using identical samples. Important contributions towards integrated microbiostratigraphy and zonations based on ammonites, echinoids and bivalves were published in the years 1976–1982 by a group of French stratigraphers co-ordinated by Amédro and Robaszynski (Amédro & Robaszynski, 1978; Amédro *et al.*, 1976, 1978, 1979; Robaszynski & Amédro, 1980; Robaszynski *et al.*, 1982), based on sections in the Boulonnais, and in the Touraine–Saumurois. Four nannofossil specialists present at the Nice meeting of IGCP No. 58, Mid-Cretaceous produced a tentative scheme of nannofossil zones for the Mid-Cretaceous (Manivit

*et al.*, 1977, in which an interrelationship between calcareous nannofossil "datum levels" and those of planktic Foraminifera was suggested.

The correlation with the type-sections and the chronostratigraphic stages presented in that paper was subsequently modified by Sissingh (1978) and Verbeek (1977a). Verbeek's zonation was used later by Wonders (1980) in conjunction with his planktic foraminiferal scheme. In 1978, Perch-Nielsen published a review paper in which a number of Cretaceous calcareous nannofossil zonations were compared with each other and in part related with planktic foraminiferal zonations and with the Cretaceous stages.

The present paper is an attempt to integrate the results so far obtained for the Mid-Cretaceous (i.e. the Albian–Coniacian). Furthermore, some potentially useful correlations with ammonite zones, magneto-stratigraphic scales, and with some radiometric results have been added. The very useful—and much quoted—"A Cretaceous time-scale" by van Hinte (1976) may be somewhat improved in this way. To establish the planktic foraminiferal zonation I have applied the philosophy that successions of bio-events within homogeneous groups are preferable. In the Albian using *Ticinella*; the Upper Albian and Cenomanian almost entirely with *Rotalipora* s.l.; in the Turonian–Santonian almost entirely with the *Margino-truncana–Dicarinella* group. Although not truly "phylozones" an underlying philosophy of phylogenetic sequences is clearly present. This method limits to a certain extent the number of zones one could recognize by using other taxa—for example, *Planomalina*, *Praeglobotruncana*, *Favosella*, which remains the privilege of individual workers in particular facies developments in different basins. It does, however, provide a sort of "skeleton" zonation which already provides a zonal succession in which each zone is close to 1 Ma; a very reasonable power of resolution.

Perhaps it is apposite to have a closer look at what a boundary or limit between biozones actually represents. Graphically, such boundaries are normally expressed by a single line, suggesting the presence of a boundary level or plane. Of course, this representation is purely pragmatic and does not normally have any relation to reality. What is such a boundary? If based on the usual absence/presence observations of a given taxon or number of taxa, it is in fact an interval of sedimentary deposits, the thickness of which is a function of (a) the spacing of the samples and (b) the recognizability of the taxon or taxa in question. Parameter (a) depends on various secondary factors, such as the type of exposure, techniques of sampling, expediency, time, money, the energy of the persons who actually execute the sampling, etc. In short, a strongly subjective influence is introduced. Parameter (b) is very much subject to agreement between taxonomists on which morphological characters should be used for classification.

This does introduce a difficulty when correlating different types of biozonations, especially when comparing sedimentary sequences with different rates of sedimentation, various intensities of bioturbation, presence of hiatuses, or the phenomena of mass-transport, etc.

There is even more of a problem when taxonomic and systematic agreement of some of the taxa has not yet been reached. This is, in fact, very probably the underlying cause for the discrepancies between the results of different groups of observers as shown in Figure 1.

Any boundary in biostratigraphy represents, in fact, an interval of uncertainty, and one should abandon the illusion of even striving for a very high degree of precision in this respect. All we can obtain is a reasonable accuracy in the vertical sequence of palaeobiologic events.

When comparing zonations based on micro-organisms, one has to keep in mind that currently such zonations are based on so-called "events", i.e. appearances and

disappearances, or "entries" and "exits", often expressed in terms of "datum planes". This procedure reflects the faith that micropalaeontologists invest in (a) their ability to recognize such "events" in the sedimentary column and (b) that such events are at least approximately synchronous at geographically separate localities.

