



# FORAMINIFERAL BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL ANALYSIS OF THE SEDIMENTS PENETRATED BY SAHAIWEI-1 WELL IN THE NORTHERN DELTA DEPOBELT, NIGER DELTA BASIN

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## ABSTRACT

Foraminifera biostratigraphy and paleoenvironmental analysis of the sediments penetrated by Sahaiwei-1 Well in the Northern Delta Depobelt, Niger Delta Basin was carried out in order to determine the foraminifera biozonation, age, paleobathymetry, depositional environment and paleo-oxygen condition of the well. The total foraminifera population recovered was two thousand, three hundred and sixty five (2365), with planktic foraminifera constituting one hundred and fifty four (154) forms, while calcareous benthic and agglutinated benthic foraminifera recovered accounted for two thousand, one hundred and sixty two (2162) and forty nine (49) of the total foraminifera population respectively. The total foraminifera species recovered was fifty nine (59); planktic accounted for twenty (20) foraminifera species, while calcareous and agglutinated benthic foraminifera accounted for thirty one (31) and eight (8) foraminifera species respectively. Five benthic foraminifera biozones were identified: lumped P7-P13, P5-P6/P7, lumped P3-P4, lumped P1-P2 and M18 Zones of Blow (1969, 1979). The result of the analysis indicates that the entire analysed interval (1800ft – 10680ft) was deposited during the Late Maastrichtian to Late Eocene epoch. The depositional environments of the Well varied from littoral, marginal, shallow and deep marine environments.

**KEYWORDS:** Biozonation, Calcareous, Arenaceous, Agglutinated, Hyposaline Marshes, Hyposaline Shelf Sea.

## INTRODUCTION

The Niger Delta is the largest basin in southern Nigeria. It is situated at the zone where the rifting and separation of Africa and South America was initiated. The basin was formed by failed arm of a triple junction (aulacogen) after rifting ceased in the Mid-Cretaceous (Short and Stauble, 1967). The Basin which has an age range of Cretaceous to Recent is located in the Southern part of Nigeria (Short and Stauble, 1967). The Niger Delta stratigraphic sequence comprises of an upward-coarsening regressive association of Tertiary clastic deposits up to 12km thick (Evamy et al., 1978). The sedimentary basin is sub-divided into three stratigraphic units. These are from the oldest to the youngest, the Marine Akata, Paralic Agbada and Continental Benin

Formations all of which are strongly diachronous (Short and Stauble, 1967; Doust and Omatsola, 1990).

The Niger Delta Geology has been studied in recent times by researchers and oil companies because of its hydrocarbon potential and economic importance. Many writers have studied and summarized the basic geology, lithology, palynological and micropaleontological characteristics, depositional environments, structural setting, geophysical characteristics among others. However, there has been limited information on the biostratigraphy of wells

of the Northern Delta Depobelt. There is therefore a need for re-visitation of this area in order to add to the limited information on the biostratigraphy of the Northern Depobelt of the Niger Delta Basin. This will further help inexploration purposes.

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The area of study is located in the Northern Delta Depobelt. The well is geographically located between latitude 6°05'N and longitude 5°15'E (Figure 1).

