

**SEDIMENTOLOGY, GEOCHEMICAL
APPRAISAL AND PALYNOFACIES OF
ARAROMI FORMATION, DAHOMEY BASIN,
NIGERIA**

BY

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**SUBMITTED TO DEPARTMENT OF
GEOLOGY**

**FACULTY OF PHYSICAL SCIENCE
UNIVERSITY OF BENIN BENIN CITY, EDO
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**A PROJECT WORK SUBMITTED TO THE
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DEDICATION

I dedicate this project to ALMIGHTY GOD for guiding my path and giving me the strength to come out triumphant and to my loving parent MR AND MRS OLOFU for their unwavering support, prayers and encouragement and lastly to myself for my perseverance and passion that brought this work to life.

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I want to give all glory, honor, and adoration to ALMIGHTY GOD for his infinite mercy, grace, wisdom and guidance throughout the course of my studies and during the successful completion of my project work.

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ABSTRACT

This study examines the sedimentology, geochemical appraisal and palynofacies of the Maastrichtian–Paleocene Araromi Formation, situated in the eastern Dahomey Basin of southwestern Nigeria. The primary objectives is to evaluate the depositional environments, organic matter quality, and the hydrocarbon-generation potential of the formation, thereby contributing to a broader understanding of the basin’s petroleum system. Integrated field observations and lithological analyses reveal an alternation of sandstones, shales, limestones, and siltstones, which collectively indicate a dynamic depositional system that evolved from fluvial to shallow marine settings. These facies transitions reflect varying energy conditions and sediment supply, suggesting periodic marine incursions during the late Maastrichtian to early Paleocene. Geochemical results show moderate to high Total Organic Carbon (TOC) values, accompanied by Hydrogen Index data consistent with a mixed assemblage of Type I and Type III kerogens. This mixture confirms the presence of both oil-prone and gas-prone organic matter, implying that the Araromi Formation possesses substantial potential for hydrocarbon generation under appropriate thermal maturity conditions. Palynofacies analyses further support these interpretations by revealing moderate palynological diversity. The presence of terrestrial pollen and spores, alongside abundant marine dinoflagellate cysts, confirms deposition during the late Maastrichtian to early Paleocene interval and indicates fluctuating terrestrial and marine influence. Amorphous organic matter dominates the offshore equivalents, suggesting deposition under reducing conditions that favored the preservation of hydrogen-rich organic material. Finally, the combined sedimentological, geochemical, and palynological evidence establishes the Araromi Formation as a significant source rock within the Dahomey Basin. The findings not only enhance understanding of the basin’s stratigraphic evolution and petroleum system but also highlight the formation’s relevance for future hydrocarbon exploration and development in southwestern Nigeria.

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CHAPTER ONE

1.0 INTRODUCTION

Sedimentological, geochemical, and palynofacies investigations of the Araromi Formation in the Dahomey Basin, southwestern Nigeria, are essential for understanding its depositional framework, organic matter characteristics, and petroleum generation potential. The Dahomey Basin is one of Nigeria's frontier basins that formed during the Early Cretaceous rifting associated with the opening of the South Atlantic Ocean. It extends from southeastern Ghana through Togo and Benin into southwestern Nigeria, containing a thick succession of Cretaceous to Tertiary sediments that reflect both continental and marine depositional phases (Njoku et al., 2021).

The Araromi Formation, part of the Late Maastrichtian to Paleocene Abeokuta Group, mainly includes shales, sandstones, siltstones, and some limestones that were deposited in environments ranging from coastal to shallow sea settings (Oluwajana et al., 2021). Its sediment layers show changes in energy conditions caused by movements of the sea along the ancient shorelines. Geochemical analyses show varying amounts of organic material, with Total Organic Carbon (TOC) between 0.5 and 4.8 wt%, containing a mix of marine and land-based organic matter, deposited in low-oxygen conditions (Adekeye et al., 2019). The maturity of this organic matter ranges from immature to early mature, suggesting deeper layers could produce oil or gas. Palynological findings demonstrate a fluctuating depositional environment marked by diverse pollen, spores, and dinoflagellate cysts, reflecting shifts between brackish and open marine conditions during the Maastrichtian–Paleocene interval (Amodu & Adeigbe, 2015). These patterns correlate with episodic sea-level changes, affecting sedimentation and organic preservation. Previous investigations often treated sedimentology, geochemistry, and palynology separately, restricting broader basin insights. Recent research underscores the importance of integrated multidisciplinary approaches for a more complete understanding of the Dahomey Basin's depositional evolution and petroleum system (Njoku et al., 2021; Oluwajana et al., 2021). Overall, combining sedimentological, geochemical, and palynofacies analyses enhances the reconstruction of the Araromi Formation's

depositional history, refining stratigraphic and paleoenvironmental models while informing its hydrocarbon potential and significance for southwestern Nigeria's petroleum exploration.

1.1 Background of study

The Dahomey Basin is a critical sedimentary basin located along the West African margin, extending from southeastern Ghana through Togo and Benin into southwestern Nigeria, where it lies adjacent to the Atlantic Ocean (Okosun, 2000; Oluwajana et al., 2021). This basin originated during the Late Jurassic to Early Cretaceous period because of the breakup of the supercontinent Gondwana and the opening of the South Atlantic Ocean, which created rift basins subsequently filled with sediments from fluvial, deltaic, and marine sources (Oluwajana et al., 2021). By the Late Cretaceous, the basin evolved into a passive continental margin marked by a succession of sedimentary units (Okosun, 2000; Oluwajana et al., 2021). Within the basin, the Araromi Formation, dated from the Maastrichtian to Paleocene epochs, stands out as a key stratigraphic unit. It consists of alternating shales, limestones, sandstones, and bituminous sediments deposited during fluctuating sea levels and enhanced terrestrial sediment influx (Okosun, 2004, 2005). This formation is significant for petroleum exploration due to its mixed organic content derived from both land plants and marine organisms, offering potential hydrocarbon source and reservoir characteristics (Amodu & Adeigbe, 2015; Ogala et al., 2019). Organic geochemical studies of the Araromi Formation reveal variability in total organic carbon content and kerogen types, although thermal maturity levels are generally low, suggesting limited hydrocarbon generation potential in some sections (Ogala et al., 2019). Palynofacies analyses provide important insights into the depositional environment, indicating conditions ranging from brackish to open marine settings, which reflect sea-level fluctuations during the formation's accumulation (Amodu & Adeigbe, 2015). The integration of stratigraphic, geochemical, and palynological data enhances the understanding of the basin's petroleum system, enabling more informed exploration strategies and reduces challenges and risks encountered during exploration (Amodu & Adeigbe, 2015; Ogala et al., 2019; Okosun, 2000, 2004, 2005)

1.2 Aim of the study

This study aims to combine sedimentological, geochemical, and palynofacies data from the Araromi Formation within the Dahomey Basin, Nigeria. The aim and objectives are as follows.

1. To reconstruct the depositional environments and identify lithofacies
2. To assess and predict its organic matter quality, type and thermal maturity for hydrocarbon production
3. Provide an integrated stratigraphic framework that enhances the understanding of the petroleum system potential of the basin
4. To determine its age and palaeoecology using palynological assemblages

1.2.1 Significance of study

This study investigates and evaluates the sedimentology, geochemical properties, and palynofacies of the Araromi Formation in the Dahomey Basin, delivering integrated insights into its depositional environments and hydrocarbon potential. Combining these approaches offers a coordinated and detailed reconstruction of ancient settings and improves stratigraphic understanding, which previous isolated studies have not fully achieved. It highlights the Dahomey Basin as a promising frontier for oil and gas exploration beyond Nigeria's Niger Delta, providing crucial information on organic richness, kerogen type, and maturity needed to refine petroleum system models. This serves to guide exploration, reduce economic risks, and support sustainable resource development. The findings also enhance knowledge of sedimentary basin evolution in West Africa and serve as a key reference for further multidisciplinary geological studies.

