31. UPPER CRETACEOUS PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY FROM THE RIO GRANDE RISE: SITE 516 OF LEG 72, DEEP SEA DRILLING PROJECT[1]

Wolfgang Weiss, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Federal Republic of Germany

ABSTRACT

During Leg 72 in the western South Atlantic, Cretaceous sediments were recovered only at Hole 516F (Rio Grande Rise). Late Cretaceous planktonic foraminifers were found in Cores 516F-89 through 516F-122 (between 964 and 1235 m sub-bottom); they are assigned to the late Coniacian to the latest Maestrichtian. Frequency and preservation of planktonic foraminifers are moderate in the upper Maestrichtian and deteriorate from there to the base. Only the upper Maestrichtian *Abathomphalus mayaroensis* Zone can be clearly delimited according to the generally accepted planktonic foraminiferal zonation; moreover, some of the more important zonal and stage boundary markers were not found. The Cretaceous/Tertiary boundary is well documented without any major hiatus, and in spite of the poorly recognized zonal boundaries, the Upper Cretaceous sequence is apparently continuous. There are possible correlations between planktonic foraminiferal distribution in Hole 516F and those in Site 356 (São Paulo Plateau) and Sites 357 and 21 (Rio Grande Rise).

INTRODUCTION

Hole 516F is situated near the crest of the Rio Grande Rise (western South Atlantic) in 1313 m of water depth (Fig. 1). At this site, a complete stratigraphic section of Upper Cretaceous through Recent sediments was recovered, terminating in basalt (Unit 8) of the Santonian-Coniacian at 1251 m sub-bottom.

Cretaceous foraminifers occur within Lithologic Units 5B (part) and 6. Subunit 5B (between 930 to 1000 m sub-bottom) consists of reddish brown nannofossil limestones and contains the Cretaceous/Tertiary boundary in Core 516F-89 (964 m sub-bottom). Unit 6 is characterized by greenish grey and reddish brown limestones interbedded with marly limestones in Subunit 6A (1000–1130 m sub-bottom) and greenish grey to dark grey recrystallized dolomitic limestones in Subunit 6B (1130–1240 m sub-bottom). Both the reddish and the greenish intervals are bioturbated. The planktonic foraminiferal distribution at Hole 516F is comparable to those established in well-known sections of corresponding age (Sites 21, 356, 357) However, some of the more important Upper Cretaceous planktonic index markers (such as *Globotruncana gansseri, G. calcarata*, and *G. elevata*) are not found. Therefore, the zonation based on planktonic foraminifers and the suggested age of the Upper Cretaceous deposits of Hole 516F discussed below is tentative except for the late Maestrichtian *Abathomphalus mayaroensis* Zone.

The specific composition of planktonic foraminifers and other characteristics of the studied samples are listed on the distribution chart in the Appendix (back-pocket); the distribution is shown in Figure 2.

Unless otherwise indicated, all core numbers in the text refer to Hole 516F.

[1] Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office).

BIOSTRATIGRAPHY

Coniacian-Santonian

Interval: Core 122 through Core 114, Section 5

The approximately 55 m of poorly lithified and recrystallized sediments (Core 125 through Core 119, Section 3) cannot be clearly delimited because of taxonomic difficulties. The lowermost microfaunal assemblage contains some very poorly preserved double-keeled planktonic foraminifers of the *Globotruncana renzi*-type, which were found in Section 516F-122-1. Within Core 119, the number of planktonic foraminifers distinctly increases. Globotruncanids (such as *G. coronata, G. paraconcavata, G. fornicata, G. sinuosa, G.* cf. *undulata, G.* cf. *concavata, G.* cf. *pseudolinneiana*, and *Archaeoglobigerina* cf. *blowi*) and heterohelicids (such as *Heterohelix* cf. *reussi, H. globulosa*, and *Ventilabrella eggeri*) occur in relatively low abundances; single-keeled globotruncanids were not found. No exact planktonic foraminiferal zonation or age assignment is given because these are mainly long-ranging planktonic species. The distribution of few specimens of *Globotruncana* cf. *concavata* (Core 119, Section 2, through Core 117) allows a possible subdivision of this interval. In Core 117, Section 1, the last occurrence of *G.* cf. *concavata* coincides with the first appearance of *Ventilabrella eggeri;* this horizon could be dated as middle to late Santonian.

