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FORAMINIFERAL AND CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL STUDIES OF SAA -1 AND SAA-3 WELLS, OFFSHORE NIGER DELTA

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Abstract

Biostratigraphic studies were carried out on the strata penetrated by SAA-1 and 3 wells in Niger Delta. A total of One hundred and fifty ditch samples from both wells were analyzed for their foraminiferal content and calcareous nannofossil with a view towards identifying biostratigraphic zones, age determination, correlating the wells and paleoenvironmental reconstruction.

The study revealed two planktonic foraminiferal zones from SAA-1 well, *Globigerinoides trilobus immaturus* zone (N9-N10) and N8 zone and three zones were identified for SAA-3 well; (N11), *Globigerinoides trilobus immaturus* (N9-N10) and *Globorotalia fohsi peripheroronda* zone (N8).

The calcareous nannofossils zones identified [*Helicosphaera bramlettei* and *Helicophaera truempyi* (NN1) and *Cyclicargolithus floridanus* and *Helicophontosphaera ampliaperta* (NN4) zones]. All the zones were dated Early to Middle Miocene age using the standard zonation scheme.

Keywords: *Planktonic foraminifera; planktic/benthic ratio; Calcareous nannofossils.*

1. Introduction

The study area lies within the Niger Delta Basin, which is situated on the continental margin of the Gulf of Guinea in equatorial West Africa [1], between latitude 3° and 6° N and longitude 5° and 8° E [2]. It ranks amongst the world's most prolific petroleum producing Tertiary deltas that together account for about 5% of the world's oil and gas reserves and for about 2.5% of the present day basin areas on earth.

Biostratigraphy is defined as *"the classification of sediment units according to observable variations in fossil content"* [3], enables sediment sequence to be divided into biostratigraphic units or biozones, each characterised by a distinctive fossil assemblage. Examples of fossils used in biostratigraphic studies include foraminifera, calcareous nannofossils and ostracods. Foraminifera, with their small size, global ecological extent and rapid evolutionary turnover provide an excellent means of biozonation [4]. Deep-water agglutinated foraminifera have been used during hydrocarbon explorations since the 1970's when the first Deep Sea Drilling Programme (DSDP) established their value for both biostratigraphical and palaeoenvironmental studies [5]. Planktonic foraminifera are good stratigraphic indicators of the interval covering the Jurassic to present, while benthic foraminifera are found since the Cambrian (Ordovician to Present for calcareous species).Calcareous nannofossils are very small microfossils (2 to 50 μm) composed of calcium carbonate. They are very good biostratigraphic markers within marine sediments by covering the Jurassic to present.

This study integrated foraminiferal and calcareous nannofossils analysis to determine biostratigraphy and environment of deposition of the strata penetrated by SAA-1 and SAA-3 wells for a better picture and a clearer understanding of delta sequences.

2. Methodology

2.1. Calcareous nannofossils

A slight modification of standard smear slide preparation method was employed. One hundred samples from SAA-3 well were used for nannofossil analysis with sampling interval of about 60ft (18m). About 5g of each sample were used for the analysis. Detailed identification of forms was made of all the taxa encountered in each slide to enable the biozonation of the strata encountered in the well using zonation scheme of [6].

2.2. Foraminifera

Two hundred samples were used for foraminiferal study; a hundred from SAA-1 well and hundred from SAA-3 well. Samples were soaked with kerosene and left overnight to disaggregate. Soaked samples were washed under running faucet water through three sieves (250, 150 and 63 micron mesh). All the foraminifera, Ostracods, shell fragments and other microfossils observed in the residue were picked under high power Olympus reflected light microscope with the aid of picking brush, counted, placed in foraminifer's slides and covered with cover slide for safety and future reference. The slides were properly labeled using both the well name and sample depth. The identified microfauna were used for biozonation and dating of the strata as well as paleoenvironmental studies.

3. Results and discussion

3.1. Foraminifera biostratigraphy

The results of this analysis are presented in the foramifera distribution charts of SAA-1and SAA-3 wells (Figures 1, 2). The charts show the stratigraphic distribution, age and paleobathymetric ranges of the species. The stratigraphic intervals studied in these wells are characterized into biostratigraphic zones based on their foraminiferal contents. The established planktic and benthic foraminifera biostratigraphic zones in the two wells were correlated.

