



Biostratigraphic Zonation and Paleoenvironmental Reconstruction of Wells 'MIC-1' and 'MIC-2' in the Southern Niger Delta, Nigeria

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Abstract

This study aims to establish biostratigraphic zonation and reconstruct the paleoenvironmental conditions of Wells MIC-1 and MIC-2 in the Southern Niger Delta using foraminiferal assemblages. Foraminiferal samples were collected at various depths, and species were identified to delineate biozones and interpret depositional environments. Key foraminiferal zones, including *Globigerinoides conglobatus*, *Globigerinoides ruber*, and *Globigerinoides obliquus*, were identified, correlating the strata with late Miocene to early Pliocene depositional periods. The paleoenvironmental reconstruction shows a transition from shallow deltaic to outer neritic conditions, corresponding to global sea-level fluctuations. The benthic foraminiferal species indicated shallow marine environments in the lower sections, while planktonic species dominated the upper sections, suggesting deeper water conditions. Chronostratigraphic correlation between the wells was achieved by identifying bioevents and matching them with global biostratigraphic records. The results provide a detailed understanding of the geological evolution of the Southern Niger Delta, with implications for hydrocarbon exploration. The integration of biostratigraphic data and paleobathymetric analysis highlights the complex depositional history and its impact on reservoir development.

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1.0 Introduction

Biostratigraphy plays a pivotal role in deciphering the geological history of sedimentary basins, providing essential information about the age, paleoenvironment, and depositional processes that shaped sedimentary sequences. By studying the fossil content within these sequences, geologists can construct a timeline of events that helps to piece together the history of a basin's development. The study of sedimentary basins is fundamental to understanding Earth's history, particularly in reconstructing depositional environments, deciphering basin evolution, and assessing resource potential. One of the most reliable approaches for establishing the relative age of sedimentary sequences and correlating strata across basins is biostratigraphy, a method that relies on fossil assemblages as chronological markers. Biostratigraphic frameworks play a crucial role in hydrocarbon exploration by providing high-resolution age constraints, refining sequence stratigraphic models, and improving reservoir characterization (Gradstein *et al.*, 1994; Berggren & Pearson, 2005). Among the various fossil groups used in biostratigraphic analysis, foraminifera have proven to be particularly valuable due to their widespread occurrence, rapid evolutionary changes, and sensitivity to paleoenvironmental conditions. Their distribution patterns provide essential insights into past marine conditions, sediment provenance, and depositional environments (Murray, 2006; Jones, 2014). The Niger Delta, one of the world's most productive hydrocarbon provinces, has a complex geological history shaped by the interplay of eustatic sea-level fluctuations, tectonic activity, and deltaic sedimentation (Doust & Omatsola, 1990; Short & Stauble, 1967). The stratigraphy of the delta consists of three main formations: the Akata Formation, which represents deep marine shales; the Agbada Formation, a mixture of sandstones and shales indicative of deltaic conditions; and the Benin Formation, which consists mainly of

continental sandstones. These formations have been extensively studied in terms of their lithostratigraphy and petroleum potential (Avbovbo, 1978; Evamy *et al.*, 1978). However, biostratigraphic studies in the Niger Delta remain less comprehensive, particularly in the southern region where depositional complexity is heightened due to its proximity to the delta front. Globally, biostratigraphy has been instrumental in refining the stratigraphy of hydrocarbon basins. In the North Sea Basin, foraminiferal biozonation has enhanced the resolution of reservoir stratigraphy, allowing for improved hydrocarbon exploration strategies (King *et al.*, 2016). Similarly, in the Gulf of Mexico, high-resolution biostratigraphic data have been used to correlate deep-water reservoirs and define sequence boundaries (Donovan & Keller, 2012). The application of foraminiferal biostratigraphy in West Africa, particularly in the Dahomey and Congo Basins, has provided valuable insights into regional depositional histories and hydrocarbon prospectivity (Ogunmoyero & Moronfoye, 2018; Petters, 1983). Despite these advances, the Niger Delta still lacks detailed, high-resolution biostratigraphic frameworks that integrate micropaleontological data with sequence stratigraphy to improve sedimentary correlation and paleoenvironmental interpretations. Previous biostratigraphic studies in the Niger Delta have primarily focused on the central and northern parts of the basin, leaving the southern region relatively underexplored (Petters, 1982; Adegoke *et al.*, 2019). This gap is particularly significant given the rapid lateral facies variations in the Niger Delta, which complicate stratigraphic correlations and necessitate the use of detailed biostratigraphic zonation. Existing studies have largely been regional assessments that lack well-defined correlations between closely spaced wells, limiting the ability to establish a high-resolution chronostratigraphic framework. Moreover, the role of paleoenvironmental shifts in shaping the

distribution of foraminiferal assemblages in the southern Niger Delta has not been thoroughly documented.

In light of these gaps, this study focuses on the biostratigraphy of Wells MIC-1 and MIC-2, located in the southern Niger Delta. By analyzing foraminiferal assemblages from these wells, the research aims to establish biozones, determine the relative ages of sedimentary sequences, and reconstruct paleoenvironmental conditions during deposition. The integration of micropaleontological data with lithostratigraphic and sequence stratigraphic interpretations is expected to refine stratigraphic correlations and enhance understanding of the depositional history of the region. Foraminiferal biozonation will be based on well-established zonation schemes, such as those proposed by Blow (1969) and Petters (1982), while paleoenvironmental interpretations will be supported by ecological and sedimentological indicators. The study also aims to improve stratigraphic correlations between MIC-1 and MIC-2, which will contribute to a more refined regional stratigraphic framework for the southern Niger Delta. This refined framework will be essential in guiding future hydrocarbon exploration and reservoir development, particularly in identifying potential reservoir, source, and seal intervals. By enhancing the resolution of chronostratigraphic frameworks, the study is expected to contribute to better sequence stratigraphic models that can predict sedimentary facies distribution, ultimately improving hydrocarbon prospectivity assessments. Beyond its immediate application to hydrocarbon exploration, the study has broader implications for the biostratigraphy of the Niger Delta and West African basins. The findings will provide a reference for future studies on the stratigraphy and basin evolution of the region, particularly in refining biostratigraphic zonation schemes for Cenozoic sequences. Given the economic significance of

the Niger Delta, improving biostratigraphic resolution in this region is crucial for optimizing exploration strategies and reducing stratigraphic uncertainties in subsurface interpretation.

