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PLANKTIC FORAMINIFERAL BIOSTRATIGRAPHY AND BIOCHRONOLOGY OF KK-1 WELL WESTERN NIGER DELTA, NIGERIA

EDWARD A. OKOSUN[1*] AND JACINTA N. CHUKWUMA-ORJI[1]
[1]Department of Geology, Federal University of Technology, Minna, Nigeria.

AUTHORS' CONTRIBUTIONS
This work was carried out in collaboration between the authors. Author EAO designed the study, wrote the protocol and interpreted the data. Author EAO gathered the initial data and performed preliminary data analysis. Author JNCO managed the literature searches and produced the initial draft. Both authors read and approved the final manuscript.

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Original Research Article

ABSTRACT

A high resolution and quantitative planktic 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 aim of subdividing the sequence penetrated by the well into planktic foraminiferal biozones and also determine the biochronology. The standard technique for foraminiferal recovery was followed. Ninety planktic foraminiferal species were identified in the well. The recovered planktics were rich and moderately preserved. Using the age diagnostic species and assemblages, the planktic foraminifera zones established in the study are the interval range zones of *Catapsydrax dissimilis* - *Globigerina baroemoenesis* Zone, *Globigerina ciperoensis ciperoensis – Globigernoides primodus* Zone, *Globigerina ouchitaensis ouchitaensis – Globorotalia opima opima* Zone, *Hastigerina bolivariana – Globigerina ampliapertura* Zone and a lineage zone of *Turborotalia cerroazulensis pomeroli -Turborotalia cerroazulensis* Zone respectively. The age of the studied interval ranged from middle – late Eocene to middle Miocene. The Eocene – Oligocene and Oligocene – Miocene boundaries were also established at the depth of 17410 ft and15720 ft respectively. Three biozones out of the five biozones established in this study correlate well with parts of the Niger delta, the Mediterranean and some other low latitude areas.

Keywords: Planktic foraminfera; biostratigraphy; biochronology; KK-1 well; Niger delta; Nigeria.

1. INTRODUCTION

The studied well (KK-1 well) is situated on the offshore part of the western Niger delta (Fig. 1). The focus of the present work is on the planktic foraminiferal biostratigraphy and dating of KK -1 well from western Niger Delta. Foraminiferal distributions within a depositional environment have been found useful in biostratigraphy and estimation of relative age of depositional sequence in sedimentary environment [1].

**Corresponding author: Email: eaokosun@gmail.com;*

Using the combination of taxa occurring in samples, the stratigraphy and the age can be precisely constrained provided that resedimentation and reworking can be excluded [2].

[3] presented qualitative benthic and planktic foraminiferal biostratigraphy and zonation of five wells (Obrikom-1, Ebegoro-1, Afam-1, Kolocreek-1 and Akata-1 wells) 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 of the western Niger Delta. They defined six foraminiferal zones (Assemblage/Partial range zones) for the middle to late Miocene Niger Delta namely; *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 glomerosa* 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 foraminfera 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 objectives of the research are to investigate and document the planktic foraminiferal species and identify biozones for the KK-1 well, offshore western Niger delta. The data and information provided will be useful in the biochronology and stratigraphic correlation of Late Paleogene and Early Neogene strata in the Niger delta.

2. GEOLOGICAL SETTING

The geology of the Niger delta has been described and defined by [9], who recognized three formations. These formations are; the Akata, Agbada and Benin Formations. The Tertiary Niger Delta is one of the major regressive deltaic sequences in the world. The delta is over 12 km thick and occupies an area of 75,000 km^2 in the Gulf of Guinea [10]. The Akata Formation is generally of open marine and prodelta dark grey shale with lenses of siltstone and sandstone. The age of the Akata Formation ranges from Paleocene in the proximal parts of the delta to Recent in the distal offshore. The Agbada Formation consists of cyclic coarsening-upward regressive sequences composed of shales, siltstones, and sandstones which include delta front and lower delta plain deposits [11]. The Agbada Formation ranges in age from Eocene to Holocene [12]. The Benin Formation is the uppermost unit in Niger Delta. The Benin Formation comprises a succession of Eocene to Holocene massive poorly indurated sandstones, thin shales, coals, and gravels of continental to upper delta plain origin.

