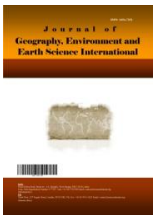

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Microfaunal Signals and Paleoenvironmental Reconstruction Sediments in Well Z-1, Offshore Dahomey Basin, South-Western Nigeria

Anthonia Nwanese Asadu[1*] and Charles Ojonuba Ameh[1]

[1]Department of Earth Sciences, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author ANA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author COA managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Fifty ditch cutting rock samples from well Z-1, OPL 310 offshore Dahomey basin, south western Nigeria were analyzed for their microfaunal and lithofacies content for the purpose of reconstructing the environment of deposition. Standard techniques of foraminifera slide processing and analysis was followed for the recovery of foraminifera while the gamma ray log complemented the rock samples for the lithofacies analysis. The lithological analysis revealed two lithofacies units in a generally fining upward sequence. The basal sandstone unit is characteristically milky white to brownish, coarse-pebbly grained, sub-angular to round and poorly to well sort with intercalation of shale. This unit is overlain by light to dark grey, moderately hard and non-fissile shale/mudstone sequence with intercalation of sand. Accessory mineral assemblage present in the formations includes mica flakes, glauconite pellets, carbonaceous detritus and ferruginous materials. The basal sandstone unit belong to the Oshosun Formation while the upper shaly unit is typical of Afowo Formation. Microfaunal study showed good recovery of abundant and well diversified

**Corresponding author: E-mail: asadu.anthonia@fupre.edu.ng;*

planktic and benthic foraminiferal species. Forty-two (42) planktic, sixty-five (65) benthic calcareous and one benthonic arenaceous foraminiferal species were recovered. Micropaleontologically, Paleoenvironmental deductions were based primarily on the assemblage, abundance and diversity of benthic foraminiferal species and presence or absence of planktic foraminifera. Accessory mineral presence also aided the interpretations. Integration of lithological and micropaleontological synthesis enhanced the delineation of two environmental subzones over the analyzed interval, the outer neritic and the upper bathyal depositional settings corresponding to Afowo and Oshosun Formation respectively. A lowstand prograding wedge which is a good exploration target offshore was recognized between intervals 3400 ft to 3500 ft. In conclusion, the rock succession studied, penetrated Afowo and Oshosun Formations, and were deposited in an environment ranging from outer neritic to upper bathyal settings.

Keywords: Micropaleontology; paleoenvironment; benthic; foraminifera; lithofacies.

1. INTRODUCTION

The Nigerian sector of the Dahomey basin contains extensive wedge of Cretaceous to recent sediments up to 3000 m thick, which thickens increasing towards the offshore. Exploration activities in this basin date back to 1908, when bituminous sand outcrop was discovered near Okitipupa in Ondo state. Most of the studies in this basin were concentrated on lithostratigraphy, organic geochemistry and age characterization, hence this study. Foraminifera, as a microfossil group is abundant and widespread in marine sediments. Consequently, they are valuable biostratigraphic tool in dating as well as reconstruction of environmental conditions of sediment deposition. This study was carried out on fifty ditch cutting rock samples from well Z-1, OPL 310 offshore Dahomey basin, south western Nigeria (Fig. 1). The aim was to establish the lithologic units penetrated by the well, analyze the sediments for foraminifera and integrate data for the purpose of reconstructing the environment of deposition of the sediments. The materials available for the research was the rock samples and the gamma ray log which aided the lithofacies analysis. Standard methods of foraminiferal slide preparation and analysis was followed for the Microfaunal recovery from the rock matrix. Accessory minerals recovered also supplemented the data for the interpretation.

1.1 Stratigraphy of the Dahomey Basin

Foraminiferal biostratigraphy of the basin has been well documented by several workers [1-8], amongst others. The stratigraphy of the eastern Dahomey Basin (Western Nigeria) has been studied and discussed by various authors [9,10]. The recent classification schemes are shown in Table 1. The stratigraphic sequence spans from Cretaceous to Recent. This includes the Cretaceous Abeokuta Group which comprises Ise, Afowo and Araromi Formations; the Paleocene Ewekoro Formation; the Late Paleocene to early Eocene Akinbo Formation; the Eocene Oshosun and Ilaro Formations and the Pleistocene to Recent Benin Formation [10-12]. Based additionally on recent works [13,14], a regional stratigraphic summary for the entire Western Nigeria coastal basin is presented below:

1.1.1 Ise formation

This formation overlies the basement rocks uncomformably and consists of basal conglomerate overlain by coarse to medium grained loose sand, sandstone and grits containing kaolinitic clay. Some sporomorphs including *Cicatricosisporites* sp., *Pilosisporites trichopapillosus*, etc; which were recovered from Ise-2 borehole by Shell-BP geologists indicate a Neocomian, probably Valanginian-Barremian age.

1.1.2 Afowo (Abeokuta) formation

In Southwestern Nigeria, Afowo Formation is the main petroliferous Formation. It overlies the Ise formation and consists of coarse to medium grained sandstone with thick intercalations of shale, siltstone and pyritic clay. According to [10], the basal part of the formation consists of well sorted sub-rounded fluviatile sand with mixed brackish to marine sediments. This formation was assigned a Turonian age by [15], on the basis of palynological assemblages which include *Elytranthe* subzone and *Multiporopollenites* aff. *M. maculosus* zone. It has been assigned a Late Cenomanian-Santonian age on the basis of *Thalmanninella greenhornensis* [16].

