FORAMINIFERAL BIOSTRATIGRAPHY AND PALEODEPOSITIONAL ENVIRONMENT OF ABARA-1 WELL, NIGER DELTA BASIN, NIGERIA

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Olubusayo Akinyele Olatunji

Department of Earth Sciences, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

Corresponding author: olubusayo.olatunji@aaua.edu.ng

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Abstract:

Foraminiferal biostratigraphic analysis was carried out for sequences within the depth interval of 200-9840 feet of Abara-1 well located onshore of the Western Niger Delta. The analysis showed that the distribution of both benthic and planktic foraminifera varied from poor to fairly rich. One planktic foraminiferal zone, *Praeorbulina glomerosa* corresponding to the N8/N9 Blow (1969, 1979) is proposed for the studied sections of the well. Middle Miocene age has been proposed for the studied intervals of Abara-1 well based on the foraminiferal assemblages. The occurrence of the biomarkers within the studied intervals aided the zonation of the sediments. A littoral (deltaic) to marine (inner neritic, middle neritic) environment of deposition has been suggested for the well on the basis of presence of environmentally benthic foraminiferal species such as *Saccammina complanata*, *Globigerinoides sp.* and *Eggerella sp.*

Keywords: Foraminifera, Middle Miocene, Western Niger Delta, Planktic, Benthic and Biomarkers

Introduction

Exploratory activities in the Niger Delta, which dated back to the 1903 recall the onset of accessibility to the subsurface formations that characterize the basin. Thousands of wells have been drilled across the delta penetrating the sediments, in which petroleum generation, migration and accumulation have occurred (Adeniran, 1997). The relatively large amount of data obtained from the wells has led to a considerable understanding of the regional geology and stratigraphy of the basin. These are information acquired largely through; 3-D seismic and interactive techniques, wireline log and most importantly sedimentology (Short and Stauble, 1967, Weber 1971, 1987, Weber and Daukoru 1975, Knox and Omatsola 1989, Doust and Omatsola 1990, Chukwu 1991, Chukwuka *et al*., 1992, Okosun *et al*. 2012, Fadiya *et al*. 2014, Adojoh *et al*. 2020, Itiowe *et al*. 2020, Adebambo and Fadiya 2021). The aim of this study is to carry out the foraminiferal biostratigraphy and paleodepositional environment of Abara-1 Well with the following objectives which are to identify the foraminiferal content of the well, age determination of the strata studied in the well, attempt a biostratigraphic zonation of the sequences penetrated by the well and determine the paleoenvironment of deposition of the penetrated strata. The scope of work involves processing for the microfauna presence within the sequences and depositional environmental analysis. Ages were assigned to the sequences and the systematics of the microfossils were undertaken.

Location of Study Well

Abara-1 Well is located around longitudes 5°50ˈE and latitude 5°5ˈN. The location of the well is shown in Figure **2**

Stratigraphy of Niger Delta Basin

The sedimentary fill of southern Nigerian basin has been controlled by three main tectonic phases and by epeirogenic movements (Murat, 1972). These have resulted in the major transgressive-regressive depositional cycle. The rate of delta advancement has been found on the rate of erosion of newly uplifted blocks in the hinterland and custatic changes in sea level (Burke *et al.*, 1972, Short and Stauble, 1967). The progressive outbuilding of the delta into the sea from Eocene to Recent is as shown in Figure 2. The thick wedges of deltaic sediments have been grouped into three diachronous units (Figure 3) (Short and Stauble, 1967; Frankl and Cordry, 1967).

