LITHOLOGIC AND BIOSTRATIGRAPHIC CORRELATIONS OF AKATA-7 AND OLOIBIRI-1 WELLS, EASTERN NIGER DELTA, NIGERIA

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Abstract
Quantitative and qualitative foraminiferal biostratigraphy has been undertaken from the ditch cutting samples of Akata-7 and Oloibiri-1 wells located in the eastern Niger Delta, in view of determining the Lithology, foraminifera biozones, relative age, depositional environments and correlation. The Akata-7 and Oloibiri-1 wells which contain both planktic and benthic foraminifera, penetrated strata of Miocene age, and have been subdivided into biostratigraphic zones. The planktic zone established for these wells is Praeorbulina glomerosa Zone whereas the benthic zone is a taxon range zone of Poritextularia panamensis. Other sections of wells were barren or have sparse foraminifera content. Lithologically, both wells are correlatable as they are composed of shale and mudstone/siltstone with intervals of sand/sandstone. Biostratigraphically also, these wells correlate well on the basis of the established planktic and benthic zones. Littoral-deltaic to marine environments of deposition has been inferred for these wells on the bases of the occurrence of environmentally restricted benthic foraminifera species.

Keywords: Lithologic, Biostratigraphic, Correlation, Akata-7 well, Oloibiri-1 well, Eastern Niger delta, Nigeria

Introduction

The Akata-7 and Oloibiri-1 wells were among the first exploratory wells drilled in the Eastern Niger Delta, in 1956 by Shell B.P Petroleum Development Company. Akata-7 well is located around latitude 4º72' N and longitude 7º81' E. Oloibiri-1 well is located around latitude 4º658' N and longitude 6º26' E (figure 1). Thousands of wells have been drilled across the Niger Delta. The wells penetrated sediments, wherein petroleum generation, migration and accumulation have been found. The relatively large amount of data obtained from the wells has led to considerable understanding of the regional geology and stratigraphy (Adeniran, 1997). The work of Short and Stauble (1967), Avbovbo (1978) and Frankl and Cordry (1967) discussed the subsurface distribution of stratigraphic units in the Niger Delta. They recognized three main formations (Benin, Agbada and Akata) within the Niger delta complex (figure 2). The Akata, Agbada and Benin Formations are interfingering facies equivalents representing pro-delta, delta-front and delta-top environment respectively. Akata Formation is oldest of the three units and is generally open marine and prodelta dark grey shale with lenses of siltstone and sandstone. Agbada Formation is a paralic sequence consisting of interbedded sands and shales. The Benin Formation comprises (Eocene to Holocene) a succession of massive poorly indurate sandstones, thin shales, coals, and gravels of continental to upper delta plain origin. Unconformities, large clay fills of ancient submarine canyons and deep-sea fans occur in the eastern and western delta (figure 2). These were formed mainly during early Oligocene lowstands of sea – level (Burke, 1972, Reijers et al., 1996). Short and Stauble (1967) defined the contact between the Agbada and Benin formations at the most shale bearing marine fauna (foraminifera) in the Agbada Formation. However, the contact is more practically defined at the base of the massive sandstones typical of the Benin Formation and generally corresponds to the base of freshwater-bearing strata (Bustin, 1988). Benin Formation lacks marine or brackish water micro-fauna (Short and Stauble, 1967).

Foraminferal biostratigraphic information of some wells in Niger Delta have been published by Fayose (1970), Peters (1979b), Adeniran (1997), Okosun and Liebau (1999). Ozumba and Amajor (1999) 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 in 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. The focus and objectives of the present work include the lithologic description, planktic and benthic foraminiferal biostratigraphy, zonation, depositional environment and correlation of Akata-7 and Oloibiri -1 wells from eastern Niger Delta.

