MICROPALEONTOLOGICAL AND PALYNNOLOGICAL ANALYSIS OF SAMPLES FROM THE DAHOMEY BASIN

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF SCIENCE DEGREE. (B. SC HONS) IN GEOLOGY

NOVEMBER, 2025.

AUTHOR'S STATEMENT

This is to certify that this project was carried out by **Eloghosa TIMOTHY** with matriculation number **PSC2105441,** of the Department of Geology, University of Benin, Benin City

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DEDICATION

This work is dedicated to the one above all, God almighty for his love, mercies and favour upon my life and also to my Parents Mr. and Mrs. Timothy Aguebor, as well as my loved ones for their unwavering support.

ACKNOWLEDGEMENT

I am highly grateful to my God whose love has sustained me thus far.

I wish to acknowledge my project supervisor Dr. Alexander Ogbamikhumi whose contribution made this work a success. I also appreciate the Head of Department Dr. S.A. Salami and Dr Godwin Okumagbe Aigbadon, Dr. (Mrs) oyovwhikowhe- Maju, Dr Alexander Ogbamikumi, Dr Nosa Igbnigie as well as other lecturers in the Department of Geology for imparting knowledge and sharpening my intellectual base.

Finally, to my lovely parents, Mr. and Mrs. Timothy Aguebor, my siblings, Mr Nelson Aguebor, Mr. Osakpolor Timothy and to every person who has made this journey a success for their unwavering support and unending prayers.

ABSTRACT

This study presents a detailed palynological analysis of subsurface well samples from the Araromi-2 well in the eastern Dahomey Basin, Southwestern Nigeria, to establish a biostratigraphic framework and interpret paleodepositional environments. 33 samples were recovered and ten (10) ditch cutting samples from depths of 830 ft to 1880 ft were processed using standard palynological techniques involving hydrochloric (HCl) and hydrofluoric (HF) acid digestion, heavy liquid separation, and microscopic examination. The analysis yielded a rich and diverse assemblage of palynomorphs, including spores, pollen, and dinoflagellate cysts. The stratigraphic distribution of key taxa such as *Proxapertites operculatus*, *Retidiporites magdalenensis*, *Palaeocystodinium australinium*, and *Cyathidites minor* enabled the recognition of the *Palaeocystodinium australinium - Cyathidites minor* Assemblage Zone. This zone indicates a **Late Maastrichtian to Early Paleocene (Danian) age** for the studied interval, correlating with the upper Araromi Formation. Palynofacies analysis revealed a vertical transition from amorphous organic matter (AOM)-dominated assemblages in the lower sections to phytoclast-rich assemblages upwards. This trend indicates a **regressive sequence**, transitioning from a shallow, anoxic marine environment to a marginal marine and finally a deltaic/coastal plain setting. The study concludes that the Araromi Formation records a critical phase of the basin's evolution across the Cretaceous-Paleogene boundary. The findings refine the biostratigraphic zonation of the basin and underscore the value of integrated palynological and palynofacies studies in petroleum exploration and paleoenvironmental reconstruction.

TABLE OF CONTENTS

COVER PAGE....................i
TITLE PAGE....................ii
AUTHOR'S STATEMENT....................iii
DEDICATION....................iv
ACKNOWLEDGEMENT....................v
ABSTRACT....................vi
TABLE OF CONTENTS....................vii
LIST OF FIGURES....................ix
LIST OF TABLES....................x
CHAPTER ONE....................1
INTRODUCTION....................1
1.1 General Statement....................1
1.2 Background of Study....................2
1.3 Aim and Objectives....................3
Aim....................3
1.4 Significance of Study....................4
1.5 Statement of Problem....................5
1.6 Scope of Study....................5
1.7 Source of Data....................6
1.8 Location of Study Area....................6
CHAPTER TWO....................8
GEOLOGICAL SETTING AND LITERATURE REVIEW....................8
2.1 Introduction....................8
2.2 Regional Geology of the Dahomey Basin....................8
2.3 Tectonic Setting and Evolution....................10
2.4 Stratigraphy and Lithostratigraphic Framework....................11
2.5 Recent Works on Palynological Studies of the Area....................14
2.6 Recent Works on Petrography and Mineralogy of the Area....................15
2.7 Integration of Petrography, Mineralogy, and Palynological Findings....................15
CHAPTER THREE....................17

MATERIALS AND METHODS........ 17
3.1 Introduction........ 17
3.2 Materials and Equipment Used........ 17
3.3 Sample Description and Preparation........ 18
3.4 Laboratory Procedures........ 19
3.4.1 Removal of Carbonates (HCl Treatment)........ 19
3.4.2 Removal of Silicates (HF Treatment)........ 19
3.4.3 Oxidation and Deflocculation (HNO_3 / KOH Treatment)........ 19
3.4.4 Heavy Liquid Separation........ 19
3.4.5 Sieving and Concentration........ 20
3.4.6 Slide Preparation and Microscopic Examination........ 20
3.5 Quantitative and Qualitative Analysis........ 20
3.6 Palynofacies Analysis........ 21
3.7 Data Presentation and Interpretation........ 22
3.8 Quality Control and Limitations........ 22
CHAPTER FOUR........ 24
RESULTS AND DISCUSSION........ 24
4.1 Description of Recovered Palynomorphs........ 24
4.2 Lithologic Description of Araromi Well (Depth Interval: 665–1900 ft)........ 26
4.3 Distribution of Palynomorphs with Depth........ 31
4.5 Palynofacies Results........ 39
4.6 Paleoenvironmental Interpretation........ 39
4.7 Discussion........ 40
Figure 4.4: Palynological interpretation of Araromi – 2 Well (830-1880 feet)........ 48
CHAPTER FIVE........ 49
5.1 Conclusion........ 49
5.2 Recommendations........ 44
References........ 52

LIST OF FIGURES

Figure **Page**

1.1: Map of Nigeria showing the major sedimentary basins, including the Dahomey Basin (modified after Okosun & Alkali, 2012)............................... 3

1.2: Geological map of the Dahomey Basin showing the study area (modified after Adagunodo et al., 2019)..8

2.3: Regional geological map of the Dahomey Basin showing major lithostratigraphic units and structural trends (modified after Billman, 1976) 5..11

2.4: Tectonic framework of the Dahomey Basin showing major fault systems and rift structures along the Gulf of Guinea margin (modified after Billman, 1992).. 14

2.5: Generalized lithostratigraphic column of the Dahomey Basin showing major formations from the Cretaceous to Recent (modified after Omatsola & Adegoke, 1981)... 17

4.1: Selected palynomorph taxa from Araromi-2 Well showing pollen, spores, and dinoflagellate cysts.. 30

4.2: Lithologic description of Araromi well..34

4.3: Composite palynostratigraphic zonation chart for Araromi-2 Well. 43

4.4: Palynological interpretation of Araromi-2 Well (830-1880 feet). 47

LIST OF TABLES

Table **Page**

4.1: Araromi-1 Palynomorph Data (Count of Palynomorphs by Depth)...................... 36 - 41

CHAPTER ONE

INTRODUCTION

1.1 General Statement

Micropaleontology is a vital branch of geology that deals with the study of microfossils that are typically less than 1 mm in size. Among these are palynomorphs - organic-walled microfossils such as pollen grains, spores, dinoflagellate cysts, and other microscopic remains of plants and plankton. The recovery and analysis of these fossils have become an indispensable tool in stratigraphic correlation, paleoenvironmental reconstruction, and petroleum exploration.

Palynological studies are especially valuable in tropical regions like Nigeria, where macrofossils are often poorly preserved due to intense weathering and oxidation. The resistant nature of palynomorphs allows them to survive in sediments where other fossils are absent, making them a powerful means of dating and correlating rock units. Beyond age determination, the abundance and diversity of palynomorphs reveal valuable information about paleoclimate, vegetation patterns, and depositional settings.

In petroleum geology, palynology plays a critical role in identifying source-rock intervals, recognizing marine transgressions and regressions, and reconstructing sedimentary environments conducive to hydrocarbon generation. For this reason, micropaleontologists and stratigraphers rely heavily on palynomorph assemblages when developing geologic models for exploration and basin analysis.

1.2 Background of Study

The Dahomey Basin, also referred to as the Benin Basin, is one of the several sedimentary basins along the West African coast. It stretches from southeastern Ghana through Togo and the

Republic of Benin into southwestern Nigeria. The basin represents a transitional continental–marine environment that evolved during the breakup of the Gondwana supercontinent and the subsequent opening of the South Atlantic Ocean in the Early Cretaceous (Omatsola & Adegoke, 1981).

In Nigeria, the Dahomey Basin occupies parts of Lagos, Ogun, and Ondo States, with the Araromi area forming part of its eastern segment. The basin contains a thick succession of sediments ranging from continental clastics to marine limestones and shales. Its formations, including the Afowo, Araromi, Ewekoro, and Akinbo Formations, record successive transgressive–regressive cycles that span the Late Cretaceous to Tertiary periods.

Over the years, various geological investigations have highlighted the significance of the basin in terms of its economic and academic importance. Early works by Omatsola and Adegoke (1981), Okosun (1990), and Billman (1992) laid the foundation for understanding its structural and depositional history. More recent palynological and sedimentological studies—such as those by Durugbo and Aroyewun (2012), Bolaji et al. (2020), and Agharanya et al. (2022)—have refined the stratigraphic framework and demonstrated the potential of palynomorphs for accurate biostratigraphic correlation across the basin.

However, despite these advances, detailed palynological data from some parts of the Araromi interval remain limited. Many earlier studies either focused on other formations or covered broader regional correlations without in-depth evaluation of this specific section. The present study therefore undertakes a focused palynological analysis of Araromi well samples to fill that gap and to provide new insights into the age and depositional environment of these sediments.

