ANALYSIS OF ROCK TYPES, FOSSIL DATING, AND OIL/GAS POTENTIAL IN THE ABC-1 WELL, GREATER UGHELLI DEPOBELT, NIGER DELTA BASIN, SOUTHERN NIGERIA.

BY

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A PROJECT WORK SUBMITTED TO THE

DEPARTMENT OF GEOLOGY,

FACULTY OF PHYSICAL SCIENCES

UNIVERSITY OF BENIN,

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DEDICATION

This work is dedicated to God Almighty, the source of my strength and inspiration. It is also especially dedicated to my beloved parents for their sacrifices, love, and constant encouragement, and to all who believed in me and supported my academic pursuit.

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Abstract

This project presents an integrated geological study to evaluate the hydrocarbon potential of the ABC-1 well within the highly prolific Greater Ughelli Depobelt of the Niger Delta. The analysis focuses on the Agbada Formation succession spanning 1881 m to 2699 m. The methodology combined high-resolution rock type analysis (lithofacies) and precise fossil dating (palynostratigraphy). A total of seventy (70) side wall core samples were microscopically examined, leading to the delineation of 39 distinct rock type zones, including critical Sandstone, Shale, and organic-rich Coal/Lignite layers. Fossil dating of the well interval identified 701 total palynomorphs, exhibiting an overwhelming dominance of terrestrial miospores (99%), which confirms a highly proximal, fluvio-deltaic depositional environment. Based on the stratigraphic distribution of index fossils, eight informal biozones were established, providing the necessary chronostratigraphic control for correlation across the depobelt. The integrated findings characterize the rock types as high-quality reservoirs (well-sorted sandstones) juxtaposed with excellent source rocks and seals (Coal and fissile Shale facies). This study is critical for assessing the overall Oil/Gas Potential and supporting detailed subsurface mapping within the Greater Ughelli Depobelt.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The Niger Delta of Southern Nigeria is one of the most thoroughly investigated hydrocarbon provinces in the world. Its exceptional petroleum endowment has shaped decades of exploration and development, supported by a complex geological history that reflects the interplay of subsidence, sediment supply, and structural reorganisation through time. The delta developed as a major Cenozoic depocenter where progressive progradation built a thick wedge of sediment over older continental and marine sequences (Evamy et al., 1978; Short and Stauble, 1967).A distinctive feature of the Niger Delta is its division into depobelts. Each depobelt records a specific phase in the outward growth of the delta. These structural provinces shift seaward with time and contain their own internal patterns of faulting, sediment dispersal, and stratigraphic architecture. This arrangement provides the framework for understanding the distribution of reservoirs, seals, and structural traps across the basin.

The Greater Ughelli Depobelt, which is central to this study, is an important Miocene depocenter. It hosts thick paralic successions and contains many of the commercially successful fields in the central Niger Delta (Doust and Omatsola, 1990). Sedimentation in this region occurred rapidly. As a result, syndepositional growth faults developed and exerted strong controls on basin-fill architecture. These faults influenced the routing of sediments, the stacking of reservoirs, and the formation of structural traps such as rollovers and collapsed crests (Corredor, 2003).The ABC 1 exploration well penetrates a representative interval of the Agbada Formation, which forms the core of the petroleum system in the Niger Delta. The Agbada Formation is characterised by repeated alternations of continental and shallow marine deposits. These cycles yield the classic sandstone reservoirs and shale seals typical of paralic basins (Weber and Daukoru, 1975). The sand bodies act as fluid conduits and hydrocarbon reservoirs, while the shales provide the necessary vertical and lateral seals. Together they form the basic reservoir seal pairs that control hydrocarbon migration and entrapment.Because the Agbada Formation was deposited under conditions of rapid subsidence and fault activity, its internal structure is often complex. The accurate interpretation of such sequences requires a combination of lithofacies analysis and biostratigraphic dating. Lithofacies analysis provides insight into depositional processes and reservoir quality, while fossil dating establishes age control and helps correlate units across fault blocks and adjacent wells. Both approaches have proven essential in resolving the complex stratigraphy of Niger Delta depobelts (Reijers et al., 1997; Adekoya, 2009; Ehinola and Olagoke, 2019).

The ABC 1 well contains seventy side wall core samples from the interval between 1881 m and 2699 m. These samples cover thirty nine lithofacies zones and record changes in sediment input, accommodation, and paleoenvironmental conditions. Evaluating these lithofacies together with their palynological content provides the framework for assessing reservoir continuity, seal effectiveness, and hydrocarbon potential. Such evaluation is important for understanding how oil and gas accumulated within the structurally controlled settings of the Greater Ughelli Depobelt (Kulke, 1995; Afolayan and Jimoh, 2021).

1.2 STATEMENT OF THE PROBLEM

The Greater Ughelli Depobelt presents a challenging subsurface environment because of its high sedimentation rates and active growth faulting. In many wells, including ABC 1, reservoir units are vertically stacked in complex cycles and often lack reliable age control. This makes it difficult to interpret their stratigraphic position or predict their lateral continuity. Without clear knowledge of the controlling rock types and their chronostratigraphic framework, uncertainties arise in identifying reservoir zones, estimating seal integrity, and defining prospective intervals.Existing data for the ABC 1 well indicate a thick paralic succession, but the internal organisation of the lithofacies and their relative ages have not been fully resolved. The absence of an integrated model that combines detailed rock type classification with fossil dating reduces the reliability of structural and stratigraphic interpretations. This research addresses the need for such an integrated model by establishing lithofacies zones, defining biostratigraphic boundaries, and relating the depositional succession to the petroleum system elements of the depobelt.

1.3 SIGNIFICANCE OF THE STUDY

This study is significant for several reasons. It provides the first detailed integration of lithofacies and palynostratigraphic data for the ABC 1 well, improving the understanding of depositional patterns within the Agbada Formation. By analysing rock types and fossil assemblages together, the study offers valuable insights into reservoir quality, seal distribution, and source rock potential.The results enhance the geological understanding of the Greater Ughelli Depobelt by refining its chronostratigraphic framework. This supports improved well-to-well correlation, more accurate reservoir characterisation, and better prediction of hydrocarbon bearing intervals. Such improvements are crucial for both exploration and development projects, especially in areas where structural complexity influences reservoir geometry.

On a broader scale, the findings contribute to ongoing regional efforts to build robust geological and stratigraphic models for the Niger Delta. These models are essential for optimising drilling decisions, guiding appraisal work, and ensuring effective field development planning in both mature and emerging fields.

1.4 GEOLOGICAL SETTING

The Niger Delta formed at the junction of the Benue Trough, the South Atlantic, and the Gulf of Guinea. Its evolution is linked to the breakup of Gondwana and subsequent rifting that created accommodation for large volumes of sediment supplied by the Niger River system. The delta is divided into three main lithostratigraphic units. The Akata Formation comprises deep marine shales that constitute the primary source rocks. The Agbada Formation contains interbedded sands and shales deposited in delta front to delta plain environments and hosts most hydrocarbon reservoirs. The Benin Formation consists of continental sands that cap the sequence and form the freshwater aquifer.

The Greater Ughelli Depobelt occupies a central position within this stratigraphic framework. It is marked by active growth faulting that generated rollover structures, fault assisted closures, and subtle stratigraphic traps. Sedimentation generally kept pace with fault movement, resulting in repeated sand shale cycles that are typical of paralic systems. These cycles represent the fundamental components of the petroleum system in the region.

1.5 AIM AND OBJECTIVES

The main aim of this research is to develop an integrated rock type and fossil dating model for the ABC 1 well in order to assess its Oil and Gas Potential within the geological and structural framework of the Greater Ughelli Depobelt.

The specific objectives are:

1. To carry out a detailed rock type (lithofacies) analysis on seventy side wall core samples and delineate the thirty nine lithofacies zones, identifying their reservoir and seal characteristics.
2. To establish a robust palynostratigraphic framework by defining eight informal biozones using First Downhole Occurrence and Last Downhole Occurrence data of key palynomorph index species (Lawal and Balogun, 2018; Ologun and Akpan, 2023).
3. To integrate lithofacies and palynological datasets to reconstruct the paleoenvironment, refine the chronostratigraphic position of the ABC 1 succession, and evaluate the overall hydrocarbon prospectivity of the well.

CHAPTER TWO

LITERATURE REVIEW

2.1 REGIONAL STRATIGRAPHIC FRAMEWORK AND THE GREATER UGHELLI DEPOBELT

The Niger Delta Basin is one of the largest regressive sedimentary provinces in West Africa. Its stratigraphic architecture is dominated by three major Cenozoic formations that reflect a long history of delta progradation and shifting depositional conditions (Short and Stauble, 1967). These formations, which are the Akata, Agbada, and Benin Formations, define the petroleum system of the basin and provide the structural and stratigraphic setting for hydrocarbon generation, migration, and entrapment.

The basin is also divided into large structural units known as depobelts. Each depobelt represents a discrete portion of the delta that developed during a particular phase of tectonic movement, sediment loading, and shoreline advance (Doust and Omatsola, 1990). The depobelts are arranged in a series of arcuate, southward younging belts that reflect the progressive seaward growth of the delta. This organization provides an important framework for understanding the geological behaviour of individual wells and fields.

Within this regional context, the Greater Ughelli Depobelt stands out as a Miocene depocenter with significant exploration and production activity. It is structurally complex and contains numerous large growth faults that developed as a response to rapid sediment accumulation and differential subsidence (Corredor, 2003). These structures influence sediment distribution and create rollover anticlines, footwall closures, and other traps that host commercial hydrocarbon accumulations.

Akata Formation

The Akata Formation forms the base of the Niger Delta stratigraphy. It is made up of thick, overpressured marine shales that were deposited in a deep marine setting. These shales are widely recognized as the primary source rock of the Niger Delta petroleum system due to their high organic content and favourable thermal maturity conditions (Evamy et al., 1978). The formation rarely forms reservoir units but plays a significant role in generating hydrocarbons that migrate upward into the overlying paralic units.

Agbada Formation

The Agbada Formation lies above the Akata Formation and is the principal petroleum reservoir unit of the basin. It consists of a complex sequence of sands and shales that record alternating continental, delta front, and shallow marine conditions. These paralic cycles are the result of repeated shifts in accommodation and sediment supply. In the Greater Ughelli Depobelt, the Agbada Formation contains some of the thickest and most productive Miocene reservoir intervals in the central part of the delta (Weber and Daukoru, 1975). The ABC 1 well penetrates this interval, and its lithofacies and palynological characteristics are essential for understanding its reservoir potential.

Benin Formation

The Benin Formation is the uppermost unit of the Niger Delta stratigraphy. It is composed of continental sands, gravels, and minor clays that were deposited in a fluvial environment. Although the formation is not a typical reservoir target at great depth, it forms the surface aquifer system and acts as an overburden overlying the productive Agbada interval.

Understanding these three formations and the position of the Greater Ughelli Depobelt within the regional framework is important for interpreting the geological signals preserved in the ABC 1 well. The growth faults in the area, combined with the thick paralic sequences of the Agbada Formation, play a key role in determining reservoir continuity, seal distribution, and hydrocarbon migration pathways.

This framework forms the basis for lithofacies analysis, biozonation, and paleoenvironmental interpretation in later chapters of this study.

The location of the study area within this structural framework is critical for interpreting reservoir migration pathways and trap formation (Abubakar & Garba, 2022). The specific position of the ABC-1 well within the Greater Ughelli Depobelt is shown in **Figure 1**.

2.2 PRINCIPLES OF ROCK TYPE (LITHOFACIES) ANALYSIS

Rock type analysis is a fundamental aspect of sedimentology and forms the basis for understanding the character and behaviour of sedimentary successions. In petroleum geoscience, lithofacies analysis is especially important because it supports the prediction of reservoir quality, the identification of sealing units, and the recognition of intervals that may serve as source rocks. These interpretations depend on careful examination of the physical, textural, and compositional attributes of the rocks (Eze and Okoro, 2022).

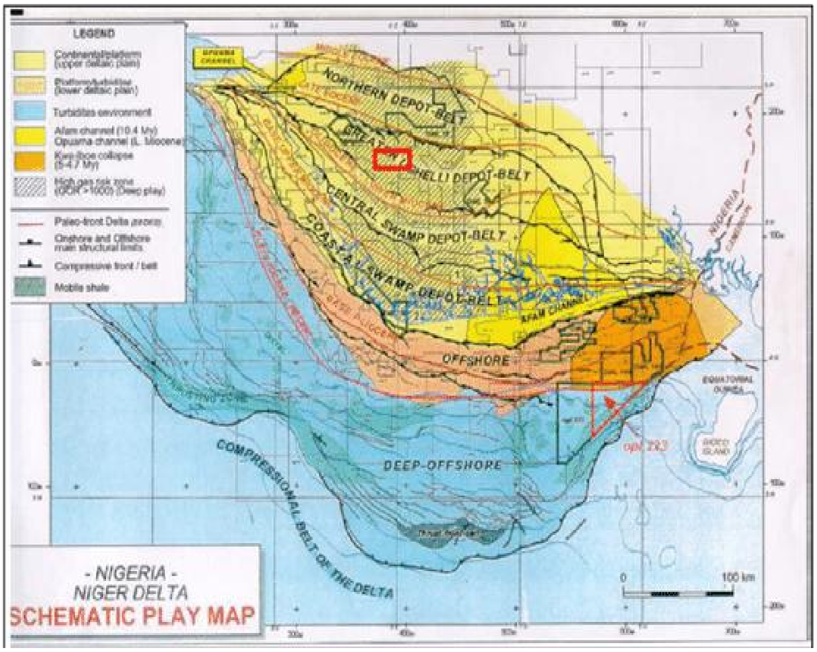

Figure 1: Map of the Niger Delta Basin Showing Major Depobelts (including the Greater Ughelli Depobelt) and the Generalized Location of the ABC-1 Study Area in red box. (Modified after Doust & Omatsola, 1990 and Adekeye & Adebisi, 2022).

In the context of the ABC 1 well, the microscopic description of seventy side wall core samples provides highly resolved information that helps define the internal organisation of the Agbada Formation. Such detailed core observations offer a direct view of the depositional processes and diagenetic alterations that have shaped the reservoir and non reservoir intervals.

Several key properties guide lithofacies interpretation.

Texture

Grain size, sorting, and roundness are primary controls on reservoir quality. These parameters influence pore space and grain packing, which in turn determine porosity and permeability (Ayodele and Oladapo, 2021). Well sorted, fine to medium grained sandstones usually form good quality reservoirs because they contain abundant interconnected pore spaces and minimal clay infiltration. This behaviour aligns with observations from several lithofacies zones in the ABC 1 well. Textural characteristics can also support environmental interpretations. Coarser or poorly sorted layers may record high energy conditions, while finer, well laminated units may record quieter, low energy settings.

Composition and Organic Content

Mineralogical and organic constituents influence both reservoir performance and stratigraphic interpretation. Quartz rich sandstones typically form stronger reservoir units because of their mechanical stability and resistance to compaction. The presence of clay minerals, on the other hand, can lead to reduced permeability and may indicate lower energy depositional environments.

Organic matter, including lignite streaks or coal beds, provides additional insight. The recognition of lignite streaks within some sandstone units in the ABC 1 well supports a delta plain setting with significant terrestrial input (Oyedele and Adebayo, 2019). Thick coal beds and fissile shales, such as those observed in Lithofacies Zone 15, can serve as regional seals and may contain organic rich intervals suitable for hydrocarbon generation (Obaje and Ndukwe, 2024; Oloto, 1993). These compositional properties allow the interpreter to differentiate between potential reservoir, seal, and source intervals.

Structural Influence on Lithofacies Distribution

The Greater Ughelli Depobelt is known for its syndepositional growth faults. These structures generate complex stacking patterns by creating variations in accommodation space during deposition. Sand rich channel bodies, floodplain muds, coal seams, and marginal marine units may shift laterally and vertically in response to fault growth. This complexity makes detailed core based lithofacies analysis critical for accurate subsurface mapping and correlation (Elias and Osun, 2024). Without such high resolution data, reservoir continuity and seal geometry may be difficult to predict with confidence.

Overall, lithofacies analysis provides the foundation for interpreting the depositional environments, diagenetic influences, and reservoir architecture of the ABC 1 well. These interpretations support the integration of palynology, stratigraphic correlation, and reservoir evaluation that appear in later chapters of this study.

2.3 PRINCIPLES OF FOSSIL DATING (PALYNOSTRATIGRAPHY)

Palynostratigraphy is the branch of biostratigraphy that uses microscopic organic walled fossils such as pollen, spores, and dinoflagellate cysts to establish a detailed time stratigraphic framework. These microfossils are highly valuable in sedimentary basins because they are abundant, widely distributed, and capable of preserving key evolutionary and environmental signals (Germeraad et al., 1968; Ehinola and Olagoke, 2019). The method is especially important in the Niger Delta where rapid sedimentation and intense structural activity often limit the effectiveness of traditional lithostratigraphic correlation (Adedapo and Obiajunwo, 2020).

Paleoenvironmental Interpretation

The relative proportions of terrestrial and marine palynomorphs form the foundation of paleoenvironmental interpretation in paralic basins. These ratios provide insight into shoreline position, sediment supply, marine influence, and overall depositional setting.

Miospores (Pollen and Spores)

These microfossils originate from terrestrial plants. Their abundance typically reflects proximity to land, strong river discharge, and the influence of floodplain or delta plain systems. A high concentration of miospores suggests a very proximal setting with significant terrestrial input (Osokpor and Aigbedion, 2022). The ABC 1 well yields approximately ninety nine percent miospores. This dominance strongly supports a fluvio deltaic environment characteristic of the inner Agbada Formation in the Greater Ughelli Depobelt.

Dinocysts (Dinoflagellate Cysts)

Dinocysts are produced by marine plankton. Their increased abundance signals deeper water conditions or phases of marine transgression. A noticeable rise in dinocyst content may indicate periods when marine influence expanded over previously terrestrial or marginal marine environments (Chukwu and Obi, 2020). The balance between dinocysts and miospores therefore helps identify transgressive and regressive phases within the paralic sequence.

