Paleoenvironments of the Gulf of Guinea

Paleoenvironment
Gulf of Guinea
Foraminifera
Transgressions-regressions
Black Shales

Paléoenvironnement
Golfe de Guinée
Foraminifères
Transgressions-régressions
Marnes noires

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ABSTRACT

Foraminiferal assemblages in three marginal basins in the Gulf of Guinea (namely, the Benue Trough, the Dahomey Embayment, the Niger Delta) show maximum development during the major marine transgressions which transpired in the Middle to Late Albian, Late Cenomanian to Early Turonian, Late Turonian to Early Santonian, Late Campanian to Maastrichtian, Middle to Late Paleocene, Middle to Late Eocene, Middle Oligocene, and Early to Middle Miocene. The Oligocene and younger transgressions are more pronounced in the Niger Delta where fossiliferous marine shales are intercalated within deltaic sands. Major transgressions in the Gulf of Guinea coincided with global Late Cretaceous to Tertiary sea level rises. The transgressive shallow shelf benthonic foraminiferal assemblages in the exposed parts of the Benue Trough and the Dahomey Embayment show a progressive increase in faunal diversity from the Albian to the Eocene. This was due to improve marine conditions in these marginal basins when oceanic circulation was established in the Gulf of Guinea. The well known Mid-Cretaceous oxygen deficiencies in the world's oceans and epicontinental seas were felt in the Benue Trough where anaerobic shales and oxygen-starved benthonic foraminiferal assemblages occur in Upper Cenomanian-Lower Turonian and in Upper Turonian-Lower Santonian black shales.

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RÉSUMÉ

Paléoenvironnements du Golfe de Guinée.

Les assemblages de foraminifères de trois bassins de la marge du Golfe de Guinée (la fosse de la Bénoué, le bassin du Dahomey, le delta du Niger) montrent un développement maximal pendant les transgressions marines majeures durant l'Albien moyen-supérieur, le Cénomanien supérieur-Turonien inférieur, le Turonien supérieur-Santonien inférieur, le Campanien supérieur-Maestrichtien, le Paléocène moyen-supérieur, l'Éocène moyen-supérieur, l'Oligocène moyen et le Miocène inférieur à moyen. Les transgressions de l'Oligocène et celles plus récentes sont plus prononcées dans le delta du Niger où des argiles marines fossilifères sont intercalées avec des sables deltaïques. Les transgressions majeures dans le Golfe de Guinée ont coïncidé avec les variations eustatiques positives globales du Crétacé supérieur et du Tertiaire. Les assemblages de foraminifères benthiques associés aux dépôts, peu profonds, transgressifs montrent une augmentation progressive de leur diversité de l'Albien à l'Éocène. Ceci s'explique par l'accentuation des influences marines dans ces bassins de marge quand la circulation océanique s'est établie dans le Golfe de Guinée. Les épisodes anoxiques bien connus du Crétacé moyen dans les océans et les mers épicontinentales ont été ressentis dans la fosse de la Bénoué. Des argiles et des assemblages de foraminifères benthiques indiquant un milieu appauvri en oxygène se trouvent dans les marnes noires du Cénomanien supérieur-Turonien inférieur et du Turonien supérieur-Santonien inférieur.

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INTRODUCTION

In a recent review of the Cretaceous history of the South Atlantic Ocean Reyment (1980) highlighted five principal stages in the paleo-oceanographic evolution of the Gulf of Guinea. These stages were controlled by tectonic-eustatic and geoidal eustatic sea level maxima and comprised 1) the initial Late Middle Albian shallow marine connexion between the North and South Atlantic Oceans and consequently the creation of the Gulf of Guinea ; 2) a Late Cenomanian to Early Turonian transgression which swamped marginal areas ; 3) a Late Turonian to Early Santonian transgression during which true oceanic conditions were established ; 4) a Late Campanian to Early Maastrichtian transgression ; and 5) the circulation of deep and well oxygenated water during the Paleogene. The approximate extent of marine influence in the Gulf of Guinea during four of these transgressive peaks is shown in Figure 1. This paleogeographic sketch map was compiled from personal field observations and from field and borehole data which are available in the following publications : Adeleye (1974), Carter *et al.* (1963), De Klasz and Jan Du Chene (1979), Jan Du Chene *et al.* (1978), Murat (1972), Offodile (1976), Petters (1978 *a*, *b* ; 1979 *a* ; 1980), Reyment (1965), Reyre (1966).