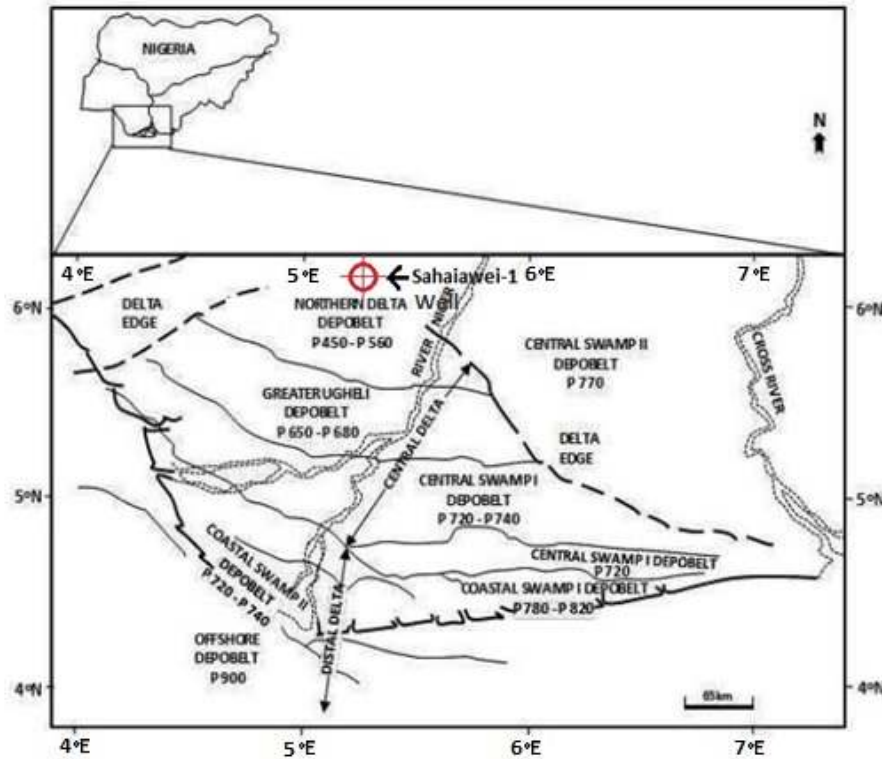


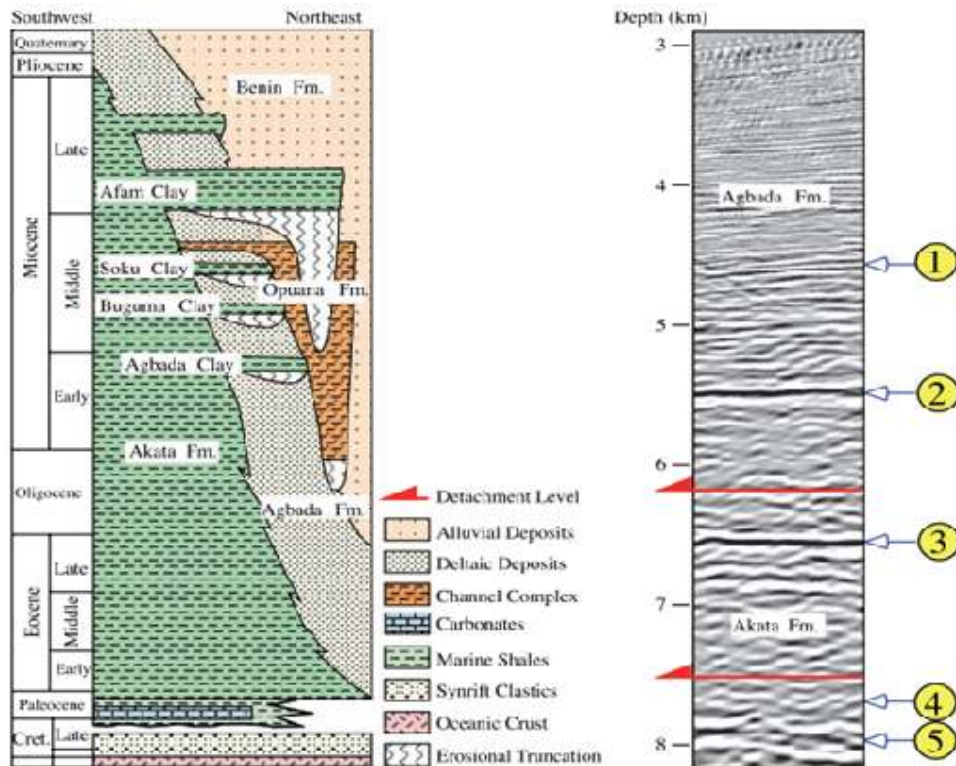
Figure 1: Location map of Study Area (Modified after Doust and Omatsola, 1990)

### GEOLOGICAL SETTING

The Niger Delta Basin is situated at the Gulf of Guinea, on the west Africa continental margin and covers all through the Niger Delta province between longitude 5°E to 8°E and 4°N to 6°N (Tuttle, Charpentier and Brownfield 1999, Whiteman 1982, Corredor, Shaw and Bilotti 2005, Emoyan 2008)