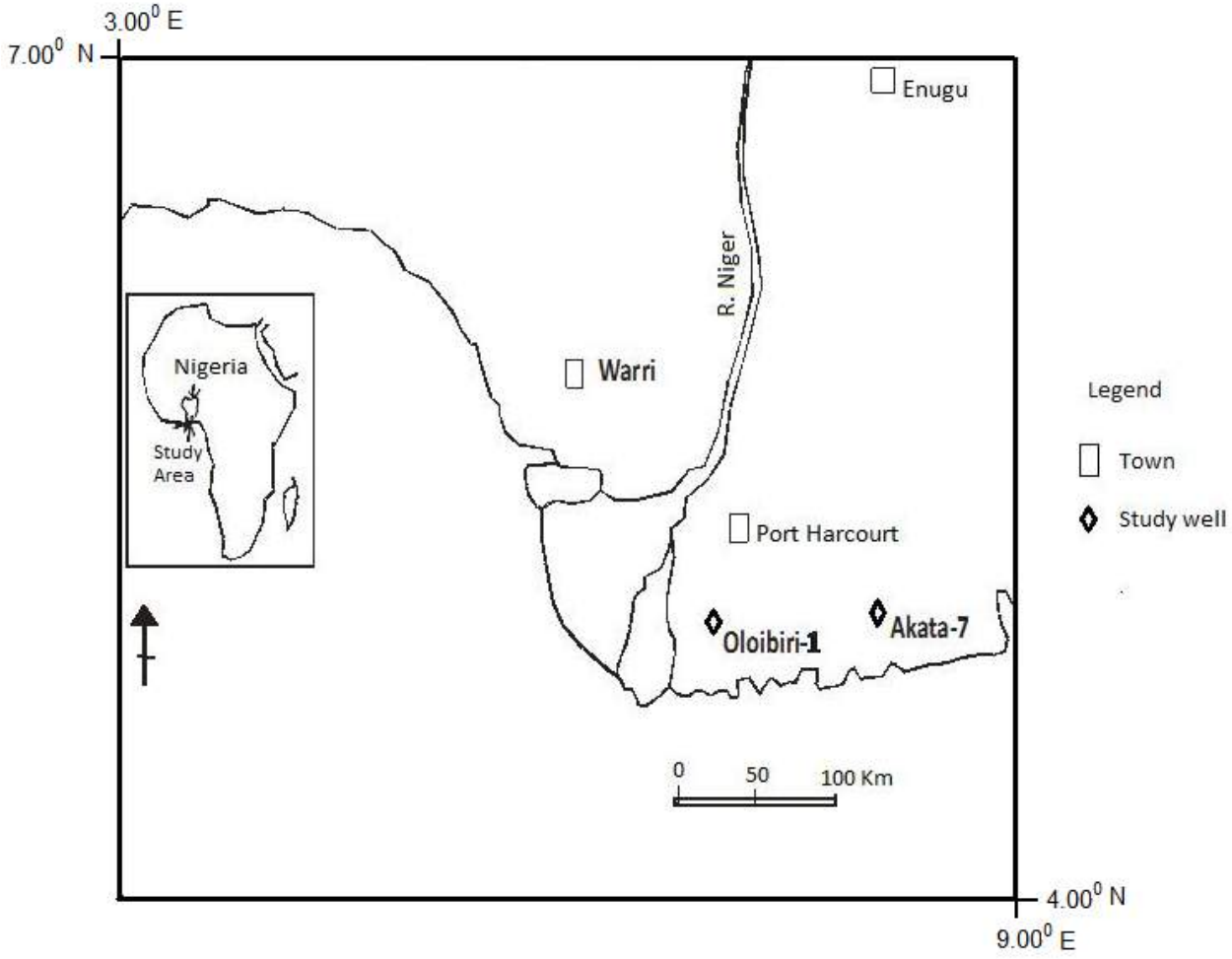

Figure 1: Location map of Oloibiri-1 and Akata-7 wells in the Eastern Niger Delta Nigeria

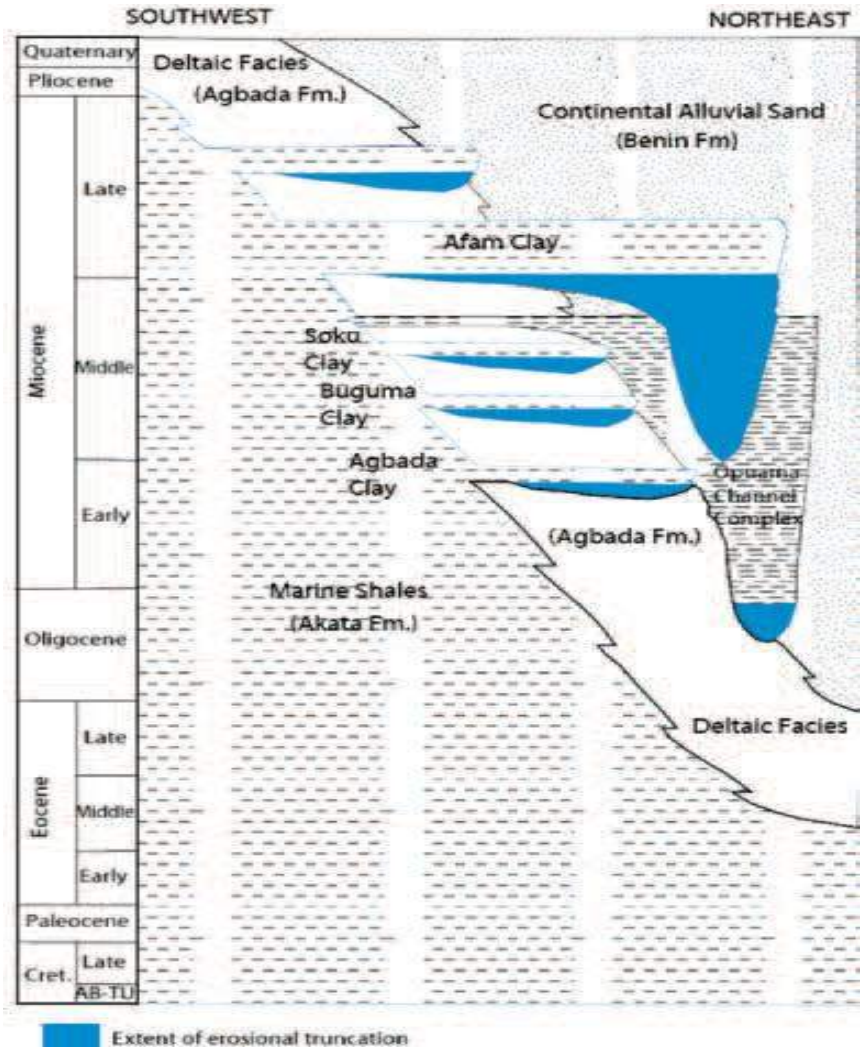

Figure 2: Schematic representation of the diachronous nature of the major lithofacies unit and the stratigraphic relationship of clay filled channels on the delta flanks (After Doust and Omatsola, 1990)

Materials and Methods

The ditch cuttings, Spontaneous Potential (SP) and Resistivity logs of the wells were obtained from Nigerian Geological Survey Agency (NGSA), Kaduna. Other materials used include 63 micron sieve, hot plates, weighing balance, binocular microscope, slides and cover slides, water, gum, sample envelopes, liquid soap, a set of 3 stacked sieves, toothpick, picking tray, hydrogen peroxide, oven, beakers, and hand lens.

