



## CALCAREOUS BENTHIC FORAMINIFERA BIOSTRATIGRAPHY AND PALEOENVIRONMENT OF DEPOSITION OF KK-1 WELL, OFFSHORE WESTERN NIGER DELTA, NIGERIA

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### AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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### ABSTRACT

A high resolution and quantitative benthic foraminiferal biostratigraphic analysis was carried out on ditch cutting samples from KK-1 well from the offshore Niger Delta. The study was undertaken within the depth intervals of 15280 to 17670 feet with the aim of subdividing the sequence into calcareous benthic foraminiferal biozones and also determine the paleoenvironment of deposition. The standard technique for foraminiferal recovery was followed. Two hundred and thirteen benthic foraminiferal species were identified. The studied depth intervals were very rich in benthic foraminifera and they were moderate to well preserved. Using the age diagnostic species and assemblages, the benthic foraminifera zones established in this study are the interval range zones of: *Eponides eshira* – *Valvulineria* sp, *Eponides berthelotianus* – *Epistominella vitrea*, *Planullaria auris* - *Buliminella multicamerata*, *Anomallinoides midwayensis* – *Lagena laevis* and *Uvigerina farinosa* – *Pullenia eocenica* respectively. The age of the studied interval ranged from middle – late Eocene to middle Miocene. The paleoenvironment of the studied intervals ranged from the outer neritic to bathyal.

**Keywords:** Benthic foraminifera; biostratigraphy; paleobathymetry; KK-1 well; Niger Delta; Nigeria.

### 1. INTRODUCTION

The studied KK-1 well is situated on the offshore part of the western Niger delta (Fig. 1). The focus of the study is on the benthic foraminifera biostratigraphy, dating and paleobathymetry of KK -1 well. Foraminifera distributions are useful in biostratigraphy and estimation of relative age of depositional sequence in sedimentary environment [1]. [2] studied the planktic foraminiferal

biostratigraphy of KK-1 well and established the planktic foraminiferal biozones.

[3] presented qualitative benthic and planktic foraminiferal biostratigraphy and zonation of five wells (Obrikom-1, Ebegoro-1, Afam-1, Kolocreek-1 and Akata-1) from the eastern Niger delta. [4] carried out a high resolution foraminiferal biostratigraphy of four wells (Kanbo-5, Egbedicreek-1, Angalalli-1 and Opukushi-5) located in the coastal and central swamp

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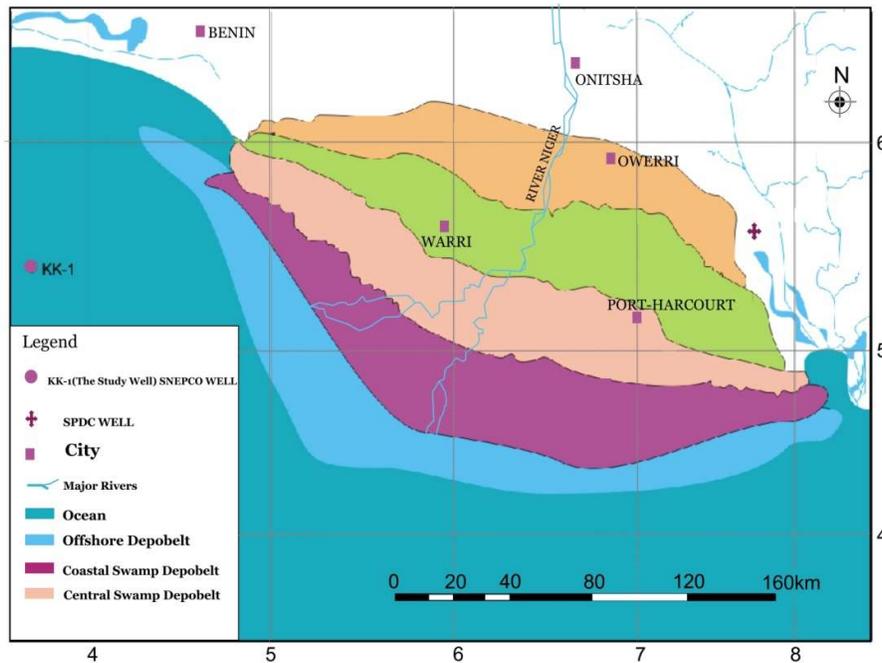