The Niger Delta Basin stratigraphy consists of marine clastic sediment which superimposes oceanic and continental crust (Corredor, Shaw and Bilotti 2005). The clastic unit is divided into three formations: Akata, Agbada and Benin Formations (Figure 2). The Akata formation, made up of thick sequence of shale at the

base of the basin is believed to be the source rock for petroleum generation. It has a thickness ranging from 2000m to 7000m at the distal part and towards the continental shelf respectively. The Akata formation is directly overlain by the Agbada formation, the main hydrocarbon bearing unit in the Niger Delta, having a thickness greater than 3500m. This petroleum bearing unit represents the deltaic portion of the sequence. This unit (Agbada formation) is overlain by the Benin formation, which consists of continental deposit from Late Eocene to Holocene with up to 2000m thick (Avbovo 1978).



**Figure 2. Stratigraphy of the Niger Delta and seismic presentation of the core stratigraphic units (1) Agbada formation top (2) Akata formation top (3) Reflection of mid-Akata (4) Top of syn-rift clastic deposit (5) Oceanic crust top (Adapted from Lawrence et al., 2002)**

## MATERIALS AND METHOD

Fifty (50) ditch cutting samples were collected from the shaly and sandy shale intervals of interest at different intervals between 1800ft to 10680ft. The samples were prepared using the standard foraminifera preparation technique and the analysis was carried out with the used of reflected light microscope.

Materials: Sieves, slides, microscope, picking trays, needles, brushes, digital camera and hot plates.

Method: Twenty five (25)gram of the samples were weighed, packaged and labeled. The samples were soaked with kerosene for about six (6) hours, after which the samples were decanted. Water was later added to the samples and allowed to stay for twenty four hours. Samples were washed through 270 mesh sieve with 53 micron ( $\mu\text{m}$ ) aperture under running tap water. Washed samples were dried on hot plate at about  $50^{\circ}\text{C}$  for about 20 minutes. Micro sieves of different sizes (coarse, medium and fine) were stacked on each other and the samples were sieved manually. Each fraction collected was spread on gridded foraminifera tray, picked and the recovered foraminifera were observed under a reflected microscope. Recognized fossils were picked and placed in the cavity of appropriately labeled slides. Sorting and grouping of fossils according to their morphological similarity. Identification of foraminifera was carried out considering the test composition, chamber arrangements, sutures, apertures, habits and ornamentation. Published references of Fayose (1970), Blow (1979) and Bolli and Saunders (1985) also aided in the identification.

## RESULTS AND DISCUSSION

The lithostratigraphic analysis was carried out on 50 ditch cutting samples selected between the intervals of 1800 feet to 10680 feet. Five (5) lithofacies types which include sandstone, clayey sandstone, shaly sandstone, sandy shale and shale were identified. Minerals identified within this well include pyrite, mica flakes, iron oxide and carbonate (Figure 3).