Campanian

Interval: Sections 516F-114-4 through 516F-101-4

Well-known zonal markers of planktonic foraminifers are absent within this sequence. The Santonian/Campanian boundary discussed by Wonders (1980) was not clearly recognized at Hole 516F because neither *Globotruncana elevata* nor any true *G. asymetrica* (= *G. carinata*) could be identified. The boundary was placed, therefore, at the first appearance of *G. arca* at Core 114, Section 4. According to various references (Pessagno,

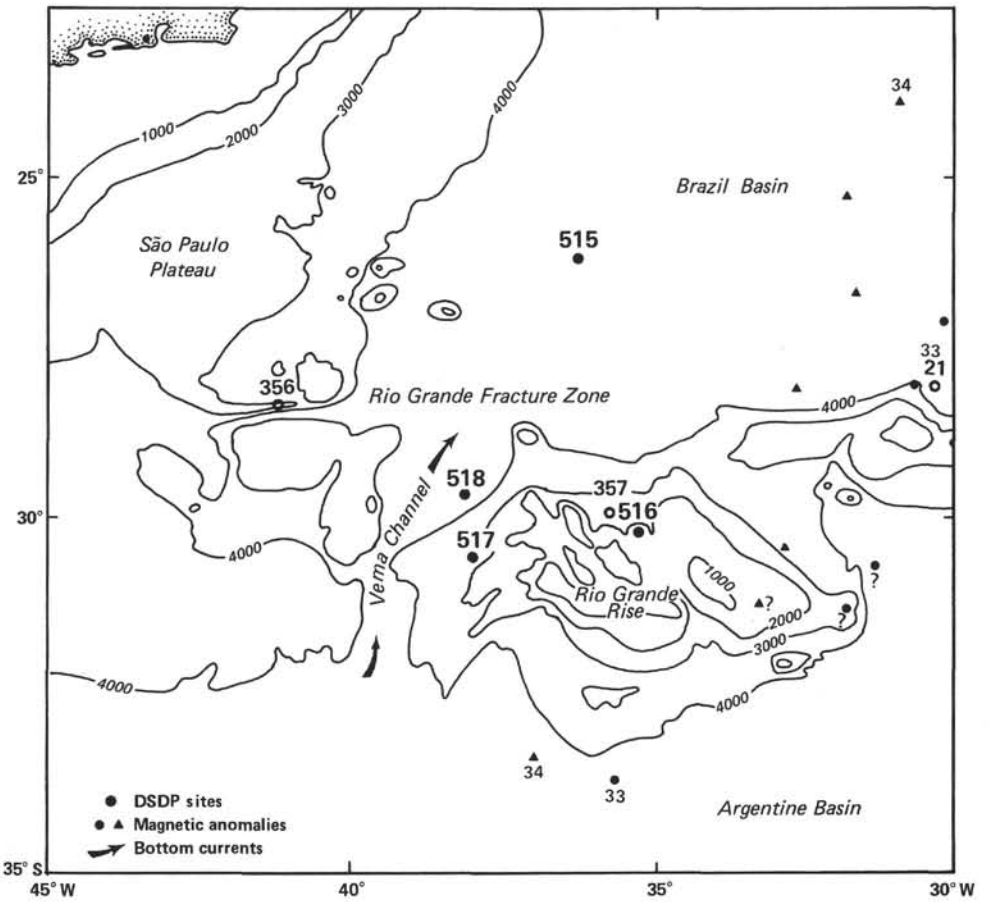


Figure 1. Locations of Sites 516 (Leg 72), 356 and 357 (Leg 39), and 21 (Leg 3).

1967; Petters, 1977), *G. arca* makes its biostratigraphic entrance in the lower Campanian.

The Campanian sequence is distinguished as follows:

1) *Globotruncana arca* Zone: Sections 516F-114-4 through 516F-112-3

Globotruncana renzi, G. coronata, G. paraconcavata, large specimens of *G. fornicata, G.* cf. *undulata, G.* cf. *pseudolinneiana, Archaeoglobigerina* cf. *blowi, G. arca, G.* cf. *asymetrica, Heterohelix reussi, H. globulosa, Pseudotextularia elegans, H. pulchra.*

P. elegans occurs together with *G. arca* at the base of the zone. *G.* cf. *asymetrica* has a very short range within this zone.

Within and at the end of the *G. arca* Zone, a sudden change in the planktonic foraminiferal assemblage becomes obvious; species belonging to the marginotruncanids (such as *G. renzi, G. coronata, G. paraconcavata, G.* cf. *undulata*, and *G.* cf. *pseudolinneiana*) disappear successively; they were followed in the overlying *G. ventricosa* Zone by those species belonging to the globotruncanids s.s. The disappearance of the multiserial heterohelicid *Ventilabrella eggeri* also characterizes this change, one typical of planktonic foraminiferal assemblages in the lowermost Campanian.

