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MICROFOSSIL BIOSTRATIGRAPHY AND STAGE-STRATOTYPES OF THE CRETACEOUS[1]

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ABSTRACT

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Correlation of the most recent Cretaceous zonations based on calcareous nannoplankton, planktonic foraminifera and calpionellids allows more precise determination of the relative position of some Cretaceous stage-stratotypes in the standard chronostratigraphical scale. In particular, those of the Santonian, Campanian and Maastrichtian stratotypes seem to be very limited in time-span. It is possible to overcome these limitations and to some extent also the problems concerning their recognition and traceability by a pragmatic extension of the type-sections and by the introduction of auxiliary hypostratotypes in the type areas. However, it is concluded that designation of one or more independent reference sections for Upper Cretaceous stages is a preferable alternative which should receive more attention. In this way also a more useful section could be proposed for the Cenomanian, Turonian and Coniacian stages.

INTRODUCTION

The last decade has shown the first significant advances in the application of calcareous nannoplankton in stratigraphical studies of the marine Cretaceous. As far as time-significance and degree of detail are concerned, the application of Cretaceous nannoplankton biostratigraphy to relative age-determinations and long-distance correlations are becoming more and more comparable to those achieved by means of the study of coeval planktonic foraminifera. In comparison with Tertiary microfossil biostratigraphy the value of Cretaceous nannofossils may be potentially greater than that of Cretaceous foraminifera. The common occurrence of a diversified nannoplankton flora in open marine sediments, the very small amount of sample material needed for an age determination as well as the normally simple and fast method of preparation and analysis of the microscopic slides are other factors which lead this group of fossils to be increasingly more attractive for biostratigraphical application, particularly at this time of increasing access to oceanic samples of, among others, Cretaceous rocks. In comparison with the Late Albian and younger Cretaceous groups of keeled planktonic foraminifera *(Rotalipora, Globotruncana),* which have provided the usual foraminiferal markers for regional and interregional correlations, it seems that the general species density and diversity of the nannoplankton flora are less drastically reduced in polar directions by environmental factors. Although fluctuations in frequency of individual nannoplankton species probably have occurred along a temperature and depth gradient more often in time and space than so far realized, the hypothesis that the majority of the species maintained a (virtually) cosmopolitan distribution pattern throughout the time of their existence remains in practice as yet unchallenged. Only a few species seem to have lived exclusively or nearly so in the Cretaceous Tethyan realm.

It is clear, however, that due to the exceptionally small size of the fossils this group inherently possesses a number of features which easily gives rise to specific misinterpretation and confusion among specialists. For that reason it is a most important requirement in nannoplankton biostratigraphy to exercise the utmost care in selecting zonal markers. At present the problems of Cretaceous nannoplankton systematics are still great but, fortunately, a clear morphologic description of a form demonstrable as a datum-indicator is basically more important in applied biostratigraphy. The correct labelling of the marker after comparison with known species, many of which are poorly described in the literature, can follow at leisure.

This paper, which may be regarded as a supplement of an earlier one (SISSINGH, 1977), does not deal with nannofossil systematics. Its primary objective is essentially the chronostratigraphical positioning of Cretaceous nannoplankton datum-planes and zones. Additional study of the distribution of planktonic foraminifera in the Dyr el Kef section in Western Tunesia allowed direct correlation of the Upper Cretaceous zonation of POSTUMA (1971) and VAN HINTE (1976) with the corresponding nannoplankton zonation previously proposed by the present author (SISSINGH, 1977). As a consequence of this exercise, a few alternative interpretations of chronostratigraphical position for some nannofossil datums and zones became apparent. More significantly, the first-order cor-

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relation of these zonations provided a better tool to control the relative positions of most of the Cretaceous stage-stratotypes.

PRESENT STATE OF THE ART

The various studies of Cretaceous nannoplankton assemblages, mainly derived from surface sections in Western Europe, North America and from core material collected during the JOIDES Deep Sea Drilling Project, have indicated the great potential stratigraphical significance of this group of organic remains. A relatively large number of datum planes and zones have been proposed during the recent years. Whilst several of these have proven by additional research to be ephemeral, several well defined biohorizons have become generally accepted, since they are recorded at a continuously increasing number of scattered localities at (sometimes assumedly) corresponding stratigraphical levels. These datums were included in the zonation recently proposed by the writer (SISSINGH, 1977) (Fig. 1).