Fig. 1. Location map of KK-1 well in the Niger delta

of the western Niger Delta. They defined six foraminiferal zones (Assemblage/Partial range zones) for the middle to late Miocene Niger Delta as follows: *Globigerina* cf. *ciperoensis* Zone, *Nonion centrosulcatum* / *Chiloguembelina victoria* Zone, *Eponides eshira* Zone, *Uvigerina sparsicostata* Zone, *Spirosigmoilina oligoceanica* Zone, and *Florilus* ex. gr. *costiferum* Zone. Biostratigraphic, paleoenvironmental and sequence stratigraphic information of Akata field in the Eastern Niger delta has been published by [5]. [6] established a planktic *Praeorbulina glomerata* Zone and a benthic *Poritextularia panamensis* Zone in Oloibiri-1 well, Eastern Niger delta.

[7] assigned Middle to Late Eocene age to the stratigraphic interval studied from AM-2 well, Niger delta due to the occurrence of Middle to Late Eocene foraminifera age diagnostic marker species such as *Globigerina eocaena*, *G. bagni*, *G. cryptomphala*, *G. inaequispira*, *Chiloquembelina cubensis*, *C. martini*, *Pseudohastigerina micra*, *P. wilcoxensis*, *Turborotalia cerroazulensis cerroazulensis*, *T. griffinae*, *T. pseudomayeri* and *T. cerroazulensis pomeroli*. [8] identified three planktic foraminifera zones: *Globorotalia margaritae margaritae* subzone (N18), *Globigerinoides obliquus extremus* - *Sphaeroidinellopsis seminulina* zone (N17), and *Globorotalia acostaensis acostaensis* zone (N16), from A, B, C and D wells in the offshore part of Niger delta. The aims of this study are to subdivide the

strata of KK-1 well into calcareous benthic foraminiferal biozones and determine their paleoenvironment of deposition.

## 2. MATERIALS AND METHODS

One hundred and forty two samples from KK-1 well have been studied, and sampled within the depth interval of 15120-17670 feet were used for this study. The lithology facies encountered were dominantly shale and mudstone with subordinate argillaceous sandstone (Fig. 2). The shale and mudstone are grey to dark grey while the sandstone are brown. Other materials used in preparing and analyzing the samples include Aluminum foil, distil water, kerosene, liquid detergent, hot plate, 63 micron sieve size, filter paper, sample bags, marker for labeling the sample bags, picking brush, picking tray, binocular microscope, slides and cover slides and gum. The aluminum foil was used to cover the soaked samples to avoid contamination while the liquid soap was to wash off the kerosene and any drilling contaminants.

The kerosene method of preparing samples for foraminifera's recovery was adopted because it is economical and could disaggregate the samples. 20 g of each sample was weighed and crushed was to loosen the bounded particles. The samples were soaked using distilled water and kerosene in a beaker over night for thorough digestion. Samples were then washed with tap water using 63 micron mesh sieve.

Afterwards, the washed samples were dried both on hot plate and in an oven at a minimum temperature of 20°C for about 30 minutes. The samples were packaged in well labelled sample bags for picking and observation under the binocular microscope.

The prepared samples were placed on a picking tray and view under a reflected light binocular microscope for any preserved foraminifera content. The foraminiferal specimens were picked out with a fine brush or wet toothpick and dropped in the micro paleontological slide cavity. Cover slips were used in covering the slides and arranged serially according to their depths in slide tray for analysis. The picked foraminifera were subjected to identification and abundance/diversity counts. In the analysis (identification), relevant published manuals were utilized, such as [3,9,10,11,12,13]. The micro fauna zonation and age determination of the studied well were carried out using the age diagnostic foraminiferal species.

### 3. RESULTS AND DISCUSSION

The result of this analysis is presented in the calcareous benthic foraminiferal distribution chart of KK- 1 well (Fig. 2). The lithofacies of the well consist of shale, mudstone and sandstone.

The stratigraphic intervals studied in the well have been subdivided into biostratigraphic zones based on the benthic foraminiferal content.