By addressing these key research questions, this study aims to contribute to a more comprehensive understanding of the biostratigraphy and paleoenvironmental evolution of the Niger Delta. The integration of biostratigraphic and stratigraphic data will not only enhance the accuracy of sedimentary correlations but also provide a framework for future investigations into the sequence development and depositional history of the basin. Ultimately, this research underscores the importance of high-resolution biostratigraphic studies in improving hydrocarbon exploration strategies and deepening geological understanding of sedimentary basins worldwide.

1.2 Study Location

The study area is an on-shore oil field located within Longitude $5^{\circ}30'1''\text{E}$ to $6^{\circ}30'1''\text{E}$ and Latitude $4^{\circ}30'1''\text{N}$ to $5^{\circ}30'1''\text{N}$. Well Mic-1 has a total drilled depth interval from 500 m to 3650 m, while Well MIC-2 has a total drill depth interval from 450 m to 3790 m. The map showing the study area is shown in figure 1, below.

The Niger Delta Basin ranks among the most significant hydrocarbon-producing regions globally, spanning an area of more than 300,000 square kilometers and containing substantial sedimentary sequences that extend to depths of approximately 12 kilometers (Doust & Omatsola, 1990; Evamy *et al.*, 1978). Its development is linked to the rifting of the African and South American plates, a tectonic event that initiated extensive deltaic sedimentation from the Cretaceous period to the present (Reijers, 2011). The basin's stratigraphy is composed of three primary formations: the Akata Formation, which consists of deep marine shales that serve as the principal source rocks for

hydrocarbons; the Agbada Formation, characterized by interbedded sandstones and shales that function as both reservoirs and seals; and the Benin Formation, made up predominantly of continental sands that act as an overburden sequence (Short & Stauble, 1967).

The geological history of the basin dates back to the Late Cretaceous, coinciding with the rifting

of the African and South American plates, which ultimately led to the formation of the Gulf of Guinea (Oa *et al.*, 2019). This tectonic activity facilitated the deposition of thick marine shales associated with the Akata Formation, followed by the gradual progradation of the deltaic sequence represented by the Agbada Formation throughout the Tertiary period (Nton & Adeyemi, 2021).

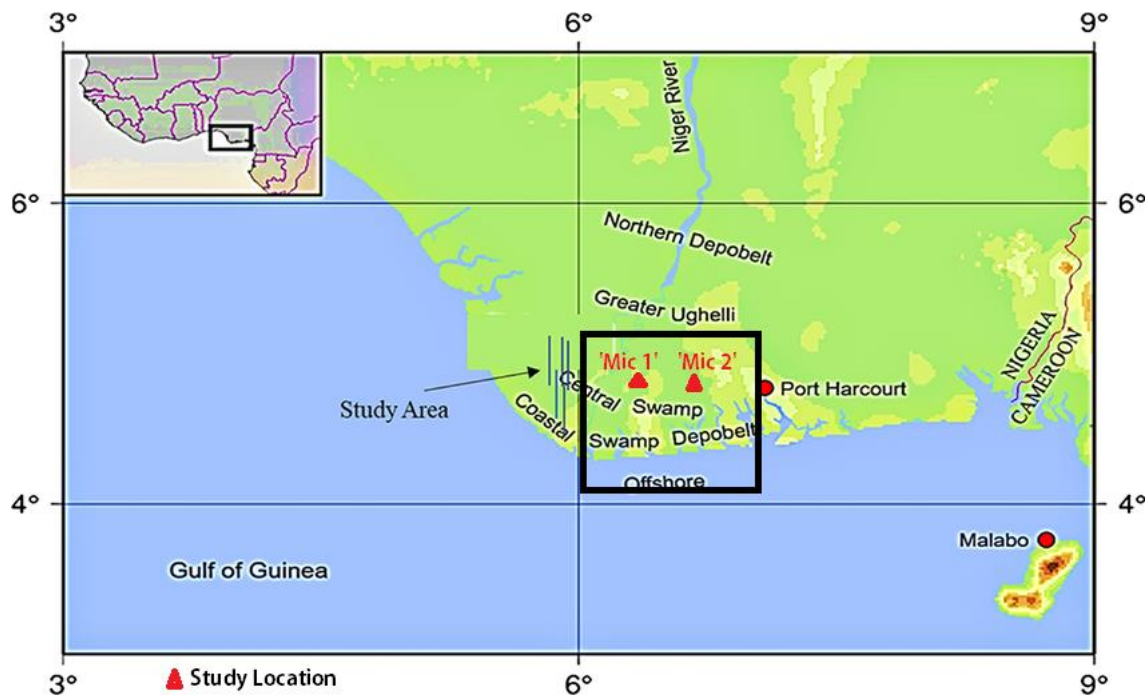


Fig. 1: Map of the Niger Delta Province showing studied Wells

2.0 Methodology

2.1 Foraminiferal Analysis

Foraminiferal assemblages from both wells were analyzed to identify biozones. The occurrence of specific foraminiferal species was used to delineate key stratigraphic surfaces, including sequence boundaries (SB) and maximum flooding surfaces (MFS). Fossil abundance and diversity peaks were associated with MFS, while diversity minima were used to identify SB.

2.2 Foraminiferal Sampling and Identification

Biostratigraphic data were obtained through the examination of foraminiferal assemblages in samples taken from Wells MIC-1 and MIC-2.