The samples of these two wells consist of shale, mudstone and sandstone. The shale and mudstone are mostly grey to dark grey. The poorly to well sorted sandstone ranges from medium to fine grained, angular through subangular to rounded. Carbonaceous matter and shell fragments were also recorded from different depth intervals besides, the accessory minerals viz. Ferruginous material, pyrite, glauconite and mica. A lithologic log of each well was prepared by integrating lithologic description data with the available SP and resistivity log.

Twenty grammes of each sample were processed for their foraminiferal content using the standard preparation technique. The hydrogen peroxide method was employed owing to the resistance of the samples to disaggregation by kerosene method. The washed residues were dried over hot plate and then sieved into coarse, medium and fine fractions, using a set of 3 stacked sieves with aperture sizes of 500, 250 and 150 microns. Each fraction was examined under binocular microscope. All the foraminifera, ostracodes, shell fragments and other

microfossils observed were picked with the aid of picking needle/tooth pick, counted, placed in foraminifer's slides and covered with cover slide for safety and future reference. The slides were properly labelled with well name and sample depth. Foraminifera identification was made to genus and species levels where possible using the taxonomic scheme of Loeblich and Tappan (1964) and other relevant foraminiferal literature e.g. (Fayose, 1970), (Bolli and Saunders, 1985), (Murray, 1991), (Okosun and Liebau, 1999), (Petters, 1979a, 1979b, 1982), and (Postuma, 1971).

Results and Discussion

The results of this analysis are presented in the foraminifera distribution chart of Akata-7 and Oloibiri-1 wells (figures 3 and 4).

Foraminifera Biostratigraphy

A total of 24 taxa including eight planktic, seven calcareous benthic, and nine arenaceous benthic foraminiferal species were identified from the studied samples of Oloibiri-1 well whereas 49 taxa (twelve planktic, thirty calcareous benthic and seven arenaceous benthic foraminiferal species) were recovered from Akata-7 well. The stratigraphic intervals studied in the wells have been characterized or subdivided into biostratigraphic zones based on their foraminiferal contents (planktics and benthics). The established planktic and benthic foraminifera biostratigraphic zones in the two wells have been correlated (figure 5) and this implies that the stratigraphic intervals within the zone are of the same age and were deposited within same time interval.

Planktic Foraminifera Zone

The planktic foraminiferal preservation in the two wells is poor. Some stratigraphically important taxa (index planktic forms) were not identifiable to generic/species levels. Therefore, they are treated as planktic indeterminate. However, based on the recognized planktic foraminiferal species, a concurrent range zone of *Praeorbulina glomerosa* Zone was established for both wells. Above this zone is an Indeterminate Zone. Above the Indeterminate Zone is the Barren Zone because there was no foraminiferal recovery in the zone.

Praeorbulina glomerosa Zone
Stratigraphic intervals: 8420 – 6210 ft (Akata-7)
11350 – 10480 ft (Oloibiri-1)

The zone is defined by the FDO (First Downhole Occurrence) of *Praeorbulina glomerosa* at the top and LDO (Last Downhole Occurrence) of *Praeorbulina glomerosa | Orbulina universa* at the base. Other planktic forms occurring within the zone are *Globigerina praebulloides, Globigerinoides immaturus, Globigerinoides sacculiferus, Globigerinoides ruber, Globorotalia mayeri and Orbulina bilobata.*

The zone is equivalent to the N8-N9 zone of Blow (1969, 1979).
Age: Base of middle Miocene.

The stratigraphic interval above this zone is assumed to be equivalent to N9/N10 of Blow (1969, 1979) because of its stratigraphic position above the positively assigned zone of *Preaorbulina glomerosa*. The age is also assumed to be middle Miocene for the same reason.

Benthic Foraminifera Zone

The benthic foraminiferal assemblages found in the studied wells are moderately well preserved. The poorly preserved are treated as benthic indeterminate. Owing to the absence of index benthic species in both wells, a taxon/range zone of *Poritextularia panamensis* was established.

Poritextularia panamensis Zone
Stratigraphic interval: 8440 – 3450 ft (Akata-7)

11980 - 7400 ft (Oloibiri-1)

The zone is characterized by the first and last downhole occurrences of *Poritextularia panamensis.* Other benthics associated with it include: *Lenticula inornata, Quinqueloculina microstata, Quinqueloculina seminulum, Textularia laminata, Textularia soldani, Heterolapa bellincionii* and many others.

Age: Miocene.