#### 3.1 Calcareous Benthic Foraminifera Biostratigraphy

The samples yielded abundant and diverse benthic foraminifera species. Two hundred and three calcareous benthic foraminiferal species and few benthic indeterminate specimens were recorded. The biozones established in this study were based on the international stratigraphic guide - an abridged version of [14].

##### 3.1.1 *Eponides eshira* – *Valvulineria* sp (interval range) zone

**Stratigraphic interval:** 15120 – 15280 feet.

**Definition:** The top of the zone is defined by the first downhole occurrence [(FDO) from the top] of *Valvulineria* sp while the base is marked by the FDO of *Eponides eshira*. The zone is an interval range zone.

**Characteristics:** It is characterized by the association and FDO of *Lenticulina grandis*, *Lenticulina inornata*, *Bolivina scalprata miocenica*, *Globobulimina ovula*, *Cibicorbis inflata*, *Hanzawai*

*strattoni*, *Uvigerina sparsicostata* and *Brizalina interjuncta*. However, the zone has little recovery and less diversity of benthic foraminifera.

**Age:** The zone is dated middle Miocene. The FDO of *Eponides eshira*, *Lenticulina grandis* *Uvigerina sparsicostata* and *Brizalina interjuncta* within the zone are diagnostic of middle Miocene [5,11,15].

##### 3.1.2 *Eponides berthelotianus* – *Epistominella vitrea* (interval range) zone

**Stratigraphic interval:** 15280 - 15720 feet.

**Definition:** The top of the zone is defined by the first downhole occurrence (FDO) of *Epistominella vitrea* while the base is marked by the FDO of *Eponides berthelotianus*.

**Characteristics:** Highly abundant and diverse benthic foraminifera were recovered within this zone. They include; *Valvulineria suturalis*, *Bulimina comis*, *Gyroidina soldanii*, *Bulimina inflata*, *Globocassidulina subglobosa*, *Cibicorbis inflata*, *Brizalina mandoroveensis*, *Cassidulina crassus*, *Uvigerina sparsicostata*, *Uvigerina manteensis*, *Spirosigmoilina oligceanica* and so many other species as is reflected in Fig. 2.

**Age:** The age is early Miocene (equivalent to N4-N5 Zone of [16,17]). *Valvulineria suturalis*, *Bolimina comis*, *Gyroidina soldanii*, *Bulimina inflata* and *Globocassidulina subglobosa* are some of the significant benthic foraminiferal species that characterize the early Miocene foraminiferal assemblages [11,16,17].

##### 3.1.3 *Planullaria auris* - *Buliminella multicamerata* (interval range) zone

**Stratigraphic interval:** 15720 - 16390 feet.

**Definition:** The top of the zone is defined by the first downhole occurrence (LDO) of *Buliminella multicamerata* while the base is marked by the FDO of *Planullaria auris*.

**Characteristics:** Other associated species include *Epistominella pontoni*, *Nonionella davillensis*, *Pullenia quinqueloba*, *Valvulineria wilcoxensis*, *Hanzawai concentrica*, *Fursenkoina howei*, and so many other benthic species (Fig. 2). The zone is very rich and diverse in benthic foraminifera.

**Age:** This zone is dated late Oligocene because of the presence of *Epistominella pontoni*, *Nonionella davillensis*, *Pullenia quinqueloba*, *Valvulineria wilcoxensis*, *Hanzawai concentrica* and *Fursenkoina howei*. These are late Oligocene diagnostic marker species [11].