Foraminiferal assemblages from mostly outcropping marine beds of Albian to Eocene age (Fig. 1) are used in this article to interprete the paleoenvironmental conditions that prevailed in the Gulf of Guinea during the major transgressions. Since they are mostly marine organisms foraminifera are more common during the marine transgressions than during regressions. The transgressive beds in this study are dated using the ammonite biochronological framework of Reyment (1965) and Reyment and Tait (1972), and the micropaleontological correlations recently presented by Petters (1980). The widely used foraminiferal paleoecologic statistics such as the planktonic/benthonic ratio, the alpha diversity index and the information function (Lipps *et al.*, 1979) enable qualitative interpretations of the paleobathymetry, paleosalinities, oxygen content, and nutrient availability in the Gulf of Guinea. Cretaceous marine beds were sampled mostly in the Benue Trough where the sparse benthonic foraminiferal microfaunas point to abnormal salinities during the initial Albian transgression. Exclusively planktonic foraminiferal assemblages attest to anoxic bottom conditions during the Late Cenomanian to Early Turonian transgression. The Late Turonian to Early Santonian predominantly planktonic microfaunas with low benthonic diversities suggest continued oxygen depletion at the bottom of the Benue Sea, while the more diverse Late Campanian to Maastrichtian assemblages especially in the Dahomey Embayment, indicate improved bottom circulation. In the Dahomey Embayment the cool water planktonic assemblages in the Eocene phosphatic beds suggest coastal upwelling.

Planktonic foraminiferal biochronological data from the regional marine shales in the subsurface of the Niger Delta allow the identification of the major rises in sea level and the construction of a complete though generalized transgressive-regressive curve for the Nigerian part of the Gulf of Guinea (Fig. 2).

ALBIAN TRANSGRESSION

Siltstones, shales and limestones referred to as the Asu River Formation in the middle Benue Trough and in the southern part where the Abakaliki Shale is also exposed have yielded Late Middle Albian and Late Albian oxytropidoceratid and diploceratid ammonites in some localities (Reyment, 1955 ; 1965 ; Offodile, Reyment, 1977). Because of its sparse molluscan fauna Reyment (1965) inferred a shallow marine environment which was diluted by run-off from land. Albian foraminifera are very rare in the Benue Trough. About 15 m of alternating limestone and shale of probably Albian age which are exposed in a recent quarry at Yandev yielded only one species of *Gavelinella* in the shaly limestone beds. This sequence rests directly on basement rocks which are exposed nearby, and represent the first marine flooding of the area during which only *Gavelinella sp.* could survive the probably lower than normal marine salinities in the basin. Another basal sequence comprising bright green shales are exposed in a recent roadcut near Wukari. These shales, which may be of Albian age, are barren and probably represent the coastal muds of the Albian transgression. Near Calabar in southeastern Nigeria, the stromatolitic, oolitic, and karstic limestone unit of the Odukpani Formation of latest Albian age (Forster, 1978) contains a very sparse assemblage of *Trocholina odukpaniensis*, *Hyperammina*, *Bathysiphon* and other arenaceous foraminifera which support shallow reefal origin for the limestone (Fayose, 1978).

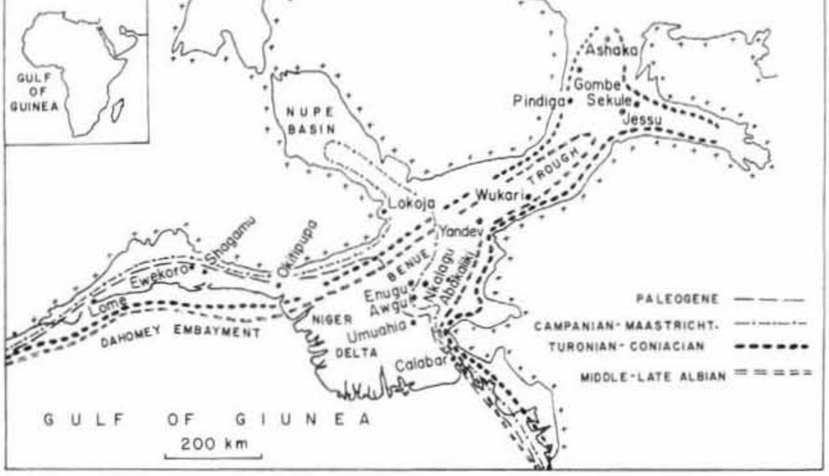

Figure 1
Sketch map of the Gulf of Guinea showing approximate limits of marine influence from Middle Albian to the Paleogene.