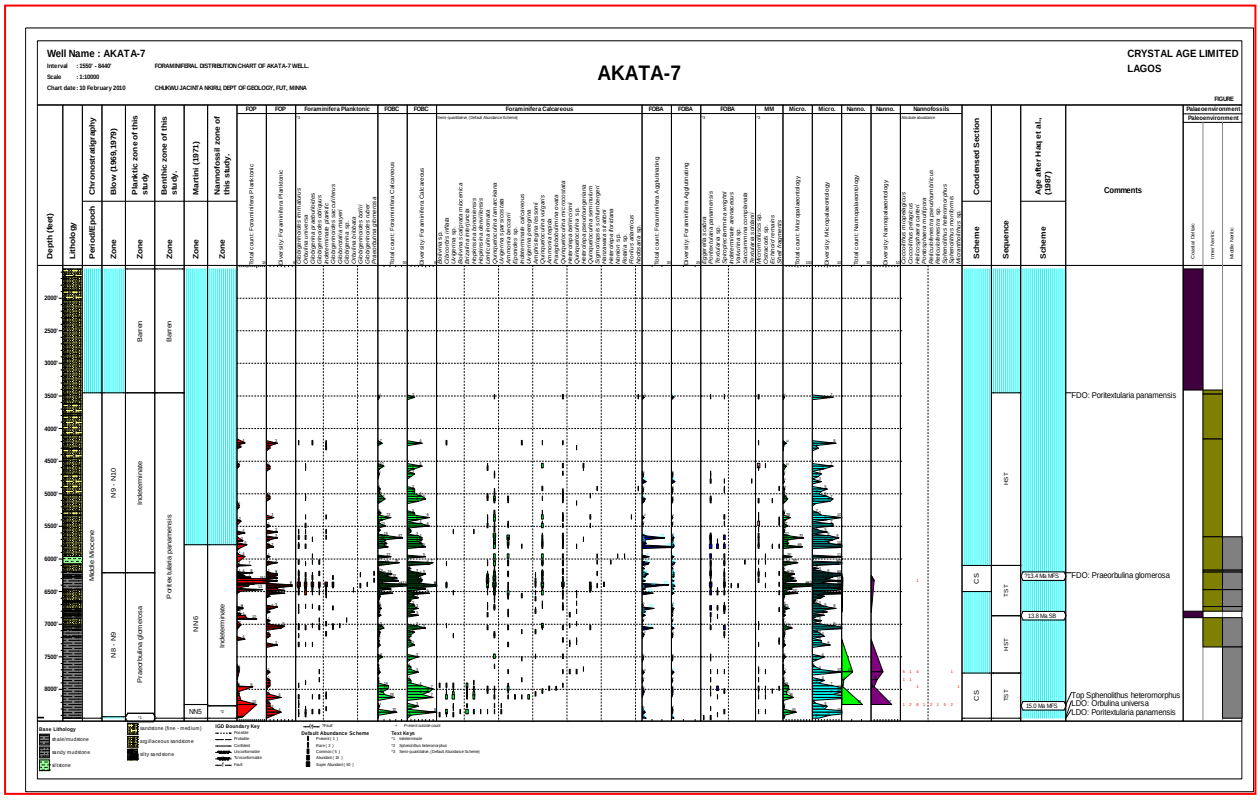

Figure 3: Foraminifera distribution chart of Akata-7 well.