2) *Globotruncana ventricosa* Zone: Sections 516F-112-2 through 516F-104-5

Globotruncana fornicata, Archaeoglobigerina cf. *blowi, G. arca, G. rosetta, G. stuartiformis, G. stephensoni, G. ventricosa, G. linneiana, G. bulloides, G. subspinosa, Rugoglobigerina rugosa, G. obliqua; Heterohelix globulosa, Pseudotextularia elegans, H. pulchra, H. striata, H. planata, Pseudoguembelina costulata.*

G. ventricosa appears together with other species of the *elevata, arca*, and *linneiana* groups. They occur in relatively low abundance, especially in the upper parts of this zone. *Pseudoguembelina costulata* occurs first in Core 109, Section 1, with slightly striate or seemingly nonstriate specimens.

3) Unzoned Interval: Sections 516F-104-4 through 516F-101-4

Globotruncana fornicata, Archaeoglobigerina cf. *blowi, G. arca, G. rosetta, G. stuartiformis, G. stephensoni, G. linneianna, G. bulloides, Rugoglobigerina rugosa, G. obliqua, G.* cf. *mariei* (= *G. cretacea*), *G. scutilla, Globotruncanella havanensis; Heterohelix globulosa, Pseudotextularia elegans, H. pulchra, H. striata, H. planata, Pseudoguembelina costulata, H. pseudotesseca, Pseudotextularia* sp., *Planoglobulina carseyae.*

The first appearance of *Globotruncana scutilla* is at the base of the unzoned third interval of this sequence. It is distinguished by the entrance of two characteristic heterohelicids, which are named in open nomenclature

by scarcity of specimens: *Pseudotextularia* sp. could be the ancestor of *Planoglobulina carseyae*, and *Heterohelix* sp. is thought to grade into *Gublerina robusta*.

The first appearances of *P. carseyae* and *Globotruncana havanensis* mark the upper part of this unzoned interval, whereas forms such as *G. obliqua, G. bulloides*, and *Archaeoglobigerina* cf. *blowi* disappear. According to Premoli Silva and Boersma (1977), *Globotruncanella havanensis* first occurs within the *Globotruncana calcarata* Zone, indicating that this interval is late Campanian.

The Campanian sequence of Hole 516F has a thickness of about 107 m. Using the van Hinte (1976) numerical time scale, the calculated accumulation rate amounts to 1.3 cm/1000 yr. This approximate value is two times higher than that for Site 356, and three times higher than for Site 21.

The upper part of the *G. ventricosa* Zone contains a lithologic interval of an unusual red coloration between Sections 516F-108-2 and 516F-104-1. The planktonic foraminifers show no direct dissolution effects; nevertheless, their diversity and abundance decrease distinctly, and their preservation is very poor (see Appendix A). Some samples contain no planktonic foraminifers and only residues of badly preserved benthic foraminifers, indicating a strong plankton diminution during this interval. The same observations were made at other sites from various depths throughout the central and South Atlantic (Premoli Silva and Boersma, 1977). An explanation for the red coloration is not clear, but together with the bioturbation, it could be interpreted "as a result of the oxidising stage of open marine sediments originally deposited under reducing conditions (originally green sediments)" (Bonatti, cited in Premoli Silva and Boersma, 1977).

Maestrichtian

Interval: Section 516F-101-3 through Sample 516F-89-5, 29.3 cm

The Campanian/Maestrichtian boundary at Hole 516F could not be exactly determined on the basis of planktonic foraminifers. *Globotruncana calcarata*, the uppermost Campanian guide fossil, is absent, and other lower Maestrichtian zonal markers, such as *G. tricarinata* or *Rugotruncana subcircumnodifer*, were missing. Generally, the lower Maestrichtian could not be recognized by the absence of *G. calcarata*. Possible signs of a lithologic or biostratigraphic break were not observed in this interval. In addition, the middle Maestrichtian could not be identified by the absence of typical specimens of *G. gansseri*. The first appearance of *G. falsostuarti* in Section 516F-101-3 apparently, therefore, indicates the approximate position of the Campanian/Maestrichtian transition.

The Maestrichtian interval at Hole 516F was subdivided into two zones:

1) *Globotruncana falsostuarti* Zone: Sections 516F-101-3 through 516F-95-3

Globotruncana fornicata, G. arca, G. rosetta, G. stuartiformis, G. stephensoni, G. linneiana, Rugoglobigerina rugosa, G. scutilla, Globotruncanella havanensis, Globotruncana falsostuarti, G. gagnebini, G. aegyptiaca, R. milamensis, G. trinidadensis, R. cf. *scotti, R. hexacamerata; Heterohelix globulosa, Pseudotextularia elegans, H. pulchra, H. striata, H. planata, Pseudoguembelina costulata, H. pseudotessera, Pseudotextularia* sp., *H.* sp., *Planoglobulina carseyae, Gublerina robusta, G. cuvillieri, P. riograndensis, P. manuelensis, Pseudoguembelina kempensis, Pseudotextularia deformis.*