1.1.3 Araromi (Nkporo) formation

Araromi Formation conformably overlies the Afowo Formation. From bottom to top, it is composed of fine-medium grained sandstone overlain by shale, siltstone and limestone inclusions with marl and lignite. The shale is dark and contain abundant planktonic and benthic foraminifera (*Globotruncana mayaroensis* and *Globotruncana stewartiformis*), ostracods, pollen and spores. The dark shale unit in the Western Nigeria offshore basin is correlated with the Nkporo Shale in the Anambra Basin by [15]. Therefore, the Nkporo shale, as it was named by [15] and is laterally equivalent to the Araromi Formation. Based mainly on faunal content, a Maastrichtian to Paleocene age is given to this Formation [10,14].

1.1.4 Ewekoro formation

The Ewekoro Formation overlies the Abeokuta Group. Four carbonate microfacies have been described. This consists of a sandy biomicrosparite, shelly biomicrite, red phosphatic biomicrite and algal biosparite with abundant skeletal debris. The structure and texture of the limestones indicate a shallow marine environment of deposition. The occurrence of *Globorotalia angulata*, *Globorotalia velascoensis*, *Globigerina triloculinoides* and *Globigerina pseudotriloba*, in Ewekoro Formation suggest a Paleocene age [16].

1.1.5 Akinbo formation

The Akinbo Formation lays unconformably on the Ewekoro Formation. Some glauconitic bands with lenses of limestone occur at the basal part. The top of the formation is pure grey, gritty sand with little clay. The claystone are rich in kaolinitic concretions. The formation is Upper Paleocene to Lower Eocene in age [17]. Akinbo Formation is not always distinguished and separated from Oshosun Formation.

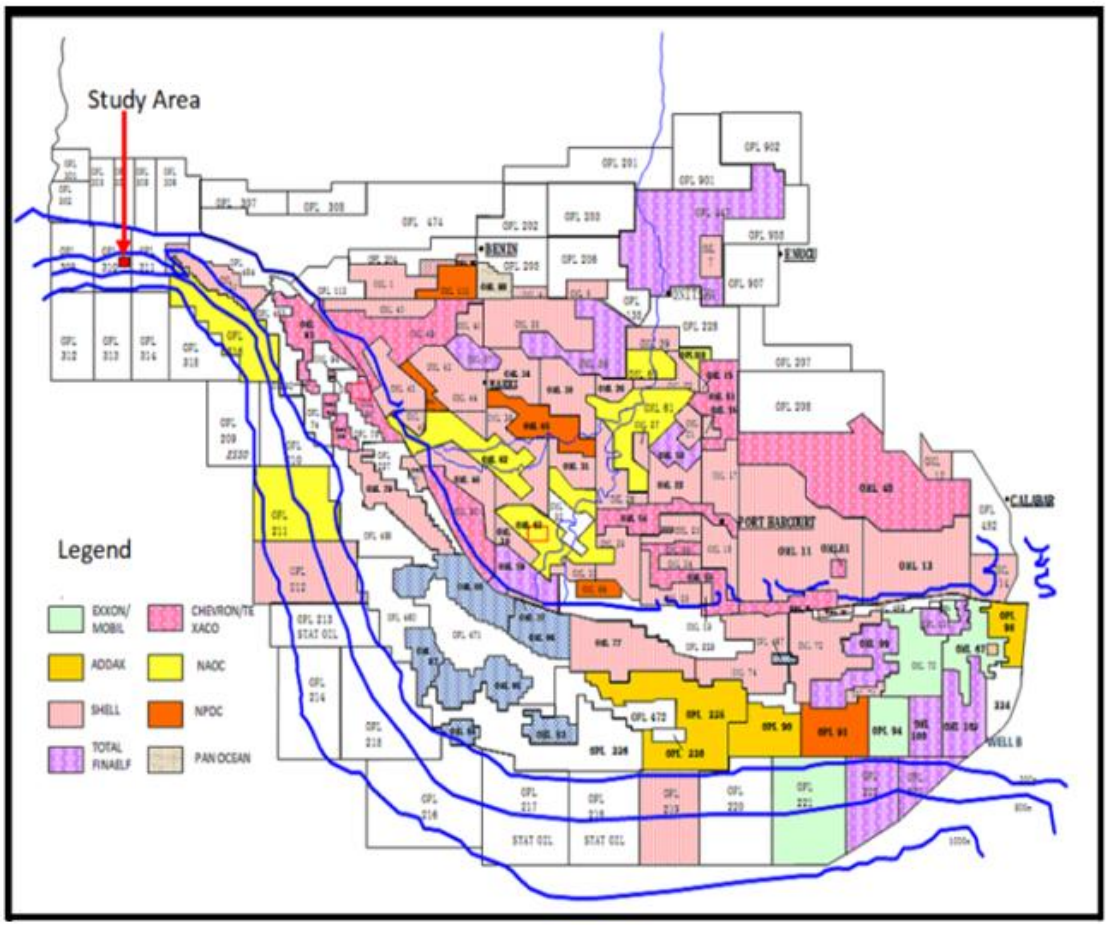

Fig. 1. Niger Delta Oil Mining Lease (OML) map showing the location of the study area [18]

