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Foraminifera Biostratigraphy of Geo 92 Well, Onshore Niger Delta, Nigeria

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ABSRTACT: This study involved the micropaleontological study of Geo-92 well, OML 95 central swamp depobelts, Niger Delta between depth interval 7,470ft and 11,190ft with the purpose of characterizing the age and environment of deposition of the sedimentary succession. The lithologic description of the samples revealed two (2) Lithofacies Units; Marine and paralic composed majorly of sandy shale and minima of shaly sands corresponding to the paralic Agbada formation. Standard foraminifera preparation procedures were involved in the disaggregation of the samples. Quantitative and Qualitative analysis yielded a well preserved stratigraphically significant foraminifera assemblage with a total of 103 species, seventy (76) benthic and twenty-seven (27) planktics, from which two (2) planktic zone and four (4) benthic zones were calibrated. The Planktic zones are Globigerina nepenthes and Globigeriniodes bollii, while the benthic zones are Uvigerina spariscostata, Quinqueloculina microstata, Uvigerina subperegrina, and Haplophragmoides narivaensis respectively. These were correlated with N11/N12-N13, N14-N15, N15-N16 and N17 [1] Global scheme and used to delineate the middle to late Miocene age. The Paleobathymetry of the well ranges from inner-upper bathyal environment based on the benthic foraminifera distribution of the well.

KEYWORDS: Foraminifera, Miocene, bathyal, Paleoenvironment, Niger Delta.

I. INTRODUCTION

Attempts have been made to integrate and verify the Shell Petroleum Development Company (SPDC) framework of [2] with unpublished and published articles of other industrial groups hampered by the use of different alpha-numerical coding systems for the foraminifera systematics [3], [4]. These efforts have been frustrated by the restriction of biostratigraphic information by oil companies in Nigeria to the Stratigraphic Committee of the Niger Delta (STRATCOMM). Over the years since discovery of hydrocarbon in the basin, many quality research work on biostratigraphy have been carried out but only a few information is available in the public domain, which has created a gap in this research line, hence this study.

II. REVIEW OF PREVIOUS STUDIES:

[4] noted that the shallow, warm tropical surface waters and the deeper, colder south atlantic central water mass, both influenced the foraminiferal biofacies of the niger delta. They developed and calibrated a unified foraminifera biozonation scheme of the Niger delta concessions by harmonizing the foraminifera zonation schemes of all the member companies of Stratigraphic Committee of the Niger delta. The chronostratigraphic compilation was done with wells that penetrated Paleocene to Pleistocene Epochs, spanning both onshore and shallow-offshore depobelts of the Niger delta. According to [5], several low latitude larger foraminifera, like Amphistegina spp. and Heterostegina spp., as well as cold water indicator planktonics like Globorotalia inflate are typical characteristics of the Neogene deeper biofacies of the Niger delta and are important in understanding the chronostratigraphy and depositional environment of the Niger delta. For an understanding of the biochronologic and biostratigraphic relevance of the main marker species in the Niger delta, [6] presented the necessary evolutionary relationships of these benthonic foraminifera genera *(Lenticulina, Bolivina/Brizalina, Nonion/Florilus, Hanzawaia, Epistominella, Eponides berthelotianus/Ammonia beccarii,* and *Uvigerina)* in the Niger delta. In the past eight decades, foraminiferal biostratigraphy has been the subject of extensive research and has been used all over the world. This has been made possible by additional detailed taxonomic documentation of[1] planktonic foraminifera of the low latitude Caribbean by [7] and [8], as well as descriptions of the biology of modern planktonic foraminifera by [9]. Excellent monographs on the evolutionary trend and paleogeographic

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distributions have been published by [10]. Several other local research works in the area such as [2]; [11], [12]; [13] and [14] are also recognised.

III. LOCATION OF THE STUDY AREA

Location of Geo 92 well: the studied well drilled to a total depth of 12,185 feet is located in the Central Swamp Depo belt of Niger Delta basin between Longitude 4.30^{1} 23^{11}E and Latitude $5^{\cdot}30^{1}$ 16^{11}N (figure 1) and located in OML 95. The aim of this study is to establish the foraminiferal biostratigraphy of Geo 92 well with the objectives of erecting the biozones consequent to establishing the age of the sediments and the characterization of the environment of deposition.