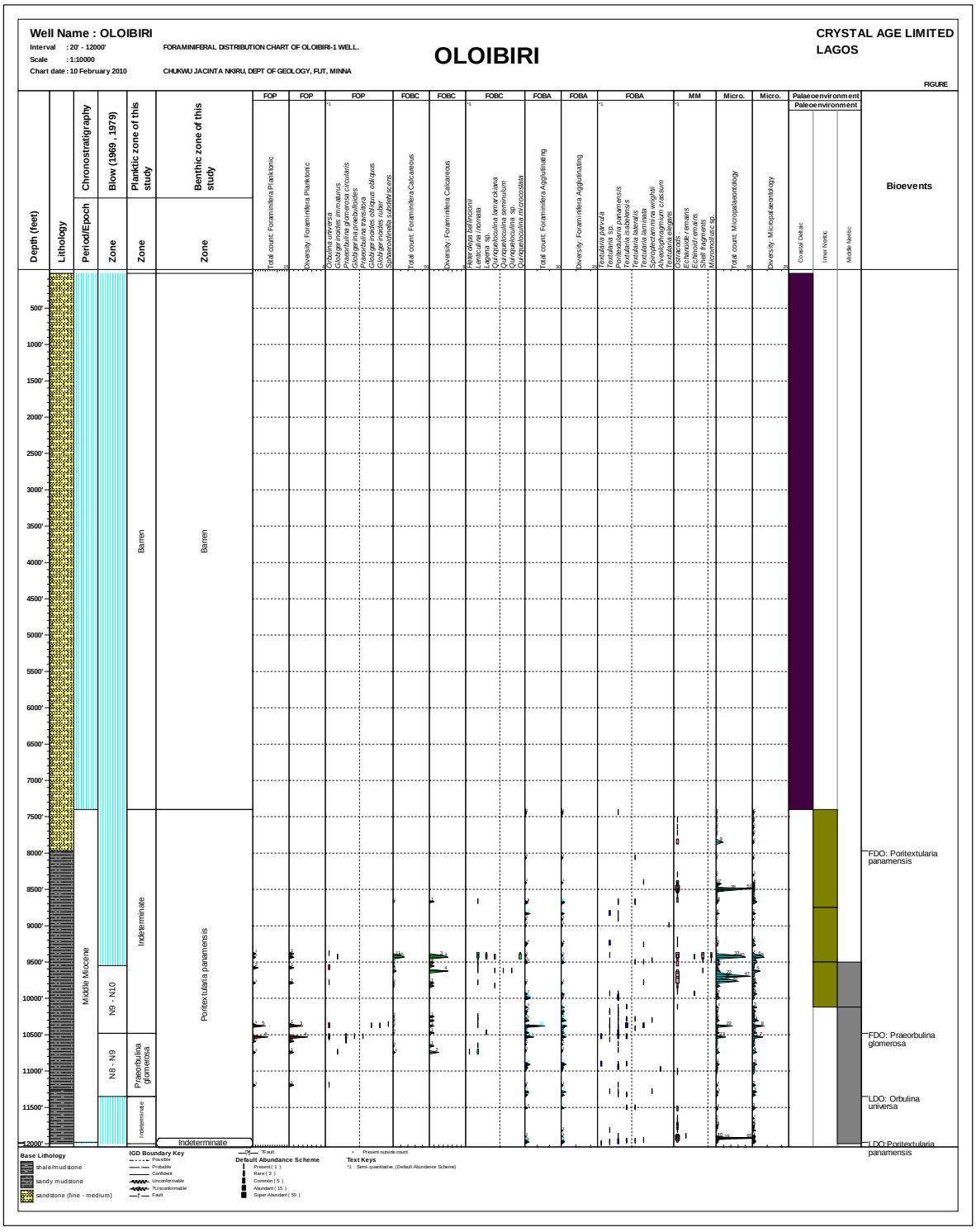

Figure 4: Foraminiferal distribution chart of Oloibiri – 1 well

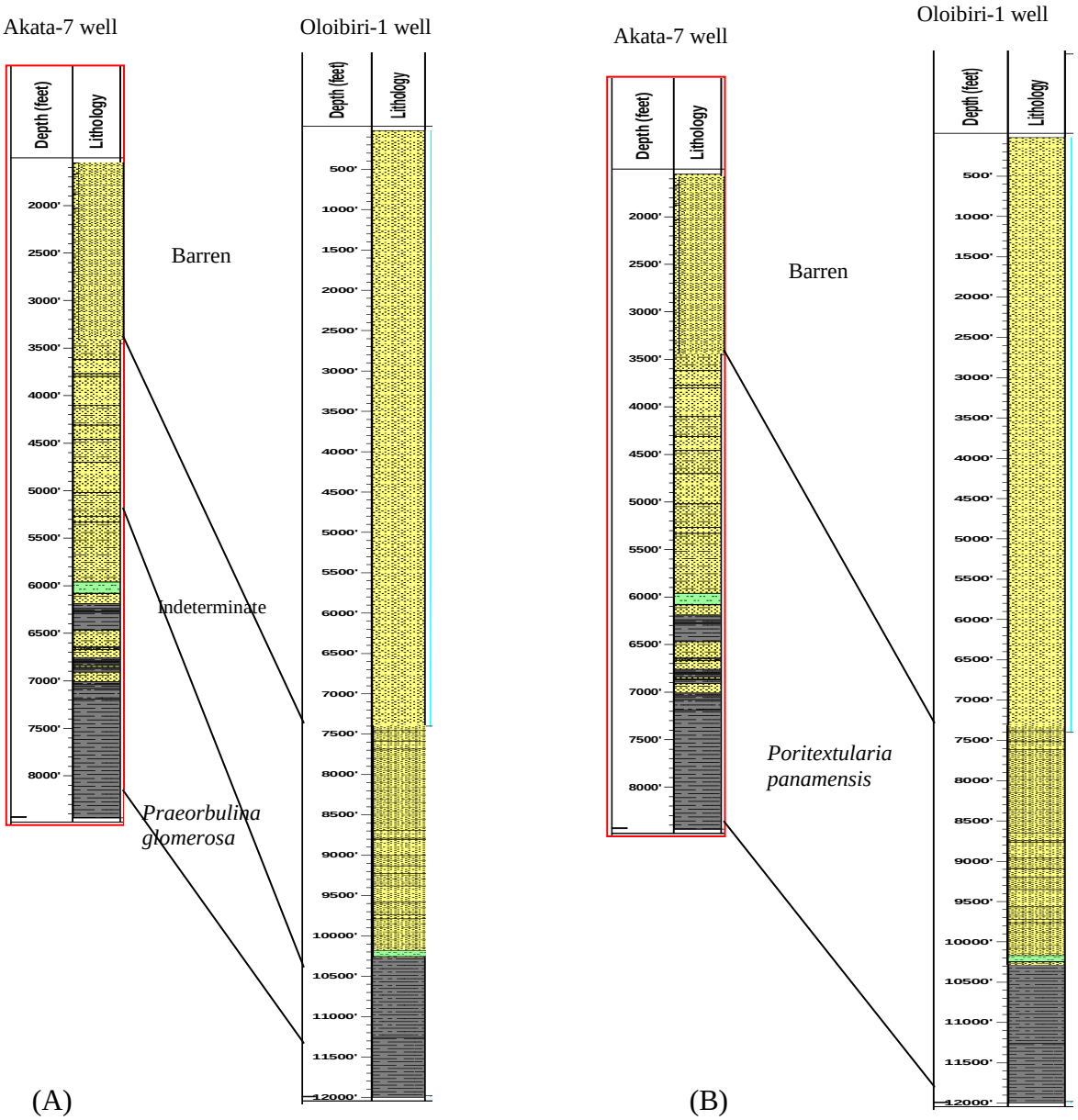

Fig. 5 (A): Planktic foraminifera zone correlation of Akata-7 and Oloibiri-1 wells.
(B): Benthic foraminifera zone correlation of Akata-7 and Oloibiri-1 wells.