Globotruncana falsostuarti, G. gagnebini, and *G. aegyptiaca* occur at the base of this zone. The rugoglobigerinids are well developed with *Rugoglobigerina milamensis, R.* cf. *scotti*, and *R. hexacamerata. G. trinidadensis* has a short range during this interval, in contrast to Site 356 where it ranges into the *Abathomphalus mayaroensis* Zone. The heterohelicids show two multiserial events with the first occurrence of *Gublerina robusta* and of *G. cuvillieri* at Core 100 followed by *Planoglobulina riograndensis* and *P. manuelensis*, which have a limited distribution between Cores 99 and 96. In the upper part of the *Globotruncana falsostuarti* Zone, *Pseudoguembelina kempensis* and *Pseudotextularia deformis* were observed.

2) *Abathomphalus mayaroensis* Zone: Section 516F-95-2 through Sample 516F-89-5, 29.3 cm

Globotruncana arca, G. rosetta, G. stuartiformis, G. linneiana, Rugoglobigerina rugosa, Globotruncanella havanensis, Globotruncana gagnebini, G. aegyptiaca, R. cf. *scotti, R. hexacamerata, Abathomphalus mayaroensis, G. lamellosa, G. stuarti, G.* cf. *gansseri, G. contusa, G. insignis, G. conica, Globigerinelloides volutus, Globotruncana patelliformis, G.* cf. *elevata, G. galeoides; Heterohelix globulosa, Pseudotextularia elegans, H. pulchra, H. striata, H. planata, Pseudoguembelina costulata, Pseudotextularia* sp., *Planoglobulina carseyae, Gublerina robusta, G. cuvillieri, Pseudoguembelina kempensis, Pseudotextularia deformis, Racemiguembelina intermedia, R. fructicosa, Pseudoguembelina costata, H. semicostata, Planoglobulina brazoensis, P. acervulinoides, Pseudoguembelina palpebra, P. punctulata, Planoglobulina multicamerata, Pseudoguembelina* sp.

The *Abathomphalus mayaroensis* Zone is the best-recognized Upper Cretaceous planktonic foraminiferal zone at Hole 516F. The moderate preservation and the relatively high abundance of late Maestrichtian planktonic foraminifers indicate favorable and stable ecologic conditions. This zone is indicated by the first occurrence of *Abathomphalus mayaroensis*, accompanied by other globotruncanids, such as *Globotruncana lamellosa, G. stuarti, G.* cf. *gansseri*, and *G. contusa. G. fornicata, G. scutilla*, and *G. falsostuarti* disappear at the base of this zone. Whereas *G. rosetta, G. gagnebini, G.* cf. *gansseri, G. insignis, G. conica*, and *Globigerinelloides volutus* are restricted to the lower part of this zone, *Globotruncana patelliformis, G.* cf. *elevata*, and *G. galeoidis* were found in the upper part of the zone. The multiserial heterohelicids are represented with *Racemiguembelina fructicosa* and *Planoglobulina acervulinoides* and related forms; *P. multicamerata* is restricted to the upper part of this zone. *Pseudoguembelina costata* (= *P. excolata*) and *P. palpebra* are common throughout the section; the last species attempts a multiserial-like stage