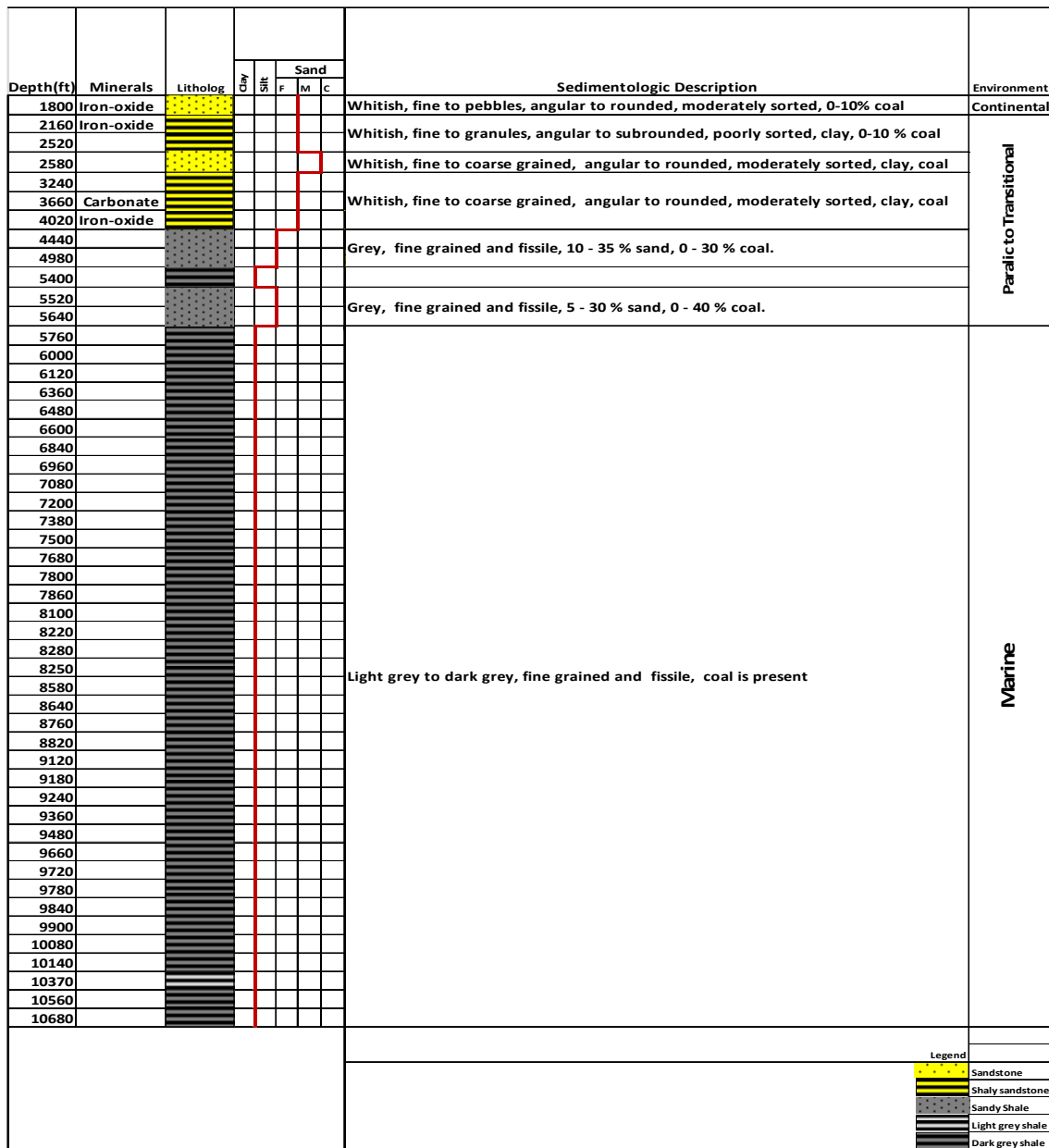


Figure 3: Lithostratigraphic model for Sahaiawei-1 Well

**QUANTITATIVE COUNT**

Planktic foraminifera species accounted for about twenty (20) out of the recovered fifty nine (59) foraminifera species in the well (Table 1). The poor recovery of arenaceous (agglutinated) foraminifera species might be due to environmental factor or paleodepth that might have occurred during the ancient time. The planktic foraminifera recovered are: *Globorotalia cerrazuellensis*, *Globorotalia rohiri*, *Globigerina ampliapertura*, *Planktic indeterminate*, *Globorotalia increbescens*, *Globigerina linaperta*, *Morozovella clavata*, *Globigerina sp.*, *Globorotariapseudomennardii*, *Globorotaria sp.*, *Globorotalia wilcoxensis*, *Globigerina trilocoliniodes*, *Globorotalia compressa*, *Globorotalia mikanna*, *Morozovella sp.*, *Acarinina mckannai*, *Acarinina primitive*, *Acarinina sp.*, *Globorotalia ehrenbergi* and *Hedbergella holmdelensis*.

The calcareous foraminifera accounted for about thirty one (31) out of the fifty nine (59) recovered foraminifera species. They include: *Heterolepapseudoungeriana*, *Ammonia beccari*, *Floriluscostiferum*, *Ammobaculites strathemensis*, *Nonionella auris*, *Eponides berthlotianus*, *Calcereous indeterminate*, *Eponides cf. eshira*, *Eponides sp.*, *Eponides eshira*, *Uvigerina hourquii*, *Epistominella berthlotianus*, *Eponides africana*, *Valvulineria sp.*, *Altistonia scalaria*, *Altistonia tenuis*, *Lenticulina pseudomamiligerus*, *Eponides pseudoelevatus*, *Valvulineria martinezensis*, *Hopkinsinabononiensis*, *Praeglobulimina ovata*, *Bolivina tennicostata*, *Fursenkoma punctata*, *Anomalinoides madrugensis*, *Bolivina afra*, *Praebulimina sp.*, *Orthokarstenia clavata*, *Praebulimina proluxa*, *Bolivina sp.*, *Praebulimina lata* and *Bulimina sp.*