Day-to-day practice has shown that, in spite of serious theoretical objections to this procedure, it does work, and has resulted in a generally accepted sequence of biozones, with relatively minor differences between authors.

## 2. Entries, exits and planktic foraminiferal zones

Virtually all micropalaeontologists working with planktic Foraminifera agree on a number of distinctive "events", which may be listed, from the Albian up to, and including, the Santonian as follows.

### Entries

1. The entry of *Ticinella*, following a fauna almost exclusively consisting of *Hedbergella*.
2. The entry of *Planomalina buxtorfi* (Gandolfi), practically together with *Rotalipora appenninica* (Renz) (= *Thalmaninella appenninica* auct.).
3. The entry of *Rotalipora cushmani* (Morrow).
4. The entry of *Helvetoglobotruncana* (= *Praeglobotruncana* auct.) *helvetica* (Bolli).
5. The entry of *Dicarinella concavata* (Brotzen). The definition of this species, evolving from *D. primitiva* (Dalbiez)-*schneegansi* (Sigal), is somewhat subject to personal interpretations.
6. The entry of *Globotruncanita elevata* (Brotzen) s.str.

### Exits

1. The exit of *P. buxtorfi* (Gandolfi), very close to the exit of *Ticinella* spp.
2. The exit of *Rotalipora*.
3. The exit of *H. helvetica* (Bolli).
4. The exit of *D. asymerica* (Sigal) (= *carinata* (Dalbiez) auct.).

Translated into zones, one could state that a majority of authors agree on a *Rotalipora cushmani* total range zone; an *H. helvetica* total range zone, and a *D. concavata*-*D. asymerica* total range zone. In between and superimposed numerous additional zones reflect the variable subjective evaluation of relevant "markers", although in practice there is very little real difference of opinion.

## 3. Correlation of planktic foraminiferal zones with the coccolith zonation

Most authors agree that *Prediscophaera columnata* enters somewhere in the Early Albian, but first-order correlation with other microfossil zones has so far nowhere been established. Tentatively its entry is placed above the entry of *Hedbergella planispira* (Tappan). The *P. columnata* Zone is an interval zone with the top at the entry of *Eiffellithus turriseiffeli* (Deflandre); this entry is contemporaneous with the