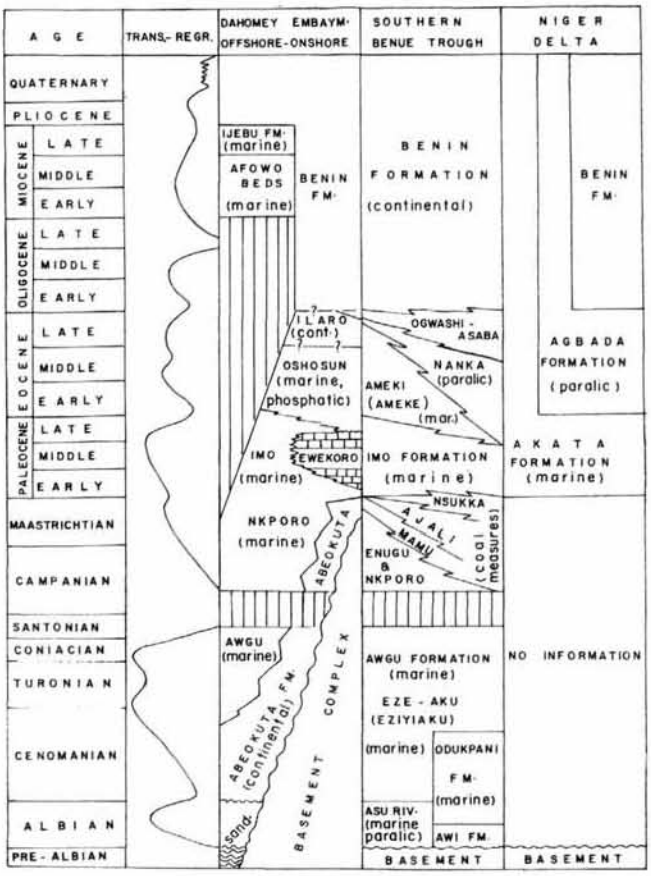

Figure 2

Stratigraphic correlation chart for coastal basins in Southern Nigeria showing a generalized transgressive-regressive curve.

LATE CENOMANIAN-EARLY TURONIAN TRANSGRESSION

Cenomanian to Turonian beds are known in the subsurface of southwestern Nigeria (De Klasz, Jan Du Chene, 1979 ; Jan Du Chene *et al.*, 1979) and are exposed in the middle and southern Benue Trough as the marine and marginal marine shales, limestones, and subtidal sandstones of the Eze-Aku (correct spelling for stratotype is Eziyiaku) Formation (Banerjee, 1980 ; Offodile, 1976 ; Reyment, 1965). In the vicinity of Calabar where Late Cenomanian to Early Turonian marine beds of the Eze-Aku Formation are exposed (Petters, 1980) the foraminiferal assemblages in some of the shales are exclusively of the neritopelagic type comprising *Heterohelix moremani* and *Hedbergella planispira*. The absence of benthonic foraminifera from these intervals suggests anaerobic bottom conditions as in coeval deposits in the Western Interior of North America (Eicher, Worstell, 1970) and in the South Atlantic Ocean (van Andel *et al.*, 1977).

Other Lower Turonian deposits in the Benue Trough are the transitional Yolde Formation, the marine Dukul Formation, and the Gongila Formation (Carter *et al.*, 1963) which represent the northeastward facies of the widespread Late Cenomanian to Early Turonian transgression.

