TITLE PAGE

SEDIMENTOLOGICAL ANALYSIS OF SANDSTONE UNITS IN THE LAFIAGI AREA, NORTHERN BIDA BASIN, KWARA STATE, NIGERIA

BY

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NATIONAL DIPLOMA IN MINERALS AND PETROLEUM RESOURCES ENGINEERING TECHNOLOGY

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CERTIFICATION

This is to certify that this research work titled "**SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENT OF SANDSTONES EXPOSED AT LAFIAGI, NORTHERN BIDA BASIN, KWARA STATE, NORTH CENTRAL, NIGERIA**" Was carried out by Abdulazeez Ayokomi **OWONIKOKO** with the matriculation number **ND/23/MPE/PT/0019** and has been read and approved as meeting part of the requirements of the award of National Diploma (ND) in Mineral and Petroleum Resources Engineering Technology.

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DEDICATION

This project is wholeheartedly dedicated to Almighty Allah, the Most Gracious and Most Merciful, for giving me the strength, wisdom, and good health to successfully complete this work.

It is also dedicated to my beloved parents, whose support, prayers, and encouragement have been the backbone of my academic journey.

To my siblings and friends, thank you for your patience, motivation, and unwavering belief in me throughout the course of this study.

ACKNOWLEDGEMENTS

All praise and gratitude are due to Almighty Allah for granting me the strength, wisdom, and perseverance to carry out and complete this project successfully.

I sincerely appreciate the guidance, encouragement, and academic support of my supervisor, Mr. Raji, whose constructive feedback and commitment were instrumental throughout the course of this research.

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May Almighty Allah reward you all abundantly.

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ABSTRACT

This project presents a detailed sedimentological study of sandstone units exposed in the Lafiagi area of the Northern Bida Basin, Nigeria. The aim was to reconstruct the depositional environment and evaluate the reservoir potential of the sandstones through integrated field and laboratory investigations. Fieldwork involved lithological logging, structural measurements, and sample collection from selected outcrops. Laboratory analyses included thin section petrography to determine mineralogical composition and textural attributes.

The field observations revealed coarse- to medium-grained ferruginous sandstones, characterized by cross-bedding, ripple marks, and planar stratification—indicating deposition in a high-energy fluvial system. Petrographic analysis of selected samples (LF1, LF3, LF5, and LF6) showed a high quartz content (>92%), comprising both monocrystalline and polycrystalline varieties. These sandstones are classified as compositionally and texturally supermature, suggesting a metamorphic provenance, likely derived from the Nigerian Basement Complex.

The depositional environment is interpreted as a braided to meandering river system operating under oxidizing, subaerial conditions during the Late Cretaceous. The high degree of maturity and the dominance of quartz

indicate that the Lafiagi sandstones possess favorable reservoir qualities such as porosity and permeability, which are essential for potential hydrocarbon accumulation.

This study contributes to the understanding of sediment dispersal and basin evolution in the Northern Bida Basin and provides useful insights for petroleum exploration in the region.

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Sedimentary rocks, particularly sandstones, provide crucial records of past depositional environments and tectonic settings. Understanding their physical and mineralogical characteristics helps geologists reconstruct paleoenvironments and evaluate potential for groundwater, petroleum, or engineering applications. In sedimentology, two essential tools for analyzing sandstone bodies are lithological description and thin section petrography.

Lithological description involves the observation and documentation of rock characteristics in the field, including grain texture, color, sedimentary structures, cementation, and bed geometry. These features provide immediate clues to depositional processes and sediment transport history. Thin section analysis complements this by revealing mineral composition, grain contact relationships, and post-depositional changes under a microscope.

The Northern Bida Basin, particularly the Lafiagi area, hosts extensive exposures of Cretaceous sandstones that have not been adequately studied in terms of their lithological and petrographic attributes. Many previous studies have focused on the broader stratigraphy and regional geology, leaving a gap in detailed sedimentological analysis of the outcrop-scale sandstone units.

This study aims to fill that gap by integrating lithological field observations with petrographic analysis of representative sandstone samples from the Lafiagi area. This approach enables the reconstruction of depositional settings, evaluation of sediment maturity, and interpretation of provenance, all of which contribute to a better understanding of the basin's geological history.

1.2 Statement of the Research Problem

Despite increasing interest in the stratigraphy and tectonic evolution of the Bida Basin, detailed sedimentological studies focusing on the physical and mineralogical characteristics of its sandstone units remain limited, especially in the Lafiagi area. Most existing works provide generalized lithostratigraphic frameworks or geochemical analyses, often overlooking the integration of field-based lithological logging and microscopic petrographic assessment.

A major challenge in understanding the depositional history and reservoir potential of these sandstones lies in the absence of systematic studies that combine lithological observations—such as grain texture, sedimentary structures, and cementation—with thin section petrography to determine textural and compositional maturity. Without this integrated approach, interpretations of provenance, depositional environments, and post-depositional processes remain incomplete and largely speculative.

This gap calls for a focused investigation using both macroscopic field techniques and microscopic mineralogical analysis to enhance understanding of the sediment dynamics and diagenetic history of the sandstone units in the northern Bida Basin.

1.3 Aim and Objectives

The aim of this study is to carry out a detailed sedimentological analysis of sandstone units in the Lafiagi area of the Northern Bida Basin, with emphasis on their lithological and petrographic characteristics in order to interpret their depositional environment, provenance, and reservoir potential.

To achieve this aim, the following objectives were set:

1. To describe and document the lithological characteristics of exposed sandstone outcrops in the study area, including texture, color, bedding features, sedimentary structures, and cementation.
2. To conduct thin section petrographic analysis of representative sandstone samples to determine their mineral composition, grain types, maturity, and diagenetic features.
3. To interpret the provenance and depositional environment of the sandstone units based on integrated field and petrographic data.
4. To contribute to the broader understanding of the sedimentary framework of the Northern Bida Basin through detailed outcrop-based sedimentological interpretation.

1.4 Significance of the Study

This study contributes to the sedimentological understanding of the Lafiagi area in the Northern Bida Basin by focusing on the lithological and petrographic characteristics of its sandstone units. Through detailed field logging and thin section analysis, the study provides insight into the depositional processes, provenance, and post-depositional modifications that have influenced these rocks.

The research is significant in several ways:

- It offers a clearer understanding of the internal composition and maturity of the sandstones through microscopic mineral identification and textural observations.
- It emphasizes the importance of observable field features such as bedding style, sedimentary structures, and cementation in interpreting depositional environments.
- It fills a gap in the existing literature by integrating macroscopic lithological data with microscopic petrographic evidence, which is often lacking in studies on the Northern Bida Basin.
- The findings may have practical implications in evaluating the reservoir potential of these sandstones for groundwater or hydrocarbon accumulation, particularly given their compositional maturity and possible porosity.

By enhancing knowledge of the Lafiagi sandstone units, the study supports future academic research and resource exploration within the Bida Basin.

1.5 Scope and Limitation of the Study

This study is focused on the sedimentological analysis of sandstone units exposed in the Lafiagi area, located within the Northern Bida Basin, Nigeria. The scope covers field-based lithological description of outcrops, including texture, color, sedimentary structures, and cementation patterns, as well as laboratory-based thin section petrography to identify mineral composition, grain characteristics, and textural maturity.

The study is limited to surface exposures of sandstone in selected accessible locations within the Lafiagi region. Subsurface data such as core samples or borehole logs were not available and therefore not included. Additionally, quantitative laboratory analyses such as X-ray diffraction (XRD), scanning electron microscopy (SEM), or geochemical tests were beyond the scope of this work due to resource constraints.

Despite these limitations, the integration of field observations and petrographic analysis provides meaningful insights into the depositional environment, provenance, and potential reservoir characteristics of the studied sandstone units.

1.6 Location of the Study Area

The study area is located in Lafiagi, within Edu Local Government Area of Kwara State, North-Central Nigeria. It lies within the Northern Bida Basin, which is part of the broader Nigerian Inland Basin system. Lafiagi is geographically situated between latitudes 9°00′N and 9°10′N and longitudes 5°30′E and 5°40′E, occupying a portion of the Cretaceous sedimentary sequence of the Bida Basin.

The area is characterized by extensive sandstone exposures along road cuts, stream channels, and eroded slopes. These outcrops display various sedimentary structures such as cross-bedding, ripple marks, and planar stratification, which make it suitable for detailed sedimentological studies. The terrain is moderately undulating, with vegetation consisting of sparse savanna grassland and shrubs.

Accessibility to most of the outcrops is fairly good, especially along the Lafiagi–Bacita road and other rural tracks. The presence of seasonal streams and minor ridges further aids the observation of geological features. Lafiagi and its surrounding areas fall under the humid tropical climatic zone with distinct wet and dry seasons, which influence weathering and erosion processes in the region.

The strategic location of Lafiagi within the Northern Bida Basin makes it an ideal area to study sandstone units and understand their depositional environment, provenance, and diagenetic evolution.

