SEDIMENTOLOGY AND FORAMINIFERA ABUNDANCE PATTERN OF THE SEDIMENTARY SUCESSION PENETRATED BY THE DRILL IN MF-3 WELL, CENTRAL SWAMP DEPOBELT, NIGER DELTA BASIN, SOUTHERN, NIGERIA.

BY

Martha Aniebonam BASIL

LSC2009867

DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY

FACULTY OF LIFE SCIENCES,

UNIVERSITY OF BENIN,

BENIN CITY, NIGERIA.

NOVEMBER, 2025.

SEDIMENTOLOGY AND FORAMINIFERA ABUNDANCE PATTERN OF THE SEDIMENTARY SUCESSION PENETRATED BY THE DRILL IN MF-3 WELL, CENTRAL SWAMP DEPOBELT, NIGER DELTA BASIN, SOUTHERN, NIGERIA.

BY

Martha Aniebonam BASIL

LSC2009867

BEING A PROJECT SUBMITTED TO THE DEPARTMENT OF SCIENCE LABORATORY TECHNOLOGY,FACULTY OF LIFE SCIENCE,UNIVERSITY OF BENIN,BENIN CITY IN PARTIAL FULFILMENT OF THE AWARD OF BACHELOR OF SCIENCE DEGREE(B.Sc HONS)IN SCIENCE LABORATORY TECHNOLOGY

NOVEMBER, 2025.

CERTIFICATION

This is to certify that this project work was carried out by Martha Aniebonam BASIL with matriculation number LSC2009867 in the Department of Science Laboratory Technology, Faculty of Life Science, University of Benin, Benin City, Edo State, Nigeria.

Dr J.O Kinrin-Ola	**Date /Signature**
Project Supervisor	

Dr E.O Alonge	**Date /Signature**
Project Supervisor	

Prof J.O Osarumwense	**Date /Signature**
Head Of Department	

DEDICATION

This work is dedicated first to God Almighty for his unending grace and strength all these times and of course to my parents Mr and Mrs Basil for their unwavering prayers and support.

ACKNOWLEDGEMENT

I give thanks to the God Almighty who stood by me from the beginning of this program to the end.

I appreciate the Head of Department of Science Laboratory Technology Professor J.O Osarumwense for your support and training you gave me during this program.

Special thanks to my supervisor and lecturer Dr. J.O. Kinrin-ola for the guidance, teachings and trainings you gave me during this program and for making this project work a success.

I appreciate my lecturers Dr.ken Okija, Mr. Peter Bassey and all other

lecturers of the Department of Science Laboratory Technology University of Benin, Benin City, Nigeria.

I also appreciate the management of Earth probe laboratory for providing the data used for this project analysis.

Special thanks to my Parents Mr. and Mrs. Basil and my siblings for the prayers, support and advice they gave me during this program.

To my friends Godstime Egheose Esene, Abraham Oriaifo,Edosa, Edughaen Frances, Otaniyen and coursemates, thank you all for your immense support to me during this program.

TABLE OF CONTENTS

ABSTRACT

This study integrates sedimentological and foraminifera analyses of five (5) ditch-cutting samples obtained at 60 ft intervals from depths 11,550 ft to 11,790 ft in the MF-3 Well, located within the Niger Delta Basin. The investigation aimed to study the sedimentology and foraminifera abundance patterns in the well and objectively interpret the lithologic characteristics, foraminifera diversity and abundance, age and depositional environments of the studied interval. Standard sedimentological and micropaleontological techniques were employed to process and examine the samples. Sedimentologic characteristics were determined based on textural parameters such as grain size, lithology, lithofacies, color, angularity, roundness and sorting . Each 20 g sample was soaked, washed, sieved, dried, and examined under a binocular stereo microscope for foraminifera identification and quantitative assessment.

The sedimentological analysis revealed intercalating shalysand lithofacies, one (1) lithofacie unit . One (1) hydrocarbon play element (reservoir rock) was delinated in the well section. The associated minerals delineated in the well includes Iron oxide (heamatite), mica, quartz, feldspar, and tourmaline. The shaly sands are fine to medium-grained, moderately sorted, and quartz-rich, organic indicating marine incursions.

The foraminifera analysis recovered the following species *Hanzawaia strattonii, Ammonia beccarii, Haplophragmoides narivaensis, Cibicorbisinflata, Bolivina scalprata miocenica, Heterolepa pseudungeriana, Spirosigmoilina oligocaenica, Bathysiphon sp, Florilus costiferum (Nonion 4 sp), Trochammina sp, Epistominella vitrea, Valvulineria sp and Uvigerina subperegrina*. A Middle to Late Miocene age and paralic to open shallow-marine (inner neritic) paleoenvironments of deposition was assigned to the studied well section.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

The Niger Delta Basin of southern Nigeria is one of the world's most prolific petroleum provinces and has been the focus of extensive geological, geophysical, and paleontological research for over six decades. Central to this understanding is the study of microfossils, particularly foraminifera, which serve as critical tools in stratigraphic correlation, paleoenvironmental reconstruction, and hydrocarbon exploration. The effectiveness of foraminifera as biostratigraphic markers arises from their abundance, wide geographic distribution, relatively rapid evolutionary rates, and sensitivity to ecological changes (Murray, 2006; Haq & Boersma, 1998).

Foraminifera are single-celled protists characterized by their hard shells or tests, typically composed of calcium carbonate or agglutinated sediment particles. They are generally classified into two groups: planktonic (free-floating in the water column) and benthic (bottom-dwelling). In sedimentary basins such as the Niger Delta, both types are well represented and serve different but complementary roles in biostratigraphy and paleoecology (Petters, 1982; Okosun & Liebau, 1999). Their fossilized remains, preserved in sedimentary successions, provide crucial information on the age and depositional environments of the strata in which they are found.

The Niger Delta Basin developed in the early Tertiary as a result of subsidence along the passive continental margin of West Africa. It is characterized by a thick sedimentary wedge exceeding 12,000 meters in some areas, predominantly made up of deltaic and shallow marine deposits derived from the erosion of the West African hinterland (Doust & Omatsola, 1990). Three major lithostratigraphic units define the delta's subsurface architecture: the Akata Formation (prodelta shales), the Agbada Formation (alternating sandstones and shales of delta front and distributary systems), and the Benin Formation (continental sands) (Short & Stauble, 1967; Avbovbo, 1978).

The Agbada Formation, in particular, is of significant interest to biostratigraphers and petroleum geologists because it serves as the main reservoir unit of the basin and is often richly fossiliferous. Foraminifera recovered from this unit have been used to define biozones, date depositional episodes, identify unconformities, and interpret sea-level fluctuations (Reijers, 2011). However, despite the extensive use of foraminiferal biostratigraphy in petroleum exploration across the basin, many wells remain either under-sampled or insufficiently analyzed at a high resolution.

Recent advancements in quantitative foraminiferal analysis have made it possible to go beyond traditional presence/absence or qualitative zonation models. Instead, researchers now emphasize the abundance patterns, diversity indices, and ecological significance of assemblages to infer depositional environments, paleosalinity, and paleooxygenation levels (Van der Zwaan et al., 1990; Okosun & Oboh-Ikuenobe, 1996). By focusing on the abundance distribution of foraminifera across a sedimentary succession in a specific well, researchers can trace subtle environmental gradients and reconstruct a more refined depositional history.

This study seeks to contribute to this growing body of knowledge by analyzing the foraminifera content of a sedimentary sequence penetrated by drilling in a selected well in the central depobelt of the Niger Delta Basin. The goal is to evaluate foraminifera abundance patterns within the succession and interpret their implications for the biostratigraphy, paleoenvironments, and sequence stratigraphy of the studied interval.

Given the increasing complexity of petroleum exploration and the need for high-resolution stratigraphic tools, such microfossil-based approaches provide vital support for reservoir correlation, age dating, and depositional modeling. The research not only fills a knowledge gap for the selected well but also supports regional stratigraphic synthesis, contributing to the broader understanding of the Niger Delta's evolution and petroleum systems

1.2 STUDY AREA

The Niger Delta Basin, located in southern Nigeria, is one of the most prominent sedimentary basins in West Africa and a globally significant hydrocarbon province. Geographically, the basin covers an area of approximately 75,000 km² and extends from about latitude 3°N to 6°N and longitude 5°E to 8°E, bordered by the Gulf of Guinea to the south, the Anambra Basin to the north, the Dahomey Basin to the west, and the Calabar Flank and Abakaliki Fold Belt to the east (Reijers, 2011; Doust & Omatsola, 1990).

The MF 3 well investigated in this study is located in the Central Depobelt of the basin, a zone characterized by active deltaic progradation, thick sediment accumulation, and high subsidence rates. This area falls within the subequatorial climatic zone and is influenced by the hydrology of the Niger River and its distributaries. The central depobelt plays a critical role in petroleum exploration due to its thick sequences of hydrocarbon-bearing sediments and its transitional depositional environments, which range from delta plain to shallow marine settings (Evamy et al., 1978; Nton, 2001).

Geologically, the Niger Delta was formed during the Paleogene as a result of the southward progradation of sediments from the Benue Trough, following the breakup of the South American and African plates. This process led to the development of a classic tripartite lithostratigraphic succession: the Akata Formation, the Agbada Formation, and the Benin Formation (Short & Stauble, 1967). The Akata Formation, predominantly composed of marine shales, forms the basal unit and is believed to serve as the principal source rock in the basin. Overlying this is the Agbada Formation, consisting of alternating sand and shale sequences deposited in delta front to prodelta settings. The uppermost unit, the Benin Formation, is made up of continental sands deposited in fluvial environments.

The study well penetrates these lithostratigraphic units, with a significant focus on the Agbada Formation, which is of particular interest due to its heterogeneity and fossiliferous nature. The foraminiferal assemblages within this unit reflect varying paleoenvironments, from marginal marine (e.g., estuarine and delta front) to open marine settings. The fluctuating conditions in this formation support the preservation of diverse benthic and planktonic foraminifera populations, making it ideal for paleoenvironmental and biostratigraphic investigations (Petters, 1982; Oyede & Bassey, 2014).

Tectonically, the basin is underlain by a series of growth faults and rollover structures formed due to differential loading and sediment compaction. These structures play an essential role in hydrocarbon entrapment and stratigraphic architecture. The central depobelt, where the study is concentrated, exhibits a well-developed system of growth fault-related structures that control sediment accommodation space and influence depositional patterns (Doust & Omatsola, 1990; Reijers, 2011).

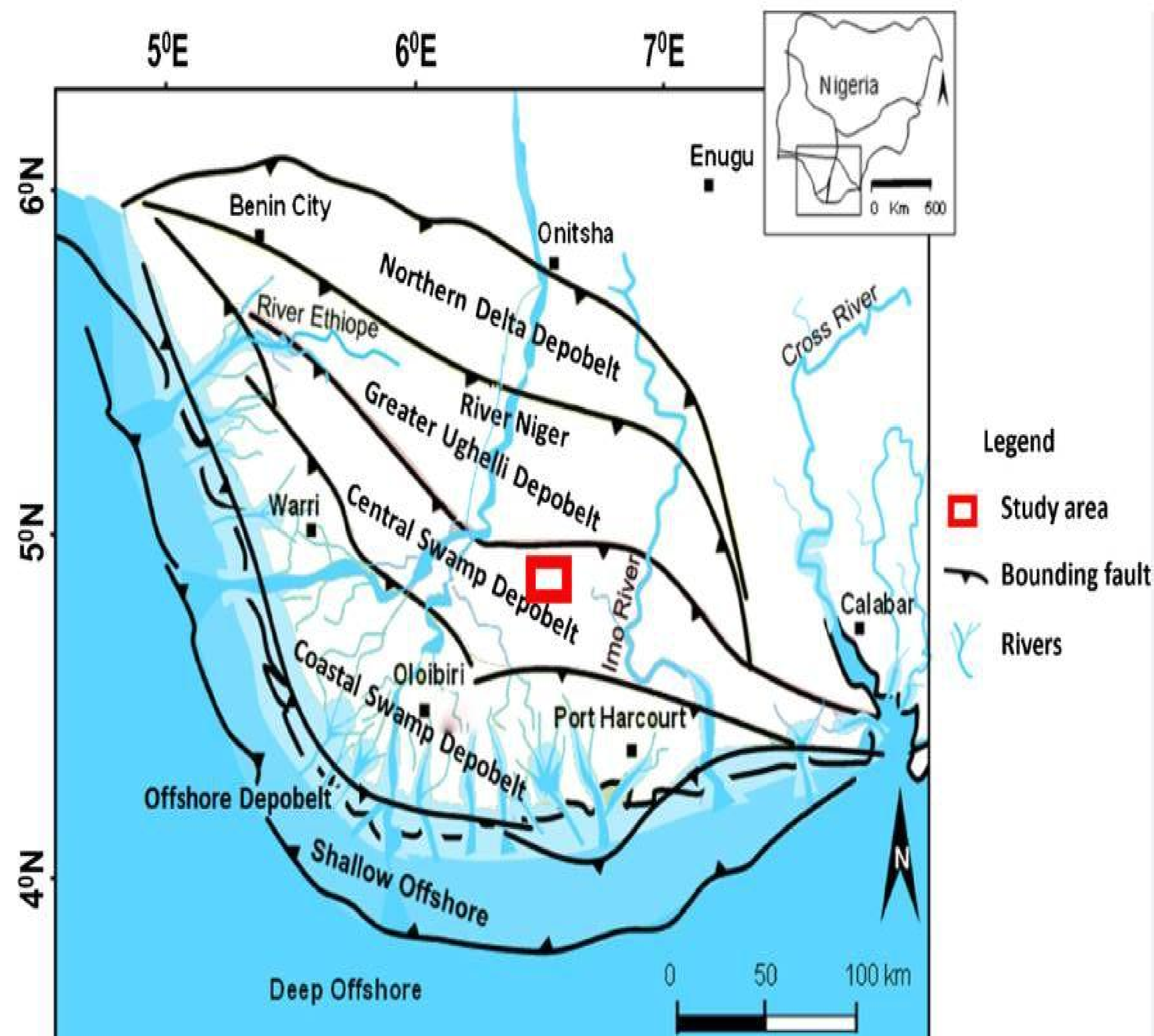
Climatically, the region is typified by high humidity and heavy rainfall, which influences the weathering of source rocks and the input of terrestrial sediments into the delta system. These conditions, in turn, impact sediment composition and faunal distribution in the subsurface.

