FORAMINIFERA BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL STUDIES OF TWO WELLS FROM OFFSHORE WESTERN NIGER DELTA

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ABSTRACT

Biostratigraphic analysis was carried out on two wells from the deep offshore western Niger Delta Basin of Nigeria. The maximum flooding surfaces encountered were dated in both wells with foraminifera data at different horizons from the top to the total depths. Five foraminiferal zones were recognized in both wells. These are (i) *Globorotalia acostaensis/Uvigerina subperegrina* zone, (9.5Ma and older); (ii) *Globorotalia merotumida/plesiotumida /Ammobaculites agglutinans* zone (7.4Ma); (iii) *Globoquadrina dehiscens/Haplophragmoides narivaensis* zone (the base of this zone is defined by the 7.4 Ma maximum flooding surface and the top bounded by an unconformity dated 6.7Ma); (iv) *Globorotalia tumida/ Cyclammina minima* zone (the top and base of this zone are defined by the 5.0 Ma maximum flooding surface and 6.7 Ma sequence boundary) and (v) *Globigerina nepenthes/Haplophragmoides compressa* zone. The paleobathymetry for the two wells ranges from Inner Neritic to Upper bathyal as confirmed by the benthonic foraminifera assemblage. Most of the documented benthonic foraminifera recovered from the two wells such as *Heterolepa*, *Globocassidulina*, *Florilus*, *Lenticulina* among others, are normal marine benthonic foraminifera. It can therefore be inferred that the sediments were of normal salinity and Early-Pliocene to Late-Miocene in age.

Keywords: Foraminifera, Biostratigraphy, Maximum Flooding Surface, Neritic, Bathyal.

INTRODUCTION

The Niger Delta is a clastic wedge in southern Nigeria in the Gulf of Guinea offshore Nigeria (Fig. 1). It is a high energy constructive arcuate delta system (Tuttle *et al*., 1999). The Niger Delta is an area of rapid sedimentation and is significant on a world level for its hydrocarbon reserve. Therefore, an understanding of its lithostratigraphy, paleoecology, biostratigraphy and sedimentology is necessary for exploration and exploitation of the hydrocarbon resources of the delta.

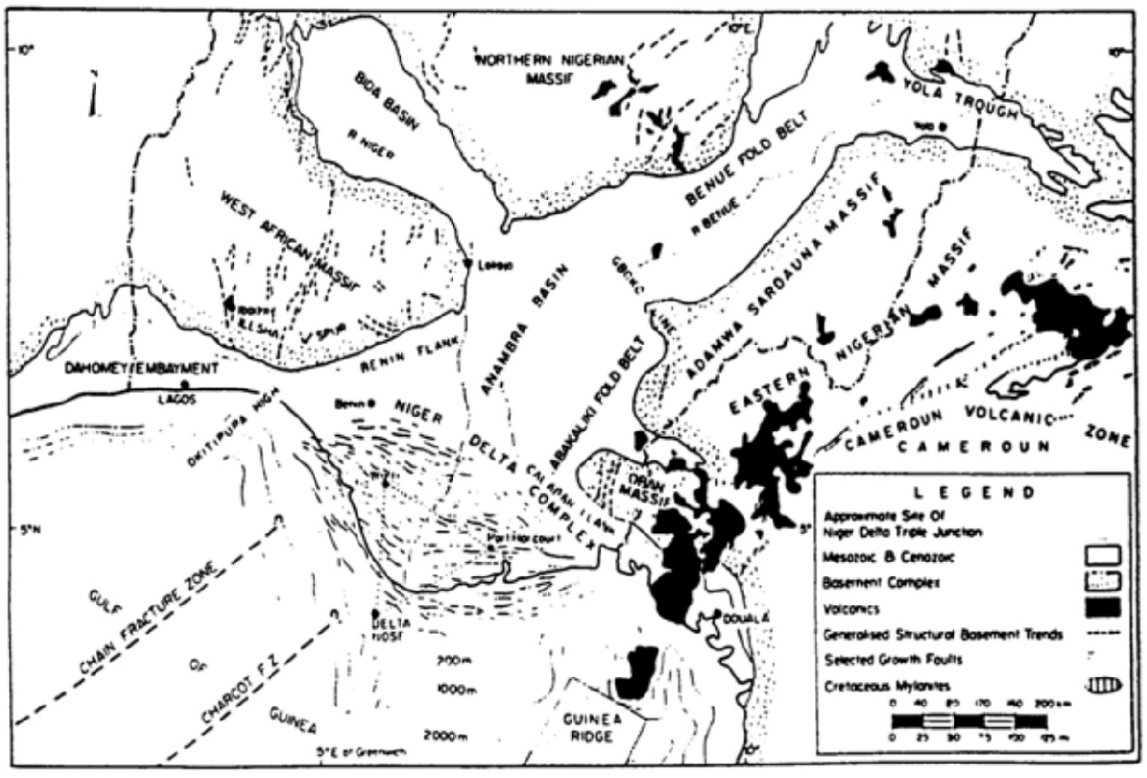

Figure 1: Map Showing the Location of the Niger Delta and its Megatectonic Settings (Whiteman, 1982)

Publications abound on the micropaleontology of the Niger Delta. Adegoke *et al.* (1971) identified four bathymetric biofacies based on the distribution and abundance of planktonic species in the Niger Delta. Adegoke *et al.* (1976) also recognized seven benthonic foraminifera biofacies based on their occurrence and diversity while working on the samples collected from the Gulf of Guinea by the Mee Cremer Expedition.

Petters (1979) established two biostratigraphic horizons in the western Niger Delta based on index planktic foraminifera of *Globorotalia tumida* (Brady) and *Globorotalia opima nana* (Bolli) from the Parabe-1 well. He gave a late Oligocene-Pliocene age for the sediments. Four distinct Bathyal biofacies were recognized by Salami (1982) based on relative abundance and depth of first and last datum appearances of benthonic foraminiferal species while working on samples from the Niger Delta. These zones are upper, middle, upper-lower and lower-lower biofacies.

Ogbe (1982) delineated the marine transgression phases from the incipient Niger Delta and recognized the prodelta transgression (Late Cretaceous), the main delta transgression (Early Miocene) and the world wide Pleistocene transgression. Peters (1992) when looking at the foraminifera assemblages within the rift deltas and continental margin deltas concluded that due to restricted marine conditions, littoral arenaceous foraminifera are pervasive in the Cretaceous rift deltas of the Benue Trough and the Nupe Basin, and that such arenaceous assemblage are very rare in the Tertiary microfossil record of the Niger Delta. The prodelta environment in the Niger Delta contains diverse benthic foraminifera upon which Inner, Middle and Outer Neritic and Bathyal foraminifera biofacies can be recognized while Cretaceous prodelta Paleoenvironments were sparsely inhabited by endemic benthic foraminifera.

The two wells, from which samples were obtained for this study, are located within the deep-offshore Western Niger Delta. The two wells studied are 1.5km apart. This paper centres on the integration of biostratigraphic data of the two wells in order to determine the age, biozones and environment of deposition of the sediments.

MATERIALS AND METHODOLOGY

A standard weight (30 g) of each sample was initially heated and demoisturised. This sample was later soaked overnight to allow for disaggregation of the samples. The disaggregated sample was then washed under a shower of water over a 63 microns sieve. More indurated samples were given a short chemical (Hydrogen peroxide, 6% conc.) treatment to enhance the disaggregation of the particles. The washed residue was then dried over a hot plate and sieved into three fractions (coarse (425 micron), medium (180 micron) and fine (63 micron)) prior to the picking of the foraminiferal contents.