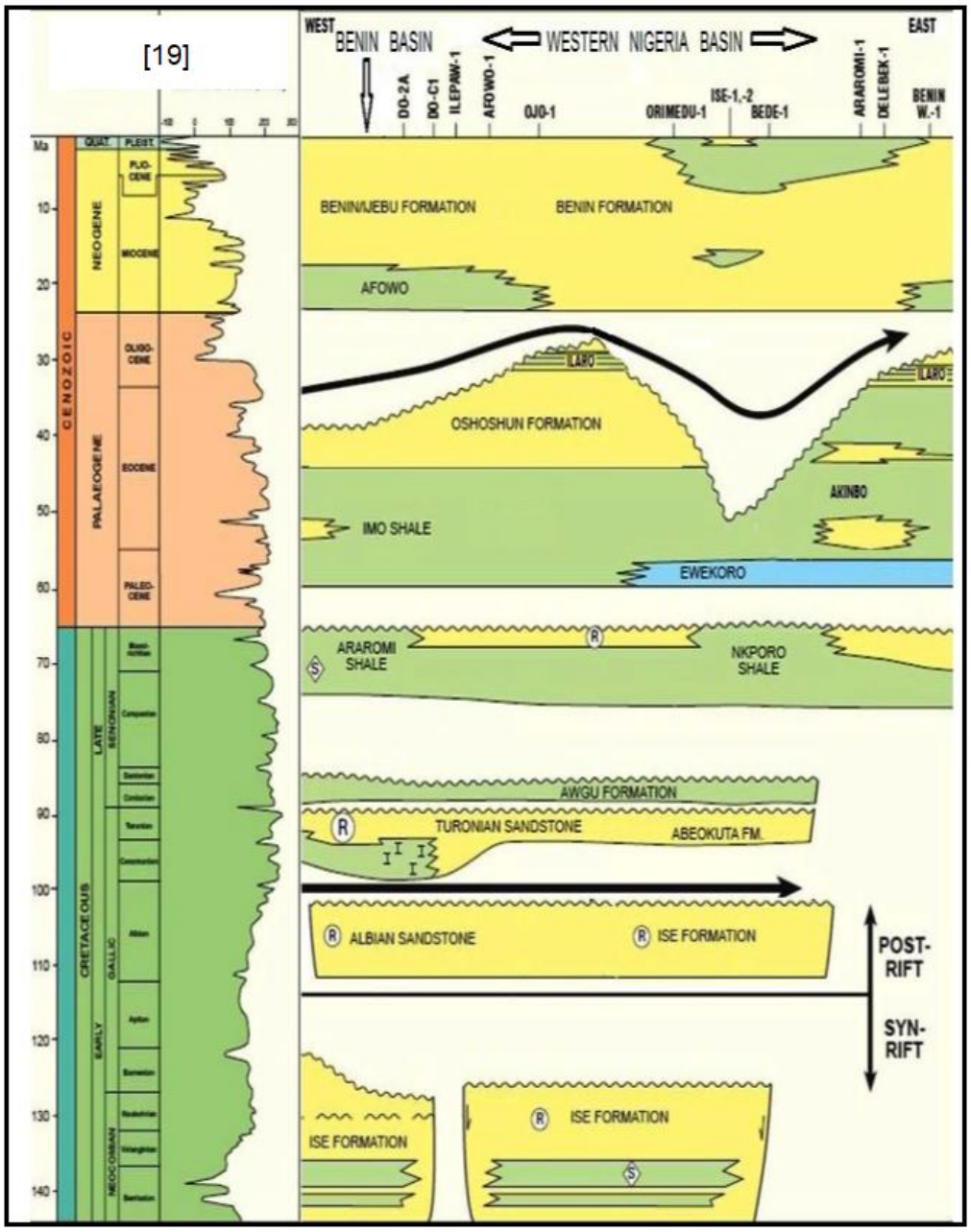

Fig. 2. Schematic cross section showing lithostratigraphic units of Dahomey and Western Nigeria offshore basins [16]

1.1.6 Oshosun formation

Above the Akinbo Formation, is the Oshosun Formation which consists of various colored laminated and glauconitic clay and shale with sandstone intercalations. The Formation is phosphate-bearing. The fossil assemblage consists of molluscs, corals, pelagic and planktonic foraminifera. A Lower Eocene-Middle Eocene age is given to this Formation [14].

1.1.7 Ilaro (Ijebu) formation

The Formation consists of massive, poorly consolidated; cross-bedded sandstones which

conformably overlie the Oshosun Formation. Sub-rounded to rounded pure quartz grains dominate the base of the formation. This texture indicates a beach or shoreline and nearshore environment. The formation is sparsely fossiliferous but the occurrences of some benthic foraminifera have been described on the basis of which the formation was assigned an Eocene-Oligocene age.

1.1.8 Benin formation (Coastal plain sand)

The Benin Formation, also called the Coastal Plain Sand [10], consists of poorly sorted sand with lenses of clay. The sand is in parts cross-bedded and show nearshore to continental distinctiveness. The Formation age covers the Miocene to Recent. The schematic diagram of the offshore representation of these formations is shown in Fig. 2.

