



Biostratigraphy and Paleoenvironment of Amansiodo-1 well, Anambra Basin, Nigeria

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ABSTRACT

Lithostratigraphic and biostratigraphic analyses were carried out on ditch cuttings samples from Amansiodo-1 well, Anambra Basin Nigeria. The lithostratigraphic description revealed the lithologies to be mainly shales, sandstones, clays, mudstones coal and siltstone. Biostratigraphic analysis shows a total of thirty benthonic foraminifera species recovered (twenty-six arenaceous and four calcareous) as a result three benthonic foraminiferal zones *Ammobaculites amabensis/Miliammina pindigensis* concurrent range zone, *Haplophragmoides sahelense* interval zone and *Haplophragmoides talokaense* interval zone was proposed for the well. The study also revealed shallow marine depositional environment based on the triangular plot of foraminifera suborders, paleobathymetric and paleo-oxygenation studies suggested the studied portion of the well belong to the Mamu Formation in the Anambra Basin. The well sediments are dated Maastrichtian based on the presence of *Haplophragmoides sahelense* an index fossil for Campanian –Maastrichtian.

Keywords: Lithofacies, Biostratigraphy, Ditch Cuttings, Amansiodo-1 Well, Foraminifera. Paleoenvironment

INTRODUCTION

Lithostratigraphic approach subdivides and correlates sequence strata by means of rock type and generally conforms to the law of superposition. Biostratigraphy uses the chronostratigraphic ranges of fossil species to correlate stratigraphic section and their paleo-environment preferences to provide information on the depositional settings (Emery and Myers, 1996). The identification of associated organisms representing a particular depositional environment (biofacies) reveals a valuable amount of information on the control of sedimentary succession and interpretation of depositional environments, the various markers of high and low sea-level phases, such as benthonic foraminifera seem to provide particularly reliable data as they are very sensitive to changes in the environment. Reliable paleoecological interpretation of past environment with regards to paleobathymetry, paleosalinity and paleo-oxygenation can be made with the aid of benthonic foraminifera, at least as far back as the Cretaceous (Sliter and Baker, 1972; Murray, 1991).

The objective of this study is to contribute to the stratigraphic investigation of the Anambra basin and hence advance our understanding of the basin. This study examines the lithofacies evaluation as well as foraminiferal biostratigraphy of the sedimentary of the Anambra Basin.

Geological Framework of the Anambra Basin

The Anambra Basin is a structural (synclinal) depression and one of the intracratonic basins in Nigeria whose sedimentary succession directly overlies the Lower Benue Trough and consists of Campanian to Paleocene sediments. The basin lies between latitude 05° 00' 00" to 08° 00' 00" N and longitude 06° 18' 00" to 08° 00' 00" E with an approximate area of 40,000 km² (Nwajide and Reijers, 1996). It is bounded to the west by the Okitipupa Ridge; to the northwest, it overlies the basement complex as seen between Auchi and Igara in the present Edo State; the northern boundary is with the basement complex of Keffi-Wamba area while the Niger Delta marks the southern limit (Fig 1)

The origin and tectonic evolution of the Benue Trough and Anambra Basin has been widely discussed (Murat, 1972; Kogbe, 1976; Petters, 1977; Petters and Ekweozor, 1982; Hoque and Nwajide, 1984; Benkhelil, 1987; Ojoh, 1992; Reijers and Nwajide, 1998). Sedimentation in the Anambra Basin commenced with deposition of the Campanian- Maastrichtian marine and paralic shales of the Nkporo and Enugu formations which represents the brackish marsh and fossiliferous prodelta facies of the late Campanian to early Maastrichtian depositional Nkporo cycle (Reijers and Nwajide, 1998) which are overlain successively by the Coal Measures (Mamu, Ajali and Nsukka formations). The coal bearing Mamu Formation and the Ajali Formation accumulated during this epoch of overall regression of the Nkporo cycle. The Nsukka and Imo formations mark the onset of another transgression in the Paleocene. The shales contain significant amount of organic matter and may be potential source of hydrocarbon expulsion (Nwajide, 2005; Obaje *et al.* 2004).