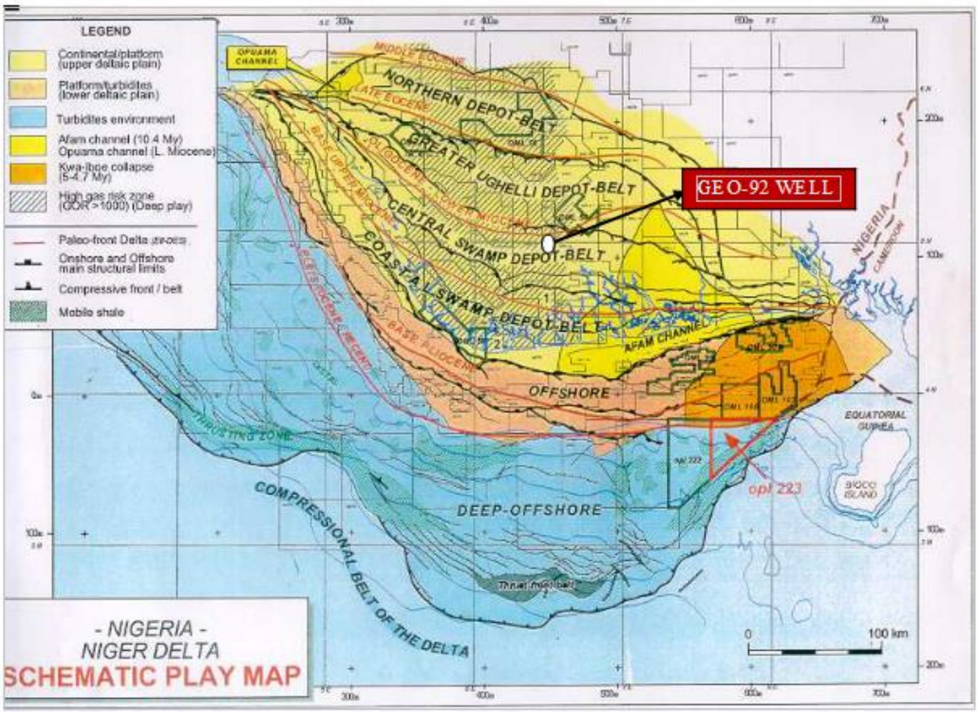

Figure 1: Location Map of GEO-92 Well

IV. GEOLOGIC SETTING

The Niger Delta is a Nigerian oil region that is located on the West African Continental Margin, between Latitude $4^{0}00^{1}00^{11}$N and $6^{0}00^{1}00^{11}$N and longitude $5^{0}00^{1}00^{11}$E and $8^{0}00^{1}00^{11}$E. The Western Africa shield, which stops at the Benin hinge line in the West and Northwest, and the Calabar hinge line in the East, define the region [15]. The Anambra basin and the Abakaliki anticlinorium form the Northern limit, while the Gulf of Guinea forms the Sourthern limit.

The Niger Delta is located in the Gulf of Guinea, Central West Africa, at the entry of the entry of the Benue Trough, according to [16]. The Niger Delta is considered as one of the world's most fertile hydrocarbon provinces.

The Niger Delta basin is one of the world's largest subaerial basins, with a subaerial area of 75,000km^2, a total area of 300,000km^2 and sediment fill of 500,000km^2 in Africa. The Niger Delta spans 14,000km^2 and sits on a thick prism of regressive clastic sequence that reaches a maximum thickness of 12,000m at the basin's center. It was formed when there was a seperation and rifting between the South American and African plate.

The Niger Delta has been classified as a river-dorminated delta, but it is actually a typical wave-dominated delta with well-developed shoreface sands, beach ridges, tidal channels, Mangrove swamps, and freshwater swamps. It demonstrate an upward transiton from marine shales (Akata Formation) to continental sands (Benin Formation) via a sand-shale paralic interval (Agbada Formation). Over time, the Niger Delta has gone through cycles of regression and transgression, which have been influenced by sea level variations, local subsidence, and sediment suppliers. The stratigraphy of the

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Niger Delta and its frame work are based on the correlation of the foraminifera and the palynomorphs zones. Stratigraphy of the Niger Delta

V. NIGER DELTA STRATIGRAPHY:

Sediments of the Tertiary Niger Delta are said to be stratigraphically superimposed. [17], established a deltaic fill of the Niger Delta which is represented by a strongly diachronous (Eocene-Recent) sequence, that consist of three lithofacies units- an overall upward transition from marine shales (Akata Formation) through a sand-shale paralic interval (Agbada Formation) to continental sands of the Benin Formation (Figure 2).
These Formations were deposited in dominantly marine, deltaic and fluvial environments, respectively [18]. The formations cut across the time stratigraphic units which are characteristically S-shaped in cross section. The type sections of these formations are described by [19]). The stratigraphic framework and the detailed Tertiary stratigraphy of the Niger Delta are based on correlation of palynomorphs and foraminifera zones [20].

A. AKATA FORMATION

The Akata Formation is the lowermost unit in the Niger Delta Basin. It is composed primarily of prodeltaic dark grey marine shales, turbidite sands and minor amounts of clays and silts [18]. Marine planktonic foraminifera may account for over 50% of the rich micro fauna and the benthonic assemblage suggest a shallow marine shelf depositional setting ranging from Eocene to Holocene in age [21]. The marine shale is usually over-pressured. It is estimated that the formation is up to 7,000 meters thick at its center [22]. It is assumed to be the source rock of the Niger Delta basin.

B. AGBADA FORMATION:

The Agbada Formation is the major hydrocarbon-bearing unit in the Niger Delta. It overlies the Akata Formation and consists predominantly of sand units with minor shale inter-beds at the top, while the lower part of the formation contains a shaly unit thicker than the upper sandy interval. It has a maximum thickness of about 3,900m at the centre and ranges in age from Eocene to Pleistocene [22], with the thickness of the formation thinning northward toward the Northwestern and eastern flanks of the delta. The sandstone vary from coarse to fine grained, poorly to very well sorted, unconsolidated to slightly consolidated, while the shales are medium to dark grey and silty with local glauconites [19]. The shaliness of the Agbada Formation increases downward gradually into the Akata formation.