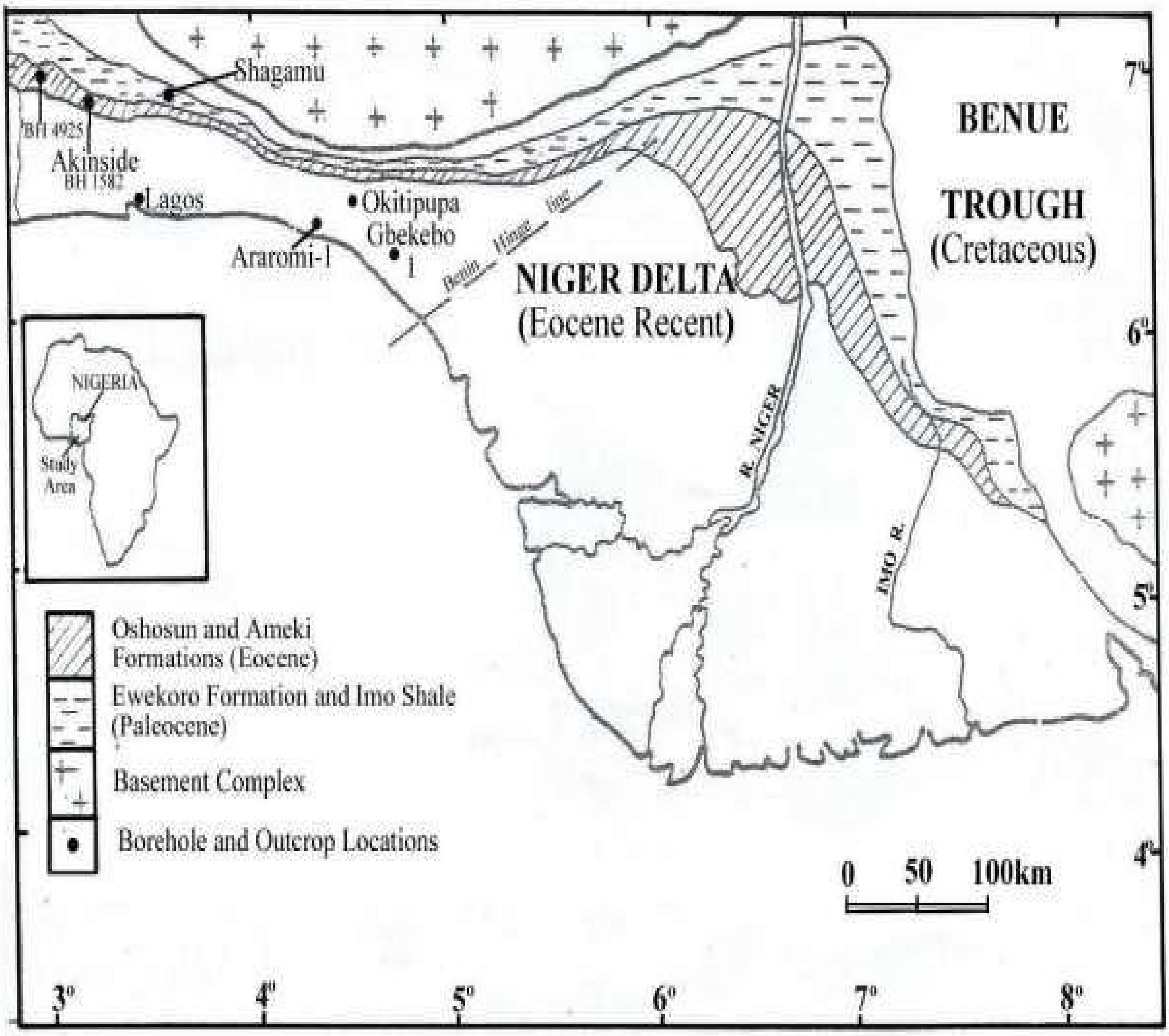


Fig. 1.1 Map of Nigeria showing the major sedimentary basins, including the Dahomey Basin (modified after Okosun & Alkali, 2012).

1.3 Aim and Objectives

Aim

To carry out a detailed palynological analysis of well samples from the Dahomey Basin in order to establish their biostratigraphic framework and interpret the depositional environment.

Objectives

1. To identify and classify recovered palynomorph taxa from the Araromi well samples.
2. To determine the stratigraphic distribution and abundance patterns of these taxa with depth.
3. To establish palynostratigraphic zones and assign an age to the studied interval.
4. To interpret the paleoenvironment of deposition using palynomorph assemblages and palynofacies characteristics.

1.4 Significance of Study

The present work contributes to a clearer understanding of the biostratigraphic and paleoenvironmental development of the Dahomey Basin. Its relevance can be viewed from three perspectives:

1. It enriches existing knowledge on the palynostratigraphy of the Dahomey Basin, providing data that can be used in further geological research, stratigraphic correlation, and postgraduate studies.
2. The results offer age-diagnostic markers that may guide subsurface correlation in petroleum exploration. Palynomorph assemblages also provide indirect evidence of depositional conditions favorable for source-rock accumulation.
3. By reconstructing ancient vegetation and marine influences, this study contributes to

understanding the paleoclimatic evolution of the coastal region during the Late Cretaceous to Paleocene.

Ultimately, this research supports the broader application of palynology in reconstructing Earth's past environments and in enhancing the geological interpretation of sedimentary basins.

1.5 Statement of Problem

Although the Dahomey Basin has been the subject of many geological and palynological studies, much of the detailed micropaleontological data remains concentrated in specific localities such as Ewekoro and Akinbo. The Araromi Formation, which represents an important transitional unit between continental and marine facies, has received comparatively less detailed palynological attention. This lack of localized data hinders precise biostratigraphic correlation and age assignment within the basin.

Furthermore, earlier works often relied on limited outcrop exposures or single well intervals, leaving uncertainties regarding the continuity and environmental interpretation of the formation. This study addresses these gaps by conducting a thorough palynological analysis on carefully selected well samples from Araromi, thereby improving both temporal and environmental resolution for this part of the basin.

1.6 Scope of Study

The scope of this study is restricted to the palynological analysis of subsurface well samples obtained from the Araromi area of the eastern Dahomey Basin. The study focuses on the identification, distribution, and interpretation of spores, pollen grains, and marine microplankton. The investigation does not include foraminiferal or other microfossil groups.

The results are interpreted within the context of established palynological zonations for West

Africa, particularly the Paleocene–Eocene zonal schemes proposed by Evamy et al. (1978) and later refined by Okosun and Alkali (2012). The study also incorporates palynofacies data, such as particulate organic matter types and amorphous organic content, to aid paleoenvironmental reconstruction.

1.7 Source of Data

All samples used in this research were obtained from the Dahomey Basin, as part of a controlled subsurface investigation. The samples originate from different depth intervals of the Araromi well, which penetrates the upper part of the Araromi Formation. Laboratory analyses, including chemical treatment, slide preparation, and microscopic examination, were performed in the Micropaleontology Laboratory of the department using standard palynological procedures.

1.8 Location of Study Area

The study area lies within the Araromi axis of the eastern Dahomey Basin, southwestern Nigeria. Geographically, it falls within latitudes 6°30′ N and 7°00′ N and longitudes 4°00′ E and 5°00′ E. The area is accessible through the Ore–Okitipupa highway and minor feeder roads leading to local villages and farmlands.

Topographically, the area is gently undulating, with elevations between 30 m and 120 m above sea level. Drainage is provided mainly by seasonal streams that flow southward into the coastal lowlands. The climate is humid tropical, characterized by distinct wet and dry seasons, while vegetation consists largely of secondary rainforest interspersed with farmland.

Geologically, Araromi occupies a transitional zone between the Ewekoro limestone belt to the north and the Afowo sandstone unit to the west. The subsurface sediments consist of alternating sandstones, shales, and siltstones belonging to the Araromi Formation. These strata were deposited in a marginal-marine environment during a major marine transgression in the Late Maastrichtian to Paleocene.

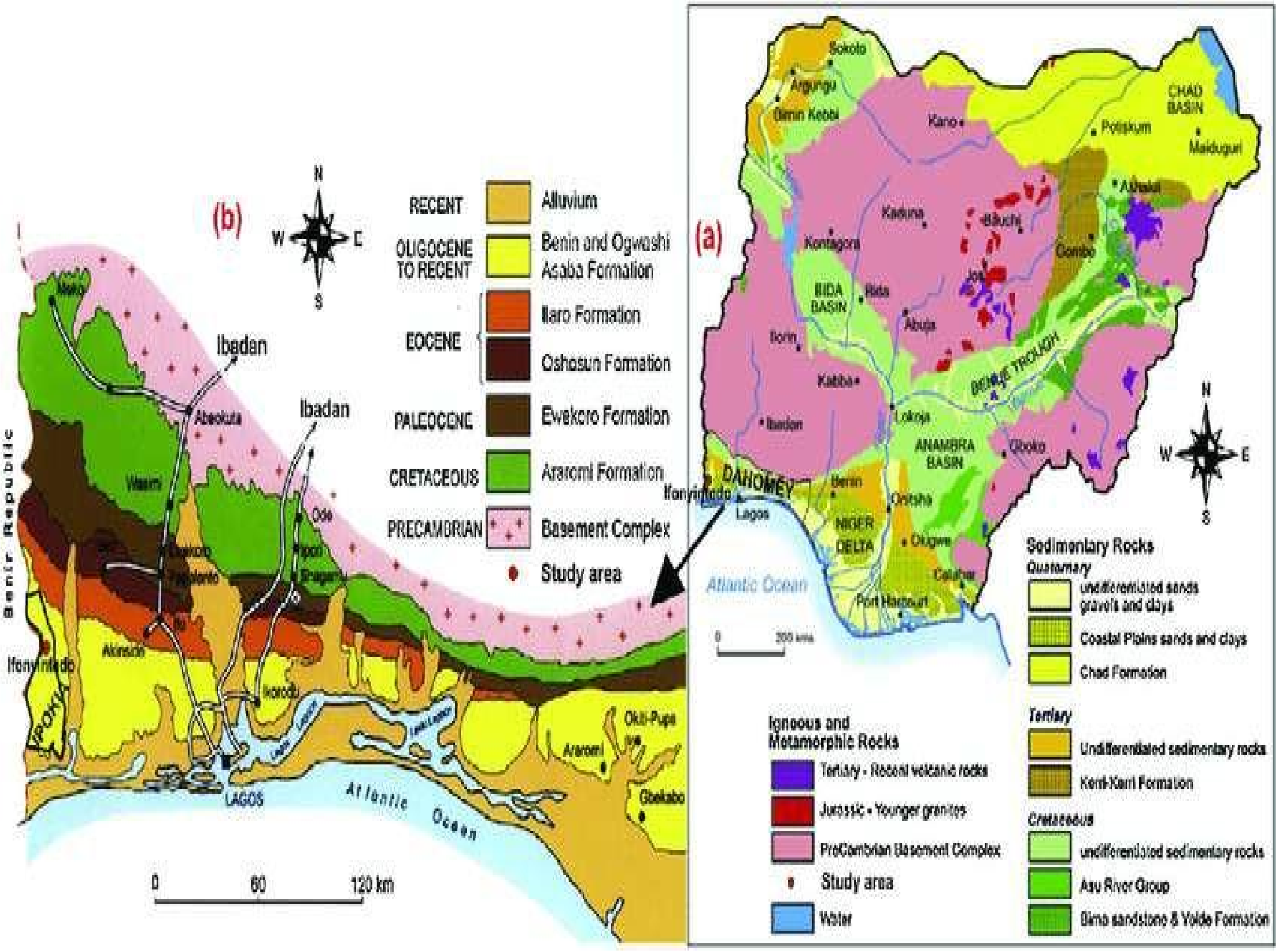


Figure 1.2: **Geological map of the Dahomey Basin showing the study area.** (modified after Adagunodo et al., 2019)

CHAPTER TWO

GEOLOGICAL SETTING AND LITERATURE REVIEW

2.1 Introduction

Understanding the geological framework of a study area provides the foundation for interpreting its palynological characteristics and depositional evolution. The Dahomey Basin, being a transitional continental–marine basin, presents a complex stratigraphic history influenced by both tectonic and eustatic controls. The basin records several phases of sedimentation from the Cretaceous to the Tertiary, during which varying depositional environments supported the preservation of diverse palynomorph assemblages.