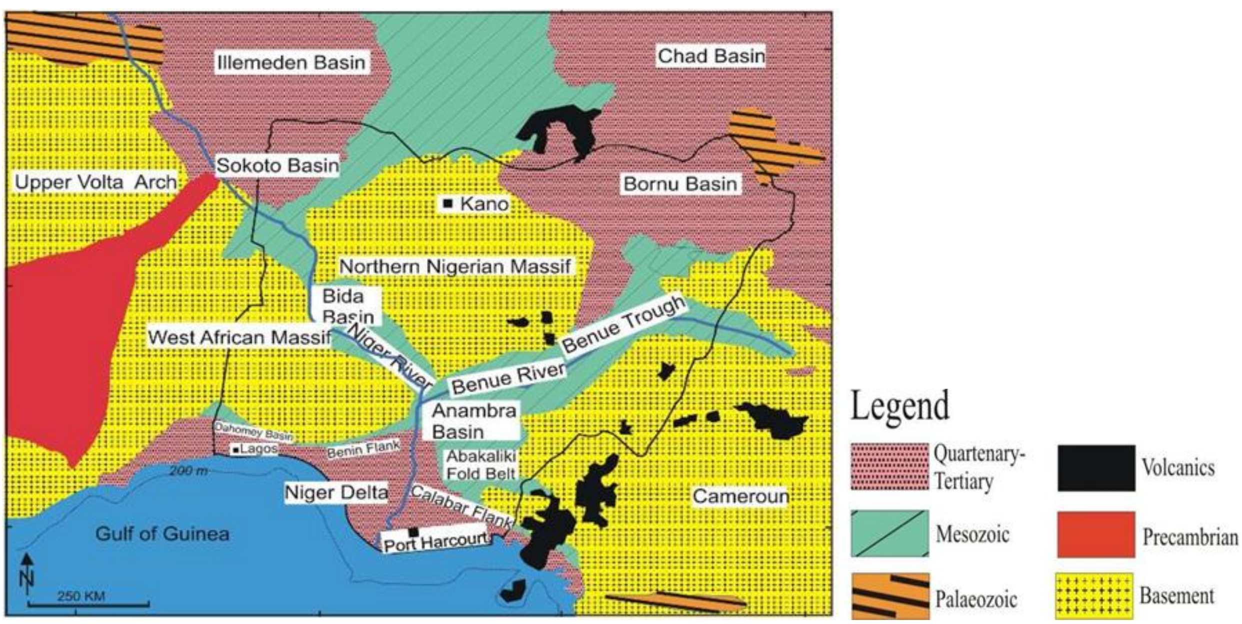

Figure 1. Simplified geological map of Nigeria showing location of the Niger Delta and some other Nigerian Sedimentary Basins.

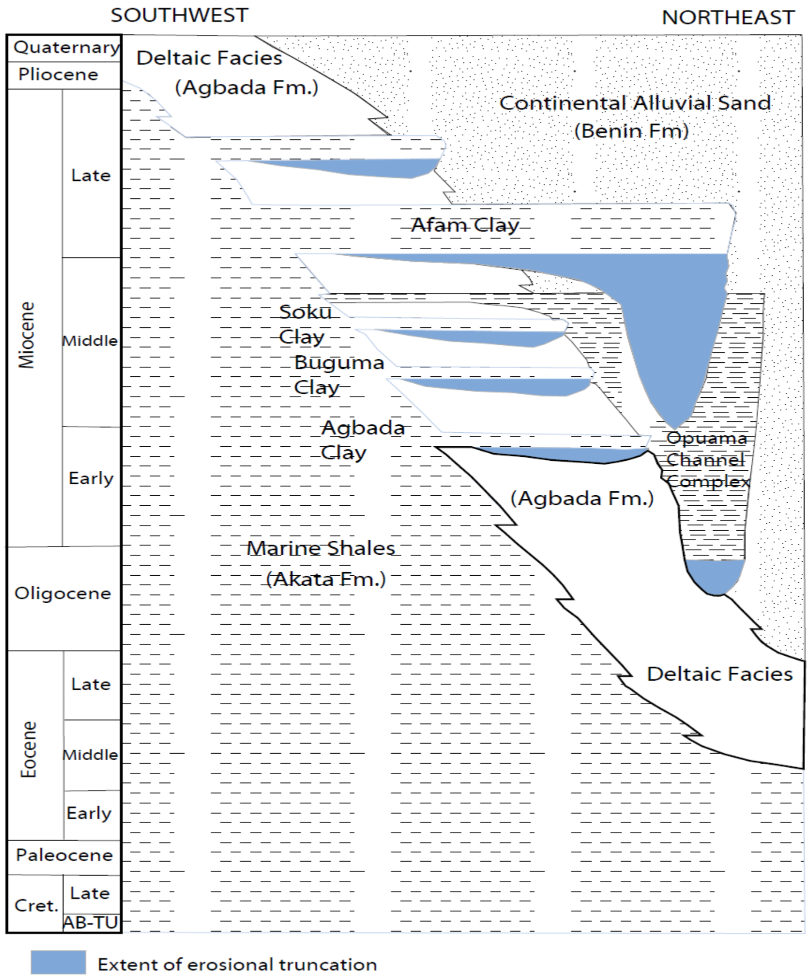

Fig. 2. Stratigraphic column showing the three formations of the Niger delta, the marine Akata shale, the paralic Agbada Formation and the continental Benin sandstone. (Modified from Doust and Omatsola, 1990).

3.1.1. SAA-1

Forty-nine foraminifera species were recovered from the studied samples; fourteen of which are planktonic species, thirty-five are calcareous benthic species and the agglutinated forms were represented by genus *Textularia* (Figure 1). Two planktonic foraminifera zones were recognized based on the planktonic foraminifera zonation scheme of Bolli and Saunders [7] and both are of Middle Miocene age.

3.1.2. SAA-3

Sixty-eight forminifera species were recovered from the studied samples. Twenty- three are planktonic species while forty-five are calcareous benthic species (Figure 2). Accessory microfauna such as ostracod, gastropod, shell fragments, echinoid remains, and sponges were also recorded. Three planktonic foraminifera zones were recognized in Minna-3 well; Middle Miocene age is proposed for the three zones.

3.2. Species abundance and diversity

There is high abundance and diversity of benthic species relative to planktic species in both wells (Tables 1 and 2, Figures 3). There is peak abundance of both benthic and planktic foraminifera at depth intervals 1241-1277m and 1277-1314m for SAA-1 well while those of SAA-3 are at 1463-1500m, 1820-1856m and 2533-2569m.