The foraminifera contents and other microfauna were picked using a picking needle under an Olympus Binocular microscope. Identification of individual foraminifera was based on published literature materials, such as Cushman (1948); Barker (1960); Loeblich and Tappan (1964); Postuma (1979) among others.

The foraminifera fauna recovered from this study were subjected to two modes of analysis: the qualitative and quantitative analyses. The qualitative analysis forms the main basis for biostratigraphic interpretation. It defines the presence or absence of a particular taxon within a group or assemblage of species in any sample regardless of its depth of occurrence. The presence of a species determines part of the stratigraphic range of the species. Thus, the total stratigraphic range is obtained when the total number of the sample containing the species were known. This analysis does not consider total number of individual species present. On the other hand, quantitative analysis considers the abundance of individual species and the sum of all recovered foraminifera species. The quantitative analysis formed the basis for paleeoecological interpretation made in this study. The total number of plankonic and benthonic foraminifera species were estimated in the studied intervals. The statistical data obtained were computerized using the StrataBug software (version 1.7). Sawtooth plots of the abundance and species diversity were made from which candidate Maximum Flooding Surfaces were selected.

RESULTS AND DISCUSSION

WELL-1 FORAMINIFERA BIOSTRATIGRAPHY

Eighty five (85) foraminifera species were identified. Of these, 66 species (78%) are calcareous, while the remaining 19 species (22%) are arenaceous. Of the calcareous forms, benthics accounted for 40 species (61%) while the

remaining 26 species (39%) are planktics. The accessory microfauna recorded include ostracodes, echinoid remains and shell fragments.

BIOSTRATIGRAPHIC ZONES IN WELL-1

Five (5) foraminifera "zones" recognized in Well-1 are highlighted below and the stratigraphic distribution of the planktonic foraminifera in well-1 is presented in figure 2. The Maximum Flooding Surfaces were used as zonal boundaries in this study, and the zones are correlated with the standard planktonic foraminifera zones of Blow (1969, 1979), Berggren *et al.* (1995) and Hardenbol *et al.* (1998). The benthonics used in these zones are localized and applicable to the Niger Delta and are believed to have chronostratigraphic importance. The recorded foraminifera marker species are shown in Plate-1.

(i) *Globorotalia acostaensis/Uvigerina subperegrina* Zone

This is the oldest foraminifera zone recognized in the studied section of Well-1. The top of the zone is placed at 9720 feet close to the last downhole occurrence (LDO) of one of the nominate zonal marker *Globorotalia acostaensis* recognized at 9840 feet. The zonal base is tentatively placed at 11,040 feet, the depth of the last sample analyzed.

The zonal foraminiferal assemblage is characterized by common deep water forms such as *Saccammina complanata, Ammobaculites strathearnensis*, *Planulina wuellerstorfi* and species of *Bathysiphon, Trochammina* and *Haplophragmoides*. The planktics recorded include *Globigerinoides immaturus* and *G. bollii*.

The top of the zone is marked by 9.5 Ma maximum flooding surface. The zone correlates with the upper N15-Lower N16 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is Late Miocene and older.

(ii) *Globorotalia merotumida/plesiotumida/ Ammobaculites agglutinans Zone*

The upper and lower boundaries of this zone are recognized at 8940 feet and 9720 feet respectively. *Ammobaculites agglutinans* whose first datum occurrence is associated with the Zone was recorded within the condensed section at 8880 feet. The last datum occurrence of *Globorotalia merotumida/plesiotumida*, the nominate zonal marker was depressed, occurring at 10,260 feet. The Zone is further characterized by the common occurrence of deep water forms particularly *Cibicidoides pachyderma, Planulina wuellerstorfi, Globocassidulina subglobosa, Trochammina proteus, Saccammina complanata, Ammobaculites strathearnensis*, and *Bathysiphon sp.* Planktonics were represented by common records of *Globigerinoides immaturus*, *G. bollii* and *Globigerinita naparimaensis*. The top and base of the zone are correlatable to the 7.4 and 9.5 Ma Maximum Flooding Surfaces respectively.

The zone correlates with the Upper N16-Lower N17 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is late Miocene.

(iii) *Globoquadrina dehiscens/Haplophragmoides narivaensis* Zone

The base of the Zone was recognized at 8940 feet while the top was bounded by an unconformity recognized at 8550 feet. *Haplophragmoides narivaensis*, the nominate zonal marker whose first datum occurrence is associated with the Zone is recorded at 8700 feet. The zonal foraminiferal assemblage is dominated by common deep water forms such as *Trochammina proteus, Saccammina complanata, Cyclammina minima*, *Glomospira gordialis*, *Ammobaculites strathearnensis, Sigmoilopsis schlumbergeri, Uvigerina auberiana,* and *Bathysiphon sp.* Planktics recorded include *Globigerinoides bollii, G. quadrilobatus*, *G. immaturus, Globorotalia pseudomiocenica* and *G. merotumida/plesiotumida*. The lower and upper boundaries of the zone are correlatable with the 7.4 Ma maximum flooding surface and 6.7 Ma sequence boundary respectively.

The zone correlates with the Middle N17 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is Late Miocene.

(iv) *Globorotalia tumida/Cyclammina minima* Zone

The top and base of the *Globorotalia tumida/Cyclammina minima* Zone are recognized at 7320 feet and 8550 feet respectively. The first datum occurrence of the nominate zonal marker, *Cyclammina minima* is recorded within the condensed section at 7440 feet. The zonal foraminifera assemblage is dominated by common records of *Cibicidoides pachyderma, Cibicidoides mexicanus, Cibicidoides pseudoungerianus, Karreriella siphonella, Uvigerina auberiana, Uvigerina asperula, Gyroidinoides neosoldanii* and *Bathysiphon sp.*

Planktics are represented by *Globigerina praebulloides, Globigerinoides bollii, G. extremus, Globorotalia merotumida/plesiotumida* and *G. mayeri*. The top and base of the zone are correlatable to the 5.0Ma maximum flooding surface and 6.7 Ma sequence boundary respectively.

The zone correlates with the upper N17- lower N18 planktonic foraminiferal zones of Blow (1969, 1979) and Berggren *et al*. (1995). The age is Late Miocene.

(v) *Globigerina nepenthes/Haplophragmoides compressa* Zone

This is the youngest Zone recognized in the studied section of Well-1. The base of the Zone is recognized at 7320 feet while the top is tentatively placed at 6360 feet, the depth of the first sample analyzed. The first datum occurrence of *Haplophragmoides compressa*, one of the nominate zonal markers associated with the Zone occurred at 9060 feet. The Zone is further characterized by rare to common occurrence of *Cibicidoides pseudoungerianus, Cibicidoides pachyderma, Uvigerina auberiana, Uvigerina asperula* and *Gyroidinoides neosoldanii*. Planktics with rare occurrence within the zone include *Globigerinoides bollii*, *G. immaturus, G. ruber, Globigerina praebulloides* and *Globorotalia merotumida/plesiotumida*. The base of the zone is correlatable to the 5.0Ma maximum flooding surface.

The zone correlates with the upper N18 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al*. (1995). The age is early Pliocene.