1.3 Statement of problem

The Araromi Formation in the Dahomey Basin remains inadequately understood despite numerous investigations. While stratigraphic research has detailed its lithological characteristics, the depositional models have not been thoroughly clarified (Okosun, 1990; Omatsola & Adegoke, 1981). Geochemical studies offer conflicting perspectives on its hydrocarbon potential; some report significant organic richness, whereas others emphasize low maturity levels that hinder petroleum generation (Ogala et al., 2012; Adekeye et al., 2020). Although palynofacies analyses have identified a diverse range of palynomorphs, interpretations of the depositional environments vary widely due to the lack of integration with sedimentological and geochemical data (Amodu & Adeigbe, 2015). This gap in integrated research approaches has led to unresolved questions about the Dahomey Basin's petroleum system. Without a comprehensive understanding of the Araromi Formation, evaluating its hydrocarbon potential in comparison to the extensively studied Niger Delta remains challenging.

1.4 Scope of the study

The scope of this study is focused exclusively on the Araromi Formation located in the Dahomey Basin of southwestern Nigeria. The study encompasses sedimentological investigations, including analysis of lithofacies, textures, and depositional sequences, geochemical assessments targeting the organic matter's richness, type, and maturity, and palynofacies examinations of kerogen and palynomorph assemblages to infer age and paleoenvironmental conditions. The scope is confined to these three analytical approaches and does not cover seismic data interpretation or large-scale petroleum system modelling. However, the results obtained are expected to provide valuable insights that could support broader basin and petroleum system studies. By integrating these methods, the study aims to develop a comprehensive depositional model and critically assess the petroleum potential of the Araromi Formation

1.5 Location of the Study Area

The study area is situated in Araromi, located in the eastern segment of the Dahomey Basin in southwestern Nigeria, between latitudes 6°00' N and 6°45' N and longitudes 4°00' E and 5°00' E. This basin forms part of the Benin-Togo-Ghana sedimentary belt, an extension of the Benin Coastal Basin developed during Early Cretaceous rifting linked to the South Atlantic Ocean's opening (Amodu & Adeigbe, 2015; Njoku et al., 2021). It is accessible via the Ondo-Igbokoda coastal road, Araromi-Obu serves as the main reference for fieldwork.

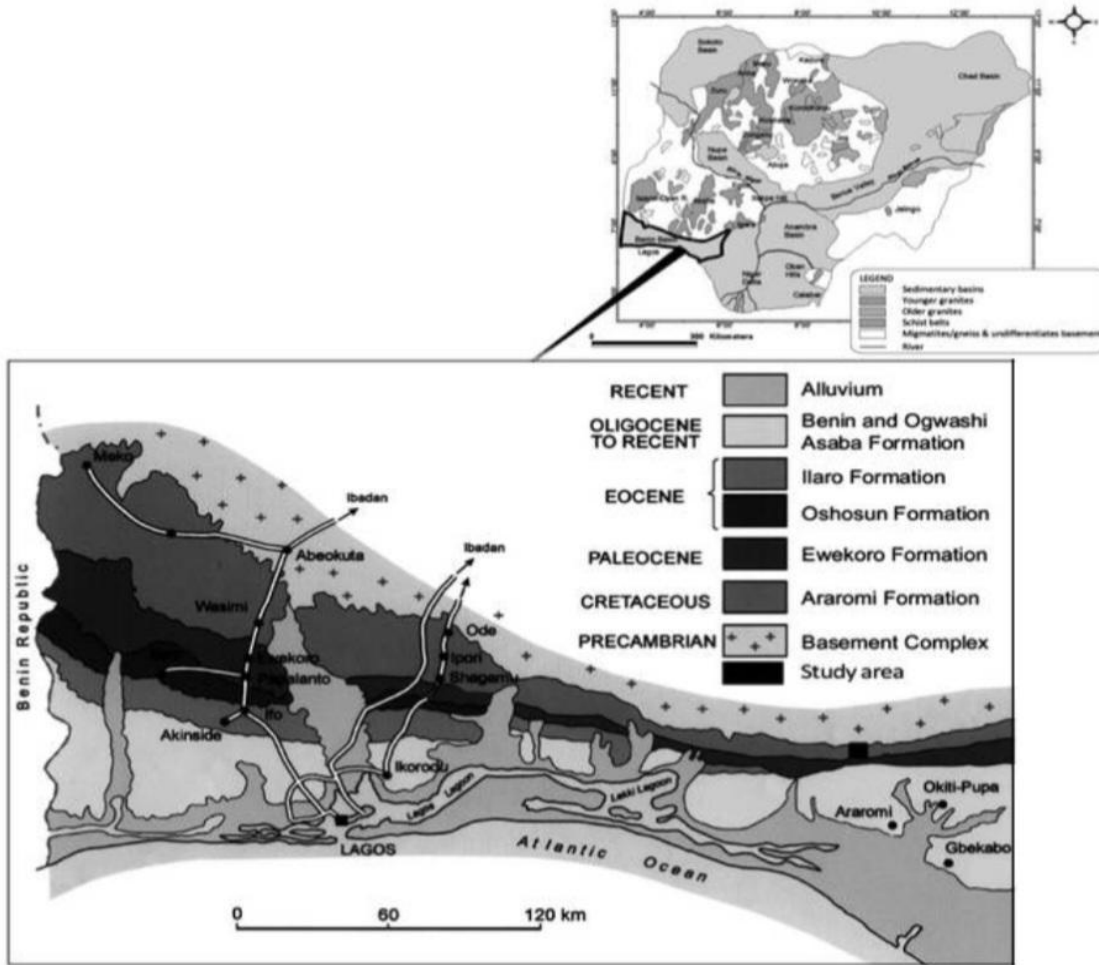


Figure 1: The Geological Map of the Eastern Dahomey Basin(Omatsola & Adegoke, 1981)

CHAPTER TWO

2.0 Literature review

2.1 introduction

The Dahomey Basin in southwest Nigeria is part of the West African coastal margin formed during the Early Cretaceous, linked to the South Atlantic Ocean's opening (Njoku et al., 2021). This tectonic activity resulted in thick layers of continental and marine sediments that capture environmental changes from the Albian to recent times. The Araromi Formation, the youngest unit of the Abeokuta Group, attracts significant interest due to its diverse sediment types, organic content, and hydrocarbon potential (Oluwajana et al., 2021). Recent research combining sedimentology, geochemistry, and palynofacies has helped to reconstruct the depositional settings and evaluate the hydrocarbon prospects of the Araromi Formation. These studies show alternating shale, siltstone, and sandstone layers typical of shifting energy conditions in shallow marine environments (Adekeye et al., 2019). Palynofacies data point to both marine and terrestrial sources, reflecting fluctuating sea levels during the Maastrichtian–Paleocene (Amodu & Adeigbe, 2015).

Despite growing research attention, uncertainties persist regarding the organic matter quality, maturity levels, and stratigraphic correlation of the Araromi Formation within the broader Dahomey Basin system. Consequently, reviewing existing studies provides a foundation for identifying knowledge gaps, improving depositional models, and refining the understanding of the basin's evolution and hydrocarbon potential (Omoboriowo et al, 2018).

2.2 Province of Study area

The Dahomey Basin, also known as the Benin Basin, is a sedimentary basin situated along Nigeria's southwestern coast and extending into Benin and Togo. It formed along the West African passive margin following the Early Cretaceous breakup of Gondwana and the opening of the South Atlantic Ocean. The basin

lies between the Okitipupa Ridge to the east, which separates it from the Niger Delta Basin, and the Keta Basin in Ghana to the west. In Nigeria, the basin stretches from Lagos through Ijebu-Ode and Okitipupa to Igbokoda, with the Araromi Formation notably exposed near Araromi, Ilaje-Epe, and Gbekebo. Sediment accumulation ranges from 2,000 to 5,000 meters and comprises continental to marine deposits reflecting multiple sea-level changes (Adekeye et al., 2019).