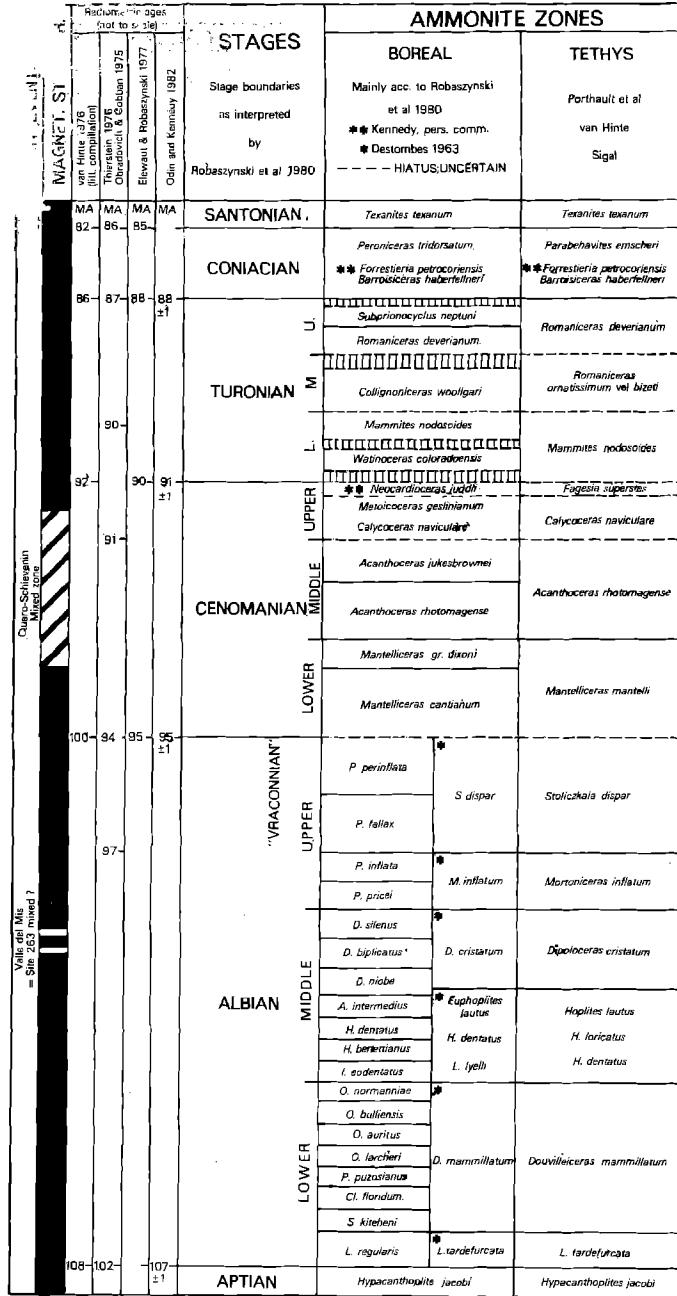


Figure 1. Integrated biostratigraphy

PLANKTONIC FORAM. ZONES		CALCAREOUS		ANKTOS ZONES		DIATHOFLAG. ZONES	STAGE	
DEFINING EVENTS ← ENTRY EXIT →		PRZ: Partial Range Zone		TRZ: Transition Zone		DEFINING EVENTS ← ENTRY EXIT →	BOUNDARIES	
H. = <i>Halbergella</i> M. = <i>Margino truncana</i> Hg. = <i>Helvetoglobotruncana</i> Wh. = <i>Whitella</i> R. = <i>Rotalipora</i> Th. = <i>Thalmaninella</i> P. = <i>Planorbolina</i> Ps. = <i>Pseudothalmaninella</i> T. = <i>Ticinella</i>		IZ: Interval Zone ROBASZYNSKI & CARON 1979 FIRST ORDER CORRELATION WONDERS 1980 *SIGNAL 1977 VERBEEK 1977		SISSINGH 1977-1978 ANIVIT in Robaszynski et al 1980		← ENTRY EXIT → Cr. = <i>Crucellips</i> M. = <i>Martbasterites</i> E. = <i>Eiffelithus</i> Q. = <i>Quadrum</i> L. = <i>Lucianorhabdus</i> G. = <i>Gartnerago</i> Ms. = <i>Microrhabdulus</i> Mi. = <i>Micula</i>	J. C. Fouchei in Robaszynski et al 1980 SANT. CONCIAC. TUR. CENOM. ALBIAN	as interpreted by van Hinte 1975 Wonders 1980
— <i>D. concavata</i>	<i>Dicarinella concavata</i> IZ	<i>Margino truncana concavata</i> IZ	<i>Braiosonia lacunosa</i> IZ	15 <i>Reinhardtites</i> IZ 14 <i>Mi. stauraphora</i> IZ	<i>Rucinolithus hayi</i> IZ	<i>Reinhardtites andriophorus</i> IZ	<i>Sponiosphaera protusa</i> IZ	SANT. concavata ↓
— <i>D. primitiva</i>	<i>D. primitiva</i> IZ	<i>M. primitiva</i> IZ	<i>Martbasterites furcatus</i> IZ	13 <i>M. furcatus</i> IZ	<i>Micula decussata</i> IZ <i>M. furcatus</i> IZ	<i>Braiosonia lacunosa</i> IZ <i>Micula stauraphora</i> IZ	<i>Sponiosphaera rotundata</i> IZ	CONCIAC. primitiva ↓
— <i>M. coronata</i> — <i>M. schneegansi</i> — <i>Margino truncana</i> spp — <i>Hg. helvetica</i>	<i>Margino truncana schneegansi</i> PRZ <i>Proeglobotruncana helvetica</i> TRZ	<i>Margino truncana sigali</i> PRZ <i>Helvetoglobotruncana helvetica</i> TRZ	<i>Eiffelithus eximius</i> IZ	12 <i>Lucianorhabdus maleformis</i> IZ 11 <i>Quadrum gartneri</i> IZ	<i>E. eximius</i> IZ <i>Q. gartneri</i> IZ	<i>E. eximius</i> Manivit IZ <i>L. maleformis</i> IZ <i>E. eximius</i> Verbeek IZ	<i>Sponiosphaera rotundata</i> IZ	TUR.