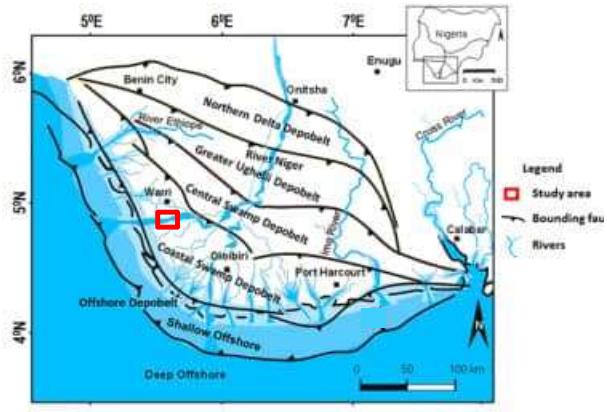


Figure 1: Location map of Abara-1 well in the Niger Delta Basin, Nigeria

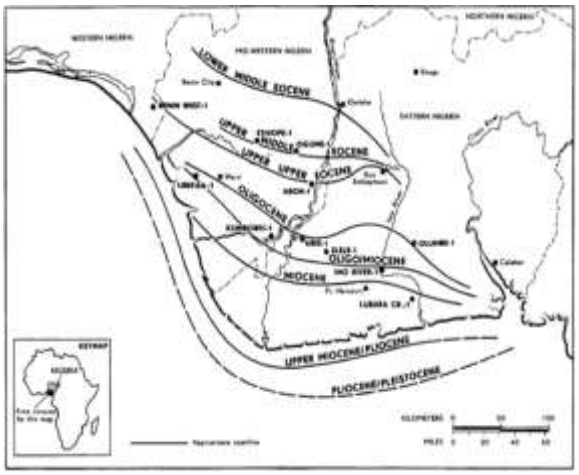


Figure 2: Palaeogeography of Tertiary Niger Delta Basin (Adapted from Short and Stauble, 1967)

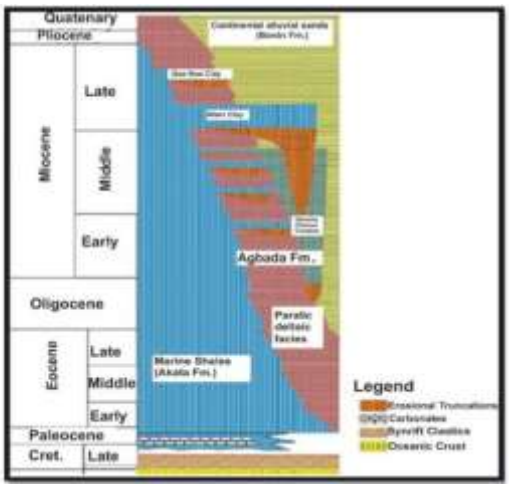


Figure 3: Schematic representation of the diachronous nature of major lithofacies units (After Doust and Omatsola, 1990)

The units are the Benin, Agbada and Akata Formations. The Benin Formation is thickest in the central area of the Delta (about 2100m) where there is maximum subsidence of the basement (Weber and Daukoru, 1975) and occurs across the whole Niger Delta from Benin to Onitsha area in the north to beyond the present coastline (Short and Stauble, 1967; Avbovbo, 1978) considers the base of the Benin Formation to be the first appearance of marine shale in a borehole. Genetically, the sand and sandstones are mainly deposits of the continental to deltaic plain environment (Short and Stauble, 1967). The Agbada Formation is a paralic sequence consisting of interbedded sands and shales, which have been shown by Weber (1971) to be cyclic. Its thickness varies from 300 m up to about 4500 m. Short and Stauble (1967) attributed the cyclicity of sequences to differential subsidence, variation in sediment supply, and shifts of depositional axes of the delta in local transgressions and regressions. The type section of the Agbada Formation is at the Agbada-2 well located 11 km northwest of Port Harcourt and most exploration wells in the Niger Delta penetrated the bottom of this lithofacies. The Agbada Formation is represented by an alternation of sandstones and shales as well as silts and clays in various proportions and thicknesses. Generally, the upper part of the Formation has a higher sandstone percentage than the lower part which is made predominantly of thicker shale units and alternating thinner units of sandstone (Short and Stauble, 1967). The sandstones are medium to fine-grained and fairly clean. Accessory glauconite and shell materials are found embedded within the sandstones and they also contain kaolinite and small amounts of mixed layers of illite and smectite (Avbovbo, 1978). This Formation forms the hydrocarbon prospective sequence in the Niger Delta with sands as reservoirs and the shales contributing as source rocks and the seals (Short and Stauble, 1967; Frankl and Cordry 1967). The Akata Formation is the basal unit of Niger Delta Basin. It is characteristically marine and composed of uniform shale development. The lithofacies is composed of shales, clays and silts and a few streaks of sand possibly of turbidite origin. It is believed that the shales of Akata Formation is the main source rock for hydrocarbon in the Niger Delta Delta (Ekweozor and Daukoru, 1984). The shales outcrop offshore in diapirs along the continental slope and onshore in the northeastern