C. BENIN FORMATION:

The Benin Formation is the top section of the Niger Delta depositional sequence that overlies the Agbada Formation. It consists mainly of massive, highly porous, freshwater-bearing sandstones, with localized clay drapes and thin shale inter-beds which increases toward the base of the formation. The massive sands were deposited in a continental environment [20]. The sandstones constitute 70 to 100% of the formation. Texturally, the sands are coarse grained, sub-rounded to well rounded, poorly sorted, partly unconsolidated, and bears lignite streaks and wood fragments. It attains a maximum thickness of 1,970m (6,000ft) in the Warri-Degema area, and the age is thought to range from Oligocene to Recent [19].

VI. METHOD OF STUDY

A total of sixty (60) Ditch cuttings samples obtained from interval 7,740-11,190ft of GEO 92, onshore Niger Delta was employed for this study. Lithologic characteristics including Well log signatures, sand/shale ratios, textural attributes of sands/shale and accessory mineral composed of samples were used to determine the lithologic unit penetrated by the well interval. Disaggregation of the foraminifera followed standard method used by oil companies. About 20g of each collected sample was weighed, packaged and labelled accordingly indicating the well name, sample type, and depth. Small aluminium bowls containing the samples were labelled for indicated sample depths contained and soaked in hot water with soap solution. Samples were washed through 230 mesh sieve with 63micron(µm) aperture under running tap water. Washed samples were dried on hot plate at about 60^0C for about 20minutes.

A set of micro sieves (coarse, medium, and fine) was stacked on each other and the dried residue was run through them and sieved manually. The respective fractions were collected and bottled in three (3) already cleansed and properly labelled bottles. Each fraction was spread on a round gridded foraminifera tray of 4.5 by 6.0cm and moved along definite

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traverse to pick all observed foraminifera under centred stereoscope with an external light source. Using a moistened brush, recognised microfossils were picked and placed in the appropriately labelled cavity slide.
Different species were grouped together with the tip of a moistened fine brush in which they were stocked in tens (10s) and twenties (20s) which depended on the richness of the interval on the slide and glued on to the cavity slide with a tragacant gum. Identification of the picked foraminifera was done with the aid of a foraminifera album considering the test composition, chambers arrangement, sutures, apertures, habits and ornamentation.

The foraminiferal content was analysed from family to species level and counted for each sample. The abundance and diversity of the recovered species were plotted in the "*Stratabug"* Software to produce the foraminifera distribution chart to show the sequence of occurrence of species.