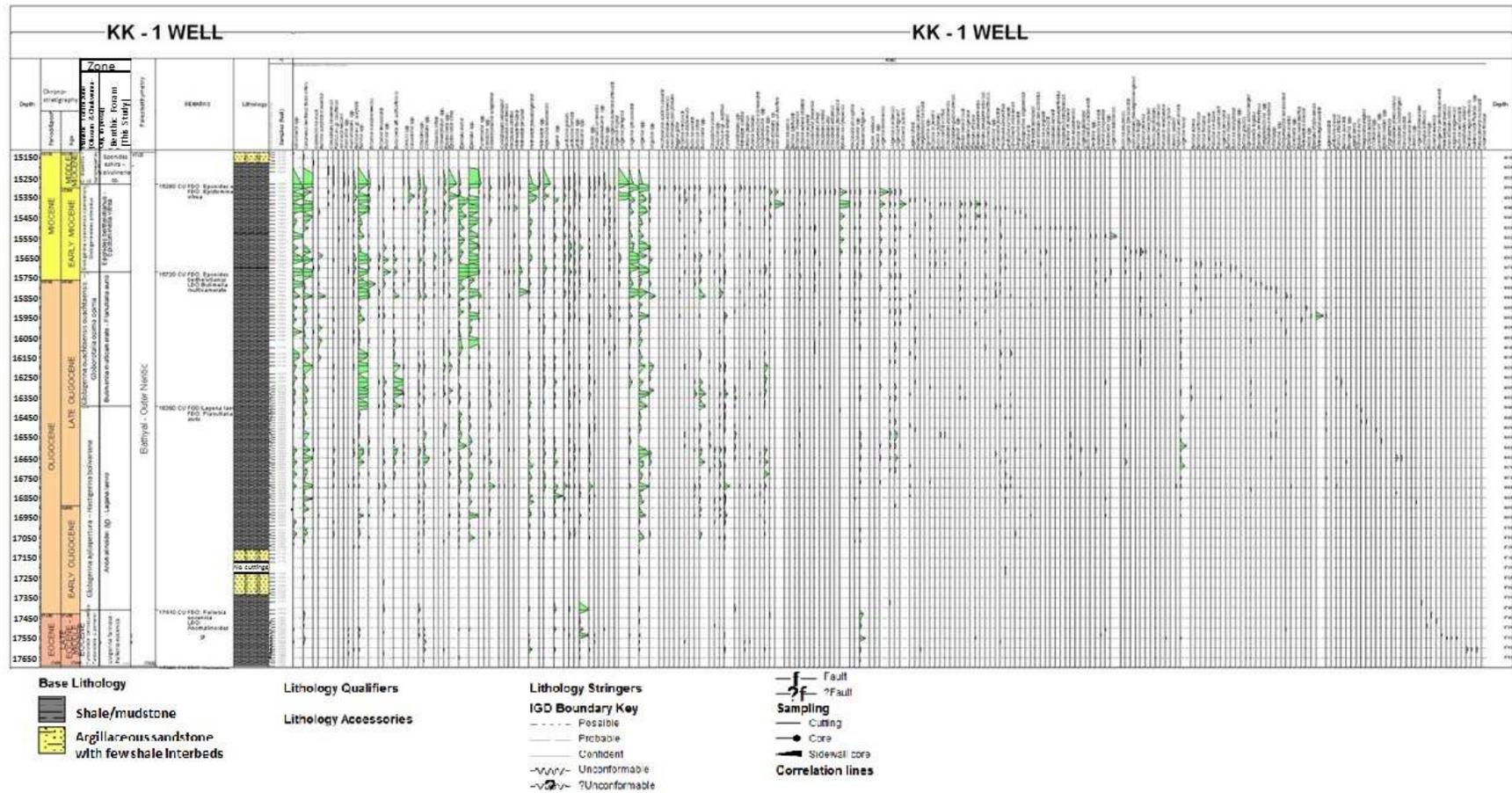


Fig. 2. Calcareous benthic foraminiferal distribution chart of KK-1 well, offshore Niger Delta

**3.1.4 *Anomallinoides* sp – *Lagena laevis* (interval range) zone**

**Stratigraphic interval:** 16390 - 17410 feet.

**Definition:** The top of the zone is defined by the first downhole occurrence (FDO) of *Lagena laevis* while the base is marked by the FDO of *Anomallinoides* sp.