3. MATERIALS AND METHODS

One hundred and forty two ditch cutting samples from KK-1 well, sampled within the depth interval of 15120 to 17670 feet were used for this study. The ditch cutting samples were studied with a magnifying hand lens for lithologic description and preparation of lithologic log.

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 to label the sample bags, picking brush, picking tray, binocular microscope, slides and cover slides and gum.

The kerosene method of preparing samples for foraminifera's recovery was adopted because it is economical and could disaggregate the samples. Twenty grams of each sample was weighed and crushed 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 20ºC for about 30 minutes. The samples were package 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

tooth pick 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 [3,13-16]. The micro fauna zonation and age determination of the studied well was done using the age diagnostic foraminiferal species. Rock samples are usually correlated to the geological timeframe based on the presence of nominate and diagnostic species whose biochronology and biozones have been calibrated to the geological timeframe from the established zonal schemes of current or previous workers.

4. RESULTS AND DISCUSSION

The result of this analysis is presented in the planktic foraminferal distribution chart of KK- 1 well (Fig. 2) and some of the recovered species are also presented in Plate 1. The lithology of the studied section consists of shale, sandstone and mudstone.

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

4.1 Planktic Foraminifera Biozones

The samples yielded abundant and diverse planktic foraminifera species within the upper part of the interval (15280-16630 ft). Eighty nine planktic foraminiferal species and planktic indeterminate specimens were recorded. The biozones established/recognized in this study were based on the international stratigraphic guide - an abridged version of [17] and the revised Cenozoic geochronologic and chronostratigraphic schemes of [18].