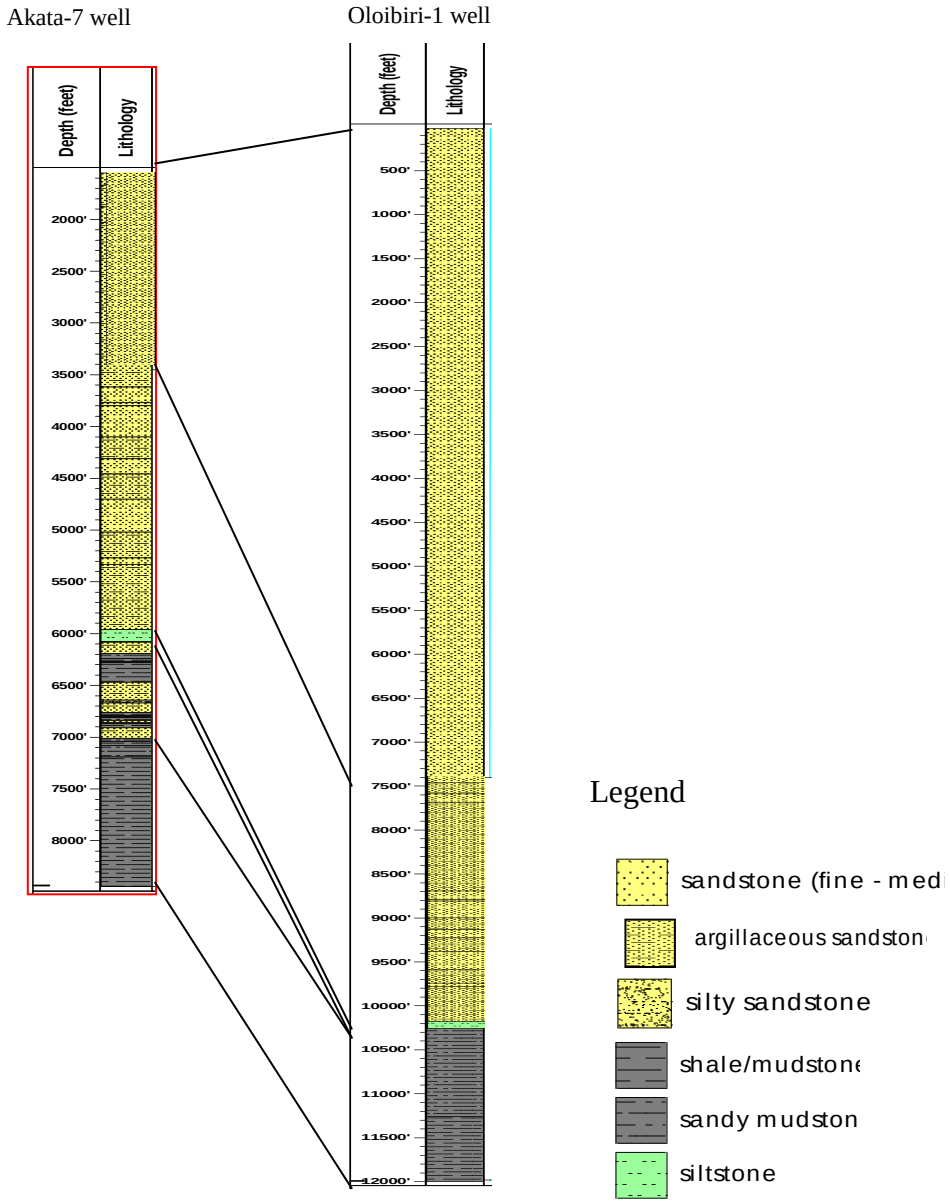

Fig. 6: Lithologic correlation of Akata-7 and Oloibiri-1 wells

Correlations of Akata-7 and Oloibiri-1 Wells

The two studied wells have been correlated on the basis of lithostratigraphy and foraminiferal biostratigraphy.

Lithologically, the sequences penetrated in the two well are similar as they are composed of shale and mudstone/siltstone with intervals of sand/sandstones (figure 6). The levels at which the lithologic boundaries are observed are deeper in Oloibiri-1 than in Akata-7 well. This could be due to lateral thickness variation of the sequences and the topography. The same biostratigaphic zones have been established in the two wells (figure 5a, b) and they correlate. The foraminifera taxa that defined the zone include *Praeorbulina glomerosa, Orbulina universa* and *Poritextularia panamensis.*

Based on the lithostratigraphy and biostratigraphy, the Benin and Agbada formations were penetrated by both wells.

The Benin Formation was encountered in Akata-7 and Oloibiri-1 wells from 1550 ft - 3450 ft and 20 ft - 7400 ft respectively. This was based on the absence of marine and brackish water micro fauna (foraminifera) and the sandy and muddy sand lithofacies. The Agbada Formation was penetrated from 3450 ft - 8440 ft and 7400 ft – 12000 ft in Akata-7 and Oloibiri-1 wells respectively. This was based on the presence of marine and brackish water foraminifera and the interbedding of sand, mudstone and shale lithofacies (Short and Stauble, 1967).

Depositional Environment

Inference of the paleodepositional environment of the studied wells was made depending on the biofacies information interpreted from the qualitative and quantitative evaluation of the benthic foraminiferal assemblages. This has been integrated with the lithologic description of the wells, the planktic/benthic foraminiferal ratio and presence/absence of ostracode. The criteria outlined for the reconstruction of marine paleoenvironment by Bandy and Arnal (1960) were also considered. It is on these bases, that the sequences of the wells are interpreted to have fluctuated from coastal deltaic to marine (inner neritic, inner to middle neritic and middle neritic).

Coastal Deltaic (Marginal-Marine) Environment

The intervals inferred to be deltaic - marine environment from the study in both wells ranges from 3450 -1550 ft and 6870 – 6810 ft in Akata-7 well while in Oloibiri-1 well, the intervals ranges from 7400 -20 ft. This inference is based on the following reasons:

(i) From 3450 – 1550 ft in Akata-7 well and 7400 – 20 ft in Oloibiri-1 well, the micro fauna are completely barren and are characterized by fine to medium grained sand.

(ii) In Akata-7 well, very few benthic and planktic foraminifera have been recovered between 6870 – 6810 ft depth. This interval is also characterized by sand and mudstone.

Inner Neritic Environment

This is a subdivision of the marine environment that lies within 0-40 m on the continental shelf.

In this study, the stratigraphic intervals that were inferred to be inner neritic environment lie from 5650-3450 ft and 9500-7400 ft in Akata-7 and Oloibiri-1 wells respectively. This inference is based on the following criteria:

(i) The indicator fauna found here are the miliolids e.g *Quinqueloculina microstata, Quinqueloculina vulgaris, Quinqueloculina seminulum, Quinqueloculina* sp and *Quinqueloculina lamarckiana* in association with *Ammonia beccarii, Lenticulina inornata, Cibcorbis inflata, Heterolepa pseudougerina, Poritextularia panamensis, Textularia soldanii* and other textularids.

(ii) The population count of the benthic forms within these intervals is higher than that of the planktic forms. The average planktic/benthic ratio is low (12%). The diversity is low; it ranges from 0-9 species. This is based on simple species diversity.