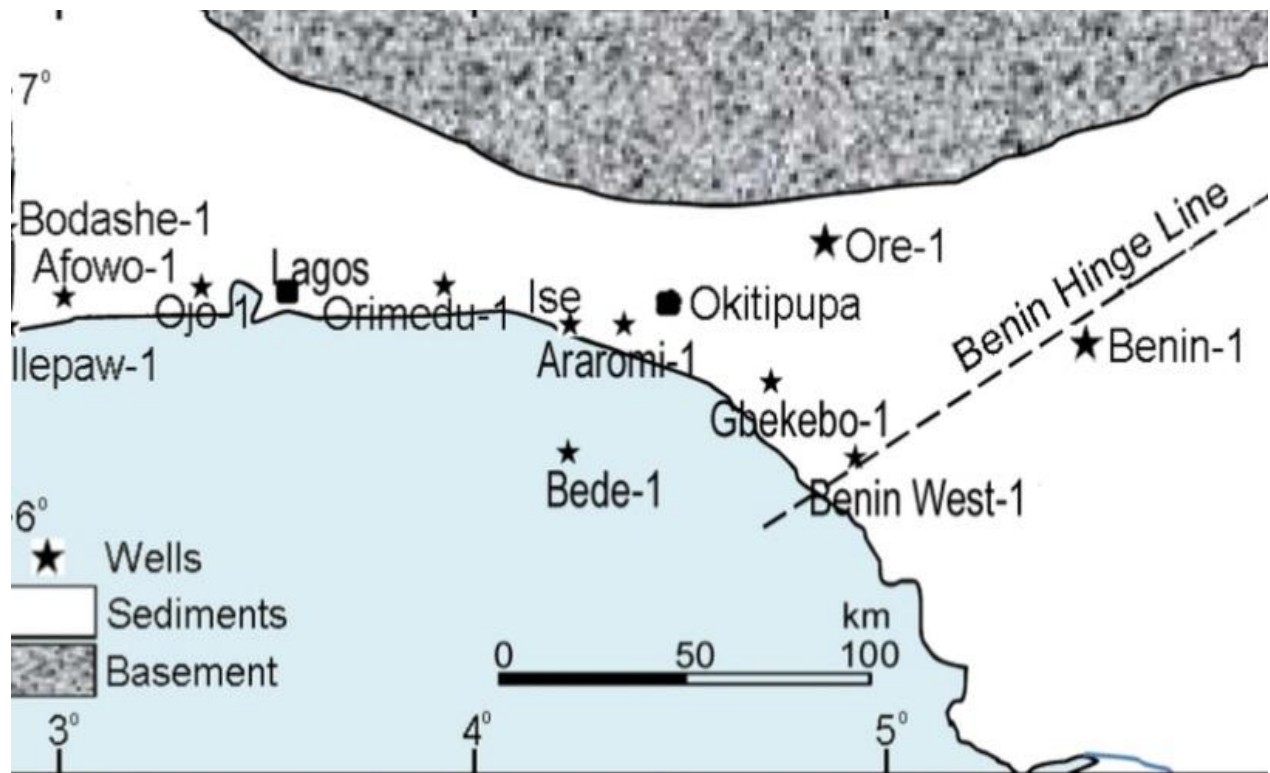


Figure 2.0: Simplified Geologic Map with borehole distribution(Modified after Ejeh 2016; Peters & Olsdon 1979)

2.3 Tectonic and structural settings

The Dahomey Basin, situated along Nigeria's southwestern coast, is a pericratonic sag basin formed in the Early Cretaceous because of the rifting and separation between the African and South American plates, coinciding with the opening of the Equatorial Atlantic Ocean around 125 million years ago. Its tectonic history is divided into four phases: pre-rift (Late Jurassic), rifting (Neocomian to Lower Cretaceous), transitional (Cenomanian to Santonian), and post-rift or drift (Maastrichtian to Holocene). These phases involved intracratonic rifting, crustal thinning, faulting, and subsidence, shaped in part by transform faults like the Romanche Fracture Zone along the basin's western edge. (Whiteman, 1982)

The Araromi Formation, the latest unit of the Cretaceous Abeokuta Group, was deposited from the Maastrichtian to Paleocene during the transition from the rift to early post-rift stages. The basin's structure, defined by horsts, grabens, normal faults created during rifting, influenced by sedimentation patterns. This formation rests unconformably on the Afowo Formation and the Nigerian Basement Complex, where tectonic subsidence formed space for shales, sandstones,

limestones, siltstones, and marls to accumulate. In the basin's eastern part, sedimentary rocks overlap the basement, reflecting a passive margin setting confirmed by geophysical studies.

Tectonic movements including episodic faulting and graben development facilitated sediment deposition ranging from fluvial to shallow marine environments, with sediments derived from erosion of the nearby basement rocks and reworked deposits from the South Atlantic. Heavy mineral analysis, particularly zircon-tourmaline-rutile indices, point to a pull-apart basin related to rifting, receiving material from acidic igneous and metamorphic sources, indicating stability during deposition. Fault systems, mainly normal and transform faults, acted as pathways for sediment transport and potential hydrocarbon migration, with offshore deeper areas experiencing more subsidence and greater maturity of source rocks than the shallower onshore regions.

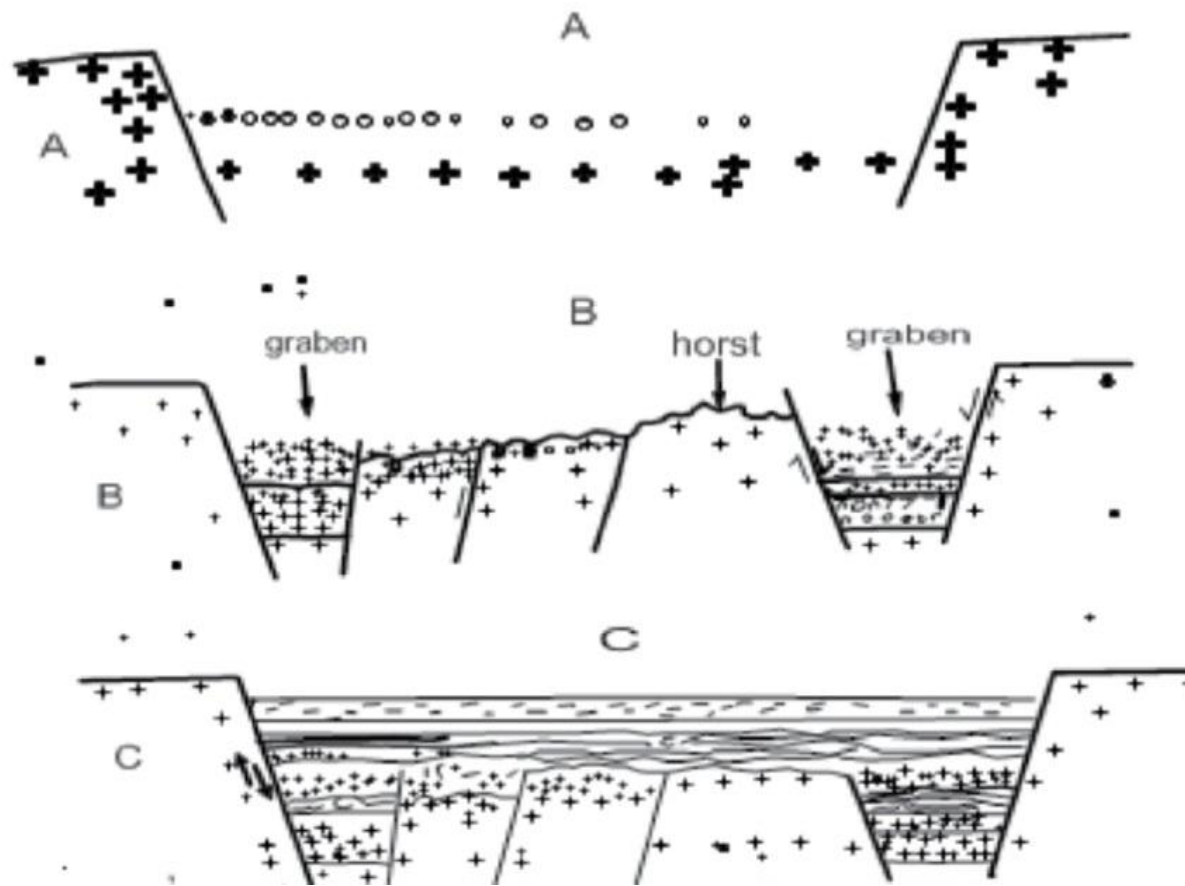


Figure 2.1: Structural and Tectonic Settings of Dahomey Basin with the occurrence of three progressive stages during the pull apart of the South continent from Africa continent