Table 1. Shows the abundance of planktic and benthic species for SAA-1 well

Depth (m)	Abundance Planktic species	Benthic species	P/N ratio
1241-1277	239	857	0.28
1277-1314	29	239	0.12
1314-1350	2	41	0.05
1570-1606	10	82	0.12
1643-1679	4	150	0.03
2018-2054	5	113	0.04

Table 2. Shows the abundance of planktic and benthic species for SAA-3 well

Depth (m)	Abundance Planktic species	Benthic species	P/N ratio
1463-1500	120	520	0.23
1500-1536	31	101	0.31
1536-1573	11	107	0.10
1783-1820	14	92	0.15
1820-1856	87	434	0.20
2277-2313	63	49	1.29
2405-2441	14	126	0.11
2533-2569	13	174	0.07

3.3. P/B ratio

Another method used to obtain paleobathymetric data is the plankton (P) to benthic (B) ratio [8]. Abundance of planktonic foraminifera is increased by intense vertical circulation. Area with intense vertical circulation are characterized by an increase in surface productivity and caused enrichment of the planktonic population. In addition, vertical circulation condition cause oxygen depletion of the bottom water and may reduce the number of benthic foraminifera. The P/B ratio is highest at interval 1241-1277m with a value of 0.28, lowest at 1643-1679m (0.03) in SAA-1 well (Table 1). There is gradational decrease in P/B ratio from 0.28 to 0.05 from the depth interval 1241-1277m to 1314-1350m (Figure 5a). The P/B ratio is highest at 2277-2313m (1.29) and lowest at 2533-2569m (0.07) in SAA-3 well (Table 2). The high P/B ratio observed at interval 2277-2313m may be due to a decrease in contribution from adjoining banks (beaches or shores) [9] or due to differential dissolution of foraminiferal tests [10]. The sharp difference in P/B observed at 2313-2405m in SAA-3 may be suggestive of surface of unconformity or stratigraphic gap (Figure 5b).

3.4. Condensed sections and Maximum Flooding Surfaces

One condensed section is recognized in SAA-1 well while two are recognized in SAA-3 well. The condensed section in SAA-1 well lies at depth interval of 1241-2054m and the peak abundances in the well fall within this range (Figs. 2, 3). The candidate condensed sections in SAA-3 well are at depth interval of 1463-1875m and 2259-2588m (Figure 4). The peak abundances (at 1463-1500m and 1820-1856m) in SAA-3 well are within the first condensed section which is associated with the 14.6Ma maximum flooding surface (Figure 4). The third peak abundance (2533-2569m) for SAA-3 falls within the second condensed section which is associated with the 15.1Ma maximum flooding surface.

3.5. Correlation of Zones for SAA 1 and SAA 3

Two planktic zones (N8, N9-N10) were recognized in SAA-1 well while three zones (N8, N9-N10, N11 and younger) were recognized in SAA-3 well. The N9-N10 zone for SAA-1 well is found at the depth interval of 1241-2054, its top correlates with the top of N9-N10 zone (1463-1801m) of SAA-3 well at the depth of 1463m and its base at the depth of 2054m correlates with that of SAA-3 at the depth of 1801m (Fig. 3). N9-N10 zone of SAA-1 well has a relatively thicker lithologic section when compared with the N9-N10 zone of SAA-3. The top of N8 zone of SAA-1 well at 2054m correlates with the top of N8 zone of SAA-3 at 1801m but their base are not correlative due to paucity of faunal assemblages at the lower part of N8 zone of SAA-1 well.

3.6. Calcareous Nannofossil Biostratigraphy

Seventy-seven ditch cutting samples from interval 1645-3063 of SAA-3 well were prepared and analysed for nannofossil at 60ft (18m) interval. The analysis revealed a fairly diverse and abundant population of calcareous nannofossils within intervals 1664-1984m and 2240-2478m while intervals 1984-2240m and 2478-2752m were characterized by rare and scattered occurrence of calcareous nannofossils (Figure 9). A total of twenty-nine nannofossil species were recognized and the most abundant is *Sphenolithus heteromorphous* occurring almost throughout the entire analysed section. The occurrence of characteristic index markers within the analyzed section of the well facilitated precise zonal delineation and recognition of dated events using the zonation schemes of Martini [6]. The condensed section was correlated to the Global Cycle Chart of Haq *et al.* [11]. The analysed section of the well has been dated Early to Middle Miocene (NN1-NN4 zones) age. The absence of the zones NN2 and NN3 is interpreted as a hiatus with an unconformity at depth 2441m [12-13]. The stratigraphic distribution of the recorded taxa is as shown in Figure 9.

3.7. Paleoenvironment

Paleoenvironmental interpretations were made from the biofacies information deduced from the qualitative and quantitative evaluation of the benthic foraminiferal assemblages. This has been integrated with the lithologic description of the wells, the planktic/benthic foraminiferal ratio and presence/absence of ostracod.

3.7.1. Coastal deltaic environment

The marginal-marine setting lies along the boundary between the continental and marine depositional realms. These are environments with non to rare recovery of foraminifera because of the unfavourable conditions of rapid sedimentation, temperature and salinity variations. The intervals inferred to be coastal deltaic ranges from 1274-1426m, 2899-3045m in SAA-3 well (Figure 11) while SAA-1 well has no coastal deltaic paleoenvironment within the studied section of the well. This inference is based on the fact that the intervals are either completely barren of microfauna or contain very few benthic and planktic foraminifera e.g. *Textularia* sp, *Lenticulina grandis* and planktic indeterminate.

3.7.2. Coastal deltaic-Inner Neritic

Depth interval inferred to be of coastal deltaic- inner neritic environment is 2091-3042 in SAA-1 well (Figure 10). Foraminiferal assemblage is characterized by scattered occurrences of *Lenticulina grandis, Bolivina isidroensis, Quinqueloculina larmackiana.*

3.7.3. Inner Neritic

This is a subdivision of marine environment that lies within 0-40 m on the continental shelf. A few species usually dominate the benthic faunas. Tests are small and weakly ornamented. Agglutinated species with simple wall structure are common foraminifera in this subenvironment [14]. The depth intervals inferred to belong to this environment are 1237-1256m, 2002-2185m and 3045-3063m in SAA-3 well only (Figure 11).