— <i>R. cushmani</i> — <i>Wh. archaeocretacea</i> — <i>D. hagni</i>	<i>Whitella archaeocretacea</i> PRZ <i>Rotalipora cushmani</i> TRZ	<i>Whitella archaeocretacea</i> PRZ <i>Rotalipora cushmani</i> TRZ	<i>Gartnerago obliquum</i> IZ	10 <i>Microrhabdulus decoratus</i> IZ	<i>Ms. decoratus</i> IZ	<i>Q. gartneri</i> Manivit Sissingh IZ <i>Q. gartneri</i> Verbeek IZ	<i>Silicosphaera ferox</i> IZ	<i>Rotalipora</i> ↑
— <i>R. cushmani</i> — <i>R. (Th.) reicheli</i> — <i>R. (Th.) reicheli</i> — <i>R. montsalvensis</i>	<i>Rotalipora reicheli</i> TRZ <i>Rotalipora brotzeni</i> IZ	<i>Rotalipora reicheli</i> TRZ <i>Thalmaninella globotruncanoides</i> IZ	<i>Lithraphidites acutum</i> IZ	9 <i>Lithraphidites acutum</i> IZ	<i>Lithraphidites acutum</i> IZ	<i>Ms. decoratus</i> Manivit IZ <i>G. obliquum</i> IZ <i>Ms. decoratus</i> Sissingh IZ <i>Cr. chiasa</i> IZ <i>Lithraphidites acutum</i> IZ	<i>Lithasphaeridium siphonophorun</i> IZ	CENOM.
— <i>R. brotzeni</i> — <i>R. (Th.) globotruncanoides</i>	<i>Rotalipora appenninica</i> IZ	<i>Th. appenninica</i> PRZ <i>appenn. buxtorfi</i> PRZ	<i>Eiffelithus turrisaiffeli</i> IZ	8 <i>Eiffelithus turrisaiffeli</i> IZ	<i>Eiffelithus turrisaiffeli</i> IZ	<i>Hayasus albensis</i> IZ	<i>Cribroperidium intricatum</i> IZ	<i>buxtorfi</i> ↑
— <i>P. buxtorfi</i> — <i>R. (Ps.) ticinensis</i> — <i>T. breggiensis</i>	<i>R. (Ps.) ticinensis</i> IZ <i>P. praebuxtorfi</i> TRZ	<i>Ps. ticinensis</i> IZ <i>Ps. subticinensis</i> IZ	<i>Eiffelithus turrisaiffeli</i> IZ	7 <i>P. columnata</i> IZ	<i>P. columnata</i> IZ	<i>Eiffelithus turrisaiffeli</i> IZ	<i>Systematophora fasciculigera</i> IZ	ALBIAN
— <i>T. breggiensis</i> — <i>T. primula</i> — <i>T. primula</i>	<i>T. breggiensis</i> IZ <i>T. primula</i> IZ	<i>T. breggiensis</i> IZ <i>T. primula</i> IZ	<i>Praedicosphaera columnata</i> IZ	6 <i>Praedicosphaera columnata</i> IZ	<i>P. columnata</i> IZ	<i>Hayasus albensis</i> IZ	<i>Pterodinium aiferum</i> IZ	ALBIAN
— <i>Favosella</i> — <i>H. planispira</i>	<i>H. planispira</i> IZ	<i>H. planispira</i> IZ	<i>Rhagodiscus angustus</i> Zone	5 <i>Rhagodiscus angustus</i> Zone	<i>P. columnata</i> IZ	<i>P. columnata</i> IZ	<i>Pterodinium aiferum</i> IZ	ALBIAN
— <i>Ticinella bejaouensis</i>	<i>T. bejaouensis</i> IZ	<i>T. bejaouensis</i> IZ	Manivit et al. 1977	4	3	2	1	ALBIAN