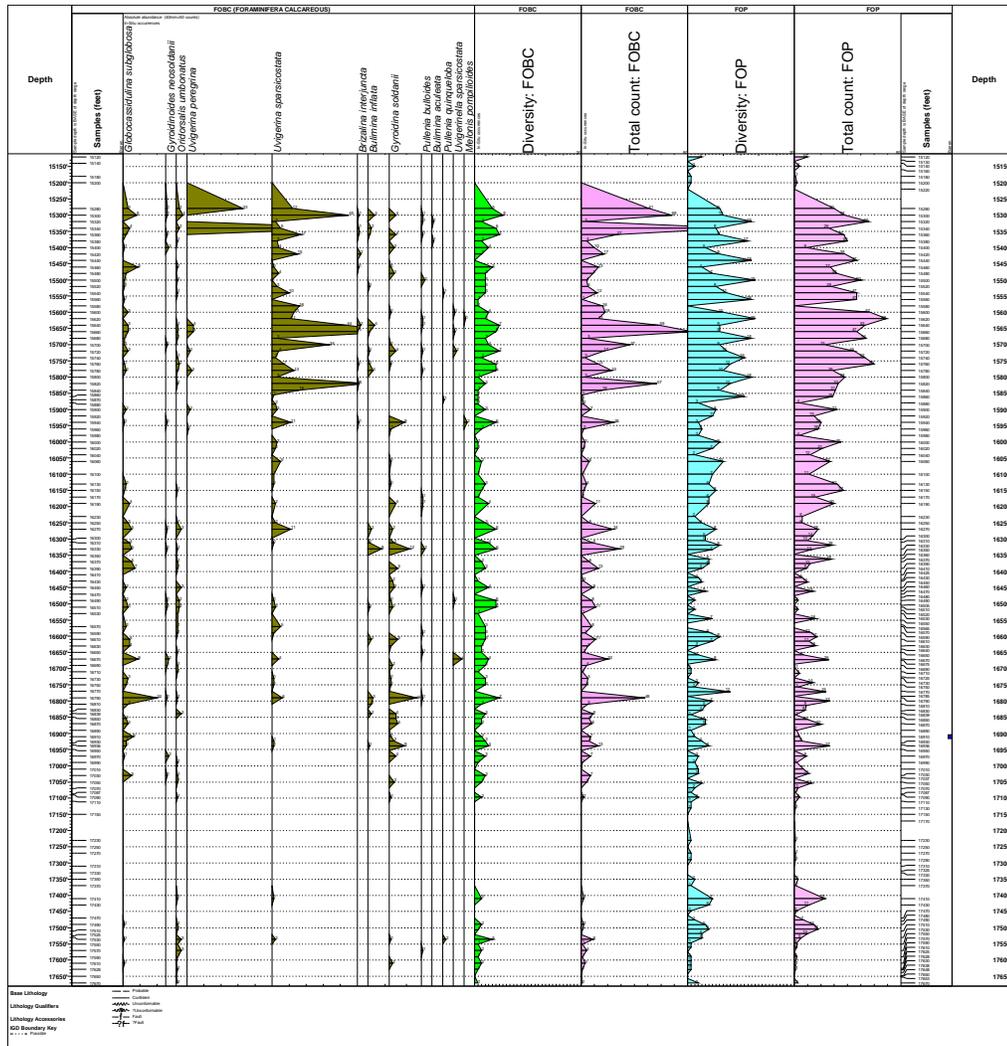
**Characteristics:** Other associated species occurring within the zone include *Spirosigmoilina oligoceanica*, *Marginulina coastata*, *Lenticulina curvisopta*, *Heterolepa crebbsi*, *Gyroidinoides* spp., *Uvigerina sparsicostata*, *Uvigerina* sp, *Bolivina* spp., *Bolivina* ex.gr. *scalprata* and other benthic species (Fig. 2). The zone is rich and diverse in calcareous benthic foraminiferal recovery.

**Age:** This zone is dated early Oligocene because of the presence of the above mentioned taxa within the zone which are early Oligocene diagnostic marker species.

**3.1.5 *Uvigerina farinosa* – *Pullenia eocenica* Zones (interval range) zone**

**Stratigraphic interval:** 17410 - 17670 feet.

**Definition:** The top of the zone is defined by the first downhole occurrence (FDO) of *Pullenia eocenica* while the base is marked by the FDO of *Uvigerina farinosa*.