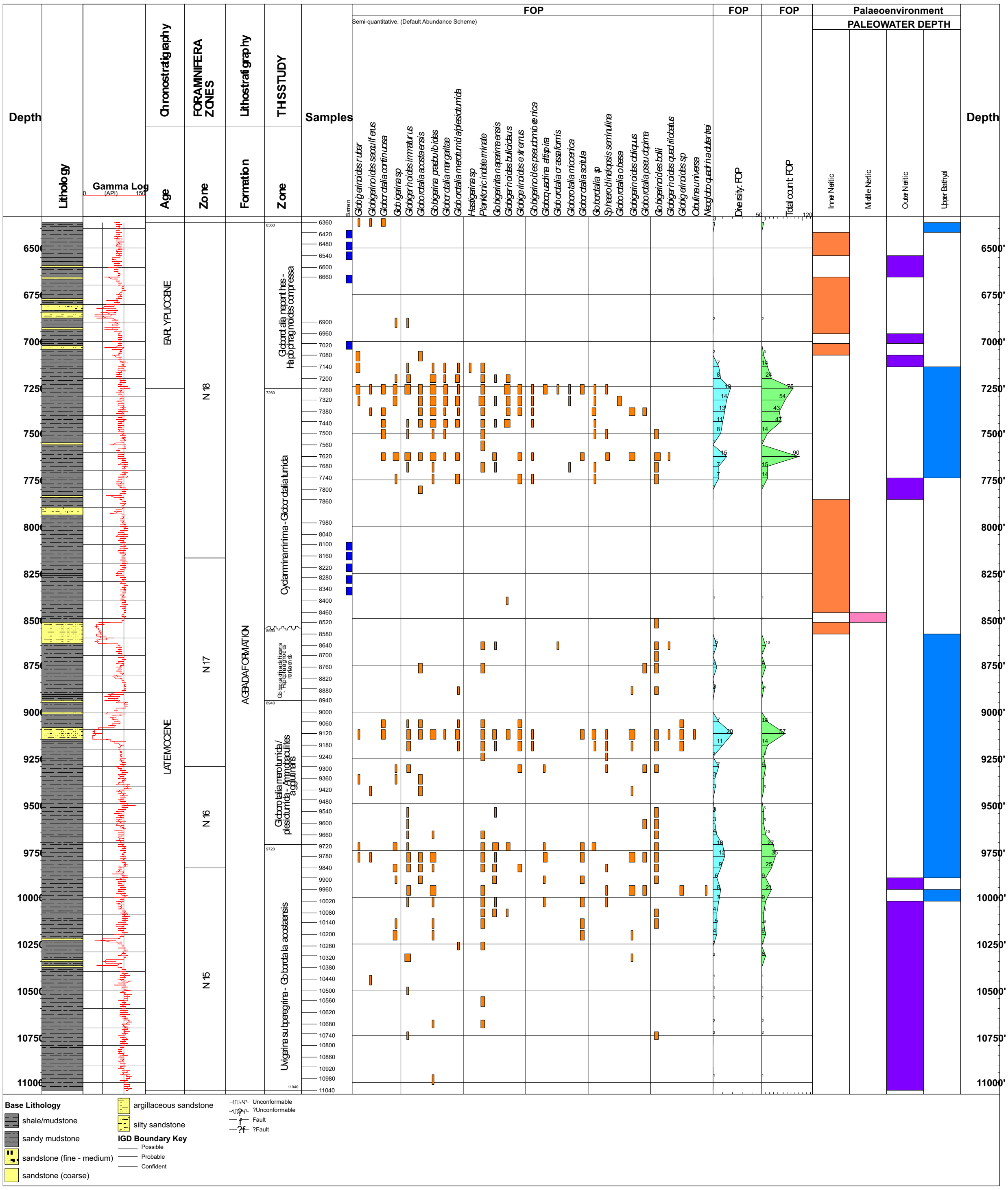

Fig. 2: Stratigraphic Distribution of Planktonic Foraminifera in Well-1

WELL-2 FORAMINIFERA BIOSTRATIGRAPHY

One hundred and ten (110) foraminifera species were identified. Of these, calcareous forms accounted for 79% (87 species) of the fauna while arenaceous forms made up the remaining 21% (24 species). Benthic forms accounted for 56% (49 species) of the calcareous forms while the remaining 44% (38 species) are planktonics. The accessory microfauna recorded include micromolluscs, bryozoans, ostracodes and shell fragments.

BIOSTRATIGRAPHIC ZONES IN WELL-2

The zones recognized are discussed below, while the stratigraphic distribution of planktonic foraminifera in the well is shown in figure 4. These zones are correlated with the standard planktonic zones of Blow (1969, 1979) and Berggren *et al.* (1995) and the global sequence chart of Hardenbol *et al.* (1998). The recorded foraminifera marker species are shown in Plate-1.

(i) *Globorotalia acostaensis/Uvigerina subperegrina zone*

This is the oldest foraminiferal zone recognized in the Well. The zonal top is placed at the 9.5Ma maximum flooding surface recognized at 12,360 feet based on the last downhole occurrence of *Globorotalia acostaensis* recorded at 12,600 feet. The base is tentatively placed at 12880 feet, the depth of the last sample studied. The first downhole occurrence (FDO) of the other nominate zonal marker *Uvigerina subperegrina* was recorded in the well at 12280 feet.

The zonal foraminiferal assemblage is characterized by deep water forms such as *Cibicidoides pachyderma, Cibicidoides mexicanus, Planulina wuellerstorfi*, *Uvigerina asperula, Cyclammina minima, Saccammina complanata* and species of *Trochammina*, *Haplophragmoides* and *Bathysiphon*. The planktics recorded include *Globigerina praebulloides, Globigerinita naparimaensis*, *Globigerinoides extremus*, *G. immaturus* and *G. obliquus*.

The zone correlates with the upper N15lower N16 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is late Miocene and older.

(ii) *Globorotalia merotumida/plesiotumida/Ammobaculites agglutinans* zone

The top and base of this zone are defined by the 7.4 Ma and 9.5 Ma maximum flooding surfaces recognized at 11,320 and 12,360 feet respectively. *Ammobaculites agglutinans* whose first downhole occurrence is associated with the 7.4Ma Maximum Flooding Surface (MFS) was recorded within the condensed section at 11,240 feet, while the last downhole occurrence of *Globorotalia merotumida/plesiotumida* was depressed occurring at 12,560 feet.

The zone is further characterized by the occurrence of deep water forms such as *Cibicidoides mexicanus, Cibicidoides pachyderma, Globocassidulina subglobosa, Planulina wuellerstorfi, Ammobaculites agglutinans*, *Saccammina complanata* and *Bathysiphon sp.* Planktics were represented by common records of *Globigerina praebulloides*, *Globigerinita naparimaensis, Globigerinoides extremus*, *G. immaturus, G. obliquus*, *G. trilobus* and *Globoquadrina altispira*.

The zone correlates with the upper N16 lower N17 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is late Miocene.

(iii) *Globoquadrina dehiscens/Haplophragmoides narivaensis* zone

The base of the *Haplophragmoides narivaensis* zone is defined by the 7.4Ma maximum flooding surface recognized at 11320 feet while the top is bounded by an unconformity recognized at 11143 feet. *Haplophragmoides narivaensis*, the nominate zonal marker whose first downhole occurrence is associated with the zone is stratigraphically depressed occurring at 11800 feet. The zonal foraminiferal assemblage is dominated by deep water forms such as *Saccammina complanata*, *Haplophragmoides compressa, Cyclammina minima*, *Trochammina proteus* and species of *Trochammina, Haplophragmoides* and *Bathysiphon*. Planktics recorded include *Globigerinoides bollii, G. sacculiferus* and *G. obliquus*.