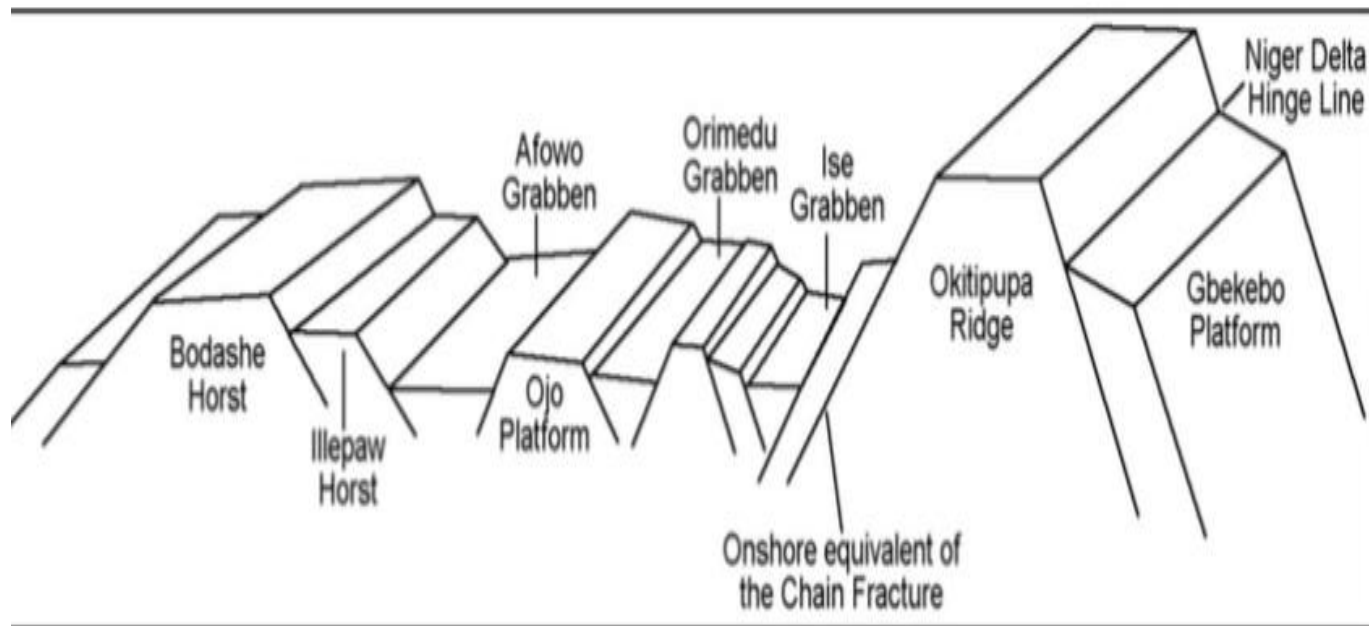


Figure 2.2: Schematic Block Diagram of Dahomey Basin floor (Omotsola & Adegoke ,1981)

2.4 Stratigraphy of the study area

The stratigraphic sequence of the Dahomey Basin records a complete rift-to-drift evolution associated with the opening of the South Atlantic Ocean. Key formations reveal different environments and geological histories, including the Ise, Afowo, Araromi, Ewekoro, Ilaro, and Coastal Plain Sands formations (Njoku, et al, 2021).

2.4.1 Ise Formation

As the oldest sedimentary unit, the Ise Formation lies directly above the Precambrian basement. It mainly consists of coarse-to-medium feldspar-rich sandstones, conglomerates, and kaolinitic clays deposited in river and alluvial settings during the Aptian–Albian period. These sediments originated from erosion of uplifted basement rocks and mark the beginning of the basin’s rift phase (Oluwajana et al, 2021).

2.4.2 Afowo Formation

Succeeding the Ise Formation, the Afowo Formation is made up of alternating layers of sandstone, shale, and bituminous mudstone. It reflects a shift to shallow marine conditions between the Cenomanian and Turonian ages. The organic-rich shales here show good potential as source rocks for hydrocarbons (Adekeye & Adeoye, 2019).

2.4.3 Araromi Formation

The Araromi Formation, deposited from the Maastrichtian to Paleocene, contains shales, siltstones, fine sandstones, and some limestones. It records changes between rising and falling sea levels in a coastal to shallow marine environment.

Studies show a mix of land and marine organic materials, highlighting its role as both a source and reservoir rock (Omoboriowo et al, 2018).

2.4.4 Ewekoro Formation

Overlying the Araromi, the Paleocene-aged Ewekoro Formation is mostly fossil-rich limestone with occasional shale and marl layers. It formed in a warm, shallow sea, supporting carbonate build-up. Its fossils are key for correlating Paleocene rocks across southwestern Nigeria (Njoku et al., 2021).

2.4.5 Ilaro Formation

The Eocene Ilaro Formation mainly consists of thick, cross-bedded sandstones mixed with thin clays and silts. These sediments were laid down in river-to-delta environments as the sea retreated after the carbonate deposition. It serves as an important water reservoir and has potential for hydrocarbons due to its good porosity (Oluwajana et al., 2021)

2.4.6 Coastal Plain Sands

The youngest layer, Coastal Plain Sands, range from Miocene to Recent and contain loose sands, gravels, and clays from river, delta, and coastal environments. These sediments cap the basin's sequence and reflect modern geological processes (Omoboriowo et al., 2018).

The Dahomey Basin's stratigraphy shows a clear shift from continental river deposits (Ise and Afowo) to marine and coastal sediments (Araromi and Ewekoro), then to deltaic and coastal deposits (Ilaro and Coastal Plain Sands). This sequence reveals the basin's geological history and helps understand its hydrocarbon potential.

| GEOLOGIC TIME | | FORMATION | | |
|---------------|---------------|---------------------|------------------------------|------------------|
| PERIOD | EPOCH | Ako et al., (1980) | Omatsola and Adegoke, (1981) | Billman (1976) |
| QUATERNARY | HOLOCENE | Coastal Plain Sands | Benin Fm | Benin Fm |
| | PLEISTOCENE | | | |
| TERTIARY | EOCENE | Ilaro Fm | Ilaro Fm | Ijebu Fm |
| | | Oshosun Fm | Oshosun Fm | Oshosun Fm |
| | PALEOCENE | Ewekoro Fm | Ewekoro Fm | Imo Shale |
| | | | | |
| CRETACEOUS | MAASTRICHTIAN | Abeokuta Fm | Abeokuta Group | Araromi Fm |
| | CAMPANIAN | | | Nkporo Shale |
| | CONIACIAN | | | Afowo Fm |
| | TURONIAN | | | Awgu Fm |
| | CENOMANIAN | | | Abeokuta Fm |
| | BARREMIAN | | | Ise Fm |
| | | | | Folded Sediments |