Samples were collected at regular intervals, washed, sieved, and chemically treated to isolate foraminiferal specimens. The foraminiferal species were identified using standard taxonomic keys, such as those provided by Loeblich and Tappan (1988). Both planktonic and benthic foraminifera were identified, with planktonic species used to establish biozones and benthic species aiding in paleo-environmental interpretations. The sample preparation process began with the collection of well cuttings and core samples at regular depth intervals. These samples were then washed and sieved using a mesh size of 63 μm to remove finer particles and isolate microfossils. To ensure the preservation of delicate tests, the

residues were carefully dried at low temperatures, mounted on slides before being subjected to microscopic examination.

Foraminiferal identification was conducted using a binocular stereomicroscope, where specimens were picked and sorted based on their morphological characteristics. Taxonomic classification followed standard reference materials, including the works of Blow (1969) for planktonic species and Murray (2006) for benthic assemblages. The identified foraminiferal species were recorded, and their relative abundances were quantified to establish species diversity and dominance trends at different stratigraphic levels.

Planktonic foraminiferal species were then used to define biozones by correlating their occurrences with established regional and global zonation schemes, such as those proposed by Blow (1969) and Petters (1982). The biozones were subsequently integrated with lithostratigraphic and chronostratigraphic data to refine age determinations for the sedimentary sequences.

Benthic foraminiferal assemblages were analyzed to infer paleoenvironmental conditions, considering ecological factors such as species diversity and dominance (planktonic/benthonic ratio) as seen in Table 1. Less focus was placed on tests morphology.

2.3 Morphologic Descriptions of Identified Foraminiferal Species

Foraminiferal analysis was conducted by carefully examining both planktonic and benthic species under a binocular stereomicroscope. The identification process was guided by key taxonomic references, including the works of Blow (1969), Petters (1982), and Murray (2006). Each species was classified based on distinct morphological characteristics, including test shape, chamber arrangement, wall texture, aperture features, and diagenetic color variations.

Globigerinoides conglobatus was identified by its high trochospiral test, which exhibits a compact, globular form. The chambers of this species increase rapidly in size as they spiral outward, forming a tight coiling pattern. The test wall is finely perforated, with a smooth to slightly hispid surface that often retains spine bases in well-preserved specimens. The primary aperture is umbilical, centrally positioned at the base of the final chamber, typically bordered by a thin lip. Fossilized specimens of *G. conglobatus* often display light brown or whitish coloration due to diagenetic processes.

Globigerinoides ruber presented a low to medium trochospiral test, with a distinctive globose shape and an inflated appearance. The chamber arrangement in this species is loose, with the final chambers progressively increasing in size. The wall texture is characterized by thin, highly perforated surfaces, often covered with fine spine bases in well-preserved samples. Its aperture is umbilical-extraumbilical, extending slightly beyond the umbilicus, and frequently bordered by a thin apertural lip. Fossilized specimens exhibit a light-colored test, although diagenetic alteration can introduce some discoloration in older sediments.

Another species identified, *Globigerinoides obliquus*, is distinguished by its low trochospiral test, with final chambers arranged in a slightly oblique manner relative to the main coiling axis. The chambers are irregularly spaced, and the test wall is perforated, often appearing rough or slightly pitted due to diagenetic overgrowth. The aperture is broad and umbilical-extraumbilical, sometimes exhibiting asymmetry. Fossilized specimens of *G. obliquus* typically display a light brown to grayish coloration, influenced by mineralization processes.

The benthic foraminiferal assemblages included *Globorotalia spp.*, which are indicative of deeper marine environments. These species exhibited planispiral to low trochospiral tests, often biconvex in outline, with chambers

symmetrically arranged around the coiling axis. The test wall was smooth and finely perforated, sometimes showing secondary calcite overgrowth. The aperture was located at the base of the final chamber, with well-defined intercameral sutures. Fossilized specimens of *Globorotalia* appeared grayish to dark brown, reflecting variations in diagenetic conditions.

In the shallow-water benthic category, *Ammonia beccarii* was identified by its low *trochospiral, lenticular* test, which appeared somewhat flattened. Its chambers were evenly sized and spirally arranged around a central umbilicus. The test wall was finely perforated and exhibited a microgranular texture. The aperture was interiomarginal, positioned at the periphery of the final chamber. Fossilized specimens of *A. beccarii* often displayed a light gray to yellowish-brown coloration, depending on preservation conditions.

Another benthic species, *Textularia* spp., displayed an elongated test, with chambers arranged in a biserial to triserial pattern. The test walls were agglutinated, composed of fine-grained sedimentary particles, giving it a rough, grainy texture. The aperture was terminal, simple, and oval-shaped, positioned at the end of the test. Fossilized specimens of *Textularia* exhibited dark brown to reddish-brown coloration, influenced by the composition of agglutinated grains.

The detailed morphological examination of these foraminiferal species facilitated accurate taxonomic classification, allowing for precise biozonation, paleoenvironmental interpretation, and stratigraphic correlation in Wells MIC-1 and MIC-2.

2.4 Biozone Delineation and Chronostratigraphic Correlation

The biozones were identified based on the first and last appearances of key foraminiferal species, which serve as bioevents for stratigraphic correlation. In Wells MIC-1 and MIC-2, species such as

Globigerinoidesconglobatus, *Globigerinoides ruber*, and *Globigerinoides obliquus* were critical in delineating biozones. These species have well-documented stratigraphic ranges, allowing for precise age dating of the sedimentary sequences (Harry *et al.*, 2017; 2018). The work of Petters (1982) on Central West African foraminifera provided a vital reference for identifying the stratigraphic ranges of foraminiferal species in this region.

The ages of the identified biozones were determined by correlating the foraminiferal species with global foraminiferal zonation charts, as discussed by Berggren *et al.* (1995). This enabled the assignment of a late Miocene to early Pliocene age to the sedimentary sequences in both wells. Chronostratigraphic correlation between Wells MIC-1 and MIC-2 was achieved by matching bioevents, particularly those associated with major transgressive-regressive cycles.