Together, these microfossil groups provide strong evidence for reconstructing the paleoenvironmental evolution of the ABC 1 interval.

Biostratigraphic Zonation

Biostratigraphic zonation is central to palynostratigraphy. It involves dividing the stratigraphic column into informal zones based on the appearance, disappearance, and distribution patterns of key index species. These zones support regional age correlation and help link stratigraphic intervals across multiple wells.

Zonation commonly relies on two key biostratigraphic markers:

First Appearance Datum (FAD)

The evolutionary first appearance of a species in the geological record.

Last Appearance Datum (LAD)

The point at which a species disappears from the record.

In subsurface studies, these events are expressed as depth based occurrences. The First Downhole Occurrence and Last Downhole Occurrence of carefully selected index palynomorph taxa are used to define the boundaries of informal biozones (Lawal and Balogun, 2018; Ologun and Akpan, 2023).

These zonal boundaries provide the chronostratigraphic control needed to correlate important sequence stratigraphic surfaces. Surfaces such as Maximum Flooding Surfaces and Sequence Boundaries can be tied to biostratigraphic events and traced across the Greater Ughelli Depobelt (Adekeye and Adebisi, 2022). This integration improves confidence in stratigraphic interpretation and enhances predictions of reservoir distribution and seal continuity.

By establishing a detailed palynological framework for the ABC 1 well, it becomes possible to refine its age, interpret changes in depositional conditions, and better understand its stratigraphic architecture within the regional Niger Delta setting.

2.4 DEPOSITIONAL ENVIRONMENTS OF THE AGBADA FORMATION

The Agbada Formation represents the main paralic interval of the Niger Delta and records the alternation of continental, marginal marine, and shallow marine depositional settings. These settings reflect repeated shifts in sediment supply, accommodation, and shoreline position during the progradation of the delta. Understanding these environments is essential for interpreting reservoir distribution, seal continuity, and facies architecture within wells such as ABC 1.

The paralic succession of the Agbada Formation is typically organised into stacked sand and shale cycles that represent transitions between fluvial, delta plain, delta front, and shallow marine conditions. These environments are influenced by changes in sea level, sedimentation rate, and tectonic activity within the depobelts (Weber and Daukoru, 1975; Doust and Omatsola, 1990).

Fluvial and Delta Plain Environments

The upper parts of the Agbada Formation commonly record fluvial and delta plain conditions. These environments are characterised by channel sand bodies, floodplain muds, crevasse splays, carbonaceous shales, and coal seams. High concentrations of terrestrial miospores, as observed in the ABC 1 well, are typical indicators of these proximal settings. Sediment textures in these zones are usually coarse to medium grained with variable sorting, reflecting the high energy conditions of channelised flow.

Coal beds and lignite streaks within sandstones signal periods of reduced clastic input and the development of swamp or marsh environments. These layers are important for stratigraphic interpretation because they represent widespread, isochronous surfaces that can act as correlatable markers within the paralic interval.

Delta Front Environments

The delta front environment forms the transition between the fluvial dominated delta plain and the more open marine settings. It is characterised by fine to medium grained sandstones, laminated silty shales, and bioturbated units that reflect oscillatory flow and tidal influence. Sedimentary structures such as ripple laminations, cross bedding, and soft sediment deformation are common in this zone.

Dinocysts may increase slightly in abundance relative to miospores as marine influence becomes stronger. These intervals often form important reservoir bodies because they contain well sorted sandstones with good vertical continuity.

Shallow Marine Environments

The lower parts of the paralic sequence may record shallow marine deposition during periods of marine transgression. These environments contain finer grained sediments, glauconitic horizons, occasional fossil fragments, and higher proportions of dinocysts. Such intervals commonly serve as regional seals because of their finer texture and lower permeability.

Shallow marine units are also useful for identifying Maximum Flooding Surfaces, which can be tied to palynological markers and traced across the depobelt.

Influence of Structural Controls

Depositional environments in the Agbada Formation are strongly influenced by the structural configuration of the depobelts. Growth faults create variations in accommodation space, which control the thickness, geometry, and stacking pattern of facies. These structural influences are pronounced in the Greater Ughelli Depobelt, where rapid subsidence and fault movement enhance lateral facies variability and complicate correlation.

The integration of lithofacies analysis, palynological data, and knowledge of depositional environments therefore provides a strong foundation for predicting reservoir continuity and evaluating hydrocarbon potential in wells located within this structurally active region.

2.5 GROWTH FAULT TECTONICS IN THE GREATER UGHELLI DEPOBELT

The structural framework of the Niger Delta is dominated by syndepositional growth faults that formed in response to rapid sediment loading, differential subsidence, and the deformation of overpressured shale units in the underlying Akata Formation. These faults influence sediment dispersal, reservoir architecture, and hydrocarbon accumulation patterns. Their impact is especially pronounced in the Greater Ughelli Depobelt where fault activity is intense and continuous throughout the Miocene (Doust and Omatsola, 1990; Corredor, 2003).

Growth faults are listric in nature. They flatten downward into detachment surfaces within the Akata shales. The hanging walls experience progressive subsidence as sediment accumulates, creating thickened sequences on the downthrown side. The footwall blocks remain relatively uplifted. This imbalance produces rollover anticlines, collapsed crest structures, and fault dependent traps that are important for hydrocarbon accumulation.

Mechanics of Growth Fault Formation

As sedimentation increases, the underlying overpressured Akata shales undergo mobilization. This creates conditions for gravitational sliding and seaward movement of the overlying stratigraphic units. The resulting extension triggers the development of fault planes that curve with depth. Continued sediment influx leads to repeated fault reactivation. This process thickens the Agbada Formation on the downthrown blocks and creates accommodation space for paralic facies to accumulate.

These mechanics explain why paralic sequences in the ABC 1 well show significant thickness variations and abrupt facies transitions. They also account for the presence of multiple sand and shale cycles that reflect both depositional changes and structural modification.

Impact on Reservoir Distribution

Growth faults exert strong control on reservoir geometry. Channel sands and delta front sand bodies may be truncated, thickened, or offset across the faults. Reservoirs on the downthrown block are often thicker and more continuous due to enhanced accommodation space. In contrast, the footwall may show thinner or missing intervals.

The structural configuration also creates numerous trapping styles. These include:

- Rollover anticlines that develop as the hanging wall bends during subsidence
- Fault dependent closures where hydrocarbons accumulate against a sealing fault plane
- Step over zones that generate compartmentalised reservoirs with complex connectivity

Such structural traps are characteristic of many producing fields in the Greater Ughelli Depobelt.

Influence on Seal Development

Shale rich intervals within the Agbada Formation tend to thicken in the downthrown blocks of growth faults. These thicker shales act as effective seals between stacked reservoir packages. Coal seams and carbonaceous units may also be preserved on the downthrown side, providing additional sealing capacity.

Therefore, understanding the relationship between fault movement and facies distribution is important for evaluating the integrity of reservoir seal pairs within the ABC 1 well.

Implications for the ABC 1 Well

The ABC 1 interval lies within a structurally active zone of the Greater Ughelli Depobelt. The observed facies changes, variations in reservoir thickness, presence of coal seams, and dominance of terrestrial palynomorphs are consistent with deposition influenced by active fault growth. These properties support the integrated geological model used in later chapters of this study.

Growth fault tectonics therefore provide essential context for interpreting both the lithofacies and the palynostratigraphic data in the ABC 1 well.

2.6 SEQUENCE STRATIGRAPHY CONCEPTS RELEVANT TO THIS STUDY

Sequence stratigraphy provides a framework for interpreting the arrangement of sedimentary deposits in relation to changes in accommodation and sediment supply. In the Niger Delta, where rapid sedimentation and active tectonism strongly influence stratigraphic architecture, sequence stratigraphic concepts are essential for understanding reservoir stacking patterns, the distribution of sealing units, and the regional correlation of paralic facies (Catuneanu, 2006; Doust and Omatsola, 1990).

A sequence consists of genetically related strata bounded at the top and base by key stratigraphic surfaces such as Sequence Boundaries and Maximum Flooding Surfaces. These surfaces reflect significant shifts in shoreline position driven by sea level fluctuations, sedimentation rate changes, and tectonic activity.

Lowstand, Transgressive, and Highstand Systems Tracts

The paralic deposits of the Agbada Formation commonly display characteristics of three major systems tracts.

Lowstand Systems Tract (LST)

This tract develops when sea level falls and fluvial systems advance across the exposed shelf. Lowstand deposits often include fluvial channel sands, incised valley fills, and basal units that may form important reservoir bodies. These deposits are typically coarser and better sorted than overlying marine influenced sediments.

Transgressive Systems Tract (TST)

The TST forms during sea level rise when marine waters advance landward. Fine grained sediments dominate this interval. Increased abundance of dinocysts and laminated marine shales may mark transgressive phases within the ABC 1 well. The TST often contains key flooding surfaces that serve as reliable correlatable markers.

Highstand Systems Tract (HST)

This tract develops when sea level stabilises after a transgression. Delta front and delta plain deposits prograde seaward as accommodation decreases. Sand shale cycles characteristic of the Agbada Formation are commonly associated with the HST and may form multiple stacked reservoir intervals.

Key Sequence Stratigraphic Surfaces

Several stratigraphic surfaces are significant in paralic basins.

Sequence Boundary (SB)

Represents a surface of erosion or non deposition. These boundaries may coincide with incised valley bases or sharp facies shifts between marine and fluvial deposits.

Transgressive Surface (TS)

Marks the onset of marine flooding over previously exposed or proximal deposits. Often associated with increased marine palynomorphs or finer grain sizes.

Maximum Flooding Surface (MFS)

Represents the greatest landward extension of marine conditions. This surface is commonly identified using peaks in dinocyst abundance, enriched organic content, or widespread marine shales. The MFS is a key chronostratigraphic marker that can be correlated across the Greater Ughelli Depobelt.

Application to the ABC 1 Well

Sequence stratigraphic concepts are central to understanding the vertical stacking pattern of the ABC 1 succession. The dominance of miospores, the presence of coal seams, and the alternation of sandstone and shale intervals suggest repeated transitions between lowstand, transgressive, and highstand phases within a fluvio deltaic system.

By combining lithofacies characteristics with palynological zonation, sequence stratigraphic surfaces can be identified and correlated within the Agbada Formation. This integration provides a stronger basis for predicting reservoir continuity, recognising seal efficiency, and interpreting subsurface heterogeneity in structurally active parts of the Greater Ughelli Depobelt.

2.7 INTEGRATION OF LITHOFACIES AND PALYNOLOGY IN RESERVOIR CHARACTERIZATION

Integrated reservoir studies combine multiple geological datasets to provide a clearer understanding of subsurface conditions. In paralic successions such as the Agbada Formation, lithofacies analysis and palynostratigraphy complement each other and allow for more accurate predictions of reservoir geometry, quality, and continuity (Reijers et al., 1997; Adekoya, 2009). Each method offers insights that are not obtainable from a single dataset.

Lithofacies analysis provides detailed information on sediment texture, composition, depositional energy, and reservoir potential. Palynology provides chronological control and supports the interpretation of paleoenvironmental conditions. When these two datasets are integrated, they strengthen geological models by linking facies architecture to precise temporal markers.

Facies Boundaries and Biozonation

Lithofacies zones often correspond to changes in depositional conditions. Palynological data help confirm whether these changes reflect shifts in shoreline position, transgressive events, or river dominated phases. Index fossils that define biostratigraphic zones provide time control on facies transitions, making it possible to determine if lithofacies variations arise from temporal changes or local sedimentary processes.

This integration is especially valuable in the Greater Ughelli Depobelt where thickness variations and facies shifts may be influenced by growth fault activity. Without palynological age control, distinguishing structural from environmental signals can be challenging.

Reservoir Quality Assessment

Lithofacies features such as grain size, sorting, and mineral composition determine the porosity and permeability of reservoir units. Palynological indicators provide additional context by showing whether reservoir deposition occurred during lowstand, highstand, or transgressive phases of the sequence stratigraphic cycle. For example:

- High miospore abundance paired with texturally mature sands may indicate fluvial channel or distributary mouth bar reservoirs.
- Intervals with increased marine dinocysts and fine grained lithologies may represent transgressive shales that serve as regional seals.

Combining these tools improves predictions of which facies serve as reservoirs, which serve as seals, and how these units vary with depth.

Stratigraphic Correlation and Subsurface Mapping

Integrated models allow stratigraphic zones to be correlated across structurally complex regions. When lithofacies transitions are linked to biostratigraphic markers, the resulting framework becomes more reliable for mapping reservoirs across growth fault blocks. This has direct implications for predicting reservoir distribution in wells adjacent to ABC 1.

Implications for Hydrocarbon Exploration

The integration of lithofacies analysis and palynostratigraphy strengthens hydrocarbon prospectivity evaluation by:

- Improving the prediction of reservoir distribution in paralic sequences
- Defining sealing intervals with greater confidence
- Supporting the identification of migration pathways
- Enhancing understanding of depositional cycles that influence reservoir architecture

This combined approach forms the foundation of modern reservoir characterisation in the Niger Delta and is central to the workflow applied to the ABC 1 well.

2.8 HYDROCARBON PROSPECTIVITY IN PARALIC SETTINGS OF THE NIGER DELTA

Hydrocarbon prospectivity in the Niger Delta is closely linked to the distribution of sand shale cycles within the paralic Agbada Formation. These cycles reflect shifts between continental, marginal marine, and shallow marine depositional conditions that control reservoir quality, sealing capacity, and trap development (Kulke, 1995; Doust and Omatsola, 1990). Paralic settings are particularly important because they host the majority of oil and gas accumulations in the central and eastern parts of the basin.

The Agbada Formation contains multiple stacked reservoir units that formed during progradation of the delta. These sands are typically medium to fine grained, moderately to well sorted, and have favourable porosity and permeability values. The interbedded shales act as effective vertical and lateral seals, allowing hydrocarbons from the underlying Akata source rocks to accumulate in discrete stratigraphic and structural traps.

Reservoir Potential of Paralic Sands

The paralic sandstones of the Agbada Formation serve as high quality reservoirs when they possess sufficient thickness, continuity, and favourable textural properties. The combination of fluvial channel sands, distributary mouth bar deposits, and delta front sands creates complex yet productive reservoir geometries. Textural maturity, clean quartz rich compositions, and minimal clay content are common characteristics of productive intervals.

The ABC 1 well shows several lithofacies zones with these properties. These zones indicate good reservoir potential in the deeper parts of the paralic succession and suggest favourable conditions for hydrocarbon entrapment.

Seal Effectiveness in Paralic Systems

Effective hydrocarbon traps require competent seals. In paralic settings, several lithologies function as seals, including:

- Marine shale units deposited during transgressive events
- Floodplain mudstones
- Coal seams and carbonaceous shale layers

These sealing intervals reduce vertical migration and compartmentalise stacked sand bodies. Seal integrity is enhanced when these units thicken in the downthrown blocks of growth faults, a common feature in the Greater Ughelli Depobelt.

Trap Styles and Structural Influence

The structural configuration of the Niger Delta exerts a strong influence on hydrocarbon prospectivity. Growth faults create numerous trap types, including rollover anticlines, fault assisted closures, and collapsed crest structures. The differential movement between fault blocks also affects facies thickness and reservoir geometry.

In the Greater Ughelli Depobelt, these traps often coincide with thick paralic sands. This combination accounts for the high concentration of producing fields in this region.

Migration Pathways and Charge Timing

Hydrocarbon generation occurs primarily in the Akata Formation where rich marine shales reach sufficient thermal maturity. Generated hydrocarbons migrate upward through fault zones, sand filled conduits, and permeable pathways. The timing of migration relative to trap formation determines whether hydrocarbons accumulate or bypass potential reservoirs.

The ABC 1 well lies in a structural domain where active faulting, paralic facies development, and favourable timing support the potential for hydrocarbon charge. The dominance of terrestrial palynomorphs, presence of coal, and distribution of sandstone units indicate strong reservoir seal pairs that could retain hydrocarbons if migration pathways are favourable.

Overall Prospectivity of the ABC 1 Well Interval

The combination of lithofacies characteristics, palynological signals, and structural features suggests that the evaluated interval in the ABC 1 well possesses significant hydrocarbon prospectivity. The thick paralic succession, high miospore content, coal development, and presence of multiple sandstone bodies support the interpretation of a fluvio deltaic to marginal marine system with good potential for reservoir development.

This understanding provides the foundation for the integrated analysis presented in subsequent chapters.

CHAPTER THREE

METHODOLOGY

3.1 INTEGRATED PROJECT WORKFLOW

The research design followed a sequential and integrated methodology that combined sedimentological analysis (rock typing) with biostratigraphic dating (palynology) to achieve a high-resolution subsurface interpretation for the ABC 1 well. This approach aligns with the recommendations of Ehinola and Olagoke (2019) for studies in structurally complex deltaic settings. The entire workflow was executed in three iterative phases, as illustrated in Figure 2.