METHODOLOGY

Lithostratigraphic descriptions were carried out by examining the ditch cutting using hand lens taking into consideration the various lithologic characteristics such as colour, grain sizes, fissility and presence of plant remains. Foraminifera species were recovered from sixty-two ditch cutting samples obtained from Amansiodo-1 well, Anambra Basin. The samples were composited at 18 m interval. The procedure adopted for microfossil extraction is similar to standard micropaleontological sample preparation technique (Pessagno, 1967; Brasier, 1980; Zingula, 1968). The foraminifera species encountered were mounted temporarily with a gum on a micropaleontological slide cavity and covered with a slip. These slides were numbered for identification by comparing with forms previously described by Sellier de Crivieux (1976), Petters (1979a, 1979b, and 1982), *Bolli et al.* (1994), Jones (1994) and Gebhardt (1997, 1998). The well data were analysed using the stratabug software. Graphic charts (lithostratigraphic log, paleo-environment

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chart, foraminiferal biostratigraphic chart) were generated using stratabug software. Foraminiferal assemblages information for paleoenvironmental interpretation such as paleosalinity (the percentage of the three morphotypes: porcelaneous, hyaline and arenaceous), paleo-

oxygenation (ratio of epifaunal to infaunal benthonic foraminifera) and bathymetry (presence/absence and diversity of foraminifera).