AGES/STAGES	CALCAREOUS NANNOPLANKTON ZONES			DATUM INDICATORS
				Last Nephrolithus frequens
MAASTRICHTIAN	26		Nephrolithus frequens	First Nephrolithus frequens
	25	C	Arkhangelskiella cymbiformis	First Lithraphidites quadratus
		B		First Arkhangelskiella cymbiformis
		A		Last Reinhardtites levis
	24		Reinhardtites levis	Last Tranolithus phacelosus
	23	B	Tranolithus phacelosus	Last Aspidolithus ex gr. parcus
		A		Last Reinhardtites anthophorus
CAMPANIAN	22	B	Quadrum trifidum	First Reinhardtites levis
		A		First Quadrum trifidum
	21	C	Quadrum nitidum	Last Ceratolithoides arcuatus
		B		First Ceratolithoides arcuatus
		A		First Quadrum nitidum
	20		Ceratolithoides aculeus	First Ceratolithoides aculeus
	19	B	Phanulithus ovalis	Last Bukryaster hayi
		A		Last Marthasterites furcatus
	18	B	Aspidolithus parcus (s.l.)	First Bukryaster hayi
		A		First Aspidolthus ex gr. parcus
	17		Phanulithus obscurus	First Phanulithus obscurus
SANTONIAN	16		Lucianorhabdus cayeuxii	First Lucianorhabdus cayeuxii
	15		Reinhardtites anthophorus	First Reinhardtites anthophorus
	14		Micula staurophora (s.l.)	First Micula ex gr. staurophora
CONIACIAN	13		Marthasterites furcatus	First Marthasterites furcatus
	12		Lucianorhabdus maleformis	First Lucianorhabdus maleformis
TURONIAN	11		Quadrum gartneri	First Quadrum gartneri
CENOMANIAN	10		Microrhabdulus decoratus	First Microrhabdulus decoratus
	9		Eiffellithus turriseiffeli	First Eiffellithus turriseiffeli
ALBIAN	8		Prediscosphaera columnata	First Prediscosphaera columnata
APTIAN	7	B	Chiastozygus litterarius	Last Micrantholithus obt./hosch.
		A		First Chiastozygus litterarius
BARREMIAN	6		Micrantholithus hoschulzii	Last Calcicalathina oblongata
	5		Lithraphidites bollii	Last Speetonia colligata
HAUTERIVIAN	4	B	Cretarhabdus loriei	Last Palaeopontosphaera salebrosa
		A		First Cretarhabdus loriei
VALANGINIAN	3		Calcicalathina oblongata	First Calcicalathina oblongata
BERRIASIAN	2		Cretarhabdus crenulatus	First Cretarhabdus crenulatus
	1		Nannoconus steinmannii	First Nannoconus steinmannii
TITHONIAN				

Fig. 1
Review of the Cretaceous calcareous nannoplankton zonation (Sissingh, 1977) (excluding alternative markers of zonal boundaries).

Some names of zones and datum indicators have been updated and some species have been redefined. This results in the following corrections:

(1) *Calculites* PRINS & SISSINGH 1977 is a junior synonym of *Phanulithus* WIND & WISE 1977. For this reason the zonal names *Calculites ovalis* and *Calculites obscurus* are replaced by *Phanulithus ovalis* and *Phanulithus obscurus,* respectively.

(2) *Tetralithus* GARDET 1955 and its genero types *T. pyramidus* GARDET 1955 are regarded as nomina dubia (see MANIVIT ET AL., 1977). As a consequence the following names of datum indicators have been changed: *Tetralithus pyramidus* GARDET 1955 = *Quadrum gartneri* PRINS & PERCH-NIELSEN 1977; *Tetralithus nitidus* MARTINI 1961 = *Quadrum nitidum* (MARTINI 1961) PRINS & PERCH-NIELSEN 1977; *Tetralithus trifidus* (STRADNER 1961) BUKRY 1973 = *Quadrum trifidum* (STRADNER 1961) PRINS & PERCH-NIELSEN 1977.

The zonal names have been changed accordingly.

(3) The specimens of *Prediscosphaera* present in the Albian appear to belong to *P. columnata* (STOVER 1966) MANIVIT 1971 and not to *P. cretacea* (see MANIVIT ET AL., 1977). For this reason the name of the Albian *Prediscosphaera cretacea* Zone is replaced by *Prediscosphaera columnata* Zone.

Comparison of this zonation with the geochronological scale shows that the zonal subdivision proposed for the Lower Cretaceous includes zones which lasted three or more millions of years. The zones suggested for the Upper Cretaceous, however, appear to have an average duration time of only one to two millions of years.

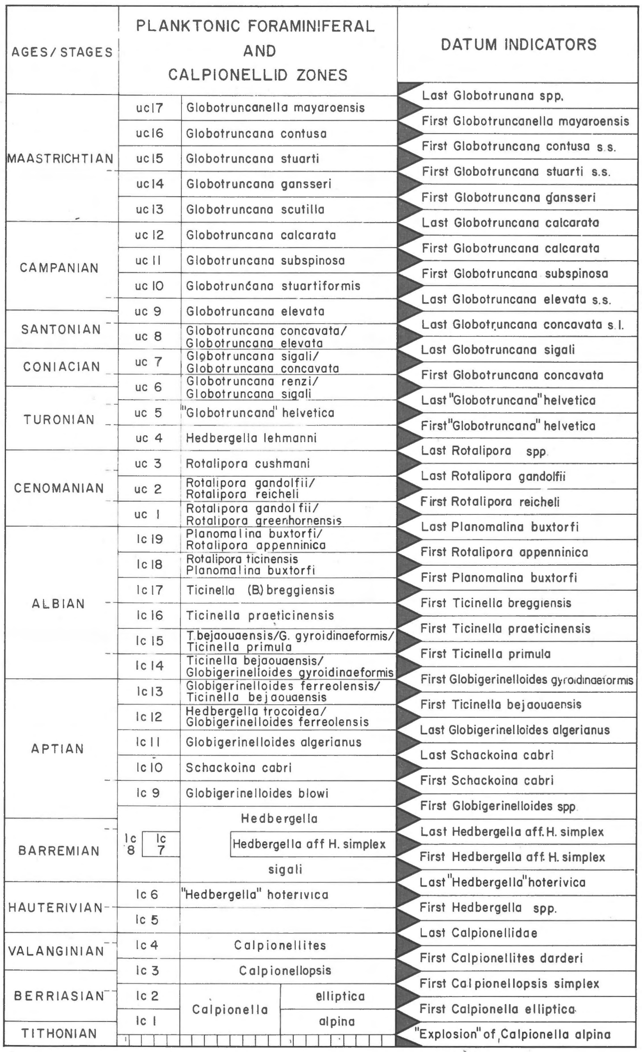
The presently assumed possibilities for application of planktonic foraminifera in Cretaceous biostratigraphy are probably best summarized by VAN HINTE (1976). The foraminiferal subdivision presented in this paper is a modification of the zonal scheme of VAN HINTE (1972) and includes, among others, data from MOULLADE (1966) whose sections were partly restudied for calcareous nannoplankton by THIERSTEIN (1971, 1973). The wide geographical recognition of several of the foraminiferal ranges and zones also allows some generalisations on the applicability of this subdivision (Fig. 2). The correlation of this biozonation with the geochronological scale suggests that the average duration of most foraminiferal zones is approximately two to three millions of years, with the exception of those covering the Aptian, Albian and Maastrichtian stages which seem to have lasted on the average between one and two millions of years.