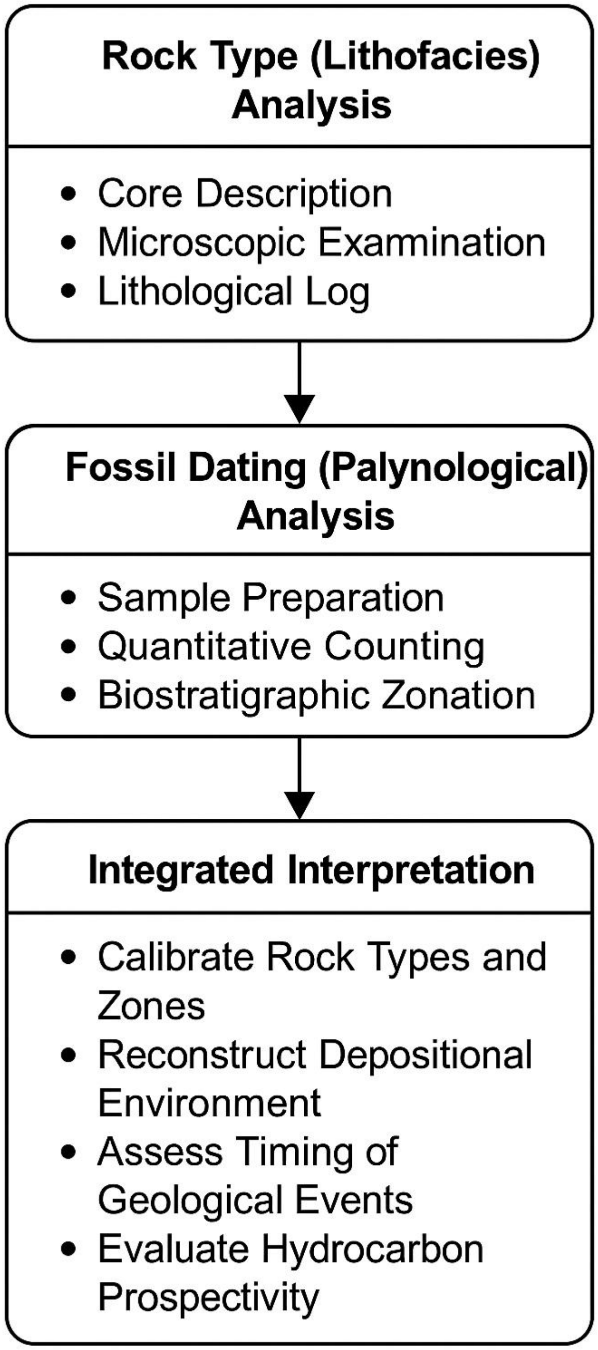

Figure 2. Integrated workflow for the ABC 1 well showing the sequential phases of rock type analysis, palynological processing, biostratigraphic zonation, and final integrated interpretation.

Phase 1: Rock Type (Lithofacies) Analysis

This phase involved microscopic sedimentological description of side wall core samples, production of a vertical lithological log, and identification of thirty nine rock type zones. The analysis helped identify key controls on reservoir quality such as grain size, sorting, mineral composition, and diagenetic effects.

Phase 2: Fossil Dating (Palynological) Analysis

This phase included laboratory preparation of samples for palynomorph extraction, quantitative counting, and identification of biostratigraphic markers. The goal was to define First Appearance Datum and Last Appearance Datum for key species.

Phase 3: Integrated Interpretation and Prospectivity

The final phase combined the spatially defined rock types (reservoirs and seals) with temporal biostratigraphic zones (biozones) to reconstruct the depositional paleoenvironment, establish correlations, and evaluate the hydrocarbon potential of the ABC 1 succession.

3.2 ROCK TYPE ANALYSIS OF SIDE WALL CORES

Seventy side wall core samples from the Agbada Formation were examined to determine lithological, mineralogical, and organic characteristics. Side wall cores provide pristine, unmixed samples that retain primary sedimentary textures, which makes them suitable for detailed facies analysis (Onyemaobi and Agbaje, 2020).

The lithological study focused on **three analytical pillars** that define the thirty nine rock type zones:

3.2.1 Textural Analysis

Grain size was measured using the Wentworth Scale, while sorting and grain roundness were documented for each sample. These parameters are primary controls on reservoir quality because well sorted, rounded grains typically provide better pore connectivity (Ayodele and Oladapo, 2021).

3.2.2 Mineralogical and Compositional Analysis

The dominant mineral components (quartz, silt, clay) were identified through microscopic inspection. Diagenetic features, such as calcareous cementation or clay coatings, were documented because these greatly influence reservoir performance by reducing pore space (Elias and Osun, 2024).

3.2.3 Organic Content Analysis

The presence of lignite streaks, woody fragments, or coal layers was recorded. High concentrations of terrestrial organic matter reflect strong delta plain influence and provide indications of source rock potential within the Greater Ughelli Depobelt (Udoma and Umoh, 2018).

All rock attributes were compiled vertically to generate genetically related lithofacies units. **The final lithological log is presented in Chapter 4 (Figure 4).**

3.3 FOSSIL DATING (PALYNOLOGICAL) SAMPLE PROCESSING AND ANALYSIS

Palynological analysis followed established laboratory protocols designed to isolate acid-insoluble organic residues and ensure high-quality fossil recovery (Germeraad et al., 1968). The workflow is summarized in **Figure 3**.

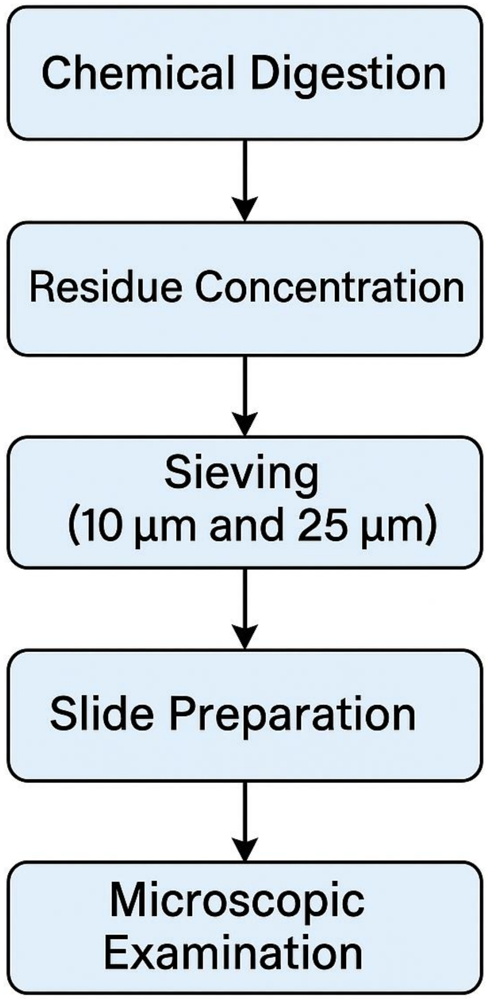

Figure 3. Workflow for palynological processing showing chemical digestion, residue concentration, sieving at 10 µm and 25 µm, slide preparation, and quantitative microscopic examination.

3.3.1 Chemical Digestion

Carbonates were removed using cold Hydrochloric Acid, followed by dissolution of silicate minerals with Hydrofluoric Acid to isolate palynomorphs (Egbuna and Ugwu, 2018; Oloto, 1993).

3.3.2 Concentration and Sieving

The residue was concentrated via heavy liquid separation and sieved at 10 µm and 25 µm to focus on the palynomorph size fraction.

3.3.3 Microscopic Counting and Identification

Mounted slides were scanned systematically. A total of **701 palynomorphs** were counted and classified into pollen (253), spores (441), and dinocysts (7) following Osokpor and Aigbedion (2022).

These data form the foundation for interpreting depositional environments in Chapter 4.

3.3.4 Biostratigraphic Zonation

First Downhole Occurrence and Last Downhole Occurrence of diagnostic taxa were used to define eight informal palynological zones. These biozones form the high-resolution chronostratigraphic framework for the well (Lawal and Balogun, 2018; Ologun and Akpan, 2023).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 ROCK TYPE DELINEATION AND INTERPRETATION

The examination of seventy side wall core samples from the ABC 1 well resulted in the identification of thirty nine distinct rock type zones across the studied interval of the Agbada Formation, covering depths from 1881 m to 2699 m. These rock types were differentiated based on grain size, sorting, mineral assemblage, organic content, and diagenetic features, following established sedimentological procedures (Adekoya, 2009). The vertical lithological succession that captures these rock type zones is presented in **Figure 4**.

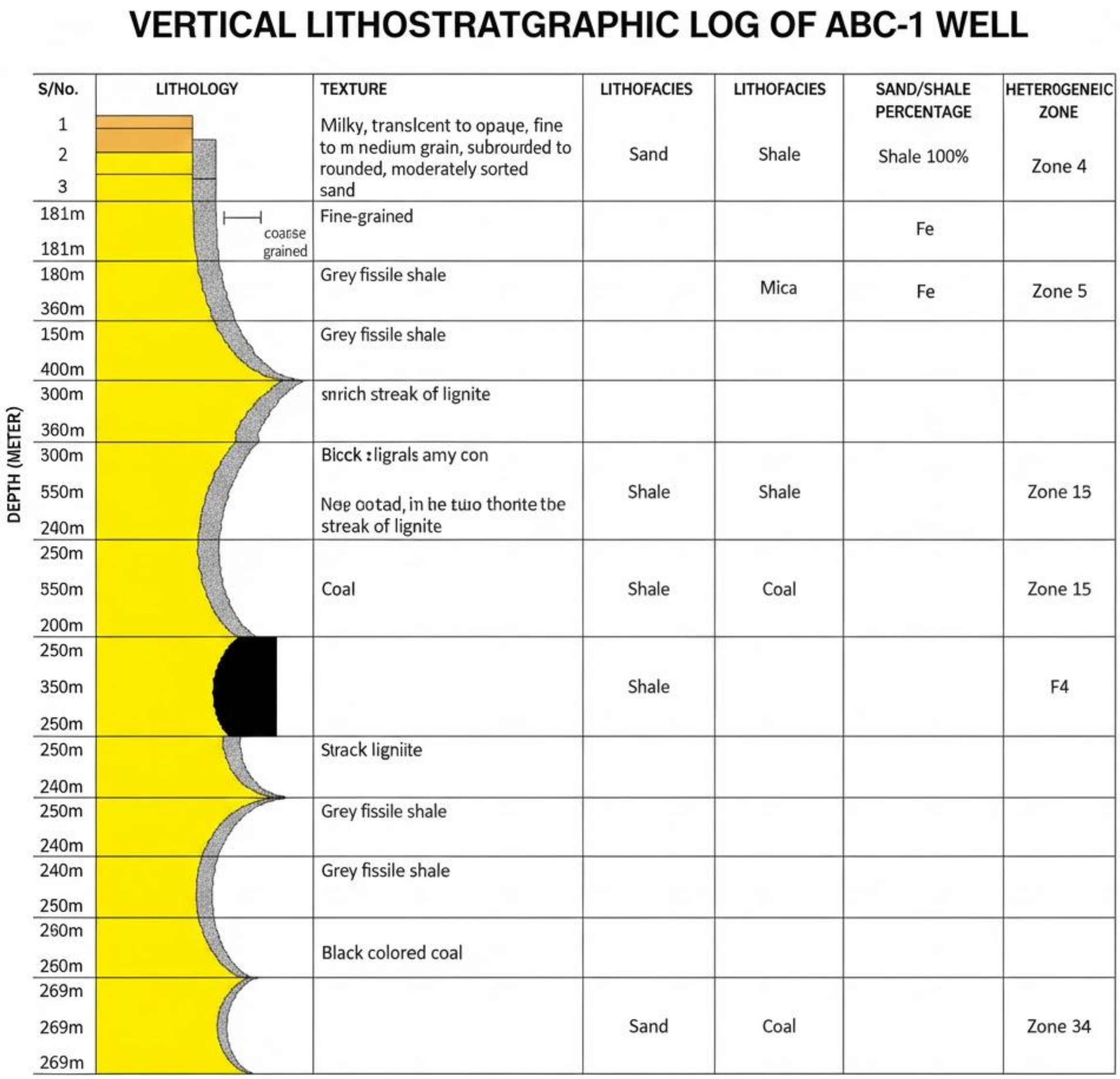

Figure 4. Vertical lithological log of the ABC 1 well showing the thirty nine rock type zones interpreted from side wall core descriptions.

4.1.1 Vertical Lithological Succession and Facies Description

The lithological succession displayed in Figure 4 reveals a characteristic alternation of coarse clastics (sandstone and siltstone) with fine clastics (shale and coal). This cyclic pattern reflects deposition under high sedimentation rates within a fluvio deltaic system typical of the Greater Ughelli Depobelt (Afolayan and Jimoh, 2021). The major facies types are summarised below.

Sandstone Facies

These units contain dominantly quartz rich sands that range from fine to medium grain size. Sorting varies from poor to well sorted, and the grains range from subangular to rounded. Representative examples include Zones 4 and 34. These facies represent high energy depositional settings such as fluvial channels, distributary mouth bars, and delta front sand bodies.

Fine Grained Facies

These units include grey, fissile shale and silty shale, typical of low energy environments such as prodelta, lagoonal, and interdistributary bay settings. The presence of finely laminated shales and silt rich intervals suggests periods of reduced sediment influx and quieter water conditions.

Organic Rich Facies

These consist of dark lignite streaks and coal layers, with Zones 15 and 24 as notable examples. Such intervals indicate swampy, waterlogged conditions associated with coastal plain or delta plain settings (Udoma and Umoh, 2018). They also point to strong terrestrial input, which is consistent with the extremely high miospore abundance documented in the palynological dataset.

4.1.2 Interpretation of Key Rock Type Zones and Their Oil/Gas Potential

The hydrocarbon prospectivity of the ABC 1 well is closely tied to the quality and distribution of its rock type zones. The alternation of reservoir and seal facies forms an effective framework for hydrocarbon migration and entrapment.

Reservoir Facies

High quality reservoir sands occur where grain sizes are fine to medium, sorting is good, and grains are well rounded. Zone 34 is an example of a reservoir interval with favourable textural properties that promote good porosity and permeability (Ayodele and Oladapo, 2021). Lignite streaks occurring within some sandstones, such as in Zone 4, indicate proximity to terrestrial sediment sources and deposition near the delta front.

Seal and Source Facies

Grey, fissile shales such as those in Zone 5 act as excellent sealing units by restricting vertical fluid movement. Thick, organic rich coal and lignite layers, such as Zone 15, represent potential source rock intervals containing Type III kerogen capable of generating gas and mixed hydrocarbons within the Niger Delta system (Obaje and Ndukwe, 2024).

Reservoir-Seal Pair Integrity

The repetitive stacking of reservoir quality sandstones immediately overlain or underlain by sealing shales and organic facies creates ideal reservoir seal pairs. This pattern supports hydrocarbon accumulation in both structural and stratigraphic traps within the Greater Ughelli Depobelt. The consistency of this stacking arrangement indicates a stable depositional pattern controlled by fluvio deltaic processes and growth fault related accommodation changes.

4.2 FOSSIL DATING (PALYNOLOGICAL) ABUNDANCE AND DISTRIBUTION

Palynological examination of the ABC 1 well interval (6172 ft to 8854 ft) yielded a total of **701 palynomorphs**. This quantitative dataset forms the basis for interpreting the paleoenvironment and for defining the informal biozones used in the chronostratigraphic framework. The overall composition of the recovered assemblage is summarised in **Table 1**.

Table 1. Total Palynomorph Recovery and Distribution in the ABC 1 Well

Palynomorph Group	Count	Percentage (%)	Paleoenvironmental Significance
Miospores (Pollen: 253 + Spores: 441)	694	99.0	High terrestrial influx → Proximal paralic conditions
Dinocysts (Marine Algae)	7	1.0	Limited marine influence (marginal marine)
Total	**701**	**100.0**	

4.2.1 Palynomorph Assemblage Composition

The assemblage is overwhelmingly dominated by terrestrial palynomorphs (miospores). The ratio of **99 percent miospores to 1 percent dinocysts** provides strong evidence for a highly proximal depositional setting. Such dominance of pollen and spores is typical of the inner Agbada Formation, where fluvial discharge and rapid sediment input restrict marine influence (Osokpor and Aigbedion, 2022).

The minimal presence of dinocysts indicates only brief or subdued marine incursions. This pattern is consistent with settings where delta plain or delta front processes deliver abundant terrestrial material, thereby diluting marine palynomorphs (Egbuna and Ugwu, 2018).

4.2.2 Vertical Distribution Pattern

The vertical distribution of palynomorphs across the studied interval is illustrated in **Figure 5**. The plot displays changes in counts with depth and highlights intervals where palynomorph abundance varies in response to depositional and preservation conditions.

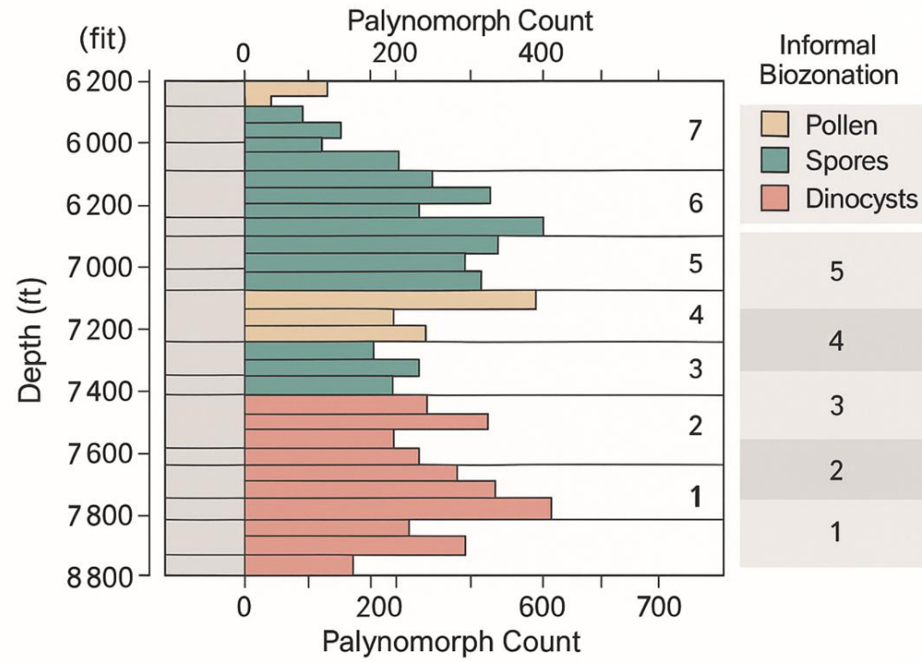

Figure 5. Downhole distribution of pollen, spores, and dinocysts in the ABC 1 well showing changes in palynomorph abundance and the intervals used for informal biozonation.

Figure 5. Downhole distribution of pollen, spores, and dinocysts in the ABC 1 well showing changes in palynomorph abundance and the intervals used for informal biozonation.

Abundance Patterns and Their Implications

The vertical pattern reveals:

- **Higher palynomorph abundance in shale dominated intervals**, reflecting lower energy deposition and favourable preservation.
- **Reduced counts in sandy units**, likely related to higher energy conditions where delicate organic particles are poorly preserved.
- **Minor fluctuations in dinocyst abundance**, corresponding to short lived marine influence or minor transgressive events.

