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Implications of Campanian to early Maastrichtian deep-sea benthic foraminiferal distribution in the western North Atlantic

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Abstract

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Deep-sea benthic foraminiferal assemblages of Campanian to early Maastrichtian age in the western North Atlantic are taxonomically similar to coeval assemblages in deep-sea sections from various parts of the world. Species composition in the sections studied is largely the product of selective dissolution of less resistant species at depth in relation to a late Cretaceous CCD and partly due to local submarine volcanism or to local incursions of corrosive bottom water.
The uniformity in distribution of these assemblages at different latitudes was also partly aided by the absence of vigorous bottom water circulation during the late Cretaceous in the world oceans.

Introduction

In deep-sea sediments, foraminifera constitute the major group of fossil organisms and therefore provide a useful paleontologic indicator of deep-sea paleoecological and paleoceaonographical changes. However, as has been demonstrated by Berger (1970) for modern planktic foraminifera and by Sliter (1976), Nyong (1984) and Nyong & Olsson (1984) for fossil planktic and benthic foraminifers, the selective removal by carbonate dissolution at depth and the consequent relative enrichment of resistant species can greatly affect paleoecologic interpretations. A good understanding of depth of deposition in relation to the calcite compensation depth (CCD) is therefore pertinent in making paleoenvironmental interpretations of deep-sea foraminiferal assemblages.

Hsü & Andrews (in Maxwell et al. 1970) proposed a bathymetric scheme related to CCD which is based on dissolution traces and foraminiferal content. In general, foraminiferal assemblages that are well preserved and that show no evidence of dissolution were deposited well above the CCD, while assemblages with little or no calcareous components or which are poorly preserved indicate deposition close to or below the CCD. In the present study, taxonomic composition and distribution of benthic foraminifers, are used to infer oceanographic conditions during the Campanian to early Maastrichtian in the western North Atlantic. The Deep-Sea Drilling Project (DSDP) sites used in this study are shown in Fig. 1.

The lithology of Campanian to early Maastrichtian sections in the western North Atlantic is dominantly variegated clay-stones. This lithology

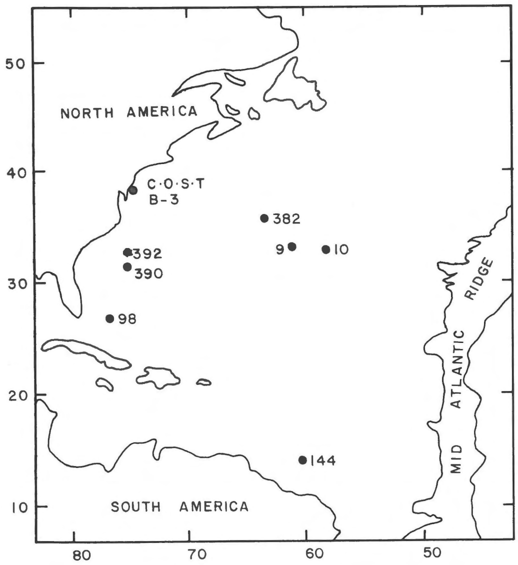

Fig. 1. Outline map of the western North Atlantic showing location of DSDP sites and C.O.S.T B-3 well analysed in this study.

is thin and widespread and probably accumulated as true pelagic clays, with very low sedimentation rates compared to other intervals (Tucholke & Vogt 1979). The lack of major terrigenous input into the basin could have been due to either the late Cretaceous transgressions, which could have restricted deposition of continental debris mostly to the wide continental shelf and marginal seas (Tucholke & Vogt 1979), or to the topographic barrier imposed by extinct shelf-edge barrier reefs which may have continued to act as dams, preventing dispersal of terrigenous debris seaward (Emery et al. 1970).

Foraminiferal recovery from most of the sections is generally good. The planktic foraminifers which constitute 40-98% of total foraminiferal population in most holes (except hole 9A) provide good biostratigraphic control and allow sub-division of the Campanian to early Maastrichtian sections (Table 1). A combination of factors such as localized terrigenous input, local preservation and dissolution characteristics, has fostered a patchy but rather uniform distribution of benthic foraminifers over the entire region. The benthic assemblages show close similarity in composition to those described from sections of equivalent age in other parts of the world.