The zone correlates with the middle N17 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is late Miocene.

(iv) *Globorotalia tumida/Cyclammina minima zone*

The top and base of this zone are defined by the 5.0Ma maximum flooding surface and 6.7Ma sequence boundary recognized at 8400 feet and 11143 feet respectively. *Cyclammina minima* and

Globorotalia tumida, the nominate zonal markers whose first downhole occurrence and last downhole occurrence are respectively associated with the 5.0Ma are recorded at 8200 feet and 8480 feet respectively.

The zonal foraminiferal assemblage is dominated by common records of *Uvigerina asperula*, *Cibicidoides mexicanus*, *Cibicidoides pachyderma*, *Cibicidoides pseudoungerianus*, *Cyclammina minima, Saccammina complanata* and *Bathysiphon sp.* Planktics were abundantly represented by *Globigerinoides bollii, G. extremus, G. immaturus, G. obliquus, Globorotalia merotumida/plesiotumida, Globorotalia pseudopima* and *Globorotalia acostaensis*.

The zone correlates with the upper N17 lower N18 planktonic foraminiferal zones of Blow (1969, 1979) and Berggren *et al.* (1995). The age is late Miocene.

(V) *Globigerina nepenthes/Haplophragmoides compressa zone*

This is the youngest zone recognized in the studied section of Well-2. The base of the *Globigerina nepenthes/Haplophragmoides compressa* zone is defined by the 5.0Ma Maximum Flooding Surface recognized at 8400 feet while its top is tentatively placed at 6880 feet, the depth of the first sample studied. The first downhole occurrence of *Haplophragmoides compressa*, one of the nominate zonal marker associated with the undeveloped 3.9ma maximum flooding surface, was recorded at 8200 feet. The first downhole occurrence of *Valvulina flexilis*, another zonal marker was stratigraphically depressed, occurring at 8520 feet.

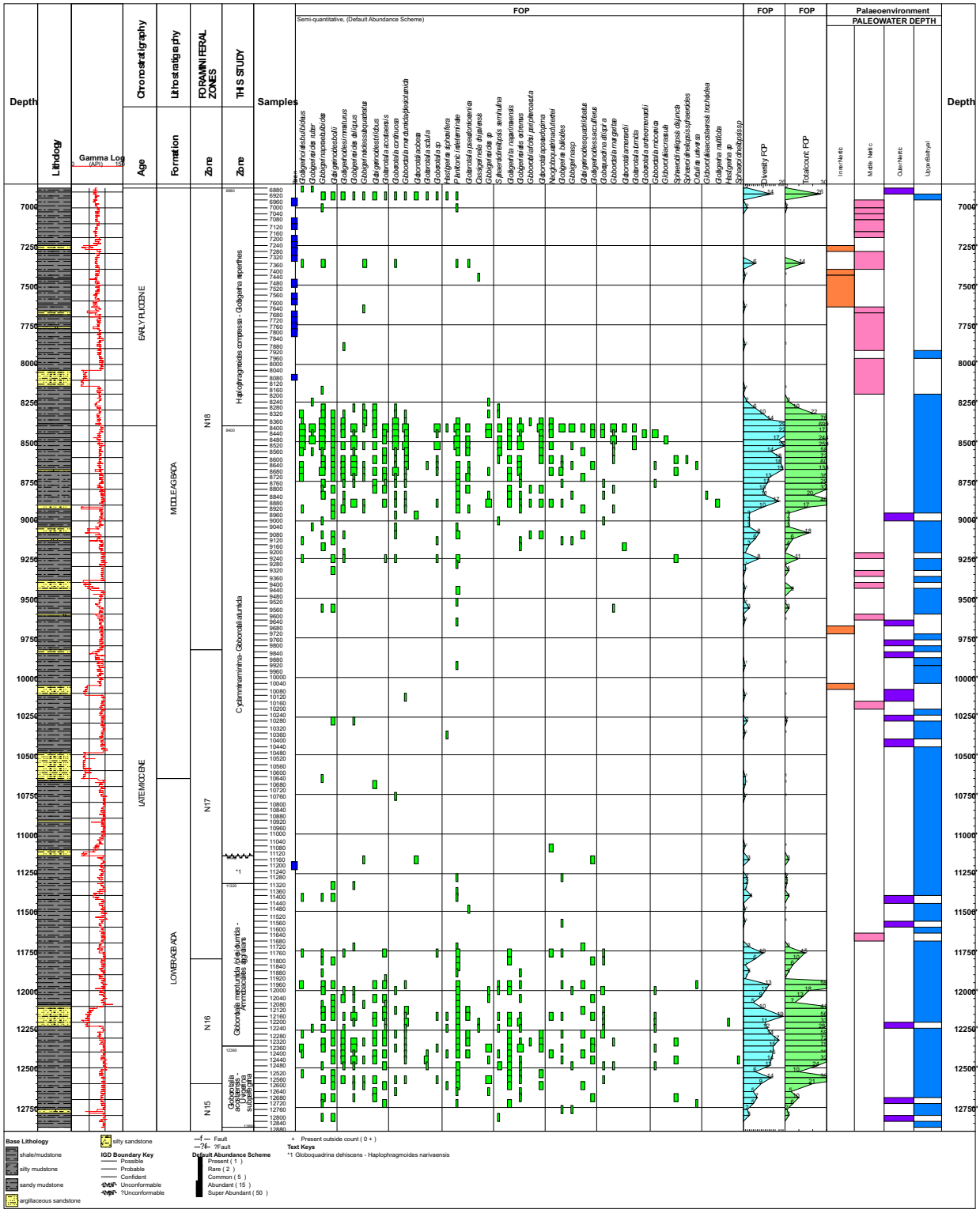

Fig. 3: Stratigraphic Distribution of Planktonic Foraminifera in Well-2

The zone is further characterized by the common occurrences of *Bolivina scalprata miocenica*, *Cibicidoides pseudoungerianus, C. pachyderma, C. incrassatus, Uvigerina asperula, Saccammina complanata* and *Bathysiphon* sp. The planktonics recorded include common occurrences of *Globigerinoides trilobus, G. obliquus, G. ruber, Sphaeroidinellopsis seminulina* and *Globorotalia merotumida/plesiotumida*. The zone correlates with the upper N18 planktonic foraminiferal zone of Blow (1969, 1979) and Berggren *et al.* (1995). The age is early Pliocene.