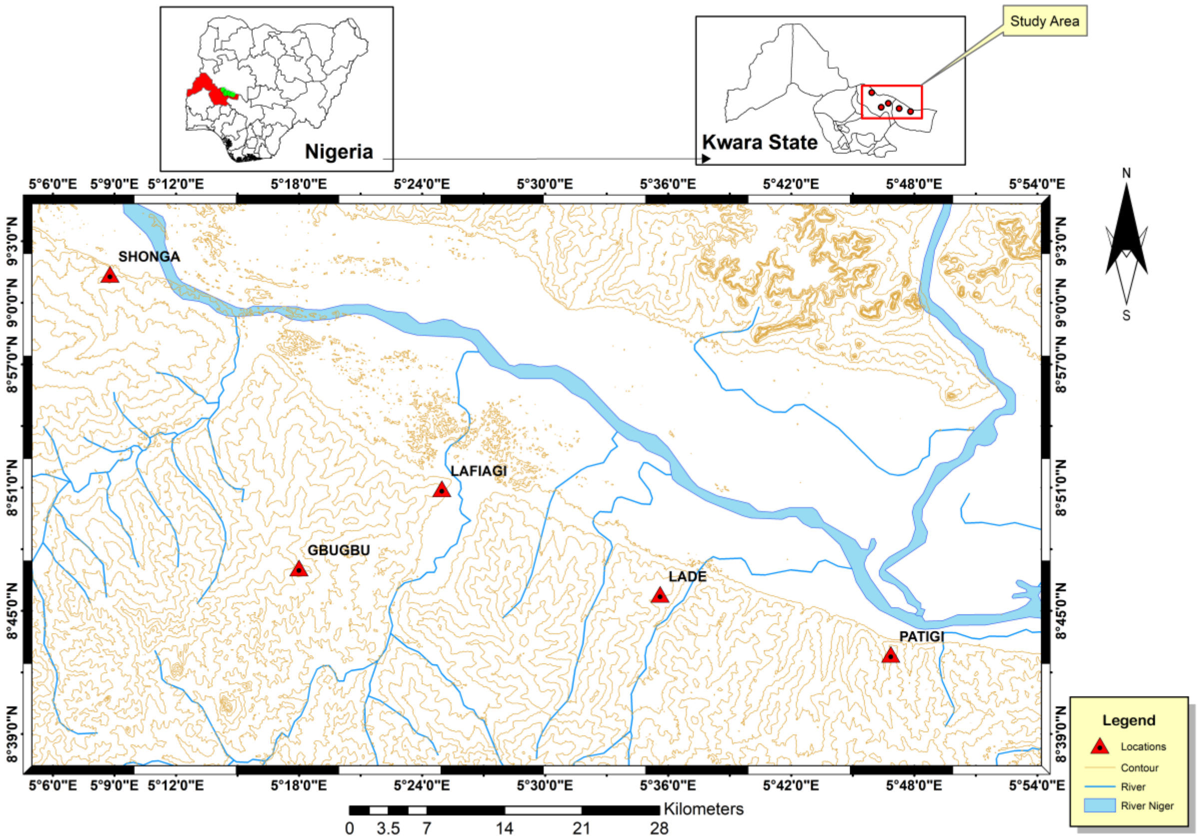


Figure 1.1: Map Showing the study area

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of Previous Works

Numerous studies have been conducted on the Bida Basin to understand its stratigraphy, sedimentology, depositional environments, and reservoir potential. These works have laid the foundation for interpreting the sedimentary processes and tectonic evolution of the basin. Below is a review of selected notable studies, with emphasis on their findings as presented in the abstracts.

Akande eto al., (2005) worked on "Paleoenvironments, organic richness, and maturity of the Maastrichtian Patti Formation, southern Bida Basin, Nigeria." This study examined the Patti Formation and revealed that the sediments were deposited in a fluvio-deltaic environment with good source rock potential. The authors emphasized the compositional maturity of the sandstone units and their reservoir characteristics.

Olabode (2014) studied “Sedimentary facies and depositional environments of the Bida Sandstone in the Bida Basin, Nigeria.” Olabode carried out facies analysis of the Bida Sandstone and identified three major facies: trough cross-bedded sandstone, planar cross-bedded sandstone, and bioturbated mudstones. The study interpreted a fluvial depositional setting with periodic flooding events.

Nwajide (2013) worked on “Geology of Nigeria’s Sedimentary Basins.” This comprehensive book includes a detailed description of the Bida Basin, classifying it as an intracratonic basin formed during the Late Cretaceous. The author discussed the sandstone-dominated successions and their tectono-sedimentary significance.

Musa and Akinbode (2012) carried out “Petrographic and granulometric characteristics of the Bida Sandstone, central Nigeria.” Although grain-size analysis was applied in this study, the petrographic component revealed dominance of quartz arenites with subrounded to rounded grains. The sandstone was interpreted as compositionally mature, derived from metamorphic source rocks.

Ojo (2012) studied “Sedimentological and stratigraphic studies of the Cretaceous Bida Basin in central Nigeria.” This research identified fluvial to shallow marine transitions in parts of the basin and emphasized the role of tectonics in controlling sediment supply and accommodation space. The Bida Sandstone was described as well-sorted and quartz-rich.

Adeleye (1971) worked on “Stratigraphy and Sedimentation of the Bida Basin, Nigeria.” He provided the foundational stratigraphic framework for the Bida Basin. He identified several formations including the Bida Sandstone, highlighting their sedimentary characteristics, depositional environments, and structural controls.

Uzoegbu and Abimbola (2014) studied “Geochemical assessment of sandstone units in the Bida Basin.” This study focused on the geochemical composition of the sandstones, confirming a passive margin setting and mature mineralogical signature, consistent with tectonically stable sources.

Akinyemi et al. (2017) carried out research on “Textural and mineralogical studies of the Lokoja Formation sandstones, southern Bida Basin.” Thin section analysis showed high quartz content and low feldspar abundance, classifying the rocks as quartz arenites. The depositional environment was inferred to be fluvial, influenced by seasonal flooding.

Agagu (2009) worked on “Geology and sedimentation of inland basins in Nigeria.” Agagu discussed the Bida Basin in the context of other Nigerian inland basins and emphasized its clastic-dominated sequences and evolving depositional environments.

Salawu et al. (2015) worked on “Sedimentology and depositional environment of sandstones in the Bida Basin, Nigeria.” This study classified the studied sandstones as moderately sorted with cross-bedding and ripple marks, indicative of fluvial deposition under fluctuating flow regimes.

2.2 Geological Setting of the Bida Basin

The Bida Basin is an elongated intracratonic sedimentary basin located in central Nigeria. It forms part of the Nigerian Inland Basins and trends in a northeast–southwest direction, lying between the Basement Complex to the west and the Anambra Basin to the east. It is bounded by the Zungeru–Ifewara fault system to the northwest and merges with the Sokoto and Chad Basins further north.

Geologically, the Bida Basin evolved during the Late Cretaceous as a result of crustal flexure related to the separation of Africa and South America. It is filled with thick sequences of predominantly clastic sediments, including conglomerates, sandstones, siltstones, and mudstones, with minor interbedded limestones and ironstones. The sediments were sourced primarily from the adjacent Nigerian Basement Complex and deposited in a variety of continental settings including fluvial, deltaic, and lacustrine environments.

The basin is divided into the Northern and Southern Bida Basin. The Northern Bida Basin, where the present study area (Lafiagi) is located, is dominated by fluvial sandstone successions such as the Bida Sandstone, while the southern part contains formations like the Lokoja, Patti, and Agbaja Formations. Tectonic influences, climatic fluctuations, and sediment supply controlled the nature of sedimentation within the basin.