These variations are important because they help identify stratigraphic intervals where conditions shifted between delta plain, distributary bay, and marginal marine settings.

Biozonation Control

The downhole changes in miospore frequency, supported by occurrences of key index taxa, form the basis for:

- Distinguishing the **eight informal biozones**,
- Establishing **chronostratigraphic markers**, and
- Correlating the ABC 1 well with regional palynostratigraphic frameworks (Lawal and Balogun, 2018).

This biozonation underpins the reconstruction of depositional history and integrates directly with the lithofacies patterns discussed in Section 4.1.

4.3 INFORMAL FOSSIL DATING ZONES (P-ZONES)

The quantitative palynological data from the ABC 1 well were used to develop a high-resolution chronostratigraphic framework based on the distribution of key age-diagnostic palynomorphs. A total of **eight informal palynological zones** were identified. These zones were defined using the First Downhole Occurrence and Last Appearance Datum of selected index fossils, following established Niger Delta biostratigraphic practice (Ologun and Akpan, 2023; Lawal and Balogun, 2018).

The zonation provides the temporal structure necessary for correlating the ABC 1 sequence with the established Miocene stratigraphy of the Greater Ughelli Depobelt.

4.3.1 Key Biozone Characteristics

The informal zones were defined using the distribution of important species, including:

1. *Praedapollis africanus* (T443)
2. *Peregrinipollis nigericus* (T399)
3. *Retibrevitricolporites obodoensis* (T178)
4. *Pachydemites diederixi* (T317)
5. *Racemonocolpites hians* (250)

6. *Psilatricolporites crassus* (535)
7. *Retitricolporites irregularis* (511)

A summary of the eight biozones is presented in **Table 2**.

Table 2. Informal Palynological Zones (P-Zones) for the ABC 1 Well

Biozone	**Thickness (m)**	**Depth Interval (m)**	**Key Defining Fossil Event**	**Stratigraphic Significance**
Biozone 1	34 & 2093–2127	FDO of *Praedapollis africanus* (T443) at 2093 m.	Marks the youngest interval in the sampled section.	
Biozone 2	70 & 2127–2197	FDO of *Retibrevitricolporites obodoensis* (T178) at 2127 m.		
Biozone 3	30 & 2197–2227	FDO of *Pachydemites diederixi* (T317) at 2227 m.		
Biozone 4	150 & 2227–2377	FDO of *Pachydemites diederixi* (T317) at 2227 m to Increase *Racemonocolpites hians* (Inc250) at 2377 m.	Represents the longest continuous stratigraphic interval.	
Biozone 5	26 & 2377–2403	Increase *Racemonocolpites hians* (Inc250) at 2377 m to Increase *Peregrinipollis nigericus* (399) at 2403 m.		
Biozone 6	76 & 2403–2479	Increase *Peregrinipollis nigericus* (399) at 2403 m to FAD *Psilatricolporites crassus* (535) at 2479 m.		
Biozone 7	15 & 2479–2494	FAD *Psilatricolporites crassus* (535) at 2479 m to Base continuous *Racemonocolpites hians* (250) at 2494 m.		
Biozone 8	54 & 2494–2548	Base continuous *Racemonocolpites hians* (250) at 2494 m to Base *Retitricolporites irregularis*	Marks the oldest interval in the sampled section.	

Biozone	Thickness (m)	Depth Interval (m)	Key Defining Fossil Event	Stratigraphic Significance
		(511) at 2548 m.		

4.3.2 Chronostratigraphic Control

The succession of bioevents defined in the eight zones provides a robust chronostratigraphic framework for the ABC 1 well. The overlap of diagnostic species, including several with known Oligocene to Pliocene ranges, confirms that the analysed interval belongs to the **Miocene section of the Agbada Formation**.

These biostratigraphic surfaces serve several crucial purposes:

1. They establish reliable time lines within the paralic succession.
2. They support correlation of reservoir and seal units across the Greater Ughelli Depobelt.
3. They provide age control for interpreting Maximum Flooding Surfaces and Sequence Boundaries.
4. They form the basis for integrating the lithofacies results with regional sequence stratigraphic models (Adekeye and Adebisi, 2022).

Together, the informal P-Zones offer a detailed temporal framework that improves geological interpretation and enhances prediction of reservoir–seal pair distribution in structurally complex deltaic settings.

4.4 INTEGRATED GEOLOGICAL INTERPRETATION AND OIL/GAS POTENTIAL

The combined interpretation of the lithofacies results (Section 4.1) and the fossil dating framework (Section 4.3) provides a coherent geological model for the ABC 1 well. This integration strengthens the evidence for a functioning petroleum system within the Greater Ughelli Depobelt and clarifies the stratigraphic and environmental controls that influence hydrocarbon occurrence.

4.4.1 Paleoenvironmental Reconstruction

The palynological dataset is dominated by miospores, which account for ninety nine percent of the total recovered assemblage (Table 4.1). This dominance indicates a strongly terrestrial setting with high sediment supply, a pattern typical of the inner Agbada Formation where fluvial systems transport large volumes of plant material into delta plain and delta front environments (Osokpor and Aigbedion, 2022).

This interpretation aligns closely with the lithological succession illustrated in Figure 5. The repeated occurrence of fluvial channel sandstones, grey fissile shales, and coal or lignite beds reflects a paralic environment shaped by alternating periods of channel migration, swamp development, and lower energy overbank deposition. The very low dinocyst content supports only minor marine influence, likely restricted to brief transgressive phases. Overall, the environment is interpreted as a fluvio deltaic system with strong terrestrial imprint and limited open marine conditions.

4.4.2 Assessment of Oil and Gas Potential

Reservoir Distribution and Quality

Several intervals within the ABC 1 well contain sandstone facies with favourable reservoir characteristics. Fine grained and well sorted sands, such as those recorded in Zone 34 between 2185 m and 2197 m, show textural features consistent with high porosity and good permeability. These sands were deposited in relatively energetic settings, such as distributary channels or mouth bar complexes, where grain size and sorting are optimal for reservoir development. Similar Miocene reservoirs in the Greater Ughelli Depobelt are productive due to their position along growth fault systems that provide structural closure (Afolayan and Jimoh, 2021; Ayodele and Oladapo, 2021).

Source and Seal Distribution

The well contains thick, laterally continuous shale intervals that serve as effective seals. These shales, such as those within Zone 5, cap the reservoir sands and restrict fluid movement. In addition, the presence of discrete coal and lignite layers, particularly Zone 15 between 2403 m and 2413 m, indicates intervals rich in Type III kerogen. These organic rich facies are capable of generating gas and gas condensate under suitable burial conditions and are important components of the Niger Delta petroleum system (Obaje and Ndukwe, 2024; Udoma and Umoh, 2018).

Chronostratigraphic Strengthening of the Model

The eight informal biozones established in Section 4.3 provide the temporal control required to correlate these reservoir, seal, and source units across the depobelt. The vertical sequence of bioevents allows age equivalent strata to be traced laterally, supporting interpretation of regional reservoir continuity, especially toward known fault controlled traps within the Greater Ughelli Depobelt (Ologun and Akpan, 2023; Adekeye and Adebisi, 2022). This chronostratigraphic framework ensures that the lithofacies relationships are interpreted within a consistent time scale.

4.4.3 Overall Petroleum System Assessment

The ABC 1 well displays a favourable combination of:

- High quality reservoir sands,
- Thick sealing shales,
- Organic rich coal and lignite source beds,
- And a well constrained Miocene timing of deposition.

This arrangement indicates a strong potential for hydrocarbon generation, trapping, and preservation. The regular alternation of reservoir and seal units, supported by a stable depositional pattern and clear biostratigraphic age control, confirms the presence of the essential components of a viable petroleum system.

In summary, the integrated geological interpretation demonstrates that the ABC 1 well has very good Oil and Gas Potential. The stacking of high quality reservoir sands within a fault influenced Miocene setting, combined with reliable chronostratigraphic constraints, provides strong indicators of prospectivity within the Greater Ughelli Depobelt.

4.4 Implications for Reservoir Architecture and Petroleum Prospectivity

The combined lithofacies, palynological, and chronostratigraphic results allow a detailed assessment of reservoir architecture within the ABC 1 well. These interpretations also provide insight into the broader petroleum prospectivity of the Greater Ughelli Depobelt, particularly within Miocene paralic sequences where structural and stratigraphic controls work together to influence hydrocarbon distribution.

4.4.1 Reservoir Geometry and Connectivity

The distribution of clean, fine to medium grained sandstone units suggests the presence of laterally extensive reservoir bodies formed in channel belts, delta front bars, and distributary mouth bars. These sandstones show good sorting in several intervals, minimal diagenetic cementation, and repeated vertical stacking. These characteristics point to favourable reservoir connectivity both vertically and laterally.

The geometry described here is comparable to known producing reservoirs in nearby Greater Ughelli fields such as Kokori, Afiesere, and Utorogu. These fields are characterised by multi-tiered Miocene sand bodies that retain good reservoir continuity over significant distances. The similarities strengthen the interpretation that the ABC 1 sand units have potential for comparable connectivity.

4.4.2 Seal Development and Effectiveness

The grey fissile shales and organic rich lignite or coal beds identified in several zones provide effective sealing intervals. Their continuity across depth suggests that they act as regional fluid barriers. In the Greater Ughelli Depobelt, strong seals are common within the Miocene Agbada Formation, where shale dominated transgressive phases cap underlying sand units. Similar patterns are present in the ABC 1 log, indicating that the well sits within a classic paralic reservoir–seal arrangement.

4.4.3 Source Rock Distribution and Maturity Potential

The presence of coal and lignite beds confirms the availability of Type III kerogen rich source material. Although maturity cannot be determined fully without geochemical data, the burial depth of the ABC 1 interval, along with the known geothermal gradients of the Ughelli East and Ughelli West fields, suggests that these organic units may have reached the early to mid gas generating window. This interpretation agrees with the dominance of gas in many Miocene reservoirs developed in the depobelt.

4.4.4 Structural Controls on Reservoir Potential

Growth fault systems dominate the structural framework of the Greater Ughelli Depobelt. These faults commonly produce rollover anticlines, fault assisted closures, and collapsed crest traps. When the reservoir sands identified in the ABC 1 well are projected into this structural setting, it becomes evident that they could form part of similar trap configurations. The biozones established in Section 4.3 provide age control that supports correlation with nearby producing structures in the Kokori and Utorogu area.

4.4.5 Overall Prospectivity Assessment

The reservoir architecture inferred from this study indicates that the ABC 1 well penetrates a stratigraphic interval with strong hydrocarbon potential, supported by:

- Multiple high quality reservoir sands with good sorting and favourable textures.
- Thick, laterally continuous shales that provide effective seals.
- Organic rich source beds capable of generating gas.
- Reliable biostratigraphic age control for regional correlation.
- A structural environment known for prolific hydrocarbon entrapment.

Taken together, these features confirm that the ABC 1 succession contains the key elements of a working petroleum system. The results support continued exploration and appraisal within the surrounding area of the Greater Ughelli Depobelt.

4.5 Sequence Stratigraphic Implications

The integration of lithofacies characteristics, palynological indicators, and the eight informal biozones provides a framework for interpreting the sequence stratigraphy of the ABC 1 well. The paralic Agbada Formation is well known for its complex stacking pattern of fluvial, delta front, and shallow marine deposits, driven by alternating periods of sediment supply, accommodation changes, and minor marine incursions. The results from this study fit neatly within that context.

4.5.1 Identification of Key Surfaces

Several stratigraphic surfaces can be inferred from the vertical alternation of sandstone, shale, and organic rich units, supported by the distribution of palynomorphs.

Maximum Flooding Indicators

Intervals with slightly increased dinocyst occurrence, although rare, likely represent brief transgressive phases where marine conditions expanded over the delta plain. These peaks, supported by shifts in palynomorph diversity, mark candidate Maximum Flooding Surfaces within the Miocene succession.

Regressive and Lowstand Indicators

Thick, well sorted sandstone bodies associated with reduced palynomorph abundance reflect phases of increased fluvial energy and sediment influx. These are consistent with regressive to lowstand conditions where channels and mouth bars prograded basinward.

Transgressive Shale Caps

The presence of laminated grey shale overlying several sandstone units indicates the onset of transgressive conditions where rising relative sea level restricted coarse clastic deposition. These shales often serve as local sealing units within the stratigraphic framework.

4.5.2 Biozones as Chronostratigraphic Markers

The eight informal palynological zones described in Section 4.3 provide the time control for distinguishing stratigraphic packages. These biozones support the identification of genetic sequences by:

- Defining age equivalent units across the interval.
- Highlighting shifts in vegetation or environmental conditions tied to sea level change.
- Serving as correlation markers for regional mapping within the Greater Ughelli Depobelt.

The succession of bioevents aligns with established Miocene sequence stratigraphic frameworks for the central Niger Delta.

4.5.3 Stratigraphic Stacking Pattern

The stacking of reservoir sands, shale dominated flooding units, and coal or lignite beds reflects a cyclic pattern typical of delta plain evolution. These cycles record:

- Rapid progradation during high sediment input.
- Short lived marine incursions during accommodation increases.
- Swamp development during periods of reduced clastic influx.

This pattern is consistent with the high frequency sequence development documented in comparable wells from Kokori, Utorogu, and Afiesere fields in the Greater Ughelli Depobelt.

4.5.4 Implications for Hydrocarbon Distribution

Understanding the sequence stratigraphic setting provides important guidance for predicting hydrocarbon presence and continuity:

- Reservoir sands are more likely to be regionally extensive in regressive to early highstand phases.
- Transgressive shale units define effective vertical seals and compartmentalise stacked reservoir intervals.
- Coal rich packages, formed during periods of limited marine influence, provide localised source rock development.

The arrangement of these elements within a clear sequence framework improves confidence in identifying prospective zones and correlating them across structurally complex areas of the depobelt.

Summary

The results presented in this chapter provide a detailed interpretation of the lithological, palynological, and chronostratigraphic characteristics of the ABC 1 succession within the Agbada Formation. The analysis of seventy side wall core samples allowed the definition of thirty nine rock type zones that reflect repeated cycles of sandstone, siltstone, shale, and organic rich units. These facies indicate a paralic, fluvio deltaic system dominated by high sediment supply and short lived marine influence.

The palynological study supported the lithological evidence. A total of seven hundred and one palynomorphs were recovered, with miospores accounting for ninety nine percent of the assemblage. This overwhelming terrestrial dominance confirms deposition on the delta plain where fluvial and swamp processes prevailed. The scarcity of dinocysts indicates that marine incursions were limited to brief transgressive phases. The eight informal biozones established from First Downhole Occurrences and Last Appearance Datums provided the time control necessary for placing the succession within the regional Miocene framework.

Integration of the rock type interpretation with the fossil dating zones allowed reconstruction of the depositional environment and assessment of hydrocarbon potential. The well contains several high quality sandstone reservoirs with favourable textural and compositional attributes, supported by thick shale and coal intervals that function as reliable seals and potential source units. The stratigraphic arrangement and stacking pattern match known productive Miocene systems in the Greater Ughelli Depobelt. The presence of growth fault related trapping configurations in the region further strengthens the petroleum prospectivity of the ABC 1 interval.

Overall, the results confirm that the ABC 1 well contains the essential elements of a working petroleum system, with strong evidence for reservoir continuity, effective sealing, and organic rich source beds. These findings form the basis for the conclusions and recommendations presented in Chapter Five.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 SUMMARY

This study applied an integrated geological approach to evaluate the Oil and Gas Potential of the ABC 1 well located in the Greater Ughelli Depobelt, a prolific Miocene hydrocarbon province of the Niger Delta Basin. The well penetrated the Agbada Formation between 1881 m and 2699 m, and the analysis combined detailed lithofacies description with high resolution fossil dating.

Rock type characterization was carried out on seventy side wall core samples, resulting in the identification of thirty nine lithofacies zones. The succession displays a clear cyclic arrangement of coarse grained sandstones, grey fissile shales, siltstone units, and organic rich coal or lignite beds. These facies confirm deposition in a high energy fluvio deltaic system typical of the Miocene Agbada Formation. The sandstone units show good reservoir qualities, while shale and coal facies offer strong potential as seals and sources respectively.

The palynological investigation yielded seven hundred and one palynomorphs, dominated by miospores which account for ninety nine percent of the assemblage. This overwhelming terrestrial signal confirms a proximal paralic paleoenvironment, where sediment influx from the delta plain was high and marine influence was minimal. Dinocysts contributed only one percent of the total count.

Eight informal biozones were established using key FAD and LAD events of index palynomorphs. These zones provide reliable chronostratigraphic control and represent the essential time markers needed for lateral correlation of reservoirs within the structurally complex Greater Ughelli Depobelt.

5.2 Conclusion

The integrated analysis shows that the ABC 1 well contains the complete elements of a viable petroleum system. The rock types are favourable for hydrocarbon generation, migration, and trapping. High quality sandstone reservoirs occur at several intervals and are consistently juxtaposed with effective seals and organic rich source beds. The close vertical association of these facies supports the presence of multiple reservoir seal pairs suitable for hydrocarbon accumulation.

The established palynological biozones provide the chronological framework for linking these rock units to regional Miocene stratigraphy. This reduces stratigraphic uncertainty and supports correlation with known producing reservoirs in nearby fields of the Greater Ughelli Depobelt. The structural setting, dominated by growth faults and rollover geometries, further strengthens the exploration potential of the ABC 1 interval.

Overall, the well is assessed to possess excellent Oil and Gas Potential, and the geological evidence supports further appraisal work aimed at quantifying reserves and refining the development strategy.

5.3 Recommendations

1. **Integration with Petrophysical Logs**
   The lithofacies boundaries and biozone markers established from core and palynology should be integrated with geophysical log data such as Gamma Ray, Resistivity, and Sonic logs. This will support detailed reservoir modelling and provide quantitative estimates of porosity, permeability, and hydrocarbon saturation.
2. **Development of a Sequence Stratigraphic Framework**
   The chronostratigraphic markers identified in this study should be used to define Maximum Flooding Surfaces, Sequence Boundaries, and Highstand or Lowstand Systems Tracts. A refined sequence stratigraphic model will improve three dimensional correlation of reservoir bodies across the depobelt.
3. **Geochemical Source Rock Validation**
   Organic rich facies, particularly coal, lignite, and shale intervals, should undergo

geochemical analysis including Rock Eval pyrolysis and vitrinite reflectance. These data will confirm kerogen type, thermal maturity, and overall hydrocarbon generation potential.