Figure 2.3: Stratigraphic Setting of the Dahomey Basin in Southwestern Nigeria (Omatsola & Adejoke, 1981)

2.5 Recent works

2.5.1 Recent works on sedimentology of the study area

Recent work and research on the sedimentology of the Dahomey Basin has revealed key depositional environments and facies patterns. Oluwajana et al. (2021) identified four main lithofacies types in the Araromi Formation which include basal limestone, medium-to-coarse sandstone, loose sandstone, and shale/siltstone that are indicative of a transition from fluvial to shallow marine settings. Jimoh et al. (2024) analyzed sandstones from the Ilaro Formation, concluding a high-energy, mixed fluvial-deltaic depositional regime influenced by tectonics and sea-level changes. These studies highlight the basin's sedimentary complexity and help clarify the Araromi Formation's

2.5.2 Recent works on the geochemical analysis

Geochemical analyses and evaluation have been very vital in assessing the hydrocarbon potential of the Araromi Formation. Adekeye et al. (2019) reported total organic carbon (TOC) values between 0.5 and 4.8 wt%, indicating moderate to rich organic content. The kerogen types, deduced from Hydrogen and Oxygen Indices, suggest a combination of marine (Type II) and terrestrial (Type III) organic matter, predicting oil and gas generation possibilities. Ogala et al., (2019) using biomarkers and Rock-Eval methods, confirmed deposition under marginal to shallow marine environments with terrestrial input. Omoboriowo et al. (2018) emphasized that redox conditions and sedimentation rates significantly influence organic matter preservation in the basin, reinforcing the formation's heterogeneous geochemical nature and petroleum source rock potential.

2.5.3 Recent works on the palynofacies and palynological studies

Palynofacies studies link organic particle types with depositional contexts. Amodu and Adeigbe (2015) found a mixture of terrestrial pollen, spores, and marine dinoflagellate cysts in the Araromi-1 well, indicating alternating brackish to marine environments. The dominance of amorphous organic matter and plant

debris suggested suboxic to anoxic depositional conditions suitable for organic preservation. Adekeye et al. (2019) dated the formation to the Late Cretaceous–Paleocene based on palynomorph assemblages rich in dinoflagellate cysts and spores. These findings underline palynofacies analysis as essential for biostratigraphy, paleoenvironmental reconstruction, and assessing source rock quality.

2.5.4 Hydrocarbon Potential and Previous Evaluations

Previous studies consistently demonstrate hydrocarbon potential within the Araromi Formation, characterized by oil-prone organic matter but showing spatial maturity variation. Both Ogala et al. (2019) and Adekeye et al. (2019) presented geochemical evidence of hydrocarbon generation in bituminous shale and limestone units, particularly in Agbabu and Araromi areas. However, variability in TOC and maturity levels suggests localized hydrocarbon generation, highlighting the importance of combining sedimentological, geochemical, and palynofacies data for comprehensive hydrocarbon assessment.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Source of data

The data for this study area was gotten through detailed fieldwork involving direct observation and rock samples were systematically collected from outcrops and borehole intervals within the Araromi locality of the Dahomey Basin, southwestern Nigeria. The samples provided the basis for Sedimentological characterization, organic geochemical evaluation, palynofacies analyses. Additionally, previously published studies on the stratigraphy, sedimentology, geochemistry and palynology of the Dahomey Basin were reviewed to provide comparative information and to place the findings within a larger geological framework of the basin.

3.1.1 MATERIALS USED

Palynological/palynofacies Materials/Equipment

1. Hydrochloric acid (10% HCl)
2. Hydrofluoric acid (40% HF)
3. Zinc chloride ($ZnCl_2$)
4. Potassium hydroxide (KOH)
5. Distilled water
6. Glycerine jelly

Equipment

1. Beakers, funnels, centrifuge tubes and filter papers
2. Sieve set (10 μ m mesh)
3. Microscope slides and coverslips
4. Binocular light microscope/petrographic microscope
5. Photomicrographic system

3.2 METHODS

3.2.1 Fieldwork and sample collection

Fieldwork was conducted within the Araromi locality of the Dahomey basin. Rock and sediments were systemically collected from outcrops and subsurface borehole intervals to represent the lithologic variations across the study sections. Each sample were properly labelled, packed in airtight bags, and accompanied by detailed notes on lithologic features, textures and stratigraphic position

3.2.2 Palynological and palynofacies analysis

Palynological and palynofacies analyses were conducted to determine the age, depositional environment, and organic matter characteristics of the studied interval from the Araromi Formation in the Dahomey Basin. Five subsurface samples from the Araromi well at depths of 750ft, 845ft, 855ft, 865ft, and 870ft were used for the analysis

3.2.3 Sample preparation and processing

1. Crushing and disaggregation: dried rock samples were gently crushed using a mortar and pestle to avoid destroying delicate organic particles
2. Removal of carbonates: the crushed samples were treated with 10% hydrochloric acid (HCl) to dissolve carbonate materials. This step continued until the effervescence ceased, after which the samples were thoroughly rinsed with distilled water
3. Dissolution of silicates: residues were subjected to 40% hydrofluoric acid (HF) to eliminate silicate minerals which make up the bulk of the rock matrix. After several hours of digestion, samples were neutralized and washed repeatedly with distilled water to eliminate residual acids.
4. Humic and organic impurity removal: occasionally, 10% potassium hydroxide (KOH) were applied to remove humic acids and fine clay particles that could interfere with organic matter observation.
5. Heavy liquid separation: the residual was subjected to heavy liquid separation using Zinc chloride ($ZnCl_2$) with a specific gravity of about

- 2.0g/cm³. This process concentrated the lighter organic particles by allowing the heavier minerals to sink
6. Sieving and washing: the organic rich residues were sieved through 10µm mesh to exclude very fine particles, followed by rinsing with distilled water to remove any remaining chemical contaminants
 7. Slide preparation: the purified residues were mounted on glass slides with glycerine jelly as the mounting medium and sealed with cover slips. Each slide was accurately labelled with sample depth and well identification

3.2.4 Microscopic analysis/ examination

Slides are studied under transmitted light microscope at x200- x1000 magnification. Palynomorphs such as pollen, spores, dinoflagelletes cysts and fungal remains were identified based on morphological features, using established taxonomic references (Salard-Cheboldaeff, 1990). Photomicrographs of key species were taken using a microscope-mounted digital camera to document diagnostic taxa

3.2.5 Quantitative analysis

Point counting under the microscope is used to determine the relative percentages of to determine the relative percentages of each organic matter category. These proportions help characterize the environment of deposition

Integration with other data

Palynofacies data are commonly combined with sedimentological, geochemical and rock eval pyrolysis to refine depositional models and source rock interpretations.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Lithologic Description of Araromi well

Lithological succession of the Araromi well from 745ft-1840ft is dominated by alternating limestones and shales units, reflecting fluctuating depositional conditions within a marginal-marine to shallow marine environment. The interval shows repeated cycles of carbonate deposition interbedded with fine-grained siliciclastics, indicating shifts in energy levels, relative sea levels and sediment supply

Lithological description of the study borehole section are highlighted below (fig 4.1)