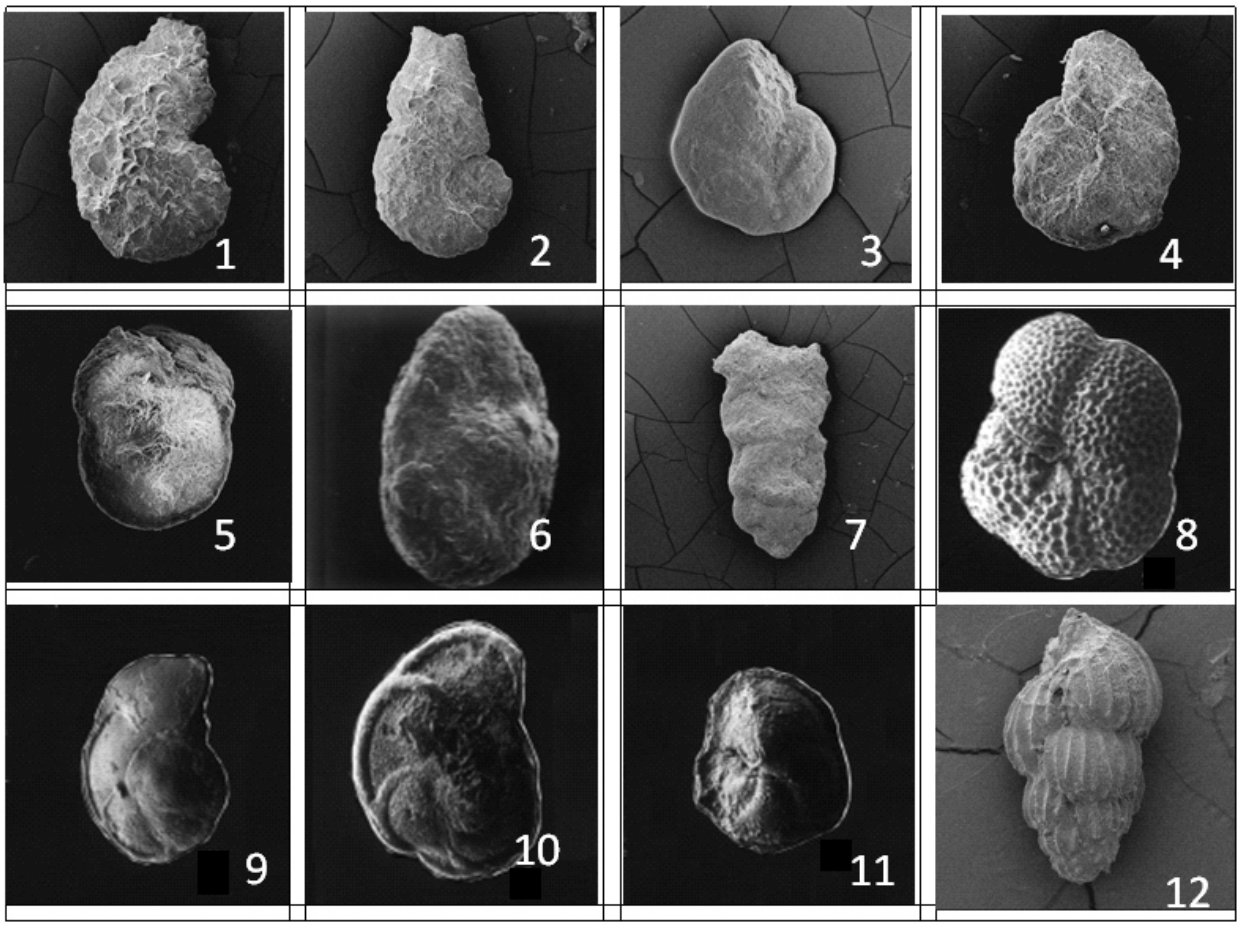

PLATE 1: *Ammobaculites agglutinans (1, 2); Cyclammina minima (3,4); Haplophragmoides narivaensis (5,6); Valvulina flexilis (7); Globorotalia acostaensis (8); Globorotalia merotumida (9,10); Globorotalia plesiotumida (11); Uvigerina subperegrina (12).*

PALEOENVIRONMENTAL STUDIES

The paleoenvironmental synthesis of Wells 1 and 2 presented below is based on the integration of the textural characteristics of the ditch cutting samples with log analytical data and the quantitative evaluation of the bathymetric ranges of selected environmentally significant benthic foraminifera. Figures 4, 5, 6 and 7 show the stratigraphic distribution of benthonic foraminifera in both wells.

WELL-1

11040-9260 feet: Hemipelagic Shales Interbedded with Trangressive Sandstones

The fining upward log signature within this interval depicts shales/mudstones with occasional fine grained, moderate to well sorted sandstones/siltstones. Spotty records of ferruginous materials and pyrite were present. The common records of deep water forms such as *Globocassidulina subglobosa, Uvigerina auberiana, Planulina wuellerstorfi, Oridorsalis umbonatus* and a species of *Bathysiphon* confirm an environment of deposition that is predominantly upper Bathyal with an Outer Neritic influence at some horizons (Bandy, 1967 and Phleger, 1960).

9260-8740 feet: Distributary Channel Sandstones Overlain by Hemipelagic Shales/Mudstones

The relatively thick coarse grained sandstones represented within this interval is overlain by hemipelagic shales/mudstones that are greyish, moderately soft and non-fissile. The accessory minerals present include spotty records of ferruginous materials and pyrite. The presence of

common deep water forms; *Uvigerina auberiana, Planulina wvellerstorfi*, *Cyclammina minima, Trochammina proteus* and species of *Bathysiphon* confirms predominantly upper bathyal environment of deposition.

8740-7860 feet: Channel Sandstones Overlain by Marine Shales/Mudstones

Fine to coarse grained, subrounded to rounded and poorly sorted channel sandstones overlain by thick marine shales/mudstones. Ferruginous materials and mica flakes are sparsely distributed within an otherwise barren sequence. The common records of *Bolivina scalprata miocenica, Cibicidoides pseudoungeriana, Lenticulina inornata, Cibicidoides mexicanus* and *Sigmoilopsis schlumbergeri* indicate