4. **Incorporation of Seismic Data**

   Two dimensional or three dimensional seismic interpretation is recommended to evaluate lateral reservoir continuity, delineate structural closures, and refine trap geometries associated with growth faults. This will help validate the reservoir distribution inferred from the well.

5. **Appraisal Drilling and Reservoir Simulation**

   Additional wells should be drilled to test reservoir continuity, validate facies models, and support volumetric estimation. Preliminary static and dynamic reservoir simulation models may then be developed to guide early field development planning.

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APPENDICES

APPENDIX I: Detailed Lithofacies Zone Descriptions (ABC-1 Well)

This appendix presents the complete microscopic description and interpretation for the 39 distinct rock type zones delineated from the seventy side wall core samples of the ABC-1 well (Agbada Formation).

Zone	Depth (m)	Lithology & Texture	Organic Content / Composition	Interpretation
Zone 39	1881–1892	Milky, translucent, fine to medium grain, subrounded to rounded, moderately sorted sand.	Non calcareous.	**Good Reservoir Sand.** Fluvial/Deltaic channel.
Zone 38	1892–2106	Milky silt with lignite streak present.	Non calcareous.	Low energy deposition, potential local seal.
Zone 37	2106–2127	Light grey fissile shale.	Streak of lignite present. Non calcareous.	**Regional Seal** / Potential source rock.
Zone 36	2127–2171	Milky, translucent, fine grained, subrounded to rounded sand, moderately to well sorted.	Non calcareous.	**Good Reservoir Sand.**
Zone 35	2171–2185	Grey fissile shale.	Non calcareous.	**Seal.**
Zone	2185–2197	Milky, fine grain,	Non	**Superior Reservoir.** High-

Zone	**Depth (m)**	**Lithology & Texture**	**Organic Content / Composition**	**Interpretation**
34		rounded sand, well sorted.	calcareous.	quality channel sand.
Zone 33	2197–2217	Milky silt with sand.	Non calcareous.	Interdistributary/Overbank deposit.
Zone 32	2217–2223	Milky silt with presence of lignite.	Non calcareous.	Low energy/swamp influence.
Zone 31	2223–2226	Milky silt with sand.	Non calcareous.	Interdistributary/Overbank deposit.
Zone 30	2226–2227	Milky silt with streak of lignite.	Non calcareous.	Localized low energy/swamp.
Zone 29	2227–2265	Grey fissile shale.	Streak of lignite present. Non calcareous.	**Regional Seal** / Potential source rock.
Zone 28	2265–2285	Grey fissile shale with silt and lignite.	Non calcareous.	**Seal** / Source rock indicator.
Zone 27	2285–2301	Grey fissile shale.	Streak of lignite present. Non calcareous.	**Seal.**
Zone 26	2301–2314	Milky silt.	Non calcareous.	Low energy/overbank deposit.
Zone 25	2314–2320	Milky silt with sand.	Non calcareous.	Low energy/overbank deposit.
Zone 24	2320–2326	Dark colour lignite.	Highly organic.	**Source Rock.**
Zone	2326–2327	Grey fissile shale.	Presence of	**Seal.**

Zone	Depth (m)	Lithology & Texture	Organic Content / Composition	Interpretation
23			streak of lignite. Calcareous.	
Zone 22	2327–2329	Milky silt.	Presence of streak of lignite. Non calcareous.	Low energy/swamp influence.
Zone 21	2329–2345	Milky, translucent, fine to medium grain, subrounded sand, moderately sorted.	Non calcareous.	**Good Reservoir Sand.**
Zone 20	2345–2352	Milky silt with sand.	Non calcareous.	Interdistributary/Overbank deposit.
Zone 19	2352–2359	Grey fissile shale.	Presence of streak of lignite. Calcareous.	**Seal.**
Zone 18	2359–2363	Milky silt.	Presence of streak of lignite. Non calcareous.	Low energy/swamp influence.
Zone 17	2363–2399	Milky, translucent, fine to medium grain sand, subrounded, moderately sorted.	Non calcareous.	**Good Reservoir Sand.**
Zone 16	2399–2403	Fine grained, light brown, subrounded, moderately sorted Sandy silt.	Non calcareous.	Low energy/overbank deposit.

Zone	Depth (m)	Lithology & Texture	Organic Content / Composition	Interpretation
Zone 15	2403–2413	Black colored coal.	Highly organic.	**High-Quality Source Rock.**
Zone 14	2413–2565	Milky, translucent, fine to medium grain, subrounded to rounded, moderately to well sorted sand.	Streak of lignite present. Non calcareous.	**Excellent Reservoir Sand.**
Zone 13	2465–2573	Milky silt.	Streak of lignite present. Non calcareous.	Low energy/swamp influence.
Zone 12	2473–2587	Grey fissile shale.	Calcareous.	**Regional Seal.**
Zone 11	2587–2504	Silt, Milky in colour with sand.	Non calcareous.	Interdistributary/Overbank deposit.
Zone 10	2504–2525	Milky, translucent, medium to coarse grain, subrounded to rounded sand with silt, poorly sorted.	Streak of lignite present. Non calcareous.	Reservoir (Fair-Poor sorting).
Zone 9	2525–2529	Silt, milky in colour.	Non calcareous.	Low energy deposit.
Zone 8	2529–2544	Milky, translucent, fine to medium grain, subrounded to rounded, moderately to well sorted sand.	Streak of lignite present. Non calcareous.	**Good Reservoir Sand.**

Zone	**Depth (m)**	**Lithology & Texture**	**Organic Content / Composition**	**Interpretation**
Zone 7	2544–2548	Milky silt with sand.	Streak of lignite present. Non calcareous.	Low energy/swamp influence.
Zone 6	2548–2561	Milky, translucent, fine to medium grain, subrounded to rounded, moderately to well sorted sand.	Streak of lignite present. Non calcareous.	**Good Reservoir Sand.**
Zone 5	2561–2623	Grey fissile shale.	Non calcareous.	**Regional Seal** / Potential source rock.
Zone 4	2623–2673	Milky, translucent, fine to medium grain, subrounded to rounded, moderately to well sorted sand.	Streak of lignite present. Non calcareous.	**Excellent Reservoir Sand.**
Zone 3	2673–2682	Milky silt.	Non calcareous.	Low energy deposit.
Zone 2	2682–2688	Milky, translucent, fine to medium grain, subrounded sand with clay, poor to moderately sorted.	Calcareous.	Fair Reservoir. Calcareous cementation may reduce porosity.
Zone 1	2688–2699	Milky silt with sand.	Non calcareous.	Low energy deposit.

APPENDIX II: Quantitative Palynomorph Count Data (ABC-1 Well)

This appendix provides the raw quantitative data for palynomorph recovery used to establish the environmental interpretations and the eight informal biozones (Table 4.1, Figure 6). The total count for all samples is 701.

S/N	Depth (m)	Depth (ft)	Pollen	Spores	Miospore Total	Dinocyst	TOTAL PALYNOMORPHS
1	2093	6866	22	11	33	0	33
2	2107	6910	17	21	38	0	38
3	2127	6977	13	25	38	0	38
4	2156	7073	8	11	19	1	20
5	2186	7170	7	10	17	0	17
6	2218	7274	8	21	29	0	29

S/N	Depth (m)	Depth (ft)	Pollen	Spores	Miospore Total	Dinocyst	TOTAL PALYNOMORPHS
7	2224	7294	5	5	10	0	10
8	2226	7302	4	8	12	2	14
9	2227	7306	3	5	8	1	9
10	2285	7496	2	5	7	0	7
11	2301	7548	4	5	9	0	9
12	2315	7592	1	2	3	0	3
13	2320	7610	3	7	10	0	10
14	2332	7648	3	6	9	0	9
15	2353	7718	0	3	3	0	3
16	2359	7739	13	21	34	0	34
17	2363	7752	6	9	15	1	16
18	2377	7797	16	32	48	0	48
19	2381	7810	9	11	20	0	20
20	2394	7852	1	4	5	0	5
21	2404	7884	5	7	12	0	12
22	2445	8021	6	11	17	0	17
23	2465	8086	8	16	24	0	24
24	2474	8114	27	61	88	0	88
25	2479	8132	2	7	9	0	9
26	2488	8145	16	22	38	0	38

S/N	Depth (m)	Depth (ft)	Pollen	Spores	Miospore Total	Dinocyst	TOTAL PALYNOMORPHS
27	2493	8161	12	15	27	1	28
28	2496	8174	1	3	4	0	4
29	2499	8182	8	12	20	0	20
30	2509	8214	2	8	10	0	10
31	2530	8285	4	9	13	0	13
32	2534	8298	3	7	10	0	10
33	2549	8346	1	4	5	0	5
34	2553	8360	6	10	16	0	16
35	2565	8401	2	0	2	0	2
36	2607	8605	4	7	11	0	11
37	2666	8799	0	2	2	0	2
38	2672	8818	1	2	3	0	3
39	2683	8854	0	1	1	0	1
TOTAL			253	441	694	7	701

APPENDIX III: Systematic Paleontology of Index Palynomorphs

This appendix provides the detailed descriptions, distribution, and affinity of the key age-diagnostic palynomorphs used to establish the chronostratigraphic framework in the ABC-1 well (Germeraad et al., 1968).

1. Genus: Germeraad, Hopping & Muller 1968

1. **Type Level:** Agbada Formation
2. **Description:** Spore trilete, amb circular, laesurae nearly extending to margin; surface striate, striae low, faint, and restricted to the distal face. Exine up to 2.5 µm thick.
3. **Distribution:** Reported in the Oligocene to Pleistocene of Colombia. Also recovered from the Late Miocene of the Gulf Coast.
4. **Affinity:** Probably derived from the freshwater, floating fern *Ceratopteris* (Pteridaceae or Parkeriaceae), common in tropical and warm, still waters.

2. Genus: Retibrevitricolporites obodoensis

- **Type Level:** Agbada Formation

- **Description:** Isopolar pollen grain, radially symmetrical, oblate, triangular convex in polar view, tricolpate. Furrows are short, and the nexine thickens around the pores, forming a small endoannulus. Sculpture is finely reticulate.
- **Distribution:** Chattian to lower Pliocene. Widespread in the Nigeria and Cameroon basins.

3. Genus: Peregrinipollis nigericus

- **Type Level:** Agbada Formation
- **Description:** Pollen grains tricolpate, subspherical to prolate. Nesocolpia coarsely reticulate. Colpi are usually indistinct. The rope-like structures grade into granulate-verrucose sculpture at the junction of the mesocolpia and apocolpia.
- **Distribution:** Very rare in the Middle to Upper Eocene; consistently present from Oligocene to Pliocene. Found in the Nigeria and Cameroon basins.

4. Genus: Praedapollis flexilis

- **Type Level:** Agbada Formation
- **Description:** Sphaeroidal to prolate pollen grain. Triporate with subequatorial apertures. Exine is two-layered, showing a thin tectum and thick foot layer. The surface is smooth (psilate).
- **Distribution:** Used as an index marker for the Miocene to Pliocene interval. Common in the paralic sequences of the Niger Delta.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The Dahomey Basin, located in the southwestern region of Nigeria, is a prominent sedimentary basin that stretches along the Gulf of Guinea. It is a Cretaceous to Tertiary-aged basin formed during the opening of the South Atlantic Ocean and has since accumulated sediments that record changes in depositional environments over time. The basin is composed of a series of clastic sedimentary formations, including sandstones, shales, and clay units, which are of considerable interest for both academic and economic studies (Olabode & Mohammed, 2016). Sedimentary rocks in the Dahomey Basin have been extensively studied to understand their facies, mineral composition, and depositional history. Sandstones, in particular, are of interest because their composition reflects both the source rocks and the transportation processes involved during deposition (Jimoh *et al.,* 2024). Understanding the sedimentology, mineralogy, and provenance of these sandstones can provide insights into past environments, tectonic settings, and reservoir quality (Adeoye et al., 2022).

Recent studies have highlighted the importance of integrating sedimentological, mineralogical, and geochemical data to reconstruct paleoenvironments and infer sediment sources in the Dahomey Basin. For example, heavy mineral analysis has proven valuable in tracing sediment provenance and interpreting depositional environments (Richard et al., 2025). These approaches provide a more comprehensive understanding of sediment accumulation processes, which is essential for both scientific knowledge and exploration purposes. The stratigraphic architecture of the Dahomey Basin reflects alternating marine and continental sequences controlled by regional tectonics (Ako et al, 2012). This study focuses on the DO - well in the Dahomey Basin, examining core samples to understand the sedimentary facies, mineral content, and provenance characteristics. This research contributes to the ongoing effort to document and interpret the complex geological history of the basin. Sedimentary basins record the interaction of depositional processes, climate, and tectonics (Nichols,2009).

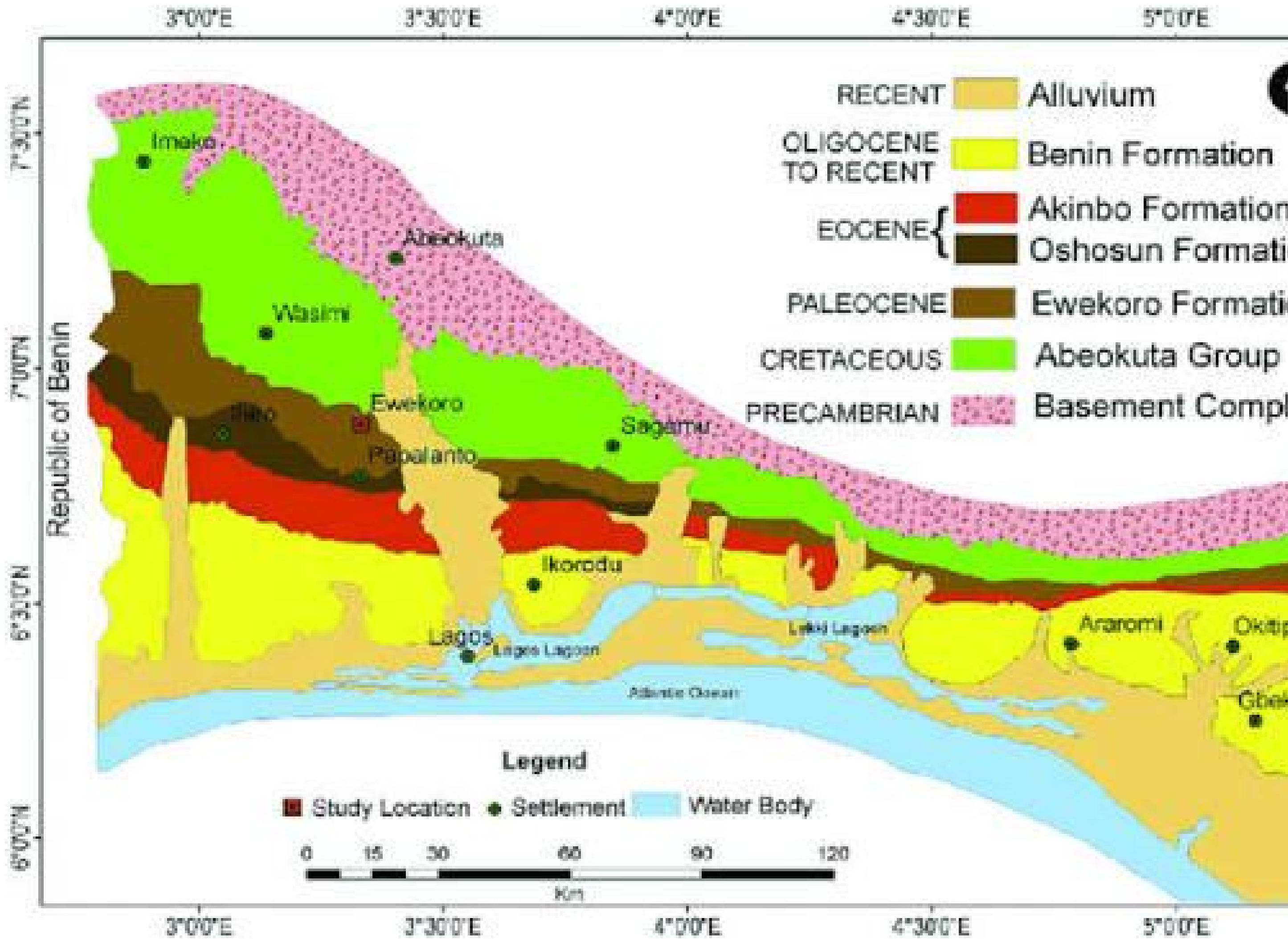

Fig 1.1: A geological map of the dahomey basin, Nigeria (after billman 1976)

1.2 STATEMENT OF THE PROBLEM

Despite previous studies on the Dahomey Basin, there remain gaps in the detailed sedimentological and mineralogical characterization of specific well sections. Many earlier works have focused on regional facies descriptions or broad geochemical assessments (Adeigbe & Oyekola, 2020; Jimoh et al., 2024). However, few studies provide a well-based analysis integrating sedimentology, mineralogy, and provenance for individual wells such as DO - well.

Understanding the sediment characteristics and provenance is critical for assessing reservoir quality, predicting subsurface facies distribution, and reconstructing depositional history. Without well-specific data, interpretations may remain generalized, limiting their applicability in exploration and basin analysis. Therefore, there is a need for focused studies that combine sedimentology, mineralogy, and provenance analysis for targeted wells in the Dahomey Basin.

1.3 AIM AND OBJECTIVES

Aim:

To investigate the sedimentology, mineralogy, and provenance of core samples and ditch cutting from DO - well in the Dahomey Basin to reconstruct depositional environments and infer sediment sources.