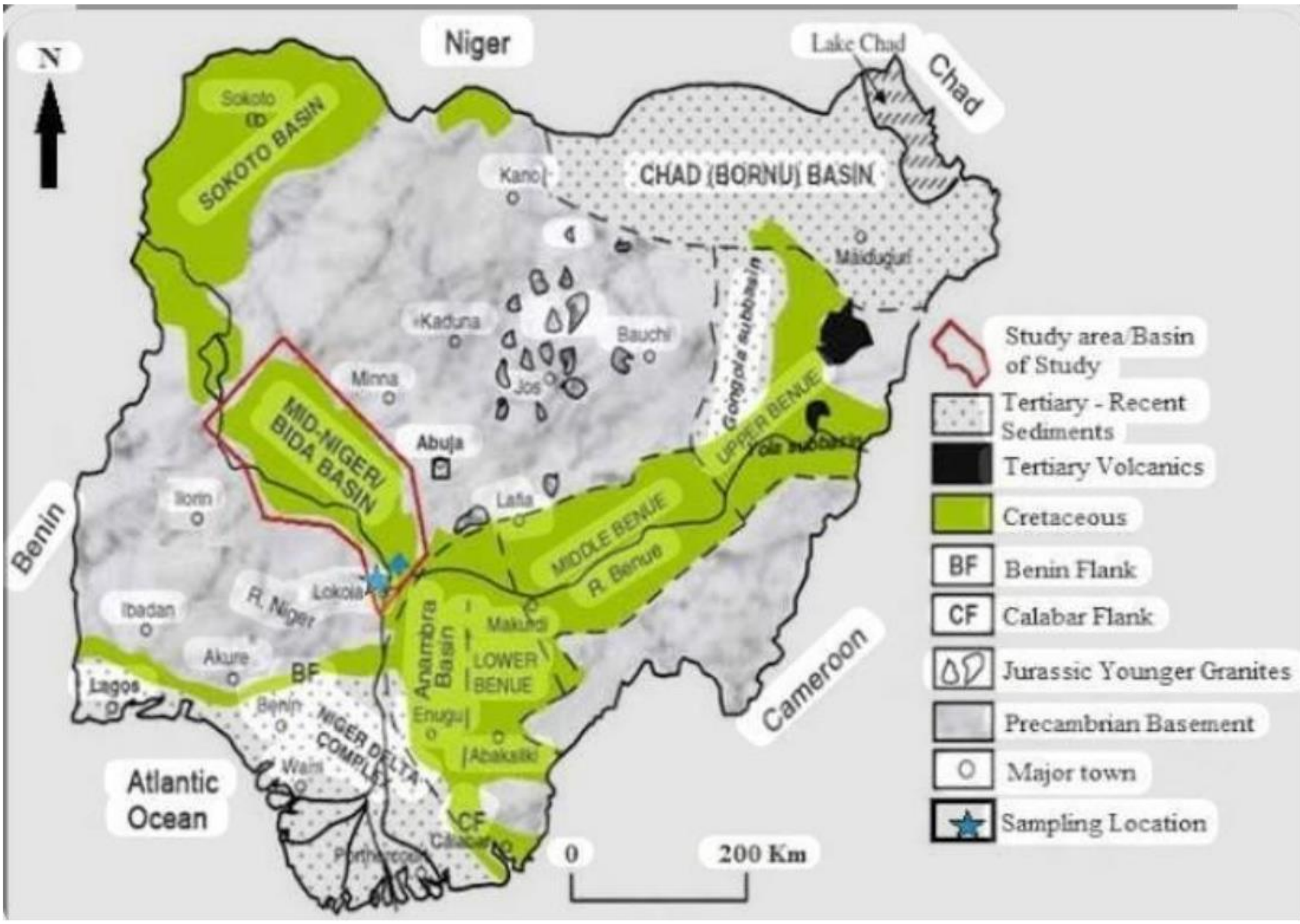


Figure 2.1: Geological Map of Nigeria showing the location of the Bida Basin."

2.3 Regional Stratigraphic Setting of the Bida Basin

The stratigraphy of the Bida Basin reflects a Late Cretaceous intracratonic sedimentary fill, comprising several lithostratigraphic units deposited in fluvial to deltaic environments. Stratigraphic studies have revealed variations in sediment thickness, facies development, and depositional styles between the northern and southern parts of the basin.

The southern Bida Basin is represented by three main formations:

- The Lokoja Formation, which consists predominantly of basal conglomerates and coarse-grained sandstones, interpreted as alluvial fan and braided stream deposits.

- The Patti Formation, composed of fine-grained sandstones, siltstones, and mudstones with interbeds of coal and carbonaceous shales, indicating a fluvio-deltaic to lacustrine environment.
- The Agbaja Formation, which consists largely of ferruginous sandstones, ironstones, and oolitic deposits, suggesting a shallow marine or coastal plain setting.

In contrast, the northern Bida Basin, where this study is focused (Lafiagi area), is dominated by:

- The Bida Sandstone Formation, comprising medium- to coarse-grained ferruginous sandstones, occasionally interbedded with siltstone and mudstone layers. It is characterized by fluvial sedimentary structures such as cross-bedding and ripple marks.

These formations are believed to be laterally equivalent to their southern counterparts but differ in grain size, sediment maturity, and depositional architecture due to regional tectonics and variations in sediment supply.

The stratigraphic succession of the Bida Basin shows evidence of progressive fining-upward sequences and reflects a transition from proximal to more distal depositional settings over time. Diagenetic processes such as ferruginous cementation, compaction, and recrystallization have significantly modified the original sediment fabrics.

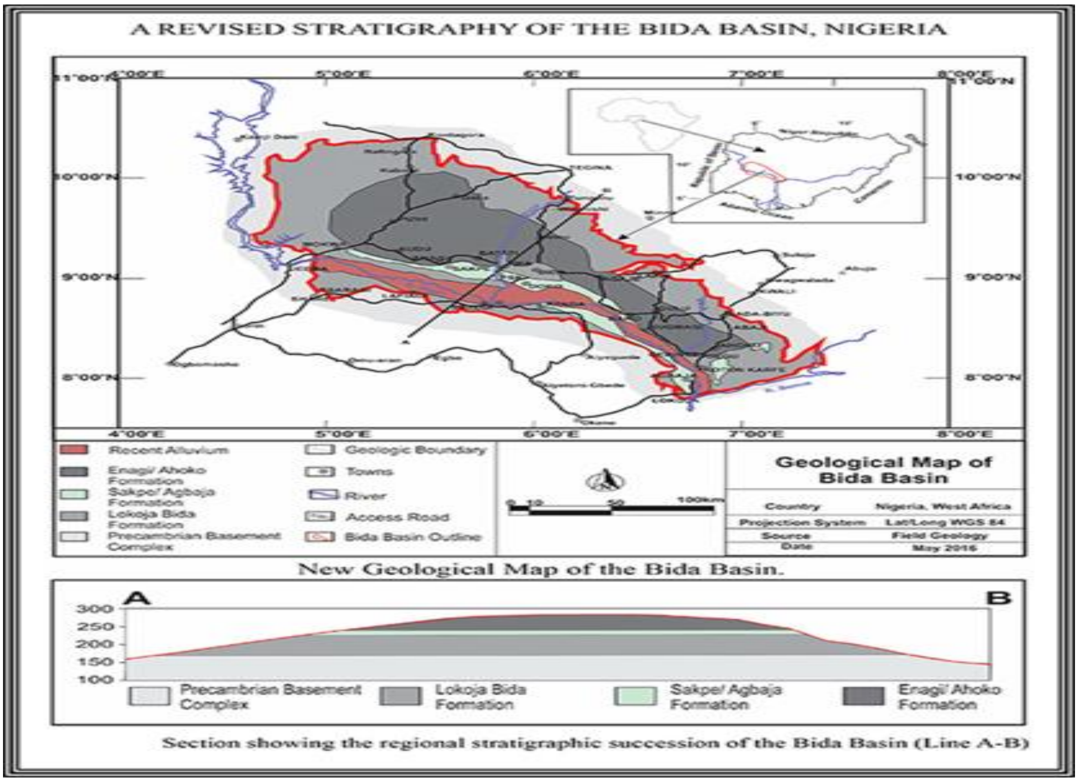


Figure 2.2: Stratigraphic map showing the distribution of lithostratigraphic units within the Bida Basin."

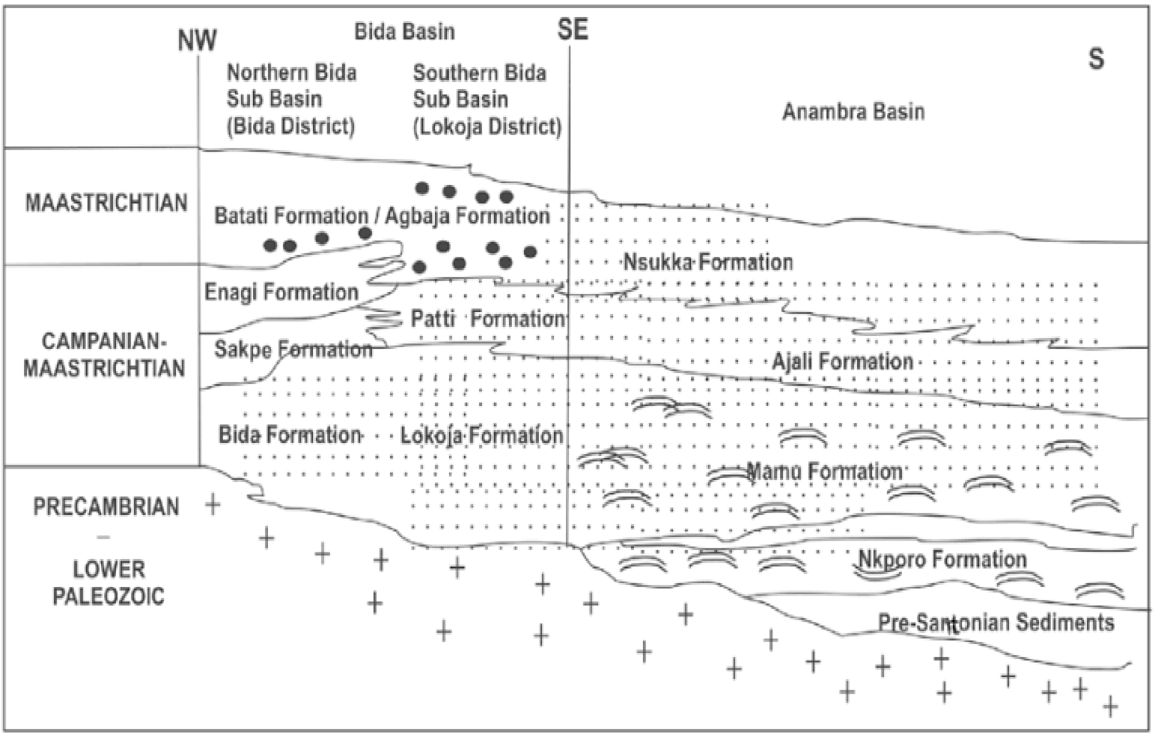


Figure 2.3: Generalized stratigraphic column of the Bida Basin showing vertical succession of formations."