### Foraminifera biozonation and age for Sahaiawei-1 Well

The foraminifera biozonation and age was guided by the work of Blow (1969, 1979), Bolli and Saunders (1985). The benthic foraminifera species whose stratigraphic distributions have been well known in the Niger Delta and has been calibrated with planktic foraminifera species were used to assign ages and zonations. Important foraminifera bio-events considered include: The first down hole occurrence (FDO) of significant foraminifera marker species, the last down hole occurrence (LDO) of significant foraminifera marker species and foraminifera abundance and diversity peaks dated with foraminifera markers species whose stratigraphic ranges are well established in the Niger Delta and worldwide.

The result of the analysis indicates that the entire analyzed section (1860 – 10,680ft) was deposited during the Late Maastrichtian to Late Eocene epoch, of estimated numerical age that exceeds 65Ma to 35.9Ma which straddle within the *Bolivina afra* (M18) and *Eponidesafricana* (P13) of Blow (1969, 1979) ( Figure 4).

#### **Zone: Indeterminate (Stratigraphic Interval: 1800ft to 6360ft)**

The lower limit of this zone is defined by the FDO of *Eponidesafricana* at 6360ft, while the upper limit is placed at the top of analysed interval (first sample analyzed). In this interval, from the first sample analysed at 1860ft to 6360ft is almost barren of foraminifera species. The few foraminifera recorded include *Floriluscostiferum*, *Heterolepapseudoungeriana*, *Ammonia beccarii*, *Epitominellavitrea* and *Ammobaculitesstrathearnensis*. The age of this zone is indeterminate.

#### **Zone: P7 – P13 (Stratigraphic Interval: 6360ft to 6840ft)**

The upper limit of this zone is defined by the FDO of *Eponidesafricana* at 6360ft, while the lower limit is marked by the FDO of *Lenticulinapseudomamillegerus* at 6840ft. The co-occurrences of foraminifera *Globorotalia cerrozuallensis*, *Globorotalia rohri*, *Altistomatenuis*, *Eponideseshira*, *Eponides Africana*, *Altistomascalaris*, *Eponidesafricana*, *Eponidesberthelothianus* and *Valvulineria sp.* within this interval confirms the Middle to Late Eocene age.

#### **Zone: P5 - P6/P7 (Stratigraphic Interval: 6840ft to 7560ft)**

The upper limit of this zone is defined by the FDO of *Lenticulinapseudomamillegerus* at 6840ft, while the lower limit is marked by the FDO *Valvulineriamartinezensis* at 7560ft. Foraminiferal species that characterize this interval include : *Globorotalia increbscens*, *Globorotalia cerrozuallensis*, *Globorotalia pseudomanardii*, *Globorotalia rohri*, *Globigerina triculinoidea*, *Eponidespseudoelevatus*, *Eponideseshira*, *Eponidesafricana* and *Uvigerinahourqi*. This foraminifera association suggests Late Paleocene to Early Eocene age.

#### **Zone: P3 – P4 (Stratigraphic Interval: 7560ft to 8640ft)**

The upper limit of this zone is defined by the FDO of *Valvulineriamartinezensis* at 7560ft, while the lower limit was marked by the FDO of *Ammobaculitescoprolithiformis* at 8640ft. The interval is

also characterized by the co-occurrence of the following foraminifera species viz : *Globigerina ampliaperata*, *Globigerina triculinoidea*, *Acarinamckannai*, *Acarinina primitiva*, *Valvulineriamartinezensis*, *Eponidespseudoelevatus*, *Haplophragmoidesexcavata*, *Eponides Africana* and *Uvigerinahourqi*. This foraminifera association suggests Early to Late Paleocene age.