part of the delta where they are known as Imo shale. The Akata Formation is a marine sequence which was laid down in front of the advancing delta during the Eocene to Recent times (Short and Stauble, 1967).

Materials and Methods

Ditch cutting samples from Abara-1 well were used in this study. Abara-1 well is located onshore of the Western Niger Delta and it was drilled by Nigerian Agip Oil Company. The Nigerian Geological Survey Agency (NGSA) Kaduna provided the ditch cutting samples of Abara-1 well for the purpose of this study. The ditch cutting samples range from 200 to 9840 ft for Abara -1 and in general, a total of 337 samples were analysed for the well. The collected samples were examined using hand lens to produce a lithologic description of the well sequences. The dominant rock types, the secondary rock types, colour and texture of constituent grains were duly determined. The foraminifera were recovered from the samples using the standard method of foraminiferal recovery. Twenty grammes of each sample was oven-dried at 10 °C for one hour. After this hydrogen peroxide solution of 3% concentration was added and then left overnight for proper disaggregation. The disaggregated samples were then washed under a jet of water over a 63 micron mesh sieve with liquid soap to remove the clay fractions. The washed residue was dried over a hot plate and sieved into coarse, medium and fine fractions. All the foraminifera, ostracods, shell fragments and other microfossils observed where then picked with a picking needle using a binocular microscope. The recovered foraminiferal specimens were counted and identified to species level where possible using taxonomic schemes of Loeblich and Tappan (1964, 1988), Cushman (1933, 1939) and the Agip s.p.a Foraminifera Padani (1982) and Petters (1983).

The interpretation of paleoenvironment is usually based on the comparison of fossil assemblages with data from modern living faunas and floras. It is assumed that the individual genera have not changed their ecologic preferences through geologic time. This assumes that the principle of uniformitarianism is operative (Ellison, 1951). A study of foraminiferal assemblages of modern seas has shown striking correlations between form and structure and environment. Evolutionary convergence may be the principal reason for correlation of form and structure with environment. General trends of this type are important corroborative criteria in paleoenvironmental studies (Bandy, 1964).

Results

Foraminifera and Biostratigraphy

The stratigraphic intervals studied in Abara-1 well have been divided into biostratigraphic zones on the basis of their planktic foraminiferal contents. Ages were assigned to the well based on their foraminiferal content. The synthesis of the biostratigraphic data is presented in the biostratigraphic synthesis charts in Figure 4. Seven planktic, five calcareous benthic, and five arenaceous benthic foraminiferal species as well as a number of accessories like shell fragments and micromolluses were identified from the studied samples of Abara-1 well (Plate 1). The proposed zones in this study were based on the rules contained in the American Commission on Stratigraphy Nomenclature (1973).