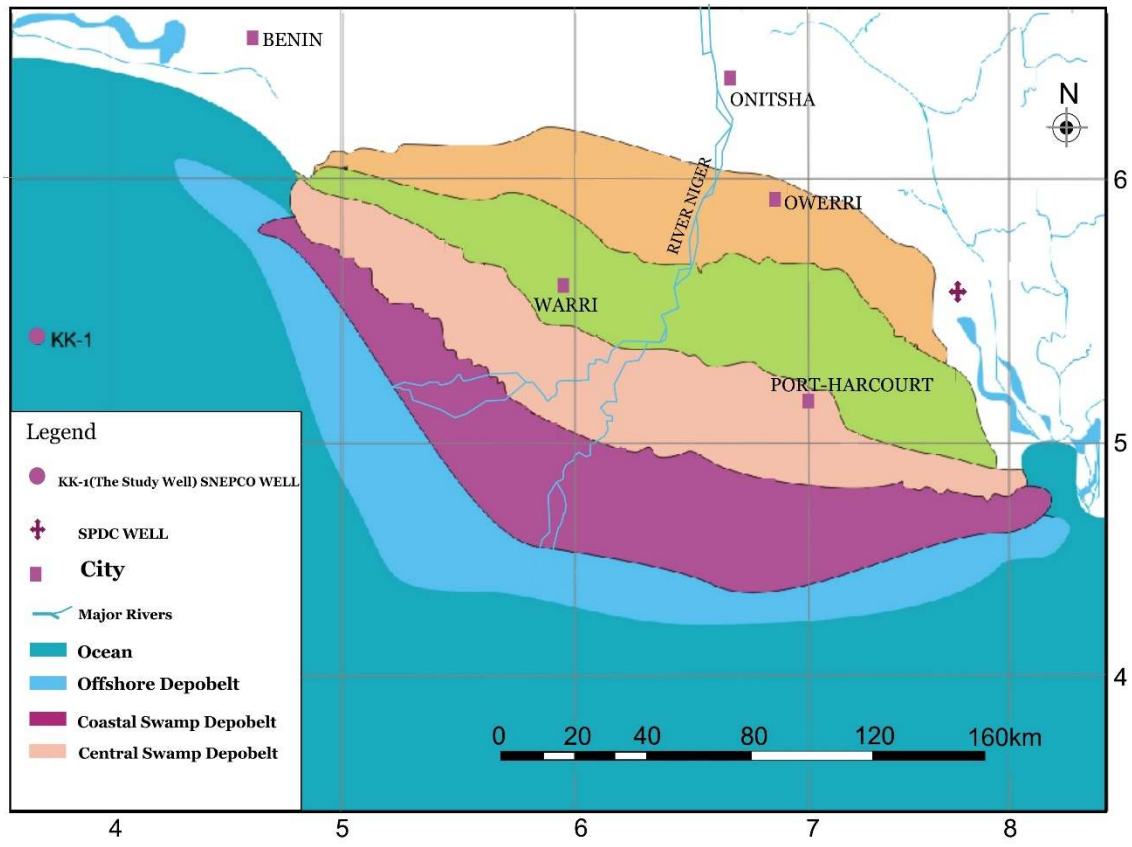

Fig. 1. Location map of KK-1 well

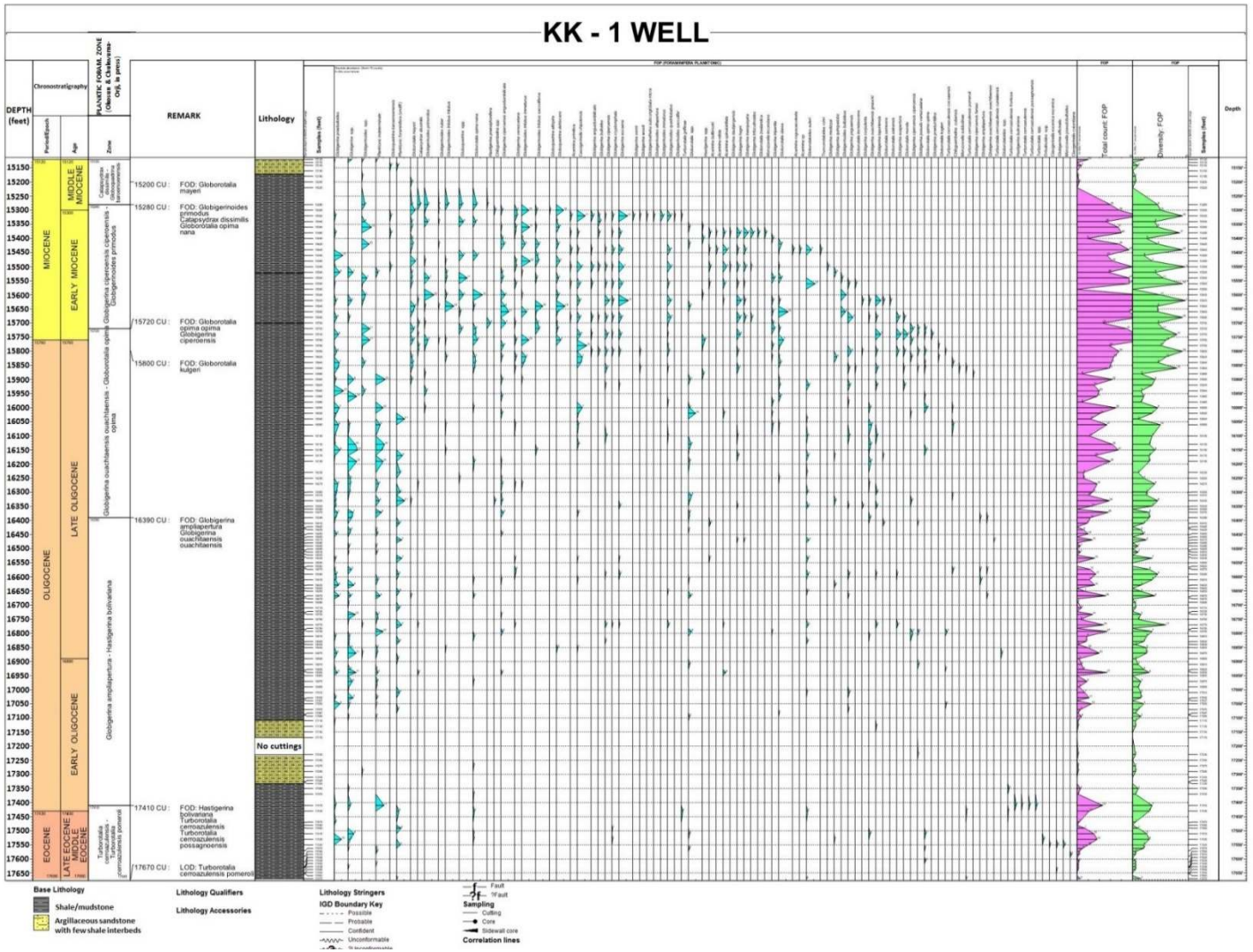

Fig. 2. Planktic foraminifera distribution chart of KK-1 well

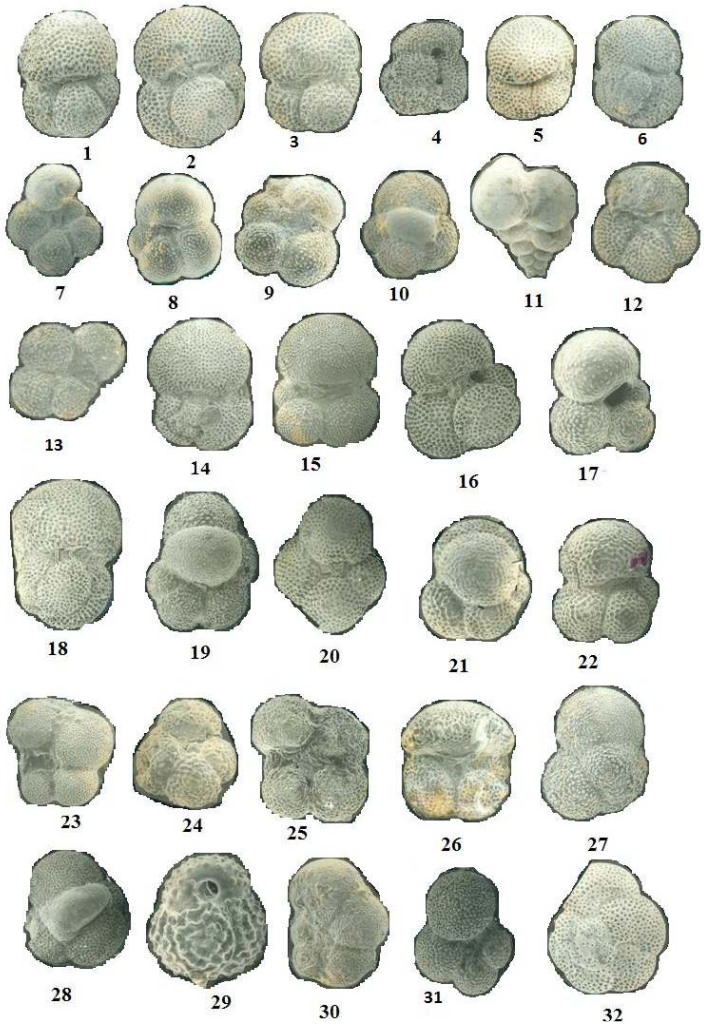

Plate 1. Planktic foraminfera species from KK-1 well

Explanation of plate 1

(All magnifications X85)

1. *Globigerinoides quadrilobatus* (d'Orbigny)
2, 3, 14, 15. *Globigerinoides primodus* (Blow & Banner)
4. *Globigerinoides ruber* (d'Orbigny)
5, 6. *Globigerinoides trilobus* (Reuss)
7. *Globigerina ciperoensis angustumbilicata* (Bolli)
8. *Globigerina euapertura* (Jenkins)
9, 25. *Globigerina officinalis* (Subbotina)
10, 21. *Catapsydrax dissimilis* (Cushman & Bermudez)
11. *Chiloquembelina cubensis* (Palmer)
12. *Globoquadrina dehiscens* (Chapman, Parr & Collins)
13. *Globigerina angustiumbilicata* (Bolli)
16, 17. *Globigerinoides quadrilobatus* (d'Orbigny)
18, 32. *Globorotalia mayeri* (Cushman & Ellisor)
19, 20. *Globigerina quinqueloba* (Natland)
22, 31. *Globorotalia obesa* (Bolli)
23. *Globigerina praebulloides* (Blow)
24. *Hastigerina* sp (d'Orbigny)
26. *Globigerina ouachtaensisouachtaensis* (Howe & Walalce)
27, 28. Species indeterminate
29. *Globigerinoides bolli* (Blow)

4.1.1 *Catapsydrax dissimilis – Globoquadrina baroemoenensis* Zone (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 *Globoquadrina baroemoenensis* while the base is marked by the FDO of *Catapsydrax dissimilis.* The zone is an interval range zone.