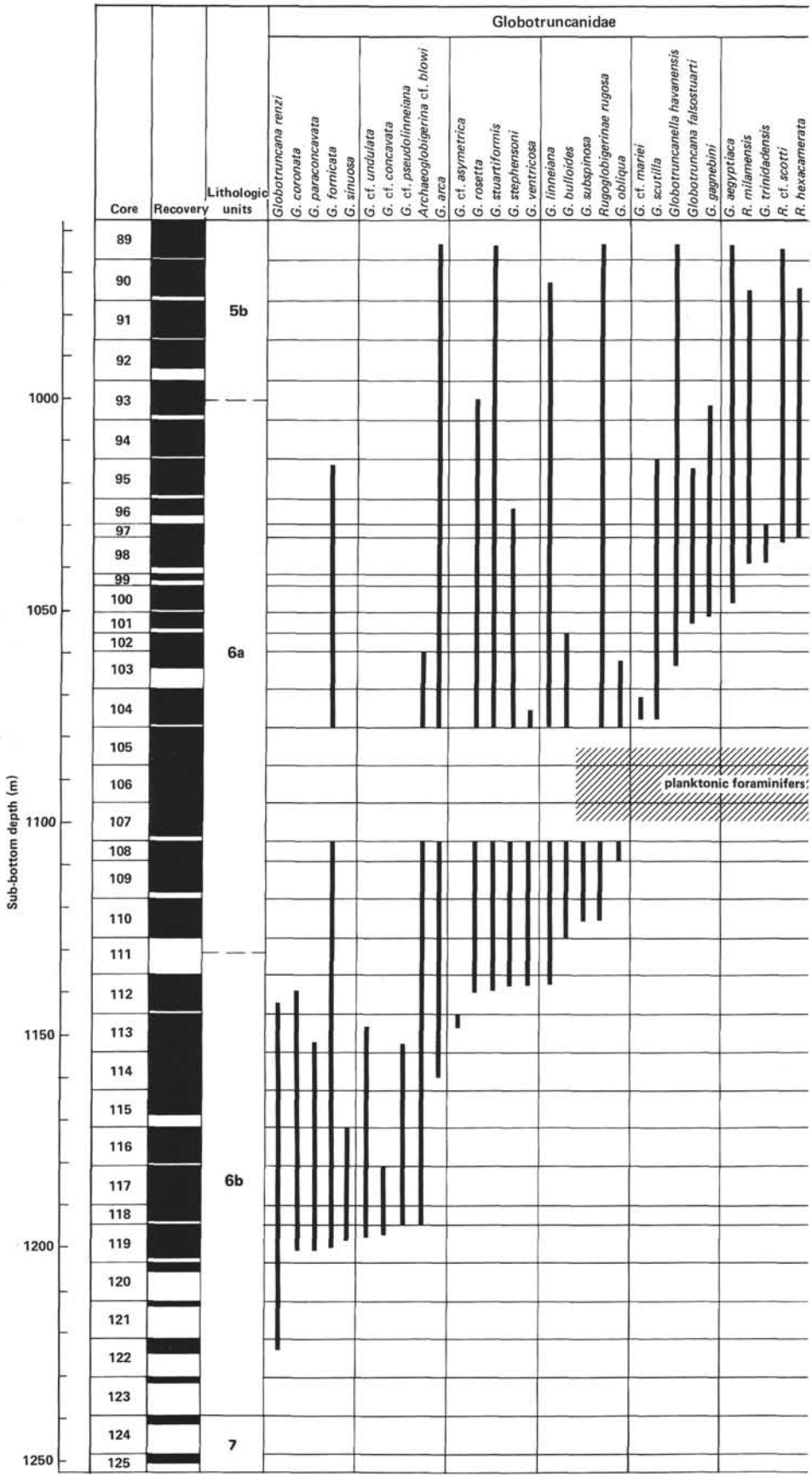
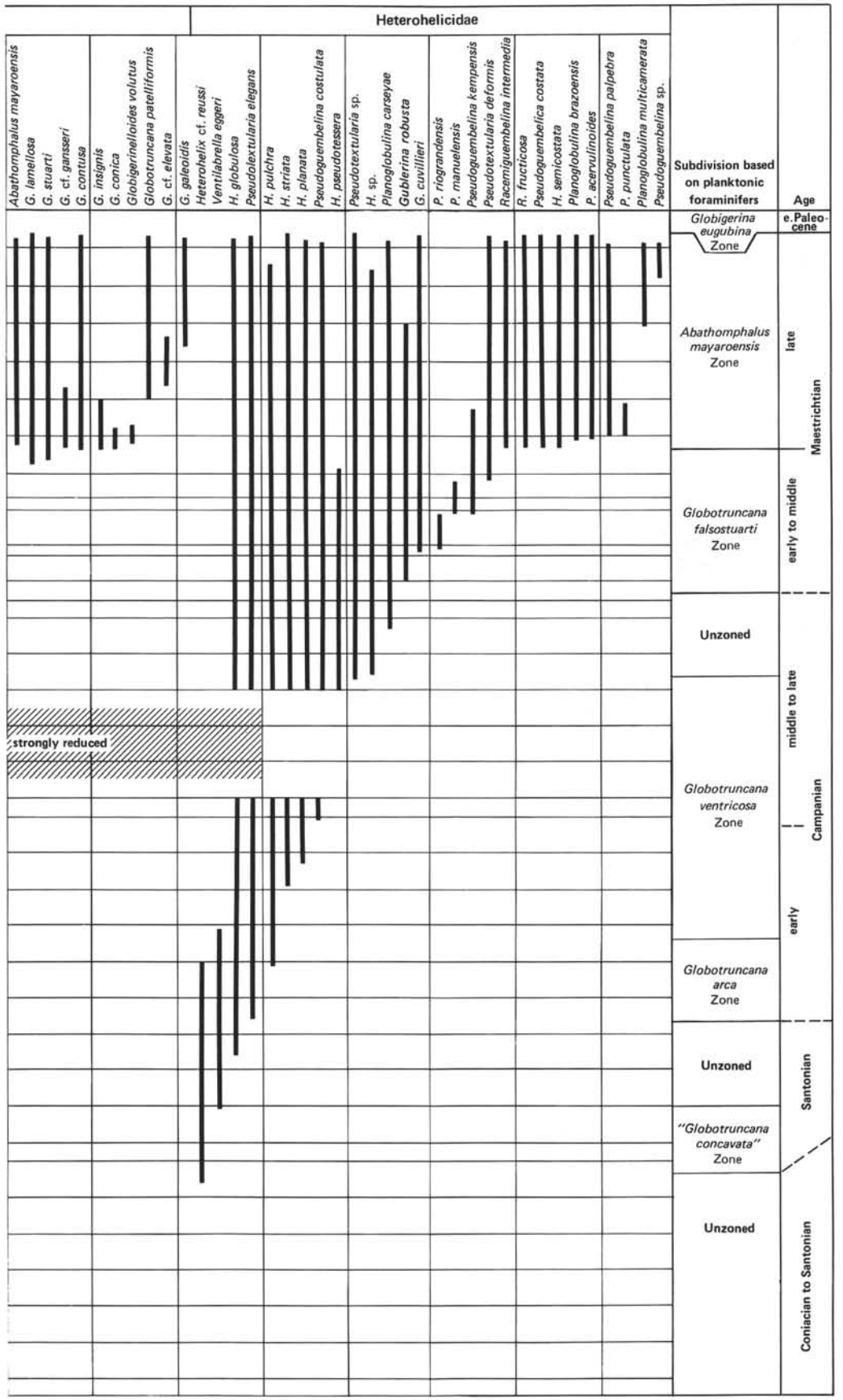