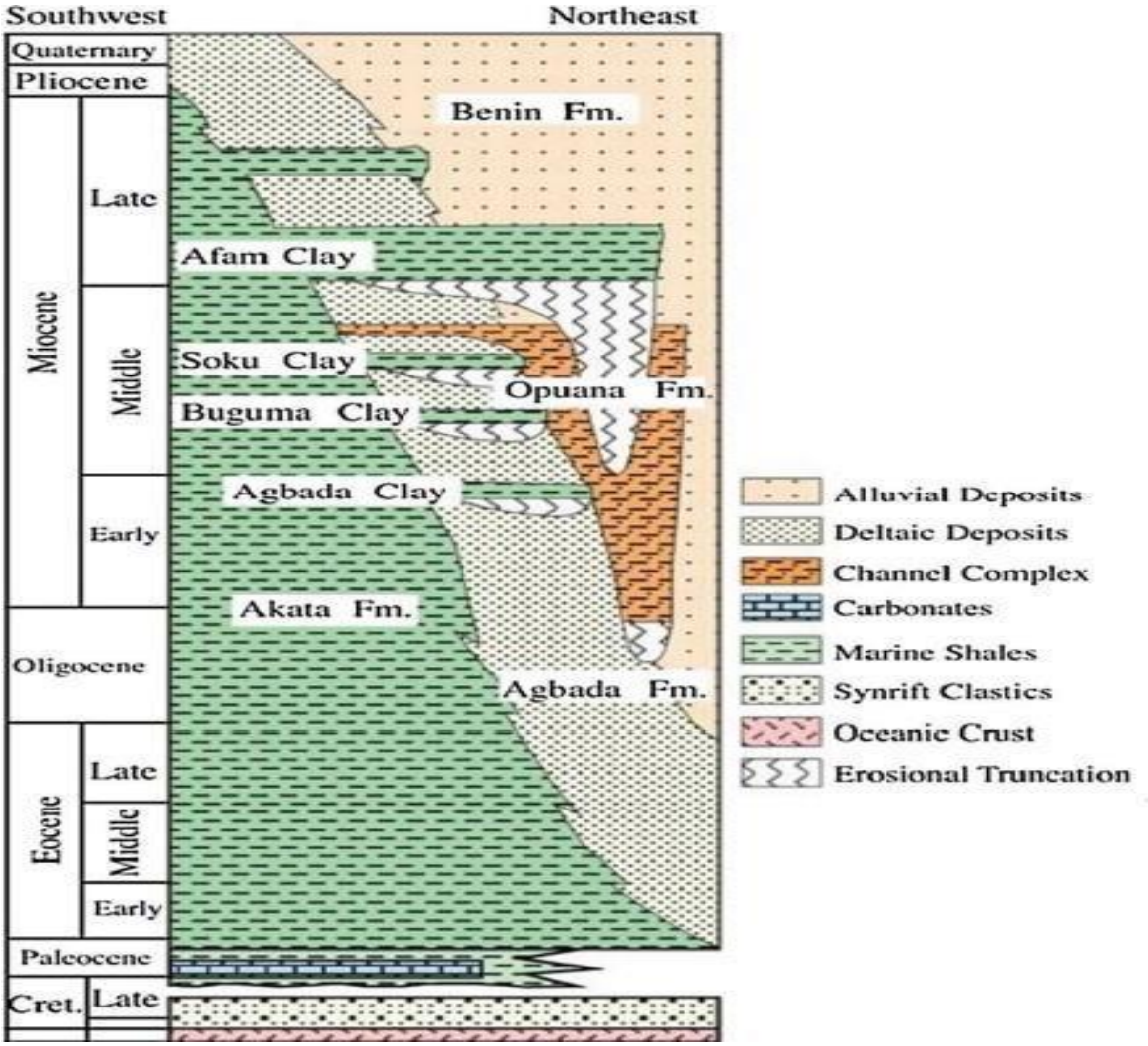

figure 2: Stratigraphic column showing the three formations of the Niger delta [17].

Foraminiferal zones were delineated in the Well based on the recognition of the Last Appearance Datum and First Appearance Datum of vital species. Furthermore, Maximum/Minimum fauna abundance/diversity peaks were also employed to assist in the correlation of the determined horizons to global bioevents on the modified Shell Petroleum Development Company global cycle chart for the purpose of age characterization.

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VII. RESULTS AND DISCUSSION

Sedimentological analysis reveal two lithofacies units the shaly sand and sandy shale alternation at the top, while the lower interval is more shaly typical of parallic upper and marine lower Agbada formation respectively. The sanstone is milky white to glassy, mostly fine subangular to subrounded, well sorted while the shale is chacteristically dark brown, blocky and moderately fissile. Both lithofacies unit contains traces of mica flakes (table 1).

VIII. BIOZONATION:

Foraminiferal recoveries were generally good and moderately preserved. Some intervals contained sparse to moderate recovery of foraminiferal species. Tidal elevation and organic matter content may have influenced the foraminifera distribution across the depth interval of 7,470 – 8,310ft, where few planktic were recorded and low to moderate recovery of the benthics

Benthic foraminiferal species (calcareous and arenaceous) and planktic species are well represented in the entire assemblage recorded in the Well. The distribution of the foraminifera in Geo 92 well is shown in figure 3.

Index forms among the recovered foraminiferal species have been used in dating and zoning the intervals into six zones as defined below:

Zone (i): Uvigerina spariscostata – Middle Miocene: The foraminiferal events that defines this zone are the Last Downhole Occurrences (LDO) of *Orbulina universa, Lenticulina inornata,, Heterolepa pseudoungeriana, Heterolepa crebbsi, Siphouvigerina auberiana attenuatta, Trifarina angulosa, Hanzawaia mantaensis, Bathysiphon sp, Eggerella scabra, Haplophragmoides narivaensis, Haplophragmoides compressa, Haplophragmoides sp, Trochammina sp, Valvulina flexilis, Cyclammina minima, Saccammina complanata, Cyclammina cancellata, Karreriella subcylindrica, Karreriella siphonella, Globigeriniodes bullodeus, Globigerinoides obliquus obliquus, Globigerinoides sp, Globigerinoides trilobus trilobus, Globorotalia obesa, Cristellaria sp, Quinqueloculina sp, Sigmoilopsis schlumbergeri, Lenticulina costata, Hanzawaia strattonii, Valvulineria sp, Alveolophragmium crissum* and First Downhole Occurrence (FDO) of Uvigerina spariscostataused to name this zone. This zone is also characterized by the Last Downhole Occurrence (LDO) of *Bolivina beyrichi, Nodosaria sp, Pseudogladulina sp, Globigerina bulloides, Cassidulina norcrossi, Buliminella sp, Ammobaculites agglutinans, Gyroidina soldanii, Cibicides sp, Globigerinoides bollii, Globigerina venezuelana, Rectogladulina comatula,Karreriella bradyi and Ammodiscus glabra. The top of this zone corresponds to the base of zone (ii) at 11070ft* within the *Uvigerina spariscostata zone.*

Zone (ii): *Globigerina nepenthes* – Middle Miocene – Late Miocene: This sub-zo*ne is characterized by Last Downhole Occurrence (LDO) of Globorotalia menardii, Ammonia beccarii, Heterelopa mckannai, Ammobaculites strathearnensis, Textularia sp, Pullenia bulliodes, Reophax sp, Globoquadrina altispira, Cassidulina neocarinata, Saccamina atlantica, Globorotalia acostaensis acostaensis, Globigerina preabulliodes, Globigerinoides ruber, Quinqueloculina seminulum, Globigerina nepenthes* and *First Downhole Occurrence (FDO) of Rotalia sp, Valvulineria sp, Pseudogladulina sp, seudonodosaria sp, Stilostomella monillis and Globorotalia obesa* which its top corresponds to the base of zone (iii) at depth 10,170ft within the *Spirosigmoilina oligocaenica* zone.