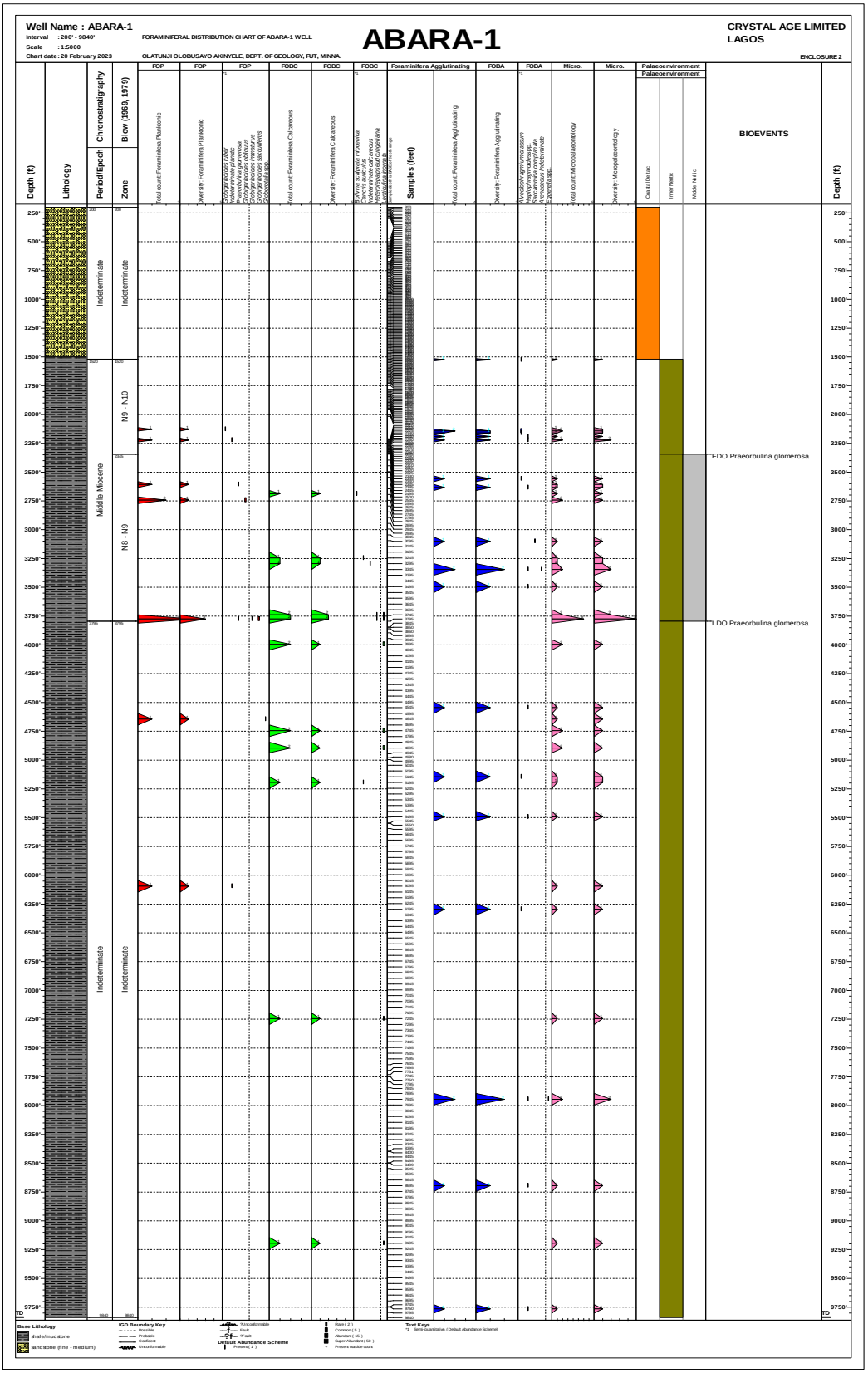
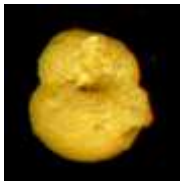