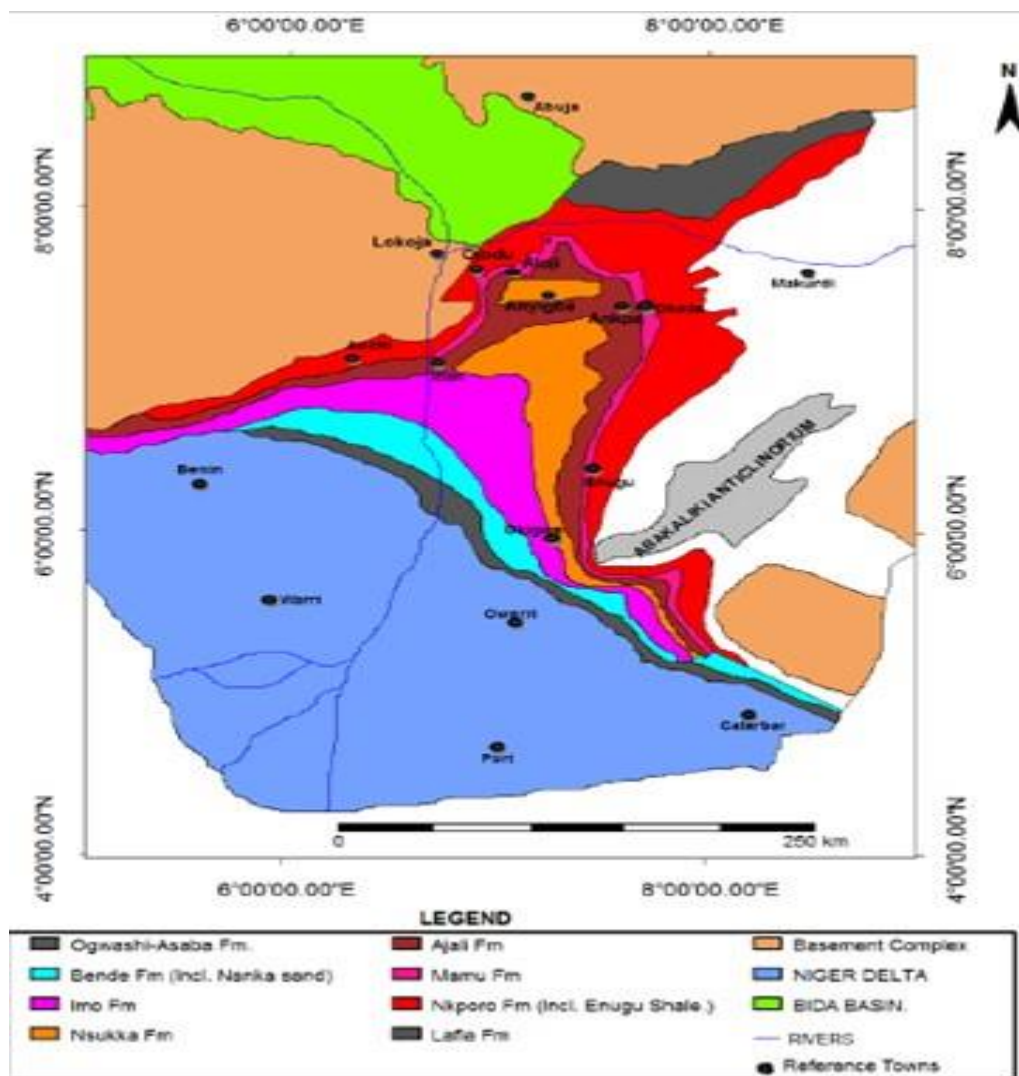


Figure 1: Geological sketch map of the Anambra Basin (After Obaje, 2009).

RESULTS

The lithostratigraphic section of the well based on samples description revealed the lithologies to be mainly shales, sandstones, clays, mudstones coal and siltstone (Fig 2). Foraminifera Microfauna The foraminifera recovered are well preserved. The forms obtained were the benthonic (arenaceous and calcareous) foraminifera. Associated fossils like ostracod, shell fragments and gastropods were recovered from some of the studied samples.

Benthonic Foraminifera

The benthonic foraminifera found in sediments of the well are made up of diverse and rich to occasionally abundant species. A total of thirty species were recovered; four of which are calcareous and twenty-six arenaceous (Table 1). The species are dominated by *Haplophragmoides sahelense*, *Haplophragmoides* sp., *Ammobaculites amabensis*, and *Ammobaculites* sp. Others have poor representation with a single occurrence as in the case of *Ammotium cf nkalangum*, *Miliammina tsogaensis*, *Marginulina dorsata*, *Lenticulina* sp. and *Marginulina* sp.