This chapter presents a concise geological description of the Dahomey Basin, including its regional geology, tectonic evolution, stratigraphic framework, and lithostratigraphic succession. It also reviews key previous studies on the palynology of the basin, with emphasis on works that contributed to understanding the age and paleoenvironmental evolution of formations within the Araromi area.

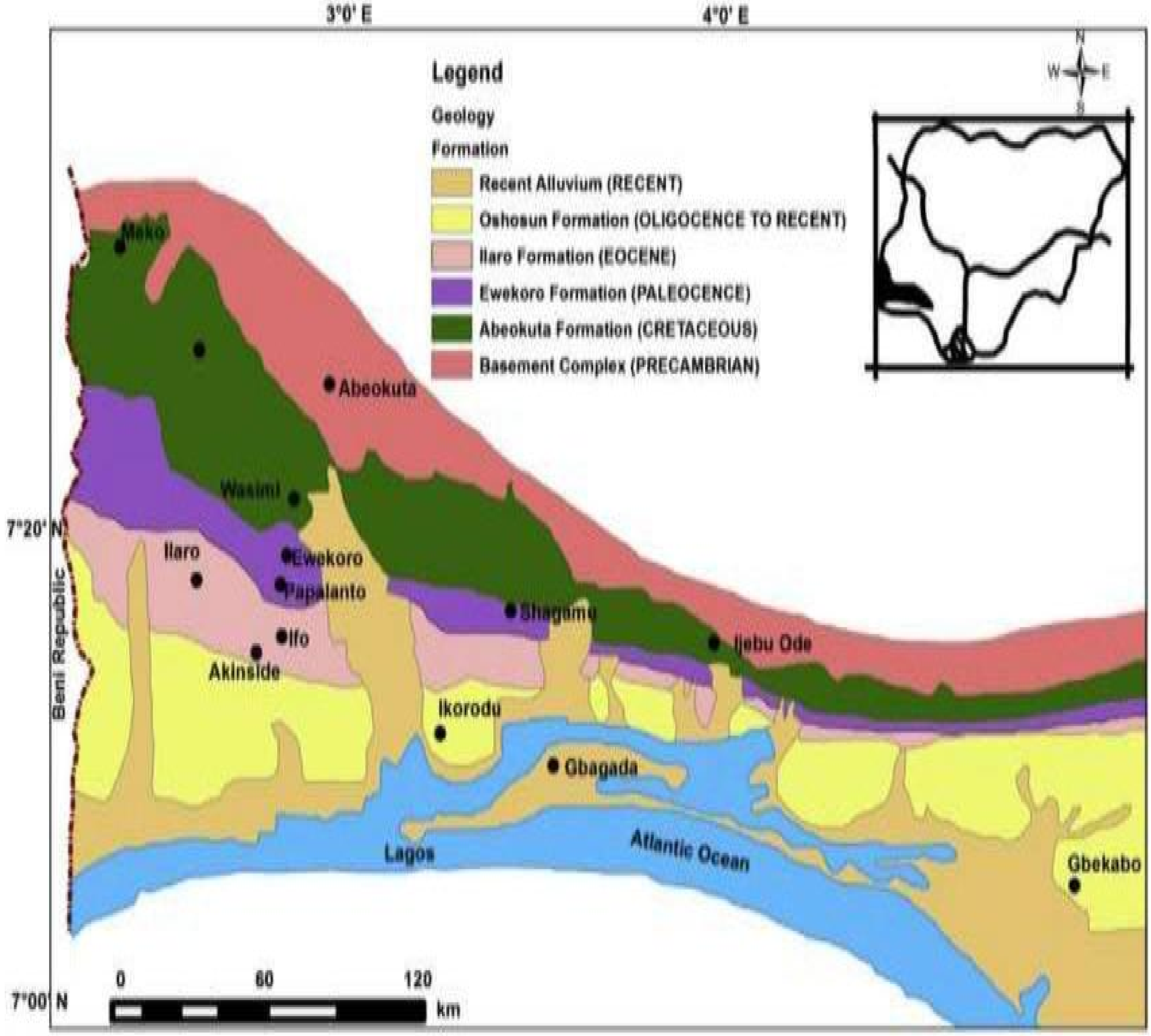
2.2 Regional Geology of the Dahomey Basin

The Dahomey Basin is part of the chain of coastal basins that extend along the West African margin from Ghana through Togo, Benin, and into southwestern Nigeria (Omatsola & Adegoke, 1981). It occupies a roughly triangular area bounded to the north by the Precambrian basement complex, to the east by the Okitipupa Ridge, and to the south by the Atlantic Ocean.

The Nigerian section of the basin trends in a northeast–southwest direction and covers an estimated area of about 2,400 km^2. It is bounded to the east by the Okitipupa High, which separates it from the Niger Delta Basin, and to the west by the Republic of Benin border. The basin is underlain by a basement composed mainly of gneiss, schist, and migmatite, which forms the structural foundation upon which younger sediments were deposited.

The sedimentary fill of the basin consists of continental to marine clastic sequences deposited from the Albian to Recent. These sediments record successive transgressive and regressive episodes related to the opening of the South Atlantic Ocean and subsequent sea-level fluctuations. The depositional environments range from continental fluvial and deltaic settings to marginal marine, lagoonal, and fully marine facies.

Structurally, the basin is characterized by normal faulting and gentle folding associated with rift tectonics. Faults trend predominantly NE–SW and are most pronounced near the Okitipupa Ridge and Ise axis. These structures influenced the deposition and distribution of sedimentary facies and created local depocenters where organic matter accumulated.



Regional geological map of the Dahomey Basin showing major lithostratigraphic units and structural trends (modified after Billman, 1976)

2.3 Tectonic Setting and Evolution

The origin of the Dahomey Basin is closely tied to the breakup of the Gondwana supercontinent and the subsequent opening of the South Atlantic Ocean during the Early Cretaceous. This rifting event resulted in the formation of several marginal basins along the West African coast, including the Benue Trough, Niger Delta, and Dahomey Basin.

The tectonic evolution of the basin occurred in several phases (Billman, 1992; Omatsola & Adegoke, 1981):

1. **Pre-rift phase (Pre-Albian):** Characterized by erosion and exposure of the Precambrian basement, creating an irregular surface that later served as a depositional foundation.
2. **Rift phase (Albian–Cenomanian):** Initiated by crustal stretching and faulting, forming grabens and half-grabens that became sites of continental sedimentation. This phase is represented by coarse clastic deposits such as conglomerates and sandstones of the Ise Formation.
3. **Transgressive phase (Turonian–Maastrichtian):** Marked by marine incursion that introduced shallow marine environments. Fine-grained sediments including shales, siltstones, and limestones of the Afowo and Araromi Formations were deposited during this period.
4. **Drift and post-rift phase (Paleocene–Recent):** Characterized by subsidence, thermal cooling, and renewed marine sedimentation. Formations such as Ewekoro, Akinbo, and Ilaro were deposited in environments ranging from open marine to coastal and deltaic systems.

Tectonic subsidence and global sea-level changes during these phases greatly influenced the distribution and preservation of organic matter and palynomorph assemblages in the basin.