LATE TURONIAN-EARLY SANTONIAN TRANSGRESSION

A more extensive marine transgression transpired in the Gulf of Guinea from the Late Turonian to the Coniacian and waned in the Early Santonian. The Awgu Formation (Fig. 2) which is lithologically continuous with the Eze-Aku Formation, was deposited in the Dahomey Embayment (Billman, 1976), and in the southern Benue Trough (Reyment, 1965) while the Jessu and Sukuliye Formations were deposited in the northeastern Benue Trough (Carter *et al.*, 1963 ; Enu, 1978). Keeled planktonic foraminifera such as *Marginotruncana renzi*, *M. difformis* and *M. sigali*, which indicate Late Turonian to Coniacian age as well as Early Coniacian coccoliths occur in the limestone and shale sequence of the Awgu Formation at the Nkalagu quarry (Petters, 1978 *a* ; 1980). On the evidence of the keeled planktonic species and the high percentage of planktonic foraminifera (Fig. 3), the Nkalagu succession is the deepest marine interval so far reported in the Benue Trough, and was assigned a maximum water depth of about 30 m (Petters, 1978 *a*). Alpha diversity values for the benthonic foraminiferal assemblages in the Nkalagu succession are generally less than 2 and with the flood abundances of only *Gavelinella sp.* at some intervals, suggest an oxygen starved assemblage. This means that the

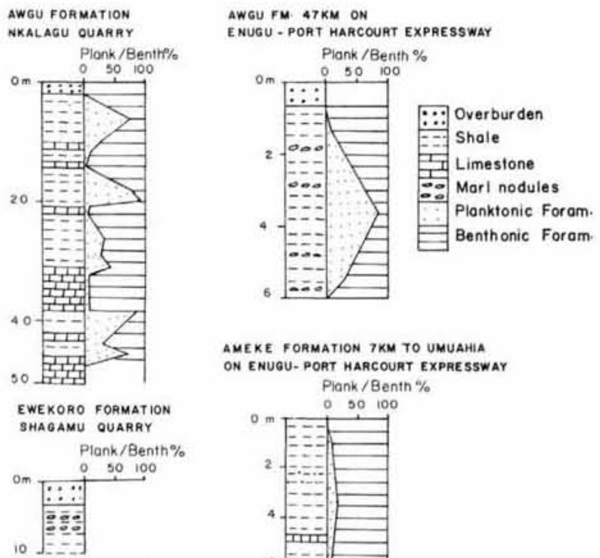

Figure 3

Generalized foraminiferal population statistics for the Coniacian to Eocene of the Benue Trough and the Dahomey Embayment.

Mid-Cretaceous oceanic anoxic event (Schlanger, Jenkyns, 1976) was still evident in the Benue Trough at the time of peak marine transgression. The reappearance of exclusively neritopelagic foraminifera with only *Whiteinella baltica* in some black shales at the top part of the Awgu Formation near Awgu town suggests complete depletion of oxygen on the sea bottom during the Early Santonian withdrawal of the sea.

CAMPANIAN-MAASTRICHTIAN TRANSGRESSION

The transgressive Nkporo Shale in southern Nigeria, which was deposited after the Santonian folding episode in the Benue Trough, contains Campanian to Late Maastrichtian heterohelicid, rugoglo-bigerinid, and globotruncanid planktonic species in the subsurface of southwestern Nigeria near Okitipupa, and in recent roadcuts near Calabar (Adegoke *et al.*, 1980 ; Petters, 1980). Although not as extensive as the earlier transgressions, the Late Campanian to Maastrichtian marine transgression supported slightly more diverse benthonic foraminiferal assemblages in southern Nigeria even at shallow depths (Fig. 3). This was due to generally improved and deeper oceanic circulation in the Gulf of Guinea. The Late Campanian-Maastrichtian transgression created a shallow embayment into the southern Benue Trough and the Nupe Basin where abundant brackish marsh arenaceous foraminifera were recorded from near Lokoja (Jan Du Chene *et al.*, 1978) and from the Enugu shale in Enugu (Petters, 1979 *a*).

PALEOCENE

With the outgrowth of the Niger Delta in the Danian (Reyment, 1980) Tertiary marine transgressions in the Gulf of Guinea could not extend as far inland as previously. Generally the shoreline of Tertiary marine transgressions migrated progressively southward because of strong deltaic progradation. Middle to Late Paleocene marine deposits in southern Nigeria include the Imo Shale and its Niger Delta equivalent, the Akata Shale, and the Ewekoro Limestone in southwestern Nigeria. Although the low planktonic per cent in the Ewekoro Formation and in exposures of the Imo Shale in southwestern Nigeria, the low alpha diversity values for benthonic foraminifera (Fig. 3), and the benthonic species composition (Petters, 1979 *b*) suggest shallow inner neritic depths, the occurrence of keeled planktonic species such as *Morozovella angulata, M. acutispira,* and *M. aequa* (Petters, Olsson, 1979) attest to the prevalence of fully oceanic conditions offshore. Barriers to deep oceanic circulation broke down in both the South and North Atlantic Oceans during the Paleogene and allowed the entry of deep well oxygenated waters (Berggren, 1978 ; Reyment, 1980).