2.5 Paleoenvironmental Interpretation

The paleoenvironmental reconstruction was largely on the analysis of benthic foraminiferal assemblages, which are sensitive to changes in water depth, salinity, and sedimentation rates. The presence of shallow-water species such as *Ammonia beccarii* and *Textularia* spp., marine protozoa, and other benthic species indicates deposition in deltaic environments, while the increasing abundance of deeper-water planktonic species such as *Globigerinoides* spp. reflected a shift towards outer neritic conditions. This approach aligns with the paleoenvironmental methodologies detailed by Petters (1982), who used benthic foraminifera to interpret water depth and sedimentary facies in the Niger Delta.

Paleobathymetric interpretations were further refined by examining the relative abundance of planktonic versus benthic foraminifera. In intervals where planktonic species dominated, deeper, more open marine conditions were inferred, while intervals dominated by benthic

species suggested shallower, more restricted environments. This method is consistent with the findings of Ojo and Gbadamosi (2013), who applied similar techniques to the biostratigraphy of the Niger Delta.

2.6 Chronostratigraphic Correlation and Geological Implications

The biostratigraphic analysis revealed a clear transition from deltaic to outer neritic environments during the late Miocene to early Pliocene. The biozones identified in Wells MIC-1 and MIC-2 allowed for precise age dating of the depositional sequences and correlation between the wells. These findings provide insights into the geological history of the Southern Niger Delta, particularly regarding relative sea-level changes and their impact on sedimentation patterns, as discussed in works by Beka and Oti (1995).

2.7 Paleobathymetric Interpretation

The benthic foraminifera species were classified according to their depth preferences, allowing for the reconstruction of Paleobathymetric

changes over time. The abundance of shallow-water species, such as *Ammonia beccarii* and *Textularia spp.*, was used to identify deltaic and nearshore environments, while the presence of deep-water species, such as *Globigerinoides spp.* and *Globorotalia spp.*, indicated outer neritic conditions.

3.0 Results and Discussion

The biostratigraphic analysis of Wells MIC-1 and MIC-2 yielded significant insights into the depositional environments, paleoenvironmental history, and chronological framework of the Southern Niger Delta. The identification of foraminiferal assemblages allowed for the establishment of biozones, which were correlated with global foraminiferal zonations. In addition, paleoenvironmental reconstruction provided a detailed understanding of the shifting depositional settings (Harry et al., 2022), from deltaic to marine environments, in response to relative sea-level changes. Table 1 and Table 2 below shows the distribution of foraminiferal species within the study area (Mic 1 and Mic 2).

Table 1: Distribution of Foraminifera species within Well MIC-1

Depth(m)	Foramineferal Species	Total Abundance	% Abundance of planktics	% Abundance of benthics	Ratio of planktics to Benthics
3650-3600	<i>Globigerinoidestrilobus</i> , <i>Planktonic spp index</i> , <i>Ammonia beccari</i> , <i>Poritextulariaaff. Panamensis</i> .	85	45	55	4:5
3600-3550	<i>Globigerinoides obliquus</i> , <i>Epistominellavitrea</i> .	217	48.4	51.6	2:3
3550-3500	<i>Planktonic sppindet</i> , <i>Ammonia beccarii</i> .	56	19.6	80	1:4
3500-3450	<i>Globigerinoidetrilobus</i> , <i>Ammonia baccarii</i> .	57	58	42	3:2
3450-3400	<i>Globigerina spp</i> <i>Epistominellavitrea</i> , <i>Orthomorphina spp</i> .	102	35.3	64.7	1:2
3400-3350	<i>Ammonia beccarii</i>	16	0	100	0:100
3350-3300	<i>Epistominellavitrea</i> , <i>Florilus atlanticus</i> .	36	21.8	72.2	1:3
3300-3250	<i>Globigerinoidestrilobus</i> , <i>Ammonia beccarii</i> .	88	8	92	1:11

3250-3200	<i>Globigerinaspp, Epistominellavitrea, Florilus atlanticus</i>	137	10.3	89.7	1:8
3200-3150	<i>Globigerina bulloides.</i>	149	3	97	1:32
3150-2950	<i>Globigerina bulloides, Globigerinoidestrilobus, Ammonia beccarii, Epistominellavitrea, Nonionspp, Bolivinadilatata.</i>	957	5	95	1:2
2950-2750	<i>Globorotaliapseudopima, Ammonia beccarii.</i>	222	32	68	1:2
2750-2550	<i>Ammonia beccarii, Florilus atlanticus, Nonion spp.</i>	260	37	63	1:2
2550-2350	<i>Globigerinoidestrilobus, Ammonia beccarii, Epistominellavitrea, Florilus atlanticus, Nonion spp.</i>	1136	13.4	86.6	1:6
2350-2150	<i>Ammonia beccarii, Shell fragment.</i>	76	11.2	82.8	1:7
2150-1950	<i>Globigerina bulloides, Ammonia beccarii.</i>	125	22.4	73.6	1:3
1950-1750	<i>Ammonia beccarii, Shell fragments.</i>	51	7.8	92.2	1:11
1750-1500	<i>Ammonia beccarii, Florilus atlanticus, shell fragement.</i>	103	6	94	1:15
1500-1250	<i>Globigerina spp, Ammonia beccarii, Epistominellavitrea, Florilus atlanticus, shell fragement.</i>	353	16.2	83.8	1:5
1250-1000	<i>Globigerina bulloides, Globigerina spp, Globigerinoidesruber, Ammonia beccarii, Epistominellavitrea, Florilus atlanticus, Heterolepa floridana, Bolovinasalpratamiocenica.</i>	604	12.6	87.4	1:6
1000- 950	<i>Globigerinoidesbulloides, Globigerinoidesruber, Ammonia beccarii, Florilus atlanticus, Amphisteginalessonii, Herterolepaflordana.</i>	43	35	65	1:2
950- 900	<i>Globigerinoidesbulloides, Globigerinoidesruber, Ammonia beccarii, Epistominellavitrea, Florilusatlanticus, Shell fragment.</i>	85	27.1	72.9	1:2
900-850	<i>Globigerinoidesbulloides, Globigerina spp, Globigerinoidesruber, Annoniabeccrii, Heterolepa floridana.</i>	107	8.5	91.5	1:10
850-800	<i>Globigerinoidesruber, Globigerinoidesspp, Globigerinoidestrilobus, Ammonia beccarii, pelyceps spp.</i>	104	8.5	68.2	1:2
800- 750	<i>Globigerinoidesruber, Ammonia beccarii, Epistominellavitrea, Florilus atlanticus, Heterolepapseudoungeriana.</i>	59	5.1	94.9	1:19
750-700	<i>Globigerinoidesruber, Ammonia beccarii,</i>	66	11.7	89.3	1:7
700- 650	<i>Globigerina bulloides, Globigerinoidesruber, Globigerinoidestrilobus, Gmmoniabeccrii, Bolivinacaudriae, Epistominellavitrea, Bolivinacatanensis.</i>	168	34	66	1:2