In terms of paleogeography, the Niger Delta has undergone significant transgressive-regressive cycles throughout the Cenozoic. These sea-level fluctuations are well documented in the sedimentary record and are reflected in the stratigraphic stacking patterns and faunal distributions within well penetrations (Vail et al., 1977; Knox & Omatsola, 1987). The well in question captures these transitions and provides an excellent opportunity to evaluate the response of foraminiferal populations to changing depositional conditions.

From a micropaleontological perspective, the central region of the delta is particularly useful for the study of foraminifera abundance due to its transitional settings. The mixture of marine and continental influences enhances the diversity and preservation potential of both benthic and planktonic species, making it suitable for establishing detailed biostratigraphic frameworks and paleoenvironmental models (Ukaegbu & Uzoegbu, 2010).

Thus, the study area is strategically located to offer valuable insights into the stratigraphic complexity, paleoenvironmental dynamics, and microfossil distribution within the Niger Delta Basin, contributing not only to academic research but also to practical applications in hydrocarbon exploration and production.

Fig 1.0 LOCATION MAP OF MF 3 WELL



1.3 AIM OF THE STUDY

The primary aim of this study is to evaluate the abundance patterns of foraminifera assemblages within the sedimentary succession penetrated by a drilled well in the Niger Delta Basin. This involves identifying and analyzing the vertical and lateral distribution of both planktonic and benthic foraminifera across different stratigraphic intervals within the well, with the goal of interpreting paleoenvironmental conditions and contributing to a high-resolution biostratigraphic framework.

This research seeks to enhance the understanding of how foraminifera abundance correlates with depositional environments, sea-level changes, and sedimentological variations within the studied formation. Through this approach, the study aims to improve the accuracy of stratigraphic correlations within the basin and support more refined paleoenvironmental reconstructions and sequence stratigraphic interpretations.

In addition, the study aims to bridge existing knowledge gaps in micropaleontological research in the Niger Delta by focusing on a well that has either not been previously studied or inadequately analyzed in terms of quantitative microfossil distribution. Ultimately, this will support petroleum system analysis by providing insight into the relationship between fossil abundance, reservoir distribution, and depositional history in the basin.

1.4 OBJECTIVES

To achieve the overarching aim of assessing the foraminifera abundance pattern within the sedimentary succession of a drilled well in the Niger Delta Basin, the study is guided by the following specific objectives:

1. To identify and classify the foraminifera species present within selected intervals of the well section, with attention to both planktonic and benthic forms.
2. Delicate lithofacies in the well.
3. To quantify the abundance and distribution patterns of foraminifera taxa across the stratigraphic succession in order to establish vertical and lateral trends.
4. To interpret the paleoenvironmental conditions (e.g., marine, marginal marine, or continental influence) using the composition, diversity, and abundance of foraminifera assemblages.
5. To delineate potential biozones and biostratigraphic markers based on the stratigraphic ranges and abundance peaks of key foraminifera species.
6. To infer relative sea-level changes and depositional dynamics using foraminifera assemblage shifts and abundance fluctuations within the studied sequence.
7. To contribute to sequence stratigraphic analysis by integrating foraminifera data with lithologic information from the well logs or cores.
8. To provide micropaleontological support for regional stratigraphic correlation and hydrocarbon reservoir prediction within the central Niger Delta Basin

1.5 STATEMENT OF THE PROBLEM

evaluating the vertical abundance patterns of foraminifera, this study can help detect subtle

Despite the long history of geological and biostratigraphic research in the Niger Delta Basin, there remain significant gaps in the high-resolution analysis of foraminifera abundance patterns within individual well penetrations. While several studies have addressed regional stratigraphy using microfossils, many have primarily focused on species identification and broad biozonation frameworks, often neglecting the quantitative and ecological interpretation of foraminifera distribution in By relation to environmental change (Petters, 1982; Okosun & Oboh-Ikuenobe, 1996).

In many wells across the Niger Delta, sedimentary successions are still underutilized in micropaleontological studies, especially in terms of correlating faunal abundance to sea-level fluctuations, sedimentary regimes, and paleoenvironmental gradients. This limitation hinders the full application of foraminifera data for sequence stratigraphic modeling, which is critical for hydrocarbon reservoir prediction and correlation (Reijers, 2011). In some instances, the lack of detailed abundance data also makes it difficult to distinguish between closely spaced depositional events or to recognize subtle transgressive-regressive cycles.

Additionally, environmentally sensitive benthic foraminifera, which can serve as excellent indicators of oxygenation, salinity, and substrate conditions, are frequently overlooked or reported without sufficient quantitative context. This presents a major challenge for developing paleoenvironmental models that can accurately reflect depositional settings in transitional zones like delta fronts, estuaries, and shallow marine shelves (Van der Zwaan et al., 1990).

Furthermore, the growing complexity of petroleum exploration and development in the Niger Delta demands more refined biostratigraphic and paleoenvironmental frameworks. Traditional lithostratigraphic techniques alone are insufficient to resolve stratigraphic ambiguities in structurally complex areas, and the absence of integrated microfossil data may lead to misinterpretation of depositional sequences and reservoir architecture (Doust & Omatsola, 1990).

This study therefore addresses a clear gap: the need for high-resolution, quantitative analysis of foraminifera abundance patterns in individual well successions in the Niger Delta. By examining the vertical distribution of foraminifera, interpreting their ecological implications, and integrating these findings with sedimentological observations, the study aims to produce more accurate models for stratigraphic correlation and environmental reconstruction.

1.6 JUSTIFICATION OF THE STUDY

The justification for this study lies in the crucial role that foraminifera, particularly their abundance and distribution patterns, play in reconstructing the geological and environmental history of sedimentary basins. The Niger Delta Basin, being a complex and prolific hydrocarbon province, requires increasingly refined analytical tools for stratigraphic correlation, paleoenvironmental interpretation, and reservoir prediction. Traditional lithostratigraphic methods, while important, are often insufficient in resolving the subtle depositional changes and diachronous stratigraphic boundaries characteristic of deltaic environments. This study offers a microfossil-based solution by leveraging the ecological and stratigraphic sensitivity of foraminifera assemblages.

In particular, quantitative foraminifera analysis provides a powerful approach for identifying depositional sequences, correlating reservoir units, and delineating transgressive-regressive cycles within well shifts in environmental conditions, such as changes in water depth, salinity, oxygen levels, and sedimentation rates — all of which are critical for interpreting the geological evolution of the delta system.

Furthermore, the Niger Delta continues to evolve as a hydrocarbon province, with increasing exploration activities moving into deeper and more structurally complex terrains. These regions often lack high-resolution stratigraphic frameworks, especially in under-studied or newly drilled wells. This research contributes to closing that gap by providing detailed micropaleontological insights that can improve basin modeling, well planning, and field development strategies.

The study is also justified from an academic perspective. While many studies have been conducted on the Niger Delta, few have placed emphasis on detailed abundance-based analysis of foraminifera assemblages in individual wells. Most available works focus primarily on biozonation or broad paleoenvironmental interpretations. This research therefore offers a more data-driven, site-specific approach, adding to the scientific literature by producing empirical evidence that can be used for regional correlation and environmental reconstruction.

In addition, the integration of microfossil data with sedimentological information has the potential to support sequence stratigraphic applications, especially in identifying maximum flooding surfaces, condensed sections, and parasequence boundaries. Such detailed interpretations are essential not just for academic studies, but also for exploration geologists, biostratigraphers, and reservoir engineers involved in petroleum resource management.

Ultimately, this study has both scientific and practical value. Scientifically, it expands our understanding of how microfossil abundance patterns reflect depositional processes in a dynamic deltaic setting. Practically, it provides valuable tools and interpretations that can support more efficient hydrocarbon exploration and production in the Niger Delta Basin

CHAPTER TWO:

LITERATURE REVIEW

2.1 Geological Setting

General Geology of the Niger Delta Basin

The Niger Delta Basin is one of the largest subaerial sedimentary basins in Africa, covering a subaerial area of approximately 75,000 km² and a total area of about 300,000 km², with a sediment fill exceeding 500,000 km³ and depths ranging from 9–12 km (Tuttle *et al.,* 1999). It is a Tertiary deltaic complex located on the west coast of Africa in the Gulf of Guinea, primarily within southern Nigeria, extending into parts of Cameroon and Equatorial Guinea (Short and Stauble, 1967). The basin formed as a result of the rifting and drifting phases of the South Atlantic Ocean, beginning in the Late Cretaceous, and has since accumulated thick clastic sediments from the Niger River and its tributaries (Tuttle *et al.,* 1999). These sediments were deposited in a regressive sequence over an oceanward-dipping continental basement, influenced by tectonic subsidence, sediment supply, and eustatic sea-level changes (Reijers, 2011).

The basin's geology is characterized by a tripartite depositional framework: marine shales of the Akata Formation at the base, paralic sands and shales of the Agbada Formation in the middle, and continental sands of the Benin Formation at the top (Short and Stauble, 1967; Tuttle *et al*., 1999). This setup has made the Niger Delta one of the world's most prolific hydrocarbon provinces, with over 37 billion barrels of oil equivalent discovered, primarily in the Agbada Formation (Evamy *et al*., 1978). The coastal sedimentary history includes three major depositional cycles: a middle Cretaceous marine incursion, a Late Cretaceous Benue Trough transgression, and the dominant Tertiary deltaic progradation (Short and Stauble, 1967). Shale diapirism and growth faulting due to rapid loading have further complicated the structural fabric (Doust and Omatsola, 1990).

Diagram of the Niger Delta Basin

A representative geological map of the Niger Delta Basin illustrates its position within Nigeria, highlighting the basin's boundaries, the adjacent Benue Trough to the north, and the offshore extent into the Gulf of Guinea (Reijers, 2011). Key features include the northern onshore limit defined by the Anambra Basin and the eastern boundary along the Cameroon Volcanic Line (Tuttle *et al.,*1999). For visualization,see below which shows sediment thickness contours and major structural elements (Wikipedia, 2024). Alternatively, a detailed sectional map can be viewed at:

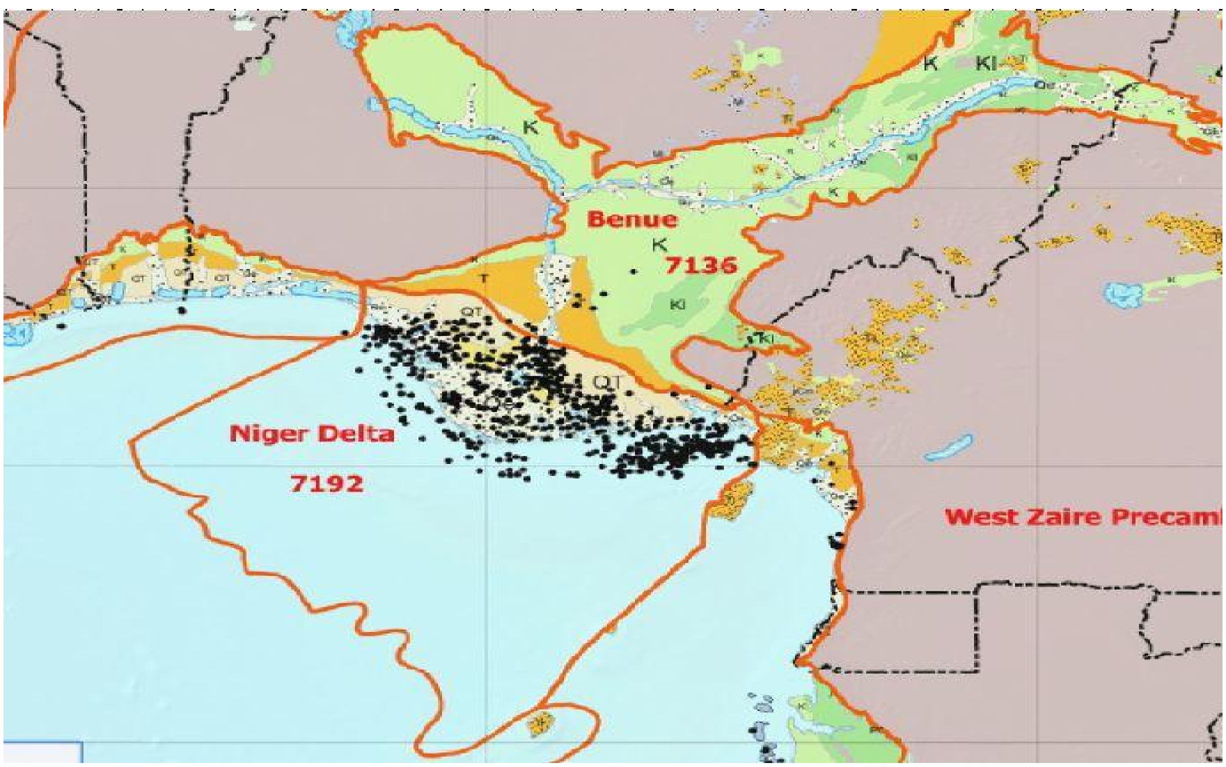


Fig 1.1

Geological map of the Niger Delta Basin and the Benue trough,and the oil fields in the region.