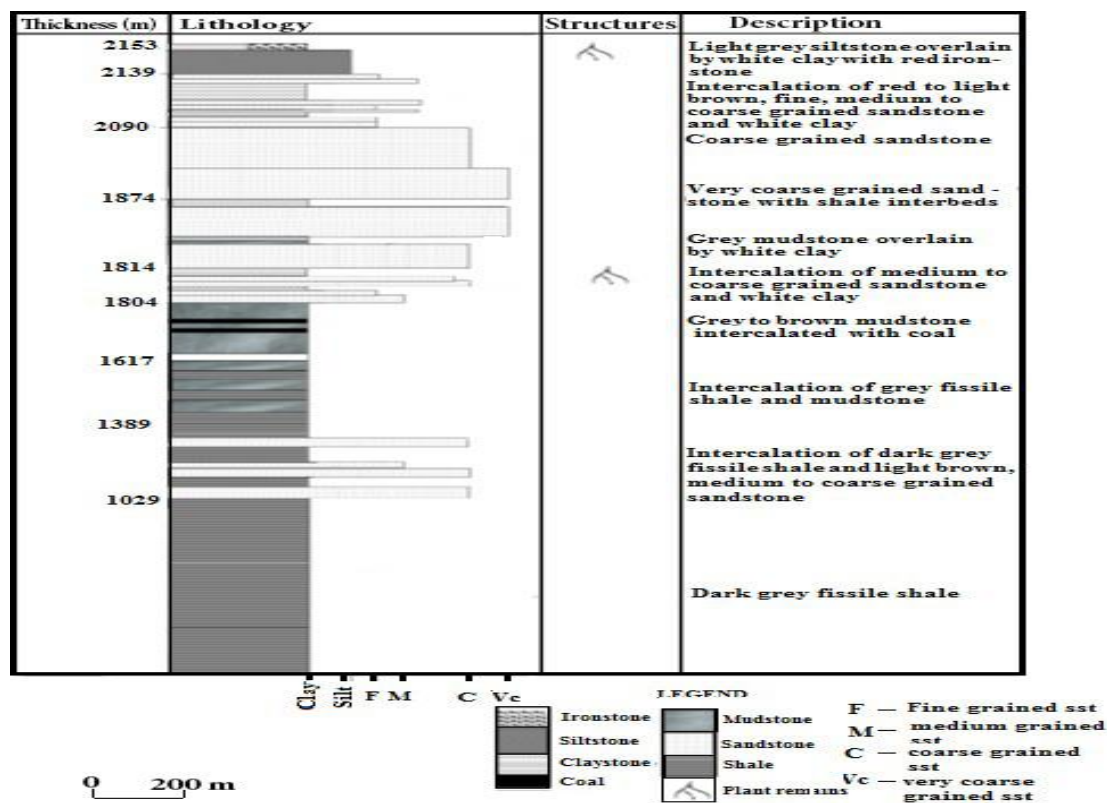


Figure 2: Lithostratigraphic section of Mamu Formation, Amansiodo-1 well.

Table 1: Benthonic Arenaceous and calcareous foraminifera species total count

Arenaceous Assemblages (FOBA)	Total Count	Calcareous Assemblage (FOBA)	Total Count
<i>Haplophragmoides saheliense</i>	93	<i>Marginulinna dorsata</i>	1
<i>Ammobaculites amabensis</i>	34	<i>Gavelinella saheliense</i>	4
<i>Ammobaculites jessensis</i>	4	<i>Lenticulina</i> sp.	1
<i>Haplophragmoides sahariense</i>	26	<i>Marginulina</i> sp.	1
<i>Haplophragmoides talokaense</i>	12		
<i>Ammobaculites numanhensis</i>	3		
<i>Ammobaculites</i> sp.	22		
<i>Ammotium</i> sp.	5		
<i>Haplophragmoides</i> sp.	24		
<i>Miliammina onyeamensis</i>	2		
<i>Miliammina pindigensis</i>	4		
<i>Textulariopsis dukamajina</i>	3		
<i>Trochammina afikpensis</i>	2		
<i>Trochammina dutsuna</i>	6		
<i>Trochammina</i> sp.	7		
<i>Arenaceous indet</i> sp.	9		
<i>Ammobaculites pindigensis</i>	2		
<i>Ammotium cf bornum</i>	1		
<i>Haplophragmoides hausa</i>	3		
<i>Ammobaculites bauchensis</i>	2		
<i>Ammotium cf nkalangum</i>	5		
<i>Miliammina tsogaensis</i>	1		
<i>Ammotium nkalangum</i>	6		
<i>Saccamina</i> sp.	1		
<i>Miliammina</i> sp.	3		
<i>Reophax</i> sp.	2		
Total count	282		7
Percentage total	97		3

Biozonation : Three zones have been proposed in this study as follows: *Ammobaculites amabensis*/*Miliammina pindigensis* concurrent range zone, *Haplophragmoides*

saheliense interval zone and *Haplophragmoides talokaense* interval zone (Fig 3)