3.7.4. Inner Neritic-Middle Neritic

This environment is recognized in SAA-1 well at depth interval of 1241-2080m and 1445-2002m, 2185-2899m in SAA-3 well (Figures 10 and 11). There is fairly abundant and diverse planktic species within these intervals. The indicator fauna found here are *Quinqueloculina seminulum, Quinqueloculina mirostata, Brizalina interjuncta, Uvigerina sparsicostata, Eponides* ssp.

The paleoenvironment in SAA-1 well shows a transition from Coastal deltaic-Inner Neritic to Inner Neritic-Middle Neritic. This transition is indicative of a regressive process (Figure 10).

SAA-3 well palaeoenvironment reveals a transition from Inner Neritic (3045-3063m) to Coastal deltaic (2899-3045m) and this is indicative of transgressive process. The transition from Coastal deltaic to Inner Neritic-Middle Neritic (2185-2899m) signifies a regression, after there is another transgression signified by the change from Inner Neritic-Middle Neritic to Inner Neritic (2002-2185). The transition from Inner Neritic to Inner Neritic-Middle Neritic (1445-2002m) shows another regression. The switch of the paleoenvironment from Inner Neritic-Middle Neritic to Coastal deltaic (1274-1426m) indicates transgressive movement of the sealevel. And finally, there is a transition from Coastal deltaic to Inner Neritic (Figure 11). The transgressive-regressive movement observed in SAA-1 and SAA-3 paleoenvironment illustrates the kind of movement proposed to be responsible for the paralic sequences found in Agbada Formation within which the studied intervals of the wells fall.

4. Conclusion

This study was carried out on ditch cutting samples of two wells; SAA-1 and SAA-3. The studied depth intervals range from 1222-3042m and 1219-3063m in both wells respectively. The lithology of the wells is composed of grey to dark grey shale and sandy shale beds.

Biostratigraphic characteristic of the wells were analysed using both foraminifera and calcareous nannofossils. Two planktic forminiferal zones were recognized for SAA-1 well, N9-N10 and N8 zones while three planktic zones were established for SAA-3 well using the biozonation scheme of Martini [6]. The studied intervals in both wells are dated Middle Miocene.

The calcareous nannofossil zones recognized for SAA-3 well are NN4 and NN11 and older. The sudden transition from NN4-NN11 assemblage such as *Cyclicargolithus abisectus, Reticulofenestra scrippsae* and *Helicosphaera truempyi* indicated a period of erosion or non-deposition and the suspected unconformity surface marked at depth 2441m where a co-occurrence of the NN4 and NN11 assemblages were observed. The nannofossil abundance/ diversity patterns were correlated to the Global Cycle Chart of Haq *et al.* [11] (1987) and this facilitated the recognition of two Maximum Flooding Surfaces dated 16.0Ma and 18.0Ma. The studied section is dated Early-Middle Miocene.

The recognized foraminiferal assemblages (mainly the benthics) together with other accessory microfauna were used in deciphering the environment of deposition of the sediments. SAA-1 well shows a paleoenvironmental transition from Coastal deltaic-Inner Neritic to Inner Neritic-Middle Neritic. The paleoenvironments observed in SAA-3 well are Coastal deltaic, Inner Neritic and Inner-Middle Neritic. The paleoenvironmental analysis shows a transgressive – regressive trend that characterizes the paralic sequences in Agbada formation.

Using the lithologic, foraminiferal, calcareous nannofossil and paleoenvironmental studies, it is inferred that the intervals penetrated by both wells correspond to Agbada Formation, and they are of Miocene age. The alternation of shales and sandy shales/mudstones within the sequence provides the combination of source, reservoir and cap rocks essential for hydrocarbon generation, accumulation and trapping.