Benthic foraminiferal distribution

In the western North Atlantic, the distribution of benthic foraminifers during Campanian to early Maastrichtian is relatively uniform. Benthic foraminiferal change involve mainly shifts in species proportions rather than changes in generic or specie composition. The generic composition of benthic foraminiferal taxa observed include *Gavelinella, Lenticulina, Dorothia, Conorbina, Osangu-*

Age	Generalized (Bolli, 1966)	Gulf Coast (Pessagno, 1967)			Western North Atlantic (Cita & Gartner, 1970)	Idealized (Van Hinte, 1976)	Present study	
E. Maast.	Globotruncana tricarinata	Globotruncana fornicata - stuartiformis	Rugoglobigerina subcircumnodifer	Rugotruncana subpennyi	Globotruncana arca	Globotruncana scitula	Globotruncana fornicata - stuartiformis - calciformis	Globotruncana arca
				Globotruncana lapparenti s.s.				
Campanian	Globotruncana calcarata		Globotruncana elevata	Globotruncana calcarata	Globotruncana calcarata	Globotruncana calcarata		Globotruncana calcarata
	Globotruncana stuarti s.l.			Pseudotextularia elegans	Globotruncana elevata	G. subspinosa		Pseudotextularia elegans
			Archeoglobigerina blowi	Planoglobulina glabrata		G. stuartiformis		G. elevata
				Dictyomitra multicostata		G. elevata		

Table 1. Planktic foraminiferal zonation for the western North Atlantic utilized in this study.

DSDP hole	Percent Carbonate	Percent foraminiferal content	Percent cassidulinacea (Average of cores per hole)	Inferred paleodepth (metres) (Nyong and Olsson 1984)
10	50 - 95	10 - 40	48	2000 - 2500
382	15 - 50	10	50	2000 - 3000
9A	0 - 1	1	?	> 3000
392A	87	80	32	1000 - 1500
390A	90	70	30	1000 - 1500
98	90	70	25	500 - 1000
144	60	60 - 70	42	500 - 1500
144A	30 - 60	60	40	500 - 1500

Table 2. Percentages of calcareous components and their relationship to paleodepth in the western North Atlantic.

laria, Gyroidinoides, Praebulimina, Bolivina, Tritaxia, Valvulineria, Nuttallinella, Nuttallides, Aragonia, Reussella, Pleurostomella, Stilostomella, Pullenia, Quadrimorphina, Ellipsoidella, Fissurina etc. Flysch – type arenaceous taxa are present in restricted sections especially in holes 9A, 10 and to a lesser extent hole 382 and include such genera as *Trochammina, Hyperammina, Rhabdammina, Haplophragmoides, Rhizammina, Saccammina, Ammodiscus, Ammobaculites, Recurvoides, Glomospira* and *Spiroplectammina*. The paleobathymetric significance of this foraminiferal composition has been presented elsewhere (Nyong & Olsson 1984). In general, the foraminiferal assemblages indicate deposition in 500 to more than 3000 metres water depth (Table 2).

The most commonly occurring species are listed with their relative abundance at respective DSDP holes (excluding hole 9A) in the western North Atlantic (Fig. 2). Benthic foraminiferal composition from sections of equivalent age in the Continental Oceanographic Stratigraphic Test (C.O.S.T.) B-3 well (Baltimore canyon, northeast U.S. Continental margin) and from sites 355 and 357 in the south Atlantic Ocean, (data from Sliter, 1977) are included for comparison. The data indicate that benthic foraminifers from Campanian to early Maastrichtian sections of the western North Atlantic occupying mid-bathyal to abyssal environments (Nyong & Olsson 1984) are similar in composition to those of equivalent age in the South Atlantic. Fauna from both ocean basins differ markedly from shelf and upper slope assemblages (Nyong & Olsson 1984) of the C.O.S.T. B-3 well (Fig. 2). A distinctive and ubiquitous deep-sea benthic foraminiferal assemblage is therefore-