Zone (iii): *Quinqueloculina Microcostata* – Late Miocene: This zone is recognized by the First Downhole Occurrence (FDO) of *Globigerina sp, Globigerina praeblluoides, Praeglobobulimina ovata, Reophax sp, Textularia sp,* and *Ammodiscus glabratus, Globorotalia sp, Gyroidina soldanii, Quinqueloculina microcostata, Cibicides sp, Bolivina sp, Rectogladulina comatula, Cibicorbis inflate and Karreriella bradyi* at depth of 10,110 – 8970ft which the top of this zone is the base of zone (iv).

Table 1: Lithologic description of samples of Geo 92 well

DEPTH(FT)	LITHOLOGY	DESCRIPTION
7470 – 7620	SANDY SHALE	Sand 30%: Milky White To Glassy, Mostly Fine Subangular to Subrounded, Well Sorted. Shale 70%: Dark Brown, Blocky, Moderately Hard Shale Accessories: Traces Of Mica Flakes
7650	SHALY SAND	Sand 55%: Milky White To Glassy, Mostly Fine Subangular To Subrounded, Well Sorted.

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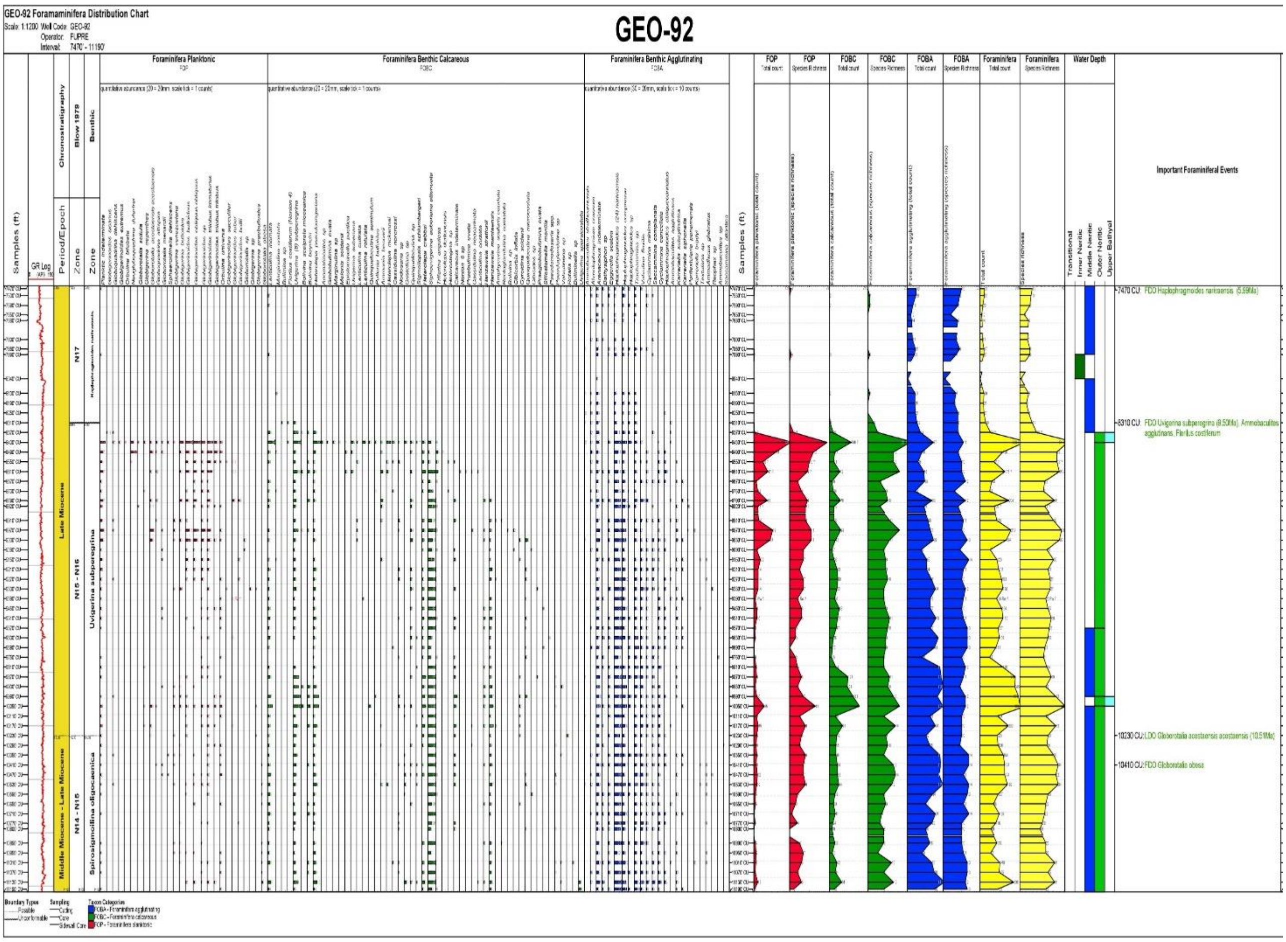
		Shale 45 %: Dark Brown, Blocky, Moderately Hard Shale Accessories: Traces Of Mica Flakes
7680 – 8730	SANDY SHALE	Sand 30%: Milky White To Glassy, Mostly Fine Subangular To Subrounded, Well Sorted. Shale 70 %: Dark Brown, Blocky, Moderately Hard Shale Accessories: Traces Of Mica Flakes
8760 – 9630	SANDY SHALE	Sand 15%: Milky White To Glassy, Mostly Fine Subangular To Subrounded, Well Sorted. Shale 85%: Dark Brown, Blocky, Moderately Hard Shale Accessories: Traces Of Mica Flakes
9660 – 11190	SANDY SHALE	Sand 10%: Milky White To Glassy, Mostly Fine Subangular To Subrounded, Well Sorted. Shale 90%: Dark Brown, Blocky, Moderately Hard Shale Accessories: Traces Of Mica Flakes