CORRELATION OF NANNOPLANKTON, FORAMINIFERAL AND CALPIONELLID ZONATIONS

In the nannoplankton study of the Dyr el Kef section in Western Tunesia the planktonic foraminiferal zonation of

POSTUMA (1971) was applied as a tool to indicate the various Upper Cretaceous stage boundaries. Comparison of this zonation with that recently proposed by VAN HINTE (1976) shows that the two definitions of stage boundaries using planktonic foraminifera do not always correspond. As a consequence the chronostratigraphical interpretation of nannoplankton biohorizons and zones needs some further consideration. The foraminiferal distribution chart compiled (by Postuma) of the Dyr el Kef section was therefore re-interpreted and a first-order correlation established between the zonations of POSTUMA (1971) and VAN HINTE (1976), and the author's corresponding nannoplankton zonation (SISSINGH, 1977) (Fig. 3). As a result of that exercise the following alternative interpretations of the position of Upper Cretaceous nannoplankton datum planes and zones emerged.

The base of the *Quadrum gartneri* Zone (zone 11) is situated above the Cenomanian/Turonian boundary, if this boundary is equated with the extinction level of *Rotalipora cushmani* (cf. VAN HINTE, 1976) instead of the biohorizon defined by the first occurrence of *Globotruncana helvetica* (cf. POSTUMA, 1971). This assumption is in line with the view given by VERBEEK (1976) and not in conflict with the data presented by CEPEK & HAY (1969).



AGES/STAGES		PLANKTONIC FORAMINIFERAL AND CALPIONELLID ZONES	DATUM INDICATORS
			Last Globotrunana spp.
MAASTRICHTIAN	uc17	Globotruncanella mayaroensis	First Globotruncanella mayaroensis
	uc16	Globotruncana contusa	First Globotruncana contusa s.s.
	uc15	Globotruncana stuarti	First Globotruncana stuarti s.s.
	uc14	Globotruncana gansseri	First Globotruncana gansseri
	uc13	Globotruncana scutilla	Last Globotruncana calcarata
CAMPANIAN	uc12	Globotruncana calcarata	First Globotruncana calcarata
	uc11	Globotruncana subspinosa	First Globotruncana subspinosa
	uc10	Globotruncana stuartiformis	Last Globotruncana elevata s.s.
SANTONIAN	uc9	Globotruncana elevata	Last Globotruncana concavata s.l.
	uc8	Globotruncana concavata/ Globotruncana elevata	Last Globotruncana sigali
CONIACIAN	uc7	Globotruncana sigali/ Globotruncana concavata	First Globotruncana concavata
	uc6	Globotruncana renzi/ Globotruncana sigali	Last "Globotruncana" helvetica
TURONIAN	uc5	"Globotruncana" helvetica	First "Globotruncana" helvetica
	uc4	Hedbergella lehmanni	Last Rotalipora spp.
CENOMANIAN	uc3	Rotalipora cushmani	Last Rotalipora gandolfii
	uc2	Rotalipora gandolfii/ Rotalipora reicheli	First Rotalipora reicheli
	uc1	Rotalipora gandolfii/ Rotalipora greenhornensis	Last Planomalina buxtorfi
ALBIAN	lc19	Planomalina buxtorfi/ Rotalipora appenninica	First Rotalipora appenninica
	lc18	Rotalipora ticinensis Planomalina buxtorfi	First Planomalina buxtorfi
	lc17	Ticinella (B.) breggiensis	First Ticinella breggiensis
	lc16	Ticinella praeticinensis	First Ticinella praeticinensis
	lc15	T. bejaouaensis/G. gyroidinaeformis/ Ticinella primula	First Ticinella primula
	lc14	Ticinella bejaouaensis/ Globigerinelloides gyroidinaeformis	First Globigerinelloides gyroidinaeformis
APTIAN	lc13	Globigerinelloides ferreolensis/ Ticinella bejaouaensis	First Ticinella bejaouaensis
	lc12	Hedbergella trocoidea/ Globigerinelloides ferreolensis	Last Globigerinelloides algerianus
	lc11	Globigerinelloides algerianus	Last Schackoina cabri
	lc10	Schackoina cabri	First Schackoina cabri
	lc9	Globigerinelloides blowi	First Globigerinelloides spp.
BARREMIAN	lc8	Hedbergella sigali	Last Hedbergella aff. H. simplex
	lc7	Hedbergella aff H. simplex	First Hedbergella aff. H. simplex
			Last "Hedbergella" hoterivica
HAUTERIVIAN	lc6	"Hedbergella" hoterivica	First Hedbergella spp.
	lc5		Last Calpionellidae
VALANGINIAN	lc4	Calpionellites	First Calpionellites darderi
	lc3	Calpionellopsis	First Calpionellopsis simplex
BERRIASIAN	lc2	Calpionella elliptica	First Calpionella elliptica
	lc1	Calpionella alpina	"Explosion" of Calpionella alpina
TITHONIAN			