Characteristics: It is characterized by *Globigerinoides* sp, *Globigerina* sp *and Globigerina praebulloides*. FDO of *Globorotalia mayeri* which also marks top of middle Miocene occurs within this zone at 15200 ft. However, the zone has poor recovery and less diversity of planktic foraminifera.

Age: The zone is dated middle Miocene. The FDO of *Globorotalia mayeri* and *Catapsydrax dissimilis* are diagnostic of middle Miocene [18]. The zone is equivalent to N9 –N15 of [19,20].

4.1.2 *Globgerina ciperoensis ciperoensis – Globigernoides primodus* Zone (interval range zone)

Stratigraphic interval: 15280 - 15720 feet

Definition: The zone is defined as the interval between the first downhole occurrences (FDO) of *Globigernoides primodus* and *Globgerina ciperoensis ciperoensis* respectively. The top of the zone is marked by the FDO of *Globigernoides primodus* at the depth of 15280 ft while the base is marked by the FDO of *Globgerina ciperoensis ciperoensis* at the depth of 15720 ft.

Characteristics: Highly abundant and diverse planktic foraminifera were recovered within this zone. They include; *Catapsydrax dissimilis, Globigerinoides ruber, Globigerina angustiumblicata, Cassigerinella chipolensis, Globorotalia obesa, Globigernoides* sp, *Globigerna ciperoensisangustumbilicata, Globigerinoides sacculifer, Globoquadrina dehiscens*, *Globigerinoides immaturus* and *Globigerinoides trilobus*. There are few occurrences of Eocene species within this zone such as *Acarinina rugosoaculeata, Acarinina nitida, Acarinina bullbrooki, Acarinina primitive, Acarininaspnuloinflata* and *Acarinina* sp. These could have resulted from samples mix during sampling exercise.

Age: The detailed examination of the planktic foramineral data gave the age of the interval to be early Miocene (equivalent to N4-N8 Zone of [19,20]. *Catapsydrax dissimilis, Globigerinoides ruber, Globigerinoides primodus, Globoquadrinadehiscens* are some of the significant planktic foraminifera species that characterize the early Miocene foraminiferal assemblages [19,20].

4.1.3 *Globigerina ouchitaensis ouchitaensis – Globorotalia opima opima* Zone (interval range zone)

Stratigraphic interval: 15720 - 16390 feet

Definition: The top of the zone is defined by the first downhole occurrence (FDO) of *Globorotalia opima opima*while the base is marked by the FDO of *Globigerina ouchitaensis ouchitaensis.*

Characteristics: Other associated species include *Globgerina ciperoensis ciperoensis, Globorotalia kulgeri, Globorotalia* sp, *Globigerna ciperoensisangustumbilicata, Globigerina praebulloides* and *Globorotaloides suteri*. There is moderate recovery and diversity of planktic foraminifera in this zone.

Age: This zone is dated late Oligocene because of the presence of the first and last downhole occurrences of *Globgerina cipoeroensis ciperoensis, Globorotalia kulgeri* and FDO of *Globorotalia opima opima* within the zone. These are late Oligocene diagnostic marker species [18]. The zone is equivalent to P20 - P22 of [19,20].

Remark: The top boundary of this zone placed at the depth of 15720 feet marks the Oligocene – Miocene boundary in the studied well. The presence of FDO of *Globorotalia opima opima* at this depth and the first and last occurrence of *Globorotalia kulgeri* within the zone aided this boundary determination. There are scanty occurrences of early-middle Miocene diagnostic marker species within the zone such as *Globoquadrina dehiscens, Globigerinoides trilobus sacculiferus, Globigerinoides primodus, Catapsydrax dissimilis,* and *Globorotalia mayeri.* These could have resulted from caving in of the ditch cuttings during drilling operation.