Zone (iv): Globigerinoides bollii – Late Miocene. This zone is characterized by the First Downhole Occurrence (FDO) of *Globigerinoides bollii, Hanzawaia strattonii, Hanzawaia mantaensis, Poritextularia panamensis, Karreriella siphonella, Nonion (6)* sp, *Praebulimina ovata, Cassidulina neocarinata, Lenticulina costata, Heterostegina sp and Karreriella subcylindrica at depth of 8790 – 8550ft, which the top of this zone is base of zone (v) which within the Uvigerina subperegrina zone.*



.Figure 3:Foraminifera Distribution Chart of Geo-92 Well

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Zone (v): Uvigerina subperegrina – Late Miocene: This zone is defined by the First Downhole Occurrence (FDO) of *Uvigerina subperegrina, Globigerinoides extremus, Orbulina bilobata, Neogloboquadrina dutertrei, Globorotalia scitula, Globigerina nepenthes, Globorotalia acostaensis acostaensis, Globoquadrina altispira, Globorotalia scitula, Globigerina menardii, Sphaeroidinella dehiscens, Globigerina venezuelana, Globigerina bulloides, Globigerinoides bulliodes, Globigerinoides obliquusobliquus, Globigerinoides sp, Globigernoides trilobus trilobus, Globigerinoides trilobus immaturus, Orbulina universa, Anomalinoides sp, Globobulimina ovata, Marginulina sp, Meloris soldanii, Epistominella pacifica, Uvigerina auberiana, Lenticulina cultrate, Lenticulina rotulata, Quinqueloculina seminulum, Pullenia bulliodes, Ammonia beccarii, Heterolepa mckannai, Cassidulina norcrossi, Nodosaria sp, Cristellaria sp, Quinqueloculina sp,Sigmoilopsis schlumbergeri, Heterolepa crebbsi, Siphouvigerina auberiana attenuatta, Trifarina angulosa, Marginulina costata, Cyclammina cancellata, Lenticulina inornata, Bulimina sp,* occurring at the depth interval of 7680 – 8430ft with the *Uvigerina subperegrina* zone which the top of the zone is at the base of the zone (vi) at depth 7860ft.

Zone (vi): Haplophragmoides narivaensis – Late Miocene: *This sub-zone is defined by the First Downhole Occurrence (FDO) of Ammobaculites strathearmensis, Alveolophragmium crissum, Bathysiphon sp, Eggerella scabra, Haplophragmoides narivaensis, Haplophragmoides compressa, Haplophragmoides sp, Trochammina sp, and Valvulina flexilis, at depth 7470ft which is the first sample analysed in Geo-92 well.*

IX. PALEOENVIRONMENT OF DEPOSITION OF GEO-92 WELL:

Sedimentological criteria including Gamma Ray log responses and sand/shale ratios supported by paleobathymetric information from microfaunal association indicate that the Geo-92 Well was deposited in an environment ranging from paralic through inner neritic to outer neritic setting and are ascribed to the Agbada Formation (table 3).

X. SUMMARY/CONCLUSION:

Micropaleontological analysis of Sixty (60) samples of Geo-92 Well within the depth interval of 7470ft – 11,190ft was carried out. A total of one hundred and three (103) species were identified, these includes seventy-seven (77) calcareous species (Foraminifera planktonic and Foraminifera Benthics) in which the benthics accounted for fifty-two (52) and the planktics accounted for twenty-seven (27) species, while the remaining twenty-four (24) are foraminifera agglutinating (Arenaceous) from which a total of six zones were recognised. The delineated zones include *Uvigerina spariscostata* zone (i), *Globigerina nepenthes* (ii), *Quinqueloculina microcostata* zone (iii*), Globigerinoides bolli* zone (iv), *Uvigerina subperegrina* zone (v), and *Haplophragmoides narivaensis* zone (vi). Three (3) of the planktonic zones (*Haplophragmoides narivaensis, (Uvigerina Subperegrina)* and *Spirosigmoilina oligocaenica*) correlates well with N 17, N15-N16 and N14-N15 of [1] respectively and were used to assign middle Miocene to Late Miocene age for the sediments (figure 4). Although two (2) other zones, N16-N17 (*Ammobaculites agglutinans*) and N11/N12-N13 (*Uvigerina Spariscostata*) were recognized, they were not considered in assigning the age because *Ammobaculites agglutinans zone (*7470ft – 8370ft) marked a period of erosion or unconformity and truncated (minima) faunal abundance and diversity at this depth interval. Also the age *Uvigerina Spariscostata zone* was not considered because "*Rectogladulina comatula"* which supposed to be the upper boundary of that zone had its Last Downhole Occurrence (LDO) at 10,900ft which may not be true since the last depth of the well was not reached signifying that they may be a possibility of it occurring below the terminal depth (11,190) of the Well, therefore not enough reason for the zone to be marked in this well. Sedimentological analysis show that a major sedimentary formation in the Niger Delta, comprising of sandy shale and minimal shaly sands which is likened to the paralic and shaly sequences of the upper and lower Agbada Formation respectively was penetrated. Integration of the qualitative and quantitative foraminiferal data with the sedimentologic information induced two (2) paleo-enviroments; paralic and marine environments. Abundance and diversity of