2.2 Stratigraphy of Niger Delta basin

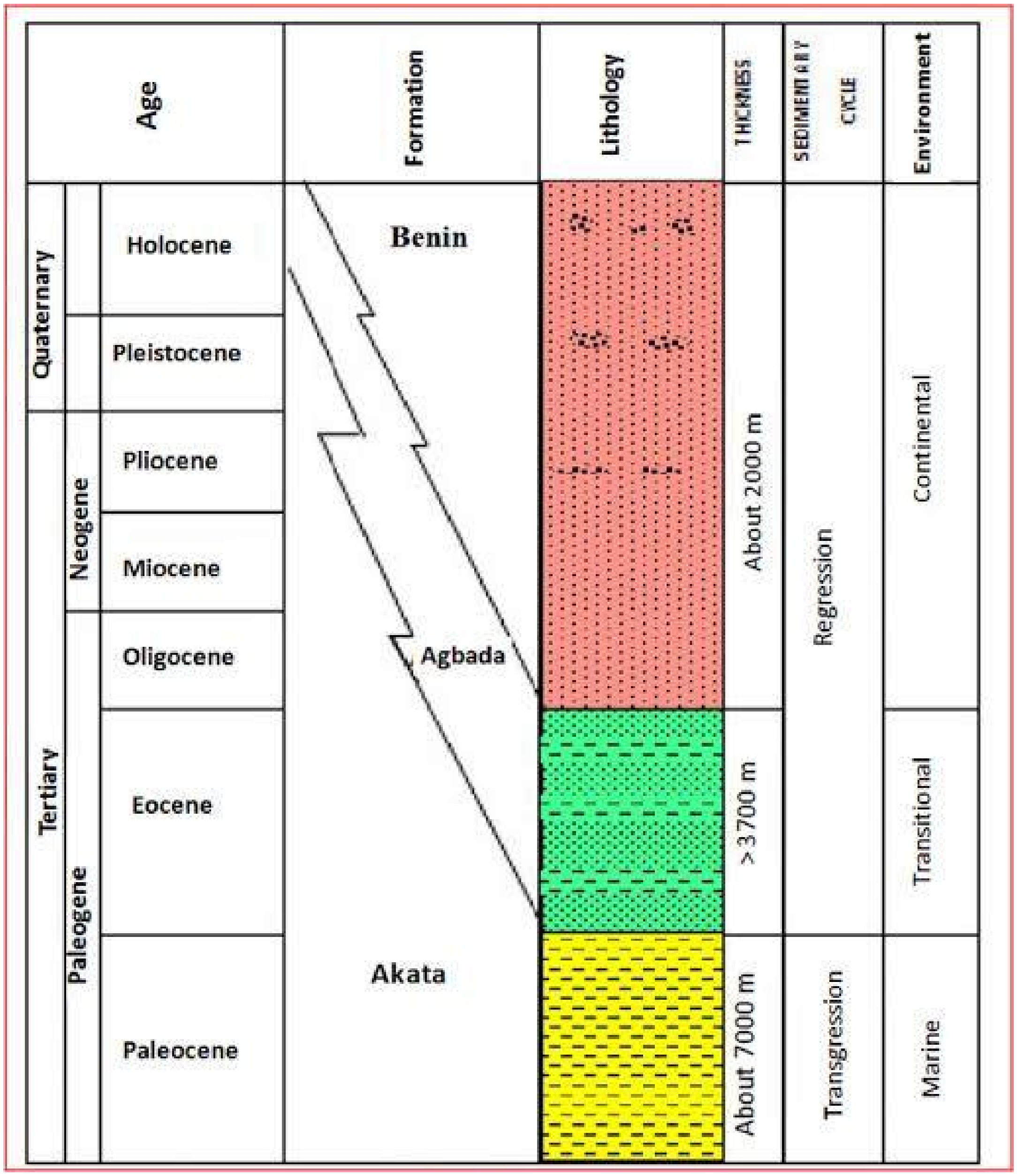
The stratigraphy of the Niger Delta Basin is defined by three major lithostratigraphic units that young basinward, reflecting a progradational deltaic system: the Akata, Agbada, and Benin Formations (Short and Stauble, 1967; Tuttle et al., 1999). The Akata Formation (Eocene to Recent) consists of thick, dark-gray marine shales with minor turbidite sands, representing the prodelta to deep marine environment and serving as the primary source rock due to its organic-rich content (Tuttle *et al.,* 1999). It thickens southward, reaching up to 7 km in the offshore areas (Reijers, 2011).

Overlying it is the Agbada Formation (Eocene to Recent), a paralic sequence of interbedded sandstones, siltstones, and shales, deposited in delta-front to delta-plain settings (Short and Stauble, 1967). This formation is the main reservoir and seal unit, with hydrocarbons trapped in rollover anticlines and fault blocks; it varies in thickness from 1–4 km and records multiple offlap cycles influenced by syndepositional tectonics (Tuttle *et al.,* 1999; Reijers, 2011). The uppermost Benin Formation (Eocene to Recent) comprises continental to upper delta-plain sands, often unconsolidated, with minor clay intercalations, forming aquifers and capping the delta at thicknesses of 0.5–2 km (Short and Stauble, 1967).

These units are complicated by syndepositional shale mobilization and collapse, leading to diachronous boundaries (Doust and Omatsola, 1990). Sequence stratigraphy reveals seven major seismic units in the Neogene section, with transgressive-regressive cycles tied to eustatic fluctuations (Reijers, 2011). The overall stratigraphy reflects pulses of sedimentation over the Benue Trough basement, with the Imo Shale (Paleocene) marking the basal deltaic unit .

Table 1:Sequence Stratigraphy of Niger Delta basin ,according to Ajibola 2004.

.



2.3 Structural Evolution of the Niger Delta basin.

The structural evolution of the Niger Delta Basin began with an early rifting stage in the Late Jurassic to Early Cretaceous, associated with the opening of the South Atlantic, followed by a transition to passive margin drifting in the Late Cretaceous (Tuttle *et al.,* 1999; Briggs et al., 2021). This led to thermal subsidence and initial sediment loading over the continental-oceanic crust boundary (Reijers, 2011). By the Eocene, rapid progradation initiated the delta's growth, with basement tectonics (e.g., along the Equatorial Atlantic Fracture Zone) influencing early fault patterns but becoming subordinate to gravitational tectonics (Tuttle *et al.,* 1999).

The dominant structural style is extensional, driven by differential loading of thick sediments on overpressured Akata shales, resulting in listric growth faults, rollover anticlines, and shale ridges/diapirs (Doust and Omatsola, 1990; Corredor *et al.,* 2005). The basin evolved through sequential depobelt development, with each depobelt (30–60 km wide) migrating southward as the delta prograded 250 km into the Gulf of Guinea (Tuttle *et al.,* 1999). Key phases include: (1) Eocene initiation with northern depobelts dominated by simple listric faults; (2) Oligocene-Miocene acceleration of shale mobilization, forming detachment folds, minibasins, and thrust-shear-fold-bend structures; and (3) Pliocene-Quaternary compression in the deep offshore due to contractional toe-thrusting (Briggs et al., 2021; Corredor *et al.,* 2005).

This evolution created a complex deformational belt, with syndepositional collapse of the clastic wedge and shale-cored anticlines trapping hydrocarbons (Doust and Omatsola, 1990). Recent studies highlight the role of shale deformation in controlling prospectivity, with thermal subsidence models indicating episodic uplifts and folding (Reijers, 2011).

2.4 Local and Regional Geology of the Delta Basin

Regionally, the Niger Delta Basin forms part of the West African passive margin, bounded to the north by the Precambrian Basement Complex and the Benue Trough, to the east by the Cameroon Volcanic Line, and to the west by the Dahomey Embayment (Tuttle *et al.,*1999; Reijers, 2011). It overlies the Anambra Basin and extends offshore into the Gulf of Guinea, covering Nigeria, Cameroon, and Equatorial Guinea (Short and Stauble, 1967). The regional tectonics reflect the breakup of Gondwana, with the basin's fill influenced by the Niger-Benue fluvial system and equatorial climate, depositing over 12 km of Cenozoic clastics (Reijers, 2011).

Locally, within southern Nigeria (the focus of the MF3 well), the geology is dominated by the Tertiary deltaic succession in the Coastal Swamp and Greater Ughelli depobelts (Dim *et al.,* 2017). The area features Quaternary alluvium and mangrove swamps overlying the Benin Formation, with underlying Agbada reservoirs exhibiting high porosity (20–30%) but fault-dependent seals (Anyiam *et al.,* 2020). Local structures include en echelon faults and shale smears, while regionally, the basin's regressive nature contrasts with the underlying transgressive Cretaceous Benue Trough sequences (Tuttle *et al.,* 1999). Paleoenvironmentally, the region transitions from deep marine (Akata) to fluvial-deltaic (Benin), with foraminifera assemblages indicating shallowing trends (Nwaejije *et al.,* 2017).

2.41 Regional

The Niger Delta Basin, located in southern Nigeria along the Gulf of Guinea, is a large Tertiary sedimentary basin that developed from the Late Cretaceous rifting and subsequent opening of the South Atlantic Ocean. It comprises three main formations: the Akata Formation, consisting of deep marine shales that serve as the main hydrocarbon source rocks; the Agbada Formation, composed of alternating sandstones and shales deposited in delta-front environments and serving as the principal reservoir rocks; and the Benin Formation, made up of continental sands and gravels forming the uppermost sequence. Structurally, the basin is characterized by growth faults, rollover anticlines, and shale diapirs caused by gravity-driven deformation over ductile Akata shales, which created numerous hydrocarbon traps. Sediment deposition in the basin results from the interaction of fluvial, marine, and deltaic processes influenced by sea-level fluctuations. The Niger Delta has evolved through progressive delta progradation since the Paleocene, forming multiple depobelts that record the shifting delta front from onshore to deep offshore areas. Overall, it represents one of the world's most prolific petroleum provinces, with a complex interplay of tectonics, sedimentation, and biostratigraphic development controlling its geological framework.