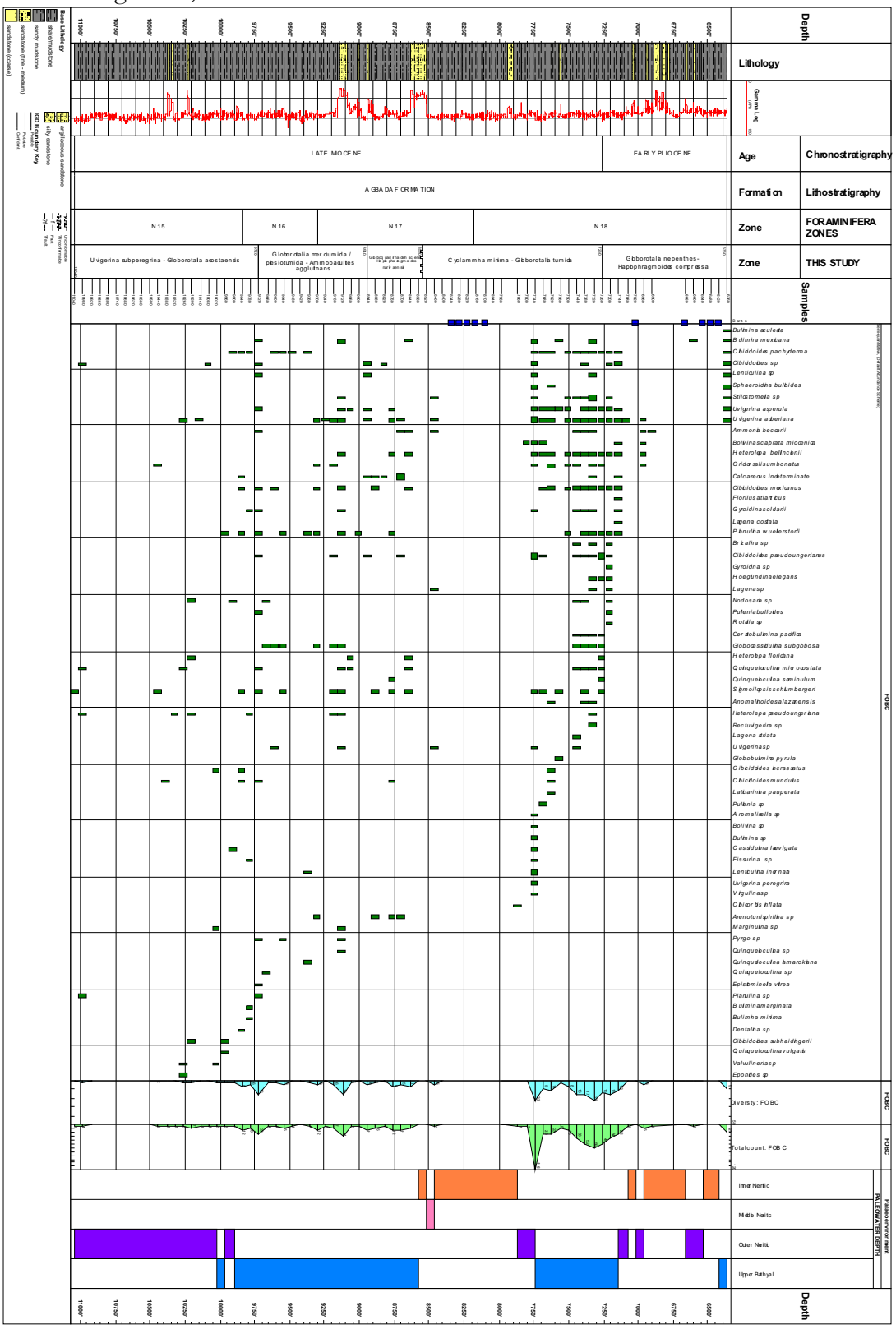

Fig. 4: Stratigraphic Distribution of Calcareous Benthic Foraminifera in Well-1

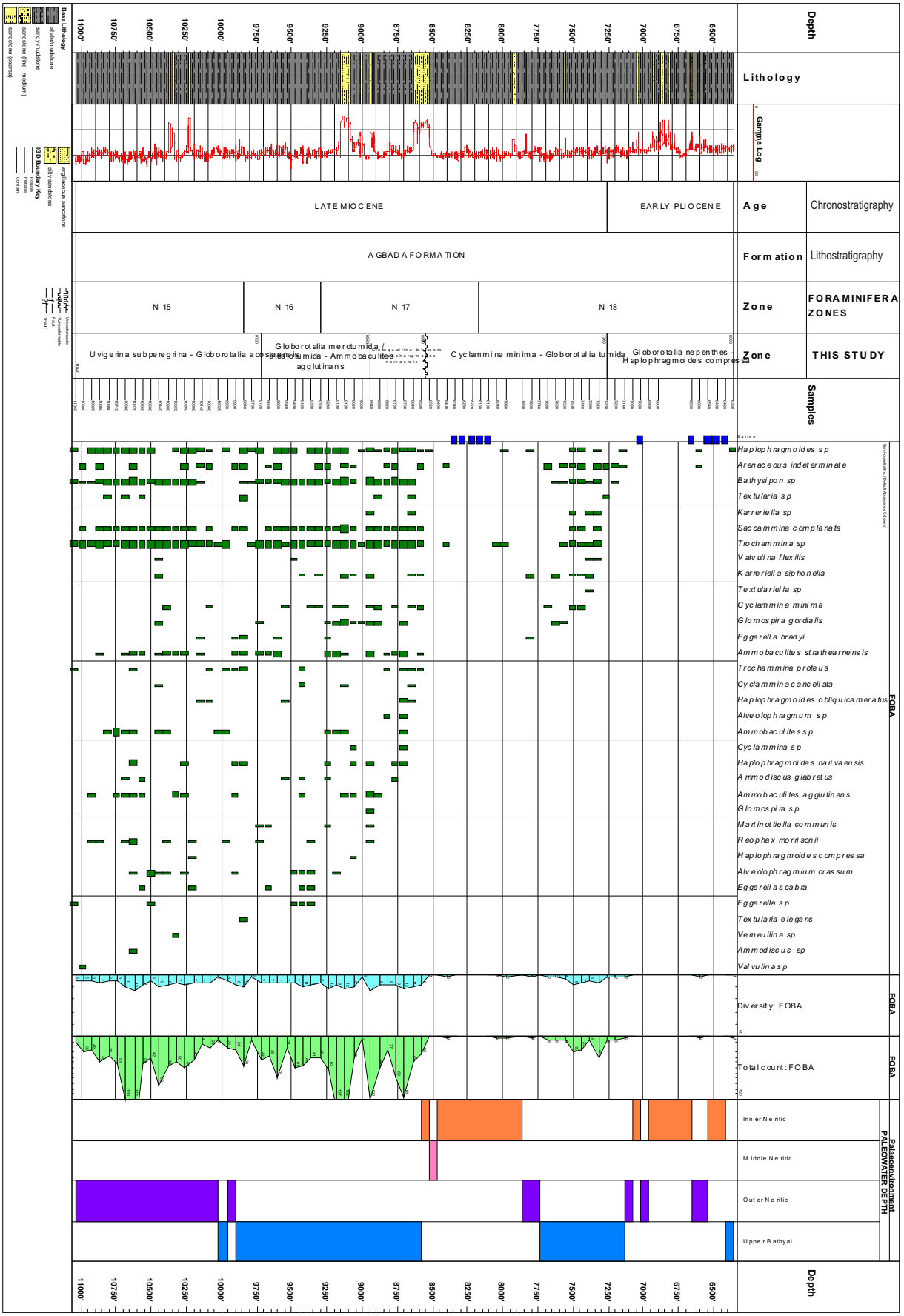

Fig. 5: Stratigraphic Distribution of Arenaceous Benthic Foraminifera in Well-1

an environment of deposition that is predominantly Inner Neritic with some Outer Neritic influence at some horizons (Adegoke *et al*., 1976 and Murray, 1991).

7860-7140 feet: Hemipelagic Shales/Mudstones Interbedded with Offshore Sandstone/Siltstones

This is a fairly homogenous sequence of dark, soft to hard and non-fissile shales/mudstones with interbeds of fine to medium grained, well rounded and moderately sorted offshore sandstones. Ferruginous materials and pyrite constitute the mineral suites. The foraminiferal record includes common *Globocassidulina subglobosa, Uvigerina asperula, Uvigerina auberiana, Cibicidoides pachyderma, Planulina wuellerstorfi* and a species of *Bathysiphon*, indicating a predominantly upper Bathyal environment of deposition.

7140-6360 feet:Tidal Channel Sandstones/Siltstones Overlain by Marine Shales/Mudstones

The coarsening upward signatures in the log motifs within this interval suggest tidal channel sandstones overlain by variably thick dark, moderately hard and non-fissile shales/mudstones. The accessory minerals include ferruginous materials and spotty records of mica flakes with pyrite. The fauna recorded include *Ammonia beccarii, Cibicidoides pseudoungerianus Uvigerina auberiana, Bulimina aculeata, Sphaeroidina bulloides* and *Cibicidoides pachyderma* indicating environments of deposition that ranged

from Inner Neritic to Outer Neritic, deepening to Upper Bathyal at the top (Adegoke *et al.* 1976, Murray, 1991).