2. MATERIALS AND METHODS

Fifty ditch cutting rock samples and gamma ray log were provided for this study. Lithologic description of the samples was done with the aid of the gamma ray log noting the textural characteristics such as colour, grain size, shape (roundness) and sorting, while foraminifera slides were prepared from each sample following the standard procedure as outlined below:

Foraminiferal sample preparation procedure: In order to facilitate the recovery and subsequent picking of all micro faunal components, the following procedure was followed having observed all safety requirements:

1. 20 g of each sample was weighed (using a Mettler PC 440 digital balance) into the sample bowl.
2. Sample depths were correctly labeled on clean aluminum sample bowls.
3. 30 ml of kerosene was poured into sample to soak for two hours.
4. The kerosene was drained out and sample was soaked in water.
5. Each sample is then washed over a 63 microns sieve with water from a hand directed water jet.
6. The residue collected from the sieve was replaced in the sample bowl and dried on the hot plate.
7. The residue is then sieved over 20 and 80-microns mesh sieves for the coarse and medium fractions while the finest residue in the receiver is treated as fine fraction.
8. The coarse, medium and fine fractions are then stored in properly labeled sample phials for onward transfer to the pickers and analyzers.
9. All the slides w ere labelled serially according to the labels on the residues.
10. Beginning with the fine fractions of each sample, the residue was scattered on a gridded picking tray and viewed using incident light from stereoscope.
11. Using a fine brush, the visible forams were picked and transferred to a labelled slide.
12. The slide containing the forams was then covered using a glass cover slip.
13. Tragacanth gum was used to attach the specimen to the slides ready for analysis.

3. RESULTS AND DISCUSSION

3.1 Results

The lithologic log of the studied interval of well Z-1 is presented in Fig. 3. Recovered foraminifera are characterized by high abundance and diversity of both planktic and benthic foraminiferal species. Forty-two (42) planktic and sixty-five (65) benthic calcareous and one

Table 1. The stratigraphic units of Eastern Dahomey Basin Summarized by authors [19]

Era	Period	[9]		[10]		[20]	
		Age	**Formation**	**Age**	**Formation**	**Age**	**Formation**
Cenozoic	Quaternary Paleogene	Recent Pleistocene Oligocene Eocene Paleocene	Alluvium Coastal plain sand Ilaro Ewekoro	Pleistocene Oligocene Eocene Paleocene	Coastal plain sand Ilaro Oshosun Akinbo Ewekoro	Recent Pleistocene Oligocene Eocene Paleocene	Alluvium Coastal plain sand Ilaro Oshosun Akinbo Ewekoro
Mesozoic	Cretaceous	Late Senonian	Abeokuta Formation	Maastrichtian-Neocomian	Araromi Afowo Ise	Maastrichtian-Neocomian	Araromi Afowo Ise
Precambrian Crystalline Basement Rocks							

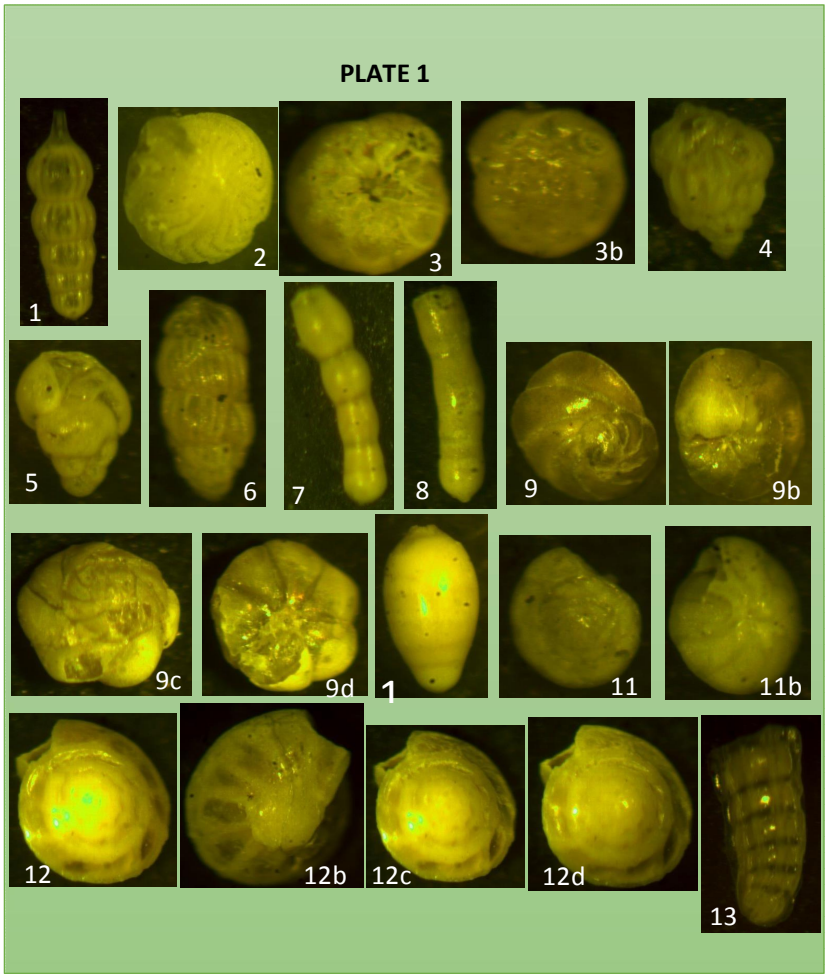

Plate 1. Photomicrographs of recovered foraminiferal species

1. Amphycorina scalaris caudate; 2. Amphistegina lessonii; 3. Ammonia beccarii; 3b. Ammonia beccarii 2; 4. Bulimina inflate; 5. Bulimina marginata; 6. Uvigerina peregrine; 7. Dentalina legumiformis; 8. Dentalina sp 9. Eponides eshira; 9b. Eponides eshira; 9c. Eponides eshira; 9d. Eponides eshira; 10. Globoglandulina sp; 11. Heterolepa crebbsi; 11b. Heterolepa crebbsi; 12. Heterolepa pseudoungeriana; 12b. Heterolepa pseudoungeriana; 12c. Heterolepa pseudoungeriana; 12d. Heterolepa pseudoungeriana; 13. Marginulina costata

benthonic arenaceous foraminiferal species were determined. The distribution chart of foraminifera in wellZ-1 is shown in Fig. 4, while the abundance and diversity chart and the interpretation of the paleoenvironment is presented in Fig. 5. Some of the photomicrographs of the recovered forms are presented in (Plates 1-2).