(iii) The lithology of the intervals is composed of fine to medium grained sand, silt and mudstone.

Inner-Middle Neritic Environment

Depth intervals of the studied wells that are inferred to belong to this environment are from 6810 - 5650 ft and 7350 – 6870 ft in Akata-7 well, and from 10,150 ft – 9500 ft in Oloibiri-1 well. The criteria for this inference are based on the following:

(i) The occurrence of the typical forms from inner, middle and outer neritic environments like *Ammonia beccarii, Heterolepa bellinocionii, Poritextularia panamensis, Uvigerina* sp., *Spiroplectamina wrightii, Lenticulina inornata, Hanzawaia strattoni, Amphistegina Lessonii, Saccammina complanata, Sigmoilopsis schlumbergeri, Quinqueloculina* sp. and *Textularia* sp.

(ii) There is an increase in the population of the planktics and increase in species diversity (ranging from 0-20 species). Also the planktic/benthic ratio is increased (28%)

(iii) The lithology is composed of mudstone, sandy mud, silts, clays and sands.

Middle Neritic Environment

This environment lies between 40 -100 m in the marine environment within the continental shelf (Boersma, 1978). This environment is recognized in Akata-7 well from 8440 ft to 7350 ft and in Oloibiri-1 well from 12,000 – 10, 150 ft.

The criteria for the recognition are:

(i) The presence of fauna like *Bolivina* sp., *Brizalina interjuncta, Uvigerina* sp., *Bolivina scalprata miocenica, Uvigerina sparsicostata, Eponides* sp., *Lenticulina inornata, Hopkinsina danvillensis, H. bonomensis, and Poritextularia panamensis, Heterolepa pseudougerina. Spiroplectamina wrightii.*

(ii) Increase in the number of planktic specimens. The average planktic/benthic ratio within the stratigraphic interval is 22%. The simple species diversity is also increased, ranging from 0-13 species.

(iii) The lithology is composed of shale, mudstone and silt.

Conclusion

This study was carried out on ditch cutting samples of Akata-7 and Oloibiri-1 wells. The studied depth intervals range from 1550-8440 ft and 20-12,000 ft in Akata-7 and Oloibiri-1 wells respectively. The lithology in both wells is composed of grey shale and mudstone/siltstone beds with intercalation of sand/sandstone beds. The topmost parts of the sequence in both wells are mainly sands.

Foraminifera biostratigraphic characteristics of the two wells were analyzed. The foraminiferal recovery was poor in Oloibiri-1 well and fairly rich in Akata-7 well. However, a planktic foraminiferal zone of *Praeorbulina glomerosa* was established in Akata-7 and Oloibiri-1 wells.

The *Praeorbulina glomerosa* Zone of both wells corresponds to N8-N9 zone of Blow (1969, 1979). The benthic foraminiferal zone established for both wells is the *Poritextularia panamensis* Zone.

The observed foramniferal assemblages especially the benthics together with other accessory micro fauna indicate that the sediments of the two wells were deposited in a lithoral (beach) – deltaic to marine (inner neritic, inner to middle neritic and middle neritic) environments.

Based on the lithologic, foraminifera and paleoenvironmental analysis of Akata-7 and Oloibir-1 wells, it is inferred that the intervals penetrated by both wells correspond to the Benin and Agbada formations, and they are of Miocene age. The two wells have also been found correlatably fairly well as they show similarities in their lithostratigraphic and biostratigraphic analyses.

The alternation of sands and shales/mudstones within the sequence provides the combination of source, reservoir and cap rocks essential for hydrocarbon generation, accumulation and trapping. Calcareous nannofossil biostratigraphic analysis was also carried out in Akata-7 well, and the

calcareous nannofossil zone established from the study is *Sphenolithus heteromorphus* Zone. This zone is equivalent to the NN5 zone of Martin (1971). This was used to assign an absolute age to the sequence in Akata-7 well. This also enabled correlation of the sequence with the global sequence cycle chart of Haq et al. (1987) and has been found to correlate with geologic events ranging from about 15.0 Ma to ?13.4 Ma.