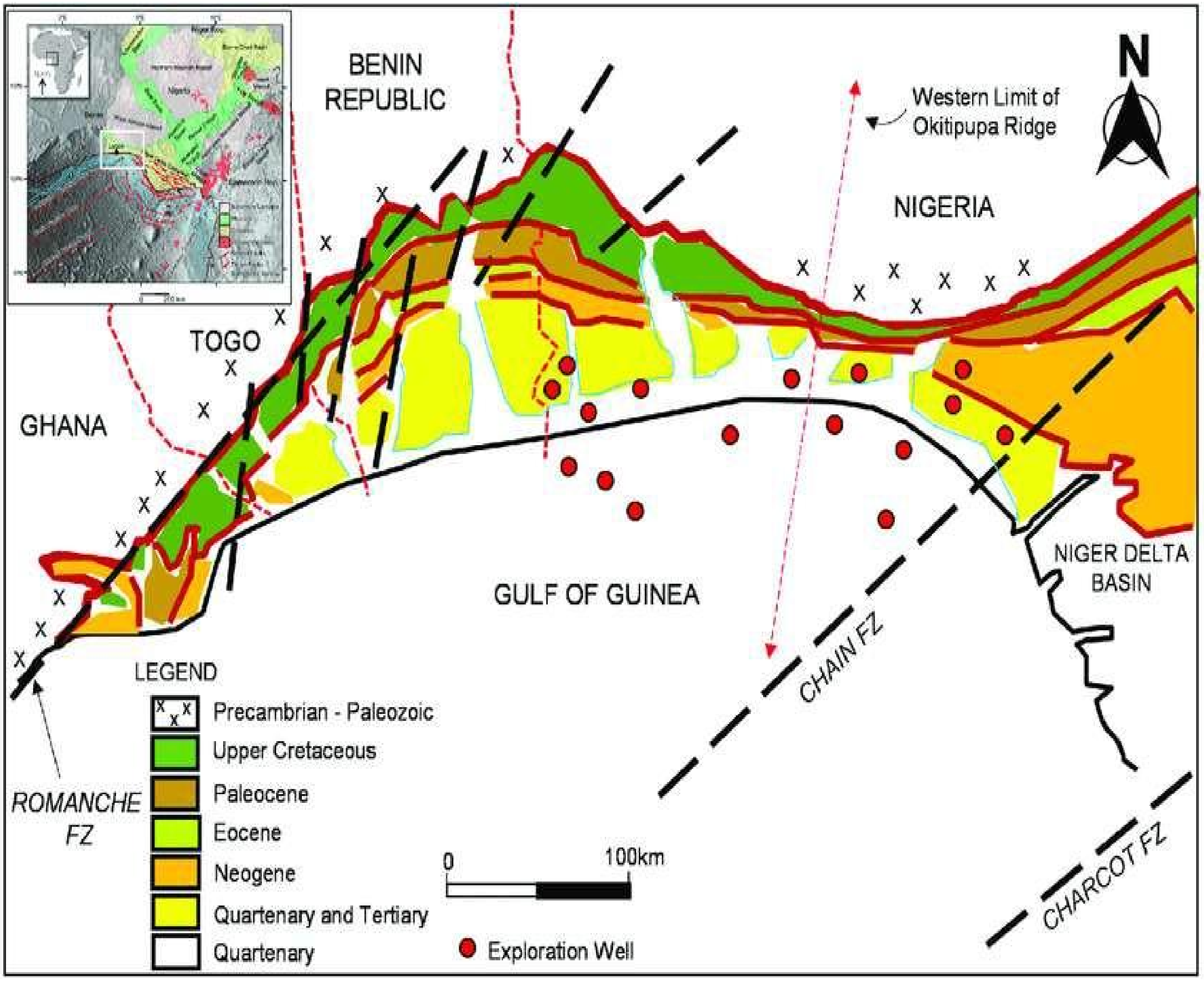


Fig 2.3: Tectonic framework of the Dahomey Basin showing major fault systems and rift structures along the Gulf of Guinea margin (modified after Billman, 1992)

2.4 Stratigraphy and Lithostratigraphic Framework

The stratigraphy of the Dahomey Basin has been established through the integration of surface outcrop studies, borehole data, and micropaleontological analyses. Omatsola and Adegoke (1981) recognized six main lithostratigraphic units in ascending order: the Ise, Afowo, Araromi, Ewekoro, Akinbo, and Ilaro Formations, capped by recent coastal deposits.

1. Ise Formation (Albian–Cenomanian): This is the oldest sedimentary unit in the basin. It unconformably overlies the Precambrian basement and consists predominantly of coarse-grained sandstones and conglomerates interbedded with kaolinitic clays. The sediments were deposited in fluvial to continental settings and represent the initial rift-phase deposits of the basin.

2. Afowo Formation (Cenomanian–Turonian): This unit overlies the Ise Formation and consists of interbedded sandstones and shales with occasional bituminous layers. The lower portions are typically coarse and ferruginous, while the upper parts grade into finer sediments. The formation is interpreted as representing transitional to shallow marine conditions.

3. Araromi Formation (Maastrichtian–Paleocene): The Araromi Formation is the focus of the present study. It comprises alternating dark grey to brown shales, siltstones, and fine-grained sandstones. The lithology indicates deposition in a marginal marine to shallow marine environment, with influences from both terrestrial and marine sources. Palynological studies have revealed abundant spores, pollen, and marine dinoflagellate cysts, suggesting deposition during a major marine transgression. The formation is conformably overlain by the Ewekoro Formation.

4. Ewekoro Formation (Paleocene): Dominated by fossiliferous limestone, the Ewekoro Formation represents a fully marine environment. It contains abundant foraminifera, echinoids, and calcareous algae. Although not the focus of this study, its rich fossil content has been used extensively for regional biostratigraphic correlation.

5. Akinbo Formation (Late Paleocene–Early Eocene): Composed mainly of grey to black shales and claystones with occasional phosphatic layers, this unit marks a return to more restricted marine conditions following regression. The palynomorph assemblage includes mangrove pollen and marine microplankton, indicative of shallow marine to lagoonal environments.

6. Ilaro Formation (Eocene): The Ilaro Formation is a massive, cross-bedded sandstone unit that signifies a continental to deltaic environment. It is interpreted as fluvial and estuarine in origin.

Above these formations lie Recent coastal plain sands, representing modern-day deposition along the coast of southwestern Nigeria.

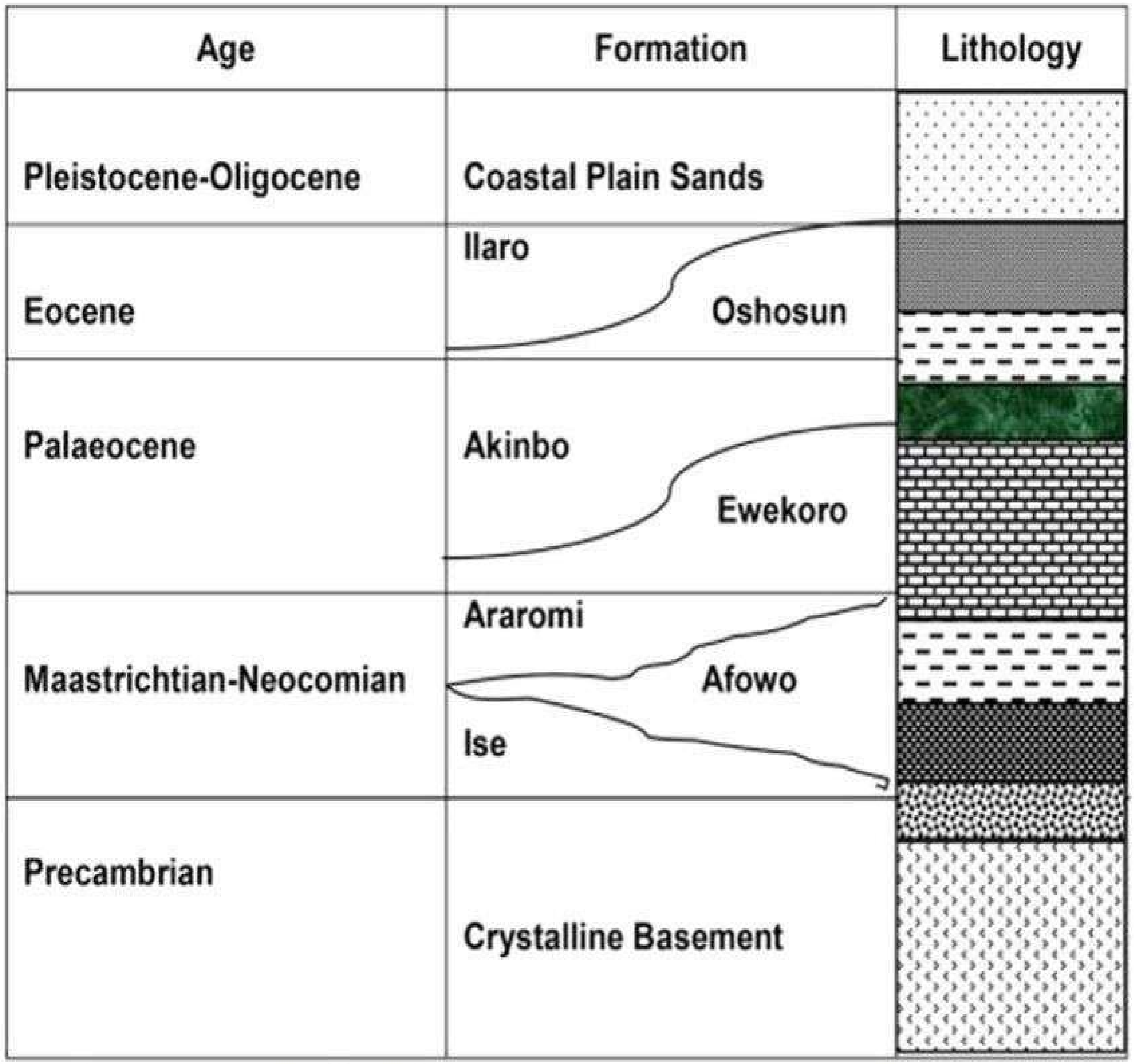


Fig 2.3: Generalized lithostratigraphic column of the Dahomey Basin showing major formations from the Cretaceous to Recent (modified after Omatsola & Adegoke, 1981)

2.5 Recent Works on Palynological Studies of the Area

Several studies have contributed significantly to the palynostratigraphic understanding of the Dahomey Basin. The most relevant works are highlighted below:

Okosun and Alkali (2012) conducted a detailed palynological study of the Paleocene–Eocene interval in the eastern Dahomey Basin. They identified diagnostic taxa such as *Proxapertites operculatus*, *Retidiporites magdalenensis*, and *Grimsdalea polygonalis*, which they used to define regional palynostratigraphic zones. Their study proposed an updated biostratigraphic framework that has become a key reference for later works.

Durugbo and Aroyewun (2012) examined the palynology and paleoenvironment of the Upper Araromi Formation, identifying both terrestrial and marine palynomorphs, including *Zonocostites ramonae*, *Laevigatosporites spp.*, and *Cleistosphaeridium spp.* They interpreted the depositional environment as marginal marine to nearshore, reflecting alternating marine incursions and continental influences.

Bolaji et al. (2020) carried out a palynological and palynofacies analysis of the Ewekoro and Akinbo Formations. Their findings revealed Late Paleocene to Early Eocene assemblages and demonstrated how shifts in dinoflagellate and pollen abundance could track transgressive–regressive cycles within the basin.

Oluwajana et al. (2021) integrated palynological data with sedimentological evidence to reconstruct depositional sequences in selected wells. Their work highlighted the utility of combining palynology with sequence stratigraphy for better interpretation of basin evolution.

Agharanya et al. (2022) performed a regional palynostratigraphic correlation across several wells in the Dahomey Basin, refining age models and identifying new marker species for the Paleocene–Eocene interval. Their research underscored the potential of integrated palynology for resolving chronostratigraphic uncertainties.

Together, these studies form a robust foundation for palynological interpretation in the Dahomey Basin and support the relevance of the current study's approach.