2.4 Overview of Sedimentary Rocks and Classification

Sedimentary rocks are formed through the deposition, compaction, and cementation of sediments derived from pre-existing rocks or biological material. These rocks constitute approximately 75% of the Earth's surface and are of great geological importance due to the records they preserve of past environments, climatic changes, and biological evolution.

Sedimentary rocks are primarily classified based on their origin into three major categories:

1. Clastic Sedimentary Rocks:

   These are composed of fragments (clasts) of pre-existing rocks that have been transported, deposited, and lithified. Common examples include sandstone, shale, siltstone, and conglomerate. Clastic rocks are further classified by grain size, composition, and texture.

2. Chemical Sedimentary Rocks:

   These form from the precipitation of minerals out of solution, typically in marine environments. Examples include rock salt, gypsum, and chert. They often show crystalline textures and may be associated with evaporitic settings.

3. Biochemical (Organic) Sedimentary Rocks:

   These rocks are formed from the accumulation of biological materials such as shells, coral, or plant remains. Examples include limestone (from calcite-secreting organisms) and coal (from plant matter in swampy environments).

The classification of clastic sedimentary rocks like sandstone—relevant to this study—is typically based on texture (grain size, shape, sorting), composition (quartz, feldspar, lithic fragments), and cement type (siliceous, ferruginous, calcareous). Framework composition is particularly important in petrographic classification, as it helps in interpreting provenance and maturity.

Sandstones are often classified into the following categories based on mineral content:

- Quartz arenite: >90% quartz; very mature.
- Arkose: >25% feldspar; less mature.
- Litharenite: >25% lithic fragments; usually immature or reworked rapidly.

In the Bida Basin, most of the sandstones studied have been identified as quartz arenites, indicating high compositional maturity and derivation from stable continental or metamorphic sources.

2.5 Sedimentary Rock Textures

Texture in sedimentary rocks refers to the physical appearance and arrangement of grains or particles within the rock. It plays a critical role in interpreting the depositional environment, transport mechanism, and maturity of the sediment. The key components of sedimentary textures include grain size (qualitatively described), grain shape (roundness), sorting, fabric, and packing.

1. Grain Size (Field-based Observation)

Grain size in sedimentary rocks ranges from clay-sized particles (<0.004 mm) to boulders (>256 mm). In the field, grain size is described qualitatively as fine, medium, or coarse. Sandstones typically fall within the 0.0625 mm to 2 mm range. Grain size gives an indication of the energy conditions of the depositional environment: coarser grains are associated with higher energy conditions (e.g. river channels), while finer grains settle in low-energy settings (e.g. floodplains, lakes).

2. Sorting

Sorting describes the uniformity of grain sizes within the rock. It is estimated visually in the field or through thin section analysis. Well-sorted rocks contain grains of similar size and are usually deposited in stable energy environments such as beaches or dunes. Poorly sorted rocks contain a wide range of grain sizes, indicating fluctuating or rapid deposition, such as in alluvial fans or glacial deposits.

3. Grain Shape (Roundness and Sphericity)

Grain shape is an important textural feature that reflects the distance and nature of sediment transport. Grains may be angular, subangular, subrounded, or well-rounded. Angular grains suggest minimal transport from the source, while rounded grains imply long-distance transportation or reworking. Sphericity refers to how closely the grain resembles a sphere.

4. Packing and Fabric

Fabric refers to the orientation and arrangement of grains within the rock. It may be random or aligned, often indicating the flow direction of the transporting medium. Packing refers to how tightly the grains are compacted. Closely packed grains usually imply compaction or cementation during diagenesis.

5. Matrix and Cement

Matrix is the fine-grained material filling the spaces between grains, while cement refers to the mineral material that binds the grains together (e.g., silica, iron oxide, or calcite). The presence and type of cement affect porosity and permeability and provide clues about diagenetic processes.

In this study, textures are evaluated through field observations and petrographic analysis. Features such as moderate to poor sorting, subangular to subrounded quartz grains, and ferruginous cementation provide insight into the sediment transport mechanisms and diagenetic alterations affecting the Lafiagi sandstones.

2.6 Deposition and Depositional Environments

Deposition is the geological process through which sediments, soil, and rock particles are laid down or settle from a transporting medium such as water, wind, ice, or gravity. The nature of deposition determines the texture, structure, and composition of the resulting sedimentary rocks. The environment in which deposition occurs is referred to as the depositional environment, and it provides crucial insights into the origin and evolution of sedimentary basins.

Depositional environments are broadly classified into continental (terrestrial), transitional (coastal), and marine settings. Each environment leaves behind characteristic features in the rock record.

1. Continental Environments

These include fluvial (river), alluvial fan, glacial, lacustrine (lake), and desert (aeolian) environments.

- Fluvial systems are characterized by sandstones with features like cross-bedding, ripple marks, and fining-upward sequences. Channelized sandstone bodies and point bar deposits are common.
- Aeolian deposits are well-sorted, well-rounded sands with large-scale cross-stratification.

2. Transitional Environments

These lie between terrestrial and marine settings and include deltas, estuaries, lagoons, and tidal flats.

- Sediments here show a mix of marine and terrestrial influence, often with alternating layers of sand, silt, and clay, along with mud cracks and bioturbation structures.

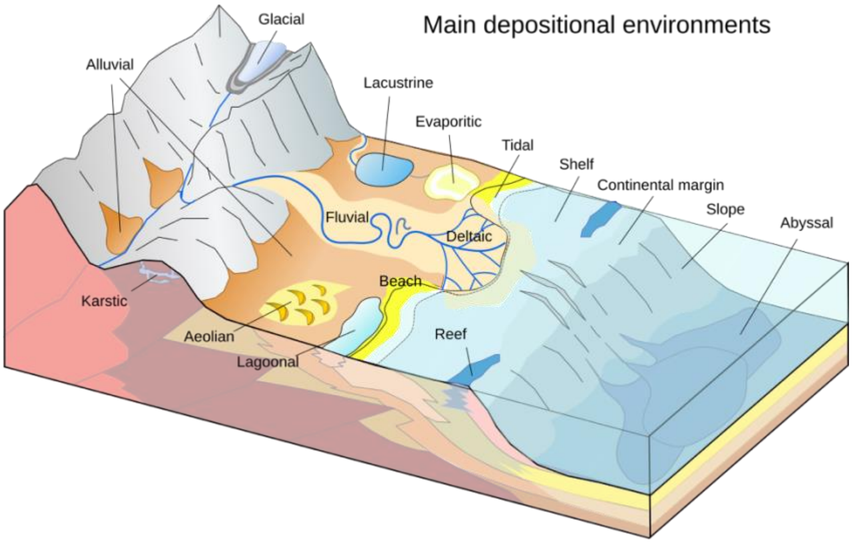
3. Marine Environments

Divided into shallow marine, deep marine, and carbonate platforms.

- Shallow marine environments produce well-sorted sands, fossiliferous limestones, and symmetrical ripple marks.
- Deep marine settings accumulate fine-grained sediments like shale and turbidites, often showing graded bedding.

In the Bida Basin, especially the Lafiagi area, the sandstone units are interpreted to have been deposited in a fluvial continental environment, as indicated by sedimentary structures such as cross-bedding, ripple marks, and the moderate to poor sorting of grains. These features suggest deposition by braided or meandering rivers with varying flow regimes and sediment supply.

Depositional Environments Overview



2.7 Sedimentary Structures

Sedimentary structures are physical features that develop during or shortly after the deposition of sediments. They provide essential clues to interpret the depositional environment, flow direction, transport mechanism, and post-depositional history of sedimentary rocks. These structures are broadly classified into primary (formed during deposition) and secondary (formed after deposition).

1. Primary Sedimentary Structures

These form at the time of sediment deposition and are directly linked to the environment and flow regime:

- Cross-bedding: Inclined layers within horizontal beds, formed by migration of ripples or dunes. Common in fluvial, aeolian, and shallow marine settings.
- Ripple marks: Small ridges formed on sandy beds by moving water or wind. Can be asymmetrical (current ripple marks) or symmetrical (wave ripple marks).
- Graded bedding: Vertical sorting of grain size, with coarser material at the bottom and finer material at the top. Typical of turbidity currents and fluvial flood deposits.
- Parallel lamination: Thin, horizontal layers indicating steady, low-energy sedimentation.
- Mud cracks: Polygonal cracks that form in drying mud, often indicating subaerial exposure in floodplain or tidal flat environments.

2. Secondary Sedimentary Structures

These develop after deposition due to processes like compaction, cementation, or bioturbation:

- Convolute bedding: Deformation of layers due to soft-sediment loading or slumping.
- Load casts: Bulges at the base of sandstone beds caused by denser sand loading over softer mud.
- Bioturbation: Disturbance of sedimentary layers by organisms (e.g. burrows or root traces).

In the Lafiagi area of the Bida Basin, several primary sedimentary structures have been observed, particularly planar and trough cross-bedding, ripple marks, and parallel lamination in sandstone outcrops. These features support a fluvial depositional model with varying energy regimes, consistent with river channel and point bar environments. The presence of weathering rinds and ferruginous crusts also suggests post-depositional alteration under oxidizing conditions.

2.8 – Study of Sedimentary Rocks

This section summarizes how sedimentary rocks are studied, particularly focusing on the practical techniques you've applied (lithological description and thin section analysis), tying everything together.