Fig. 2
Review of the Cretaceous planktonic foraminiferal-calpionellid zonation (Van Hinte, 1976) (excluding alternative markers of zonal boundaries).

Some shifting of the *Lucianorhabdus maleformis* Zone (12) is necessary if the Turonian/Coniacian boundary is no longer equatable with the extinction level of *'Globotruncana' helvetica* (cf. POSTUMA, 1971) but falls within the next higher zone (cf. VAN HINTE, 1976). At present the Turonian/Coniacian boundary is retained within the *Lucianorhabdus maleformis* Zone, since its delimiting marker *Marthasterites furcatus* (13) is not known from Turonian deposits (cf. e.g. MANIVIT, 1971; VERBEEK, 1976).

Similarly, the Coniacian/Santonian boundary must lie higher within the *Micula staurophora* (s.l.) Zone (14), if this boundary is equated with the first occurrence of *Globotruncana elevata* or the last occurrence of *Globotruncana sigali* and *G. schneegansi* (cf. VAN HINTE, 1976) rather than with the first occurrence of *Globotruncana concavata* (cf. POSTUMA, 1971).

If the last occurrence of *Globotruncana carinata/concavata* does not mark the Santonian/Campanian boundary (cf. POSTUMA, 1971), but falls lower, within the Santonian (cf. VAN HINTE, 1976), then the base of the *Phanulithus obscurus* Zone (17) must lie within the (Upper) Santonian. However, the boundary between the stages lies below the base of the *Aspidolithus parcus* (s.l.) Zone (18), since the first appearance of *Aspidolithus* ex gr. *parcus* is agreed to be in the Lower Campanian. A Santonian age for the base of the *Phanulithus obscurus* Zone is supported by the apparent presence of the zonal nominator in the Santonian Gingin Chalk in the Perth Basin, Australia (THIERSTEIN, 1974, p. 626).

THIERSTEIN (1973) studied a number of Lower Cretaceous sections in S.E. France for their nannoplankton content and was able to correlate his zonation with the Barremian to Albian foraminiferal zonation established by MOULLADE (1966). In figure 3 a similar correlation with that part of the planktonic foraminiferal zonation of VAN HINTE (1976) is shown. Also a correlation of the older part of the nannoplankton zonation with the Tithonian to Valanginian 'standard calpionellid zonation', valid for the Mediterranean realm, is given. No important discrepancies in chronostratigraphical interpretations are apparent from these correlations.

CHRONOSTRATIGRAPHICAL POSITION OF CRETACEOUS STAGE-STRATOTYPES

The juxtaposition of the nannoplankton, foraminiferal and calpionellid data allows discussion of the relative position of most Cretaceous stage-stratotypes on a firmer basis (Fig. 3).

The Berriasian stratotype at Berrias (S.E. France) was studied for its calpionellids by LE HEGARAT & REMANE (1968).