Figures 3-11

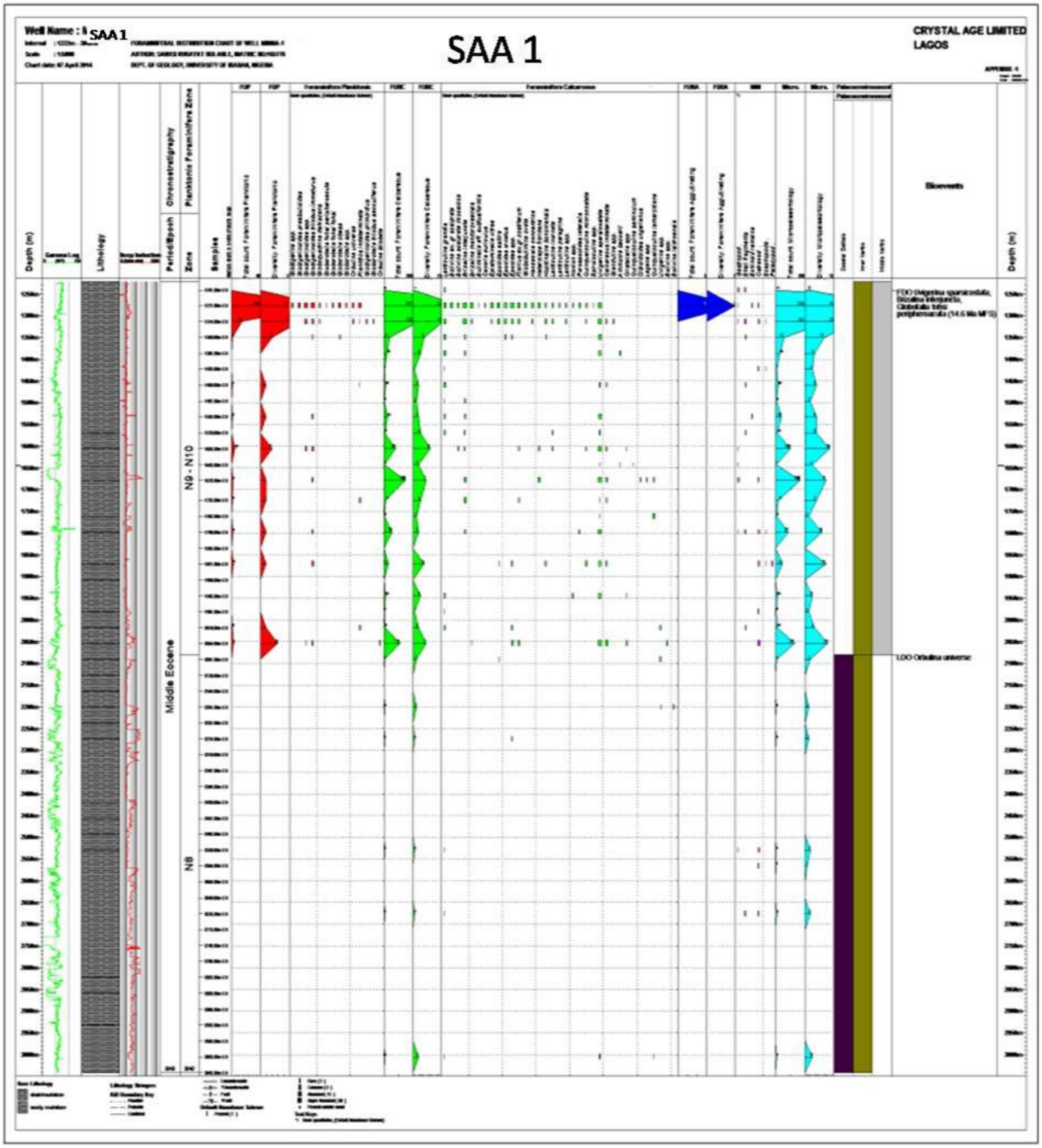

Figure 3. Distribution Chart of SAA-1 well showing the depth, biozones, abundance and diversity of microfauna

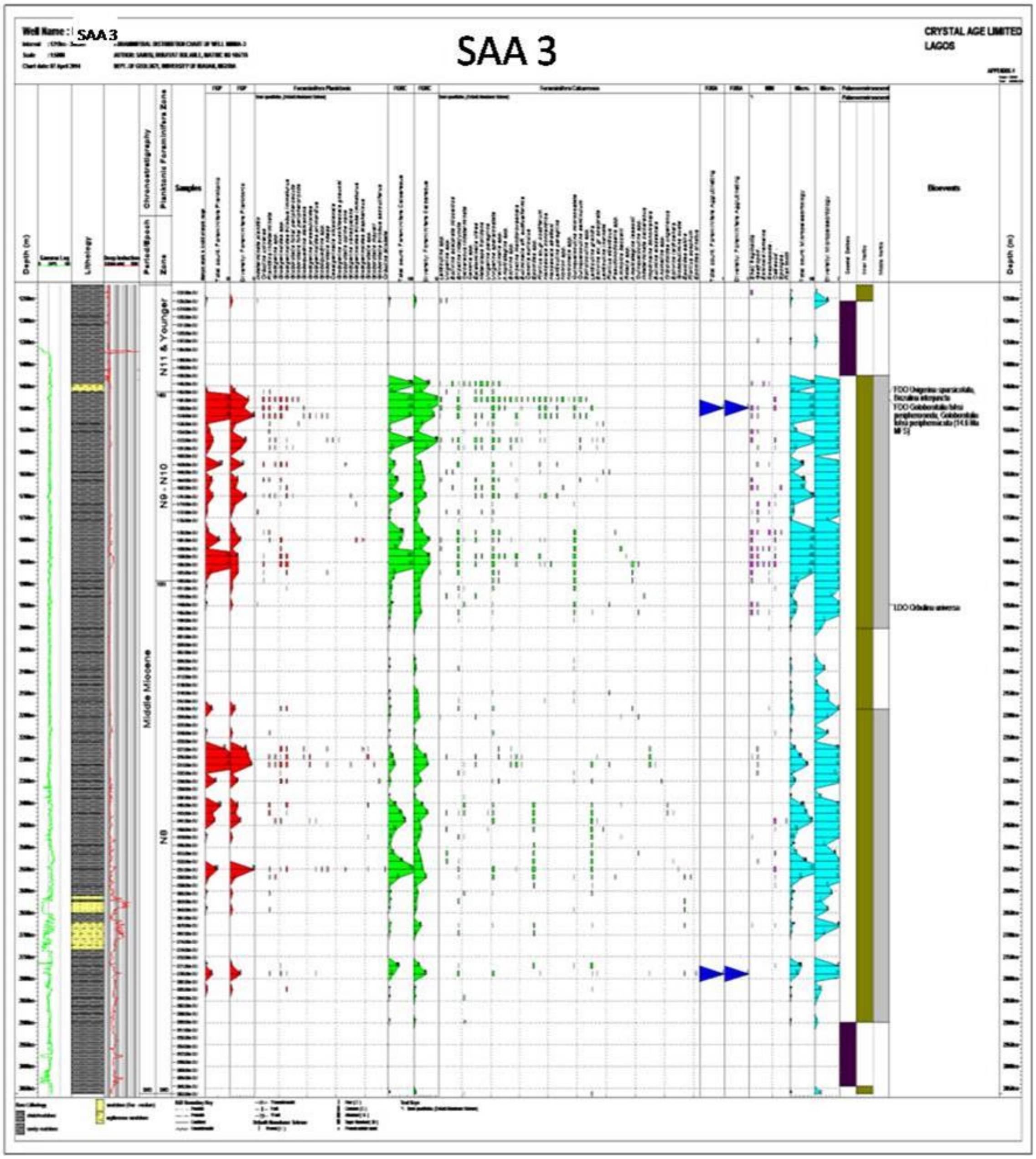

Figure 4. Distribution Chart of SAA-3 well showing the depth, biozones, abundance and diversity of microfauna.