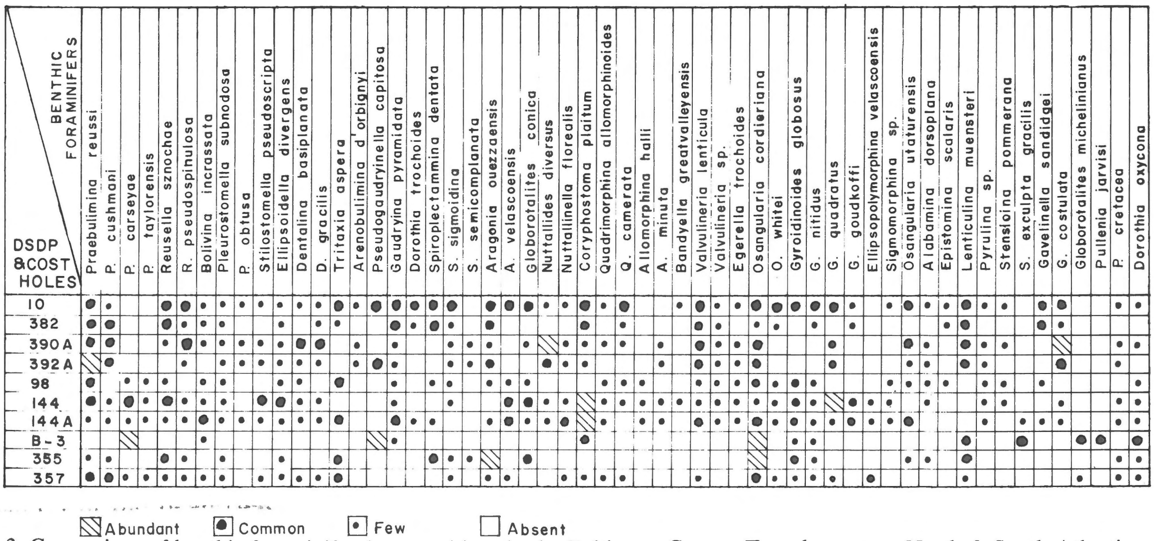

Fig. 2. Comparison of benthic foraminiferal compositions in the Baltimore Canyon Trough, western North & South Atlantic.

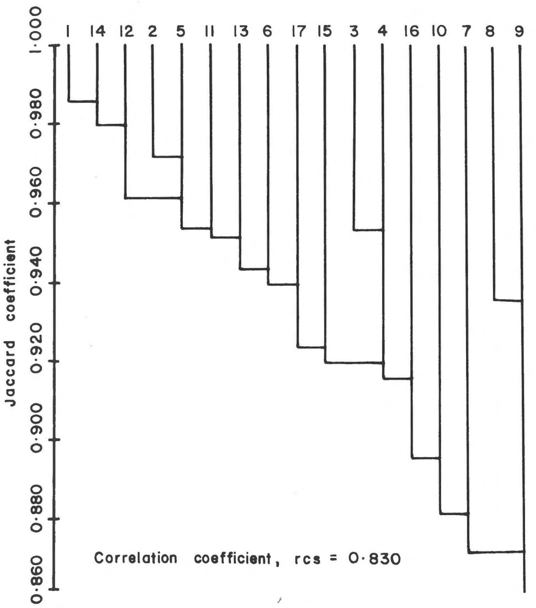

Fig. 3. Q-mode dendrogram of cores from the western North Atlantic. (For core identification, see appendix).

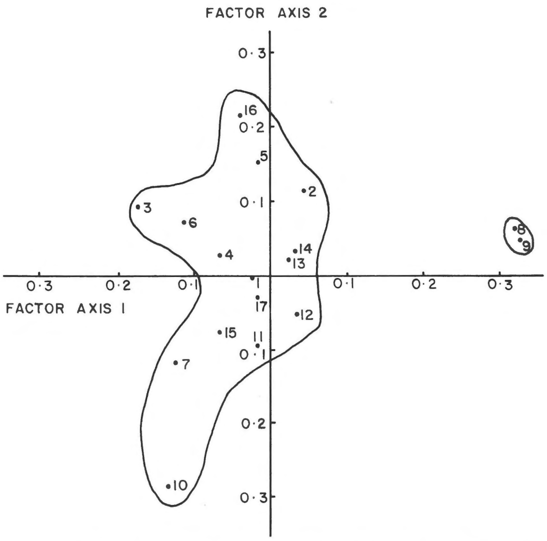

Fig. 4. Q-mode factor analysis of cores from the western North Atlantic. (For core identification, see appendix).

characteristic of the Campanian to early Maastrichtian in this area.