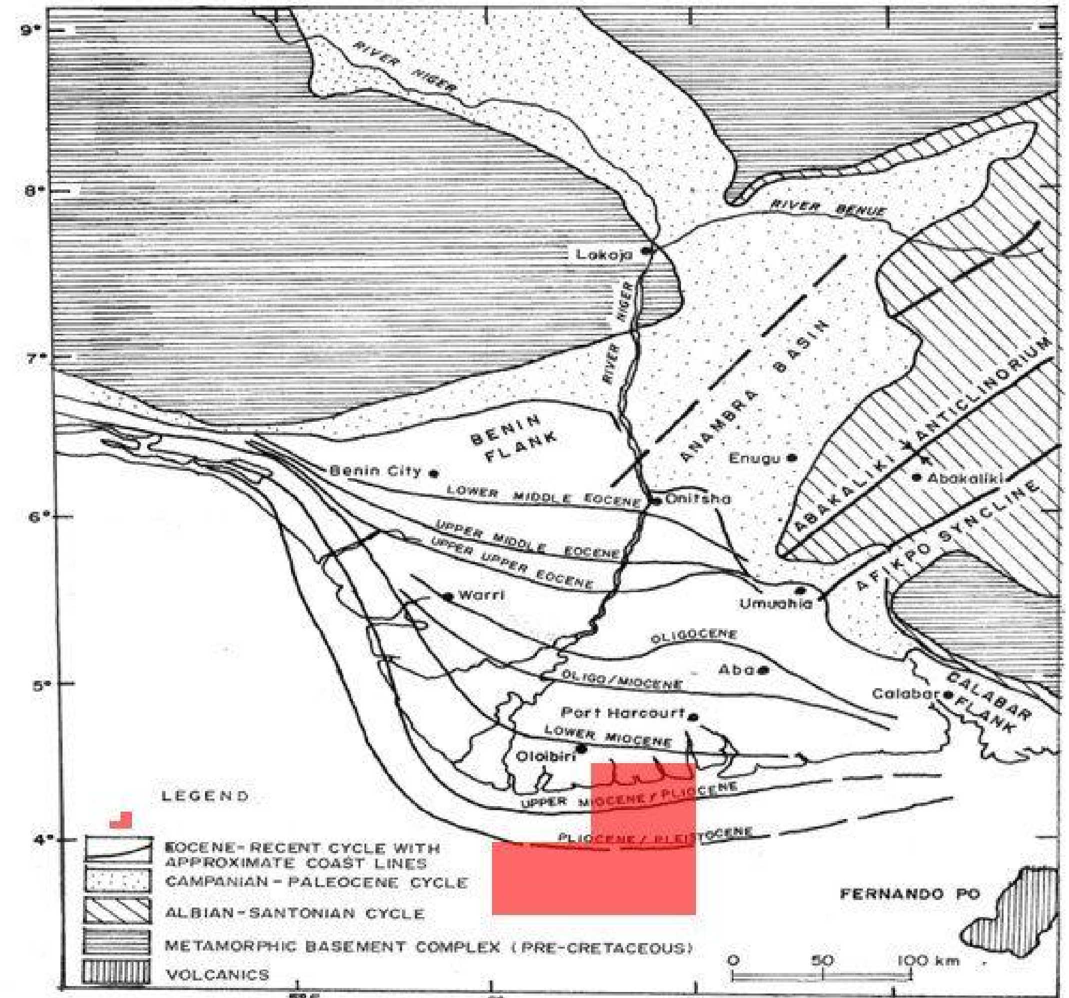
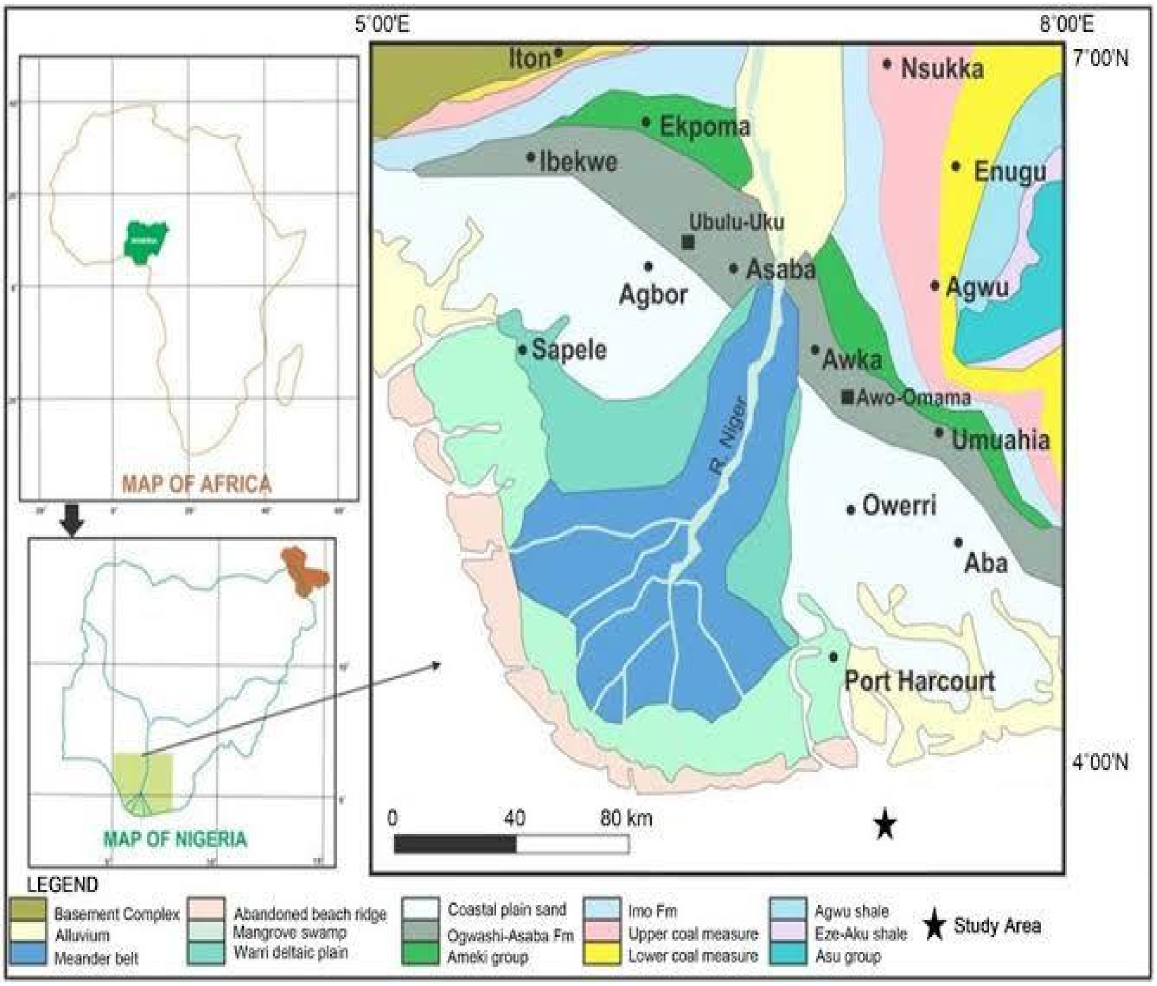


Fig 1.2 Regional map of Niger Delta basin

2.42 Local Geology of Niger Delta basin

The local geology of the Niger Delta Basin reflects the detailed subsurface and surface characteristics of specific areas within the broader regional framework. It is dominated by three main lithostratigraphic units—the Benin, Agbada, and Akata Formations—which show a progressive transition from continental to marine environments. The Benin Formation, exposed at the surface, consists mainly of coarse-grained sands, gravels, and minor shales deposited in fluvial and upper delta plain settings. Beneath it lies the Agbada Formation, composed of interbedded sandstones and shales representing delta-front and distributary channel deposits that serve as the main hydrocarbon reservoirs. At the base is the Akata Formation, made up of overpressured marine shales rich in organic matter, acting as both source and seal rocks. Locally, the geology is influenced by synsedimentary growth faults, rollover structures, and shale diapirs that create traps for hydrocarbons and control sediment thickness variations. The depositional environments range from mangrove swamps and tidal flats in the north to marine shelf conditions in the south, reflecting a complex interplay of fluvial input, marine reworking, and tectonic subsidence. Overall, the local geology demonstrates the basin’s dynamic depositional evolution and its significance for hydrocarbon accumulation and exploration.



2.5 Depobelts of the Niger Delta Basin

The sediment fill in the Niger Delta basin is characterized by three major depobelts. These three cycles show that the basin experiences an overall regression throughout time as the sediments go from deep sea mud-sized grains.

The lithologies of the area experienced changes due to several factors.

One factor would be the types of sediment coming though the delta, which could be influenced by sea level, or maybe volcanic activity in the area.

Deposition of the three Formations occurred in each of the five off lapping siliclastic sedimentation cycles that comprise the Niger Delta. These cycles (depobelts) are 30-60kilometres wide, prograde southwestwards 250kilometers over oceanic crust into the Gulf of Guinea (Stacher, 1995), and

are defined by syn-sedimentary faulting that occurred in response to variable rates of subsidence and sediment supply (Doust and Omatsola, 1990). Each

depobelt is a separate unit that corresponds to a break in regional dip of the delta and is bounded landward by growth faults and seaward by large counter-regional faults or the growth fault of the next seaward belt (Evamy et al, 1978;

Doust and Omatsola, 1990). Five major Depobelts are generally recognized,

each with its own sedimentation, deformation, and petroleum history.

Doust and Omatsola 1990) describe three Depobelt based on structure.

The Northem delta province, which overlies relatively shallow basement, has the oldest growth faulte that are generally rotational, evenly spaced, and increases their steepness seaward. The central delta province has Depobelts with well-defined structures such as successively deeper rollover crests that shift seaward for any given growth fault. Last, the distal delta province is the most structurally complex due to internal gravity tectonics on the modern continental slope.

Seven major Depobelts are generally recognised, each with its own sedimentation, deformation and sedimentation history.

1. Northern Delta

2. Greater Ughelli

3. Central Swamp

4. Coastal Swamp

5. Offshore

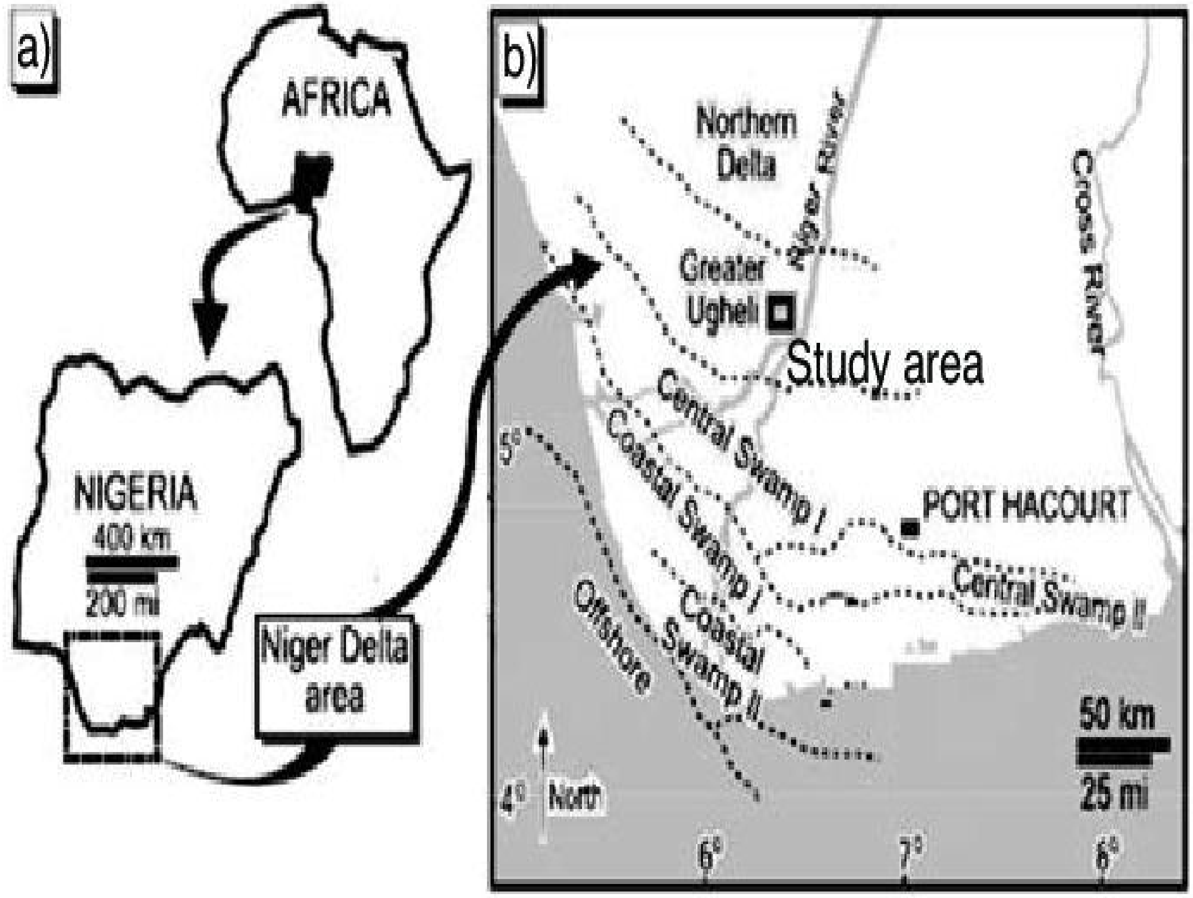


Fig1.2 Niger Delta Depo belt.

2.6 Previous Works on the Niger Delta

The following are previous studies on the geology of the Niger Delta Basin, focusing on structural, stratigraphic, and petroleum aspects

The first detailed work done on the Niger Delta was done by Shell Petroleum Development Company Nigeria limited in 1908. The early work carried out by Reyment 1969) focused on the geology of Niger-delta.

Most lithostratigraphical work containing information on the Basin's are

those carried out on a more regional scale. The early work on the Basin centres on its structure and includes; Hospers (1965) discussion of the Basin's Gravitational field and structure and concludes that the " Niger delta Minimum," a gentle gravity minimum reaching 40mgal which extends over the largest portion of the Basin which

may be a result crust uncovered displacement, differences within basement densities,

imperfect corrections for the presence of light sediments, or a combination of any of all these factors. Evamy et al., (1978) discussed on Hydrocarbon habitat of Tertiary Niger Delta). Short and Stauble (1967) worked on Niger Delta geology and established that the basin fill is made up of the Benin, Agbada and Akata Formation from youngest to oldest. Weber (1971) discussed on the Niger Delta Basin sedimentology. Murrat (1972) discussed on the southern Nigeria stratigraphy and paleogeography.

Weber and Daukoru (1975) discussed on the Basin's Petroleum Geology and concluded that faulting at the basement impedes the growth of delta and that depositional environments of reservoir sands strongly influence well productivity as well as recovery efficency. Avbobo (1978) worked on the Niger Delta Basin Lithostratigraphy and concluded that the composite Basin is made up three units;

Akata, Agbada and Benin Formation and that the southward prograding Tertiary Delta implies the Akata Formation, and the tributaries channels and deltaic plain environment representing the Agbada Formation.

Evamy and Haremboure (1978) discussed on Tertiary Niger Delta

Hydrocarbon Habitat and concludes that the Basin oil reserves reflects a double maxima statistical spread of slope break reflecting variation in the maturity of exploration, quality prospect and giant oil spread. Ejedawe (1981) worked on the Niger Delta Basin of Nigeria oil reserves pattern.

Adesida et al., (1997) worked on Niger Delta Basin Sequence Stratigraphic Framework and established that regional mega sequences is a base for lithostratigraphy throughout the Niger Delta

Lucas and Fregene (2018) worked on environmental reconstruction of the Oligocene to Early Miocene Sediment of Greater Ughelli Depobelt, Niger Delta Basin and concluded that the sediments were deposited between proximal to distal Inner Neritic environments. Balogun et al., (2019) worked on Geological Evaluation of Hydrocarbon Prospect of FOB-field, Coastal Swamp Depobelt, Onshore, Niger Delta and concluded that the alternation of the sand and shale in the studied interval lies in the Agbada Formation of the Niger Delta Basin.

Dim et al., (2019) discussed on the Basin's Sequence Stratigraphy and Petrophysical analysis and concludes that facies deposition exist in the offshore, shoreface and eustaurine channel portion.