#### **Zone: P1 – P2 (Stratigraphic Interval: 8640ft to 9120)**

The upper limit of this zone is defined by the FDO of *Ammobaculitescoprolithiformis* at 8640ft, while the lower limit is marked by the FDO of *Bolivina afra* at 9120ft. The interval is also characterized by the following foraminifera species viz: *Globorotalia compressa*, *Valvulineriamartinezensis*, *Eponidespseudoelevatus*, *Haplophragmoidesexcavata*, *Ammobaculitescoprolithiformis*, *Bolivina tenuicostata*, *Fursenkoina punctata*, *Lenticulinapseudomamillegerus* and *Altistomascalaris*. This foraminifera association suggests Early Paleocene age.

#### **Zone: M18 (Stratigraphic Interval: 9120ft to 10680)**

The upper boundary of this zone is defined by the FDO of *Bolivina afra* at 9120ft and the lower limit is tentatively placed at the terminal depth (10680ft). The interval is also characterized by the co-occurrences of the following foraminifera species viz: *Hedbergellaholmdellensis*, *Praebuliminaprolixa*, *Praebulimimalata*, *Anomalinooidesmadrugeensis*, *Haplophragmoidesexcavata*, *Orthokastenioclavata*, and *Bolivina tenuicostata*. The above foraminifera assemblage confirms the Late Maastrichtian age for this interval (10680 – 9120ft).

#### **Paleoenvironmental Analysis for Sahaiawei-1 Well:**

The depositional environment and paleobathymetry were obtained by integrating sedimentological data and foraminifera appearance at certain depths over the analyzed intervals of the well (Figure 4). The sedimentological data was derived from analyzing ditch cutting samples, while the foraminifera bathymetry was guided by various micropaleontological criteria which include the occurrence of certain environmental benthic foraminifera species (Bandy, 1967; Adegoke et al., 1971; Murray et al., 1994). Other criteria such as benthic foraminifera assemblage, abundance and diversity plot were considered. The marine environment is known to be the home for many microfossils. These foraminifera live in different compartments based on water depth (bathymetry) which is an indication of the different depositional environments (Loeblich and Tappan, 1964). Microfossils have been known to live within this compartment, so recognition of these fossils corresponds to water depth in which they are associated.

Paleo-oxygen is an indicator of how conducive the environment may be for some foraminifera taxa to populate. Low oxygen areas favour high diversity and equable conditions and high oxygenated areas have low number of foraminifera species and suggest stressed environment (Murray et al., 1994).

The interval 1800ft to 6000ft is characterized by sandy shale, shaly sandstone and sandstone intervals. The presence of *Floriluscostiferum* and *Ammonia beccarii* within this interval characterize this zone as littoral to inner neritic zone (marginal to shallow marine environment). The scarcity of foraminifera in this zone

suggest environmental stressed and highly oxygenated zone which will not favours organic matter influx.

The interval 6000ft to 7560ft is characterized by mainly shale unit. The presence of paleobathymetric indicators such as *Praeglobulimina Ovata*, *uvigerinahourqi*, *Eponideseshira*, *Altistoniascalaris*, *Altistoniatenius*, *Lenticulinapseudomamillegerus*, *Eponidespseudoelevatus* and *Valvulinamartinezensis* characterize this area to fluctuate between inner to outer neritic zone (shallow to deep marine environment).

The interval 7560ft to 8280ft is characterized by mainly shale unit. The paleobathymetric indicators such as *Bolivina tenuicostata*, *Uvigerinahourqi*, *eponides Africana*, *Eponideseshira*, *Lenticulinapseudomamillegerus*,

*Haplophragmoidesexcavata* and *Praeglobuliminaovata* within this interval characterize this zone to vacillate between inner to middle neritic paleowater depth suggesting shallow to deep marine environment.

The interval 8280ft to 10680ft is characterized by mainly shale unit. Paleobathymetric indicators such as *Bolivina afro*, *Bolivinatenuicostata*, *Praebuliminaprolixa*, *Anomalinoidesmadrugaensis*, *Altistoniascalaris* and *Eponidespseudoelevatus* characterize this area. It fluctuates between middle to outer neritic zone (deep marine). The presence of *haplophragmoidesexcavata*, *ammobaculites sp.*, *textulariasp.* are infaunal deposit feeders that live on muddy and sandy substrates in low oxygen concentrated areas.