Objectives:

1. To describe and classify the sedimentary facies of DO -well.

2. To conduct mineralogical analysis using X-ray diffraction (XRD) techniques.

3. To determine the provenance of the sediments using heavy mineral assemblages and geochemical proxies.

4. To interpret the depositional environments and tectonic settings of the DO - well sediments.

1.4 SCOPE OF STUDY

This study focuses on the DO - well located within the onshore region of the Dahomey Basin. Core samples, ditch cuttings, and well logs will be examined to provide sedimentological, mineralogical, and provenance data. The study will emphasize sandstone units, as these provide significant information about sediment sources, depositional processes, and reservoir potential (Adeoye et al., 2022; Jimoh et al., 2024). While this work primarily focuses on one well, the findings may be extrapolated to similar stratigraphic units across the basin.

1.5 LOCATION AND GEOLOGICAL SETTING OF THE STUDY AREA

The Dahomey Basin extends along the southwestern margin of Nigeria, from the Niger Delta to the Republic of Benin. The basin is bounded by the Precambrian basement rocks of the Nigerian Shield to the north and the Atlantic Ocean to the south. Sedimentary sequences range from Cretaceous to Tertiary in age, with marine, transitional, and continental depositional environments documented (Olabode & Mohammed, 2016).

The DO -well is situated within the onshore segment of the basin. Organic geochemical parameters are effective for distinguishing marine from terrestrial organic matter input (Elueze & Nton, 2004). The stratigraphy in this area includes interbedded sandstones, shales, and clays, with sedimentary structures indicating varying energy conditions during deposition. Previous studies in nearby wells have documented evidence of fluvial to shallow marine depositional settings, with mineralogical and geochemical compositions suggesting mixed provenance sources (Adeigbe & Oyekola, 2020).

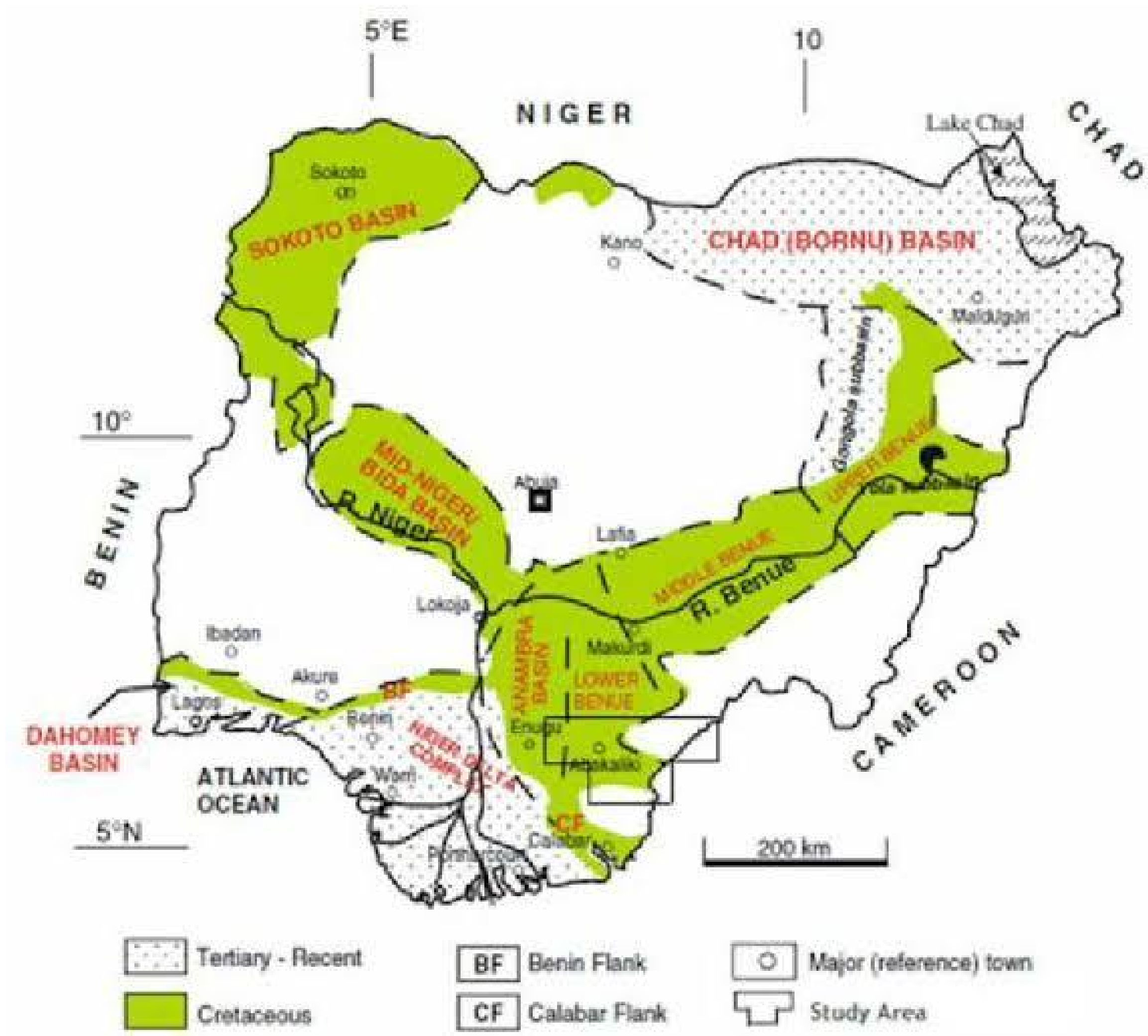

Fig 1.2: A geological map of Nigeria showing the location of study, Do – well.

1.6 JUSTIFICATION/SIGNIFICANCE OF STUDY

Studying the sedimentology, mineralogy, and provenance of DO - well sediments has both scientific and practical significance. Scientifically, it provides detailed insights into the depositional history and tectonic evolution of the Dahomey Basin. Practically, the study contributes to reservoir characterization, which is essential for hydrocarbon exploration, groundwater assessment, and mineral resource evaluation. By integrating sedimentological and mineralogical data with provenance analysis, this research offers a comprehensive understanding of the sedimentary system and enhances the predictive framework for similar wells in the basin.

CHAPTER TWO: LITERATURE REVIEW

2.1 REGIONAL GEOLOGY OF THE DAHOMEY BASIN

The Dahomey Basin is a Cretaceous to Tertiary sedimentary basin situated in southwestern Nigeria, extending into the Republic of Benin and Togo. It lies between the Precambrian basement rocks to the north and the Atlantic Ocean to the south. The basin developed during the early stages of the South Atlantic rifting, influenced by the separation of the African and South American plates (Olabode & Mohammed, 2016).

The stratigraphy of the basin consists of interbedded sandstones, shales, and clay units, deposited under varying marine, transitional, and continental environments. The sedimentary succession reflects a history of fluctuating sea levels, tectonic activity, and sediment supply changes. The Ilaro, Ewekoro, and Afowo formations are among the major stratigraphic units, with the Ilaro Formation characterized by sandstone-dominated sequences that record significant provenance signals (Jimoh et al., 2024).

Geological mapping and previous studies have emphasized the basin's structural features, including faulting and minor folding, which influenced sediment transport and deposition. Understanding the regional geology provides the necessary context for interpreting well-based sedimentological and mineralogical data.

2.2 PREVIOUS SEDIMENTOLOGICAL STUDIES

Several studies have investigated sedimentological characteristics in the Dahomey Basin. Olabode and Mohammed (2016) focused on depositional facies and sequence stratigraphy, demonstrating the occurrence of shallow marine, fluvial, and deltaic facies within Tertiary successions. Jimoh et al. (2024) combined petrography and geochemistry to evaluate sandstones from the Ilaro Formation, highlighting the significance of source rock composition and depositional energy in controlling sandstone texture and mineralogy.

Adeoye et al. (2022) reconstructed paleoenvironments for sandstones in the onshore Dahomey Basin, showing that depositional environments ranged from fluvial to shallow marine settings.

They also highlighted the role of provenance in controlling sandstone composition and reservoir quality. Adeigbe and Oyekola (2020) conducted a well-based geochemical study of Lewumeji and Idogun wells, emphasizing the importance of combining geochemistry and sedimentology for accurate environmental reconstructions.

Overall, these studies underline the importance of detailed sedimentological analysis for understanding basin evolution and sedimentary processes. This project builds upon these works by focusing on DO - well, providing well-specific sedimentological data integrated with mineralogical and provenance analyses.

2.3 MINERALOGICAL ANALYSIS TECHNIQUES

Mineralogical analysis is crucial for interpreting sediment origin, diagenetic history, and reservoir properties. Petrographic examination under a microscope allows the identification of framework grains, cement types, and textural relationships. X-ray diffraction (XRD) provides quantitative mineral identification, including clay and heavy mineral content, while scanning electron microscopy XRD provides the Geochemical characteristics by producing results for major oxides and trace element.

Heavy mineral analysis has been widely used as a provenance tool. Minerals such as zircon, rutile, garnet, and tourmaline are resistant to weathering and transport, preserving signals of the source rocks. The abundance and assemblage of heavy minerals in sandstones can indicate tectonic setting, source lithology, and sedimentary pathways (Richard et al., 2025; Jimoh et al., 2024).

Combing XRD, and XRF provides a robust approach to characterizing sediment composition and interpreting depositional history. For DO-Well, these techniques will be employed to assess mineralogy and derive provenance information.

2.4 PROVENANCE CONCEPTS AND INTERPRETATIONS

Provenance studies aim to identify the original source of sediments and the processes influencing their transport and deposition. Provenance analysis often combines petrographic data, heavy mineral assemblages, and geochemical indicators to trace sediment sources (Adeoye et al., 2022; Jimoh et al., 2024).

Tectonic settings, including passive margins and continental collision zones, influence the type and composition of sediments entering the basin. For example, sandstones derived from felsic continental sources tend to contain abundant quartz and feldspar, whereas mafic sources contribute heavy minerals like pyroxene and amphibole (Richard et al., 2025). Geochemical proxies, such as major and trace element ratios, also help infer source lithology and weathering intensity.

In the Dahomey Basin, previous provenance studies indicate contributions from Precambrian basement rocks, metamorphic terrains, and older sedimentary units. Understanding provenance provides insights into sediment dispersal patterns, tectonic history, and reservoir heterogeneity (Adeigbe & Oyekola, 2020).

2.5 SUMMARY OF KNOWLEDGE

The literature indicates that the Dahomey Basin records complex depositional environments influenced by tectonics, sea-level changes, and sediment supply variations. Sandstones in the basin have been studied for facies, mineral composition, and provenance, but well-specific studies remain limited. Mineralogical techniques, including XRF, XRD, are essential for characterizing sediments and reconstructing provenance.

This project will address gaps by providing an integrated sedimentological, mineralogical, and provenance study for DO well. It will complement existing regional studies and contribute to a detailed understanding of basin evolution, sediment dispersal, and reservoir potential.

CHAPTER THREE: MATERIALS AND METHODS

3.1 MATERIALS USED

The study relies on both physical and digital materials, including:

1. Core samples from DO well, collected at various depths. These provide intact sedimentary sequences for petrographic and mineralogical analysis.

2. Ditch cuttings obtained during drilling. These samples supplement cores where continuous core recovery was not possible.

3. Laboratory instruments, including:

- X-ray diffraction (XRD) for bulk mineral composition
- X-ray Fluorescence for geochemical data acquisition. These datasets are useful for interpreting clastic sediment evolution in passive margin settings. (Zhao, Chen & Li, 2018).

4. Geochemical datasets, where applicable, for trace element and major oxide analyses to assist provenance interpretations (Jimoh et al., 2024; Adeigbe & Oyekola, 2020).

3.2 METHODS OF SEDIMENTOLOGICAL ANALYSIS

Sedimentological analysis aims to describe facies, textures, and depositional features. The steps are:

1. Visual Description: Each core and ditch cutting is described for color, grain size, sorting, and sedimentary structures (e.g., cross-bedding, ripple marks).

3. Facies Classification: Based on field observations and laboratory data, sediments are classified into facies types such as fluvial, shallow marine, deltaic, or estuarine.

4. Stratigraphic Logging: Core sections are logged to produce a stratigraphic column, showing lithology, thickness, and facies transitions.

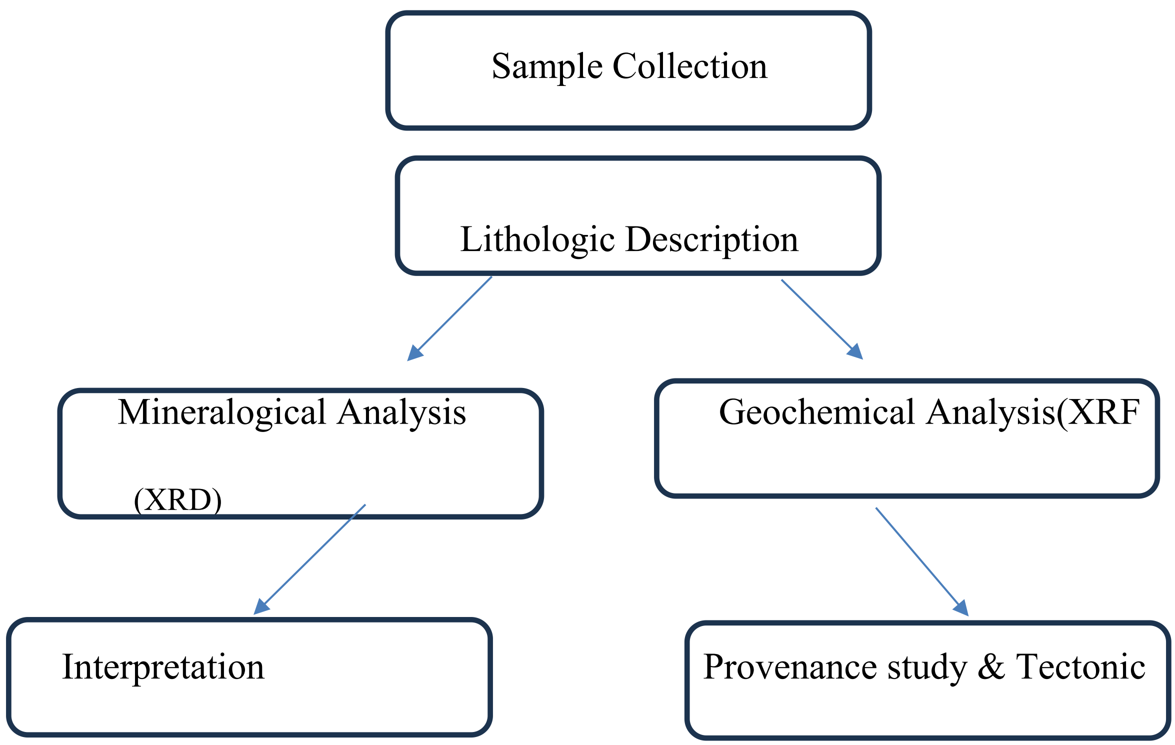

Fig 3.1: A flowchart showing the materials and analysis used

3.3 MINERALOGICAL AND GEOCHEMICAL ANALYSIS METHOD

Mineralogical analysis involves identifying the mineral composition of sandstone samples. The approach includes:

1. X-ray Diffraction (XRD): Powdered samples are analyzed using XRD to quantify major and minor minerals, including quartz, feldspar, clay minerals, and accessory heavy minerals.
2. X-ray Fluorescence (XRF): Powered samples are analyzed busing XRF to provide results for the major oxides and trace element.

3.4 PROVENANCE DETERMINATION

Provenance analysis integrates sedimentological and mineralogical data to trace sediment sources and tectonic settings. The method includes:

1. Petrographic Composition: Quartz, feldspar, and lithic fragment proportions are plotted on QFL (Quartz-Feldspar-Lithic) diagrams to determine tectonic provenance.

2. Geochemical Proxies: Major and trace element data are interpreted using discrimination diagrams to support source rock interpretations.

3. Integration: Sedimentological facies, mineralogy, and geochemical indicators are combined to propose a likely source area and depositional setting.

CHAPTER FOUR

RESULTS AND DICUSSIONS

This chapter presents the results from the sedimentological, mineralogical and geochemical analyses of samples obtained from DO – Well in the Dahomey Basin. The results organized into three major parts, which includes sedimentological observations, X-ray Diffraction (XRD) mineralogical data and X-ray fluorescence (XRF) geochemical data. The significance of the results is discussed in relation to provenance, weathering conditions, depositional processes and tectonic settings.

4.1 LITHOLOGIC DESCRIPTION

Twenty-one (21) samples were processed for sedimentological studies. The studied interval of DO – Well penetrated sedimentary succession from 2100ft to 3200ft. The main lithofacies identified in DO – Well were shales.

Table 4.1: LITHOLOGICAL LOG

DEPTH INTERVAL (FT)	LITHOLOGY	COLOUR	MINERALOGY
2100 – 2120		Dark shale	Quartz, clay minerals
2125 – 2150		Dark shale	Quartz, illite, pyrite
2155 – 2180		Dark shale	Quartz, illite, pyrite
2200 – 2220		Dark shale	Quartz, clay minerals
2225 – 2240		Light grey shale	Quartz, clay minerals, carbonate
2260 – 2279		Dark grey shale	Illite/chlorite, Quartz
2280 – 2290		Dark grey shale	Quartz, clay minerals
2300(single depth)		Dark grey shale	Quartz, clay minerals
2300 – 2320		Dark grey shale	Quartz, illite, organic matter
2330 – 2350		Dark grey shale	Quartz, organic matter
2357 – 2390		Light grey shale	Quartz, clay minerals
2400 – 2440		Light grey shale	Quartz, clay minerals
2430 – 2450		Light grey shale	Quartz, clay minerals,

2450 – 2470		Light grey shale	Quartz, clay minerals
2475 – 2495		Light grey shale	Quartz, clay, carbonate
2500 – 2520		Dark grey shale	Quartz, clay, organics
2525 – 2540		Dark grey shale	Quartz, clay, organics
2980		Dark grey shale	Quartz, clay, organics
3050 – 3056		Dark grey shale	Quartz, clay, organics
3200		Dark grey shale	Quartz, clay, organics
3220		Dark grey shale	Quartz, clay, organics

LEGEND

DARK SHALE

DARK GREY SHALE

LIGHT GREY SHALE

4.1.1 INTERPRETATION OF DEPOSITIONAL ENVIRONMENT

The shale succession represents deposition in quiet, low energy offshore to outer shelf marine environment, below storm wave base, The provenance of dark, organic – rich and pyritic shale indicates anoxic to dysoxic bottom water conditions, whereas the light grey shale intervals reflect periods of increased oxygenation. This suggests variations in sediment supply. (Jimoh et al., 2024; Adeoye et al., 2022; Olabode & Mohammed, 2016)

4.2 MINERALOGY RESULTS

Four samples comprising of shales at varying depth were chosen for this research making use of the method discussed earlier in chapter three. The mineralogical and geochemical characterization of DO – Well was done using the results derived from this analysis.