4.1.4 *Hastigerina bolivariana – Globigerina ampliapertura* Zone (interval range zone)

Stratigraphic interval: 16390 - 17410 feet

Definition: The top of the zone is defined by the first downhole occurrence (FDO) of *Globigerina ampliapertura* while the base is marked by the FDO of *Hastigerina bolivariana.*

Characteristics: Other associated species occurring within the zone include *Globorotalia opima nana, Globorotalia* sp, *Globigerina* sp, *Globigerina officinalis* and *Globigerina praebulloides.* The zone has sparse recovery and low diversity of planktic foraminifera.

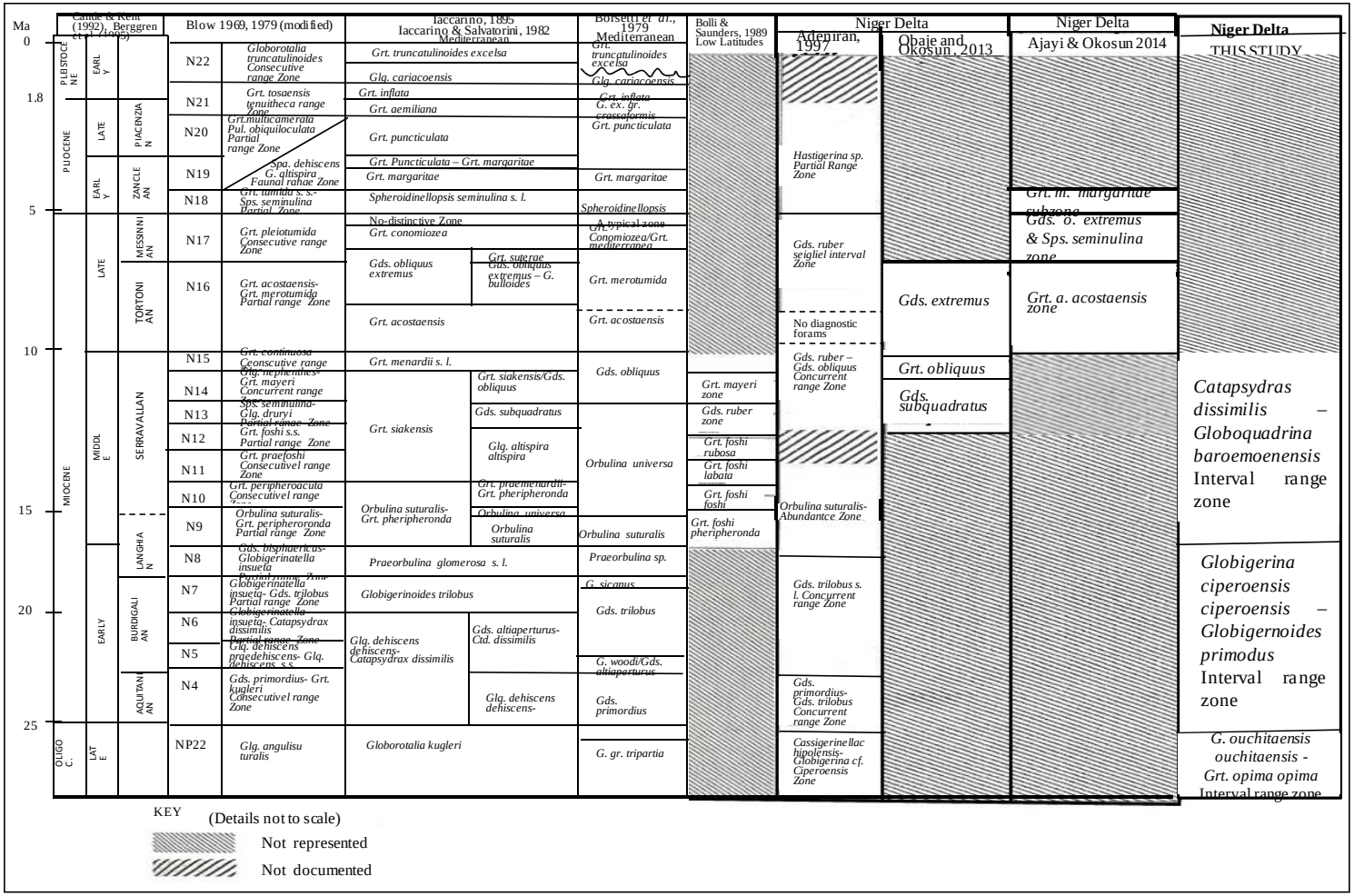

Fig. 3. Correlation of the study well with the Mediterranean, Low Latitude Areas and parts of Niger Delta

Age: This zone is dated early Oligocene because of the presence of the first downhole occurrences of *Globigerina ampliapertura* and*Hastigerina bolivariana* within the zone. These are early Oligocene diagnostic marker species [17]. The zone is equivalent to P18 – P20 of [18,19].

4.1.5 *Turborotalia cerroazulensis pomeroli - Turborotalia cerroazulensis* (lineage zone) Zone

Stratigraphic interval: 17410 - 17670 feet

Definition: The top of the zone is defined by the first downhole occurrence (FDO) of *Turborotalia cerroazulensis* while the base is marked by the LDO of *Turborotalia cerroazulensispomeroli.*

Characteristics: This zone is a phylogenetic zone because it is believed to represent the evolutionary or developmental trend of the taxon *Turborotalia cerroazulensis*. Other associated species occurring within the zone include *Turborotalia cerroazulensis frontosa*, *Morozovella pseudoulloides*, *Clavigerinella eocenica eocenica*, *Clavigerinella colombiana*, *Orbulinoides* sp.

Age: This zone is dated middle – late Eocene because of the presence of the first downhole occurrences of *Turborotalia cerroazulensis pomeroli*,*Turborotalia cerroazulensis*and the other associated Eocene species within the zone. These are middle - late Eocene diagnostic marker species [18,7]. The zone is equivalent to P12 – P17 of [7,19,20].