2.6 Recent Works on Petrography and Mineralogy of the Area

Complementary research on the petrography and mineralogy of the Dahomey Basin has improved the understanding of its depositional processes and diagenetic evolution. Studies such as Nton and Adesina (2015) and Adekeye (2017) documented the mineralogical composition of sandstones and shales within the Afowo and Araromi Formations, identifying quartz, feldspar, kaolinite, and illite as dominant minerals. These studies link mineral assemblages to depositional environments, revealing that fine-grained shales with high clay and organic content were often deposited in low-energy marine settings favorable for palynomorph preservation.

2.7 Integration of Petrography, Mineralogy, and Palynological Findings

Integrating petrographic, mineralogical, and palynological data provides a multidimensional view of basin evolution. Mineralogical characteristics influence palynomorph preservation by controlling porosity, permeability, and redox conditions. For example, shales rich in organic matter and pyrite often yield abundant, well-preserved palynomorphs. Conversely, sandy facies with high permeability may experience oxidation and mechanical destruction of microfossils.

By comparing mineralogical and palynological data, researchers can distinguish between depositional environments such as fluvial, deltaic, and open marine systems. This integrated approach forms the backbone of modern basin analysis and will be applied in interpreting the results presented in Chapter Four.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter outlines the materials, laboratory equipment, and analytical techniques employed in this study. Palynological analysis is a laboratory-based method that involves extracting and identifying organic-walled microfossils (spores, pollen, and marine palynomorphs) from sedimentary rocks. The process requires a combination of chemical treatment, mechanical separation, and microscopic examination to recover well-preserved palynomorphs suitable for biostratigraphic and paleoenvironmental interpretation.

The procedures adopted in this research follow standard micropaleontological methods as outlined by Wood et al. (1996) and modified by Evamy et al. (1978) for tropical sedimentary basins. Each stage of the analysis from sample preparation to data interpretation was carefully carried out in the Micropaleontology Laboratory.

3.2 Materials and Equipment Used

The materials and laboratory tools used during the study include:

I. Rock samples from selected depth intervals in the Araromi well
II. Hydrochloric acid (HCl, 10%)
III. Hydrofluoric acid (HF, 40%)
IV. Nitric acid (HNO_3, 10%)
V. Potassium hydroxide (KOH, 10%)
VI. Zinc bromide ($ZnBr_2$) heavy liquid (specific gravity ≈ 2.0)
VII. Distilled water

VIII. Acetolysis mixture (acetic anhydride + sulfuric acid)

IX. Centrifuge tubes and beakers

X. Nylon sieves (10–15 µm mesh size)

XI. Glass slides and cover slips

XII. Microscope (binocular transmitted-light model)

XIII. Hot plate and drying oven

XIV. Forceps, pipettes, and sample spatulas

XV. Permanent mounting media (e.g., Canada balsam)

XVI. Labels, sample log sheets, and range chart templates

All reagents were handled with appropriate laboratory safety protocols, including the use of gloves, aprons, and fume hoods.

3.3 Sample Description and Preparation

A total of 10 well samples (from 830 ft to 1,880 ft) were analyzed from the Araromi well. The samples consisted mainly of dark grey shales, siltstones, and fine-grained sandstones. Lithologic observations indicated that the lower intervals contained carbonaceous shales rich in organic matter, whereas the upper intervals included sandy beds interbedded with thin shale laminations.

Each sample was assigned a laboratory number and arranged sequentially according to depth. About 10 g of each crushed and air-dried sample was used for the palynological extraction process.

3.4 Laboratory Procedures

The extraction of palynomorphs from sedimentary rocks followed the general steps outlined below.

3.4.1 Removal of Carbonates (HCl Treatment)

Each sample was placed in a 50 ml centrifuge tube and treated with 10% hydrochloric acid to dissolve carbonates (calcite, dolomite). The reaction was allowed to proceed until effervescence ceased, ensuring complete removal of carbonates. The residue was then washed repeatedly with distilled water and decanted to remove acid traces.

3.4.2 Removal of Silicates (HF Treatment)

The decarbonated residue was treated with 40% hydrofluoric acid to dissolve silicate minerals such as quartz and feldspar. This process was carried out carefully due to the corrosive nature of HF. After digestion, the samples were left overnight, decanted, and repeatedly washed with distilled water to remove fluoride residues.

3.4.3 Oxidation and Deflocculation (HNO_3 / KOH Treatment)

To remove humic substances and oxidize excess organic material, the samples were lightly treated with 10% nitric acid or potassium hydroxide solution, depending on the degree of coloration. Over-oxidation was avoided to prevent damage to the palynomorphs. This step improved visibility and clarity of specimens during microscopic examination.

3.4.4 Heavy Liquid Separation

The cleaned residue was suspended in zinc bromide ($ZnBr_2$) heavy liquid with a specific gravity of approximately 2.0. This separation method helps to concentrate the organic-walled microfossils by allowing heavier mineral grains to settle while lighter palynomorphs float. The supernatant containing the palynomorphs was carefully decanted, washed with distilled water, and centrifuged to remove remaining chemicals.

3.4.5 Sieving and Concentration

The recovered organic residue was sieved through a 10–15 µm nylon mesh to remove fine debris. The retained fraction contained well-preserved spores, pollen, and dinoflagellate cysts suitable for mounting.

3.4.6 Slide Preparation and Microscopic Examination

Cleaned residues were pipetted onto glass slides, air-dried, and mounted with a drop of Canada balsam. The slides were gently heated on a hot plate to remove air bubbles and ensure even spreading of the mutant. Each slide was then labeled with the sample code, depth, and formation.

Microscopic examination was carried out using a transmitted-light binocular microscope under magnifications of ×200 and ×400. Identification of palynomorphs was based on comparison with published atlases, reference collections, and standard taxonomic keys such as those by Jan du Chêne et al. (1978), Bolaji et al. (2020), and Durugbo and Aroyewun (2012).

Representative specimens were photographed and stored as part of the permanent slide collection in the Micropaleontology Laboratory of the department.

3.5 Quantitative and Qualitative Analysis

The palynological analysis involved both **quantitative** and **qualitative** assessments.

I. **Quantitative analysis:** Counts of all identifiable palynomorph taxa were recorded per depth interval. The relative abundance of each species was expressed as a percentage of the total palynomorph count in the sample. Abundance categories were classified as *dominant (>30%)*, *common (10–30%)*, *rare (<10%)*, and *trace (<1%)*.

II. **Qualitative analysis:** Focused on taxonomic diversity, preservation quality, and the ecological significance of the recovered species. Observations included dominance of terrestrial vs. marine palynomorphs, presence of reworked specimens, and morphological variations indicative of paleoenvironmental conditions.

Results from both analyses were tabulated and plotted as range charts, showing the vertical distribution and relative abundance of palynomorph taxa across the studied interval.

3.6 Palynofacies Analysis

Palynofacies studies were performed to complement the palynological interpretation by examining the types and proportions of organic particles preserved in the sediments. The palynofacies components considered include:

I. **AOM (Amorphous Organic Matter)**

II. **Phytoclasts** (woody and cuticular debris)

III. **Palynomorphs** (spores, pollen, dinoflagellates, and other microfossils)

Each residue slide was examined under low magnification to estimate the percentage of each component visually. The classification followed the system proposed by Tyson (1995). High proportions of AOM and marine palynomorphs indicate marine or anoxic environments, while phytoclast-dominated assemblages suggest proximal continental or deltaic deposition.

The integration of palynofacies and palynomorph data provided insights into the paleoenvironmental gradients - ranging from continental influence near the shoreline to offshore marine conditions in the deeper sections of the formation.

3.7 Data Presentation and Interpretation

The processed results were compiled into tables and graphs. Range charts were generated to display the stratigraphic distribution of taxa and their respective abundance patterns.

Each stratigraphic zone was delineated based on the first and last occurrences (FOD and LOD) of key index taxa, following the methodology of Evamy et al. (1978) and Okosun & Alkali (2012). Palynostratigraphic zones were correlated with established regional zonations such as the *Proxapertites operculatus – Retidiporites magdalenensis* and *Zonocostites ramonae – Grimsdalea polygonalis* zones of the Paleocene–Eocene.

Paleoenvironmental interpretations were derived by comparing the relative proportions of terrestrial to marine taxa and assessing the associated palynofacies composition. The interpretation also considered known ecological preferences of species, such as the dominance of mangrove pollen (*Zonocostites ramonae*) in deltaic settings and the presence of dinoflagellate cysts in marine conditions.

3.8 Quality Control and Limitations

To ensure reliability, all samples were processed under identical laboratory conditions. Reagents were replaced periodically to prevent contamination. Duplicate slides were prepared for selected intervals to confirm consistency in palynomorph recovery and identification.

However, a few limitations were encountered:

i. Some samples showed signs of oxidation and mechanical damage, reducing the number of identifiable specimens.
ii. Depth intervals with high sandy content yielded fewer palynomorphs due to poor preservation potential.
iii. Despite these limitations, the recovered assemblages were sufficient for meaningful biostratigraphic and paleoenvironmental interpretation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Description of Recovered Palynomorphs

The micropaleontological analysis of ditch cutting samples from the Araromi-2 samples yielded a moderately rich and diverse assemblage of pollen, spores, and marine microplankton. The recovered palynomorphs were generally well preserved, although some samples showed slight oxidation and fragmentation, particularly at shallow depths. The wells yielded a rich and diverse assemblage of palynomorphs, which can be categorized into terrestrial and marine groups.

The terrestrial palynoflora was abundant and varied, dominated by pollen and spores. Key elements include:

- Spores: Fern spores were particularly common, with *Cyathidites minor* being a consistently present species across both wells. Other significant spores
- include *Laevigatosporites* sp., *Gleicheniidites senonicus*, *Polypodiaceoisporites* sp., and *Cingulatisporites ornatus*.
- Gymnosperm Pollen: Pollen from coniferous trees, such as *Inaperturopollenites* sp. and *Araucariacites* sp., was frequent, especially in the Araromi-1 well.
- Angiosperm Pollen: A variety of flowering plant pollen was recovered, including *Monocolpites marginatus*, *Proxapertites operculatus*, *Proxapertites cursus*, *Longapertites* sp., *Retimonocolpites* sp., and *Tricolporopollenites* sp.