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of the European Mid-Cretaceous.

first appearance of a number of long-ranging taxa. It is generally thought to coincide with the entry of the earliest *Rotalipora* (*Pseudothalmanninella* Wonders, 1977), which is somewhat before the appearance of *R. appenninica* (Renz).

The next zone in nannofossil biostratigraphy is the *Eiffellithus turriseiffeli* Zone, by general consent a very large zone, corresponding with at least three (and in Wonders' paper with nearly six) planktic foraminiferal zones. There is very little difference of opinion on the entry of the nominative taxon, but the top of the zone is very much dependent on individual opinions of various nannofossil specialists: it is put by several authors at the entry of *Lithraphidites acutum* (Verbeek & Manivit), base of the eponymous Interval Zone. Intercorrelations of this entry with planktic foraminiferal events are less straightforward than was the case in previous instances. Wonders (1980) finds *Rotalipora montsalvensis* Mornod to appear earlier; Manivit, in Robaszynski & Amédro (1980) to appear later in the column; Sissingh (1978) does not use this taxon at all. There is, however, general agreement that *L. acutum* enters in the upper range of *R. appenninica*, before the entry of *R. reicheli* Mornod, and in fact the deviation is only very slight.

Manivit (in Robaszynski & Amédro, 1980), Sissingh (1977, 1978) and Verbeek (1977a) agree fairly well as to the entry of *Microrhabdulus decoratus* Deflandre but the latter author did not employ this species to define a zone. Its entry coincides very nearly with the entry of *R. cushmani* (Morrow).

The entry of *Quadrum gartneri* Prins & Perch-Nielsen is close to the very top part of the range of *Rotalipora cushmani*; the apparent deviation in Sissingh's table being due to Postuma's inclusion of the *Whiteinella archaeocretacea* Zone in the *R. cushmani* Zone. Manivit (in Robaszynski & Amédro, 1980) reports an entry just above the exit of *R. cushmani*; this entry seems to be acceptable for many nannofossil specialists.

On the interval equivalent to the *H. helvetica* and *M. sigali* Zones (Middle–Upper Turonian) little agreement exists between calcareous nannofossil specialists. Verbeek and Manivit propose quite different entries for *Eiffellithus eximius* (Stover), which is not used by Sissingh as a marker.

There is general agreement upon the entry of *Marthasterites furcatus* (Deflandre) and the base of the eponymous Zone, the species appears nearly together with very early representatives of the *Marginotruncana* ("Dicarinella" auct.) *concovata* group [*M. primitiva* (Dalbiez)]. Above this level authors tend to apply quite different zonal markers. As we are here beyond the reach of the discussed interval (Santonian) this problem will not be discussed in this paper.

#### 4. Correlation between the above zonations and those based on other groups of microfossils

So far the only attempts in this direction seem to have been made by Foucher (in Robaszynski & Amédro, 1980) (and in Robaszynski *et al.*, 1982) for the dino-flagellates. In the Albian–Coniacian interval this author distinguishes six dino-flagellate zones.

#### 5. Integrated microfossil biostratigraphy and the recognition of Mid-Cretaceous Stages

##### *Albian*

In the type-area both the lower and the upper boundary of this stage are badly defined (Rat, 1980; Magniez-Jannin & Rat, 1980). In microfossil practice the lower

boundary is placed very close to the first appearance of the genus *Ticinella*, which may fall in the Late Aptian zone of *Hypacanthoplites jacobi* (Moullade, 1966, 1974). Another useful planktic foraminiferal marker is *Planomalina cheniouriensis* Sigal; the total range zone of this species is virtually at the top of the Aptian (Sigal, 1977). Very close to the base of the Albian *Hedbergella planispira* (Tappan) appears.