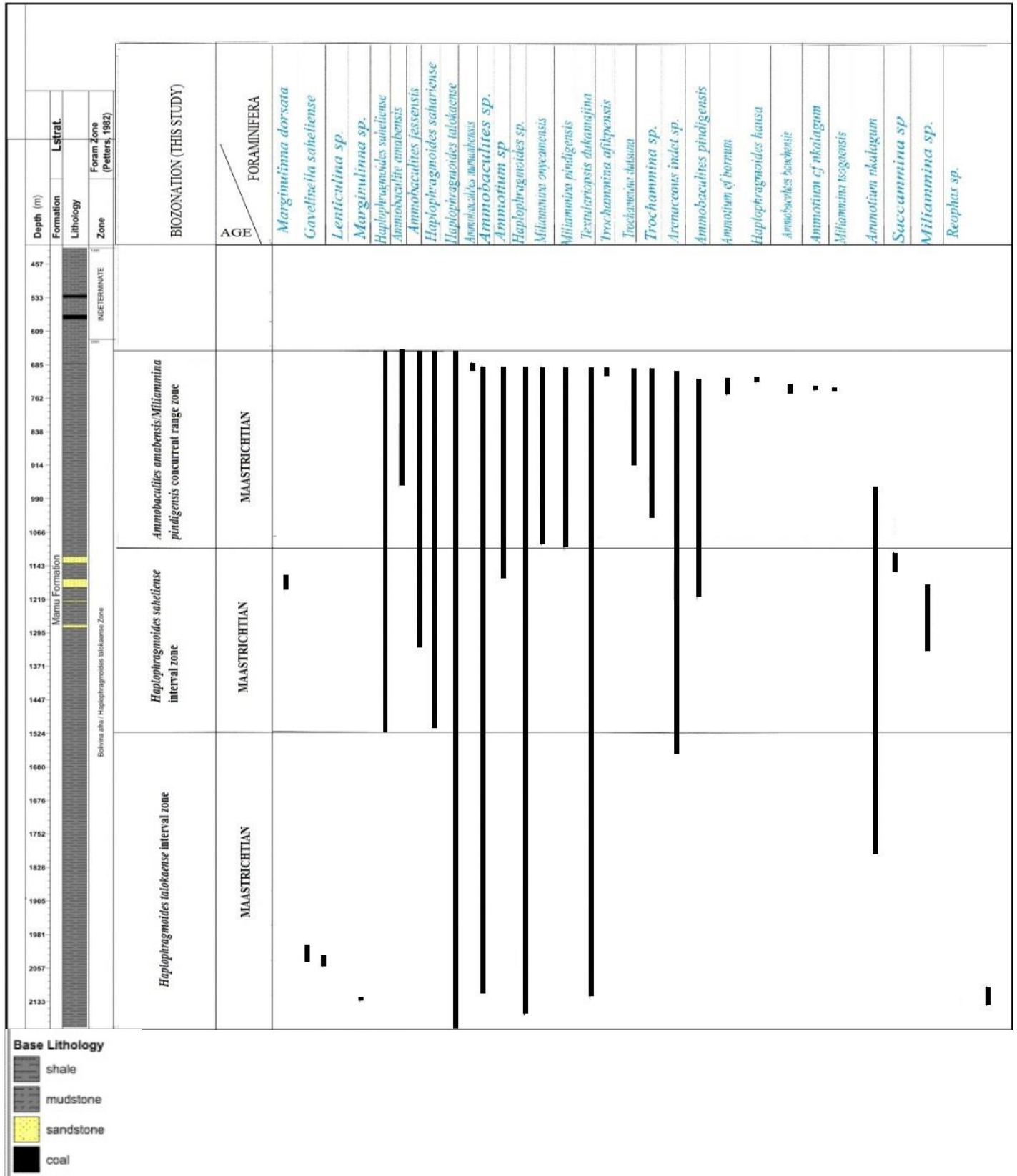


Figure 3: Biozonation for Amansiodo-1 well

Paleoenvironment: The paleoenvironment interpretation of the well was approached based on the evaluation of the benthonic foraminiferal assemblages and integrated with the lithostratigraphic analysis of sediments of the well and shows the sediments have fluctuated from non-marine to coastal deltaic to marine environments (that is, non-marine to shallow inner neritic to inner neritic and middle neritic) (Fig. 4).