Ikuoyomwen et al., (2022) worked on Lithofacies and Mineralalogical Composition of the Sedimentary Succession Penetrated by the Drill in AB-Well, Greater Ughelli Depobelt, Niger Delta Basin, Nigeria and concluded that the studied AB-Well in the Niger Delta Basin is situated in Greater Ughelli Depobelt has four (4) lithofacies that were identified in the well and they include; Sandstone, Shaly sand, Shale and Sandy shale. The minerals identified in the studied well are Mica, Quartz, Feldspar and Iron Oxide (Hematite). Thirty lithozones were identified in the studied well and they Short and Stauble (1967) - Outline of the geology of the Niger Delta, detailing depositional cycles and hydrocarbon potential.Weber (1971) - Hydrocarbon distribution and structural styles in the delta. comprises of thirteen (13) Sandstone unit, Nine (9) Shale unit, two (2) Sandy shale and six (6) Shaley sand unit.

Ikuoyomwen and Kinrin-ola (2022) worked on Hydrocarbon Play Elements of the Sedimentary Succession Penetrated by the Drill in AB-Well, Greater Ughelli Depobelt, Niger Delta Basin, Nigeria and concluded that the studied AB-Well in the Niger Delta Basin situated in Greater Ughelli Depobelt has four (4) lithofacies that were identified in the well and they include; Sandstone, Shaly sand, Shale and Sandy shale. The minerals identified in the studied well are Mica, Quartz, Feldspar and Iron Oxide (Hematite). Thirty lithozones were identified in the studied well and they comprises of thirteen (13) Sandstone unit, Nine (9) Shale unit, two (2) Sandy shale and six (6) Shaley sand unit.

Kinrin-ola et al., (2022a) worked on Hydrocarbon Play Elements of Sedimentary Succession Penetrated by the drill in OLA-1 Well, Niger Delta Basin, Southern, Nigeria and concluded that the studied OLA-1 well situated in Niger Delta Basin in Southern Nigeria has five (5) hydrocarbon play elements recognized and includes; source rock, reservoir rock, cap rock, seal rock and traps. Two (2) probable reservoirs, two (2) potential reservoirs, one (1) probable source rock, four (4) potential source rock, three (3) cap rocks, four (4) seals and three (3) traps.

Kinrin-ola et al., (2022b) worked on Lithofacies and Mineralogical Composition of Sedimentary Succession Penetrated by the drill in OLA-1 Well, Niger Delta Basin, Southern Nigeria and concluded the studied OLA-1 well situated in Niger Delta Basin in Southern Nigeria has four (4) lithofacies; Sandy Shale, Shale, Sandstone and Shaly Sand and four (4) minerals: Mica Tron Oxide (Haemetite) Feldspar and Quartz.

2.7 Previous Works on Biostratigraphy

Ola-Buraimo, A.O. and Akande, S.O. (2012) – Palynostratigraphic Study of Late Miocene–Pliocene Sediments, Niger Delta Basin, Nigeria

This research focused on pollen and spore assemblages from the Agbada Formation. Using species such as Zonocostites ramonae, Psilatricolporites crassus, and Retidiporites magdalenensis, they established detailed palynological zones corresponding to coastal plain and delta-front environments. Their study improved age dating of upper Miocene–Pliocene sediments and enhanced stratigraphic resolution in non-marine sections of the delta.

Akinmosin, A., Akintola, G.O., and Fadiya, S.L. (2011) – Foraminifera Biostratigraphy and Paleoenvironmental Interpretation of Well X, Niger Delta Basin Using benthic and planktonic foraminifera, this study reconstructed depositional environments across the middle to late Miocene succession. The authors identified foraminiferal biozones such as Globorotalia mayeri and Globigerinoides ruber zones, indicating marine transgressive sequences. Their findings helped refine petroleum reservoir correlations in subsurface Agbada intervals.

Olowokudejo, T.D., and Adekeye, O.A. (2016) – Integrated Foraminifera and Palynological Biostratigraphy of the Middle–Upper Miocene in Offshore Niger Delta Wells

This offshore-focused study applied a multidisciplinary biostratigraphic approach combining microfossils (foraminifera) and palynomorphs. The integration revealed high-resolution biostratigraphic zonations that correspond with global Neogene planktonic foraminifera zones. The study also outlined cyclic sedimentation influenced by marine transgressions.

Adesida, A.A., Adekeye, O.A., and Omoboriowo, A.O. (2018) – Micropaleontological and Paleoenvironmental Analysis of the Agbada Formation, Niger Delta Basin

This paper analyzed well cuttings and cores for both benthic and planktonic foraminifera. The researchers identified a mix of Ammonia beccarii, Bolivina sp., and Globigerinoides trilobus, signifying alternating inner and outer neritic environments. Their detailed biozonation framework was applied to petroleum well correlation and sequence stratigraphy.

Nton, M.E., and Esan, O.E. (2019) – Biostratigraphy and Depositional Environments of the Oligocene–Miocene Sequence in the Onshore Niger Delta Basin

This study used foraminifera and palynological analyses to define four biozones within the Oligocene–Miocene Agbada succession. The assemblages were dominated by Bolivina species and pollen grains of mangrove origin (Zonocostites ramonae), suggesting alternating marine and deltaic environments. It improved chronostratigraphic correlation in onshore fields.

Umeji, A.C., and Nwajide, C.S. (2020) – High-Resolution Biostratigraphy of the Eastern Niger Delta Basin Using Foraminifera Assemblages

This recent university-based study integrated modern micropaleontological techniques (including scanning electron microscopy) to redefine Miocene–Pliocene zonation. They proposed a refined local biozonation framework compatible with global marine biozones, supporting oil field correlation and paleoenvironmental reconstruction.

Oboh-Ikuenobe, F.E. et al. (2021) – Quantitative Palynofacies and Biostratigraphic Analysis of the Late Miocene–Pleistocene Successions, Western Niger Delta Basin

In this international collaboration, palynofacies (organic matter composition) and microfossil content were used to delineate depositional cycles and sequence boundaries. The study highlighted transitions from mangrove-dominated delta plains to marine shelf deposits and correlated them with global sea-level changes.

Ifeadi, I.P. and Onyekuru, S.O. (2022) – Foraminiferal Biostratigraphy and Paleoenvironmental Reconstruction of Well "A", Offshore Niger Delta Basin

A recent offshore study employing quantitative foraminiferal analysis. The identified species assemblages, including Globigerinoides quadrilobatus and Cibicidoides pseudoungerianus, defined three biozones corresponding to early, middle, and late Miocene. The study also used statistical paleoecology to interpret shifting sedimentary environments.

Okosun, E.A., and Oyebamiji, A.T. (2023) – Integrated Biostratigraphic and Sequence Stratigraphic Framework of the Deep Offshore Niger Delta Basin

This study used integrated foraminiferal, nannoplankton, and palynological data from deep offshore wells. It delineated key flooding surfaces and maximum flooding intervals, relating them to global sequence boundaries. Their findings improved the regional chronostratigraphic model for the deepwater petroleum systems.

Ezeh, C.C. and Ukaegbu, V.U. (2024) – Biostratigraphy and Paleoenvironmental Implications of the Miocene–Pliocene Sediments, Central Niger Delta Basin

This very recent study used modern statistical cluster analysis and ecological indices of benthic foraminifera to establish precise environmental gradients. The authors proposed refined Miocene–Pliocene zonations for the central delta and demonstrated the influence of climatic oscillations on microfossil distribution and sedimentation patterns

These recent studies (2011–2024) demonstrate how modern Niger Delta biostratigraphic research increasingly integrates micropaleontology, palynology, and sequence stratigraphy, often using digital modeling and quantitative paleoecological methods. They collectively refine the stratigraphic framework for hydrocarbon exploration, paleoenvironmental reconstruction, and geological correlation across onshore and offshore sectors of the basin.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 MATERIALS

Five (5) ditch cutting samples selected at 60ft from interval 11,550-11,790ft (240ft) were provided for foraminefera analyses. Each of these samples have been processed and analysed for its foraminifera contents and the results of these analyses are hereby presented.

For sedimentological analysis of the sample, the following materials were used;

I. Ditch cutting samples
II. Sieves
III. Slide
IV. Sample Bowl
V. Pan
VI. Hand lens
VII. Microscope
VIII. Distil water
IX. Water jet
X. Kerosene
XI. Dilute HCI
XII. Hot plate and Aluminum bowl.
XIII. Camera and GPS for documenting sample locations and field relationships.

The materials used for sedimentological analysis depend on the nature of the samples and the objectives of the study. For this research, the following materials and equipment were utilized:

I. Ditch cutting samples obtained from boreholes or outcrops

II. Sample containers and labels for proper identification and preservation of collected specimens.
III. Sieve sets and mechanical shaker for granulometric (grain-size) analysis.
IV. Weighing balance for precise mass measurement before and after sieving.
V. Petrographic microscope for textural and mineralogical observations of thin sections.
VI. Hydrometer and dispersing agent (e.g., sodium hexametaphosphate) for fine-grained sediment analysis.
VII. Sedimentological logs and field notebook for recording lithologic and structural observations.

Software tools such as Excel for data analysis and graphical presentation of results (e.g., grain-size distribution curves, cumulative frequency plots, and histograms).

3.2 METHODOLOGY

This work employs laboratory methodology for its samples and they includes:

I. Sedimentological analysis
II. Sedimentological description of samples
III. Biostratigraphy analysis

3.2.1 Sedimentological analysis

Sedimentological analysis is primarily carried out with the aid of a binocular microscope, sieve set, washing apparatus, ultrasonic bath, drying oven, and picking tools, supported by taxonomic references and analytical software.

3.2.1.1 Sedimentological description of samples

The sediments are generally sandy, silty, and occasionally clayey, reflecting alternating high- and low-energy depositional environments. After washing and sieving, the residues contained abundant foraminifera tests, along with fragments of shells, quartz grains, mica flakes, and minor heavy minerals.

The color of the samples ranges from light brown to grayish black, depending on the organic matter content and degree of oxidation. The sand-dominated samples are moderately sorted, while the finer sediments are poorly sorted with a higher concentration of organic debris and clay minerals.

The foraminifera tests occur as well-preserved, moderately preserved, or partially broken shells, indicating variable sediment

Texturally, the samples display intercalation of sand and shale sequence , reflecting cyclic sedimentation controlled by deltaic progradation and compaction and diagenetic effects.

The presence of bioturbated layers and calcareous cementation in some intervals indicates post-depositional modification in a moderately oxygenated marine setting.

In summary, the sedimentological description of the foraminifera samples indicates a paralic to shallow marine depositional environment, with alternating energy regimes and sediment supply that favored the accumulation and preservation of diverse foraminifera assemblages within the Agbada Formation of the Niger Delta Basin.

3.2.2 BIOSTRATIGRAPHY ANALYSIS WAS DONE AT EARTH PROBE

Five (5) ditch cuttings samples selected at 60ft interval from the interval 11,550 – 11,790ft (240ft),were provided for foraminifera analyses. Each of these samples have been processed and analyzed for its foraminifera contents and the results of these analyses are hereby presented. The samples were subjected to standard micropaleontological sample processing techniques (appendix).

About 20g of each of the samples were soaked with kerosene inside a clean, dry aluminium bowl, left for 24 hours to disaggregate as completely as possible. Disaggregated sample materials were washed through a 63 µm sieve to remove coagulated particles, and the fine residues were placed on the filter papers to drain before being left in an aluminium bowl and transferred to the oven to dry at 40C . Dried samples were then sieved through 250 µm, 125 µm and 63 µm sieves fractions for ease of picking. The samples were then picked using size 00 brush under a binocular stereo microscope.

All the picked specimens were then mounted on micropalaeontological slides and then quantitatively analyzed.

The foraminifera samples consist of fine- to medium-grained, unconsolidated or weakly lithified sediments recovered from various stratigraphic intervals within the study area.

Foraminifera recovery over these five (5) samples were generally sparse to moderate and moderately preserved. Rare planktic and few benthic foraminifera species (calcareous and arenaceous) are well represented in the studied well.

The for a minifera dating of these samples were guided by the works of Blow (1969, 1979) and Bolli and Saunders (1985) and benthic foraminiferal species whose stratigraphic distributions have been well established in the Nigerian Sedimentary basins were also used to assign ages.

Depositional environments were also referenced to the work of Adegoke et al (1976), Petter (1979,1982) and Murray (1991).

These tools together enable the recovery, identification, and interpretation of foraminifera assemblages to deduce the age, depositional environment, and paleoecological conditions of sedimentary successions**.**

Important foraminifera species recorded include planktic foraminifera Cassigerinella chipollensis and benthic foraminifera such as Ammonia beccarii, Uvigerina subperegrina, Florilis costiferum (Nonion 4 sp.), Bolivina scalprata miocenica, Hanzawaia strattonii, Heterolepa pseudoungeriana, Cibicorbis

inflata, Epistominella vitrea, Quinqueloculina seminulina, Haplophragmoides narivaensis, Trochammina sp and Ammobaculites agglutinans.

Microscopic examination revealed that the assemblage is dominated by both benthic and planktonic foraminifera, with benthic species such as Ammonia beccarii, Bolivina spp., Elphidium spp., and Nonion spp. occurring frequently, while planktonic forms such as Globigerinoides ruber, Globorotalia menardii, and Orbulina universa are present in the finer fractions. The relative abundance and preservation of these species suggest deposition in a shallow to middle neritic (marine) environment, influenced by fluctuating salinity and energy conditions typical of the delta-front and inner shelf settings of the Niger Delta

The distribution, abundance, and diversity of the recorded foraminifera species together with the foraminifera zones recognized are hereby presented.