The upper part of the Albian is characterized by a large number of biological events in rapid succession: the important genera *Praeglobotruncana*, *Rotalipora* (*Pseudothalminella*) and *Thalminella* (*sensu* Wonders, 1977) appear, while *Ticinella* disappears. Within this interval *Planomalina buxtoni* (Gandolfi) is a common constituent in tropical-subtropical regions. This species disappears when *Rotalipora appenninica* (Renz) is joined by its descendants *R. brotzeni* (Sigal) and *R. globotruncanoides* (Sigal). The combination of these events can be used to recognize the top of the Albian Stage, although it may occur slightly earlier than the boundary as "defined" by Ammonites. In nannofossil biostratigraphy this interval concurs with the lower part of the *Eiffellithus turriseiffeli* Interval Zone, which straddles the Albian-Cenomanian boundary. So far no particular event has been observed that can be used for a closer definition, but the entry of *Eiffellithus turriseiffeli* (Deflandre & Fert) may very well be a useful index for the base of the Upper Albian (Manivit, *in* Rat, 1980).

In dinoflagellate zonation the Upper Albian practically concurs with the *Cribroperidium intricatum* Zone (Foucher, *in* Robaszynski & Amédro, 1980). All together, the Albian can be defined roughly as the interval in which the genera *Ticinella* and *Planomalina* both are present: the Upper Albian by the addition of *Biticinella*, *Rotalipora* s.l. and *Praeglobotruncana*.

### *Cenomanian*

Again, the base of this stage is difficult to define in terms of planktic Foraminifera in its type area, owing to the peculiar facies of the sediments (Juignet, 1980, pp. 130-138). In actual practice the boundary is usually put at the appearance of the ventro-convex, ornamented descendants of *Rotalipora appenninica* (Renz): *R. brotzeni* (Sigal) and *R. globotruncanoides* (Sigal); *R. appenninica* itself continues to be present throughout the Lower and Middle Cenomanian. There is no particular calcareous nannofossil event to mark the lower boundary of the stage; in the Dinoflagellate zonation the appearance of *Lithosphaeridium siphoniferum* may be a useful marker event. Typically the Cenomanian is the interval dominated by the genera *Rotalipora* and *Praeglobotruncana* (*gr. stephani*) co-occurring, without *Ticinella* and *Planomalina*. The top of the stage is particularly well "defined", both by planktic foraminiferal and calcareous nannofossil events. *Rotalipora* becomes extinct, the last representatives being *R. cushmani* (Morrow), *R. greenhornensis* (Morrow) and *R. deecke* (Franke), the latter two probably disappearing very slightly earlier than the first. In calcareous nannofossil associations, the first appearance of *Quadrum gartneri* (Perch-Nielsen & Prins) is a good marker for the base of the Turonian. No particular event has so far been reported to my present knowledge in dinoflagellate successions at this level.

### *Turonian*

This is one of the best defined and easiest to recognize Cretaceous stages, in terms of both planktic Foraminifera and calcareous nannofossils (Butt, 1966; Bellier, 1971; Robaszynski *et al.*, 1982). At the base a very widely recognized zone, defined

...ca ... J. ... braminifera, and the abundant presence of *Whiteinella medberrina* and *P. eglobotruncana* (inflated forms) occurs ("Zone à grosses Globigérines"). In several places a "bloom" of *Gumbelitra* has been observed at this level. This interval is followed by the appearance of the very characteristic *Praeglobotruncana* (*Helvetoglobotruncana* auct.) *helvetica* (Bolli), a taxon with a short vertical range in the Mid-Lower and Middle Turonian.

*N.B.* It should be noted, however, that, if Juignet's proposal (Juignet *et al.*, 1973; Juignet, 1980) to include the "Craie à *Terebratella carentonensis*" Formation in the type section of the Cenomanian is adopted, the *Whiteinella archaeocretacea* Zone ("Zone à grosses Globigérines") would form the top part of that stage (Marks, 1977). At Saint Calais this formation contains a very typical association of that zone.