4.2.1 XRD - MINERALOGICAL RESULTS

SAMPLE DO 2115 – 2180

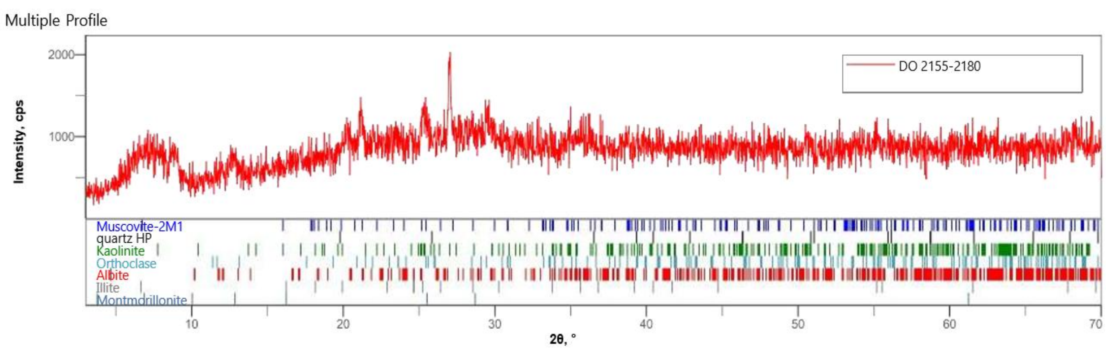

Table 4.2 XRD - MINERALOGICAL COMPOSITION FOR SAMPLE DO 2155 - 2180

MINERALS	WEIGHT %
Muscovite	29
Quartz	22
Kaolinite	10
Orthoclase	7.5
Albite	11
Illite	13
Montmorillonite	7

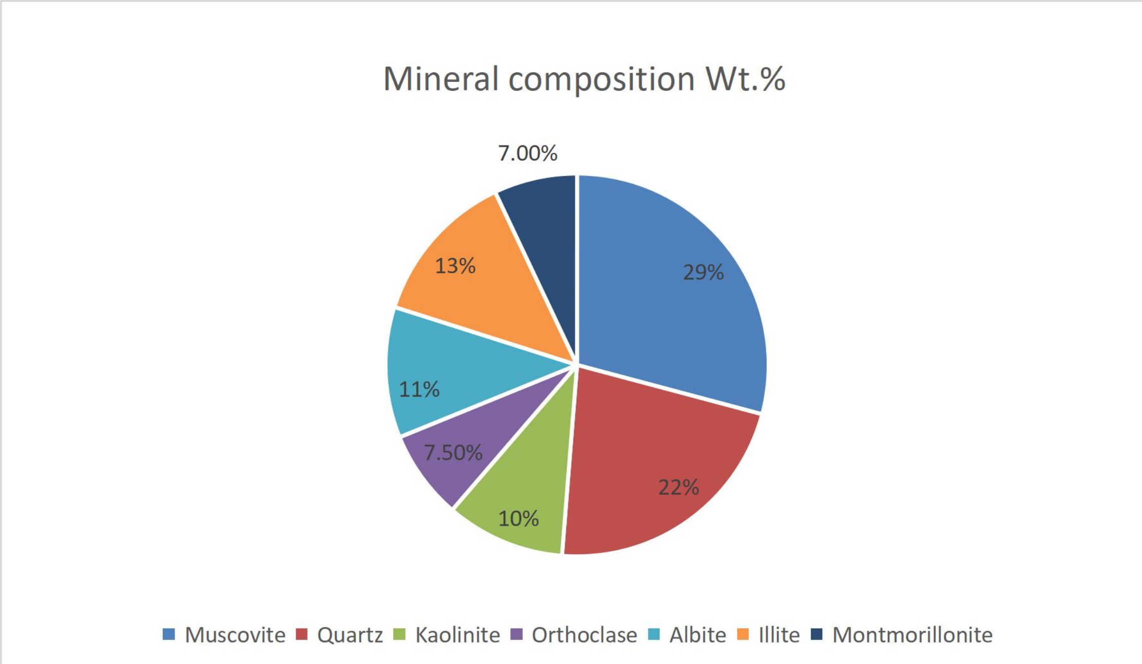

FIG 4.1: A PIE CHART SHOWING THE MINERAL COMPOSITION OF SAMPLE DO 2115 - 2180

4.2.1.1 MINERALOGICAL COMPOSITION DICUSSION

The sample implies texturally and chemically immature, derived from nearby granitic/ metamorphic source terrain in a humid tropical regime. Deposition likely occurred in a proximal fluvial to nearshore setting with variable redox conditions that produced a mixed clay assemblage. Reservoir quality would be heterogenous – quartz/feldspar framework could give decent porosity, but the Illite/montmorillonite and high mica will impair permeability and stability. (Jimoh et al., 2024; Adeoye et al., 2022; Olabode & Mohammed, 2016).

SAMPLE DO 2330 – 2350

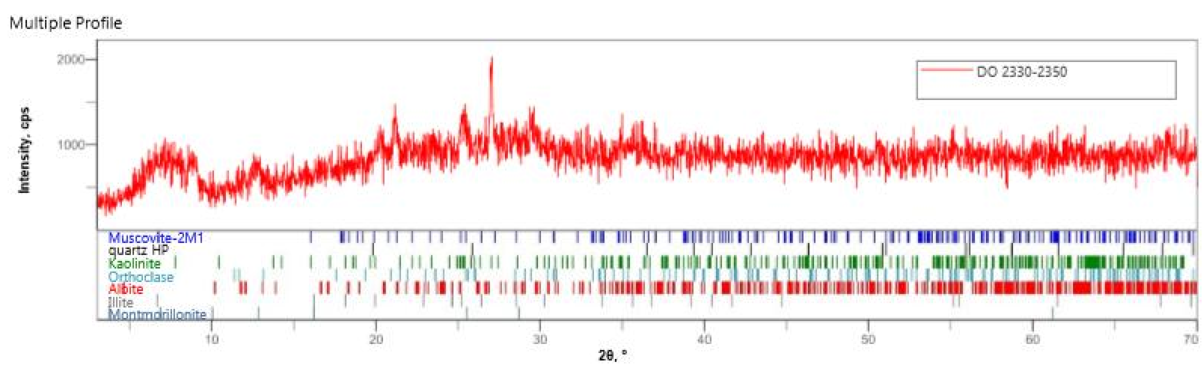

Table 4.3 XRD - MINERALOGICAL COMPOSITION FOR SAMPLE DO 2330 - 2350

MINERALS	WEIGHT %
Muscovite	32
Quartz	24
Kaolinite	7
Orthoclase	5.5
Albite	10
Illite	12.5
Montmorillonite	8.0

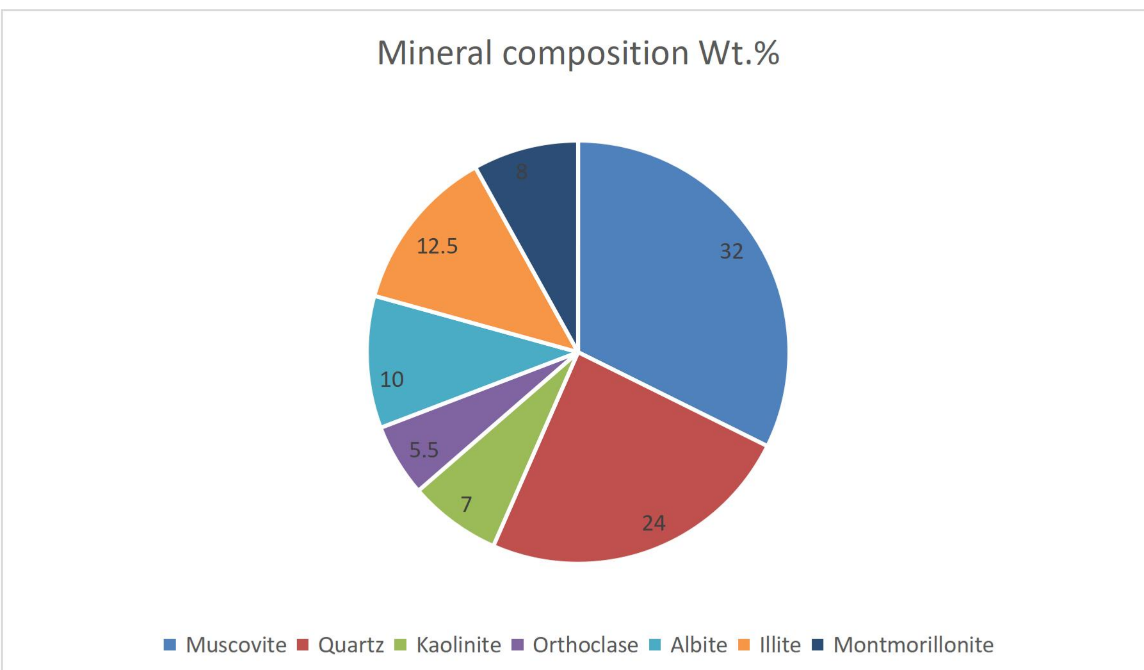

FIG 4.2: A PIE CHART SHOWING THE MINERAL COMPOSITION OF SAMPLE DO 2330 - 23350

4.2.1.2 MINERALOGICAL COMPOSITION DICUSSION

The mineral composition points to a proximal, immature fluvial/ deltaic environment with rapid deposition of clay – rich mudstones. The presence of feldspar, quartz 24% and muscovite 32% indicates a mixed igneous and metamorphic provenance with humid tropical weathering likely influencing the mineral assemblage (kaolinite, illite, montmorillonite). The high mica content suggests that the rock is texturally immature with an heterogenous reservoir quality. .(Jimoh et al., 2024; Adeoye et al., 2022; Olabode & Mohammed, 2016)

SAMPLE DO 2900

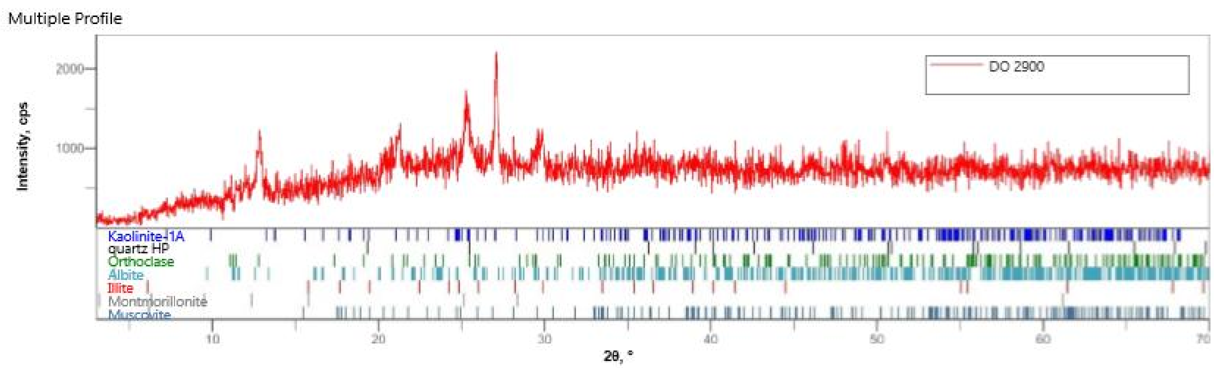

Table 4.4 XRD - MINERALOGICAL COMPOSITION FOR SAMPLE DO 2900

MINERALS	WEIGHT %
Kaolinite	30.5
Quartz	24
Orthoclase	20
Albite	4.5
Illite	3.5
Montmorillonite	7.0
Muscovite	8.5

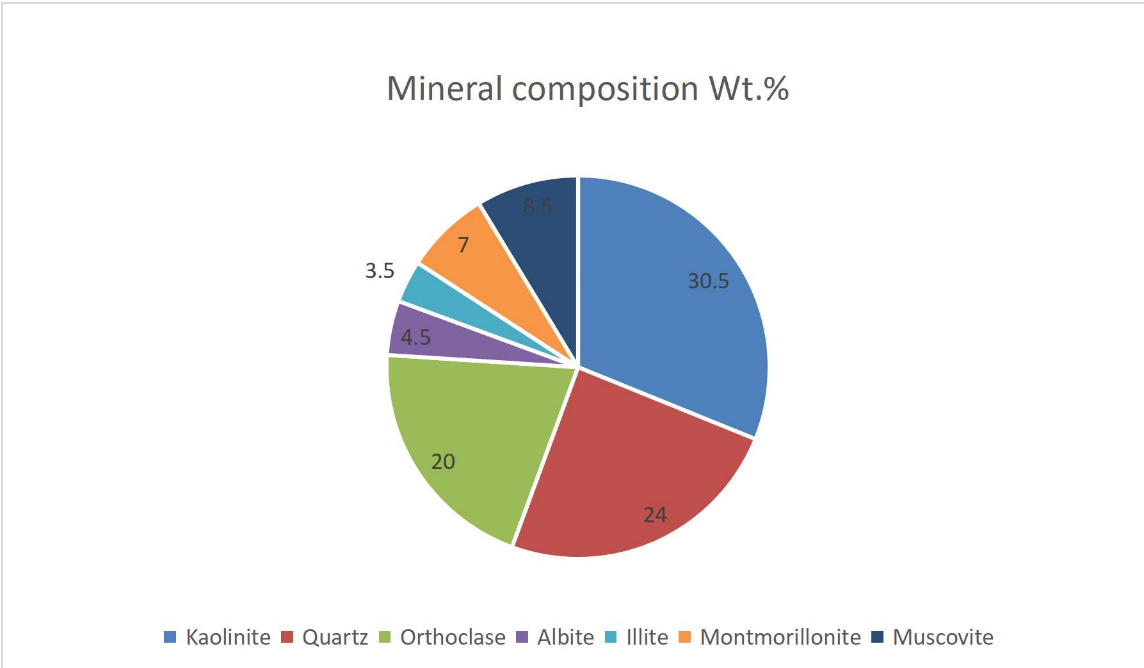

FIG 4.3: A PIE CHART SHOWING THE MINERAL COMPOSITION OF SAMPLE DO 2900

4.2.1.3 MINERALOGICAL COMPOSITION DISCUSSION

The mineral composition points to proximal, immature fluvial or deltaic environments with significant humid tropical weathering and the transport of feldspar- rich sediments from granitic/metamorphic sources. The high kaolinite 30.5% content indicates extensive chemical weathering in a tropical climate with moderate clay diagenesis (illite and montmorillonite). The presence of both kaolinite and montmorillonite suggests alternating high leaching and low drainage conditions, possibly in deltaic or lacustrine settings with seasonal fluctuations in water chemistry. (Jimoh et al., 2024; Adeoye et al., 2022; Olabode & Mohammed, 2016)

SAMPLE 3300

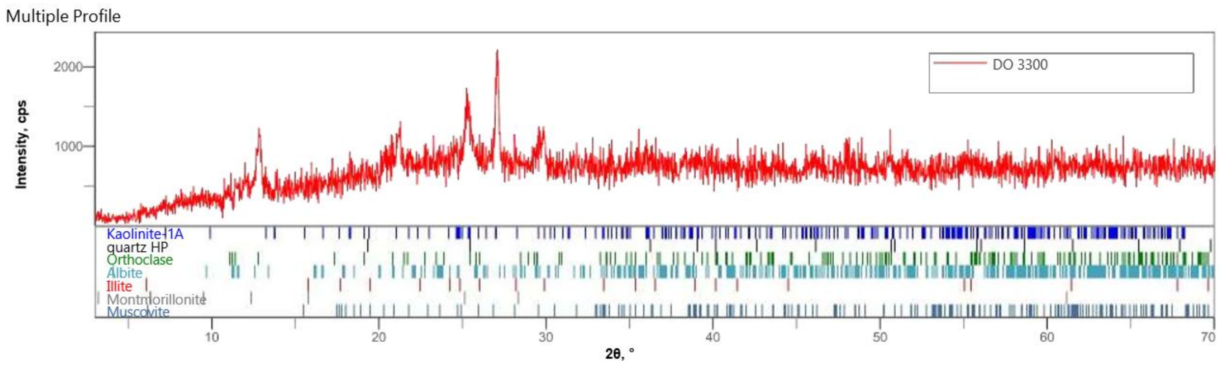
Multiple Profile
DO 3300
Intensity, cps
2000
1000
Kaolinite-1A
quartz HP
Orthoclase
Albite
Illite
Montmorillonite
Muscovite
10
20
30
40
50
60
70
2θ, °

Table 4.5 XRD - MINERALOGICAL COMPOSITION FOR SAMPLE DO 3300

MINERALS	WEIGHT %
Kaolinite	33.5
Quartz	20.0
Orthoclase	18.0
Albite	6.5
Illite	4.5
Montmorillonite	9.0
Muscovite	6.5

FIG 4.4: A PIE CHART SHOWING THE MINERAL COMPOSITION OF SAMPLE DO 3300

4.2.1.4 MINERALOGICAL COMPOSITION DISCUSSION

The XRD results for this studied interval show a clay dominated assemblage with kaolinite as the abundant phase 33.5%, followed by quartz 20%, and a significant feldspar component. Mica is present in small amounts, muscovite 6.5, illite 4.5%, and others present. This mineral association indicates intense chemical weathering in a tropical to subtropical source area, and a dominant felsic continental provenance. High kaolinite content implies significant leaching of mobile cations and reduced sediment maturity, with feldspar and mica content indicating episodes of rapid erosion and transport from nearby basement sources. (Jimoh et al., 2024; Adeoye et al., 2022; Olabode & Mohammed, 2016)

4.2.2 XRF - GEOCHEMICAL RESULTS

Geochemical characterization of DO – Well was done using the results derived from this analysis. This analytical method produced results for Nine (9) major elements, given as oxide percentage by weight (SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, P_2O_5, K_2O, MnO, MgO). Results for Eight trace elements (Ba, Cu, Ni, Zn, Co, Zr, Nb, Cr, V) reported in ppm recorded.