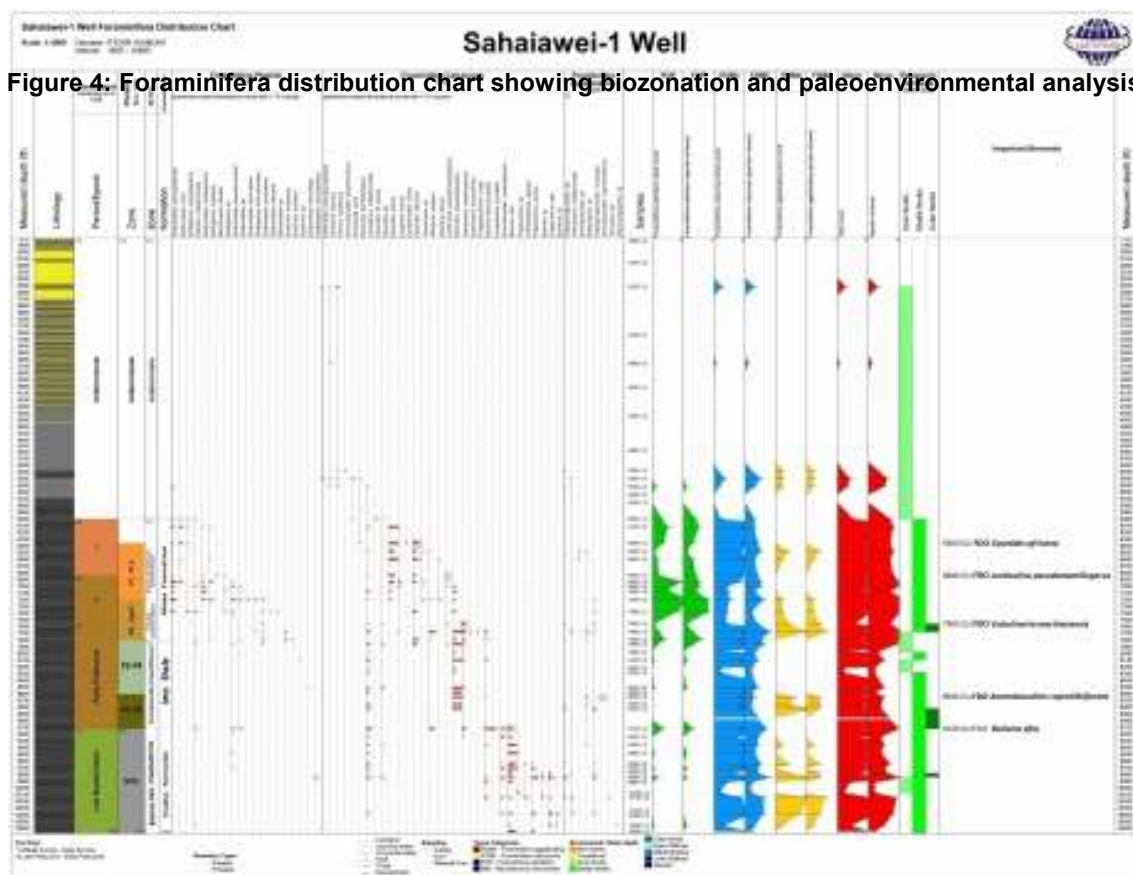


Figure 4: Foraminifera distribution chart showing biozonation and paleoenvironmental analysis

## CONCLUSION

Foraminifera biostratigraphy and paleoenvironmental analysis of the sediments of Sahaiawei-1 Well was carried out to determine the age, paleobathymetry, depositional environment and paleo-oxygen of the well. Five (5) benthic foraminiferabiozones were identified: lumped P7-P13, P5-P6/P7, lumped P3-P4, lumped P1-P2 and M18 Zones which correspond to late Maastrichtian and late Eocene age were identified. The Late Maastrichtian sediment signifies Cretaceous age. It could be that the Cretaceous Formation in the Anambra Basin is lithostratigraphically continuous to the subsurface stratigraphy of the Niger Delta. The paleobathymetry of the well ranges from littoral to outer neritic; while the depositional environment of the sediments penetrated by the well at different depth

intervals are littoral, marginal, shallow and deep marine environments.

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