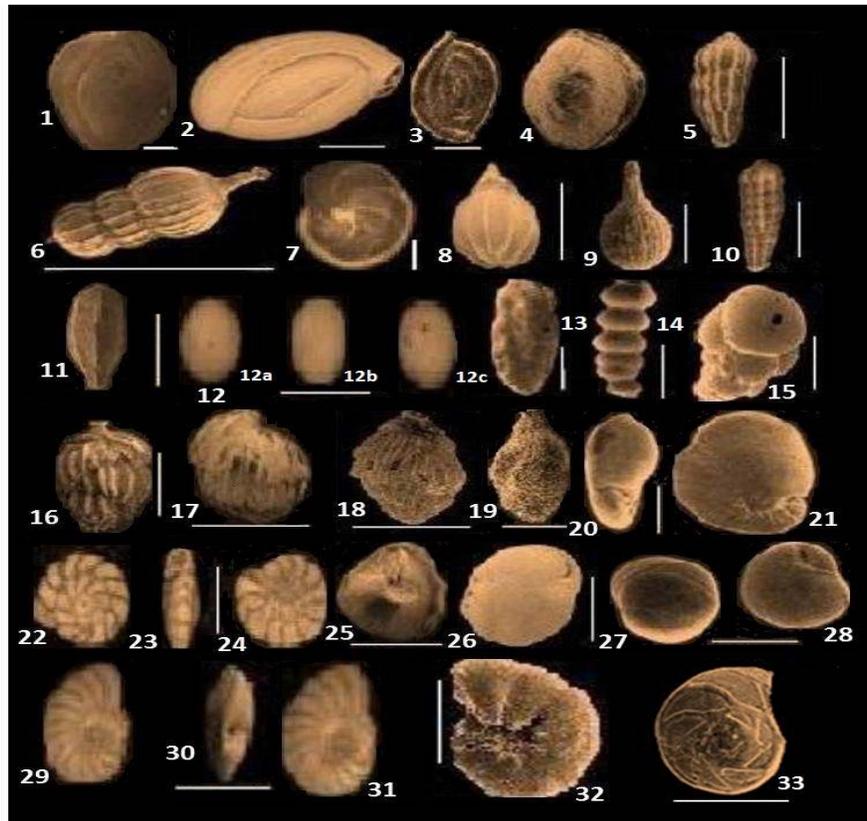


**Fig. 3. Distribution of outer neritic to bathyal key calcareous benthic foraminiferal biofacies and the diversity of the calcareous benthic and planktic foraminifera in the KK-1 well**

**Characteristics:** The associated species occurring within the zone include *Pleurostomella incrassata*, *Dentalina leguminiformis*, *Gryoidinoides soldanii*, *Bulimina semicostata*, *Aragonia aragonensis*, *Anomalinoidea nobilis*, *Heterolepa dertonensis*, *Eouvigerina dentioullocamenata*, *Oriddorsalis umbonatus*, *Nodosaria* spp and *Siphouvigerina auberiana attenuate* [18]. *Pleurostomella incrassata* has been reported from the Eocene to Miocene from the Indian Ocean [19]. *Pullenia eocenica*, *Aragonia*

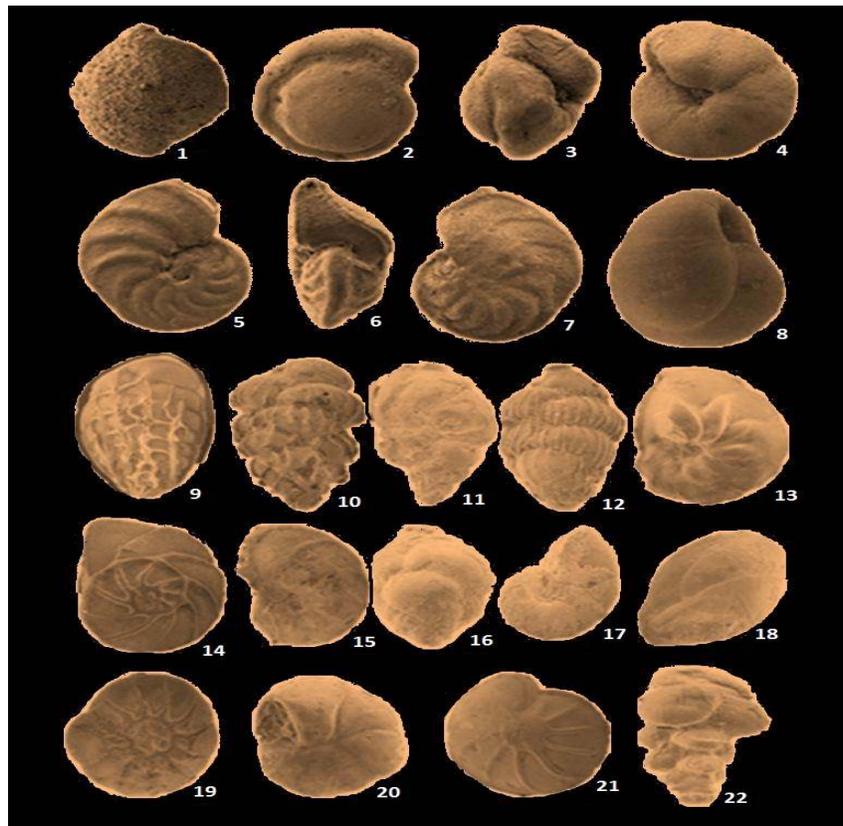
*aragonensis* were previously reported from the Eocene of Trinidad, while *Oridosalis umbonatus* was also reported from the Eocene to Miocene of Trinidad [18].