WELL-2

12880-12340 feet: Hemipelagic Shales Interbedded With Transgressive Sandstones

This is a fairly homogenous shale/mudstone sequence with occasional sandstone/siltstone interbeds. The shales/mudstones are grey/dark grey, moderately soft to hard, and non-fissile to sub-fissile. The interbedded sandstones are fine grained with few coarse fractions, subangular to subrounded, and moderately sorted. The interval contains predominantly deep water foraminifera dominated by *Saccammina complanata, Cyclammina minima, Ammobaculites agglutinans, Planulina wuellerstorfi, Oridorsalis umbonatus, Cibicidoides pachyderma* and species of *Bathysiphon.* This assemblage indicates an environment of deposition that is predominantly upper bathyal with outer neritic influence at some horizons (Bandy, 1967; Phleger, 1960).

12340-11240 feet: Channel Sandstones Overlain By Hemipelagic Mudstones/Shales

This interval is dominantly made up of fine to medium grained, occasionally coarse, pebbly, subangular to subrounded, moderately sorted sandstones overlain by a thick shale column. Carbonaceous matter and ferruginous materials occur sparingly within an otherwise barren sequence suggesting possible allochtonous materials transported down slope within a confined channel. The foraminiferal assemblage of this interval contains common *Saccammina complanata, Haplophragmoides* compressa, *Ammobaculites agglutinans, Sigmoilopsis schlumbergeri, Cibicidoides pachyderma* and species of *Bathysiphon.* These species suggest an environment of deposition that is predominantly upper bathyal with outer neritic influence at some horizons (Bandy, 1967; Phleger, 1960).

11240-10760 feet: Transgressive Sandstones Overlain By Hemipelagic Shales

This is a fining upward sequence of fine, occasionally coarse, pebbly, and subangular to subrounded, moderately sorted sandstones that are overlain by grey/dark, moderately soft to hard, non-fissile to sub-fissile shales. An upper bathyal environment of deposition is suggested between 3280-3353 metres by the occurrence of *Cyclammina minima*, *Haplophragmoides compressa, Saccammina complanata* and species of *Bathysiphon.* The lower part of the interval fluctuates between coastal deltaic and inner neritic environments (Murray, 1991; Bandy, 1967).

10760-9460 feet: Distributary Channel Sandstones with Interbedded Hemipelagic Shales

This is a stacked, multistory, fine, occasionally coarse, pebbly, and subrounded to rounded, moderately sorted sandstones interbedded with buff/grey, moderately soft to hard and non-fissile to sub-fissile shales/mudstones.