2.8 Study of Sedimentary Rocks

The study of sedimentary rocks involves the examination of their physical, chemical, and mineralogical characteristics to reconstruct depositional environments, understand provenance, and evaluate diagenetic history. These rocks serve as valuable records of past geological processes and are essential in petroleum geology, hydrogeology, and environmental reconstruction.

Sedimentary rocks are primarily studied through a combination of fieldwork and laboratory analysis:

1. Field-Based Lithological Description

This includes the examination and documentation of:

- Grain texture (size, shape, roundness, and sorting)
- Sedimentary structures (e.g. cross-bedding, ripple marks, laminations)
- Color and weathering features
- Cementation and matrix content
- Bedding geometry and thickness

These observations help classify rock types, infer depositional energy conditions, and identify changes in sediment supply or environment over time.

2. Petrographic (Thin Section) Analysis

In the laboratory, representative samples are cut into thin sections and examined under a polarizing microscope. This technique helps identify:

- Mineral composition (e.g., quartz, feldspar, lithic fragments)
- Grain relationships and contacts
- Textural maturity (based on sorting and roundness)
- Diagenetic features (e.g., cement type, grain overgrowths, compaction)

In this study, thin section analysis of sandstone samples from the Lafiagi area revealed high quartz content, low matrix presence, and ferruginous cementation, supporting their classification as compositionally and texturally mature sandstones.

3. Integration and Interpretation

By integrating field and laboratory data, geologists can interpret:

- Depositional environments (e.g., fluvial, deltaic, marine)
- Sediment provenance and transport history
- Post-depositional changes (e.g., cementation, compaction)

Such integrated approaches are essential for evaluating sedimentary basins like the Bida Basin, particularly in understanding their potential for groundwater storage, hydrocarbon reservoirs, and broader basin evolution.

CHAPTER THREE

METHODS OF STUDY

3.1 MATERIALS AND METHODS

This study involves both field work and laboratory analysis.

3.2 SAMPLE COLLECTION AND FIELD STUDY

Field study entailed carrying out a geological mapping of the rock types in the study area Lafiagi, Northern Bida Basin. The mapping exercise was basically aimed at identifying the rocks and establishing stratigraphic succession of the rocks on the basis of their field relationships. It also involved collection of spot rock samples for laboratory studies. Field observations including grain texture, colour, grains orientation, mineralogical composition, measurements of coordinates and elevation with GPS, taking photographs of important sedimentary structures and logging of exposed vertical sections were done.

Five (5) samples of sandstones were collected from the road cut exposures with the aid of geological hammer. The samples were properly kept in the sample bags and labelled accurately with masking tape and permanent marker for easy identification. They were labelled as follows: LF1, LF2, LF3, LF4 and LF5 respectively. The samples were then taken to the laboratory for further analysis.

3.3 LABORATORY ANALYSIS

The thin section petrography analysis was aimed at determining the mineralogy of the sandstones. The experiment was performed in the Sedimentological Laboratory, Geology Department, Kwara State University, Malete.

3.3.1 Petrographic Analysis

Petrographic analysis was conducted using thin section microscopy to study the sandstone's mineralogy and texture. All the sandstones sample from the field are poorly consolidated, fragile, and friable. Due to friable nature of these sandstone, firing impregnation and cool moulding. Impregnation was employed before mounting on slide for microscopic view. Four (4) samples LF1, LF3, LF5 and LF6 were selected for thin section petrography. The samples were dried over an acetone bath, impregnated with polyester resin mix, cut and polished using minor modification of standard hard rock thin sectioning equipment and techniques. The materials used are hardener and resin, in which their mixture is ratio 1:3 giving thin araldite. The moulding container acetone had to be lubricated with vaseline or engine oil to allow the mould to remove easily. A small quantity of the prepared araldite was poured at the bottom of the container after which the loose sample was poured and packed with a glass rod to prevent space from being created between the grains. The prepared araldite was applied to it and the sample number was written on the sample before it solidified.

After impregnation, the thin section slides were prepared by grinding one side perfectly flat with carborundum powder on a glass plate. Slides to be used are heated after which Canada balsam is placed on it. Further grinding is done until a thickness of 0.03m was reached and this is checked under a microscope with cross polar to see the polarization color attribute of some known mineral such as quartz (grey or white of the first order). When the correct thickness is reached, the thin sections were thoroughly washed and all remaining resin scraped away from around the chip. The slides were later covered with cover slips which was pressed down to remove any air bobbles present. Excess cement was removed with methylated spirit. The thin sections were observed under the polarizing microscope to determine the mineral composition of the rock samples.

CHAPTER FOU

RESULTS AND DISCUSSIONS

4.1 LITHOLOGICAL DESCRIPTION AND DEPOSITIONAL ENVIRONMENTS

Location: Lafiagi, Northern Bida Basin, Kwara State, Nigeria

Coordinates: 8° 50’ 56.8’’ N, 5° 24’ 58.1’’ E

Elevation: 127m

The lithological section from Lafiagi in the Northern Bida Basin reveals a sedimentary succession indicative of a dynamic fluvio-deltaicdepositional system. The Bida Basin is known for its Cretaceous sediments deposited in fluvial, deltaic, and shallow marine environments (2013Obaje, 2009; Nwajide,).

Environmental Interpretation

LF 1 (0 – 0.6m)

Massive, pinkish-milky, lithified, clay-supported medium-grained sandstone

This interval suggests deposition under low to moderate energy conditions, characteristic of distal floodplain or lower delta plain environments, where clay matrix accumulation is common (Nichols, 2009). The lithification points to post-depositional diagenetic processes (Allen, 1982).

Environment: Floodplain to Lower Delta Plain

LF 2 (0.6 – 1.3m)

Massive, pinkish, clay-supported, medium to coarse-grained sandstone

The coarse grain size and massive bedding reflect higher energy conditions, typical of fluvial channels or point bar deposits within a meandering river system (Allen, 1982; Nwajide, 2013).

Environment: Fluvial Channel or Point Bar

LF 3 (1.3 – 2.2m)

Reddish to brownish, lithified, laminated, clay-supported, pebbly sandstone

The presence of laminations and pebbles indicates periodic high-energy flows interspersed with finer sediment deposition, consistent with braided river or proximal delta front settings (Nichols, 2009).

Environment: Braided Fluvial System or Proximal Delta Front.

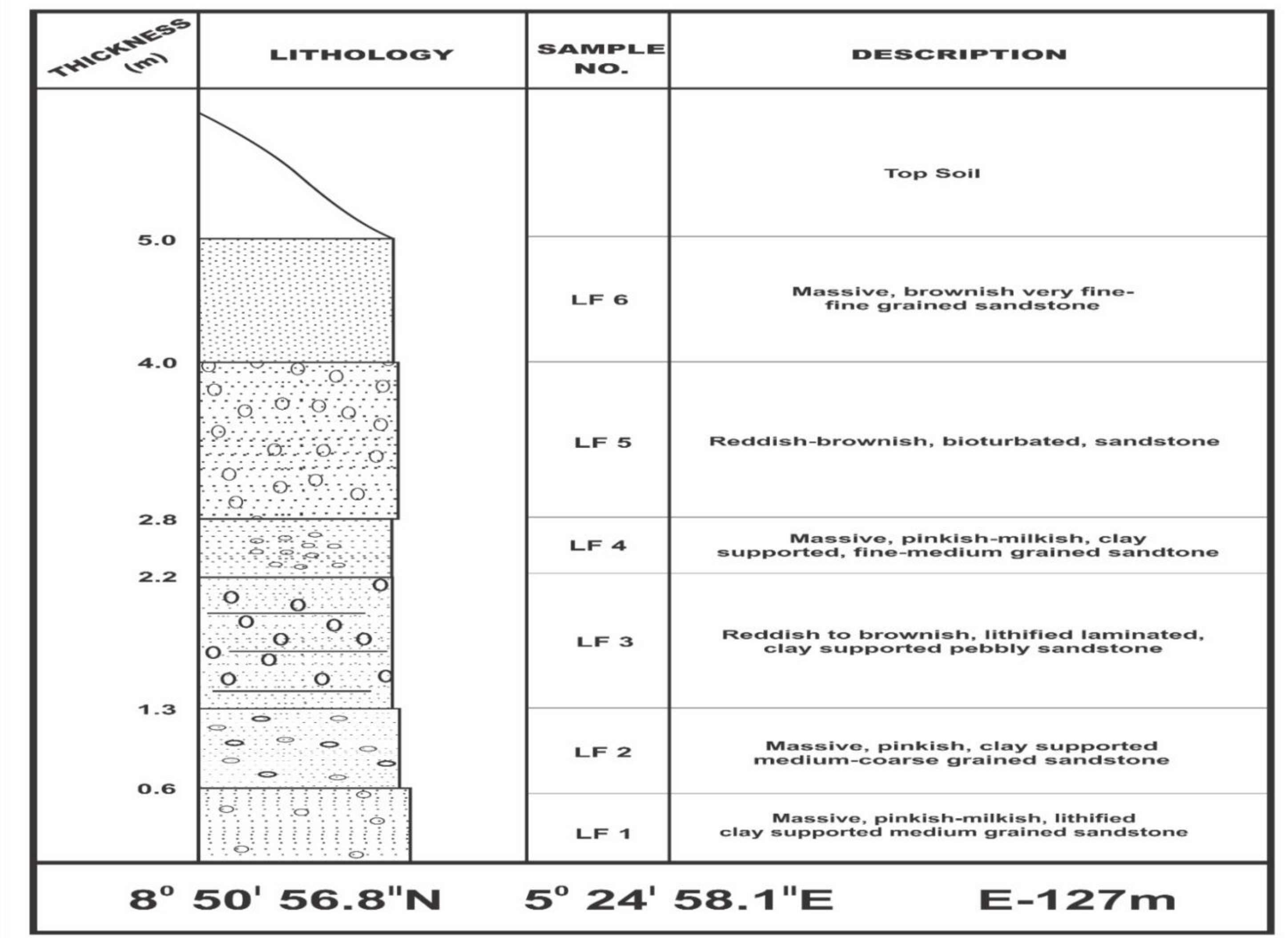


Figure 4.1: Lithological section of Bida sandstone exposed at Lafiagi

LF 4 (2.2 – 2.8m)

Massive, pinkish-milky, clay-supported, fine to medium-grained sandstone

This reflects a reduction in depositional energy compared to LF 2 and LF 3, pointing to floodplain or distal point bar environments within a fluvial system (Obaje, 2009).