**Age:** This zone is dated middle – late Eocene because of the presence of the first downhole occurrences of *Uvigerina farinose*, *Pullenia eocenica* and the other associated Eocene species within the zone. These are middle - late Eocene diagnostic marker species.



**Plate 1. Photomicrographs of selected foraminiferal species from KK-1 well, western Niger Delta (White scale bars: 100 μ)**

- |   |  |
|---|--|
| 1. <i>Quinqueloculina seminulum</i> LINNÉ             | 15. <i>Bulimina aculeata</i> BROTZEN                             |
| 2. <i>Quinqueloculina microcostata</i> NATLAND        | 16. <i>Uvigerina peregrina</i> CUSHMAN                           |
| 3. <i>Sigmoilina tenuis</i> ČŽIŽEK                    | 17. <i>Uvigerina subperegrina</i> CUSHMAN & KLEINPELL            |
| 4. <i>Spirosigmoilina oligoceanica</i> CUSHMAN        | 18. <i>Uvigerina sparsicostata</i> CUSHMAN & LAIMING             |
| 5. <i>Nodosaria</i> sp. LAMARCK                       | 19. <i>Uvigerina auberiana</i> D'ORBIGNY                         |
| 6. <i>Amphicoryna scalaris caudate</i> BATSCH         | 20, 21. <i>Cancris auriculus</i> FICHTEL & MOLL                  |
| 7. <i>Lenticulina inornata</i> D'ORBIGNY              | 22, 23, 24. <i>Ammonia beccarii</i> LINNÉ                        |
| 8. <i>Lagena striata</i> D'ORBIGNY                    | 25. <i>Eponides eshira</i> DE KLASZ & RÉRAT                      |
| 9. <i>Lagena costata</i> WILLIAMSON                   | 26. <i>Cassidulina neocarina</i> THALMANN                        |
| 10. <i>Marginulina costata</i> BATSCH                 | 27, 28. <i>Globocassidulina subglobosa</i> BRADY                 |
| 11. <i>Rectoglandulina comatula</i> LOEBLICH & TAPPAN | 29, 30, 31. <i>Florilus</i> ex. gr. <i>N. costiferum</i> CUSHMAN |
| 12 a, b, c. <i>Oolina</i> sp. D'ORBIGNY               | 32. <i>Nonionella</i> sp. CUSHMAN                                |
| 13. <i>Brizalina</i> sp. LOEBLICH & TAPPAN            | 33. <i>Eponides berthelotianus</i> (d' Orbigny)                  |
| 14. <i>Stilostomella</i> sp. GUPPY                    |  |



**Plate 2. Photomicrographs of selected benthic foraminiferal species from KK-1 well, western Niger Delta (All magnifications x85)**