The marine palynoflora consisted of dinoflagellate cysts (dinocysts), which were predominantly found in the Araromi-1 well. Significant species recorde d include *Spiniferites* sp., *Cleistosphaeridium* sp., *Palaeocystodinium australinium*, *Cerodinium diebelii*, *Senegalinium* sp., *Phelodinium* sp., and *Achomosphaera* sp.

Other organic micro-fossils present include the freshwater alga *Botryococcus braunii*, diatom frustules, and fungal spores, were also common.

a. **Terrestrial pollen and spores** dominate the lower and middle intervals, with common taxa such as *Zonocostites ramonae*, *Laevigatosporites spp.*, *Proxapertites operculatus*, *Grimsdalea polygonalis*, *Longapertites marginatus*, *Retitricolporites irregularis*, and *Mauritiidites franciscoi*. These taxa are indicative of vegetation derived from mangrove, freshwater swamp, and tropical rainforest environments.
b. **Marine palynomorphs**, notably dinoflagellate cysts such as *Palaeocystodinium australinum*, *Cleistosphaeridium diversispinosum*, and *Spiniferites ramosus*, occur throughout the studied interval but are more frequent in the lower sections of the well, suggesting proximity to an open marine setting.

Sporomorph diversity and preservation vary with depth: deeper intervals (below 1,500 ft) show greater species richness and higher counts of marine taxa, while upper intervals are dominated by terrestrial pollen forms and degraded organic matter.

Figure 4.1: Selected palynomorph taxa from Araromi-2 Well showing pollen, spores, and dinoflagellate cysts.

4.2 Lithologic Description of Araromi Well (Depth Interval: 665–1900 ft)

The lithologic succession of the Araromi Well from 665 ft to 1900 ft is dominated by alternating shale units and interbedded limestone horizons, with several intervals of unidentified lithologies. The sequence reflects repeated episodes of fine-grained sediment deposition with occasional carbonate development, likely under varying energy and environmental conditions within a shallow marine to marginal marine setting.

665–700 ft

The uppermost part of the interval begins with dark grey shale, indicating a low-energy, oxygen-poor depositional environment. This is followed by a thin layer of unidentified lithology, possibly representing a transitional or poorly preserved unit.

700–770 ft

This interval is marked by the first occurrence of limestone, suggesting a shift to more carbonate-rich conditions. Limestone appears between 700–730 ft and 740–770 ft, separated by a thin layer of unidentified lithology. These alternating units may reflect short-term changes in water chemistry or depositional energy.

770–900 ft

A sequence of shale, limestone, and intervening unidentified lithologies dominates this interval. Shale units at 770–830 ft and 890–900 ft indicate fine-grained clastic deposition, while limestone at 830–860 ft and 900–920 ft points to intermittent carbonate buildup.

900–1030 ft

From 900–980 ft, alternating limestone and unidentified lithologies persist. At 1030–1050 ft, a light grey shale unit occurs, representing deposition under relatively oxygen-rich but still low-energy conditions.

1050–1200 ft

The section contains limestone at 1050–1060 ft, followed by unidentified lithologies toward 1200 ft. The persistence of limestone suggests continued conditions favouring carbonate sedimentation.

1200–1290 ft

A clear alternation between light grey shale (1200–1220 ft), unidentified lithology, and dark grey shale (1270–1290 ft) occurs. The colour variation reflects subtle changes in organic content, water depth, and bottom-water oxygenation.

1290–1390 ft

The interval consists mostly of grey shale, with occasional unidentified lithologies. These shale units indicate sustained fine-grained sedimentation, characteristic of quiet offshore or semi-restricted environments.

1390–1520 ft

Shale continues to dominate, including silty shale at intervals such as 1500–1520 ft. The presence of silt suggests slightly higher energy conditions compared to earlier, more clay-rich shales.

1520–1630 ft

Dark grey shale occurs at 1570–1580 ft, while silty shale appears again around 1600–1610 ft. Unidentified lithologies occupy intervening depths. Recurrent dark grey shale hints at periodic anoxic or dysoxic bottom conditions.

1630–1760 ft

The lithology alternates between silty shale, dark grey shale, and several intervals of unidentified lithology. These sediment types suggest fluctuating conditions between quiet-water sedimentation and episodic input of slightly coarser material.

1760–1900 ft

This lower section contains repeated dark grey shale and silty shale units, including significant shale thickness from 1670–1690 ft and 1880–1900 ft. The dominance of shale indicates persistent fine-grained deposition until the deepest logged interval.

General Interpretation

1. Shale Dominance: The well is predominately shale-rich, showing long periods of quiet, low-energy deposition. Dark grey shales indicate intervals of higher organic content and reduced oxygenation.
2. Limestone Intervals: Recurrent limestone beds point to episodes where carbonate production increased, likely due to clearer waters or shallower conditions. These may mark brief environmental shifts or transgressive events.
3. Unidentified Lithologies: The missing section represent poorly preserved lithologies, transitional beds, or sediments whose textures were not recognizable in the available log.
4. Environmental Setting: The entire sequence reflects a marine to marginal marine depositional environment, fluctuating between quiet-water shale deposition and brief carbonate-forming episodes.

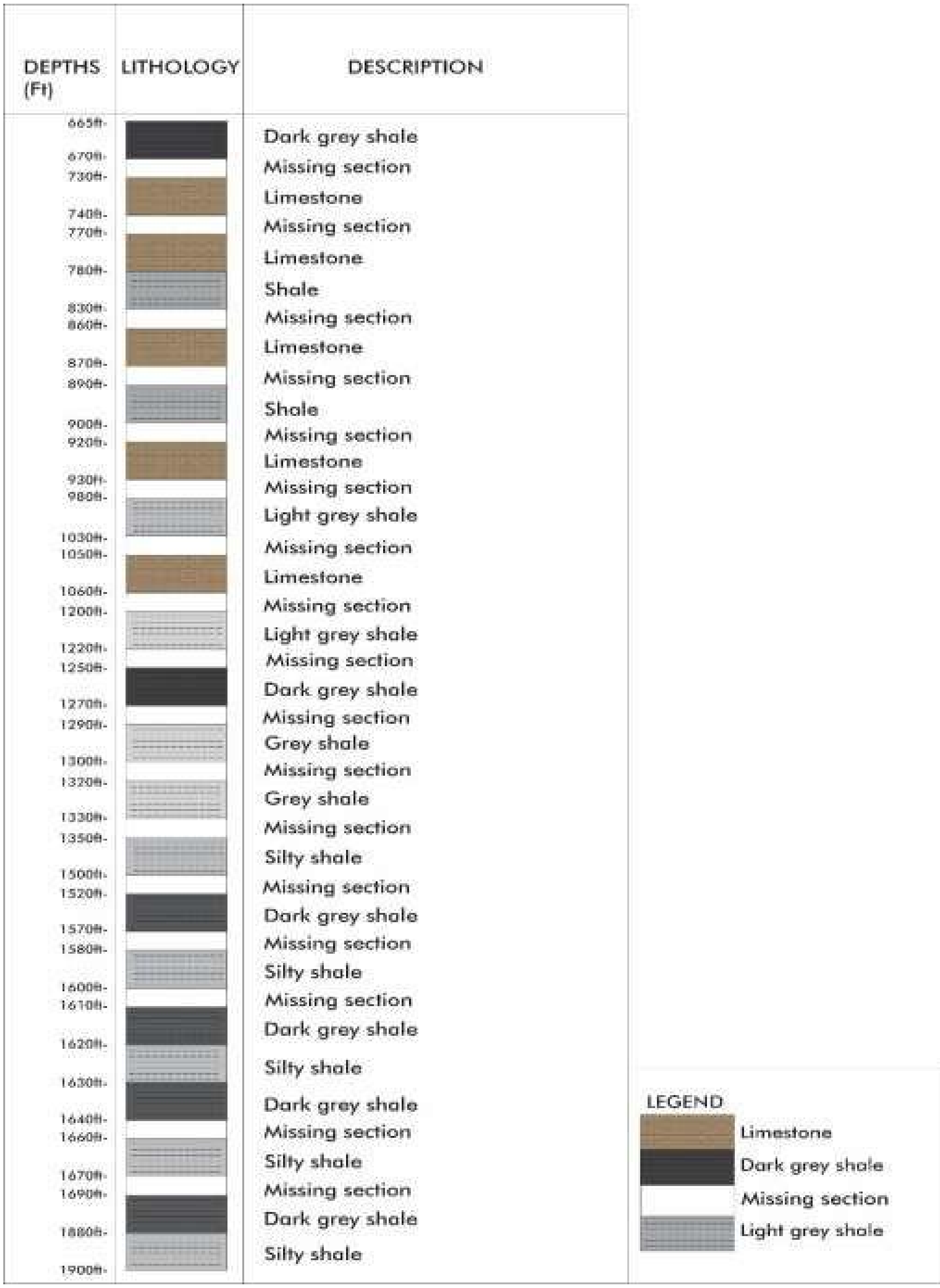


Figure 4.2: Lithologic description of Araromi well

4.3 Distribution of Palynomorphs with Depth

The vertical distribution of palynomorphs across the analyzed interval (830–1,880 ft) is illustrated in **Figure 4.1 (Range Chart)**. The chart reveals clear changes in species composition with depth, reflecting stratigraphic and environmental variations.

i. Lower interval (1,880–1,550 ft): Characterized by abundant *Proxapertites operculatus*, *Zonocostites ramonae*, *Retidiporites magdalenensis*, and *Palaeocystodinium australinum*. The high frequency of marine dinoflagellates, coupled with subordinate terrestrial pollen, suggests deposition under nearshore to shallow marine conditions during a major transgressive phase.
ii. Middle interval (1,550–1,200 ft): Shows a mix of marine and continental taxa. Terrestrial elements such as *Grimsdalea polygonalis* and *Mauritiidites franciscoi* become more common, while dinoflagellates decrease in abundance. This interval represents a transitional phase, possibly a marginal marine or delta-front environment.
iii. Upper interval (1,200–830 ft): Dominated by *Zonocostites ramonae* and *Laevigatosporites spp.*, with rare dinoflagellates. The predominance of mangrove and swamp pollen indicates regression and increased continental influence toward the end of deposition.

Preservation is generally good in the lower and middle intervals, while upper samples show reduced palynomorph yield and greater evidence of oxidation, likely due to shallower burial and post-depositional alteration.