Environment: Distal Fluvial Channel or Floodplain

LF 5 (2.8 – 4.0m)

Reddish-brownish, bioturbated sandstone

Bioturbation reflects the presence of benthic organisms, which suggests deposition in marginal marine to lower delta plain environments such as tidal flats or shoreface zones (Nichols, 2009; Nwajide, 2013).

Environment: Marginal Marine (Tidal Flat or Shoreface)

LF 6 (4.0 – 5.0m)

Massive, brownish, very fine-grained sandstone

The very fine grain size and massive structure indicate low-energy suspension fallout, likely in a lagoonal, lower delta plain, or shallow marine shelf setting (Allen, 1982).

Environment: Lagoonal, Sheltered Delta Front, or Lower Floodplain

Topsoil (Surface Layer)

The topsoil represents modern pedogenic processes and does not reflect the ancient depositional environment.

Overall Interpretation

The vertical succession indicates a transition from high-energy fluvial channel deposits (LF 2 and LF 3) to floodplain environments (LF 1 and LF 4), followed by more marine-influenced conditions in the upper layers (LF 5 and LF 6). Such a sequence is consistent with deltaic progradation or a transgressive trend in a fluvio-deltaic system, characteristic of the Bida Basin during the Cretaceous (Obaje, 2009; Nwajide, 2013).

4.2 THIN SECTION PETROGRAPHIC INTERPRETATION

The results of the thin section petrographic analysis are used to deduce the provenance, maturity, depositional environments and implementations for Petroleum exploration.

4.2.1 PROVENANCE INTERPRETATION

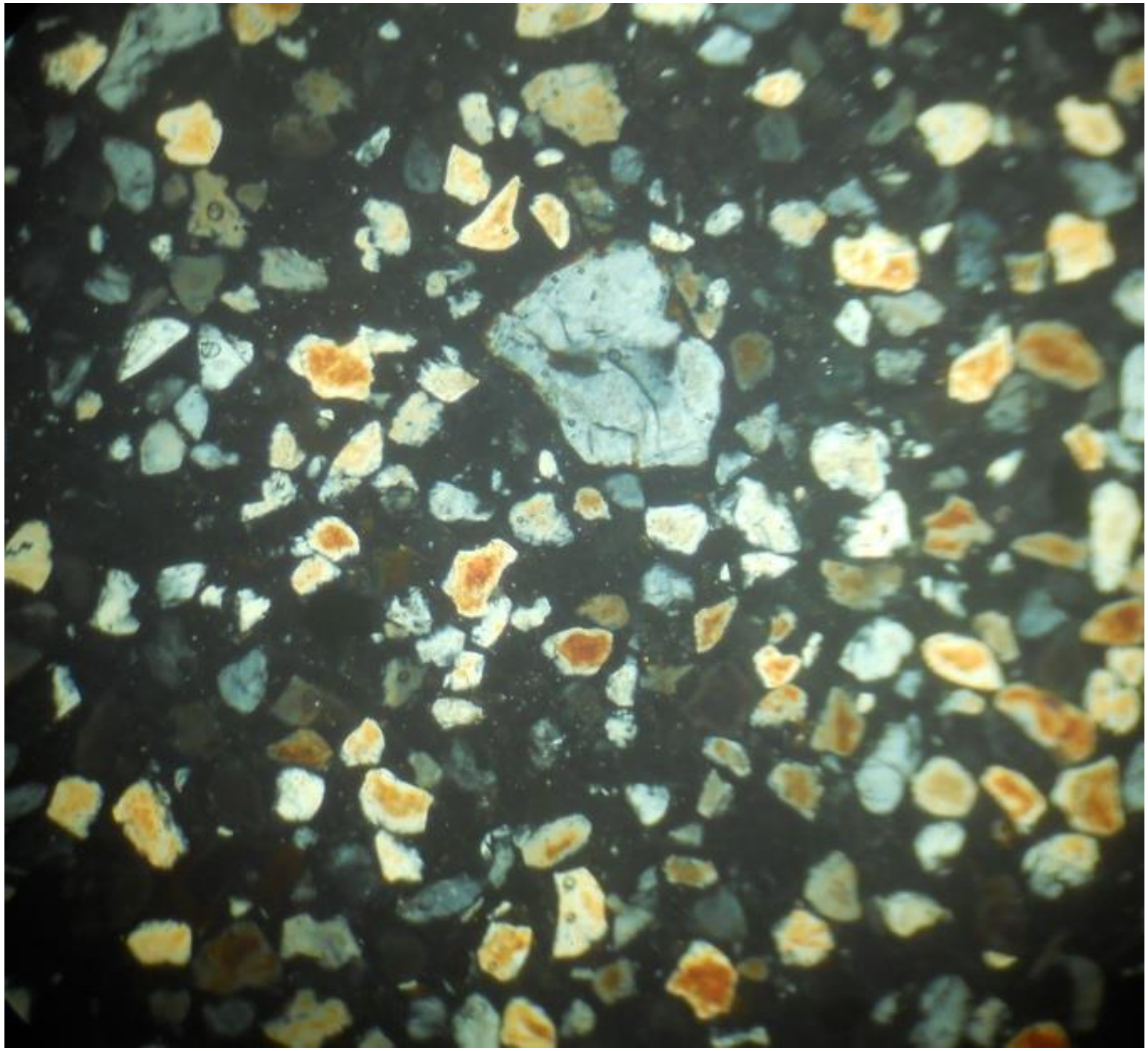
Provenance analysis aims to determine the origin and nature of the parent rocks that supplied sediments to the depositional basin. In the study of clastic sedimentary rocks such as sandstone, the provenance is interpreted from petrographic, textural, and compositional characteristics. These attributes reveal insights into the geological history, tectonic setting, and weathering conditions that affected the source area. In this study, petrographic analysis of thin sections from sandstone samples LF1, LF3, LF5, and LF6 was used to interpret provenance in the Northern Bida Basin.

The petrographic results revealed an overwhelming dominance of quartz grains (both monocrystalline and polycrystalline), which collectively accounted for more than 90% of each sample's composition. Specifically:

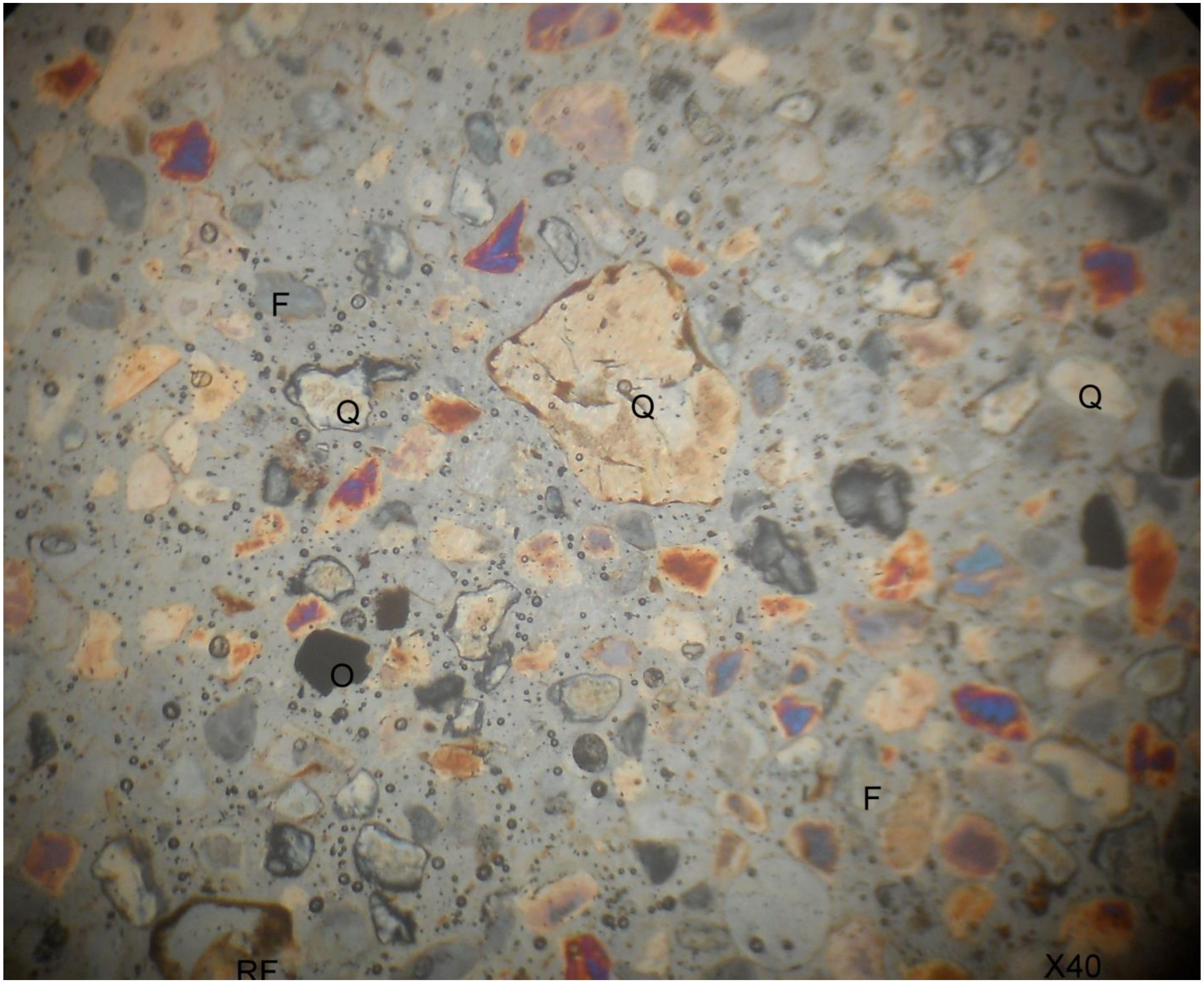
LF1: Polycrystalline (53), Monocrystalline (25)