Depth 745-750ft

Within depth 745-750ft display a light grey limestone

Depth 840-845ft

Within depth 840-845ft display a light grey limestone

Depth 850-855ft

Within depth 850-855ft display a light grey limestone

Depth 860-865ft

Within depth 860-865ft display a light grey limestone

Depth 865-870ft

Within depth 865-870ft display a dark grey shale

Depth 1340-1350ft

Within depth 1340-1350ft display a silty shale

Depth 1386-1390ft

Within depth 1386-1390ft display a light grey limestone

Depth 1440-1450ft

Within depth 1440- 1450ft display a light grey limestone

Depth 1622-1625ft

Within depth 1622-1625ft display a light grey limestone

Depth 1780-1790ft

Within depth 1780-1790ft display a dark grey shale

Depth 1840-1850ft

Within the depth 1840- 1850ft display a dark grey shale

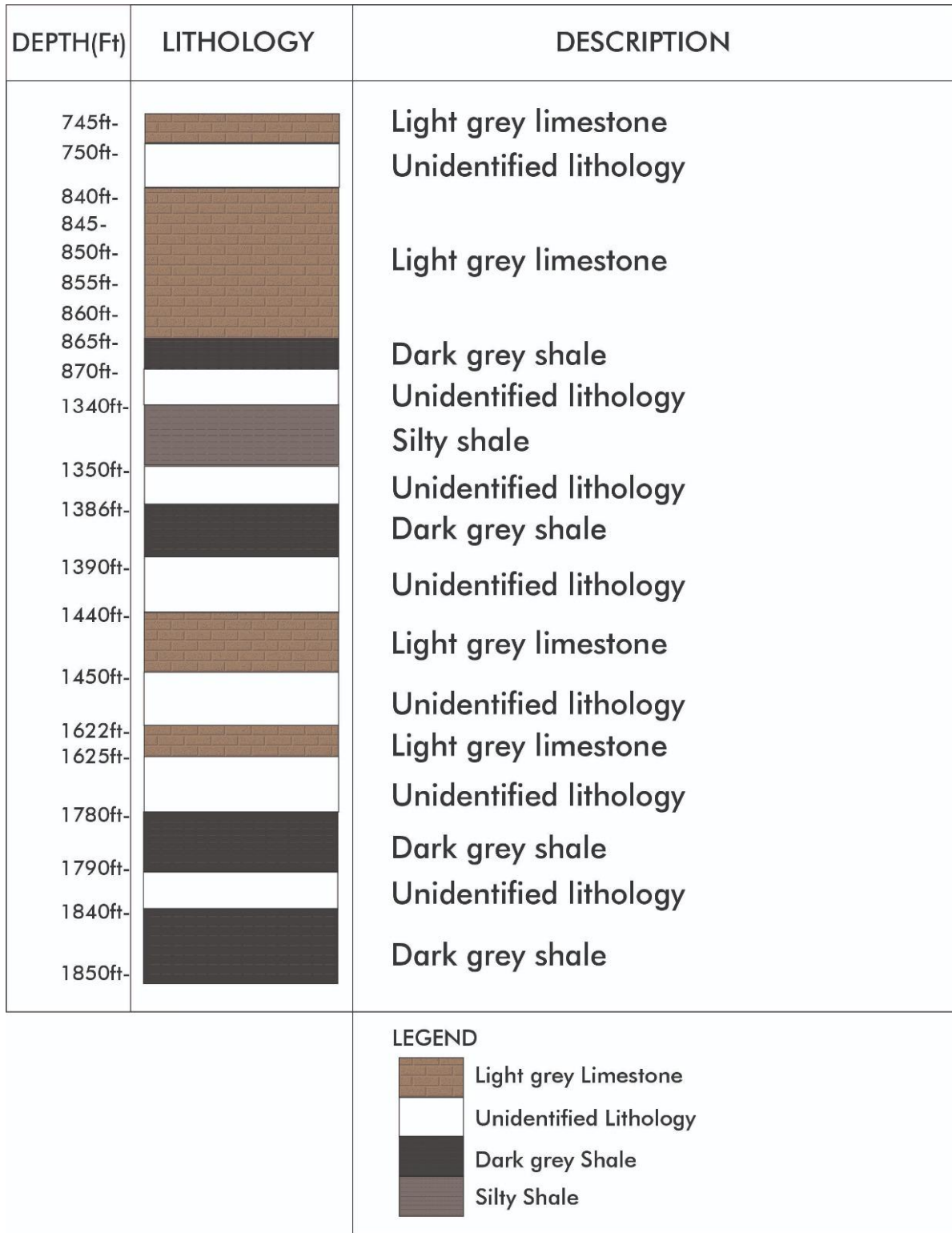


Figure 4.1: Lithological log of Araromi well

4.2 PALYNOLOGICAL ANALYSIS AND INTERPRETATION OF ARAROMI-1 WELL

4.2.1 Introduction

Five (5) selected well samples (750, 845, 855, 865 and 870 ft) of the Araromi-1 well were palynological processing and analysis for their palynomorphs contents. The results were used to decipher the age and possible paleoenvironment of deposition of the outcrop section.

4.2.2 Microflora characterization.

The samples were poorly fossiliferous with palynomorphs such as characterized by few species of *Cingulatisporites ornatus*, *Monocolpites marginatus*, *Tricolporopollenites* sp. and *Cyathidites minor* few records of fungal spores, diatom frustules and rare dinocysts such as *Senegalinium* sp. were also identified.

4.2.3 Biostratigraphy

One informal palynological biozones namely *Cyathidites minor* zone was established based on the common records of marker species *Cyathidites minor*. This biozone correlates with the *Echitriporites trianguliformis* zone of Salard Cheboldaef (1990). Thus, Late Cretaceous (Maastrichtian) age is interpreted for the studied interval. Details of the palynological results are discussed below and shown graphically as table 4.2.1

***Cyathidites minor* zone**

Depth: 750 – 870 feet

Age: Late Cretaceous (Maastrichtian)

Discussion: The top and base of this zone coincided with the first sample (750 ft) and base (870 ft) respectively. The interval is characterized by the occurrences of Late Cretaceous species such as *Monocolpites marginatus*, *Cyathidites minor*, *Tricolporopollenites* sp. and *Cingulatisporites ornatus*. This assemblage suggests Maastrichtian age and falls within the *Echitriporites trianguliformis* zone of Salard Cheboldaef (1990)

Table 4.2.1: Palynological Distribution Data for Araromi-1 Well

PALY DATA for Araromi-1 Well

| Depth | Palynomorphs | counts |
|-------|----------------------------|--------|
| 750 | Inaperturopollenites sp. | 2 |
| | Dinocysts indeterminate | 1 |
| | Diatom frustules | 4 |
| | Tricolporopollenites sp. | 1 |
| 845 | Fungal spores | 3 |
| | Senegalinium sp. | 1 |
| | Cyathidites minor | 1 |
| 855 | Tricolporopollenites sp. | 2 |
| | Fungal spores | 4 |
| | Monocolpites sp. | 1 |
| | Diatom frustules | 3 |
| | Cyathidites minor | 2 |
| | Monocolpites marginatus | 1 |
| 865 | Dictyophyllidites harrisii | 1 |
| | Polypodiaceoisporites sp. | 1 |
| | Cyathidites minor | 2 |
| | Cingulatisporites ornatus | 1 |
| 870 | Tricolporopollenites sp. | 2 |
| | Monocolpites sp. | 1 |
| | Diatom frustules | 5 |
| | Inpaerturopollenites sp. | 1 |
| | Fungal spores | 4 |

Palynological interpretation of Araromi – 1 Well (750-870 feet)

| Depth (feet) | SYSTEM/ PERIOD | SERIES/ EPOCH | STAGE /AGE | Salard Cheboldaeff, (1990) | This study | BIO-MARKER EVENTS |
|--------------|-------------------|------------------|---------------|---------------------------------------|-------------------------------|--|
| 750 | CRETACEOUS | LATECRETACEOUS | MAASTRICHTIAN | <i>Echitriporites trianguliformis</i> | <i>Cyathidites minor</i> zone | → Occurrence of <i>Tricolporopollenites</i> sp.. |
| 845 | | | | | | |
| 855 | | | | | | → Occurrence of <i>Monocolpites marginatus</i> |
| 865 | | | | | | → Occurrence of <i>Cingulatisporites ornatus</i> / <i>Cyathidites minor</i> . |
| 870 | | | | | | |

Table 4.2.2: Schematic Diagram of Palynozone Identified in Araromi-1, Dahomey Basin, Nigeria

4.2.5 Paleoenvironment

The palynomorphs is dominated by land derived species such as *Cyathidites minor*, *Monocolpites marginatus*, *Tricolporopollenites* sp. and *Cingulatisporites ornatus*. This assemblage suggests terrestrial (rainforest) paleoenvironment of deposition.