650-600	<i>Globigerinoidesruber</i> , <i>Globigerinoidestrilobus</i> , <i>Globorotaliaacostaensis</i> , <i>Ammonia beccarii</i> , <i>Epistominellavitrea</i> , <i>Florilus atlanticus</i> , <i>Uvigerina peregrine</i> .	96	44.8	55.2	4:5
600-550	<i>Bolivinacaudriae</i> , <i>Epistominellavitrea</i> , <i>Florilus atlanticus</i> , <i>Rectuvigerinamulticostata</i> , <i>Nonionspp</i> , <i>Uvigerinamantaensis</i> .	216	7.9	92.1	1:9
550-500	<i>Globigerina spp</i> , <i>Globigerinoidestrilobus</i> , <i>Ammonia beccarii</i> , <i>Epistominellavitrea</i> , <i>Florilusatlanticuc</i> , <i>Quinqueloculinaseminulum</i> , <i>Rectuvigerinamulticostata</i> , <i>Bigernerinanodosaria</i> , <i>Textularia</i> <i>panamensis</i> .	499	5	95	1:19

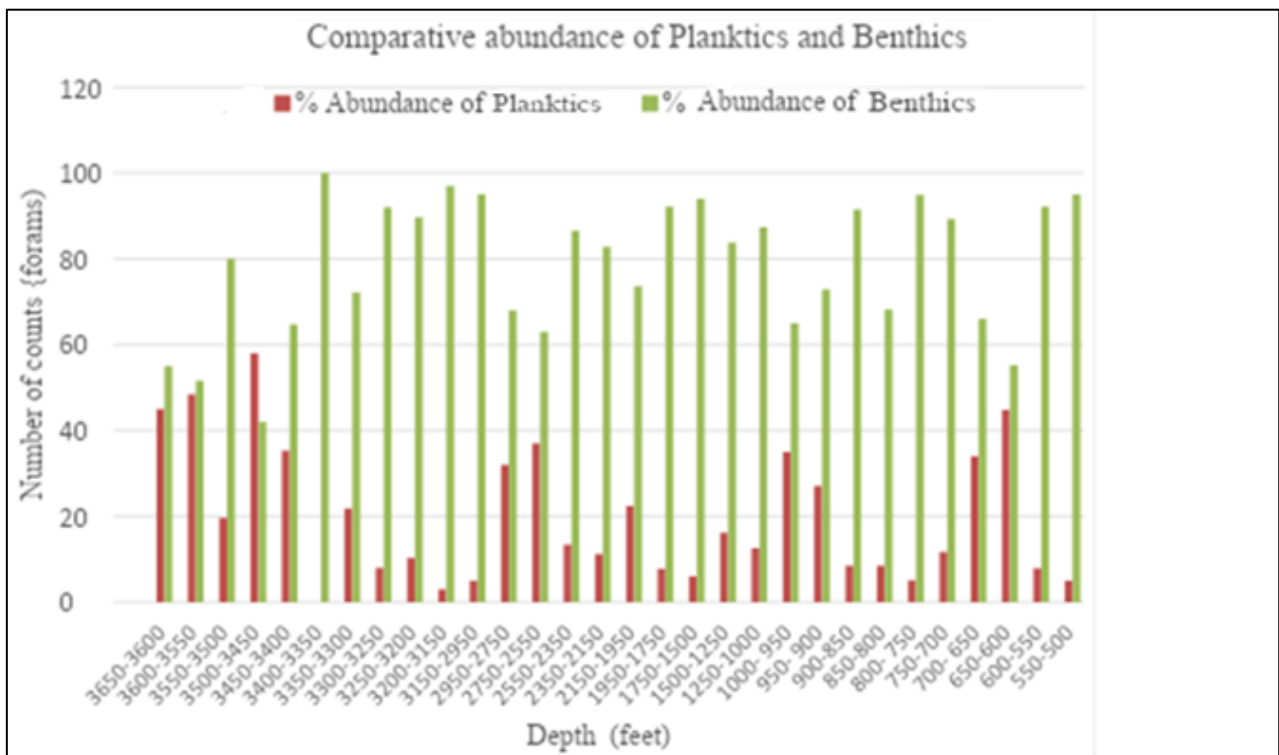


Fig. 2: Comparative Abundance of Planktics and Benthics in Well MIC-1

Table 2: Distribution of Foraminifera species within Well MIC-2

Depth	Species	Total Abundance of Forams	% Abundance of Planktics	% Abundance of Benthics	Ratio of Abundance of Planktics to Benthics
3800-3650	<i>Saccamminacomplanata</i>	10	10	90	1:9
3650-3500	<i>Alveolophragmium crissum</i> , <i>Haplophragmoidescompressa</i> , <i>Gastropoda spp.</i> <i>Haplophragmoidessp.</i>	18	5.5	94.5	1:15
3500-3350	<i>Ammobaculitesstratheamensis</i> , <i>Haplophragmodescompressa</i> , <i>Alveolophragmium spp.</i> <i>Planktic indet, Globorotaliascitula</i> , <i>Bolivinacaudriae, Ammonia beccarii</i> , <i>Haplophragmoidessp.</i>	54	1.8	98.2	1:49
3350-3200	<i>Ammobaculitessp, Arenaceous indet</i> , <i>Alveolophragmium crissum</i> , <i>Ammobaculitesstratheamensis</i> , <i>Cyclamminacancellata, Cyclamina minima</i> , <i>Textularia parvula</i> , <i>Valvulinaflexilis, Gaudryinaeiles</i> . <i>Ammonia beccarii</i> , <i>Haplophragmoidesspp.</i>	1270	4.8	95.2	1:19
3200-305-	<i>Ammobaculitesstratheamensis</i> , <i>Textularia parvula</i> , <i>Haplophragmoidescompressa</i> .	385	2.8	97.1	1:32