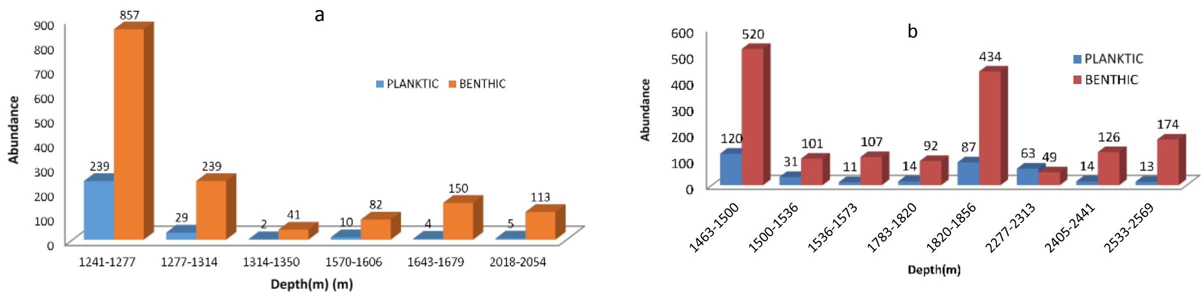

Figure 5. (a) Chart illustrating the relative abundance of planktic and benthic foraminifera in SAA-1 well, (b) Chart illustrating the relative abundance of planktic and benthic foraminifera in SAA-3 wells.

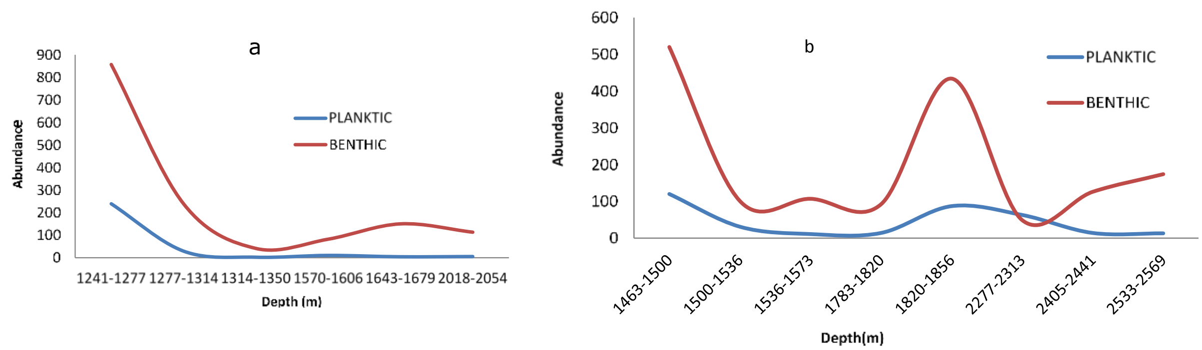

Figure 6. (a) Chart illustrating the relative abundance of planktic and benthic foraminifera in SAA-1 well; (b) Chart illustrating the relative abundance of planktic and benthic foraminifera in SAA-3 well

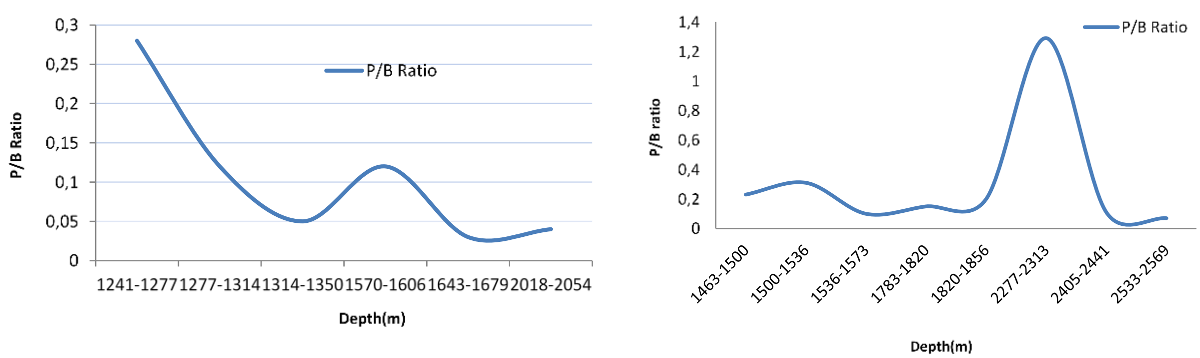

Figure 7. (a) Illustrating the variation in P/B ratio of SAA-1 well, (b) illustrating the variation in P/B ratio of SAA-3 well