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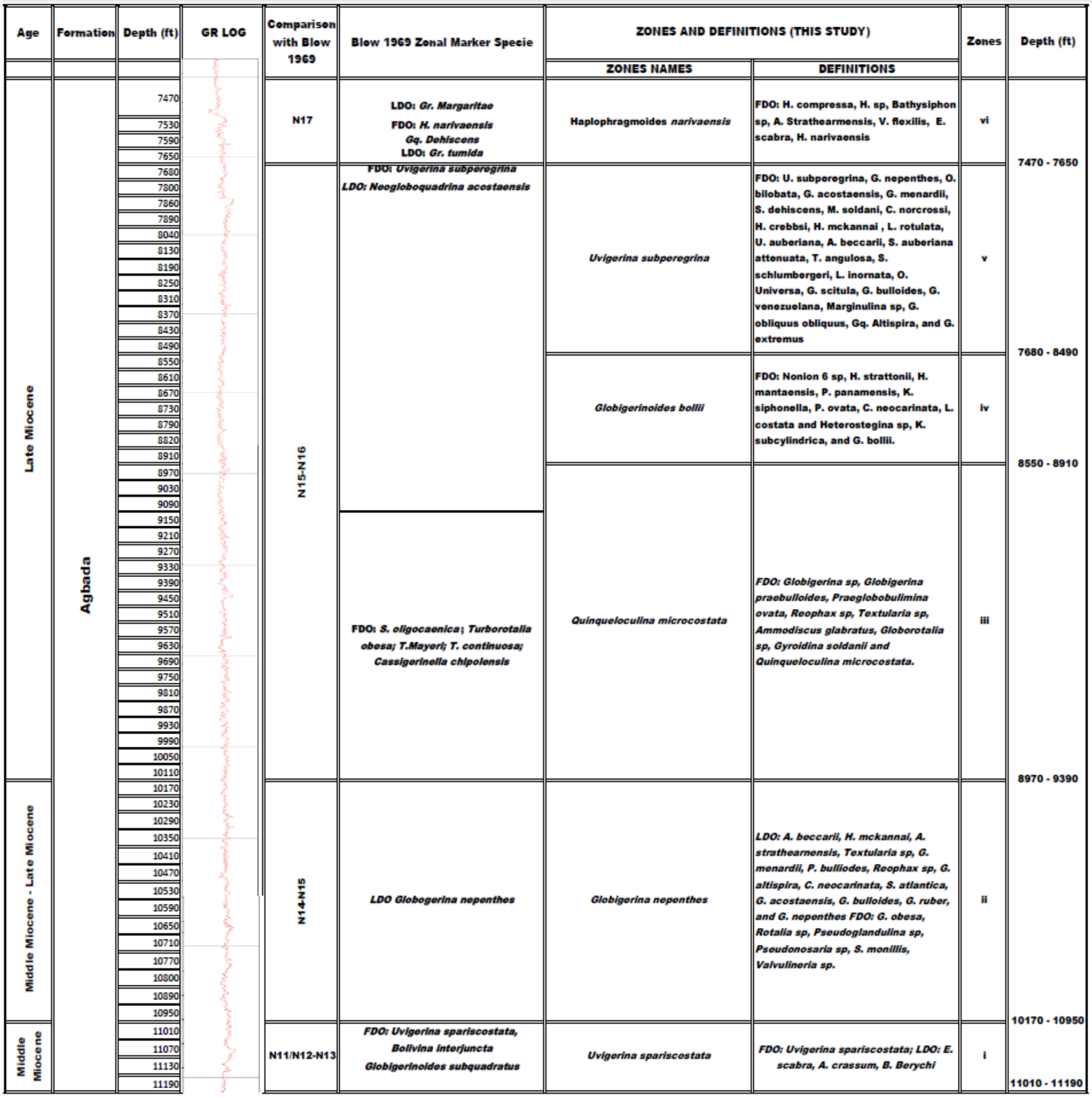

Figure 4. Biozonation chart of Geo-92 Well in comparison with Blow (1969) zonation scheme

.benthonic foraminiferal assemblage (Calcareous and the Agglutinating) suggest that the sediments of the Geo-92 Well were deposited in a pre-dorminantly inner neritic to outer neritic settings with occasionally deepening to Upper Bathyal environment (table 2).

In conclusion, this study has established that the well interval penetrated the Agbada formation with deposition of the sediments occurring during the Late and Middle Miocene in a parallic to marine setting.

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Table 2: Paleoenvironmental summary of Geo 92 well

Interval (Ft.)	Formation	Lithofacies Units	Paleoenvironment		Diagnostic Criteria
7,470 – 8,000	AGBADA	Shaly sand	Paralic setting		Sand/shale ratio of approximately 40:60. Regular intercalation of sand units with shale units. Low recovery of fauna abundance and diversity of foraminifera species. Inner and Middle neritic species dominates this interval.
8,000 – 11,190		Sandy shale	**Marine setting**	**Inner Neritic**	Dorminance of agglutinated species, low Planktic/Benthic ratio and diversity. Tests are small and weakly ornamented e.g Trochammina sp, Egerella scabra
				Outer Neritic	.Sand/shale ratio of approximately 10:90. Associated largely with shallow marine foraminifera. Increase in fauna abundance and diversity at 10,200 – 11,190ft. Moderate Planktic/Benthic ratio and high abundance and diversity of shallow marine foraminifera species e.g Cyclammina sp, Uvigerina sp, and Bulimina sp.