Table 4.1: Results of Thin section Petrographic analysis

Sample no	**Quartz (grain type)**	**ANGULAR/BOUNDRY**	**NO OF COUNT**	**RATIO OF PLYXTALINE TO MONOXTALINE**	**TEXTURAL MATURITY**	**COMPOSITIONAL MATURITY**
LF1	POLYXTALINE MONOXTALINE	Angular to subangular Rounded to subrounded	53 25	53;25	Super mature (=92% qtz)	Super mature
LF3	POLYXTALINE MONOXTALINE	Angular to subangular Rounded to subrounded	45 42	45;42	Super mature (=92% qtz)	Super mature
LF5	POLYXTALINE MONOXTALINE	Angular to subangular Rounded to subrounded	53 32	53;32	Super mature (=92% qtz)	Super mature
LF6	POLYXTALINE MONOXTALINE	Angular to subangular Rounde to subrounded	36 19	36;19	Super mature (=92% qtz)	Supermature

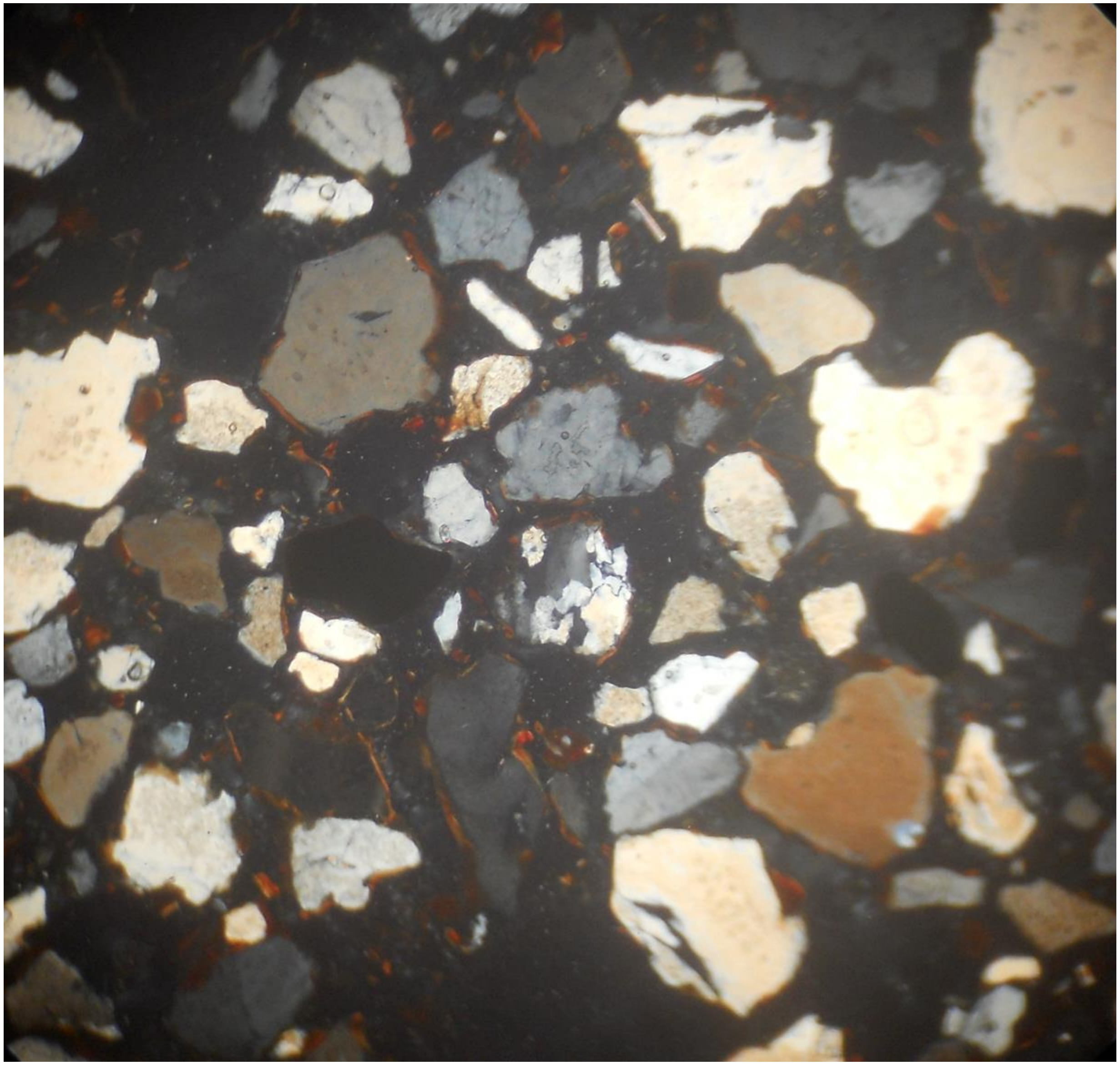


LFigure 4.1a – Photomicrograph of Sample LF1 under Plane Polarized Light (PPL) showing angular polycrystalline quartz grains.

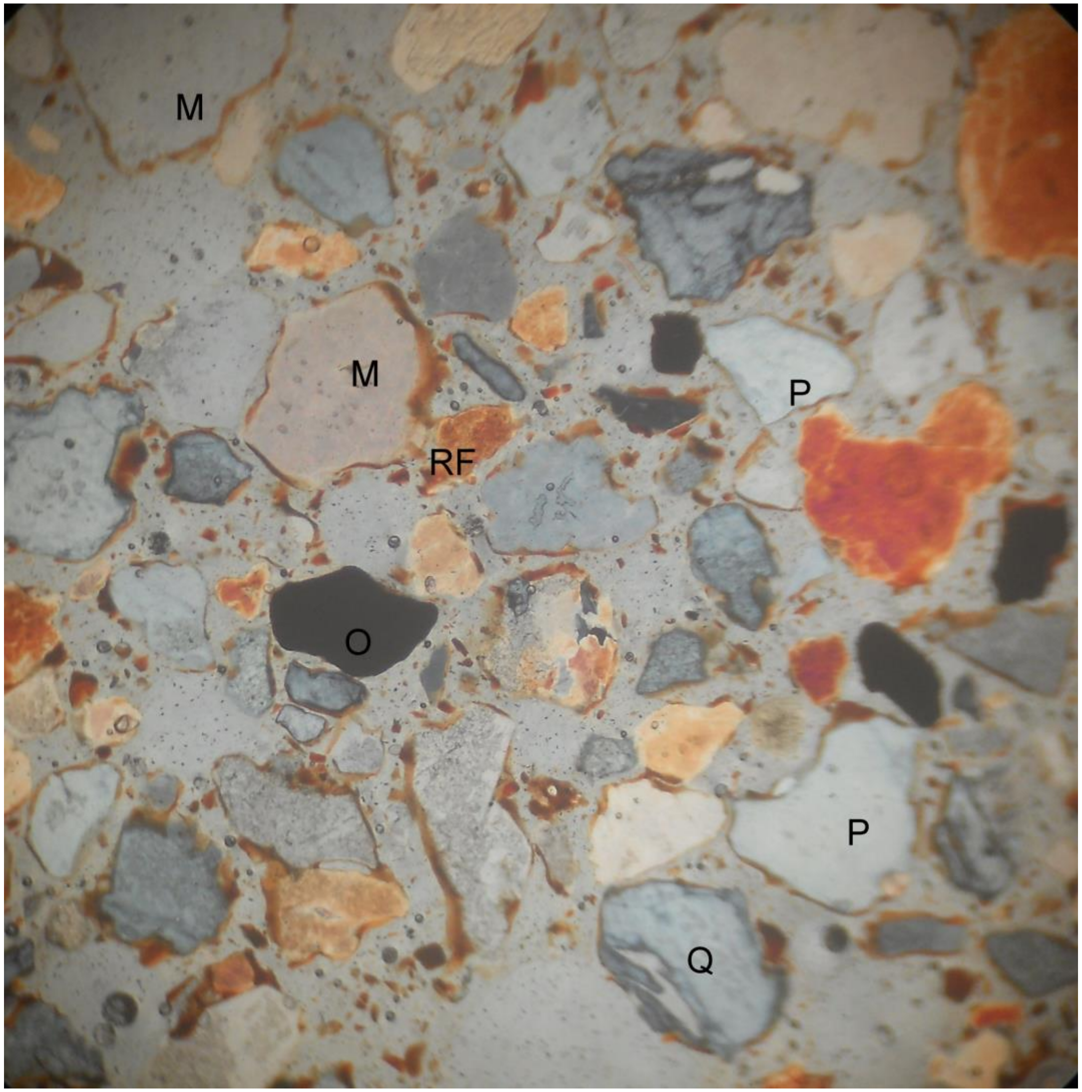


- Figure 4.1b – Photomicrograph of Sample LF1 under Cross Polarized Light (XPL) showing undulose extinction and quartz overgrowths.