DISCUSSION

From the lithostratigraphic section of sediments (Fig 2), the sandstone is generally fine to medium to coarse grained with intercalation of shale; mudstone, clays, coal occurs within specific intervals of the mudstone while siltstone/clay occur at the top of the section.

The deposition of the shale, clay and mudstone is largely by suspension settling mode in quiet low energy setting, probably swamps and flood plains (Miall, 1990). Lithostratigraphic analysis of the studied interval (16 - 2191 m) reveals that it penetrated the Mamu Formation of the Anambra Basin. (Fig. 2).

The general architecture of deposition of the section shows a low energy environment at the base of the section characterized by shales, mudstone and a change to high energy towards the top characterized by sands and a continental environment at the topmost part characterized by siltstone/clays.

The presence and abundance of benthonic foraminifera shows the sediments to be deposited in a marine environment. The micro fauna obtained did not yield any index planktonic foraminifera. However, Castelain *et al.* (1962) and Petters (1980, 1982) have used *Haplophragmoides sahelense* as an index of Campanian-Maastrichtian. Petters (1982) dated the *Bolivina afra* / *Haplophragmoides talokaense* zone to be Maastrichtian which corresponds to the benthonic zonation of the studied well interval. Hence, the Mamu Formation is assign Maastrichtian.

Three zones proposed in this study (base on the International Stratigraphic Guide and the observation of the range of benthonic foraminifera) are as follows: *Ammobaculites amabensis*/*Miliammina pindigensis* concurrent range zone, *Haplophragmoides sahelense* interval zone and *Haplophragmoides talokaense* interval zone (Fig. 4).

Ammobaculites amabensis / *Miliammina pindigensis* Concurrent Range Zone

Depth: 646 - 1121 m (Age: Maastrichtian). This zone is marked at the top by the first downhole occurrence (FDO) of *Ammobaculites amabensis* and at the base by the last downhole occurrence (LDO) of *Miliammina pindigensis*. Other enclosing benthonic species include: *Ammobaculites jessensis*, *Haplophragmoides sahariense*, *Haplophragmoides talokaense*, *Ammobaculites numanensis*, *Ammobaculites* sp., *Ammotium* sp., *Haplophragmoides* sp., *Textulariopsis dukamajina*, *Trochammina afikpensis*, *Trochammina dutsuma*, *Trochammina* sp., *Arenaceous indet* sp., *Ammobaculites pindigensis*, *Ammotium* cf *bornum*, *Haplophragmoides hausa*, *Ammobaculites bauchensis*, *Ammotium* cf

nkalagum, *Miliammina tsogaense*, and *Ammotium nkalagum*.

Haplophragmoides sahelense Interval Zone

Depth: 1121 – 1520 m (Age: Maastrichtian). This zone is characterized at the top by the last downhole occurrence (LDO) of *Miliammina pindigensis* and at the base by the last downhole occurrence (LDO) of *Haplophragmoides sahelense*. Other enclosing benthonic species include: *Ammobaculites jessensis*, *Haplophragmoides sahariense*, *Haplophragmoides talokaense*, *Ammobaculites* sp., *Ammotium* sp., *Haplophragmoides* sp., *Textulariopsis dukamajina*, *Arenaceous indet* sp., *Ammobaculites pindigensis* and *Ammotium nkalagum*.

Haplophragmoides talokaense Interval Zone

Depth: 1520 – 2173 m (Age: Maastrichtian). This zone is characterized at the top by the last downhole occurrence (LDO) of *Haplophragmoides sahelense* and at the base by last downhole occurrence of *Haplophragmoides talokaense*. Other enclosing species are *Gavelinella sahelense*, *Lenticulina* sp., *Marginulina* sp., *Haplophragmoides talokaense*, *Ammobaculites* sp., *Haplophragmoides* sp., *Textulariopsis dukamajina*, *Arenaceous indet* sp., *Ammotium nkalagum* and *Reophax* sp.