A Q-mode cluster and factor analysis using a presence or absence data matrix for the more common benthic species observed from each core at the respective DSDP sites in the western North Atlantic yielded no distinct groups (Figs. 3 and 4). Similar results were obtained when data from sites 355 and 357 in the South Atlantic were included in the analysis (Figs. 5 and 6). There is a tendency for the core sections numbered 8, 9 and 19 to group together as clearly shown in the factor and to a lesser extent in the cluster analysis. The cores numbered 8 and 9 in the analyses belong to site 382 (see appendix), which is located near the Nashville seamount. Lithologic examination of the Campanian section in this hole indicates volcanic outpouring at this time (Nyong 1983). Excess silica, associated with this volcanism could have caused locally increased acidity and subsequent dissolution of foraminifers. Foraminifers recovered from this site are generally very poorly preserved with abundant test fragments. The core numbered 19 represents data from site 357 in the South Atlantic (see appendix). Sliter (1977) suggested the influence of corrosive bottom waters during deposition of the Campanian section in the vicinity of site 357 in the south Atlantic. The observed grouping of these cores therefore probably represents dissolution at these respective DSDP sites.

From these results, it can be suggested that Campanian to early Maastrichtian benthic foraminiferal were uniformly distributed in both the North and South Atlantic Oceans and that strong fauna similarities existed between both oceans. The results also indicate that slight variations in taxonomic composition and differences in species abunbance observed in these deep-sea sections can be attributed to selective dissolution of less resistant species.

The North and South Atlantic assemblages also show strong affinities to assemblages of the same age from Czechoslovakia (Hanzlikova 1972, Australia (Belford 1966), Sweden (Brotzen 1936), Poland (Stejn 1957; Ganerbicdowa 1972), Indian Ocean (Scheibnerova 1974; Sliter 1976), Southeast Atlantic Ocean (Beckmann 1978). Thus, it is apparent, that Campanian to early Maastrichtian deep-sea foraminifers were widely distributed across latitudinal lines. This pattern of global uniformity can probably be explained by the existance of a weakly stratified oceanic water column and consequently absence of vigorous bottom water circulation in the deep seas of the Late Cretaceous.

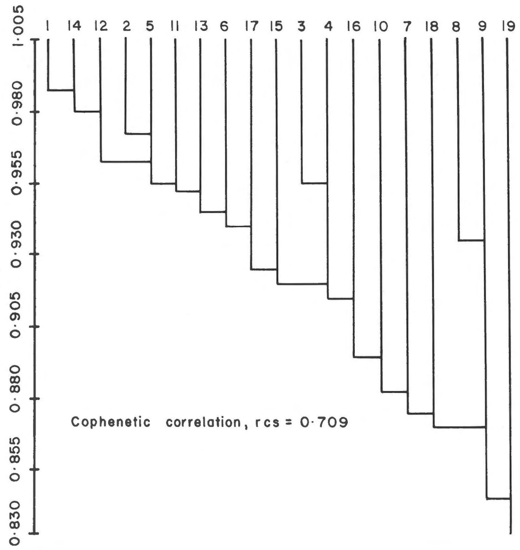

Fig. 5. Q-mode dendrogram of cores from the western North Atlantic including sites 355 and 357 from the South Atlantic. (For core identification, see appendix).

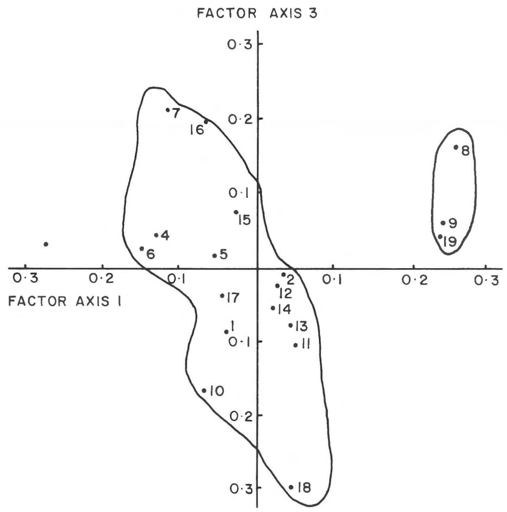

Fig. 6. Q-mode factor analysis of cores from the western North Atlantic including sites 355 and 357 from the South Atlantic. (Fore core identification, see appendix).