3050-2950	<i>Haplophragmoides spp.</i>	21	19	81	1:4
2950-2850	<i>Haplophragmoidesspp</i> , <i>Saccamminacomplanata, Eggerella ex.gr. forestensis</i> .	125	0	100	0:100
2850-2750	<i>Shell fragment, Lenticulinainomata</i> .	5	0	100	0:100
2750-2650	<i>OrbulinaUniversa, Ammonia beccarii</i> ,	0	0	0	0:0
2650-2550	<i>Ammonia beccarii</i> ,	2	0	100	0:100
2550-2350	<i>Ammonia beccarii</i> , <i>Haplophragmoidesspp</i> , <i>Ammobaculitessp, Cyclamminasp</i> , <i>Haplophragmoides cf. obliquicqmeratus, shell fragment</i> .	346	2.9	97.1	1:32
2350-2150	<i>Ammonia beccarii, shell fragment</i> .			11 0	100 0:100

2150-1950	<i>Heterolepapseudoungerina</i> , shell fragment	12	33	66.6	1:2
1950-1750	<i>Ammonia beccarii</i> , <i>Heterolepa floridana</i> , <i>Textularia panamensis</i> , Shell fragment.	22	9.09	90.90	1:10
1750-1550	<i>Globigerina bulloides</i> , <i>Heterolepapseudoungerina</i> , <i>Ammonia beccarii</i> , <i>Cibicorbis inflata</i> , <i>Textularia panamensis</i> .	162	20.9	79.01	1:3
1550-1350	<i>Planktic indet</i> , <i>Ammonia inflata</i> , <i>Florilus atlanticus</i> , <i>Florilusex.gr.costiferum</i> , <i>Heterolepapseudoungerina</i> , <i>Epistominellavitrea</i> , <i>Ammonia beccarii</i> , <i>Cibicorbis inflata</i> , <i>Nonionella auris</i> , Shell fragment.	426	11	88.9	1:11
1350-1200	<i>Florilus atlanticus</i> , <i>Ammonia beccarii</i> , Shell fragment.	153	7.2	92.8	1:13
1200-1050	<i>Florilusatlanticuc</i> , <i>Heterolepapseudoungerina</i> , <i>Ammonia beccarii</i> , <i>Cibicorbis inflata</i> , Shell fragment.	67	7.5	67.2	1:15
1050-900	<i>Globigerinoidesruber</i> , <i>Heterolepapseudoungerina</i> , <i>Quinqueloculina vulgaris</i> , <i>Ammonia beccarii</i> , <i>Cibicorbis inflata</i> , <i>Textularia panamensis</i> , <i>Gastropodaspp</i> , shell fragment, <i>Pelycepada spp</i> .	174	32.75	70	1:2
900-750	<i>Ammonia beccarii</i> .	37	30	70	1:2