The upper part of the stage is typified by the dominance of numerous intergrading species of *Marginotruncana*, both double- and single-keeled. In calcareous nannofossil biostratigraphy the appearance of *Quadrum gartneri* (Perch-Nielsen & Prins) marks the base of the stage, while the upper portion contains *Eiffellithus eximius* (Stover). There is some disagreement among authors as to the exact entrance level of the latter species (Figure 1).

The top of the Turonian, i.e. the base of the Coniacian, is essentially defined by the entry of representatives of *Dicarinella* (*D. primitiva* Dalbiez) on the one hand and *Marthasterites furcatus* (Deflandre) on the other. This boundary, badly defined both in the type area (van Hinte, 1979; Séronie-Vivien, 1972, 1980a; Robaszynski *et al.*, 1982) and by ammonite zonation [doubt is cast on the existence of the much-cited "*Barroisiceras haberfellneri* Zone", Kennedy (personal communication)] is provisionally linked with the presence of *Marthasterites furcatus* (Deflandre) in the "2e Sous-étage" or the upper part of Coquand's "1er étage": the Coniacian in the type area (Verbeek, 1977a; van Hinte, 1979; Damotte, 1980). By first-order correlation the entry of *M. furcatus* is linked to the entry of the *Dicarinella concavata* group, i.e. *D. primitiva* (Dalbiez). For practical purposes this combined event can be used to define the base of the Coniacian Stage.

### Coniacian

The lower boundary is discussed above. In itself the interval represented by the stage seems to be inordinately short, hardly more than a single recognizable biozone. A succinct discussion of the stage, and its type area can be found in van Hinte (1979) and Seronie-Vivien (1980a).

The top of the stage (i.e. the base of the Santonian) can pragmatically be placed at the appearance of *Dicarinella* (*Marginotruncana* auct.) *concavata* (Brotzen) in appreciable numbers (Wonders, 1980). According to Porthault (*in* Donze *et al.*, 1970) the Upper Coniacian-Lower Santonian is recognizable by the presence of *Marginotruncana paraconcavata* (see also Robaszynski & Caron, 1979). A useful heteroheliced taxon is *Gublerina* (*Sigalia* auct.) *deflaensis* (Sigal), the range of which practically coincides with the Santonian.

In terms of calcareous nannofossil zonation the upper part of the Coniacian is placed in the zones of *Broinsonia lacunosa* and/or *Micula staurophora*; the boundary with the Santonian slightly higher, at the entry of *Rucinolithus hayi* (Stover). Good first-order correlations between planktic Foraminifera and calcareous nannofossils are not available from land sections in Western Europe (Wonders, 1980; Robaszynski & Amédro, 1980). In the dinoflagellate zonation the base of the Santonian is very close to the entry of *Senoniansphaera protrusa*.

## 6. Correlation with the magnetic stratigraphy

The Mid-Cretaceous coincides with the larger part of the Cretaceous Normal palaeomagnetic Interval. However, two reversed zones have been reported: one near the top of the *T. breggiensis* Zone (consisting of two closely spaced small zones), and the other in the *R. globotruncanoides*-*R. cushmani* Zones consisting of three closely spaced reversed intervals combined with normal and intermediate directions. The latter group was christened the "Quero-Schevenin Mixed Zone" by Vandenberg & Wonders (1979). The results were obtained from pelagic limestones of the Southern Alps in Northern Italy, and could be dated accurately with planktic foraminiferal assemblages. The Albian reversals are considered to be very probably identical to the reversals reported by Green & Brecher (1974) and Jarrard (1974) from Albian deposits of Site 263 of the Deep Sea Drilling Project.

## 7. Correlation with radiometric time-scales

Van Hinte (1976) has used a numerical time-scale from literature compilations available at the time of publishing. This time-scale is still very widely used. In the Mid-Cretaceous interval several other, slightly deviating values have been proposed, the last of which (by Odin & Kennedy, 1982) is given in the last radiometric age column of Figure 1. It should be noted that, apart from the Albian-Cenomanian boundary, which is now rather firmly dated at  $95 \pm 1$  Ma, the proposed values are not considerably different from those proposed by earlier authors.