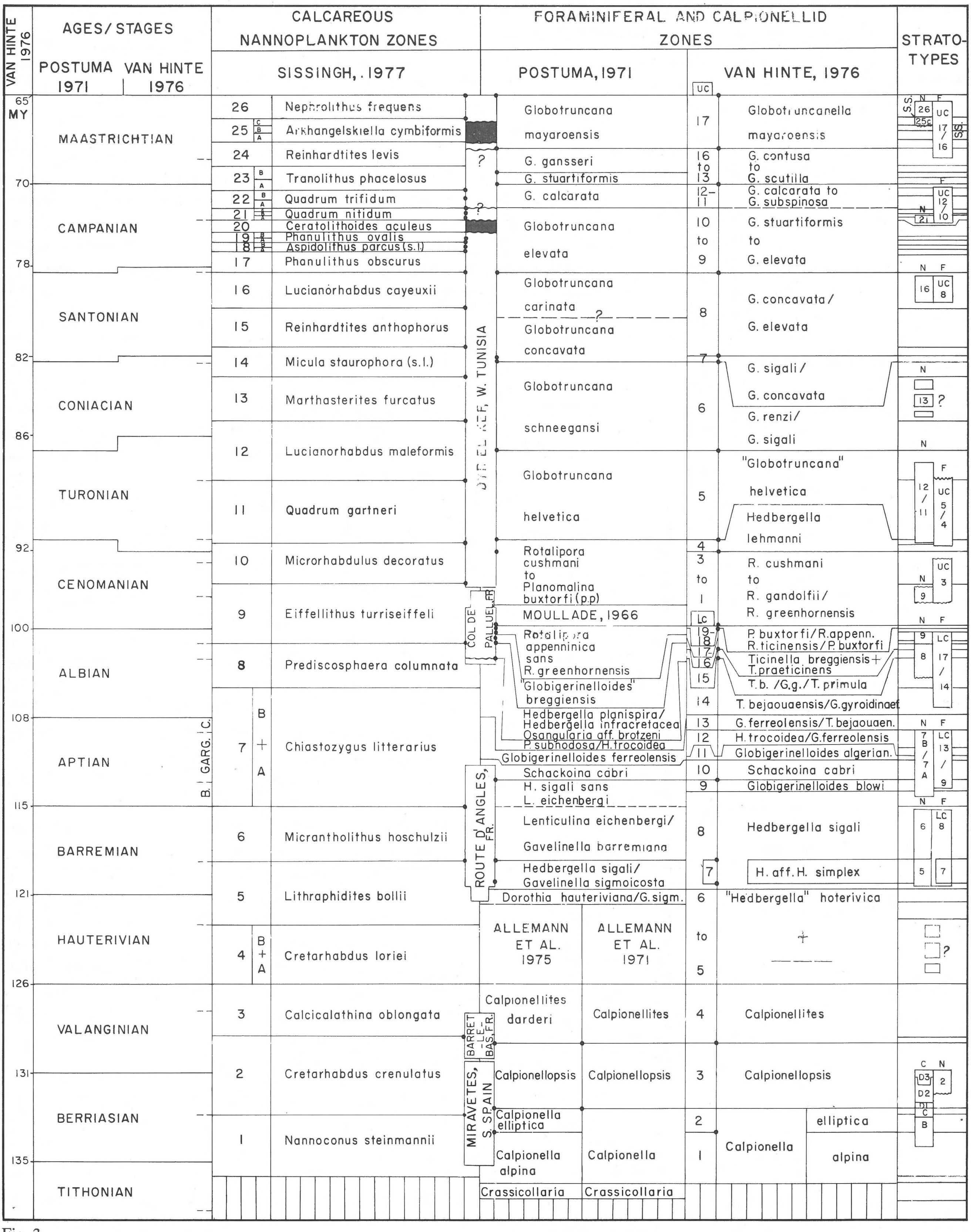


Fig. 3
Correlation of Cretaceous microfossil zonations and assumed position of stage-stratotypes based on calcareous nannoplankton (N), planktonic foraminifera (F) and calpionellids (C).

These authors recognized all their zones and subzones from Zone B to Zone D (subzone 3), which interval corresponds to that of the *Calpionella* Zone to *Calpionellopsis* Zone of ALLEMANN ET AL. (1971, 1975) and VAN HINTE (1976). THIERSTEIN (1973) examined nannoplankton from the upper part of the section only and there identified the *Cretarhabdus crenulatus* Zone (sensu THIERSTEIN, 1971) (zone 2, SISSINGH, 1977).

As far as the writer is aware, the Valanginian stratotype has not yet been studied for calpionellids and calcareous nannoplankton. Both groups may be absent or very rare.

THIERSTEIN (1973) studied the type Hauterivian deposits at Hauterive (Switzerland). However, the assemblages reported did not allow the present author to make a correlation with his nannoplankton zonation (SISSINGH, 1977). The position of this stage-stratotype can only be bracketed by the datums defined by the last occurrence of Calpionellidae (s.s) and the first occurrence of *'Hedbergella' hoterivica.*

The lower part of the Barremian type-section at Angles (S.E. France) falls in the *Lithraphidites bollii* Zone (5). The upper part of the type section is referred to the *Micrantholithus hoschulzii* Zone (6) (SISSINGH, 1977). The foraminiferal data presented by MOULLADE (1966) allow recognition of both the *Hedbergella* aff. *H. simplex* Zone (LC 7) and the *Hedbergella sigali* Zone (LC 8) of VAN HINTE (1976). The top of the *Hedbergella* aff. *H. simplex* Zone in the section virtually coincides with the base of the *Micrantholithus hoschulzii* Zone.

In the Bédoulian and Gargasian type sections, at La Bédoule and Gargas (S.E. France), which jointly represent the type Aptian, the lower and the upper informal subzones of the *Chiastozygus litterarius* Zone (7a and 7b) are recognizable (SISSINGH, 1977). According to FABRE-TAXY ET AL. (1965) both substage-stratotypes contain *Globigerinelloides ferreolensis* which MOULLADE (1966) and VAN HINTE (1976) consider to be confined to post-Bédoulian strata. The upper part of the Bédoulian stratotype is also said by Fabre-Taxy et al. to contain *Globigerinelloides algerianus,* a typical Gargasian marker. However, as *Schackoina* (ex gr.) *cabri* appears higher in this section, the specific determination of the preceeding *G. ferreolensis* and *G. algerianus* seem questionable and therefore correlation with Moullade's *Globigerinelloides ferreolensis* Zone seems not to be justified. Based on the presence of *Schackoina* (ex gr.) *cabri* close to the Bédoulian/Gargasian boundary and the occurrence of *Globigerinelloides esheri (= G. blowi?)* from the base of the type section, it seems more likely that the type Bédoulian largely correlates with the *Globigerinelloides blowi* Zone (LC 9) of VAN HINTE (1976). The restricted occurrence of *S.* (ex gr.) *cabri* in the basal type Gargasian strata could allow a correlation with the *Schackoina cabri* Zone (LC 10) and higher Aptian zones containing *G. ferreolensis. Ticinella* is not present in the Bédoulian-Gargasian interval, but it occurs from the uppermost, Clansayesian substage of the Aptian (MOULLADE, 1966).