Remark: The zone is the last zone penetrated by the KK-1 well. The top of the zone placed at the depth of 17410 feet marks the Eocene – Oligocene Boundary in the studied well because of the lone occurrence of *Turborotalia cerroazulensis* - a keeled globorotalid that characterized late Eocene [18].

4.2 Correlation of the study well with the Mediterranean, Low Latitude Areas and parts of Niger Delta

The zones established in this study correlate partly with the work of [7,18-21]. Three biozones of the study well correlate well with parts of the Niger delta, the Mediterranean and some other low latitude areas (Fig. 3). The zones encountered in this study range from Middle-Late Eocene to Middle Miocene, however only Late Oligocene to Middle Miocene is represented in Fig. 3.

5. CONCLUSIONS

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 foraminifera species within the upper part of the interval (15280-16630 ft). The planktic foraminiferal biozones established in this study are the interval range zones of *Catapsydrax dissimilis - Globigerina baroemoenesis* Zone, *Globigerina ciperoensis ciperoensis – Globigernoides primodus* Zone, *Globigerina ouchitaensis ouchitaensis – Globorotalia opima opima* Zone, *Hastigerina bolivariana – Globigerina ampliapertura* Zone and a lineage zone of *Turborotalia cerroazulensis pomeroli - Turborotalia cerroazulensis* Zone. The age assigned to the studied interval ranged from middle – late Eocene to middle Miocene. The Eocene – Oligocene boundary was placed at the depth of 17410 feet in the studied well because of the lone occurrence of *Turborotalia cerroazulensis* - a keeled globorotalid that characterized late Eocene [18]. The Oligocene – Miocene boundary was also established at the depth of 15720 feet. The presence of FDO of *Globorotalia opima opima* at this depth and the first and last occurrence of *Globorotalia kulgeri* within the zone aided this boundary determination. Three biozones of the study well correlate well with parts of the Niger delta, the Mediterranean and some other low latitude areas.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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