EOCENE

Lower and Middle Eocene deposits in the Gulf of Guinea include the clastic exposed Ameke and Nanka Formations in eastern Nigeria, the subsurface Agbada Formation in the Niger Delta, and the phosphatic Oshosun Formation in the Dahomey Embayment (Fig. 2). Exposures of the top part of the Ameke Formation near Umuahia and subsurface samples of the Oshosun Formation contain abundant and well preserved foraminifera, ostracods, and radiolaria. Foraminiferal indicators of shallow inner neritic depths for the top part of the Ameke Formation include the low planktonic foraminiferal per cent, the low alpha diversity value (Fig. 3), and the low information function of 1.2 to 1.7. However, the common occurrence of radiolarians in the Ameke and Oshosun samples and the abundance of subbotinid and acarininid planktonic foraminifera in the Oshosun Formation suggest the influence of the cold Benguela Current and coastal upwelling. In this study, borehole samples of the phosphatic beds in Benin Republic yielded abundant planktonic foraminifera including *Acarinina esnaensis, A. pentacamerata, A. pseudotopilensis, A. soldadoensis soldadoensis, Globorotalia wilcoxensis,* and *Subbotina inaequispira.* This subbotinid-acarininid association characterized Eocene high latitude regions (Berggren, 1978) and probably appeared at shallow depths in the Gulf of Guinea as a result of coastal upwelling, a process that favoured phosphate sedimentation in the Dahomey Embayment.

TERTIARY TRANSGRESSIONS IN THE NIGER DELTA

Recent foraminiferal biostratigraphic analysis (Petters, 1979 *c*) and work in progress have shown that the Niger Delta offlap sequence contains highly fossiliferous marine shales which were deposited during major marine transgressions. The occurrence of abundant planktonic foraminifera in these widespread marine shales allow the recognition of some of the major transgressions (Fig. 2) which were reported by Vail *et al.* (1977) in their account of global episodes of sea level rises. Diagnostic planktonic foraminiferal associations and markers have enabled the identification of the Middle to Early Late Paleocene *Globorotalia pusilla pusilla-Morozovella angulata* Zone and the lower part of the *Planorotalites pseudomenardii* Zone, the Late Early Eocene *Acarinina pentacamerata* Zone, the Early Late Eocene *Truncorotaloides rohri* extinction datum, the Early to Middle Oligocene *Cassigerinella chipolensis-Pseudoha Stigerina micra* Zone, the Early Miocene *Globorotalia kugleri* Zone, and the Middle Miocene *Globorotalia fohsi fohsi* Zone.

CONCLUSIONS

Late Cretaceous to Early Tertiary marine transgressions in the Gulf of Guinea are well represented by the rich foraminiferal assemblages in the marginal basins such as the Benue Trough and the Dahomey Embayment. In the Niger Delta the highly fossiliferous marine shales intercalated within the thick deltaic sequence were deposited during Late Eocene, Middle Oligocene, and Early to Middle Miocene sea level rises.

The high planktonic foraminiferal percentages and exclusively planktonic assemblages in some black shales in the Upper Cenomanian to Lower Santonian of the Benue Trough attest to neritopelagic habitats for the heterohelicids and globigerine taxa which dominate these microfaunas. Benthonic foraminifera are either completely absent from some of these shales due to anaerobic bottom conditions or have very low diversities on account of insufficient oxygen at the sea bottom. Oceanic circulation ameliorated in the Gulf of Guinea from Late Campanian onwards and caused slightly higher benthonic diversities at shallow depths. The lower planktonic percentages in Tertiary shallow water assemblages in the Gulf of Guinea was due to the preference of Tertiary planktonic foraminifera for oceanic habitats. The prevalence of cool water planktonic foraminifera in Eocene phosphatic beds in the Dahomey Embayment was due to the coastal upwelling of deep nutrient-rich waters, a process that favoured phosphatization.

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