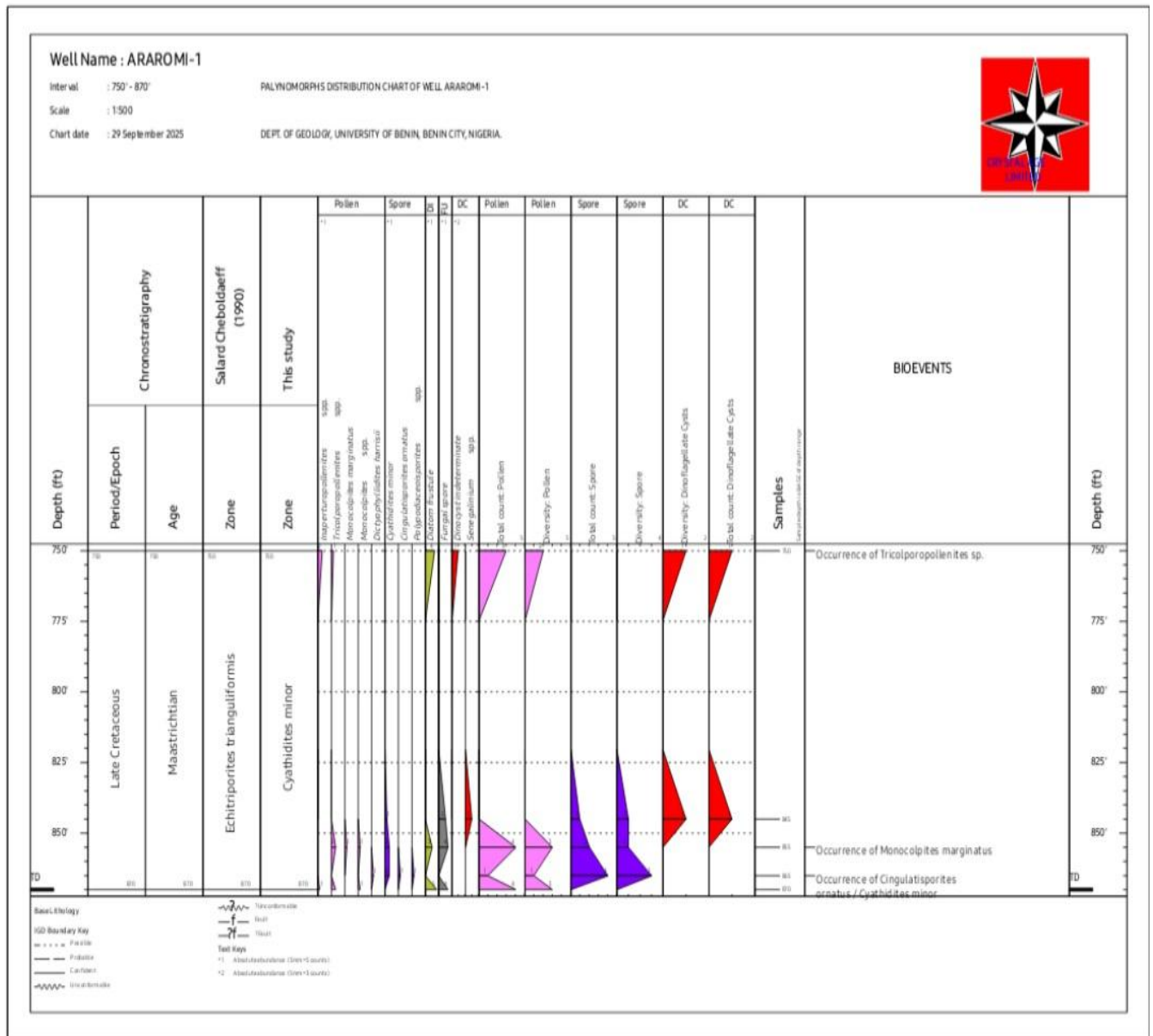


Figure 4.2.1: Palynomorphs Distribution Chart of Araromi-1 Well

Discussion

The palynological investigation of the araromi well-1 indicates the presence of diverse palynomorphs, including pollen, spores, dinoflagellate cysts, and algal fragments. This mixture of terrestrial and marine-derived organic remains suggests sediment deposition within a marginal-marine zone. Several intervals are dominated by land-derived pollen and spores, highlighting strong continental influence, while increases in dinocyst abundance signal phases of enhanced marine penetration and rising sea levels. Freshwater algae and fungal remains further point to intermittent river input associated with deltaic to lagoonal conditions. The recovered assemblage is characteristic of a late Cretaceous to Paleogene age, aligning with biostratigraphic records of the Dahomey basin. Good palynomorph preservation and moderate thermal maturity indicate that the sediments experienced limited alteration, supporting their potential for hydrocarbon generation.

4.3 BIOSTRATIGRAPHY AND PALEOENVIRONMENT OF ARAROMI-2 WELL

4.3.1 Ostracod Distribution

Five (5) samples from the Araromi -2 borehole were analysed for their ostracod and foraminiferal content. The samples yielded moderately abundant ostracod taxa. Species of ostracod recorded are *Aegyptiana duwiensis*, *Buntonia jordanica subjordana*, *Bythocypris* spp., *Cytherella sylvesterbradleyi*, *Actinocythereis coronata*, *Actinocythereis denticulata*, *Bairdia ilaroensis*, and *Leguminocythereis lokossaensis*. Stratigraphic distribution of foraminifera and ostracod taxa are shown in figure 4.3.1

4.3.2 Foraminifera Distribution

The samples studied yielded highly abundant and diverse assemblage of foraminifera which include planktics, calcareous benthics and agglutinated forms. Planktic species recorded include *Morozovella acuta*, *Pseudohastigerina*

wilcoxensis, *Planorotalites pseudomenardii*, *Hedbergella holmdelensis* and *Globigerina triloculinoidea*. Calcareous benthics include species such as *Anomalinoidea midwayensis*, *Anomalinoidea umbonifera*, *Eponides pseudoelevatus*, *Lenticulina midwayensis*, *Gavelinella guineana*, *Fursenkoina elongata*, *Cibicides succedens* and *Afrolivina afra*. Agglutinated taxa are represented by *Haplophragmoides excavata*, *Gaudryina* spp., *Ammobaculites* spp. Stratigraphic distribution of foraminifera and ostracod taxa are shown in figure 4.3.1

4.3.3 Biostratigraphy and Age

The studied section of the Araromi – 2 borehole consist of diagnostic Maastrichtian (Upper Cretaceous) to Paleocene foraminifera and ostracod assemblages. Based on these assemblages, the borehole section was delineated into zonal intervals as follows.

Interval 1625 - 1790 ft

Description: The interval consists of foraminiferal species such as *Hedbergella holmdelensis*, *Anomalinoidea midwayensis*, *Lenticulina midwayensis*, *Dentalina* sp., *Cibicides succedens*, *Eponides pseudoelevatus*, *Buliminella* spp., and *Afrolivina afra*. Ostracod are represented within the interval by *Leguminocythereis lokossaensis*, and *Actinocythereis coronata*.

Age: Maastrichtian (Upper Cretaceous)

Diagnostic criteria: Occurrences of *Hedbergella holmdelensis* and *Afrolivina afra*.

Interval 1350 – 1450 ft

Biozone: P4 Zone (Toumarkine and Lutherbacher, 1985)

Description: The base of the zonal interval is placed at the influx of foraminifera 1450 ft, Top is placed at the top of the analysed section at 1350 ft.

Planktic species: *Morozovella acuta*, *Globigerina triloculinoides*, *Planorotalites pseudomenardii*, and *Pseudohastigerina wilcoxensis*.