The type Middle Albian 'Argiles tégulines' exposed at Côtes Noires de Moeslains, Courcelles and Villemoyenne (N.E. France) entirely belong to the *Prediscosphaera columnata* Zone (8). The type Upper Albian 'Marnes de Brienne' at Vallentigny (N.E. France) most likely belong to the *Eiffellithus turriseiffeli* Zone (9) (SISSINGH, 1977). The foraminifera at the latter locality were studied by MAGNIEZ-JANNIN (1975), who found *Ticinella primula* and *Hedbergella delrioensis* without *Rotalipora appenninica.* This association is most characteristic for the (middle and upper part of the) *'Globigerinelloides' breggiensis* Zone of MOULLADE (1966), which is equivalent to VAN HINTE's (1976) *Ticinella (Biticinella) breggiensis* Zone (LC 17). The type Middle Albian deposits at Courcelles and Villemoyenne yielded *Hedbergella infracretacea* (without *Ticinella bejaouensis, T. primula* and *H. trocoideax*) and for this reason might be correlatable with the lower part of the *Hedbergella planispira/H. infracretacea/Osangularia* aff. *brotzeni* Zone of MOULLADE (1966). These strata, however, may be correlatable with the *Ticinella praeticinensis* Zone (LC 16) of VAN HINTE (1976) if the absence of *T. praeticinensis and T. primula* is not considered significant. The type Lower Albian beds of Bois-du-Perchois (S.E. France) also contain *H. infracretacea* as the only planktonic marker species. Hence biostratigraphical assignment of the foraminiferal assemblages from the Lower Albian type deposits is not yet possible in detail, seemingly since palaeoecological factors precluded the presence of the crucial zonal markers.

The type Middle Cenomanian 'Craie de Théligny' near St. Ulphace (N.W. France) falls within the upper part of the *Eiffellithus turriseiffeli* Zone (sensu THIERSTEIN, 1973) (9) (SISSINGH, 1977). The occurrence of *Rotalipora cushmani* (as only species of the genus) indicates that the formation also correlates with the *Rotalipora cushmani* Zone (UC 3) (MARKS, 1967), the lower part of which, according to figure 3, overlaps stratigraphically with the uppermost portion of the *Eiffellithus turriseiffeli* Zone.

The sections at Fretevou, Ricoisne, Bourré and Chisseux (N. France), which comprise the type-Turonian, fall within the interval of the *Quadrum gartneri* Zone (11) and the lower part of the *Lucianorhabdus maleformis* Zone (12) (SISSINGH, 1977). The lower part of the composite Turonian typesection belongs to the *Hedbergella lehmanni* Zone (UC 4) (VAN HINTE, 1969; BELLIER, 1971) and yielded some *Praeglobotruncana* without *Rotalipora.* The younger type-Turonian beds do not contain planktonic foraminifera, but could range into the *'Globotruncana' helvetica* Zone (UC 5) (VAN HINTE, 1969). VERBEEK & WONDERS (1977) do not report *Q. gartneri* from the lowermost few meters of the basal type Turonian. Consequently, this interval, which apparently lies below the interval from which my lower Fretevou Chalk samples (SISSINGH, 1977) are taken, is referred to their *Gartnerago obliquum* Zone. It should be excluded from the diagnosis of the typesection for the Turonian according to MARKS (1977), as well as some higher beds.

The author has assumed (SISSINGH, 1977) that the type Coniacian strata at Cognac (S.W. France) approximately correlate with the *Marthasterites furcatus* Zone (13); the most reasonable conclusion for these virtually barren deposits.

The nannoplankton flora obtained from the very limited section representing the type-Santonian sediments at Javresac, a short distance West of Cognac, allows their assignment to the *Lucianorhabdus cayeuxii* Zone (16) (SISSINGH, 1977). SÉRONIE-VIVIEN (1972) reports *Globotruncana* cf. *bulloides* from the same locality, thus suggesting a correlation with the *Globotruncana concavata/G. elevata* Zone (UC 8) of VAN HINTE (1976).