Figure 2: Range of planktonic foraminifers at Hole 516F, Coniacian/Santonian to upper Maestrichtian (water depth = 1313 m).


Heterohelicidae
Abathomphalus mayaroensis
G. lamellosa
G. stuarti
G. cf. gansseri
G. contusa
G. insignis
G. conica
Globigerinelloides volutus
Globotruncana patelliformis
G. cf. elevata
G. galeoidis
Heterohelix cf. reussi
Ventilabrella eggeri
H. globulosa
Pseudoextularia elegans
H. pulchra
H. striata
H. planata
Pseudoguembelina costulata
H. pseudotessera
Pseudotextularia sp.
H. sp.
Planoglobulina carseyae
Gublerina robusta
G. cuvillieri
P. riograndensis
P. manuelensis
Pseudoguembelina kempensis
Pseudotextularia deformis
Racemiguembelina intermedia
R. fructicosa
Pseudoguembelica costata
H. semicostata
Planoglobulina brazoensis
P. acervulinoides
Pseudoguembelina palpebra
P. punctulata
Planoglobulina multicamerata
Pseudoguembelina sp.
strongly reduced
Subdivision based on planktonic foraminifers
Age
Globigerina eugubina Zone
e.Paleo-cene
Abathomphalus mayaroensis Zone
late
Maestrichtian
Globotruncana falsostuarti Zone
early to middle
Unzoned
middle to late
Globotruncana ventricosa Zone
Campanian
early
Globotruncana arca Zone
Unzoned
Santonian
"Globotruncana concavata" Zone
Unzoned
Coniacian to Santonian

(*P.* sp.) in the upper part of the *Abathomphalus mayaroensis* Zone.

The Uppermost Cretaceous at Hole 516F is assigned to Sample 516F-89-5, 29.3–31.2 cm, and is characterized by a total extinction of all globotruncanids and heterohelicids. The following earliest Tertiary *Globigerina eugubina* Zone is present and indicates that no major hiatus exists at the Cretaceous/Tertiary boundary at this site.

Within the Maestrichtian interval, two other layers with conspicuous red coloration are noticed; the first red layer ranges between Sections 516F-96-2 and 516F-94-2, (dated as middle to late Maestrichtian, below the *Abathomphalus mayaroensis* datum line), whereas the second lies within the late Maestrichtian *A. mayaroensis* Zone between Sections 516F-92-2 and 516F-91-2. In contrast to the first interval of red coloration (Sections 516F-108-2 through 516F-104-1), these two intervals show no change in relative abundance and diversity of planktonic foraminifers. Dissolution effects on the planktonic foraminifers are absent within all three red intervals.