Benthic species: *Eponides pseudoelevatus*, *Anomalinoides midwayensis*, *Anomalinoides umbonifera*, *Lenticulina midwayensis*, *Gavelinella guineana*, and *Fursenkoina elongata*.

Ostracod species: *Bairdia ilaroensis*, *Aegyptiana duwiensis*, *Buntonia jordanica subjordanica*, *Paracypris* spp., *Actinocythereis coronata*, *Leguminocythereis lokossaensis* and *Cytherella sylvesterbradleyi*.

Age: Late Paleocene

Diagnostic criteria: Occurrence of *Planorotalites pseudomenardii*, *Globigerina triloculinoides* and *Aegyptiana duwiensis* at 1350 ft indicate late Paleocene P4 zone.

4.3.4 Paleoenvironment

The occurrence of species such as *Anomalinoides midwayensis*, *Anomalinoides umbonifera*, *Lenticulina midwayensis*, *Fursenkoina elongata* and *Afrobolivina afra* (foraminifera); *Actinocythereis coronata*, *Bairdia ilaroensis*, *Aegyptiana duwiensis*, *Buntonia jordanica subjordanica*, *Paracypris* spp., and *Cytherella sylvesterbradleyi* in the studied section of the Araromi – 2 borehole suggest inner to middle neritic setting. Stratigraphic Distribution of Ostracods and Foraminifera taxa in Araromi-2 Well shown in figure 4.3.1



Figure 4.3.2: Plates of Stratigraphic Distribution of Ostracods and Foraminifera taxa in Araromi-2 Well

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

This study delivers a very detailed evaluation of the sedimentological, geochemical, and palynofacies characteristics of the Araromi Formation within the Dahomey Basin, located in southwestern Nigeria. The Araromi Formation consists predominately of shales, siltstones, sandstones and deposited within transitional to shallow marine environments influenced by alternating fluvial and deltaic processes. These lithofacies variations reveal cycles of marine transgression and regression that controlled sediment supply and organic matter distribution. Geochemical analyses reveal moderate to high total organic carbonate (TOC) Values and mixed type II and type III kerogens, suggesting that the formation possess both oil and gas generating potential. Palynofacies and palynomorph assemblages comprising abundant amorphous organic matter, phytoclasts, spores, pollen grains and marine dinoflagellates cyst indicate deposition under suboxic to anoxic conditions conducive for organic matter preservation. The identification of cretaceous to paleocene palynomorphs such as *Monocolpitr marginatus*, *Cingulatisporites ornatus*, *Tricolporopellenites sp*, and *Cyathidites minor* confirms deposition during a marginal marine transgressive to regressive sequence. In conclusion, the integrated results demonstrate that the Araromi Formation holds significant hydrocarbon potential within the Dahomey Basin. Its organic rich shales and bituminous limestones serve as effective source rock, while the interbedded sandstones provide potential reservoir facies. The multidisciplinary approach adopted in this study improves the understanding of the basin depositional evolution and supports future exploration strategies aimed at developing the Dahomey Basin as an emerging hydrocarbon province in southwestern Nigeria.

5.1 SUGGESTIONS FOR FURTHER STUDIES

1. Expanding palynological sampling across broader stratigraphic sections and multiple wells is necessary to develop a more detailed palynostratigraphic framework for the Araromi Formation and to enhance age correlations throughout the Dahomey basin

2. Conducting 1D and 2D basin modelling with help simulate burial history, thermal gradients, timing of hydrocarbon generation, and migration routes within the Araromi Formation
3. Comparative geochemical studies between the Dahomey basin and the neighbouring basins like the Niger Delta and Benin basin could reveal regional patterns in organic richness, source rock maturity, and petroleum system characteristics.

5.2 RECOMMENDATIONS

1. It is recommended that future investigation encompasses a broader region of core samples and well logs from multiple locations across the Dahomey Basin to enhance understanding of facies distribution and lateral continuity of source rock intervals.
2. Integrating sedimentological, palynofacies and geochemical data with seismic reflection and structural mapping will advance reservoir characterization and the identification of prospective hydrocarbon traps

REFERENCES

- Adekeye, O. A., Akande, S. O., & Adeoye, J. A. (2019). *The assessment of potential source rocks of Maastrichtian Araromi Formation in Araromi and Gbekebo wells, Dahomey Basin, southwestern Nigeria*. **Heliyon**, 5(5), e01561.
- Adegoke, O. S. (1977). *Stratigraphy and paleontology of the Ewekoro Formation (Paleocene) of southwestern Nigeria*. **Bulletin of American Paleontology**, 71(295), 1–379.
- Amodu, O. I., & Adeigbe, O. C. (2015). *Palyno-environmental study of the Araromi-1 Well, eastern Dahomey Basin, south-west Nigeria*. **Journal of Science Research**, 14(1), 71–82.
- Amodu, O. I., & Ogala, J. E. (2018). *Integrated palynological and organic geochemical characterization of the Maastrichtian–Paleocene Araromi Formation, eastern Dahomey Basin, southwestern Nigeria*. **Journal of African Earth Sciences**, 140, 150–163.
- Jimoh, A. Y., Saadu, M. B., Adetoro, A. A., Ajadi, J., & Issa, T. (2024). *Sedimentological and geochemical evaluation of sandstones of the Ilaro Formation, Dahomey Basin, Southwestern Nigeria*. **Journal of the Nigerian Society of Physical Sciences**, 6(2), 1726.
- Njoku, C. E. (2021). *Palynological, palynofacies and geochemical assessment of the Maastrichtian–Paleocene Araromi Formation, Dahomey Basin, southwestern Nigeria*. **Nigerian Journal of Earth and Environmental Sciences**, 7(1), 45–61.
- Nton, M. E., & Adesina, A. D. (2009). *Aspects of source rock evaluation and hydrocarbon potential of the Tertiary sediments in the eastern Dahomey Basin, southwestern Nigeria*. **Pacific Journal of Science and Technology**, 10(1), 590–603.
- Ogala, J. E., Oboh-Ikuenobe, F. E., Sonibare, W. A., Akinlua, A., & Nytoft, H. P. (2019). *Geochemical and organic petrological study of bituminous sediments from*

the Dahomey Basin, southwestern Nigeria. Marine and Petroleum Geology, 99, 577–595.

Ogunyele, A. C., & Omatsola, M. E. (2011). *Sedimentological and geochemical characteristics of Cretaceous to Tertiary sediments in the Dahomey Basin, southwestern Nigeria. Nigerian Journal of Mining and Geology*, 47(2), 159–172.

Oluwajana, O. A., Opatola, A. O., Adamolekun, O. J., Adekeye, O. A., & Ayeni, R. O. (2021). *Sedimentation, depositional environments, and hydrocarbon potential of the Maastrichtian–Paleocene Araromi Formation, eastern Dahomey (Benin) Basin, southwestern Nigeria. Journal of Petroleum Exploration and Production Technology*, 11, 3917–3934.

Omoboriowo, A. O., Akande, S. O., & Adekeye, O. A. (2018). *Organic geochemical characterization and hydrocarbon potential of Late Cretaceous sediments from the eastern Dahomey Basin, southwestern Nigeria. Journal of African Earth Sciences*, 145, 1–12.

Osinowo, O. O., & Odewande, A. A. (2015). *Structural and depositional analysis of the Dahomey Basin, southwestern Nigeria: Implications for hydrocarbon prospectivity. Journal of Geology and Mining Research*, 7(2), 13–24.

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

Salard-Cheboldaeff, M. (1990). Intertropical African palynostratigraphy from Cretaceous to Late Quaternary times. *Journal of African Earth Sciences*, 11(1–2), 1–24.

Whiteman, A. J. (1982). *Nigeria: Its petroleum geology, resources, and potential (Vol. 1 & 2)*. Graham & Trotman.