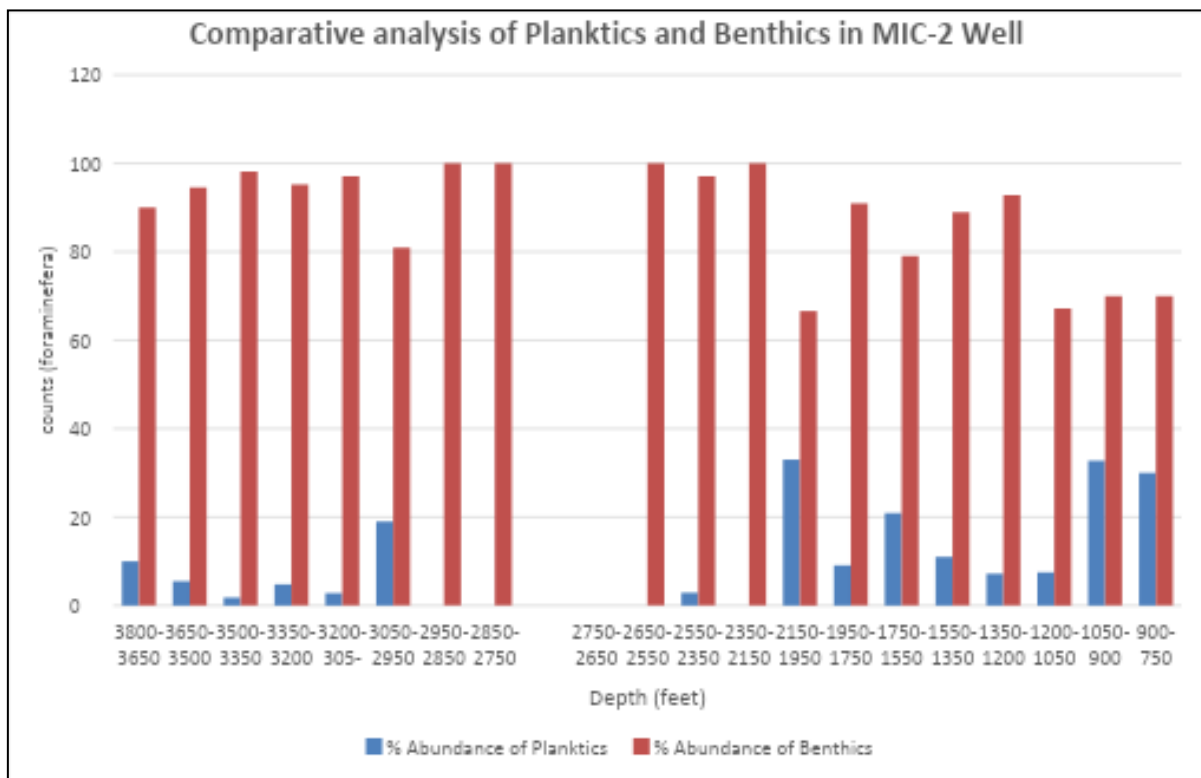


Fig. 3: Comparative Abundance of Planktics and Benthics in Well MIC-2

3.1 Biostratigraphic Zonation

The identification of key foraminiferal species in Wells MIC-1 and MIC-2 led to the delineation of several biozones, each corresponding to distinct depositional periods. The foraminiferal zones identified in this study included *Globigerinoidesconglobatus*, *Globigerinoidesruber*, and *Globigerinoides obliquus*, which are widely recognized as markers for the late Miocene to early Pliocene (Petters, 1982).

In Well MIC-1, the *Globigerinoidesconglobatus* zone, located between 3150 m and 3650 m, represents deposition during the late Miocene (around 5.6 million years ago). This biozone is characterized by benthic foraminiferal species that indicate shallow deltaic conditions, suggesting deposition in a deltaic front environment. As noted by Ojo & Gbadamosi (2013), deltaic foraminiferal assemblages are typical of such nearshore environments, reflecting periods of high sediment influx and shallow water depths.

The *Globigerinoides ruber* zone, found between 1000 m and 3150 m in Well MIC-1, and the corresponding interval in Well MIC-2, represents a shift toward outer neritic conditions during the late Miocene to early Pliocene. The dominance of planktonic species in this zone indicates deepening water as a result of transgression. This interpretation is supported by studies such as Berggren et al. (1995), which describe the *Globigerinoides ruber* zone as a key marker for transgressive systems in tropical marine environments.

The uppermost zone, *Globigerinoides obliquus*, found between 500 m and 1000 m in Well MIC-1, marks the transition to a fully marine, outer neritic environment in the early Pliocene (3.8 to 3.4 million years ago). This biozone is characterized by abundant planktonic foraminifera, which thrive in deeper marine settings. The presence of deep-water benthic species, such as *Globorotalia spp.*, further

confirms the deepening of the depositional environment.

3.2 Paleoenvironmental Reconstruction

The paleoenvironmental reconstruction of Wells MIC-1 and MIC-2 reveals a significant shift from shallow deltaic to deeper marine environments over time (Fig. 2 and Fig. 3). The lower sections of both wells (3150-3650 m in MIC-1 and 3200-3790 m in MIC-2) are dominated by benthic foraminiferal species indicative of deltaic environments. The abundance of species such as *Ammonia beccarii* and *Textularia spp.* suggests deposition in a deltaic front or prodelta setting, where fluvial input was strong and water depths were relatively shallow (Petters, 1982).

As the section progresses upward, a clear transition to outer neritic conditions is observed. The *Globigerinoides ruber* zone (1000-3150 m in MIC-1) marks the onset of transgression, with increasing planktonic foraminiferal diversity indicating deeper water conditions. The presence of deep-water benthic species, such as *Globorotalia spp.*, suggests deposition in an open shelf environment, consistent with global sea-level rise during the late Miocene to early Pliocene.

The uppermost sections of both wells, dominated by planktonic species, indicate a fully marine, outer neritic environment. This transition reflects continued sea-level rise, with the sedimentary system evolving from deltaic to open marine conditions. The deepening of the depositional environment is further supported by the identification of maximum flooding surfaces (MFS) within the stratigraphic column, as these surfaces are often associated with peak transgression and deep-water conditions (Mitchum et al., 1977).

3.3 Chronostratigraphic Correlation

Chronostratigraphic correlation between Wells MIC-1 and MIC-2 was achieved by identifying key bioevents, such as the first and last

appearances of significant foraminiferal species. The correlation of biozones between the two wells demonstrates the lateral continuity of depositional events across the Southern Niger Delta, with clear trends in sedimentation reflecting regional sea-level changes. The biostratigraphic framework established in this study aligns with global foraminiferal zonation schemes, providing a robust timeline for the deposition of sediments in the Niger Delta during the late Miocene to early Pliocene (Berggren et al., 1995). Table 2 shows the established foraminiferal zones, ages and paleobathymetry while Table 3 shows the foraminiferal abundance and diversity.

3.4 Paleoenvironmental Conditions and Hydrocarbon prospectivity

The study of Wells MIC-1 and MIC-2 in the Southern Niger Delta provided a comprehensive evaluation of the paleoenvironmental conditions and hydrocarbon prospectivity through biostratigraphic analysis. By examining the distribution and diversity of foraminiferal assemblages, it was possible to assess critical environmental factors such as water depth, salinity, oxygenation, and sediment supply. The research revealed a significant transition from shallow deltaic to deeper outer neritic conditions, reflecting the influence of global sea-level fluctuations during the late Miocene to early Pliocene.