CORRELATIONS TO PREVIOUS DSDP SITES IN THE WESTERN SOUTH ATLANTIC (Sites 21, 356, 357)

In Figure 3, the Cretaceous of Hole 516F is compared with the Cretaceous sequence drilled in Leg 39, Holes 356 (São Paulo Plateau) and 357 (Rio Grande Rise), and in Leg 3, Hole 21 (Rio Grande Rise).

The spot-cored Mesozoic sequence at Site 356 (São Paulo Plateau) extended from Section 356-29-3 through Core 356-44 with a total thickness of 333 m. Several zones from the *Ticinella breggiensis* Zone (late Albian) to the *Abathomphalus mayaroensis* Zone (late Maestrichtian) are recognizable. Hole 356 differs from Hole 516F, which has no Middle Cretaceous record of sediments. Basaltic basement was reached below Santonian-Coniacian strata. In contrast to Hole 356, the Coniacian-Santonian sequence of Hole 516F cannot be assigned to distinct planktonic foraminiferal zones. The lower and upper Campanian boundaries are also not clear because of the absence of *Globotruncana elevata* and *G. calcarata.* However, the change within the planktonic foraminifers from the marginotruncanids to the globotruncanids, recognizable in the lower Campanian at Hole 516F, corresponds to a similar change between Cores 356-35 and 356-34. The early to middle Maestrichtian of Hole 516F is not so well defined as that of Hole 356 because of the lack of zonal markers such as *Globotruncana tricarinata* and *G. gansseri.* The first appearance of *Abathomphalus mayaroensis* is the best equivalent datum plane at both sites.

The Cretaceous sequence at Site 357, located near Site 516, was also spot-cored from Core 357-31 through Core 357-51 with a total penetration of 209 m. Although Site 357 is characterized by slumping and mixing of sediments throughout many levels, several zones from the *Globotruncana concavata* Zone (Santonian) through the *Abathomphalus mayaroensis* Zone (late Maestrichtian) were recognized. The preservation of planktonic foraminifers is also generally poor and reworked, and *in situ*

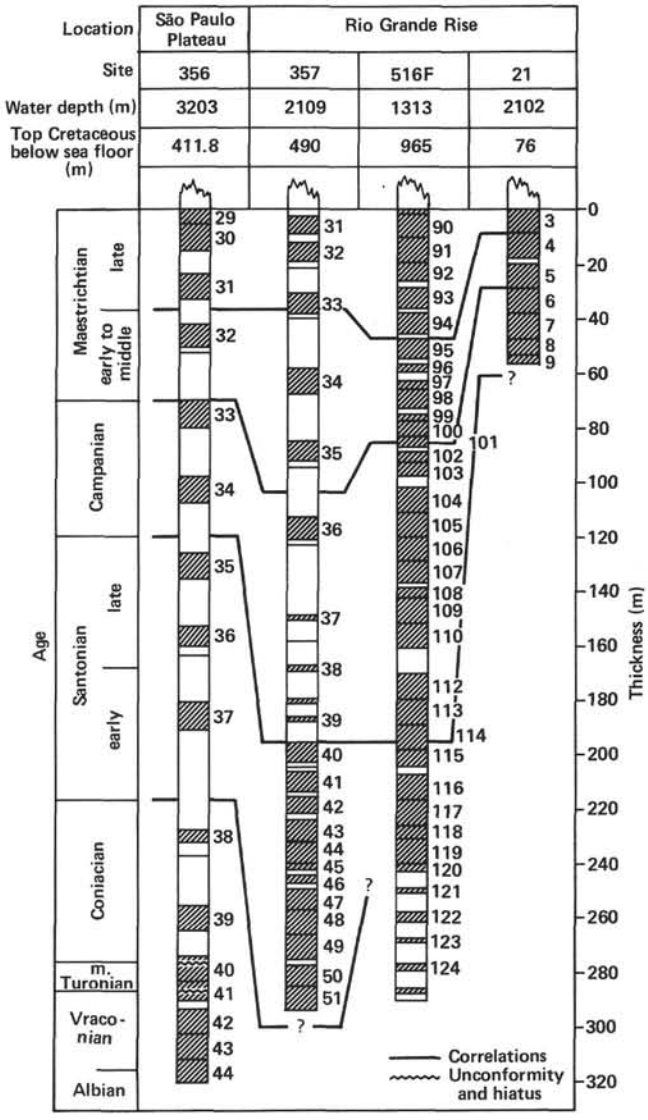


Figure 3. Thickness of Cretaceous sediments versus age at Site 356 (São Paulo Plateau) and at Sites 357, 516, and 21 on the Rio Grande Rise (after Premoli-Silva and Boersma, 1977). Shaded areas show the recovery per each core; core numbers are to the right of shaded columns.

assemblages are not distinguishable. The Campanian interval between Cores 357-39 and 357-36 shows zonal marker species only at its base. Most of the overlying sediments are barren of planktonic foraminifers; this could be correlated with the interval of fewer planktonic foraminifers between Cores 516F-107 and 516F-105. The *Globotruncana tricarinata* Zone and the *G. gansseri* Zone between Cores 357-36 and Section 357-33-5 could be tentatively attributed to the early to middle Maestrichtian *G. falsostuarti* Zone between Cores 516F-100 and 516F-95, Section 2. Where *Abathomphalus mayaroensis* appears at both sites, the diversity and abundance of planktonic foraminifers is also high; correlation is easy and indicates the widespread favorable paleooceanic conditions at the end of the Maestrichtian.