The Campanian stratotype at Aubeterre (S.W. France) (sensu VAN HINTE, 1965 and others) apparently falls within the *Quadrum nitidum* Zone (21) (SISSINGH, 1977). VAN HINTE (1969) could only tentatively correlate the section with the interval from the upper *Globotruncana stuartiformis* Zone (UC 10) to the lower *Globotruncana calcarata* Zone (UC 12). On the correlation-scheme in figure 3 it is suggested that the top part of the type section probably does not extend into the *Globotruncana subspinosa* Zone (UC 11), but is still situated in the *Globotruncana stuartiformis* Zone. This conclusion is favourably supported by the study of *Bolivinoides* by VAN HINTE (1967). According to SÉRONIE-VIVIEN (1972) the Campanian/Maastrichtian boundary in the Aquitanian Basin is definable by the first occurrence of the larger foraminifer *Orbitoides media.* As a consequence of this assumption she referred the larger part of the Aubeterre section to the Maastrichtian. This opinion is not shared by COLIN (1974) and VAN HINTE (1976) and cannot be supported by the observations on the nannoplankton assemblage. Even if the absence of the marker *Quadrum trifidum* is not taken into account, the only possible Maastrichtian to which the deposits of Aubeterre could belong is the very restricted interval delimited by the extinction levels of *Globotruncana calcarata* and *Aspidolithus* ex gr. *parcus.* SÉRONIE-VIVIEN (1959, 1972), having rejected the section of Aubeterre as the Campanian stratotype, designated instead other sections in the vicinity of Cognac as representing the type Campanian. Among these sections those at Genté and Gimeux were studied for their nannoplankton assemblages by the author (SISSINGH, 1977). At Genté the assemblage is characteristic for the Lower Campanian interval of the *Aspidolithus parcus* (s.l.) Zone (18) to the *Ceratholitoides aculeus* Zone (20) and that studied from Gimeux belongs to the Santonian *Lucianorhabdus cayeuxii* Zone (16) and/or the Upper Santonian to lowermost Campanian *Phanulithus obscurus* Zone (17). Thus these deposits are older than those exposed at Aubeterre. As a compromise between the current difference in opinion concerning the location of the Campanian type section, it would seem possible to propose a composite stage-stratotype which includes both the Aubeterre section and one designated in the Grande Champagne, south of Cognac (cf. VAN GORSEL, 1973). In this way a better recognizable Campanian stratotype could become available, which represents a much larger part of the stage as currently in general use. This new concept of the stratotype would also be in agreement with its original description by COQUAND in 1858.

A drawback, however, would be that the *Globotruncana* assemblages reported by SÉRONIE-VIVIEN (1972) from the Cognac area are not diagnostic for any particular interval of the Campanian.

In the Lichtenberg section of the ENCI quarry at Maastricht (The Netherlands) the interval exposing Maastrichtian Chalk (Ma-Md), and overlying the Gulpen Chalk (Cr 4), represents the most current concept of the Maastrichtian stratotype and there the uppermost subzone of the *Arkhangelskiella cymbiformis* Zone (25c) and the suceeding *Nephrolithus frequens* Zone (26) are present (SISSINGH, 1977). The stratotype as thus defined is very poor in planktonic foraminifera. However, the underlying deposits contain richer planktonic assemblages. Therefore, the concept of the type Maastrichtian in the sense of older authors has been resumed by the inclusion of locally underlying Gulpen Chalk (Cr 4). It is thought that this change is permissable since there are already uncertainties about the downward extension of the stratotype (see VAN GORSEL, 1973) while no doubt exists about the Maastrichtian age of the Gulpen part of the section. Such a redefinition is also in agreement with an earlier description of the stage given by A. Dumont, who originally introduced the Maastrichtian.

The classification given by SEITZ (1952) defined the Upper Cretaceous stages in terms of ammonite and belemnite zones and it seems that his Campanian/Maastrichtian boundary is approximately co-incident with the top of the *Globotruncana calcarata* Zone, which datum, in foraminiferal biostratigraphy, is commonly equated with the same stage boundary. In the Maastrichtian type area Seitz's Campanian/Maastrichtian boundary is situated within a stratigraphical gap on top of a hardground in the Cr 3b subunit of the Gulpen Chalk (VAN GORSEL, 1973). The interval between this horizon and the base of the Maastrichtian Chalk in the stage-stratotype falls within the middle and lower part of the Maastrichtian and includes the Gulpen Chalk (sub)units Cr 3b (p.p.), Cr 3γ, Cr 3c and Cr 4. Thus, an auxiliary hypostratotype including these (sub)units could, in principle, be designated, in the type area, to supplement the traditional type section.

VAN HINTE (1969, 1972) regards the planktonic foraminiferal association from the Maastrichtian Chalk characteristic for the *Globotruncana contusa* Zone (UC 16) and the *Globotruncanella mayaroensis* Zone (UC 17), a conclusion in agreement with the data recently presented by BELLIER & VILLAIN (1975). In this interpretation, HOFKER's (1966) determination of *G. mayaroensis* from the basal Ma(coprolite) layer of the type-section is rightly questioned. However, correlation with the nannoplankton zonation strongly suggests that the Maastrichtian type-deposits (Cr 4 to Md) fall entirely within the *Globotruncanella mayaroensis* Zone.

DISCUSSION

Stages are meant to be typified by their stratotypes. The present proliferation of independent zonal schemes based on planktonic foraminifera, calcareous nannoplankton, microplankton, radiolaria and other fossil groups increases their significance as a standard of reference to test stratigraphical results. However, the practical importance of stage-stratotypes should not be over-estimated as general usage is now much more based upon known full (planktonic) faunal sequences than upon the actual stratotypic time-span. Recognizing the guidance value of stratotypes, it follows that it is a considerable advantage for the stratotype not only to be biostratigraphically recognizible, but to represent the stage as completely as possible in terms of biozones and timespan.