Water depth changes were interpreted from shifts in foraminiferal assemblages, where benthic species dominated the lower sections of the wells, indicating inner neritic, deltaic conditions, while planktonic species dominated the upper sections, reflecting deeper marine environments. Species diversity and abundance trends also provided insights into oxygenation levels, with lower diversity in certain benthic zones suggesting intermittent oxygen depletion. Salinity levels and sediment supply were inferred from ecological preferences of the identified species and sedimentary facies, with

high sediment influx typical of deltaic settings transitioning to more stable, open marine conditions in deeper zones. These observations demonstrate the interplay of local depositional processes and global palaeoceanographic events, such as eustatic sea-level changes, in shaping the sedimentary record of the Niger Delta.

The paleo-climatic and paleo-oceanographic conditions during the late Miocene and early Pliocene were reflected in the dominance of warm-water, tropical species, such as *Globigerinoides ruber* and *Globigerinoides obliquus*, in the upper sections of both wells. These species indicate deposition in a warm, tropical marine environment. The abundance of planktonic foraminifera in these zones points to periods of transgression, where rising sea levels deepened the depositional environment. As the water depth increased, sediment input from deltaic sources diminished, giving way to more open marine conditions. These findings highlight the influence of global climatic fluctuations and oceanographic shifts on the sedimentary evolution of the Niger Delta during the late Cenozoic era.

In addition to reconstructing past environments, the study provided valuable insights into the hydrocarbon prospectivity of the region. By identifying key stratigraphic intervals and biozones, the research was able to delineate source rock, reservoir, and seal intervals that are critical components of a functioning petroleum system. The deep marine shales associated with the Akata Formation in the lower sections of the wells were identified as potential source rocks, given their organic-rich composition and anoxic depositional conditions. These shales, deposited in outer neritic settings, provide the primary source of hydrocarbons for the Niger Delta.

Reservoir potential was identified within the Agbada Formation, which consists of interbedded sandstones and shales. The

sandstones, deposited in deltaic front and prodelta environments (Table 3 and Table 4), are characterized by good porosity and permeability, making them ideal reservoirs. The shales within this formation serve as effective seals, preventing the upward migration of hydrocarbons. Biostratigraphic correlation between Wells MIC-1 and MIC-2 confirmed the lateral continuity of these stratigraphic units, indicating the presence of regionally extensive reservoirs and sealing intervals.

The study also revealed how paleoenvironmental conditions influenced reservoir quality and hydrocarbon migration pathways. High-energy deltaic environments in the lower sections likely enhanced the porosity of reservoir sandstones, while the transition to marine conditions in the upper zones improved the preservation of organic material necessary for hydrocarbon generation.

Table 3: Foraminiferal Zones, Ages, and Paleobathymetry for Well MIC-1

Depth (m)	Foraminiferal Zone	Age (Ma)	Paleobathymetry
3150-3650	N17: Globigerinoides conglobatus	5.6 and older	Deltaic Front (Inner Neritic)
1000-3150	N18-N19: Globigerinoides ruber	5.6 - 3.8	Open Shelf (Outer Neritic)
500-1000	N19: Globigerinoides obliquus	3.8 - 3.4	Deltaic Plain (Shallow Inner Neritic)

Table 4: Foraminiferal Abundance and Diversity in Wells MIC-1 and MIC-2

Well	Depth (m)	Total Foraminiferal Abundance	% Planktics	% Benthics	Paleobathymetry
MIC-1	500-1000	500	60%	40%	Outer Neritic
MIC-1	1000-3150	1100	75%	25%	Open Shelf
MIC-2	450-1000	600	50%	50%	Deltaic Plain
MIC-2	1000-3790	1300	80%	20%	Outer Neritic

4.0 Conclusion

This study has provided a comprehensive biostratigraphic zonation and paleo-environmental reconstruction of Wells MIC-1 and MIC-2 in the Southern Niger Delta. The identification of key foraminiferal biozones has allowed for the precise dating of the sedimentary sequences, correlating them with global biostratigraphic frameworks. The integration of biostratigraphic data with paleoenvironmental indicators has provided valuable insights into the depositional history of the Niger Delta, particularly during the late Miocene to early Pliocene.

The biostratigraphic analysis revealed a clear transition from shallow deltaic environments in the lower sections of the wells to deeper outer neritic conditions in the upper sections. This shift corresponds to significant global sea-level fluctuations during the late Miocene and early Pliocene, reflecting the dynamic nature of sediment deposition in the Niger Delta. The presence of shallow-water benthic foraminifera in the lower sections indicates deposition in a deltaic front environment, while the increasing abundance of planktonic species in the upper sections marks the onset of deeper marine

conditions. These findings are consistent with the regional geological history of the Niger Delta, where episodic transgressions and regressions have shaped the stratigraphy of the basin.

The chronostratigraphic correlation between Wells MIC-1 and MIC-2 further underscores the lateral continuity of these depositional systems across the study area. The identification of key bioevents and the matching of biozones between the wells have provided a robust chronostratigraphic framework that can be applied to other wells in the region. This biostratigraphic framework is crucial for understanding the timing and extent of hydrocarbon-generating processes, particularly in relation to source rock deposition and the timing of hydrocarbon migration.

This study has highlighted the vital role of biostratigraphy in reconstructing the geological evolution of sedimentary basins, particularly for hydrocarbon exploration. By integrating biostratigraphic data with sequence stratigraphy and well log analysis, the research has provided a clearer picture of depositional environments in the Southern Niger Delta, refining the understanding of sediment distribution and hydrocarbon potential. The identification of key biozones and their correlation with global stratigraphic frameworks facilitated precise age dating of sedimentary sequences, shedding light on the timing of major depositional events. To build on these findings, future research could incorporate geochemical analyses to further evaluate source rock characteristics and hydrocarbon generation potential. Expanding the biostratigraphic framework across a broader regional dataset would enhance predictions of sediment distribution and improve hydrocarbon exploration strategies. The high-resolution stratigraphic framework established in this study will serve as a valuable tool in reducing subsurface uncertainties and guiding exploration efforts in the Niger Delta. Ultimately, these

findings reinforce the importance of micropaleontological data in refining sequence stratigraphic models and advancing our understanding of sedimentary basin evolution.

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