Foraminiferal data (benthonic foraminifera) was most useful in paleobathymetric estimation, this involved utilizing relative abundance and diversity of benthonic foraminifera. Benthonic foraminifera have evolved to exist in a range of environments, from marginal marine to deep ocean. The ratio of planktonics to benthonics in sediments provide paleoenvironmental guide (proportion of planktonic specimen increases from 0% in shallow marine environment to more than 90% in deep marine environment, Culver 1987) on this basis the recovered foraminifera shows a shallow marine environment due to absence of planktonic foraminifera. The ratio of calcareous benthonic to arenaceous benthonic foraminifera (FOBC/FOBA) also provides useful paleoenvironmental guide, the higher the FOBC, the shallower the paleodepths, conversely, the higher the FOBA, the deeper the paleodepths (Boersma, 1978). The ratio of arenaceous which is greater than calcareous depicts a greater depth of deposition of the sediments.

The approach adopted by Petters (1982, 1995), where various biofacies were styled after bathymetric features was used in this study. In the well, the paleobathymetry ranges are discussed:

Non Marine

Non marine environment is observed at 591 - 627 m, 1066 – 1069 m, 1267 – 1286 m, 1303 – 1319 m, 1392 – 1411 m, 1539 – 1557 m, 1594 – 1667 m, 1990 – 2008 m and 2081 – 2136 m. The interpretation is based on the absence (barren) of foraminiferal species at these intervals and also the dominance of sandstone at the various intervals (Fig. 5).

Shallow Inner Neritic

The intervals inferred to be shallow inner neritic environment range from 627 – 646 m, 938 – 993 m, 1030 – 1066 m, 1158 – 1194 m, 1231 – 1249 m, 1286 – 1303 m, 1319 – 1392 m, 1484 – 1539 m, 1557 – 1594 m, 1770

– 1789 m, 2008 – 2081 m and 2136 – 2191 m (Fig. 5). Species dominance is low and the number of species (diversity) is much. Species diversity increases from zero to seven. The interval contains few benthonic foraminifera (e.g. *Ammobaculites* sp., *Ammobaculites amabensis*). Abundance of Shell fragments is common at this environment.

Inner Neritic

The intervals are 701 – 774 m, 829 – 865 m, 993 – 1030 m, 1121 – 1158 m and 1249 – 1267 m. This interval is marked by increased foraminiferal diversity and abundance (Fig. 4). The foraminiferal count ranges from three to twenty-three and the foraminiferal diversity two to eight species. This indicates a prograding of the shoreline basinward.

Middle Neritic

This environment is recognized at 682 – 701 m. The interval contains the highest abundance and diversity of foraminifera (with thirteen species). This shows that the sediments progressed from non-marine to a marine condition. The presence of

Ammobaculites and *Haplophragmoides* sp. suggest delta front environment of deposition (Petters, 1979).

CONCLUSION

Lithostratigraphic and biostratigraphic analyses were carried out on Amansiodo-1 well, Anambra Basin Nigeria. The lithostratigraphic description revealed shales, sandstones, clays, mudstones, coal and siltstone lithologies. The Biostratigraphic analysis shows a total of thirty benthonic foraminifera species recovered (twenty-six arenaceous and four calcareous) as a result, three benthonic foraminiferal zones *Ammobaculites amabensis/Miliammina pindigensis* concurrent range zone, *Haplophragmoides sahelense* interval zone and *Haplophragmoides talokaense* interval zone was proposed. The study also revealed a non-marine to middle neritic environments, suggesting a shallow marine depositional environment. The sediments are dated Maastrichtian based on the presence of *Haplophragmoides sahelense* as an index of Campanian-Maastrichtian.