Plate 1: photomicrographic plate of some diagnostic foraminifera specie from the studied well.

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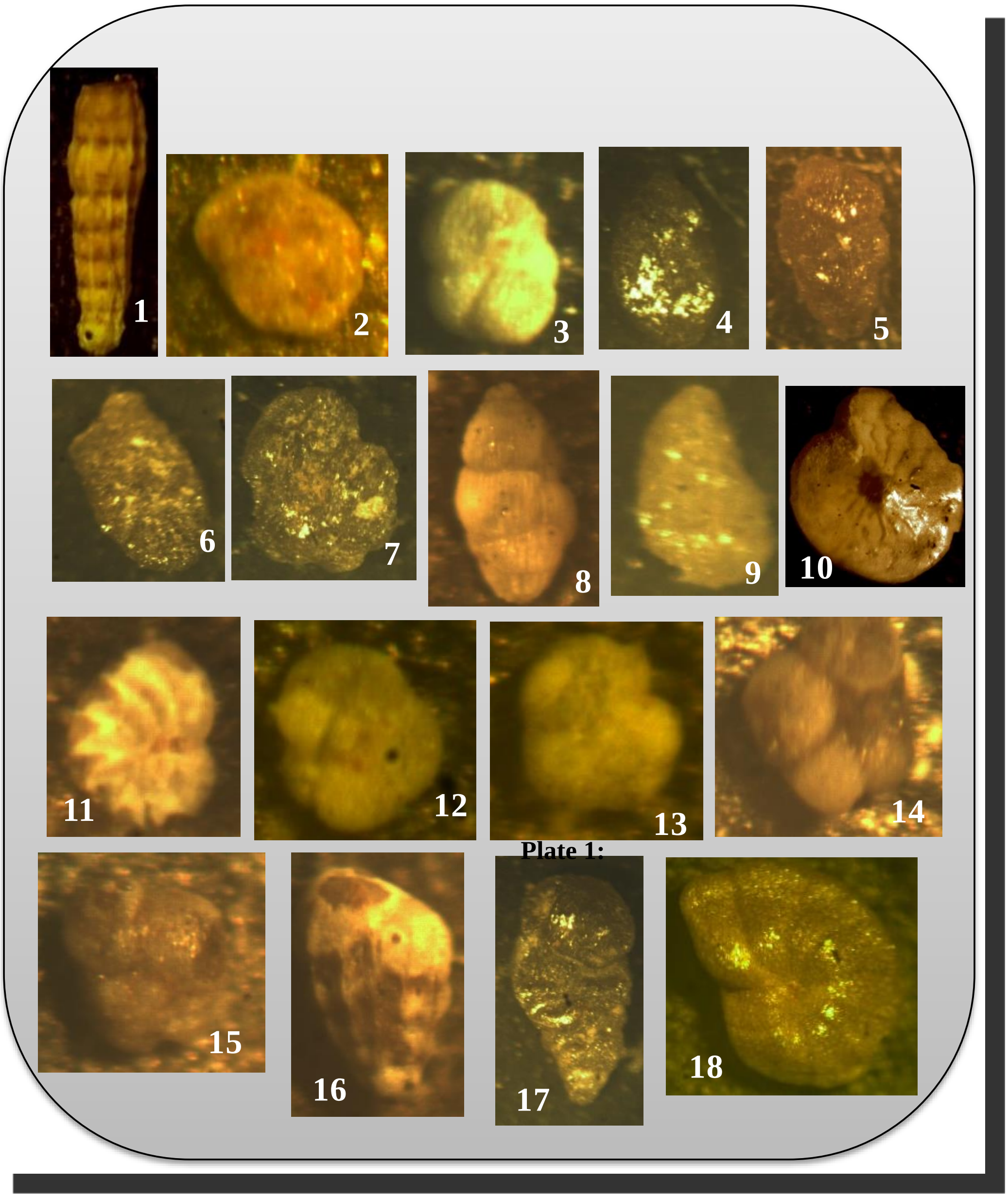

1. *Marginulina costata* **2.** *Haplophragmoides compressa* ***3.*** *Globigerina nepenthes*
4. *Cyclammina minima* **5.** *Eggerella scabra* **6.** *Ammobaculites strathearnensis*
7. *Haplophragmoides narivaensis* **8.** *Uvigerina subperegrina* **9.** *Ammobaculites agglutinans* ***10.*** *Amphistegina lessonii* **11.** *Florilus costiferum* **12.** *Globorotalia acostaensis (spiral side)* ***13.*** *Globorotalia acostaensis (Umblical side)* **14.** *Globorotalia obesa (Spiral side)*
15. *Globorotalia obesa (Umblica side)* **16.** *Uvigerina sparsicostata* **17.** *Valvulina flexilis* ***18.*** *Cyclammina cancellata.*

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