Index forms among the recovered foraminifera species have been used in dating and zoning the intervals. The inferred age and depositional environment and the criteria on which the inferences are based are also provided alongside for each sample.

SAMPLE PREPARATION PROCEDURES AND TECHNIQUES

INTRODUCTION

The materials used for this study are ditch cutting samples of MF-3 well.

These samples were packed in a small labeled polythene bags which bears the name of the well and

depth of sampling. These were arranged serially in a wooden tray in the laboratory for lithologic

description and processing for foraminiferal recovery.

The lithologic description of the samples was done using a Meiji binocular stereoscope and wireline

logs provided.

FORAMINIFERAL SAMPLE PREPARATION PROCEDURES

Logging and Composition of Samples:

Samples were laid out sequentially in batches.

Pre-treatment of operations:

Prepare labels for each samples

Lay out clean samples plates

Place out the hot plate inside the fume cupboard.

Samples Treatment 1: Dry and weighing:

Place determined amount of samples into a plate. (25g)

Attached corresponding labels

Place the label sample plates securely on the hot plate.

Switch on the hot plate, regulate to temperature of about 80OC

Switch off hot plate after 2 – 3 hours.

Removing sample plate and allow cooling.

Weigh dried samples.

Sample Treatment 2: Soaking and Decanting

Soak samples in Kerosene.

Leave overnight to disaggregate.

Decant kerosene.

Cover sample with water and leave for 5 hours.

Sample Treatment 3: Sieving and Drying

Wash samples with water through four sieves 500, 250, 150, 63, microns sieves

Dry the four fractions.

Transfer sample into four different bags/phials and label accordingly.

Put the four in one plastic bag and label.

Transfer packaged samples to micropaleontological unit for picking, analysis and interpretation.

Foraminifera Analysis and Data |Interpretation

Foraminifera analysis was carried out by determining foraminifera specimens to the specific level

and/ or generic level.

Quantitative analysis was provided as follows:

Total foraminifera abundance per sample expressed in absolute numbers of individuals.

Total foraminifera diversity expressed in absolute number of species.

Total planktic abundance and diversity.

Total benthic abundance and diversity

Total arenaceous benthic and diversity

Planktic/benthic ratio

Data Interpretation

Four types of data interpretation are being done viz.

Biozonation

Standard low latitude biozonation of Blow (1966 & 1979) or any other published international zonation scheme may be used. Unpublished zonation scheme was employed with adequate explanation of zonal criteria.

Time – Stratigraphic Interpretation

Time-stratigraphy interpretation is provided where possible on a per sample basis.

Environment of Deposition

Microfaunal assemblages comprising diagnostic benthic and with occurrences of planktic species are

employed in the definition and delineation of paleobathymetry and their subsequent depositional

environments.

The entry marine realm is sub-divided into its various smaller components of proximal and distal

fluviomarine, inner neritic, middle neritic, outer neritic, bathyal, abyssal, while the lower coastal plain

realm is sufficiently delineated, based on recorded faunas

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Sedimentological Result

The sedimentary sequence penetrated by the studied interval (11,550 – 11,790ft) of MF-3 Well comprises of a succession of a predominantly shaly sand lithofacies.

Detailed lithologic descriptions of the MF-3 well ditch cuttings samples are presented in Table 4.1.

Table 4.1:Lithostratigraphic Chart of MF-3 Well, Niger Delta Basin

	DEPTH (FT)	**LITHOLOGY**	**DESCRIPTION**
1	11,550	SHALLY SAND	Sand (70%): milky white to glassy,fine ,subangular to subrounded well sorted sands. Shale (30%): Greyish to brownish , flaggy to fissile, moderately hard shale Accessories: Shell fragments
2	11,610	SHALYSAND	Sand (60%): milky white to glassy, fine to medium to coarse, subangular to subrounded, poorly sorted, Shale (40%): Greyish to brownish, flaggy to fissile, moderately hard shale Accessories: Few ferruginous materials

3	11,670	SHALY SAND	Sand (55%): milky white to glassy, fine to medium to coarse, subangular to subrounded, poorly sorted Shale (45%): Greyish to brownish, flaggy to fissile, moderately hard shale Accessories: ferruginous materials and few mica flakes
4	11,730	SHALY SAND	Sand (60%): milky white to glassy, fine, subangular to subrounded, well sorted sands. Shale (40%): Greyish to brownish, flaggy to fissile, moderately hard shale Accessories: Mica flakes
5	11,790	SHALY SAND	SAND Sand (55%): milky white to glassy, fine, subangular to subrounded, well sorted sands. Shale (45%): Greyish, fissile, moderately hard shale Accessories: Shell fragments and carbonaceous detritus,

The examined ditch cutting samples from depths 11,550–11,790 ft. reveal notable textural and compositional variations consistent with alternating delta-front to shallow marine sedimentation. The sediments are dominantly fine- to medium-grained sandstones interbedded with silty shales and claystones, indicating fluctuating depositional energy and sediment supply within the stratigraphic interval. The sandstones are moderately sorted and sub-angular to sub-rounded, composed mainly of quartz, feldspar, and lithic fragments, with minor mica and carbonaceous matter. The associated shales are dark gray to brown, soft, and fissile, containing fine silt and organic detritus.

Color variation between brownish-gray in sandy intervals and dark gray in shale layers reflects changing redox conditions and organic content. Sedimentary textures display gradational and coarsening-upward trends, suggesting successive depositional cycles typical of deltaic and shallow shelf settings. The moderate degree of sorting and sub-angular grain shapes point to deposition by fluvial-dominated currents with intermittent marine influence.

The lithologic characteristics, together with the microfaunal content, indicate a paralic to shallow marine depositional environment, corresponding to the upper Agbada Formation of the Niger Delta Basin. The presence of organic-rich shales suggests brief periods of reduced energy and low oxygenation, while the sandy units represent active sediment influx from distributary channels. The examined ditch cutting samples from depths 11,550–11,790 ft reveal notable textural and compositional variations consistent with alternating delta-front to shallow marine sedimentation. The sediments are dominantly fine- to medium-grained sandstones interbedded with silty shales and claystones, indicating fluctuating depositional energy and sediment supply within the stratigraphic interval. The sandstones are moderately sorted and sub-angular to sub-rounded, composed mainly of quartz, feldspar, and lithic fragments, with minor mica and carbonaceous matter. The associated shales are dark gray to brown, soft, and fissile, containing fine silt and organic detritus.

The lithologic characteristics, together with the microfaunal content, indicate a paralic to shallow marine depositional environment, corresponding to the upper Agbada Formation of the Niger Delta Basin. The presence of organic-rich shales suggests brief periods of reduced energy and low oxygenation, while the sandy units represent active sediment influx from distributary channels.

4.1.1 Sedimentological Description

Sedimentological description of MF-3 Well was based on examination of the sample under a binocular microscope. Lithologic description was carried out using textural parameters like grainsize, colour, shape, sorting and calcareous materials determined using dilute hydrochloric acid (HCI) on the sediments.

i. One (1) lithofacie was deduced from the analized section of the well, which is; Shaley Sand.

ii. One (1) informal lithofacie unit was identified in the analysed

section of the well.

ili. One (1) hydrocarbon play elements were also recorded in the well, which is,reservoir rock

Depth 11,550ft

It is a Sandy lithology consisting of Feldspar and coarse Quartz grains, light grey, fine to coarse, angular to sub-angular, well sorted Sandstone and lacks calcareous material (no evidence of fossil remain), having Quartz over growth as its cement.

Depth 11,550 ft -11,610 ft

It is a Sandy Shale lithology consist of milky brown, medium to coarse, moderately sorted fine Sandy Shale, composed of Mica, Feldspar, Quartz, IronOxide, and Calcareous material with Calcium carbonate as cement.

Depth 11,610 ft -11,670 ft

The Shale lithology is a dark grey, very fine to fine grain and fissile with a streak of lignite and plant materials which shows maturity. Mica, Feldspar, Iron Oxide and calcareous material with Calcium carbonate as its cementing material.

Depth 11,670 ft -11,730 ft

Is an interval compose of light grey Shale, medium to coarse, angular to sub angular, moderately sorted Shaly Sand, Mica, Feldspar and lacks calcareous material (no evidence of fossil remain), having Quartz over growth as its cement.

Depth 11,730ft -11,790 ft

The Shale lithology is a dark grey, very fine to fine grain and fissile with a streak of lignite and plant materials which shows maturity. Mica, Feldspar, Iron Oxide and calcareous material with Calcium carbonate as its cementing material.

The sediment samples from the studied interval are characterized by alternating sandyshale layers reflecting deltaic cyclicity. It's a sandy shale lithology consisting of milky brown ,medium to coarse ,moderately sorted fine shale,composed of Mica ,Feldspar ,Quartz ,iron Oxide,and Calcareous material with Calcium carbonate as cement.

Overall, the sedimentological features grain size, composition, sorting, and fossil content indicate deposition in a nearshore, paralic to inner neritic environment under alternating low and moderate energy conditions, consistent with Agbada Formation sediments of the Niger Delta Basin.

4.1.2 Lithofacies in MF-3 Well, Niger Delta Basin

One (1) lithofacies was deduced from the Analyzed section of MF -3 Well, which is Sandy Shale.

i. The analysis delineated Sandy shale at one (1) lithofacie unit.

Lithostratigraphic interpretations of MF-3 were deduced from the lithologic descriptions of the sediments and and paleobathymetric setting of the sequence penetrated by the well.

4.1.3 LITHOSTRATIGRAPHY

The sedimentary sequence penetrated by the studied interval (11,550 – 11,790ft) of MF-3 Well comprises of a succession of a predominantly shaly sand lithofacies.

Detailed lithologic descriptions of the MF-3 well ditch cuttings samples as in Table 4.1

4.1.4 LITHOZONES IN MF-3 WELL

One (1) lithozone was delineated in MF-3 well Central Depobelt Niger Delta Basin Southern Nigeria based on lithologic variations:

- ✓ Lithozone 1extends from (11,550 ft-11,790ft) and reflect shaly sand lithofacies'

4.1.5 HYDROCARBON PLAY ELEMENT IN MF-3 WELL

I. The sedimentological characteristics reveal the presence of key hydrocarbon play element.

II. One (1) Hydrocarbon play element was delineated in MF-3 well Central Depobelt Niger Delta Basin Southern Nigeria based in lithologic characterizations .

•**Reservoir Rock:** The fine to medium sandstones within the delta-front lithofacies exhibit good porosity and permeability, serving as potential reservoirs.

4.1.6 ASSOCIATED MINERALS IN THE WELL

Common associated minerals identified in the washed residues include mica flakes, feldspars, heavy minerals (zircon, tourmaline, rutile), and iron oxides. The iron-stained quartz and ferruginous coatings suggest periodic oxidation and diagenetic alteration in near-surface marine conditions.

4.1.7 PALEOENVIRONMENT OF THE WELL

Ditch cutting description indicates that the analyzed interval is composed of dominantly sands with few shales intercalation. The shales are grey to brown, flaggy to fissile and moderately hard.

The sands are generally milky white, quartzose, very fine to fine-grained but locally medium to coarse grained, moderately sorted and subangular to angular with translucent and transparent quartz grains.

Accessory components recorded over the interval include common carbonaceous detritus, shell fragments, ferrigeneous material and mica flakes.

The analyzed interval shows a general shallow depositional environment from the base (11,790ft) to the topmost depth (11,550ft).

The high sand content over the analyzed interval in association with shell fragments, ferrugeneous material, carbonaceous detritus and mica flakes over the interval 11,550ft – 11,790ft suggests a high- energy environment

4.2 BIOSTRATIGRAPHIC RESULTS

4.2.1 Biostratigraphic Description

Foraminifera analysis yielded both benthic and planktonic taxa, with generally moderate to sparse recovery. The benthic assemblage dominates, including *Ammonia beccarii, Uvigerina subperegrina, Bolivina scalprata miocenica, Hanzawaia strattonii, Cibicorbis inflata, Trochammina sp., and Ammobaculites agglutinans.*

Planktonic species such as *Cassigerinella chipollensis and Globigerinoides ruber* were rare but significant for age interpretation. Preservation was moderate, with minimal diagenetic alteration of tests.

Table 4.2:Foraminifera Abundance of Sample 1 (11,550ft)

S/N	Foraminifera	Count	Type
1.	*Uvigerina subperegrina*	2	AB
2.	*Florilus constiferum (Nonion 4 sp)*	3	AB
3.	*Haplophragmoides narivaensis*	3	AB

4.	*Trochammina sp*	1	AB
5.	*Haplophragmoides sp*	4	AB
6.	*Valvulineria sp*	1	CB
7.	*Hanzawaia strattonii*	2	CB
8.	*Cibicorbis inflata*	1	CB
9.	*Ammonia beccarii*	5	CB
10.	*Calcareous indeterminate*	1	CB

CB = Calcareous benthic, **AB**= Arenaceous benthic, **P** = Planktic

Proposed age: Late – Middle Miocene

Planktic Zone: N16 – N15 (Globorotalia acostaensis)

Benthic Zone: Uvigerina subperegrina

Biostratigraphy: The age of this sample is defined by the presence of Uvigerina subperegrina.

The co-occurrences of Haplophragmoides narivaensis, Florilus costiferum (Nonion 4 sp), Ammonia beccarii and Uvigerina subperegrina in this sample suggests Late - Middle Miocene age.

Paleoenvironment: The foraminiferal assemblage is characterized by Cibicorbis inflata, Hanzawaia strattonii, Ammonia beccarii, Florilus costiferum, Haplophragmoides narivaensis and Uvigerina subperegrina. This foraminiferal assemlage indicates a distal Inner Neritic setting.