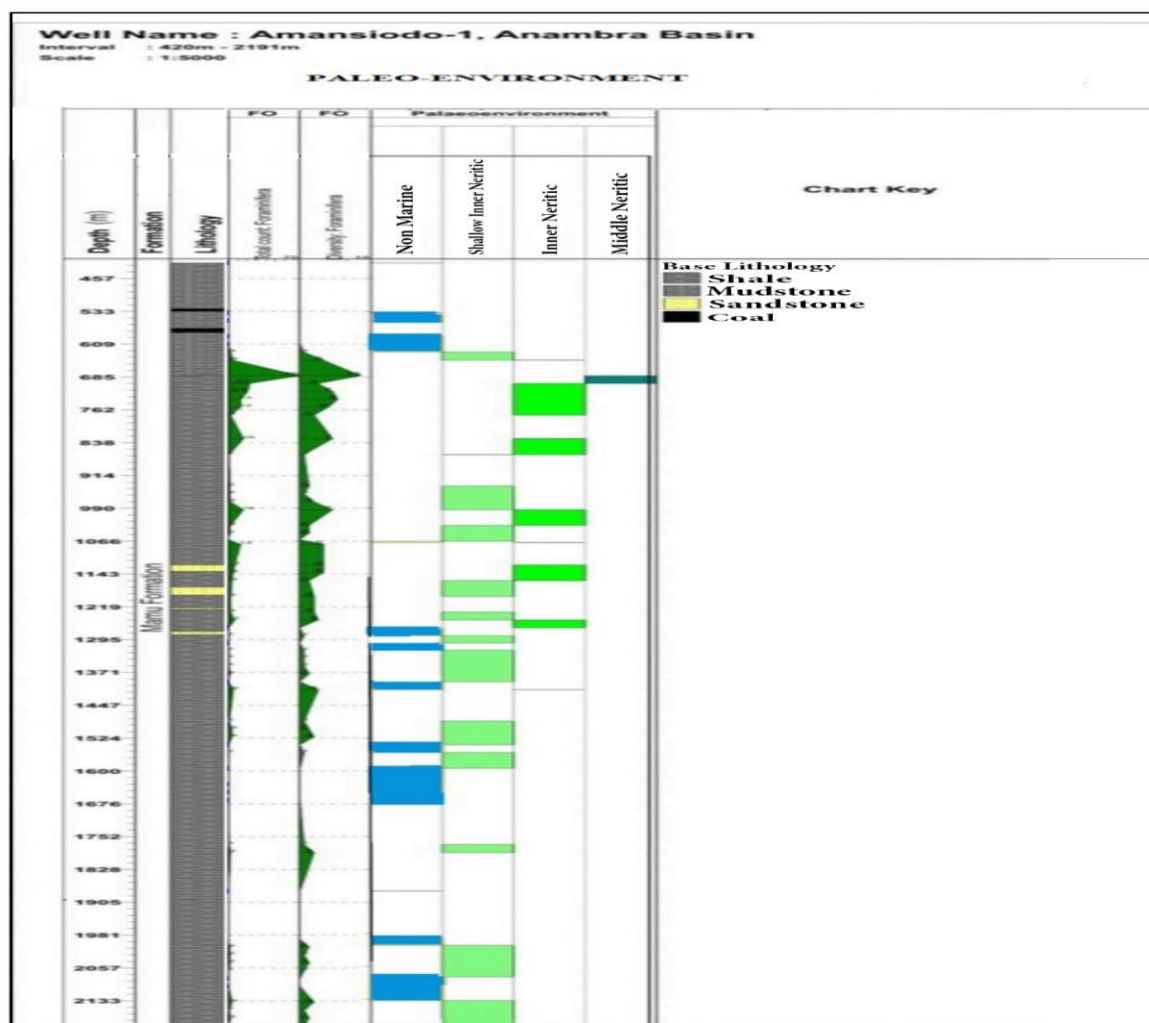


Figure 4: Paleoenvironmental chart of Amansiodo-1 well

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