The study of both planktonic foraminifera and nannofossils from Cretaceous stratotypes indicates, particularly, that the current stratotypes for the Santonian, Campanian and Maastrichtian stages each represent only a small part of the complete stage as applied in stratigraphy. Data provided by VAN HINTE (1976) indicates that the duration of each of the time intervals represented by the stratotypes is probably not more than two million years, corresponding roughly to one third, or less, of the assumed total time span of these stages as generally used. Intensified by the scarcity of known age-diagnostic markers, the problems posed by incomplete sedimentary representation of these intervals yield these stratotypes unsatisfactory for stages defined as unifying correlation units. Moreover, the inaccuracy intervals in practical correlation exercises based on evolutionary lineages are estimated to be in the order of magnitude of one million years (DROOGER, 1974). Consequently the accuracy in isochroneity of long-distance correlations, based on evolutionary or unexplained biostratigraphical events, between the present, time-restricted stratotypes of the three youngest Cretaceous stages and other rock sequences is best considered to be very limited.

Existing feelings of dissatisfaction regarding the nature of the current Santonian, Campanian and Maastrichtian stratotypes could be reduced to some extent by a procedure which, in general, is pragmatic rather than accurate in historical exegesis. In order to offer better possibilities for world-wide correlation, one could reconsider the present concepts of the three stage-stratotypes under discussion and attempt to redefine the stratotypes in such a way that they equate better with the span of time assumed by general biostratigraphical usage.

It is questionable whether new stages should be introduced for the gaps present below and between the intervals occupied by the current Santonian, Campanian and Maastrichtian stratotypes. In addition to possible historical and procedural objections, this could well only increase the number of poorly recognizable and traceable stages. Moreover, it would damage the standard chronostratigraphical scale.

As already indicated, it is in principle possible to redefine the Campanian stratotype, without violation of the principle of priority, by combining the Aubeterre section with a Grande Champagne section still to be selected. In that way, the major part of the Campanian, according to current usage, would be covered by a composite section.

Similarly, the concept of the Maastrichtian stratotype, now most commonly comprising only the Maastrichtian Chalk (unit Ma-Md) exposed in the Lichtenberg section, near Maastricht, could be resumed in the sense of older authors (see SISSINGH, 1977), by inclusion of locally underlying Gulpen Chalk (unit Cr 4) and indication of a hypostratotype for the middle and lower part of the stage.

The same procedure could be followed for the Santonian. A hypostratotype with strata covering a larger time-interval than that shown in the unsatisfactory stratotype of a few meters of chalk situated to the west of Javresac, may possibly be found in the area near Cognac and Saintes.

It is doubtful whether such redefinitions of stagestratotypes would provide the improvement necessary to satisfy present day requirements, since the gain in age-diagnostic fossil assemblages would most probably be too limited.

Thus, it seems that more emphasis must be given to the only other possible solution: designation of an independent reference section which satisfies the requirements of modern biostratigraphy. Such a section (or sections) should comprise stages corresponding as much as possible to current biostratigraphical and geochronological concepts and expose soft sediments deposited in a consistently open marine ('oceanic') facies. Individual stages redefined in such a section, or sections, should obviously encompass the stratigraphical intervals represented by their classical stratotypes. The boundary between two successive stages should be selected within the interval stratigraphically situated between those occupied by the classical stratotypes of the two stages involved. The stage boundary could, for instance, be defined primarily by a lithostratigraphical horizon, which is secondarily correlatable or equetable with a particular 'global' biostratigraphical event (e.g. the first appearance of an ammonite, foraminiferal or nannoplankton marker species) and formally represent the base of the upper stage only. However, the acceptability and accuracy of this, 'golden spike', method is widely questioned and it could well be that, in sections which serve simultaneously as unit- and as boundary stratotype, the definition of the unit delimited by the two stage-boundaries is more important than the definition of the delimiting boundaries (cf. DROOGER, 1974). Certainly, after additional study of the transitional zones between successive stages, general agreement concerning the eventually selected stage-boundary marker is required. Preferably, boundary markers should be selected in such a pragmatic manner that damage to traditional correlations will be minimal.

By this method, the ease with which the Coniacian, Turonian and Cenomanian stages could be recognized would also be increased. Where the troublesome Coniacian stage is concerned, it is clear that the type section of virtually barren deposits cannot be supplemented sensibly with another, distinctly fossiliferous, Coniacian reference section in the vicinity of Cognac. Consequently, if no reference section is designated elsewhere, discussions regarding the Coniacian will remain as abstract as ever. Similar comments can be made regarding the Middle and Upper Turonian and also the Lower and Upper Cenomanian. The corresponding intervals in their stratotypes vary from virtually to completely barren of fossil remains.

However, in the case of the latter stage, it is fortunate that, in the type area, there exists the Lower Cenomanian section of 'Couches à *Orbitolina complanata*' seen at the classical locality of Ballon. This section could be used as a reference for further clarifications of this stratigraphical interval. The section at Mezières-Sous-Ballon is very usefull for the study of the Cenomanian-Turonian boundary problem (MARKS, 1977).

Surface sections apparently approaching the ideal, and easily accessible for repeated sampling, are known to be available in Tunesia. An actual proposal to designate stage-reference sections in that country, was made during the Sixth African Micropaleontological Colloquium held in April, 1974, in Tunis. Furthermore, a working group of specialists in various fossil groups was then established for the study of potential reference sections. The review of the relative stratigraphical position, recognition and traceability of the Upper Cretaceous stage-stratotypes, presented in this paper, strongly re-emphasises the importance and urgency of this search for an independent reference section, or sections, for these stages. The first results of the above mentioned working group are therefore awaited with interest.

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