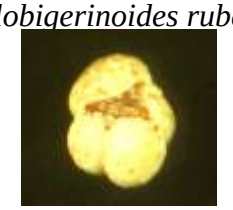
Figure 4: Biostratigraphic Chart of Abara-1 well

1. *Globigerinoides ruber*



4. *Globigerinoides immaturus*

7. *Alveolophragmium crassum*



2. *Globigerinoides obliquus*

5. *Praeorbulina glomerosa*

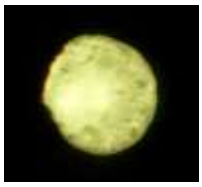
8. *Lenticulina inornata*

3. *Globigerinoides sacculiferus*

6. *Haplophragmoides spp.*

9. *Bolivina scalptrata miocenica*

X 600 µm



10. *Heterolepa pseudoungeriana*

Plate I: Some recovered planktic and Benthic foraminifera

Explanation of Plate 1

Globigerinoides ruber (d'Orbigny)

Globigerinoides obliqus (Bolli)

Globigerinoides sacculiferus (Brady)

Globigerinoides immaturus (LeRoy)

Praeorbulina glomerosa (Blow)

Haplophragmoides sp.

Alveolophragmium crissum (Crushman)

Lenticulina inornata (Linne)

Bolivina scalprata miocenica (MacFadyen)

Heterolepa pseudoungeriana (Franzenau)

Foraminiferal Zonation and Dating

The planktic foraminiferal species were almost completely neglected as biomarkers before 1940 because the morphologic differences between species were not appreciated leading to relatively few description, mostly long ranging taxa. However, there was a change in attitude

by Grimsdale (1951) who compared the ranges of 41 Tertiary planktic species from the Gulf of Mexico and the Carribean with their equivalent in the Middle East. Stainforth *et al*. (1975) produced a comprehensive review of zonations based on planktic foraminifera and the impact of such zones on classical Tertiary stratigraphy. Banner and Blow (1965) added a letter/number (alphanumeric) designation for each zone e.g *Globorotalia humerosa* Zone of Late Miocene N17. Biostratigraphers and oil exploration and producing companies have adopted the alphanumeric nomenclature which apart from Foraminiferal (F) Zones includes Palynomorph (P), Calcaceous Nannoplankton (NN), Diatoms, Dinoflagellate and Radiolarian Zones. The American Commission on Stratigraphic Nomenclature (1973) defined Interval, assemblage and abundance biozones for zonation purposes. The interval bizone has been most useful for biostratigraphic resolutions whereby strata are defined by the first appearance datum (FAD) and last appearance datum (LAD) of taxa. Based on this, taxon, concurrent, partial and range zones have been defined and used for zonation.

Planktic Foraminiferal Zonation

The planktic foraminiferal preservation in the well is poor. Some stratigraphically important taxa (index planktic forms) were not identifiable to specific/generic level. They are thus placed in the planktic indeterminate group. As a result of this, one planktic foraminifera zone was recognized each within the studied intervals of Abara-1 well. This zone was based on the First Downhole Occurrence (FDO) and the Last Downhole Occurrence (LDO) of diagnostic species (*Praeorbulina glomerosa* and *Orbulina universa*). In Abara-1 well, the First Downhole Occurrence (FDO) and the Last Downhole Occurrence (LDO) of *Praeorbulina glomerosa* confirmed the zone as a range zone (Table 1).