Geochemical result for Major oxides and trace element of the selected samples from Do – Well.

Table 4.6: Major Oxides Result (Wt.%)

SAMPLE NUMBER	LITHOLOGY	SAMPLE INTERVAL (FT)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	P_2O_5	K_2O	MnO	MgO
1	Shale	2155-2180	54.84	16.57	15.74	1.81	4.38	0.08	1.87	0.04	-
2	Shale	2330-2350	48.93	31.73	6.72	2.22	0.47	-	1.02	0.04	-
3	Shale	2900	45.36	15.50	14.93	1.56	8.38	0.07	2.08	0.05	-
4	Shale	3300	34.35	18.68	14.99	1.99	15.60	-	1.85	0.02	-

4.2.2.1 MAJOR OXIDE DISCUSSION

The geochemical results of analyzed shales are presented in Tables 4.5 and 4.6. As shown in the table 4.5, the percentage composition of SiO_2 is far higher than the percentage composition of the other oxides for all samples analyzed. For instance, the SiO_2 contents ranges from 34.35wt.% to 54.84wt.% in DO – Well with an average of 44.59 wt.%. Silica content is a function of the nature and composition of the source area. It is also a reflection of the duration and intensity of weathering and destruction of other minerals during transportation (Jones, & Manning,1994). The value of Al_2O_3 content in DO – Well ranges from 15.50wt.% to 31.7wt.% with an average of 23.61wt.%, High Al2O3 indicates an abundance of alumino-silicate minerals such as kaolinite, illite and muscovite (Adeigbe and oyekola, 2022). The value of Fe_2O_3 content ranges from 6.72wt.% to 15.74% with an average of 11.23wt.%. The content of TiO_2 ranges from 1.56wt.% to 2.22wt.% with an average of 1.89wt.%. CaO ranges from 0.47wt.% to 15.60wt.% with an average value of 8.03wt.%. P_2O_5 ranges from 0 to 0.08wt.% with an average of 0.04wt.%. K_2O ranges from 1.02wt.% to 2.08wt.% with an average value of 1.55wt.%. MnO ranges from 0.02wt.% to 0.05wt.% with an average value of 0.03wt.%. MgO was not found acquired from these depths in DO – well results.

Table 4.7: Trace Element Result (ppm)

SAMPLE NUMBER	LITHOLOGY	SAMPLE INTERVAL(FT)	Ba	Cu	Cr	Ni	Zn	Co	Nb	Zr	V
1	Shale	2155-2180	-	0.07	0.03	0.03	0.03	0.05	0.01	0.08	0.14
2	Shale	2300-2350	0.08	0.03	0.03	-	0.03	0.02	0.01	0.12	0.12
3	Shale	2900	-	0.03	0.03	0.02	0.03	0.05	0.01	0.08	0.10
4	Shale	3300	-	0.05	0.08	0.01	0.04	0.05	0.02	0.08	0.14

4.2.2.2 TRACE ELEMENTS DISCUSSION

The geochemical attitude of trace elements during sedimentary processes has often been applied to determine paleo-environmental conditions of deposition (Adeoye, JA., Balogun, O.B., Okunubi, M.O., Akinwale, R., & Ayolabi, E.A. 2022). Trace element abundance in sedimentary rocks have added immeasurably to our knowledge of crustal evolution with rare earth element (REE) patterns useful in determining provenance (McLennan, Taylor, & Eriksson,1993). Trace elements area usually vital part of the tectonic setting due to their really short residence times in freshwater or seawater and their distinctive behavior during fractional crystallization, weathering and recycling (Taylor & McLennan, 1985). Vanadium (V) is a redox – sensitive element that is enriched in sediments underlying anoxic or near - anoxic waters. Dymond *et al*. 1992 identified Barium (Ba) as a factor for biotic paleo productivity in the oceans due to its strong correlation with settling biogenic matter. High concentration of Ba combined with high palynofloral content infers that most of the Ba provided Is in relation with bio-productivity.

Table 4.8: Major oxides ratio for DO-Well

SAMPLE NUMBER	Sample 1	Sample 2	Sample 3	Sample 4
SAMPLE INTERVAL	2155-2180	2300-2350	2900	3300
Al2O3/TiO2	9.15	14.29	9.94	9.39
Log (SiO2/AL2O3)	0.52	0.19	0.47	2.65
Log (Fe2O3/K2O)	0.93	0.82	0.86	0.91
TiO2/Ni	60.3	-	78	199
Log (SiO2/Al2O3)	0.52	0.19	0.47	2.65

SiO2/Al2O3	3.31	1.54	2.93	1.84

Table 4.9: Trace elements ratios for DO-Well

SAMPLE NUMBER	SAMPLE INTERVAL	Ni/Co	Ni/Cr	V/Cr	Cu/Zn
Sample 1	2155-2180	0.60	1.00	4.67	2.33
Sample 2	2300-2350	-	-	4.00	1.00
Sample 3	2900	0.40	0.67	3.33	1.00
Sample 4	3300	0.20	0.13	1.75	1.25

4.3 PROVENANCE STUDIES

The concept of Floyd et al. (1989) was adopted to determine the origin of the sediments penetrated by DO – Well. TiO_2 versus Ni bivariate was used.

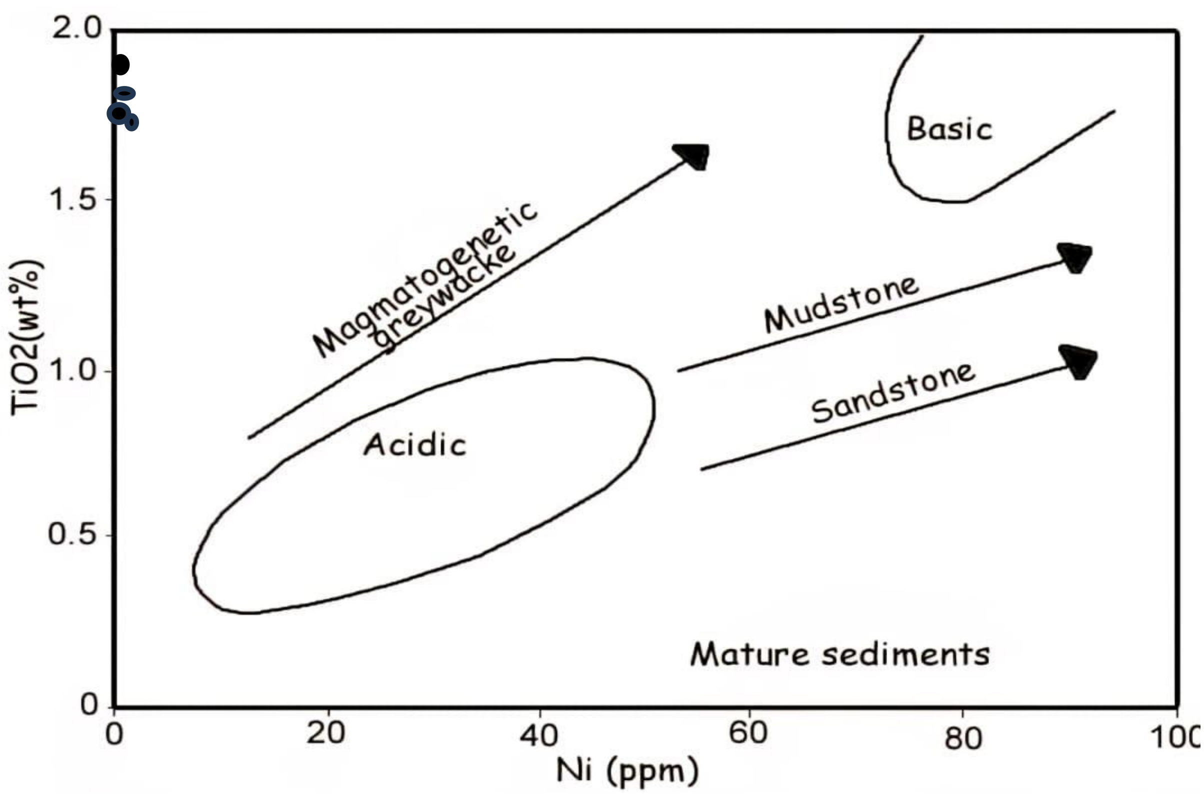

FIG 4.1: TiO2 versus Ni bivariate of samples (After Floyd *et al.* 1989)

The TiO_2–Ni plot shows the samples clustering at low Ni and outside the mafic/basic field, indicating negligible mafic input. This distribution suggests a felsic-dominated provenance (e.g., granite/gneiss) or recycled sediments that have undergone chemical weathering and Ni depletion. The samples' alignment toward the mature-sediment trend implies significant transport and reworking (chemical maturity). Overall, the geochemistry supports a continental (passive-margin/cratonic) source with limited volcanic/mafic contribution.

4.4 TECTONIC SETTINGS AND GEOLOGICAL IMPLICATIONS

The processes involved in plate tectonics give sediments specific geochemical characteristics in two different ways. First, various tectonic environment exhibits various provenance characteristics, and secondly, they are distinguished by different sedimentary processes. Sedimentary basins can be categorized into the following tectonic settings: active continental margin, passive continental margin, oceanic island- arc, collisional settings and continental island arc. All samples exhibit geochemical signatures characteristic of an Oceanic Island Arc tectonic setting. This is based on consistently low SiO_2 contents, low Al_2O_3/TiO_2 ratios (mafic source), low SiO_2/Al_2O_3 ratios (low sediment maturity), and high Fe_2O_3 + MgO values (mafic volcanic input). The geological implications include proximal deposition, immature sediments, and variable carbonate content, reflecting a volcaniclastic-dominated environment with limited sediment transport.

4.4.1 KEY RATIOS AND THRESHOLDS FROM TEMPLATES

Setting	Typical Ratios	Interpretation
Oceanic Island Arc	Low SiO_2, high Fe_2O_3+MgO	Mafic volcanic input
Continental Island Arc	Moderate SiO_2, moderate oxides	Mixed volcanic + continental
Active Continental Margin	Moderate-high SiO_2, variable	Granitic / recycled
Passive Margin	Very high SiO_2, low Fe_2O_3, TiO_2	Mature quartz-rich sediments

Table 4.10 Tectonic discrimination

Sample Number	Sample Interval	SiO2(wt.%)	Al2O3/TiO2	SiO2/Al2O3	Fe2O3+MgO(wt.%)	Inferred Tectonic setting
Sample 1	2155-2180	54.84	9.15	3.31	15.75	Oceanic Island Arc
Sample 2	2300-2350	48.93	14.24	1.54	6.72	Oceanic Island Arc
Sampe 3	2900	45.37	9.95	2.91	14.93	Oceanic Island Arc
Sample 4	3300	34.36	9.39	1.84	14.40	Oceanic Island Arc

4.4.2 TEMPLATE FOR GEOLOGICAL INTERPRETATION

Oxide / Ratio	Threshold / Range	Geological Interpretation	Application
SiO_2 (wt%)	>70	Quartz-rich, mature sediment	Reservoir quality, maturity
Al_2O_3 (wt%)	>15	Clay-rich, immature	Shale mineralogy
Fe_2O_3 (wt%)	>5	Ferruginous input, oxides	Diagenesis, red beds
CaO (wt%)	>10	Carbonate-rich	Carbonate content, marine settings
MgO (wt%)	>4	Dolomite, chlorite	Diagenesis, dolomitization
K_2O/Na_2O	>1	Felsic source, weathered	Provenance
Al_2O_3/TiO_2	>21	Felsic source	Provenance discrimination
SiO_2/Al_2O_3	>6	High maturity	Sediment maturity

Table 4.11 Geological interpretation

Sample Interval	Geological interpretation
2150-2180	Low maturity sediments, Mafic rock, Ferruginous input, Moderate carbonate Content
2300-2350	Very low maturity, Clay rich immature sediments, Mafic source, Low carbonate content.
2900	Low maturity, Mafic source rock, Ferruginous input, Moderate carbonate content.
3300	Very low maturity, Mafic source, Ferruginous conditions, High carbonate content.

4.4.3 Template for Kerogen type determination

Indicator	Type I	Type II	Type III
V/Cr	>4	2–4	<2
V/(V+Ni)	>0.75	0.54–0.75	<0.54
Ni/V	Low	Moderate–High	Very Low
U/Th	>1.25	~1	<0.75
TOC (wt%)	High (>5)	1–5	<2
Environment	Lacustrine	Marine	Terrestrial

4.5 ORGANIC MATTER DETERMINATION

Table 4.12: Kerogen types

SAMPLE	INTERVAL	V/Cr	V/(V+Ni)	Ni/V	U/Th	TOC	ENVIRONMENT	KEROGEN TYPE
Sample 1	2155-2180	4.67	0.82	0.21	-	-	Anoxic	Type II
Sample 2	2300-2350	4.00	-	-	-	-	Suboxic	Type II/III
Sample 3	2900	3.33	0.83	0.20	-	-	Suboxic	Type II/III
Sample 4	3300	1.75	0.93	0.07	-	-	Suboxic	Type III/IV

4.5.1 ORGANIC MATTER DISCUSSION

Sample 1 shows high V/Cr and V/(V+Ni) values with low Ni/V, reflecting anoxic bottom-water conditions. This enhanced organic matter preservation resulted in Type II kerogen, which is oil-prone and primarily marine in origin.

Samples 2, 3, and 4 display moderate V/Cr values and relatively lower V/(V+Ni), indicating suboxic depositional environments with limited oxygen. The kerogen types range from mixed Type III/II (Samples 2 and 3) to Type III/IV (Sample 4), suggesting a shift from mixed marine–terrestrial organic input to dominantly terrestrial material. These samples therefore have lower hydrocarbon potential, being mainly gas-prone or inert.

Overall, the data reveal a transition from an anoxic, oil-prone setting in Sample 1 to suboxic, terrestrially influenced, gas-prone conditions in Samples 2–4, reflecting changes in organic matter source and preservation across the sequence.

CHAPTER FIVE

5.1 SUMMARY OF FINDINGS

This study examined the sedimentology, mineralogy and geochemistry of selected intervals from DO well locate within the Dahomey Basin, southwestern Nigeria. The work provided detailed information on the composition of the sediments, their depositional characteristics, provenance and the likely tectonic setting of the basin during sedimentation.

Lithologic description and sedimentological observations revealed that the well section is dominated by shale units with alternating fine grained sandstone beds, indicating fluctuating energy conditions within the depositional system. The shale is general dark grey to brown, fissile and moderately compacted, while the sandstone intervals are fine to medium grained with occasional evidence of bioturbation and lamination. These features point to a low to moderate energy environment typical of shallow marine or transitional settings. This interpretation aligns with earlier works in the basin which documented the influence of marine transgressions, tidal processes and marginal marine sedimentation (Olabode and Mohammed, 2016).

XRD mineralogical results show that sediments are composed mainly of quartz, muscovite, kaolinite, illite, montmorillonite and feldspars. Samples with high kaolinite content indicate strong chemical weathering of the source rocks under humid tropical conditions. The presence of muscovite and illite suggests contribution from metamorphic and felsic basement terrains, consistent with the regional geology of the Dahomey Basin hinterland. Similar minerals assemblages were documented by Jimoh et al. (2024) and Adeoye et al. (2022), who also reported quarts-rich and mica-bearing sediments in nearby wells and outcrop sections.

The XRF geochemical results reveal moderate silica values, relatively high alumina and iron oxides, and significant concentrations of calcium oxide in some intervals. Elevated alumina contents correspond with clay-rich mineralogy observed in the XRD data, while the iron oxide concentrations ferruginous cementation and the presence of heavy minerals. Geochemical ratios such as SiO_2/Al_2O_3 and K_2O/Na_2O indicates moderate chemical maturity and substantial weathering of felsic crystalline sources. Trace elements such s Zr, Cr band V point to the presence of resistant heavy minerals including zircon and chromite, with are typically associated with continental crustal provenance. These findings correspond with the results of Adeigbe and oyekola (2020) who identified similar geochemical signatures in wells within the eastern Dahomey Basin. Discriminant function analysis of major elements helps differentiate active margin sediment signatures (Roser & Korsch, 1988).

Integrating the sedimentological, mineralogical and geochemical results shows that sediments in DO – Well were sourced mainly from the Precambrian basement located north of the basin. The overall composition and maturity of the sediments support a margin tectonic setting. This agrees with the geological evolution model of the Dahomey Basin reported by the earlier researchers.

5.2 CONCULSION

The results from this study provide a clearer understanding of depositional, mineralogical and geochemical characteristics of the DO – Well sediments. The sediments represent a mixture of shallow marine and transitional deposits controlled by fluctuating depositional energy and periodic marine incursions. Mineralogical data indicates that the sediments are dominated by quartz, clay minerals and mica, reflecting intense chemical weathering of felsic and metamorphic basement sources. Geochemical results support this interpretation, confirming the dominance of continental crustal provenance with minor contributions from recycled sedimentary sources.

The combination of elevated clay minerals, moderate silica values, and trace element signatures indicates that the sediments were deposited in a passive margin setting consistent with the known tectonic history of the Dahomey basin.

5.3 RECOMMENDATION FOR FURTHER STUDIES

- More samples from wider depth intervals should be analyzed using XRF and possibly ICP-MS to obtain a broader geochemical profile of the well. This will help refine provenance and weathering interpretations.
- The incorporation of gamma ray and density logs to improve facies classification and depositional environment interpretations.

- Mineralogy and geochemical results from DO – Well should be compared with data from other wells in the Dahomey basin in order to establish regional trends, sediments dispersal patterns and basin – wide tectonic controls.
- Techniques such as SEM-EDX, FTR and clay fraction separation should be incorporated in future research to better understand diagenesis and clay mineral transformations in the basin.

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