3.2 Discussion

3.2.1 Lithostratigraphy

The lithological analysis revealed a generally fining upward sequence of basal sandstone is characteristically milky- white to transparent and brownish color, fine- to coarse-grained, pebbly, sub-angular to rounded and poorly to well sorted sandstone facies with intercalation of shale is overlain by light to dark grey, moderately hard and non-fissile shale/mudstone facies with intercalation of sand. Accessory mineral assemblage includes: mica flakes, glauconite pellets, carbonaceous detritus and ferruginous materials. The basal sandstone unit belong to the Oshosun Formation while the upper shale unit is typical for the Afowo Formation (Fig. 3).

3.2.2 Paleoenvironmental analysis

Integration of lithological and micro-paleontological characteristics has enhanced the

deductions of varying depositional environments over the analyzed interval. Lithological characteristics considered include well log signatures, sand/shale ratios, textural attributes of sands and accessory mineral compositions of samples. Micropaleontologically, paleo-environmental deductions were based primarily on benthic foraminiferal assemblage, abundance and diversity of species as well as known environmental preferences of modern species or genera. Presence or absence of planktic foraminifera also helped in deciphering open ocean environments. On the basis of the above criteria, the following depositional environments were deduced for well Z-1.

3.2.2.1 Upper bathyal (Hemipelagic shales interbedded with tidal channel sands): interpreted for interval, 1620 to 2,750 ft

This interval contains the shale facies with the intercalation of sand at the top. Few mica flakes and glauconite pellet are accessory minerals present within this interval. It is also characterized by a general abundance and diversity of both planktic and benthic foraminiferal species. Deep water benthic foraminiferal species such as *Amphycoryna scalaris caudata, Bulimina aculeata, B. inflata, B. marginata, Globocassidulina subglobosa, Trifarina reussi, Hoeglundina elegans,*