TABLE 4.1: ARAROMI-1 PALY DATA

S/No	DEPTH	PALYNOMORPHS	COUNT
1	830	Inaperturopollenites sp.	4
		Araucariacites sp.	5
		Spiniferites sp,	2
		? Oligosphaeridium sp.	1
		Leoisphaeridia sp.	2
		Homotryblium sp.	1
		Dinocysts indeterminate	3
		Monosulcites sp.	2
		Diatom frustules	5
		Cordosphaeridium sp.	1
		Laevigatosporites sp.	2
		Monocolpites marginatus	2
		Cleistosphaeridium sp,	1
		Cyathidites minor	2
		Gleicheniidites senonicus	1
2	1030	Cyathidites minor	2
		Diatom frustules	7
		Proxapertites cursus	2
		Laevigatosporites sp.	6
		Monoporites annulatus	3
		Inaperturate pollen	3
		Palaeocystodinium australinium	5
		Cyathidites sp.	1
		Retimonocolpites sp.	1
		Proxapertites operculatus	2
		Leoisphaeridia sp.	1
3	1060	Monoporites annulatus	3

		Inaperturate pollen	13
		Araucariacites sp.	2
		Leoisphaeridia sp.	2
		Inaperturopollenites sp.	14
		Selenopemphix nephroides	1
		Monosulcites sp.	2
		Palaeocystodinium sp.	1
		Tricolporopollenites sp.	1
		? Pachydermites diederixi	1
		Cyathidites minor	1
		Dinocysts indeterminate	2
		Tasmanites sp.	1
		Diatom frustules	3
		Spiniferites sp.	1
4	1330	Palaeocystodinium australinium	2
		Retitricolporites irregularis	3
		Phelodinium sp.	1
		Cyathidites minor	6
		Cleistosphaeridium sp.	1
		Leptodinium sp.	3
		Dinocysts indeterminate	1
		Diatom frustules	4
		Laevigatosporites sp.	2
		Selenopemphix nephroides	1
		Araucariacites sp.	2
		Inaperturopollenites sp.	1
5	1480	Hystrichosphaeridium sp.	1
		Achomosphaera sp.	2
		Senegalinium sp.	2

		Dinocysts indeterminate	3
		Cerodinium diebelii	2
		Canningia sp.	1
		Subtilisphaera sp.	2
		Inaperturopollenites sp.	1
		Isabelidinium sp.	1
		Leptodinium sp.	1
		Cordosphaeridium sp.	1
6	1620	Leoisphaeridia sp.	3
		Diatom frustules	8
		Subtilisphaera sp.	4
		Dinocysts indeterminate	7
		Apteodinium sp.	1
		Senegalinium sp.	4
		Spiniferites sp.	2
		Canningia sp.	1
		Achomosphaera sp.	8
		Tricolporopollenites sp.	1
		Inaperturopollenites sp.	2
		Monosulcites sp.	1
		Cyathidites minor	2
		Laevigatosporites sp.	4
		Systematophora sp.	1
		Monoporites annulatus	2
		Selenopemphix nephroides	1
		Heterosphaeridium sp.	2
		Cerodinium diebelii	6
		Cleistosphaeridium sp.	1
		Callatosphaeridium sp.	1

		Spiniferites sp.	1
7	1670	Subtilisphaera sp.	5
		Senegalinium sp.	11
		Cerodinium diebelii	6
		Palaeocystodinium australinium	12
		Leoisphaeridia sp.	2
		Tricolporopollenites sp.	2
		Phelodinium sp.	1
		Dinocysts indeterminate	4
		Achomosphaera sp.	2
		Odontochitina sp.	1
		Palaeocystodinium sp.	3
		Inaperturopollenites sp.	1
		Spirosyncolpites bruni	2
		Spinizonocolpites sp.	1
8	1800	Senegalinium sp.	36
		Cometodinium sp.	2
		Dinocysts indeterminate	12
		Subtilisphaera sp.	43
		Cerodinium diebelii	21
		Palaeocystodinium australinium	3
		Leptodinium sp.	2
		Phelodinium sp.	4
		? Lejeunecysta sp.	4
		Leoisphaeridia sp.	6
		Cerodinium depressum	2
		Cerodinium sp.	4
		Apectodinium sp.	1
		Palaeoperidinium pyrophorum	1

		Gonyaulacysta sp.	1
		Monosulcites sp.	3
		?Thalassiphora sp.	1
9	1860	Palaeocystodinium golzowense	8
		Senegalinium sp.	11
		Palaeocystodinium australinium	25
		Dinogymnium sp.	2
		Leoisphaeridia sp.	2
		Subtilisphaera sp.	13
		Cerodinium sp.	2
		Phelodinium sp.	3
		Monosulcites sp.	1
10	1880	Cyathidites minor	4
		Leoisphaeridia sp.	1
		Monosulcites sp.	2
		Araucariacites sp.	6
		Palaeocystodinium australinium	12
		Tricolporopollenites sp.	2
		Senegalinium sp.	4
		Inaperturopollenites sp.	2
		Longapertites sp.	2
		Lingulodinium machaerophorum	1
		Dinocysts indeterminate	5
		Deflandrea sp.	1
		Palaeocystodinium golzowense	7
		Subtilisphaera sp.	11
		Homotryblium sp.	1
		Cerodinium diebelii	2
		Achomosphaera sp.	1

		Apectodinium sp.	1
		Phelodinium sp.	2
		? Pachydermites diederixi	1
		Pollen indeterminate	5
		Lejeunecysta fallax	1
		Cicatricosisporites sp.	1
		Cribroperidinium sp.	1
		Isabelidinium sp.	1
		Cerodinium sp.	1
		Selenopemphix nephroides	1
		Systematophora sp.	1
		Canningia sp.	13
		Trichodinium sp.	2

4.4 Palynostratigraphic Zonation and Age Determination

Based on the distribution and stratigraphic occurrence of diagnostic species, the Araromi-2 Well sequence is divided into a single composite palynostratigraphic zone corresponding to the Palaeocystodinium australinum – Cyathidites minor Assemblage Zone (sensu Salard-Cheboldaeff, 1990).

Zone Characteristics:

- **Key taxa:** *Palaeocystodinium australinum*, *Cyathidites minor*, *Proxapertites operculatus*, *Retidiporites magdalenensis*, *Zonocostites ramonae*.
- **Age assignment:** Late Maastrichtian to Early Paleocene (Danian).
- **Correlation:** Equivalent to the *Echitriporites trianguliformis – Proxapertites operculatus Zone* of southwestern Nigeria (Okosun & Alkali, 2012) and to Zone VI of Evamy et al. (1978).

The co-occurrence of *Proxapertites operculatus* and *Retidiporites magdalenensis* strongly supports a Paleocene (Danian) age. The decline of Cretaceous dinoflagellates and the absence of typical Late Eocene species further confirm this temporal assignment.

Thus, the studied interval in the Araromi-2 Well represents sedimentation across the Cretaceous–Tertiary transition, corresponding to the upper part of the Araromi Formation.

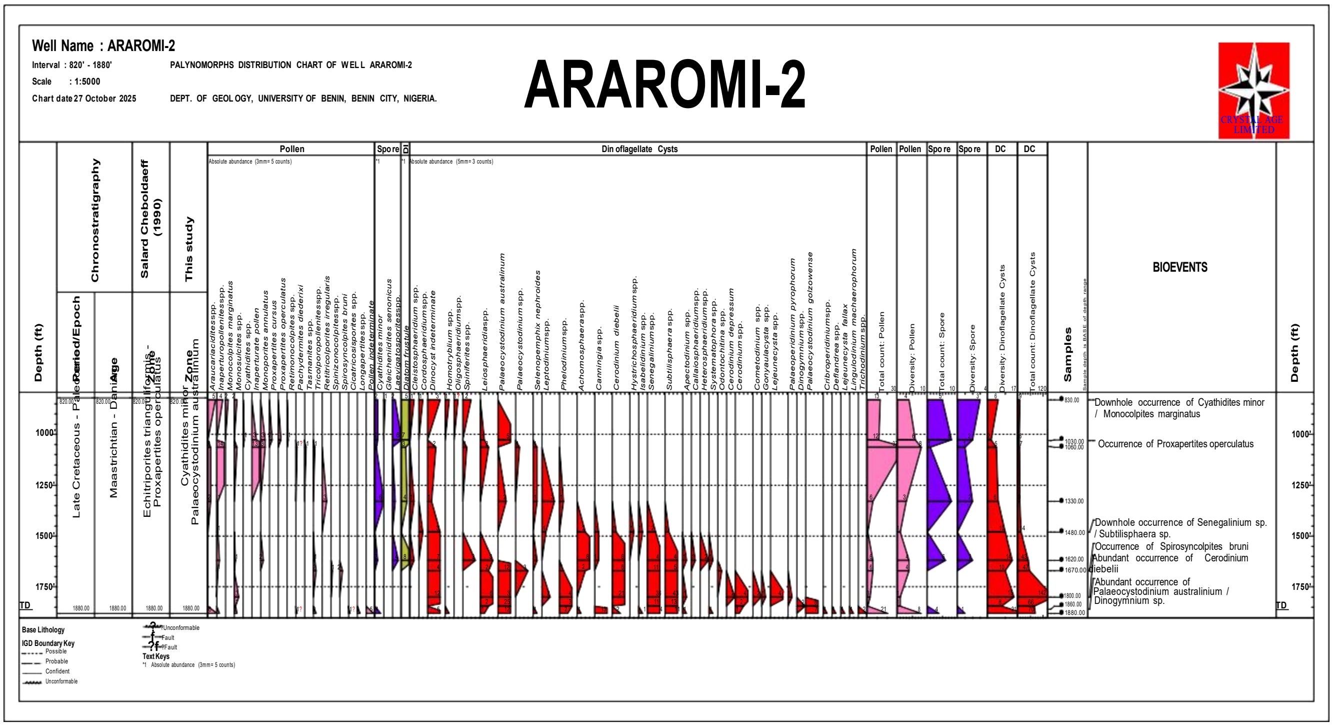


Figure 4.3: Composite palyno-stratigraphic zonation chart for Araromi-2 Well.