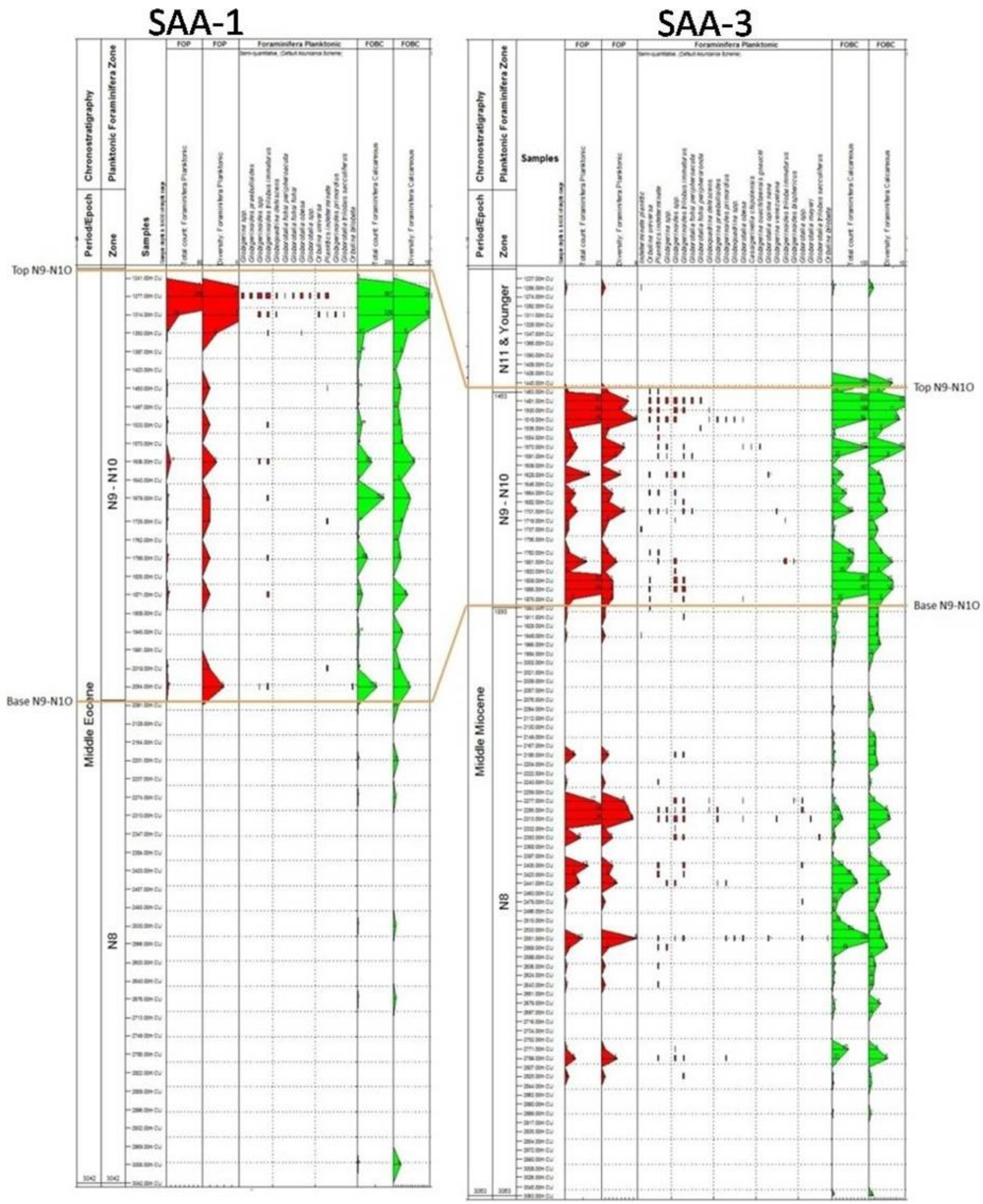

Figure 8. Correlation of SAA-1 and SAA-3 wells

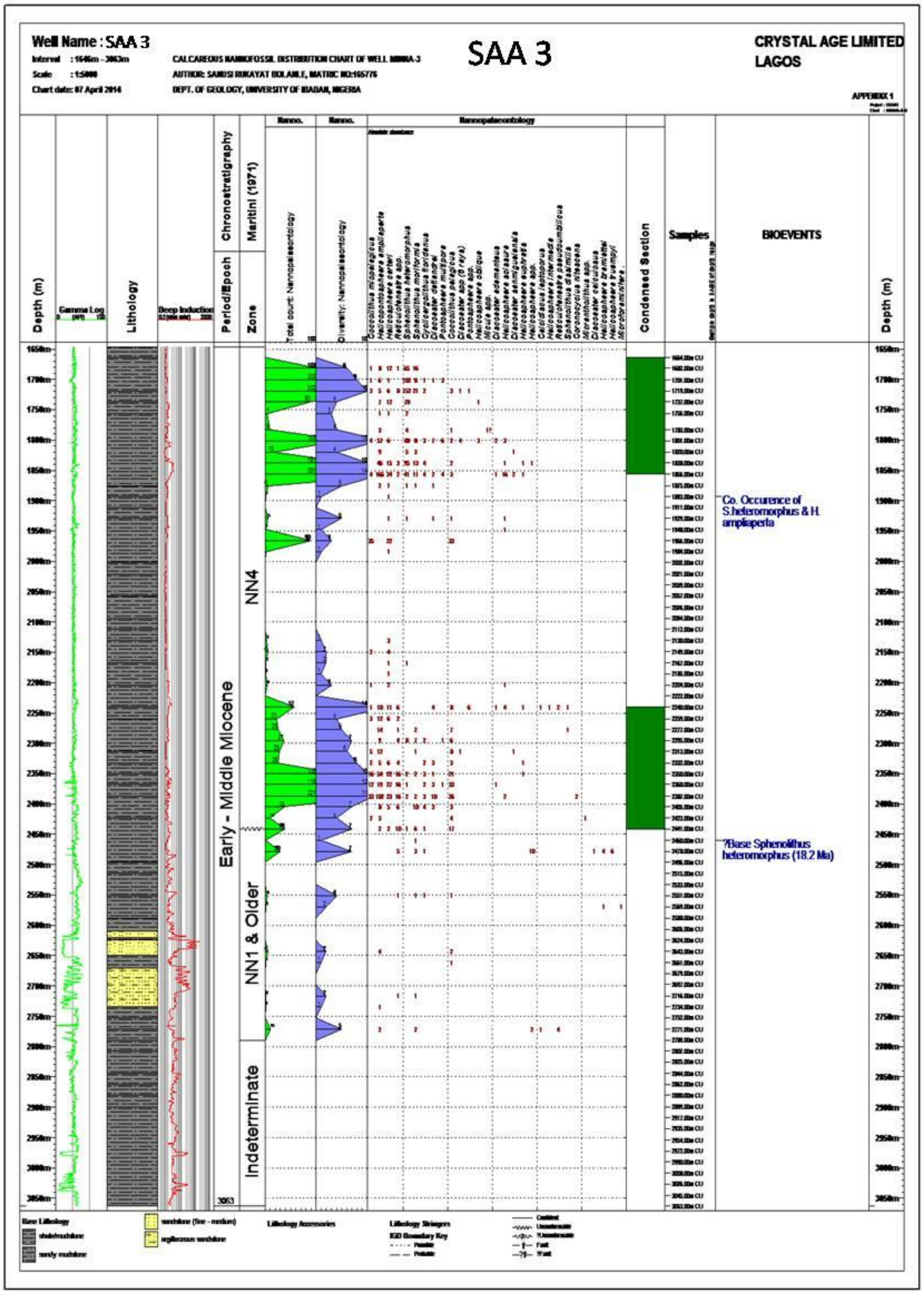

Figure 9. Showing stratigraphic interval, zones and distribution of calcareous nannofossils in SAA-3 well