A complete sequence about 65 m thick was recovered at Site 21, situated northeast of Hole 516F. All plank-

tonic foraminiferal zones from the *Globotruncana ventricosa* Zone (lower to middle Campanian) to the *Abathomphalus mayaroensis* Zone (upper Maestrichtian) are documented by well-preserved microfaunas. Although no break or hiatus of the deposition record was observed at Site 21, the *G. tricarinata* Zone and the *G. gansseri* Zone of lower to middle Maestrichtian were surprisingly not found in my own post-cruise studies. Correlation is possible, however, for the *Abathomphalus mayaroensis* Zone and the Campanian/Maestrichtian boundary at both sites.

The comparison between Holes 356, 357, 516F, and 21 shows the different beginnings of the stratigraphic history; a generally much greater thickness of Cretaceous sediments and poorer biostratigraphic record, especially in the lower and middle Campanian, characterizes Holes 356, 357, and 516F. In contrast, the Campanian sequence of Site 21 is complete and well documented. The upper Maestrichtian *Abathomphalus mayaroensis* Zone is the best-correlated interval at all sites.

CONCLUSIONS

The examination of the planktonic foraminifers in the Upper Cretaceous sediments recovered at Site 516 (Rio Grande Rise, South Atlantic) allows the precise dating of only one interval, the *Abathomphalis mayaroensis* Zone; only broad age determinations are possible for the others. In all, five planktonic foraminiferal zones and three unzoned intervals are recognized. From bottom to top these are:

1) Unzoned interval, possibly Santonian to Coniacian; Sections 516F-122-1 to 516F-119-3.

2) "*Globotruncana concavata*" Zone, possibly Santonian; Section 516F-119-2, to Core 516F-117.

3) Unzoned interval, possibly upper Santonian; Sample 516F-116,CC to Section 516F-114-5.

4) *Globotruncana arca* Zone, possibly lower Campanian; Sections 516F-114-4 to 516F-112-3.

5) *Globotruncana ventricosa* Zone, possibly lower to upper Campanian; Sections 516F-112-2 to 516F-104-5.

6) Unzoned interval, possibly upper Campanian; Sections 516F-104-4 to 516F-101-4.

7) *Globotruncana falsostuarti* Zone, possibly lower to middle Maestrichtian; Sections 516F-101-3 to 516F-95-3.

8) *Abathomphalus mayaroensis* Zone, upper Maestrichtian; Sections 516F-95-2 to 516F-89-5.

This Upper Cretaceous planktonic foraminiferal zonation is very tentative mainly because of the very poor preservation of the planktonic foraminifers and the absence of some important zonal and stage markers, such as *Globotruncana elevata, G. calcarata*, and *G. gansseri*. However, the sedimentary record seems to be continuous from Santonian-Coniacian through the upper Maestrichtian.

The Cretaceous/Tertiary boundary is intact in Section 516F-89-5, at a sub-bottom depth of about 964 m. The top of the Uppermost Cretaceous *A. mayaroensis* Zone is assigned to Sample 516F-89-5, 29.3–31.2 cm, whereas rare specimens of *Globigerina eugubina* date Sample 516F-89-5, 28–29.3 cm, as lowermost Paleocene. The relative abundance of planktonic foraminifers indicates that no major hiatus is present at the Cretaceous/Tertiary boundary at Hole 516F.

The upper Cretaceous sequence of Site 516 contains three remarkable intervals of conspicuous red coloration. The first, between Sections 516F-108-2 and 516F-104-1, is possibly middle to late Campanian and is characterized by a distinct decrease of planktonic foraminifers. The others, between Sections 516F-96-2 and 516F-94-2 and between Sections 516F-92-2 and 516F-91-2, are dated as middle to late Maestrichtian and show no change in the distribution and abundance of planktonic foraminiferal species.

Site 516 can be correlated with São Paulo Plateau Site 356 and Rio Grande Rise Sites 357 and 21. Exact correlation is difficult because of the absence of some of the generally accepted zonal markers.

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