4.5 Palynofacies Results

The palynofacies analysis of the Araromi-2 Well provides further evidence for the depositional environment. The organic residue in most samples consists predominantly of amorphous organic matter (AOM), phytoclasts, and palynomorphs in varying proportions.

i. Lower interval (1,880–1,550 ft): AOM constitutes about 60–70% of the organic residue, with minor woody fragments and well-preserved marine palynomorphs. Such assemblages are typical of low-energy, anoxic marine settings where organic matter preservation is high.
ii. Middle interval (1,550–1,200 ft): Contains nearly equal proportions of AOM and phytoclasts. The presence of both marine dinoflagellates and land-derived woody debris suggests a marginal marine setting influenced by terrestrial input.
iii. Upper interval (1,200–830 ft): Dominated by coarse phytoclasts (60–80%), with reduced AOM and sparse marine elements. The composition indicates deposition in a proximal deltaic or lagoonal environment under higher oxygenation conditions.

Overall, the vertical variation in organic matter type and palynomorph abundance indicates a regressive sequence, transitioning from shallow marine to marginal marine and finally to continental deposition.

4.6 Paleoenvironmental Interpretation

Integration of the palynological and palynofacies data indicates that the Araromi-2 Well sediments were deposited in environments ranging from shallow marine to coastal deltaic settings.

The dominance of *Proxapertites operculatus*, *Zonocostites ramonae*, and *Laevigatosporites spp.* reflects extensive mangrove and swamp vegetation bordering the coastline, while the occurrence of marine dinoflagellate cysts such as *Palaeocystodinium australinum* points to periodic marine incursions.

The abundance of AOM in the lower interval indicates deposition under reducing (anoxic) conditions, characteristic of an offshore marine environment. Upsection, the increasing proportion of woody phytoclasts and terrestrial pollen suggests progressive shallowing and increased fluvial influence.

This interpretation aligns with the depositional model of the Araromi Formation, which represents the terminal transgressive phase of the Late Cretaceous followed by regression into Paleocene nearshore environments.

4.7 Discussion

The palynological assemblage of the Araromi-2 Well provides valuable insights into the biostratigraphic and paleoenvironmental evolution of the Dahomey Basin during the Late Maastrichtian to Early Paleocene.

The identified *Palaeocystodinium australinum – Cyathidites minor Zone* corroborates the findings of Okosun and Alkali (2012), who recognized similar assemblages in the eastern Dahomey Basin and assigned them a Paleocene age. Likewise, the abundance of *Zonocostites ramonae* and *Grimsdalea polygonalis* supports earlier interpretations by Durugbo and Aroyewun (2012) that the Araromi Formation was deposited under alternating marine and terrestrial influences.

The transition from marine-dominated facies at depth to terrestrial dominance upward reflects a regressive depositional sequence, consistent with the global sea-level fall across the Cretaceous–Tertiary boundary (Bolaji et al., 2020; Agharanya et al., 2022).

In comparison to other formations within the Dahomey Basin, such as the Ewekoro and Akinbo Formations, the Araromi interval exhibits a higher abundance of terrestrial palynomorphs and reduced carbonate content, indicating deposition closer to the shoreline. The presence of well-preserved AOM further suggests favorable conditions for hydrocarbon source rock development in the lower sections.

Overall, the integration of palynological, palynofacies, and stratigraphic data demonstrates that the Araromi Formation records the transition from a Late Cretaceous shallow marine system to an Early Paleocene marginal marine–deltaic environment, marking a key phase in the post-rift evolution of the Dahomey Basin.

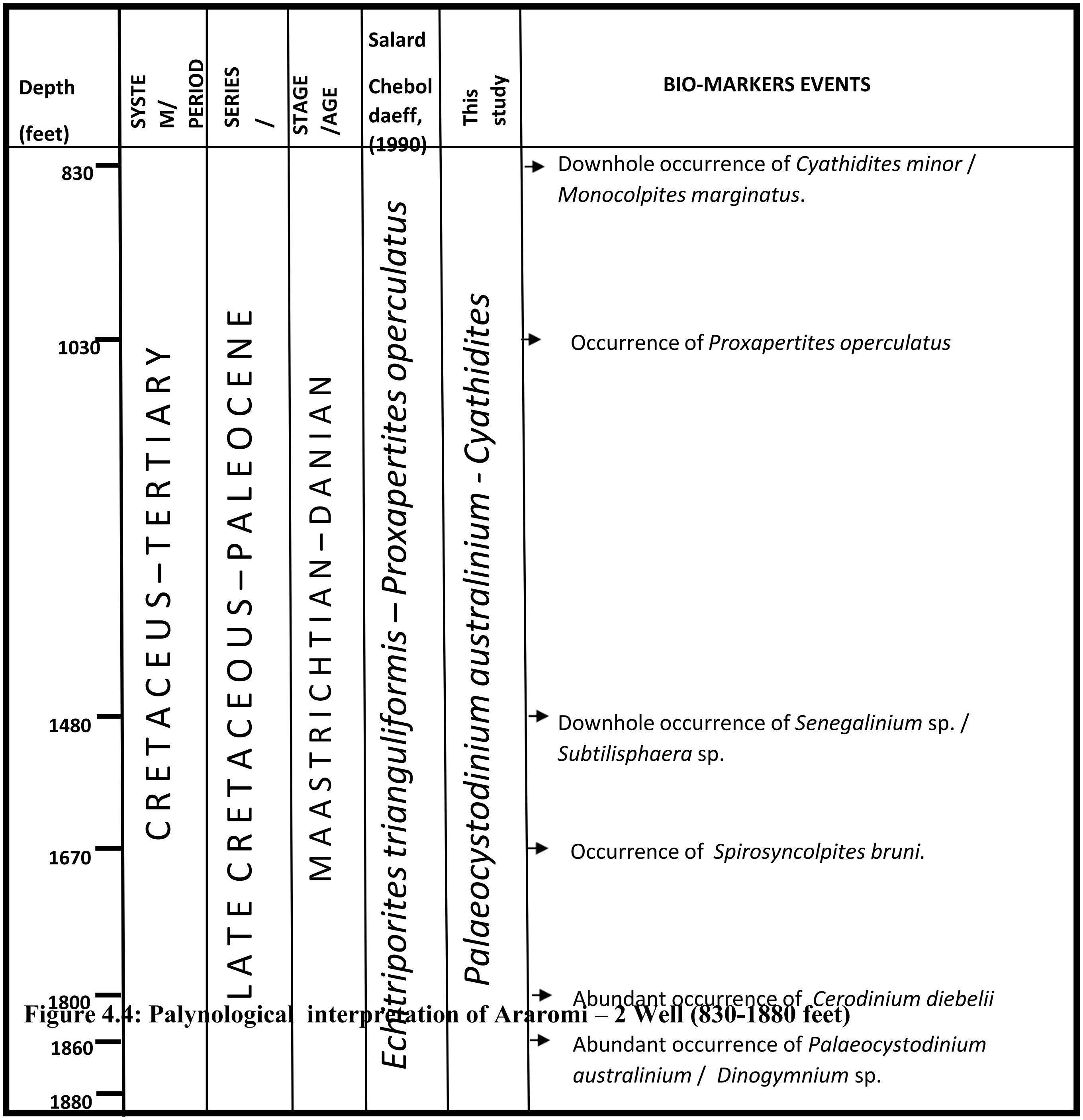


Figure 4.4: Palynological interpretation of Araromi – 2 Well (830-1880 feet)

CHAPTER FIVE

5.1 Conclusion

This study presents the results of a detailed palynological analysis ofditch cutting samples obtained from the Araromi-2 Well, located in the eastern Dahomey Basin, southwestern Nigeria. The analyzed samples, collected between the depths of 830 ft and 1,880 ft, represent a lithologic succession dominated by dark grey shales, siltstones, and fine-grained sandstones, characteristic of the upper Araromi Formation.

Standard palynological preparation methods were employed, including acid digestion using hydrochloric and hydrofluoric acids, heavy-liquid separation, sieving, and microscopic identification. The palynomorph recovery was generally moderate to rich comprising more than forty (40) identifiable palynomorph taxa, including both terrestrial and marine forms, with good preservation in the lower and middle intervals, and slight oxidation observed in the uppersections.

A diverse assemblage of pollen, spores, and marine dinoflagellate cysts was recovered, representing both terrestrial and marine origins. Diagnostic taxa such as *Proxapertites operculatus*, *Zonocostites ramonae*, *Retidiporites magdalenensis*, *Palaeocystodinium australinium*, and *Cyathidites minor* were identified. Based on the stratigraphic distribution of these key species, the studied interval was assigned to the Palaeocystodinium australinium – Cyathidites minor Assemblage Zone, corresponding to a Late Maastrichtian to Early Paleocene (Danian) age.

Palynofacies analysis revealed a vertical variation in organic matter composition. The lower interval (1,880–1,550 ft) is dominated by amorphous organic matter (AOM), suggesting deposition in a quiet, reducing shallow marine setting. The middle interval (1,550–1,200 ft) shows mixed AOM and phytoclast content, indicating marginal marine to nearshore conditions, while the upper interval (1,200–830 ft) is dominated by woody phytoclasts, reflecting increased continental influence in a deltaic or coastal plain environment.

The integration of palynological and palynofacies results indicates a regressive depositional sequence, transitioning from shallow marine to marginal marine and deltaic settings. This study therefore refines the biostratigraphic framework of the Araromi Formation and provides additional insight into the depositional and paleoenvironmental history of the Dahomey Basin during the Late Cretaceous to early Tertiary period.

5.2 Recommendations

1. **Expanded Sampling and Integration:**

   Future research should involve the analysis of additional wells and outcrop sections within the Dahomey Basin to establish basin-wide palynostratigraphic correlations. Integrating palynological data with sedimentological, geochemical, and geophysical datasets will yield a more complete understanding of basin evolution.

2. **High-Resolution Zonation:**

   A finer subdivision of the Paleocene interval using quantitative biozonation methods is recommended to improve stratigraphic precision and enhance the correlation of offshore and onshore sequences.

3. **Source Rock Assessment:**

   Given the high proportion of AOM in some intervals, detailed organic geochemical studies (TOC, Rock-Eval, biomarker analysis) are encouraged to evaluate the hydrocarbon generation potential of the Araromi Formation.

4. **Digital Archiving of Palynomorph Data:**

   Establishing a standardized digital database of palynological occurrences from Nigerian basins would serve as a valuable reference for future micropaleontological and exploration studies.

5. **Environmental Reconstruction Studies:**

   Further paleoecological and palynofacies modeling should be conducted to reconstruct climatic and vegetation patterns during the Late Cretaceous–Paleocene transition in West Africa.

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