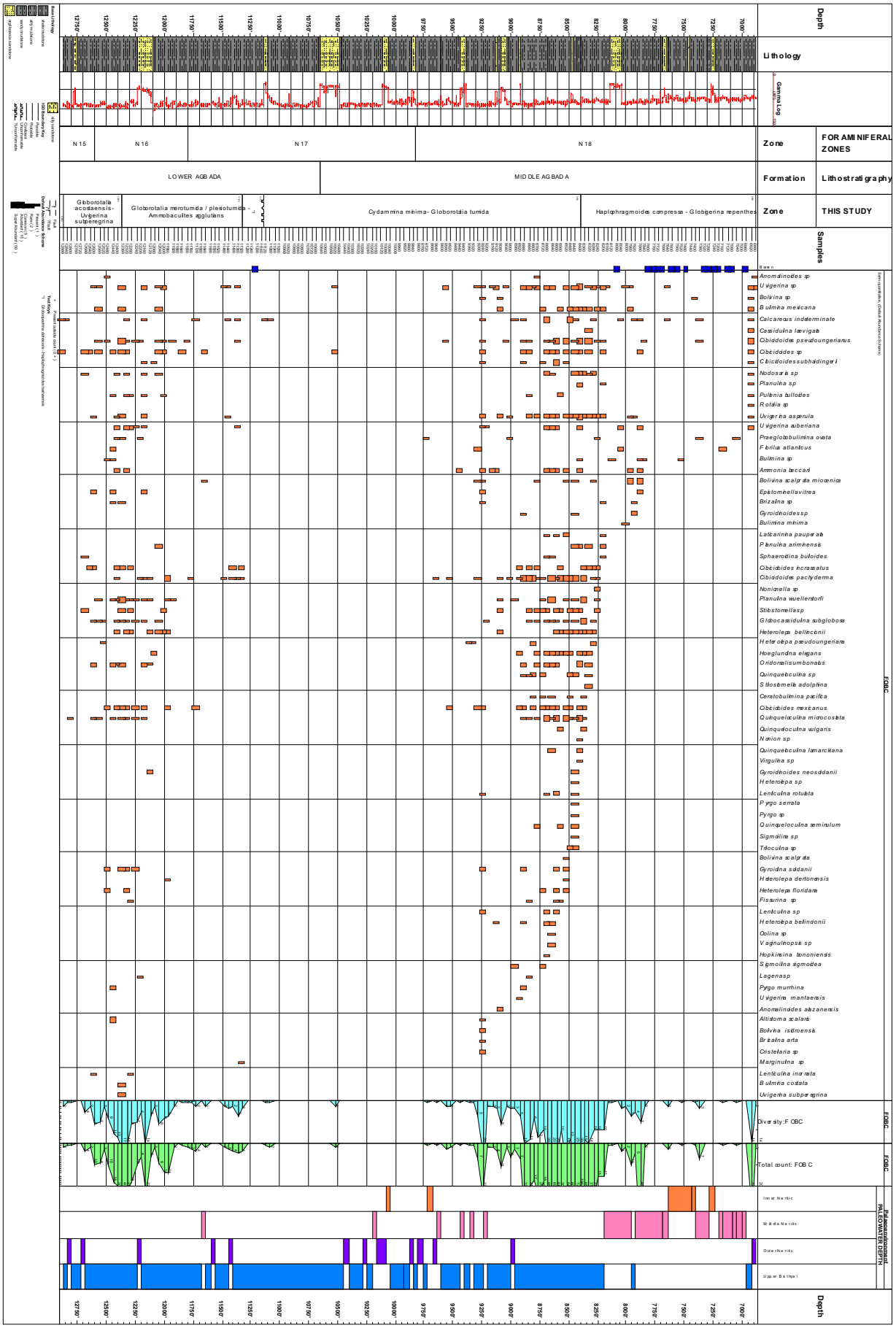

Fig. 6: Stratigraphic Distribution of Calcareous Benthic Foraminifera in Well-2

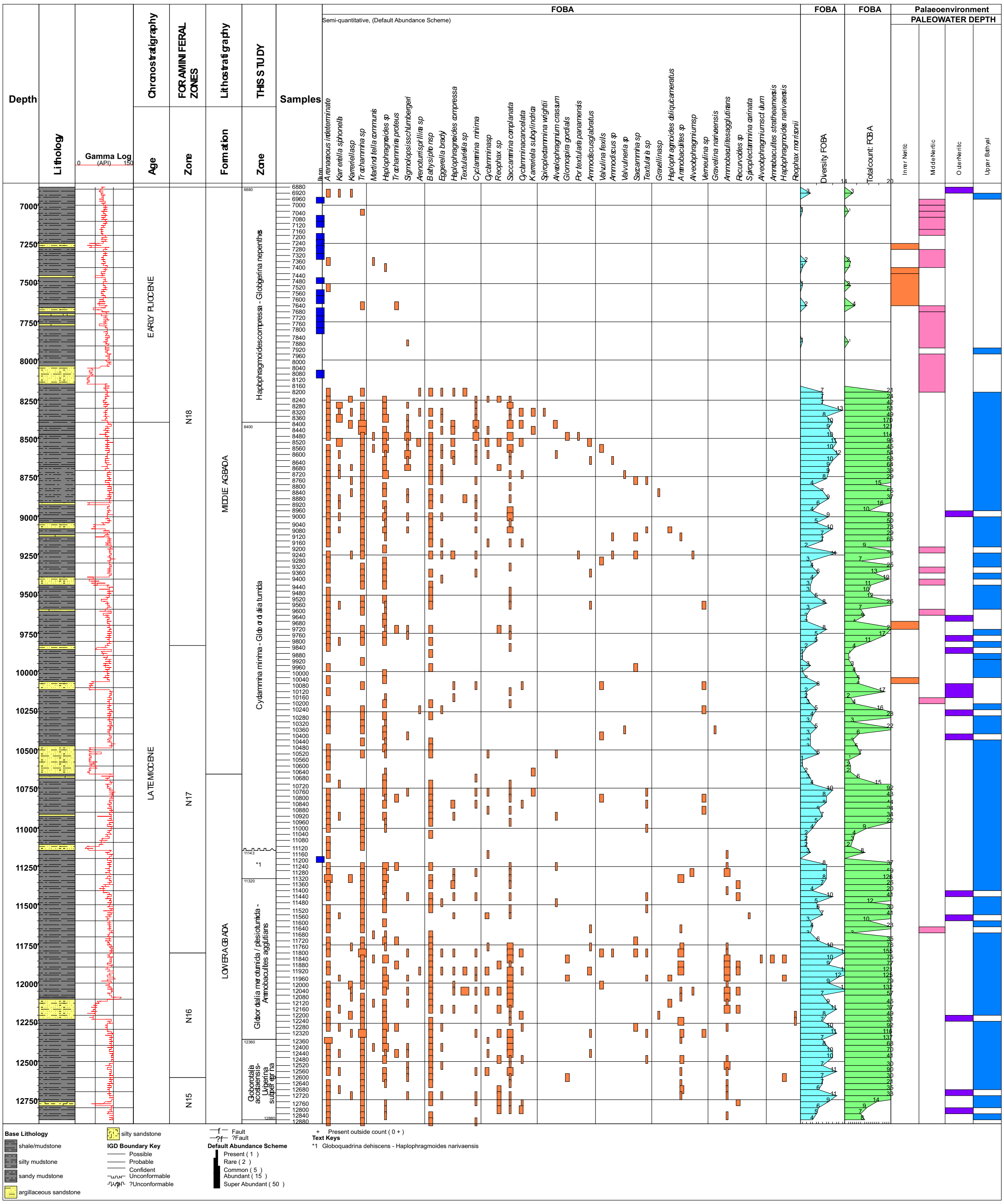

Fig. 7: Stratigraphic Distribution of Arenaceous Benthic Foraminifera in Well-2

The foraminiferal fauna of this interval includes few *Haplophragmoides compressa, Saccammina complanata* and species of *Trochammina, Haplophragmoides. Sigmiolopsis schlumbergeri and Bathysiphon sp.* occur towards the base of this interval. These species suggest environments of deposition that ranged from inner neritic at the upper part of this interval to upper Bathyal at the lower part (Adegoke *et al.*, 1976; Phleger, 1960).

9460-8220 feet: Hemipelagic Shales Interbedded With Transgressive Sandstones

This is an intercalated sequence of dark, soft to moderately hard, non-fissile to sub-fissile shales and fine to medium grained, occasionally coarse, subrounded to rounded and poorly sorted sandstones. The accessory minerals present include spotty records of mica flakes and rare pyrite. Carbonaceous matter is also present. The foraminiferal assemblage of this interval is dominated by *Saccammina complanata, Karreriella bradyi, Eggerella bradyi, Cyclammina minima, Cibicidoides pachyderma, Planulina wuellerstorfi, Sigmoilopsis schlumbergeri Uvigerina asperula* and species of *Bathysiphon* suggestive of an environment of deposition that is predominantly Upper Bathyal with some Middle Neritic influence at the base (Phleger, 1960; Bandy, 1967).

8220-7340 feet: Distributary Channel Sandstones Interbedded With Shelf/Prodelta Mudstones

This is a stacked sequence of multistory, fine to coarse, occasionally pebbly, subangular to rounded and poorly sorted sandstones, interbedded with silty, grey/dark grey, moderately hard, non-fissile to sub-fissile mudstones of shelf provenance. The accessory minerals include spotty records of mica flakes and ferruginous materials. The foraminiferal assemblage contains common records of *Ammonia beccarii, Bolivina scalprata miocenica, Cibicidoides pseudoungerianus, Uvigerina auberiana* and species of *Bulimina* and *Uvigerina,* an assemblage that indicates environments that ranged from Inner Neritic to middle neritic (Adegoke *et al.*, 1976; Murray, 1991).

7340-6880 feet: Transgressive Sandstones/Siltstones Overlain By Prodelta /Shelf Mudstones

This is a fining upward sequence of fine grained, occasionally coarse, subangular to subrounded, moderately sorted sandstones, overlain by calcareous, buff/grey/dark grey, moderately hard to hard, occasionally bulky, non-fissile to fissile mudstones of shelf provenance. The accessory minerals present include spotty records of ferruginous matter. carbonaceous matter was also recorded. The foraminiferal assemblage of this interval consists dominantly of rare *Karreriella siphonella, Florilus costiferum, Cibicidoides pseudoungerianus, Cassidulina laevigata* and species of *Uvigerina*. This assemblage indicates environments of deposition that ranged from Inner Neritic to Middle Neritic, deepening to Upper Bathyal towards the top (Bandy, 1967; Murray, 1991).

CONCLUSION

The biostratigraphic and lithological analyses of ditch cutting samples from both wells show that both wells penetrated the paralic sand/shale sequence known as the 'Upper' Agbada Formation, and a sequence of thick shale intercalated with thin sands horizons known as the 'Lower' Agbada Formation. From the analysis of Foraminifera contents of the two wells, five foraminfera zones were established;

(v) Globigerina nepenthes/Haplophragmoides compressa zone
(iv) Globorotalia tumida/Cyclammina minima zone
(iii) Globoquadrina dehiscens/Haplophragmoides narivaensis zone
(ii) Globorotalia merotumida/plesiotumida/Ammobaculites agglutinans zone
(i) Globorotalia acostaensis/Uvigerina subperegrina zone

Based on the association of Foraminifera marker species that make up the different zones encountered in the two wells, an Early-Pliocene to Late-Miocene age has been established for both Wells. Also paleobathymetric data of species of benthonic foraminifera recovered showed that the sediments were deposited in shallow to deep water environments ranging from Inner-Neritic through Outer - Neritic to Upper - Bathyal environments.

In conclusion, the two wells reasonably show similarities in faunal contents, lithology, paleoenvironment of deposition and biozonation. This has contributed to the knowledge of understanding the nature of Neogene deep-offshore sediments in terms of their foraminifera biostratigraphy and the depositional environments.

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