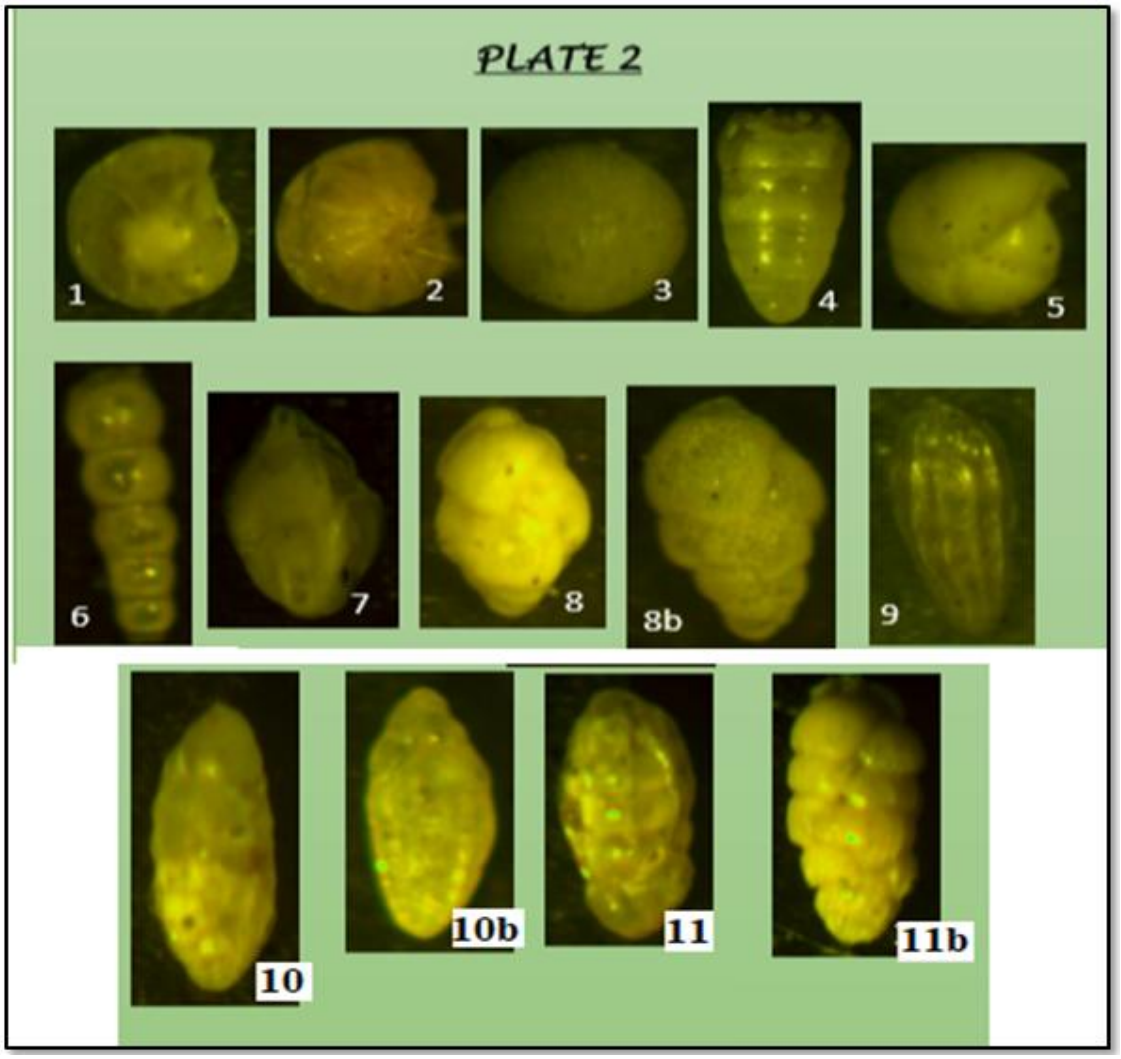

Plate 2. Photomicrographs of recovered foraminiferal species

1. Lenticulina inornata; 2. Lenticulina grandis; 3. Orbulina universa; 4. Pseudoglandulina; 5. Pullenia bulloides 6. Stilostomella monilis; 7. Trifarina reussi; 8. Uvigerina hispida; 8b.Uvigerina hispida; 9. Uvigerina peregrina 10.Uvigerina hourqi; 10b. Uvigerina hourqi; 11. Uvigerina sparsicostata; 11b. Uvigerina sparsicostat

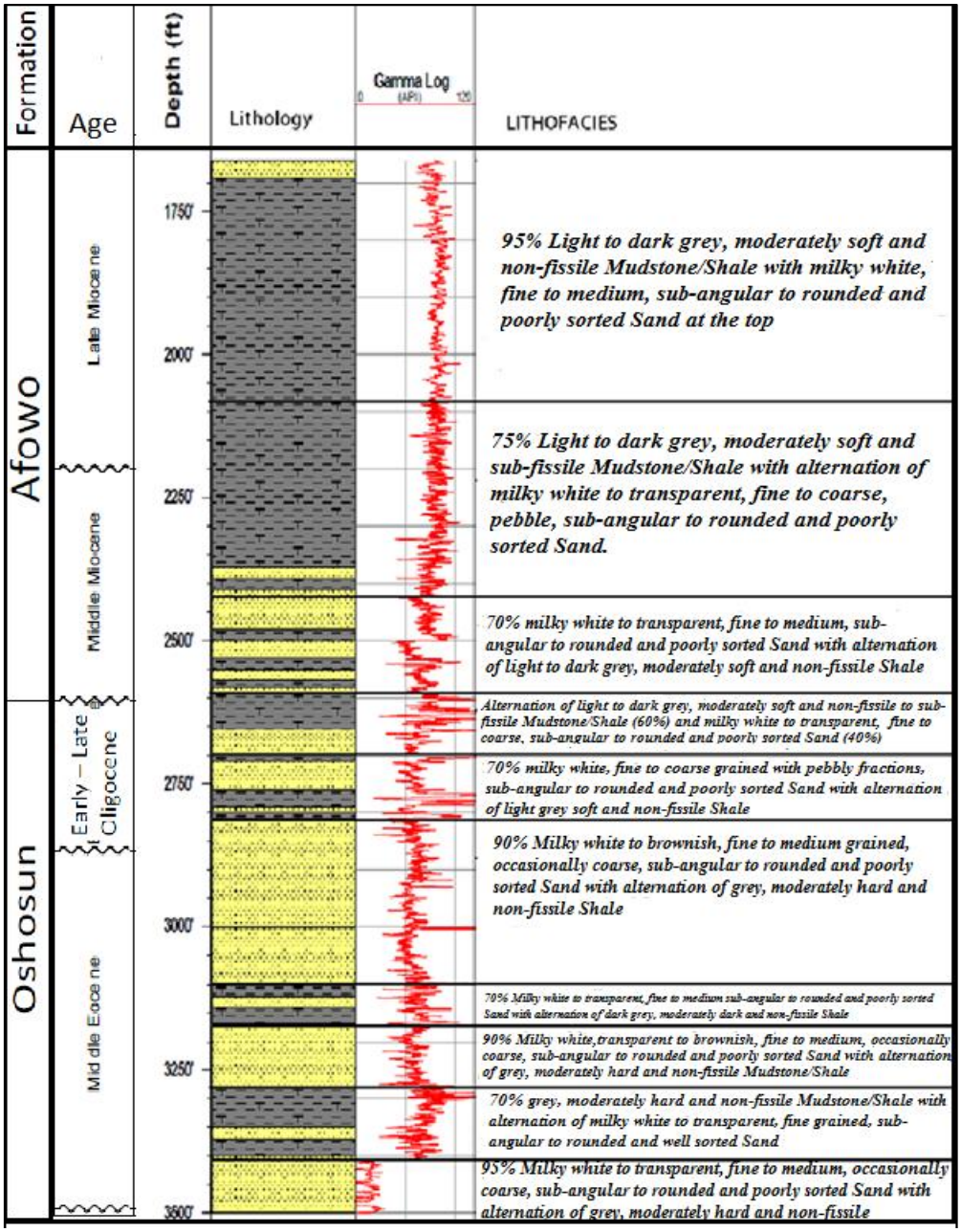

Fig. 3. Lithostratigraphy of well Z-1

Stilostomella monilis, Planulina arimanensis, Sphaeroidina bulloides, Pullenia bulloides, Heterolepa crebbsi, Pseudoglandulina sp, *Dentalina leguminiformis, Heterolepa pseudoungeriana, Marginulina costata, Oridorsalis umbonatus, Lenticulina grandis, Uvigerina hispida, Uvigerina peregrina, Uvigerina sparsicostata* and *Nodosaria* sp dominated the assemblage and this foraminiferal association is indicative of upper bathyal environment.