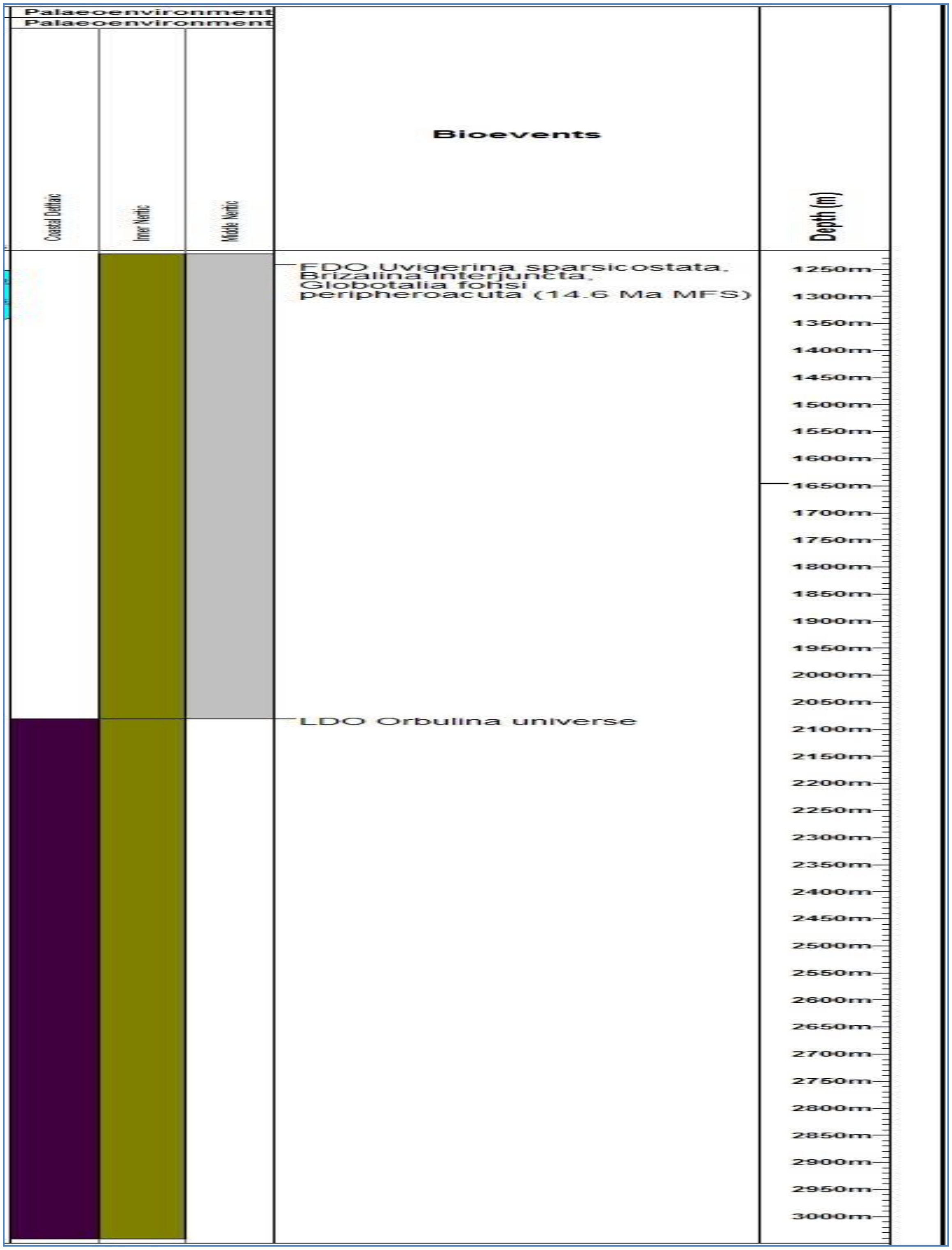

Figure 10. Shows the depth, bioevents and paleoenvironment of SAA-1 well

Figure 11. Shows the depth, bioevents and paleoenvironment of SAA-3 well

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