Discussion

Benthic foraminiferal species composition and relative abundance observed in the present study from the western North Atlantic can be related to dissolution phenomena. Generally, thick-walled benthic foraminifers such as the cassidulinids are likely to be more resistant to dissolution and hence should show higher dominance in sections deposited closer to the CCD. Cassidulinids represent about fifty percent of all benthic foraminifers recovered from sections deposited at about 2000-3000 metres water depth and about thirty percent in sections deposited at about 1000-1500 metres water depth (Table 2). The slightly enhanced dominance of cassidulinid taxa observed from holes 144 and 144A in estimated paleodepths of 500-1500 metres (Table 2), can be attributed to the influence of corrosive bottom waters in the western South Atlantic during the Campanian as reported by Sliter, 1977. Figure 7 shows a linear regression using the least squares method for percent cassidulinacea in each core analysed versus factor loadings on axis – 2 for these cores from the western North Atlantic. The result shows a strong correlation ($r = -0.774$) between the factor loadings and percentage cassidulinacea. This correlation indicates that variations in the distribution of the deep-sea benthic foraminifers observed in this study are closely related to variation in percentage cassidulinacea. Since this percentage is seen to increase with increased depth of deposition (Table 2), it is suggsted that the composition and distribution of deep-sea benthic foraminifers in the western North Atlantic is a function of dissolution, related to depth of deposition. The observed similarity in taxonomic composition of deep-sea benthic foraminifers in the western North and South Atlantic and in other parts of the world can therefore in part be related to the selective dissolution of less resistant calcareous benthic foraminiferal groups such as buliminids, nodosariids etc. This dissol-

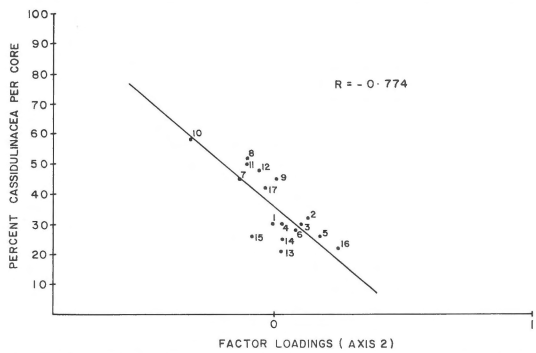

Fig. 7. Correlation between factor loadings (axis-2) and percent cassidulinacea in cores from DSDP holes in the western North Atlantic.

ution is enhanced with increasing depth and proximity to the CCD.

Measurements of oxygen and carbon isotopes on benthic foraminifera in South Atlantic deep-sea cores (Saito & Van Donk 1974) indicate that bottom water temperatures were about 10 degrees higher than today in the Late Cretaceous. Oxygen isotope analysis on benthic and planktic foraminifera from DSDP sites in the North Pacific Ocean (Douglas & Savin 1975) indicate warm bottom water in the latest Cretaceous with a difference between surface and bottom waters in tropical regions being less than one to half of present day values. Thus, it appears that warm waters were widespread in the Late Cretaceous oceans and since most continents had not drifted very far from the equator at the time, it can be inferred that thermal gradients between surface and bottom waters were generally low. Such low gradients would imply less stratification of the water column and subsequently an unlikely or very slow bottom water circulation. The absence of any strong bottom circulation did not encourage provincialisation, but rather aided a uniform and broad distribution of benthic foraminifers, such as is observed in this study.

Conclusion

Deep-sea Campanian to early Maastrichtian benthic foraminifers of the Western North Atlantic show uniform distribution. These assemblages are significantly different in taxonomic composition from shelf to upper bathyal assemblages of the adjacent continental margin, but show strong affinities to deep-sea assemblages of similar age from other regions of the world.

Dissolution at depth, in relation to the late Cretaceous CCD or locally due to submarine volcanism or the introduction of corrosive bottom waters along with the absence of vigorous bottom water circulation are suggested as the key factors controlling the compostion and distribution of deep-sea foraminiferal assemblages during Campanian to early Maastrichtian.

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Appendix

Explanation of numbers used in Cluster and Factor Analysis (Figs. 3, 4, 5 & 6)

Numbers	*Core and related DSDP holes*	
	Core	Hole
1	13	10
2	14	10
3	15	10
4	16	10
5	17	10
6	18	10
7	19	10
8	16	382
9	17	382
10	3	144
11	3	144A
12	4	144A
13	13	390A
14	14	390A
15	1	392A
16	13	98
17	14	98
18		355
19		357

Samples from site 9 in the western North Atlantic were excluded from analysis as foraminifers were recorded only from one sample.

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