3.2.2.2 Outer neritic to upper bathyal (Overbank/channel sands interbedded with marine shales): Interpreted for Interval, 2750 – 3400 ft

This interval contains the sandstone facies with intercalation of shale. Common to rare mica flakes and carbonaceous detritus are accessory minerals also found within this interval. It is also characterized by a relatively high abundance and

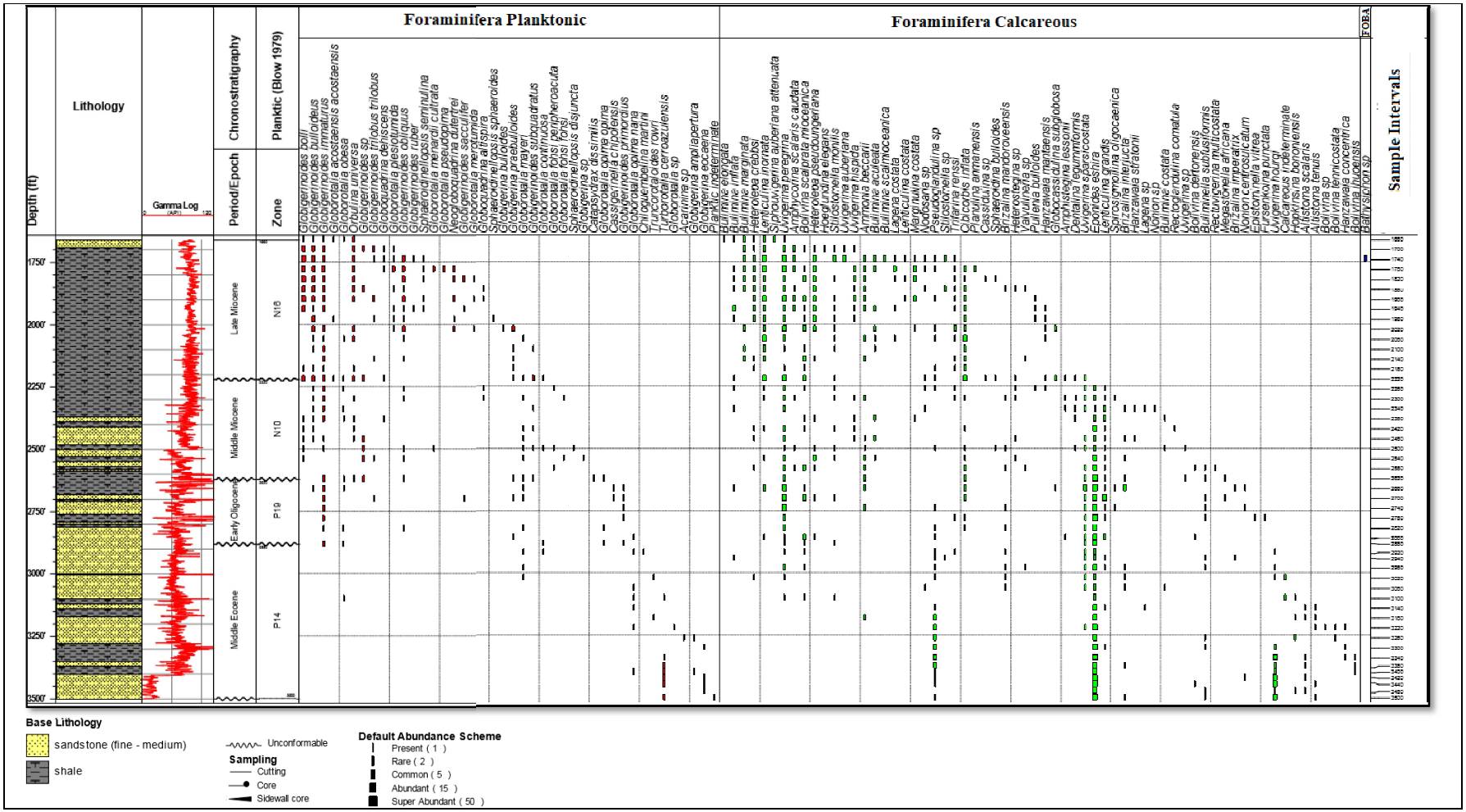

Fig. 4. Foraminifera distribution chart of well Z-1

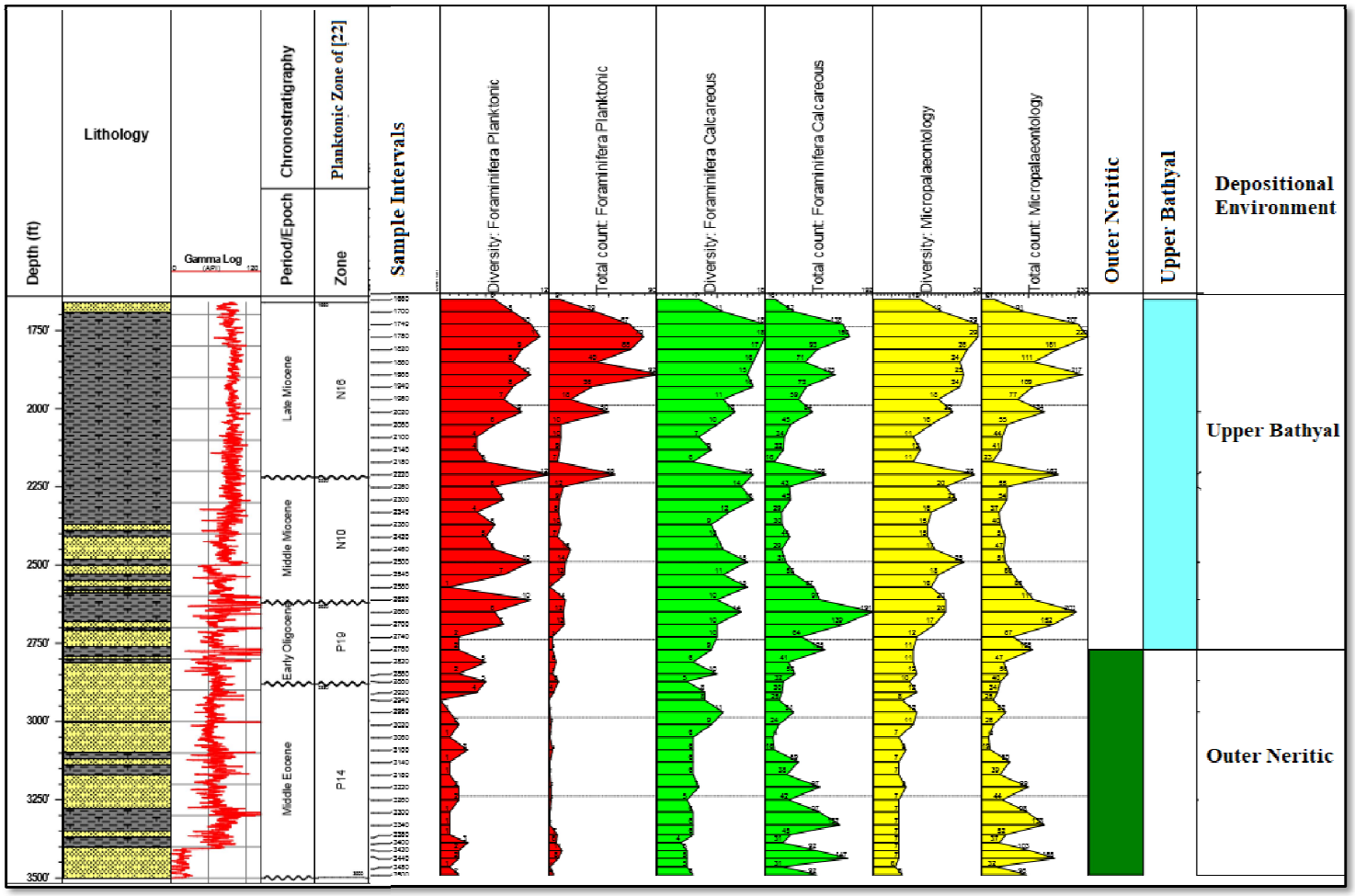

Fig. 5. Abundance and diversity charts and paleoenvironmental interpretation of Well Z-1

diversity of planktic and benthic foraminifera fauna species. Planktic species are very common over this interval and this suggests deposition in open marine environment. Rich and diverse foraminiferal species of deep water origin such as: *Heterolepa pseudoungeriana, Bulimina inflata, Buliminella subfusiformis, Brizalina tenuicostata, Brizalina interjuncta, Brizalina mandoroveensis, Brizalina imperatrix, Uvigerina hourqi, Uvigerina peregrina, Uvigerinella sparsicostata, Altistoma tenuis, Altistoma scalaris, Trifarina reussi, Stilostomella monilis, Nonion centrosulcatum, Fursenkoina punctata, Hopkinsina bononiensis, Hanzawaia concentrica, Lenticulina grandis* and *Eponides eshira* also characterize this unit and this benthic foraminiferal association suggests deposition in outer neritic to upper bathyal environments.

3.2.2.3 Lowstand prograding complex: Inferred for intervals 3,400 - 3,500 ft

This is a massive sequence of sandstone with occasional siltstone. The sandstone is milky white to transparent, fine to medium, occasionally coarse, sub-angular to rounded and poorly sorted. The shale/mudstone is grey, moderately hard and non-fissile. Rare mica flakes and carbonaceous detritus are accessory minerals also contained within this interval. Foraminiferal species over this interval are relatively high, characterized by both planktic and benthic species. The benthic assemblage includes: *Bolivina fastigia var. dertonensis*, *Buliminella subfusiformis, Brizalina interjuncta, Uvigerina hourqi, Altistoma tenuis, Altistoma scalaris, Nonion centrosulcatum, Rectuvigerina bononiensis, Pseudoglandulina* sp. and *Eponides eshira.* This association suggests deposition in outer neritic setting. The age of the sediments has been interpreted to range from middle Eocene to Late Miocene epoch.

4. CONCLUSION

In conclusion, the rock succession studied in well Z-1 penetrated Oshoshun and Afowo Formations, offshore Dahomey Basin and were deposited in an environment ranging from outer neritic to upper bathyal settings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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