- |  |   |
|--|---|
| 1. <i>Sigmoilopsis schlubergeri</i> (SILVESTRI)    | 12. <i>Uvigerina</i> sp OKOSUN & LIEBAU           |
| 2. <i>Gyroidinoides soldanii</i> (d' ORBIGNY)      | 13. <i>Eponides</i> sp OKOSUN & LIEBAU            |
| 3. <i>Gyroidinoides soldanii</i> (d' ORBIGNY)      | 14. <i>Eponides eschira</i> (de KLASZ & RERAT)    |
| 4. <i>Gyroidinoides soldanii</i> (d' ORBIGNY)      | 15. <i>Hanzawaia</i> sp OKOSUN & LIEBAU           |
| 5. <i>Hanzawaia mantaensis</i> (GALLOWAY & MORREY) | 16. <i>Uvigerina mantaensis</i> CUSHMAN & EDWARDS |
| 6. <i>Hanzawaia mantaensis</i> (GALLOWAY & MORREY) | 17. <i>Eponides eschira</i> (de KLASZ & RERAT)    |
| 7. <i>Hanzawaia mantaensis</i> (GALLOWAY & MORREY) | 18. <i>Globobulimina</i> sp OKOSUN & LIEBAU       |
| 8. <i>Globocassidulina subglobosa</i> (BRADY)      | 19. <i>Ammonia beccari</i> LINNE                  |
| 9. <i>Bolivina interjuncta</i> (CUSHMAN)           | 20. <i>Epistomina vitrea</i> PARKER               |
| 10. <i>Uvigerina</i> sp OKOSUN & LIEBAU            | 21. <i>Lenticulina inornata</i> (d' ORBIGNY)      |
| 11. <i>Bulimina obuzuensis</i> PETERS              | 22. <i>Bulimina obuzuensis</i> PETERS             |

### 3.2 Paleoenvironment of Deposition

Foraminiferal biofacies models obtained from several investigations of Recent deltas have been proposed for the recognition of the different paleodepths of inner, middle, outer and bathyal environments of the Niger delta [11,12,13,20,21,22]. Biofacies models from these studies provide the most empirical and actualistic technique for the identification of the ancient analogues.

Inference on the paleodepositional environment of the studied well was made based on the biofacies information interpreted from the qualitative and quantitative evaluation of the benthic foraminiferal assemblages and integration of the lithologic description of the section.

The parameter considered in the interpretation of the paleoenvironment is the presence/absence of environmental diagnostic marker species [23,24]. Outer neritic to bathyal depositional environment is inferred for the entire studied interval of KK-1 well because of the distribution of the following taxa:

*Globocassidulina subglobosa*, *Gyroidinoides neosoldanii*, *Oridosalis umbonatus*, *Uvigerina sparsicostata*, *Brizalina interjuncta*, *Bulimina inflata*, *Gyroidina soldanii*, *Pullenia bulloides*, *Pullenia quinqueloba*, *Uvigerinella sparsicostata*, *Melonis pompilioides*, *Bulimina aculeate* and *Uvigerina peregrina* (Figs. 2 and 3). The foregoing foraminiferal biofacies is diagnostic of the outer neritic to bathyal in the Niger delta [13].

*Globocassidulina subglobosa* was also reported to have dominated the Late Neogene bathyal zone of the northeastern Gulf of Mexico [25]. The lower bathyal *Oridorsalis* spp., *Gyroidinoides* spp and *Globocassidulina subglobosa* dominated assemblage reported from the Late Neogene of northeastern Gulf of Mexico further corroborates the paleodepth interpretation [25]. The high planktic foraminiferal diversity reported for KK-1 well (Fig. 3) also supports the interpreted depositional environment. *Globocassidulina subglobosa* and *Oridorsalis umbonatus* have been reported from the Eocene to Recent deep sea strata of the Central Equatorial Pacific Ocean [26].

#### 4. CONCLUSION

One hundred and forty two ditch cutting samples from KK-1 well, sampled within the depth intervals of 15120 to 17670 feet yielded abundant and diverse benthic foraminifera species. The benthic foraminiferal biozones established in this study are the interval range zones of *Eponides eshira* – *Valvulineria* sp, *Eponides berthelotianus* – *Epistominella vitrea*, *Planullaria auris* - *Buliminella multicamerata*, *Anomallinoides* sp – *Lagena laevis* and *Uvigerina farinosa* – *Pullenia eocenica* Zones. The age assigned to the studied interval ranged from middle – late Eocene to middle Miocene. Outer neritic to bathyal depositional environment is inferred for the entire studied interval of KK-1 well because of the frequent occurrence of the diagnostic species of the following genera: *Uvigerina*, *Bolivina*, *Globocassidulina*, *Eponides*, *Buliminella*, *Bulimina*, *Brizalina*, *Melonis*, *Pullenia*, *Oridorsalis*, *Gyroidina* and *Gyroidinoides* known to inhabit outer neritic to bathyal environment.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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