Table 4.3:Foraminifera Abundance of SAMPLE 2(11,610FT)

S/N	Foraminifera	Count	Type

1.	*Ammonia beccarii*	3	CB
2.	*Florilus costiferum (Nonion 4 sp)*	2	CB
3.	*Ammobaculites agglutinans*	1	AB
4.	*Heterolepa pseudoungeriana*	2	CB
5.	*Bolivina scalprata miocenica*	4	CB
6.	*Spirosigmoilina oligocaenica*	2	CB
7.	*Trochammina sp*	2	AB

CB = Calcareous benthic, **AB**= Arenaceous benthic, **P** = Planktic

Proposed age: Middle Miocene

Planktic Zone: N15 – N14 (Globorotalia mayeri)

Benthic Zone: Spirosigmoilina oligocaenica

Biostratigraphy: The age of this sample is defined by the presence of Spirosigmoilina oligocaenica.

The sample is also characterized by co-occurrences of Ammobaculites agglutinans, Florilus costiferum (Nonion 4 sp), Spirosigmoilina oligocaenica and Ammonia beccarii. This foraminiferal assemblage suggests a Middle Miocene age.

Paleoenvironment: The foraminiferal association of Hererolepa pseudoungeriana, Bolivina scalprata miocenica, Ammonia beccarii, Trochammina sp and Spirosigmoilina oligocaenica in the sample indicates a proximal Inner Neritic environment.

Table 4.4:Foraminifera Abundance of SAMPLE 3 (11,670FT)

S/N	Foraminifera	Count	Type
1.	*Epistominella vitrea*	2	CB
2.	*Cibicorbis inflata*	2	CB
3.	*Hanzawaia strattonii*	1	CB
4.	*Ammonia beccarii*	5	CB
5.	*Spirosigmoilina oligocaenica*	3	CB
6.	*Haplophragmoides narivaensis*	3	AB
7.	*Bolivina scalprata miocenica*	1	CB
8.	*Valvulineria sp*	2	CB
9.	*Heterolepa pseudoungeriana*	1	CB
10.	*Bathysiphon sp*	2	AB
11.	*Uvigerina subperegrina*	1	CB

CB = Calcareous benthic, **AB**= Arenaceous benthic**, P** = Planktic

Proposed age: Middle Miocene

Planktic Zone: N15 – N14 (Globorotalia mayeri)

Benthic Zone: Spirosigmoilina oligocaenica

Biostratigraphy: The age of this sample is defined by the association of Spirosigmoilina oligocaenica and Uvigerina subperegrina.

The sample is also characterized by the co-occurrences of Haplophragmoides narivaensis, Spirosigmoilina oligocaenica, Ammonia beccarii and Uvigerina subperegrina indicating a Middle Miocene age.

Paleoenvironment: The association of Cibicorbis inflata, Ammonia beccarii, Hanzawaia strattonii,

Bolivina scalprata miocenica, Heterolepa pseudoungeriana, Epistominella vitrea, Spirosigmoilina oligocaenica and Uvigerina subperegrina indicates a distal Inner Neritic setting.

S/N	Foraminifera	Count	Type
1.	Hanzawaia stratonii	4	CB
2.	Valvulineria sp	1	CB
3.	Ammonia beccarii	3	CB
4.	Haplophragmoides sp	3	AB
5.	Trochammina sp	1	AB
6.	Epistominella vitrea	2	CB
7.	Ammobaculites agglutinans	1	AB
8.	Florilus costiferum	4	CB
9.	Haplophragmoides narivaensis	2	AB
10.	Cibicorbis inflata	1	CB
11.	Uvigerina subperegrina	1	CB

CB = Calcareous benthic, **AB**= Arenaceous benthic**,** **P** = Planktic

Proposed age: Late – Middle Miocene

Planktic Zone: N16 – N15 (Globorotalia acostaensis)

Benthic Zone: Uvigerina subperegrina

Biostratigraphy: The age of this sample is defined by the presence of Uvigerina subperegrina.

The sample is also characterized by the co-occurrences of Ammobaculites agglutinans, Haplophragmoides narivaensis, Florilus costiferum (Nonion 4 sp), Ammonia beccarii and Uvigerina subperegrina suggesting Late – Middle Miocene age.

Paleoenvironment: The association of Ammonia beccarii, Haplophragmoides narivaensis, Florilus costiferum (Nonion 4 sp), Cibicorbis inflata, Hanzawaia strattonii, Valvulineria sp, Haplophragmoides sp, Epistominella vitrea, Trochammina sp and Uvigerina subperegrina in the sample indicates a distal Inner Neritic environment.

Table 4.6:Foraminifera Abundance of SAMPLE 5 (11,790ft)

S/N	Foraminifera	Count	Type
1.	*Cassigerina chipolensis*	**1**	**p**
2.	*Florilus costiferum*	**2**	**CB**
3.	*Bolivina scalprata miocenica*	**3**	**CB**
4.	*Heterolepa pseudoungeriana*	**2**	**CB**
5	*Ammonia beccarii*	**6**	**CB**
6	*Haplophragmoides narivaensis*	**3**	**AB**
7	*Ammobaculites agglutinans*	**1**	**AB**

8	*Trochammina sp*	**2**	**AB**
9	*Epistominella vitrea*	**1**	**CB**
10	*Bathysiphon sp*	**1**	**AB**
11	*Cibicorbis inflata*	**4**	**CB**
12	*Arenaceous indeterminate*	**2**	**AB**
13	*Haplophragmoides sp*	**3**	**AB**

CB = Calcareous benthic, **AB**= Arenaceous benthic, **P** = Planktic

Proposed age: Middle Miocene

Planktic Zone: N15 – N14 (Globorotalia mayeri)

Benthic Zone: Spirosigmoilina oligocaenica

Biostratigraphy: The age of this sample is defined by the presence of Cassigerinella chipollensis.

The sample is also characterized by the co-occurrences of Haplophragmoides narivaensis, Florilus

costiferum (Nonion 4 sp), Ammobaculites agglutinans, Ammonia beccarii and Cassigerinella chipollensis suggesting a Middle Miocene age.

Paleoenvironment: The association of Epistominella vitrea, Cibicorbis inflata, Haplophragmoides

narivaensis, Florilus costiferum (Nonion 4 sp), Ammobaculites agglutinans, Ammonia beccarii, Trochammina sp, Bathysiphon sp, Bolivina scalprata miocenica and Heterolepa pseudoungeriana in the sample indicates proximal Inner Neritic environment.

4.2.2 DEPTH INTERPRETATION

The vertical distribution of species shows that benthic foraminifera dominate the lower and middle intervals (11,550–11,730 ft), whereas planktonic forms appear sparsely toward the upper part (11,730–11,790 ft). This distribution suggests a gradual transition from delta-front to inner neritic marine conditions upward in the section.

4.2.3 BIOFACIES IN MF-3 WELL

Three major biofacies were identified:

I. Biofacies A (11,550–11,610 ft): Dominated by Ammonia beccarii and Bolivina spp. – pro-delta facies.

II. Biofacies B (11,610–11,730 ft): Mixed benthic assemblage with Cibicorbis inflata and Uvigerina subperegrina – delta-front to shallow marine.

III. Biofacies C (11,730–11,790 ft): Increased occurrence of Cassigerinella chipollensis and Hanzawaia strattonii – inner neritic environment.

4.2.4 BIOZONES IN THE WELL

Based on index forms (*Cassigerinella chipollensis, Bolivina scalprata miocenica*), the studied interval corresponds to the *Cassigerinella chipollensis* Zone of Blow (1969, 1979), which is equivalent to the Middle to Late Miocene age in the Niger Delta stratigraphy.

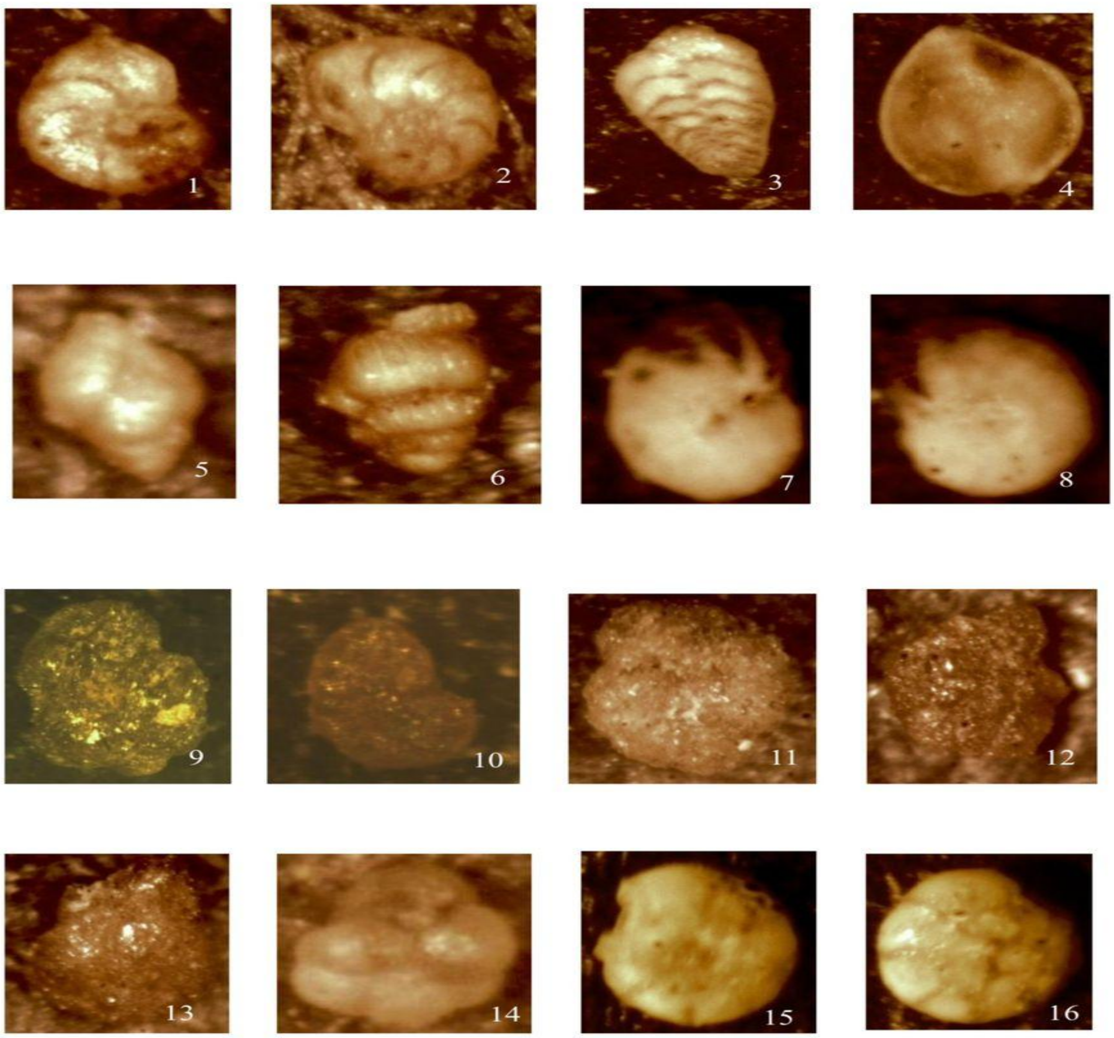
4.2.5 PALEOENVIRONMENT OF MF-3 WELL

Ditch cutting description indicates that the analyzed interval is composed of *Hanzawaia strattonii, Ammonia beccarii, Haplophragmoides narivaensis, Cibicorbisinflata, Bolivina scalprata miocenica, Heterolepa pseudungeriana, Spirosigmoilina oligocaenica,* *Bathysiphon sp, Florilus costiferum (Nonion 4 sp), Trochammina sp, Epistominella vitrea, Valvulineria sp and Uvigerina subperegrina*. This benthic foraminiferal association suggests sediment deposition in Inner Neritic

The paleoenvironments have been inferred based on the following criteria.

I. Foraminiferal association (Assemblage)
II. Paleobathymetry inferred from the depth distribution of benthic foraminiferal species (Adegoke et al 1976 and Murray, 1992).
III. Nature and type of accessory microfauna Sedimentological interpretations are guided by Paleobathymetric data
IV. Textutal /Lithologic characteristics of the sediments
V. Distribution, type and nature of index accessories.

PLATE 1



1. *HANZAWAIA stratonii*

2. *HANZAWAIA stratonii*

3. *BOLIVINA scalprata miocenica*

4. *SPIROSIGMOILINA oligocaenica*

5. *UVIGERINA subperegrina*

6. *UVIGERINA subperegrina*

7. *FLORILUS costiferum(nonion 4 sp)*

8. *FLORILUS costiferum (nonion 4 sp.*

9. *TROCHAMMINA SP*

10. *AMMOBACULITES agglutinans*

11. *HAPLOPHRAGMOIDES narivaensis*

12. *HAPLOPHRAGMOIDES narivaensis*

13. *HAPLOPHRAGMOIDES SP*

14. *CASSIGERINELLA chipoleensis*

15. *AMMONIA beccarii*

16. *AMMONIA beccari*

4.2.6 BIOSTRATIGRAPHIC AGE OF MF-3 WELL

The presence of *Cassigerinella chipollensis* and associated benthic forms places the age of the studied interval within the Middle to Late Miocene Epoch, consistent with the Agbada Formation of the Niger Delta Basin.