Table 1 Planktic foraminifera Zone in Abara-1 well

Depth (feet)	**Epoch**	**Blow (1969, 1979)**	**Planktic foraminiferal zone of this study**	**Bioevents**
200			Indeterminate	
1520	MIDDLE MIOCENE	N9/N10	Indeterminate	
2345		N8/N9	PRAEORBULINA GLOMEROSA	FDO LDO } *Praeorbulina glomerosa*
3795				
TD 9840			Indeterminate	

Zonal Characteristics of *Praeorbulina glomerosa* zone

This zone is equivalent to the N8/N9 zone as correlated with the standard planktic foraminiferal zone of Blow (1969, 1979)

Age: Middle Miocene

Planktic forms associated with this zone include, *Globigerina falconensis*, *Globigerinoides obliquus*, *Globigerina praebulloides* and *Globigerinoides sacculiferus.*

Biostratigraphic Age of Abara-1 Well

Due to the wide geographic distribution of planktic foraminiferal assemblage, age determination in microbiostratigraphy has traditionally been based on planktic forms. On the other hand, benthic foraminifera have been found not to provide reliable correlation even in sequences of uniform facies (Stainforth *et al*., 1975). The planktic foraminiferal data gave the age of the studied intervals in Abara-1 to be Middle Miocene (N8/N9 zone). Characteristic Middle Miocene planktic foraminifera confirmed the age range. Some of these are, *Praeorbulina glomerosa*, *Orbulina universa* and *Globigerina Praebulloides* (Blow, 1969, 1979; Petters, 1979, 1983).

Lithologic Description and Depositional Environments

The intervals of 200-1500 ft for Abara-1 consist of siltstone, silty sandstone and sandstone, 1500-9840 ft comprise sandy mudstone/shale and mudstone/shale. The sandstones are fine to coarse grained sub-angular to sub-rounded. The mudstone/shale layers vary from grey to

dark. Index accessory minerals including ferruginous materials, pyrite, glauconite and mica as well as carbonaceous matter and shell fragments of micromollusc and ostracods were recorded for the different depths.

The depositional environments of the sequences in Abara-1 well are interpreted to have ranged from a Littoral-Deltaic to Marine (inner neritic and middle neritic) environments. These environments are as shown in Figure. 4.

Littoral-Deltaic Environments

These environments have rare to non- recovery of foraminifera in the studied well. The dominant lithology here is fine to coarse-grained sub-angular to sub rounded, poorly sorted sands interbedded with mudstone and clay. The intervals for this environment in Abara-1 are 200-1520 ft.

Inner Neritic Environment

This environment is considerably rich in terms of the foraminiferal content. The characteristic foraminifera for this environment include; *Lenticulina inornata, Bolivina scalprata miocenica* and *Alveolophragmuim crassum*. Only a few planktic species are present. The bulk of the fossiliferous sequences of Abara-1 were deposited in the inner neritic environment. The lithology is mainly composed of shale and mudstone/siltstone with some coarse-grained, clean, well sorted sand containing abundant shell fragments.

Inner-Middle Neritic Environment

The environment is characterized by abundant and diverse foraminifera which comprise: *Saccammina complanata, Globigerinoides sp.* and *Eggerella sp.*. Diverse planktic foraminiferal taxa found here include; *Globigerinoides ruber* and *Globorotalia sp.* The main lithology of the environment is constituted by shale and mudstone. Sands were deposited at some intervals in the studied sequences. The inner to middle neritic environment sequences were recorded from 2345 to 3795 ft in Abara-1.

Conclusion

Abara-1 well sequences within the depth intervals of 200-9840 ft have been analysed for their biostratigraphic characteristics. One planktic foraminiferal zone that corresponds to the N8/N9 zone of Blow (1969, 1979) was established as well as the planktic zone of *Praeorbulina glomerosa*. A Middle Miocene age has been assigned to the studied intervals in both wells based on the foraminiferal assemblages. The environment of deposition for the studied wells ranges from Littoral Deltaic to Marine (Inner Neritic and Middle Neritic) environments due to the observed foraminiferal assemblages coupled with the other associated fauna. The lithologic, foraminiferal and paleodepositional analyses of Abara-1 well showed that the sequences penetrated by the well corresponds to Benin and Agbada Formations and they have been assigned Miocene age. The alternation of sand and shale sequences within the well gives the information on source, reservoir and seals needed for hydrocarbon generation, accumulation and trapping.

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