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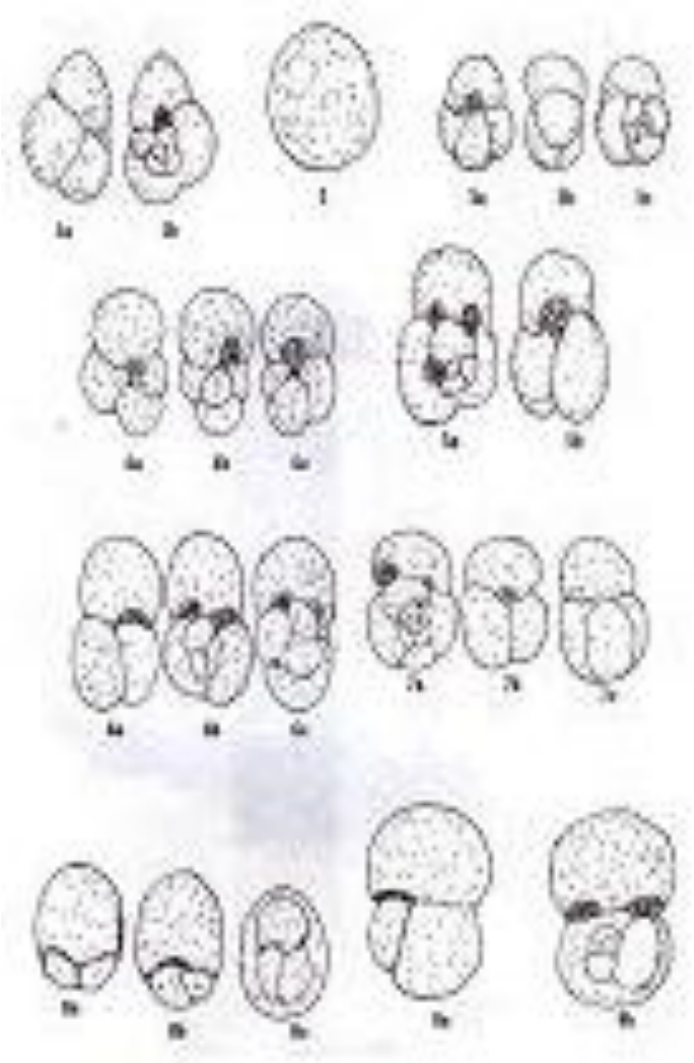
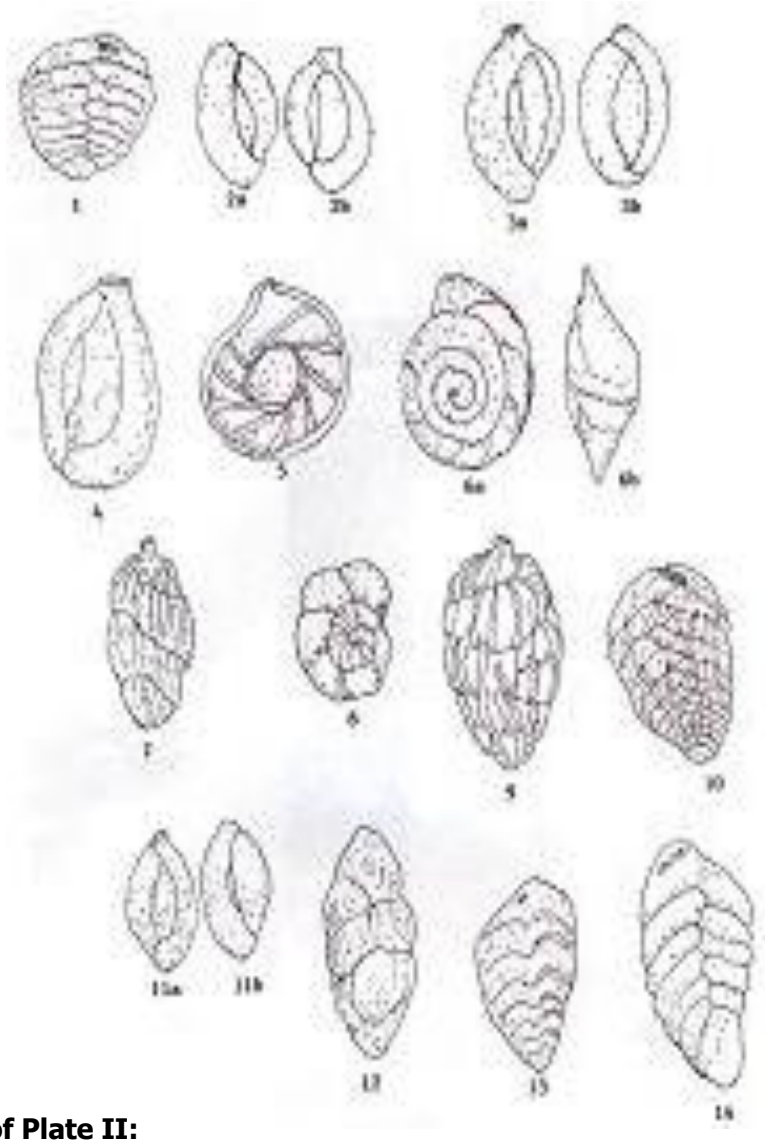
PLATE I (PLANKTIC FORAMINIFERA)



Explanation of Plate I

1. *Globigerinoides sacculiferus* (Brady), X60 (a) Umbilical (b) spiral view
2. *Orbulina universa* (d'Orbigny), X60.
3. *Globigerinoides bolli* (Blow), X50, (a) Umbilical view (b) side view (c) Spiral view
4. *Globigerina praebulloides* (Blow), X70, (a) spiral view (b) side view (c) umbilical view
5. *Globigerinoides ruber* (d'Orbigny), X70, (a) dossal view (b) ventral view
6. *Globigerinoides immaturus* (Le Roy), X100 (a) dorsal view (b) side view (c) umbilical view
7. *Globigerinoides obliquus* (Bolli), X60 (a) spiral view (b) side view (c) Umbilical view
8. *Praeorbulina glomerosa* (Blow) X100 (A) side view (b) umbilical view (c) Spiral view
9. *Praeorbulina transitoria* (Blow) X100 (a) side view (b) spiral view

PLATE II (BENTHIC FORAMINIFERA)_



Explanation of Plate II:

1. *Poritextularia panamensis* (Cushman) X70
2. *Quinqueloculina microstate* (Natland) X65 (a) dorsal view (b) ventral view
3. *Quinqueloculina lamarckiana* (d'Orbigny) X45 (A) ventral view (b) dorsal view
4. *Quinqueloculina seminulum* (Linne) X100
5. *Lenticulina inornata* (Linne) X50
6. *Heterolepa pseudeoungeriana* (Franzenau) X70
7. *Uvigerina peregrina* (Cushman) X70
8. *Ammonia becarii* (Linne) X60
9. *Uvigerina peregrina* (Cushman) x49, side view
10. *Bolivina interjuncta* (Galloway and MeCulloch) X45, side view
11. *Quinqueloculina lamarckiana* (d'Orbigny) X64 (a) side view (b) opposite side view
12. *Uvgerina sparsicostata* (Cushman and Laiming) X70
13. *Textularia laminata* (Cushman) X70
14. *Bolivina scalprata miocenica*