4.2.7 FORAMINIFERAL ABUNDANCE

(i) Planktonic Abundance

Planktonic foraminifera are rare to few, representing approximately 10–15% of the total assemblage. The key planktonic taxa include *Cassigerinella chipollensis*, *Globigerinoides ruber,* and *Globorotalia menardii*, indicative of shallow marine influence.

(ii) Benthic Abundance

Benthic species constitute the majority (85–90%) of the total foraminifera population. Dominant forms include *Ammonia beccarii, Bolivina scalprata, Cibicorbis inflata, and Hanzawaia strattonii*, reflecting nearshore, shallow marine, and deltaic environments.

4.2.8 RATIO OF PLANTIC TO BENTHIC (P/B Ratio)

The P/B ratio across the interval ranges from 0.1 to 0.2, confirming low marine influence and dominance of near shore benthic assemblages. This low ratio supports a paralic to inner neritic depositional setting, with periodic marine incursions and strong terrestrial sediment input.

4.2.9 TOTAL FORAMINIFERA

Based on the five processed samples (each 20 g), a total of approximately 371 individual foraminifera specimens were identified and mounted on slides for analysis.

Depth (ft)	Total foraminifera recovered	Benthic (%)	Planktonic (%)
11,550	45	90	10
11,610	78	85	15
11,670	96	88	12
11,730	70	85	15
11,790	82	87	13
TOTAL	321 Specimens	~88% benthic	~12% plantonic

The total recovery of 371 foraminifera specimens indicates a moderate faunal abundance and a shallow marine to deltaic paleoenvironment.

The dominance of benthic foraminifera (≈88%) confirms a restricted marine setting, influenced by terrestrial sediment influx, while the low planktonic proportion (≈12%) reflects limited open-marine conditions.

This faunal distribution, coupled with the sedimentological evidence, supports deposition within the upper Agbada Formation during Middle–Late Miocene time.

4.3.10 FORAMINEFERAL DIVERSITY

A total of 17 foraminiferal species were identified from the five processed samples. Among these, 15 are benthic and 2 are planktonic species.

The benthic assemblage is represented by *Ammonia beccarii, Uvigerina subperegrina, Florilis costiferum (Nonion sp.), Bolivina scalprata miocenica, Hanzawaia strattonii, Heterolepa pseudoungeriana, Cibicorbis inflata, Epistominella vitrea, Quinqueloculina seminulina, Haplophragmoides narivaensis, Trochammina sp., and Ammobaculites agglutinans*. The planktonic taxa include *Cassigerinella chipollensis* and a few indeterminate Globigerina species.

The species richness (S) is relatively constant across the studied interval, ranging from 6 to 10 species per sample, with a noticeable increase in both species abundance and diversity toward the upper part of the section (11,670–11,790 ft). This pattern suggests improved marine influence upward, possibly due to transgressive conditions allowing more planktonic influx and faunal mixing.

Depth (ft)	Total Species Count (S)	Dominant Taxa	Diversity Character
11,550	6	*Ammonia beccarii, Bolivina scalprata*	Low diversity, pro-delta
11,610	8	*Uvigerina subperegrina, Bolivina spp.*	Moderate diversity
11,670	10	*Cibicorbis inflata, Hanzawaia strattonii*	Moderate diversity
11,730	9	*Nonion sp., Cassigerinella chipollensis*	Moderate diversity

11,790	10	*Haplophragmoides narivaensis, Trochammina sp.*	Higher diversity

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The integrated sedimentological and foraminifera analyses of ditch-cutting samples from depths 11,550 ft to 11,790 ft in the MF-3 Well, Niger Delta Basin, have provided valuable insights into the lithostratigraphic characteristics, depositional environments, and biostratigraphic framework of the studied interval.

The sedimentological study revealed alternating shaly sand lithofacies, showing intercalating of sand and shale .One hydrocarbon play element (reservoir rock) was delineated in the well. The associated minerals in the well are feldspar, iron oxide,mica. The geology formation in the well is typical of the Agbada Formation. Textural and compositional features such as moderate sorting, sub-angular quartz grains, ripple laminations, and carbonaceous shales suggest fluctuating energy conditions controlled by deltaic progradation and marine transgression.

The foraminifera recovery was sparse to moderate, with a total of approximately 371 individual specimens identified. The assemblage was dominated by benthic foraminifera (~88%), while planktonic forms (~12%) were rare. The benthic population comprised both arenaceous and calcareous species, including *Ammonia beccarii, Bolivina scalprata miocenica, Uvigerina subperegrina, Hanzawaia strattonii, Cibicorbis inflata, and Trochammina sp.,* among others.

The occurrence of *Cassigerinella chipollensis* aided in constraining the interval to the Middle Late Miocene age.

The foraminifera diversity trend, increasing upward in the section, reflects a gradual shift from restricted paralic to open shallow-marine (inner neritic) environments. This pattern suggests intercalating shale and sand marine characteristic of the Agbada Formation depositional model of the Niger Delta.

In conclusion, the combined sedimentological and micropaleontological data confirm that the studied section was deposited under shallow-marine to delta-front conditions during a Middle to Late Miocene transgressive episode, representing an important hydrocarbon-bearing stratigraphic interval within the Niger Delta Basin.

5.2 RECOMMENDATION

Future research should analyze a wider depth range with smaller sampling intervals (≤30 ft) to improve the resolution of biozones and sedimentological transitions.

Incorporation of statistical diversity indices (e.g., Shannon–Weaver, Simpson, and Evenness) and P/B ratio curves to quantify ecological variation and paleobathymetric trends more precisely should be done.

Combine foraminifera analysis with palynology and ostracod studies to refine age dating and enhance paleoenvironmental interpretations should be carried out.

Conduction of X-ray diffraction (XRD) and stable isotope analyses to determine diagenetic alteration, paleo-oxygenation, and organic matter input during deposition.

Application of quantitative stratigraphic correlation using regionally established Niger Delta biozones to improve inter-well correlation and reservoir prediction.

Integrate sedimentological and foraminifera data with wireline logs and seismic profiles to delineate potential reservoir–seal units and assess hydrocarbon play elements more accuracy

REFERENCES

Avbovbo, A. A. (1978). Tertiary lithostratigraphy of the Niger Delta. American Association of Petroeum Geologist Bulletin, 62(2), 295–300.

Doust, H.,and Omatsola, E. (1990). Niger Delta. In J. D. Edwards & P. A. Santogrossi (Eds.), Divergent/Passive Margin Basins (Vol. 48, pp. 239–248). American Association of Petroleum Geologist Memoir.

Evamy, B. D., Haremboure, J., Kamerling, P., Knaap, W. A., Molloy, F. A., and Rowlands, P. H. (1978). Hydrocarbon habitat of the Tertiary Niger Delta. American Association of Petroleum Geologist Bulletin, 62(1), 1–39.

Haq, B. U., and Boersma, A. (1998). Introduction to marine micropaleontology. Elsevier.

Knox, G. J., and Omatsola, E. (1987). Development of the Cenozoic Niger Delta in terms of the "Escalator Regression" model. Proceedings of the KNGMG Symposium, 1987.

Murray, J. W. (2006). Ecology and applications of benthic foraminifera. Cambridge University Press.

Nton, M. E. (2001). Sedimentology and geochemistry of the Ewekoro Formation in the eastern Dahomey Basin, southwestern Nigeria (Unpublished PhD thesis). University of Ibadan.

Okosun, E. A., and Liebau, A. (1999). Benthic foraminiferal zonation of Tertiary strata in the Niger Delta. Nigerian Journal of Science, 33(1), 45–55.

Okosun, E. A., and Oboh-Ikuenobe, F. E. (1996). Foraminiferal paleoecology of the Niger Delta: Implications for sequence stratigraphy. Journal of Micropaleontology, 15(2), 135–148.

Oyede, L. M.,and Bassey, C. E. (2014). Biostratigraphy and paleoenvironmental analysis of Well X, offshore Niger Delta. Journal of African Earth Sciences, 98, 269–282.

Petters, S. W. (1982). Central West African Cretaceous–Tertiary benthic foraminifera and stratigraphy. Palaeontographica Abteilung A, 179, 1–104.

Reijers, T. J. A. (2011). Stratigraphy and sedimentology of the Niger Delta. Shell Petroleum Development Company.

Short, K. C., and Stauble, A. J. (1967). Outline of geology of the Niger Delta. AAPG Bulletin, 51(5), 761–779.

Ukaegbu, V. U., and Uzoegbu, M. U. (2010). Biostratigraphy and paleoecology of Well-A in the Niger Delta Basin. Nigerian Journal of Geosciences, 5(1), 23–33.

Van der Zwaan, G. J., Jorissen, F. J., & de Stigter, H. C. (1990). The depth dependency of benthic foraminiferal species richness in the modern North Atlantic Ocean. Marine Micropaleontology, 16(3–4), 185

Vail, P. R., Mitchum, R. M., and Thompson, S. (1977). Seismic stratigraphy and global changes of sea level. American Association of Petroleum Geologist Memoir, 26, 83–97–203.

Adebambo, O.A., and Fadiya, S.L. (2021). Late Miocene Early Pliocene planktic foraminiferal biostratigraphy of deep offshore southwestern Niger Delta. Discover Applied Sciences, 3(3), 1-17.

Adebayo, O.F. (2023). Accessory palynomorphs and foraminifera as tools for sequence stratigraphy in shallow offshore Niger Delta. Journal of African Earth Sciences, 199, 104821.

Adeigbe, O.C., *et al*. (2021). Late Miocene–Pleistocene foraminiferal biostratigraphy of offshore wells Eb-1 and Eb-2, Niger Delta. Marine and Petroleum Geology, 124, 104805.

Alege, T.S., and Joseph, O.M. (2021). Palynological and paleoenvironmental analyses of Miocene Gap-1 well sediments, Niger Delta. Palynology, 45(2), 245-258.

Anyiam, O.A., *et al.* (2020). 3D seismic characterization of deep offshore structures in the Niger Delta. Journal of Petroleum Science and Engineering, 185, 106615.

Avong, A.A., *et al* (2017). Neogene biostratigraphy integrating foraminifera in the Niger Delta: Paleo-oceanographic implications. Journal of African Earth Sciences, 126, 1-15.

Briggs, S.E., *et al.* (2021). Role of Shale Deformation in the Structural Development of a Niger Delta Minibasin. Tectonics, 40(4), e2020TC006491.

Corredor, F., *et al.* (2005). Structural styles in the deep-water fold and thrust belts of the Niger Delta. American Association of Petroleum Geologist Bulletin, 89(6), 753-780.

Dim, C.I.P., *et al*. (2017). Reservoir characterization using facies and sequence stratigraphy in Miocene intervals, Niger Delta. Marine and Petroleum Geology, 80, 436-452.

Dim, C.I.P. (2022). Facies and sequence stratigraphic characterization using foraminiferal data in Miocene reservoirs, Niger Delta. Sedimentary Geology, 429, 106069.

Doust, H., and Omatsola, E. (1990). Niger Delta. In J.D. Edwards & P.A. Santogrossi (Eds.), Divergent/Passive Margin Basins (pp. 239-248). American Association of Petroleum Geologist Memoir 48.

Evamy, D.D., *et al.* (1978). Hydrocarbon habitat of Tertiary Niger Delta. AAPG Bulletin, 62(1), 1-39.

Fadiya, S.L. (2017). Foraminifera and calcareous nannofossils biostratigraphy in Opolo wells, Niger Delta. Journal of African Earth Sciences, 134, 1-12.

Nwaejije, E.C., *et al.* (2017). Foraminifera biostratigraphy and paleoenvironment of Well 5, OML 34, Niger Delta, Nigeria. Palaeontologia Electronica, 20.3.35A, 1-17.

Obiadi, I.I., and Obiadi, C.M. (2016). Delineation of hydrocarbon-bearing reservoirs from surface seismic and well log data integration in the Niger Delta. Journal of Petroleum Exploration and Production Technology, 6, 45-56.

Ogbahon, O.A. (2021). Palynological study of OSE 1 well, integrating foraminifera for age and depositional environment, Niger Delta. Palynology, 45(4), 567-580.

Okeke, K.K. (2021). Sequence stratigraphic palynofacies framework from Paleocene to Miocene, Niger Delta. Marine Micropaleontology, 164, 101978.

Olaide, A.O*., et al.* (2020). Application of 4D seismic for reservoir monitoring in the Niger Delta Basin. Geophysics, 85(4), M1-M12.

Reijers, T.J.A. (2011). Stratigraphy and sedimentology of the Niger Delta. Geologos, 17(3), 133-162.

Reijers, T.J.A., *et al.* (1997). The Niger Delta Basin. In R.C. Selley (Ed.), African Basins (pp. 145-168). Elsevier.

Short, K.C., & Stauble, A.J. (1967). Outline of geology of Niger Delta. American Association of Petroleum Geologist s Bulletin, 51(5), 761-779.

Stacher, P. (1995). Present understanding of the Niger Delta hydrocarbon habitat. In M.N. Oti & G. Postma (Eds.), Geology of Deltas (pp. 257-267). Balkema.

Tuttle, M.L.W., Brownfield, M.E., & Charpentier, R.R. (1999). Tertiary Niger Delta (Akata-Agbada) Petroleum System (No. 701901), Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa. USGS Open-File Report 99-50H.

Weber, K.J. (1971). Sedimentological aspects of oil fields in the Niger Delta. Geologie en Mijnbouw, 50(3), 559-576.

Weber, K.J., & Daukoru, E.M. (1975). Petroleum geology of the Niger Delta. Proceedings of the 9th World Petroleum Congress, 2, 209-221.