## 8. Correlation with ammonite Zones

Recent papers by Robaszynski & Amédro (1980), and Robaszynski *et al.* (1982) have added valuable first-order correlations between microfossil and ammonite zonations. Even so, sediments containing abundant planktic Foraminifera, and those with abundant ammonites, seem to be mutually exclusive, and intercorrelation remains based on a good deal of conjecture.

However, some events in microfossil biostratigraphy can be placed with reasonable accuracy in relation to ammonite biostratigraphy, if not on a very precise scale. The entrance of *Planomalina buxtorfi* (Gandolfi) which is very close to the appearance of *Thalmaninella* (*Rotalipora* auct.) *appenninica* (Renz), and which represents a well-recognizable biostratigraphic level, is certain to be close to the *Stoliczkaia dispar* Zone (Moullade, 1966). The exit of *Planomalina buxtorfi* (Gandolfi), very close to the appearance of the *brotzeni-globotruncanoides* group of *Rotalipora*, is within the *S. dispar* Zone. Several microfossil workers have used the *buxtorfi* exit as a marker for the Albian-Cenomanian boundary, which may therefore be somewhat below the classical, ammonite-based boundary. *Rotalipora cushmani* (Morrow) has been reported from several localities in formations firmly placed in the *Acanthoceras rhotomagense* Zone (e.g. Marks, 1967; Robaszynski & Amédro, 1980). There is also little doubt that the extinction of *R. cushmani* is near the top of the *Metoicoceras geslinianum* Zone (Robaszynski & Amédro, 1980; Porthault *et al.*, 1966). *Neocardioceras juddii* and *Watinoceras coloradoense*, somewhat doubtfully present in the classical deposits of the Cenomanian and Turonian (Robaszynski *et al.*, 1982) very probably have a distribution very close to the *W. archaeocretacea* Zone.

The important marker *Praeglobotruncana* (*Helvetoglobotruncana* auct.) *helvetica* (Bolli) is reported to enter in the upper range of *Mammites nodosoides* in the Boulonnais (Robaszynski & Amédro, 1980), but together with the entrance of *C. woollgari* in Central France (Robaszynski *et al.*, 1982). There are several indications that the

*Ammonites texanum* Zone is at least in part coeval with the range of *Dicarinella concavata* (Dalbiez). A great deal of finer order correlation between ammonite and microfossil zonations, based on identical samples or samples closely spaced from sequences containing both groups of taxa, has still to be done. The correlation presented here is very tentative.

For want of an improved one, the zonation with ammonites in the column headed "Tethys" is the one presented by van Hinte (1976) and others (Figure 1) and almost certainly represents a zonation frowned upon by ammonite colleagues. It could and should be replaced presently by a better one, which is, however, beyond the ken of this author. Particularly the Middle Albian still appears to be a lacuna in well-documented ammonite successions; the essentially boreal group of Hoplitidae apparently serving in the "tethyan" region of southern France.

## 9. Concluding remarks

The results of recent teamwork towards establishing integrated biozonations, as presented in this paper, obviously represents only a blurred snapshot of reality, coloured by subjective evaluation. For the time being it may, however, be helpful to give an idea of the possibilities for further refinement of zonation by means of biological events in the Mid-Cretaceous. Microbiostratigraphy thus proves to be quite useful for chronostratigraphic evaluation of samples from tropical-subtropical marine pelagic deposits; yet it also proves to be still a far cry from the ideal situation. Only in the Turonian does a combined approach with planktic Foraminifera and calcareous nannofossils seem to give a resolution of one biozone per Ma; a somewhat similar resolution seems to be possible in the Cenomanian. The Albian, which according to the latest data has a duration of 10–12 Ma, is still not covered by more than about nine biozones, of which five are in the Upper Albian. This is far from the precision presumably reached by ammonite biostratigraphy.

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