- LF3: Polycrystalline (45), Monocrystalline (42)

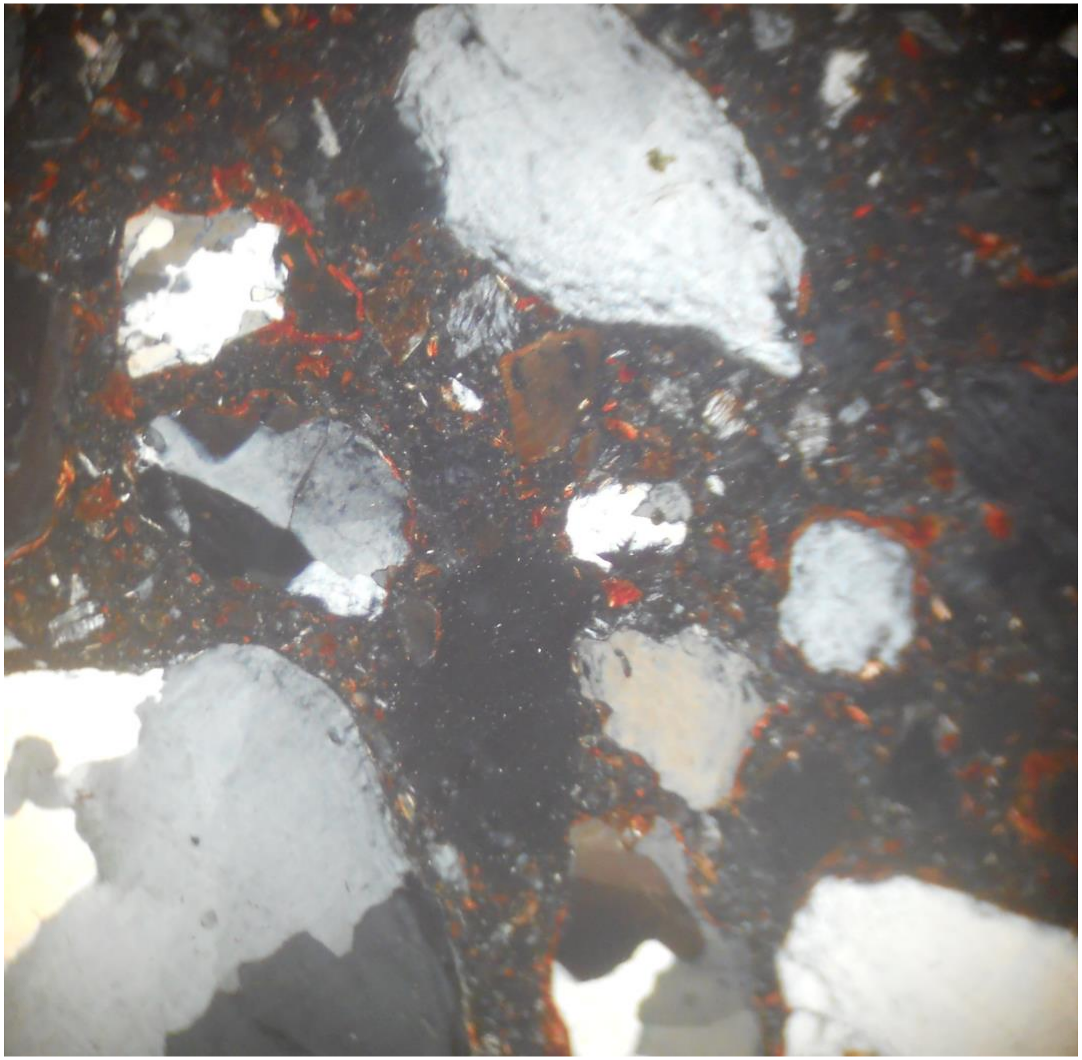


- Figure 4.2a – Photomicrograph of Sample LF3 under Plane Polarized Light (PPL) showing subrounded monocrystalline quartz grains.

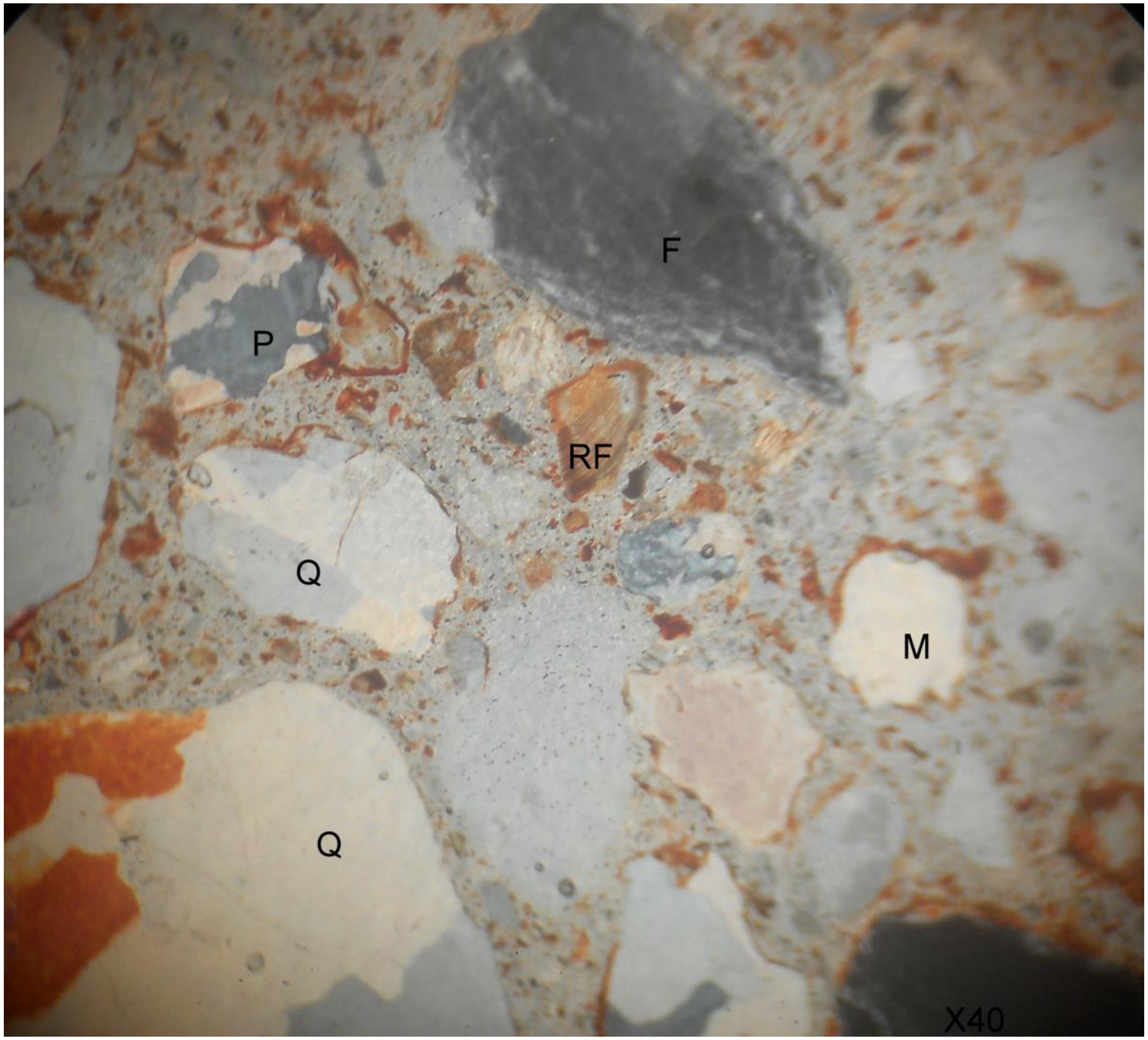


- Figure 4.2b – Photomicrograph of Sample LF3 under Cross Polarized Light (XPL) revealing quartz twinning and cementation textures.

- LF5: Polycrystalline (53), Monocrystalline (32)

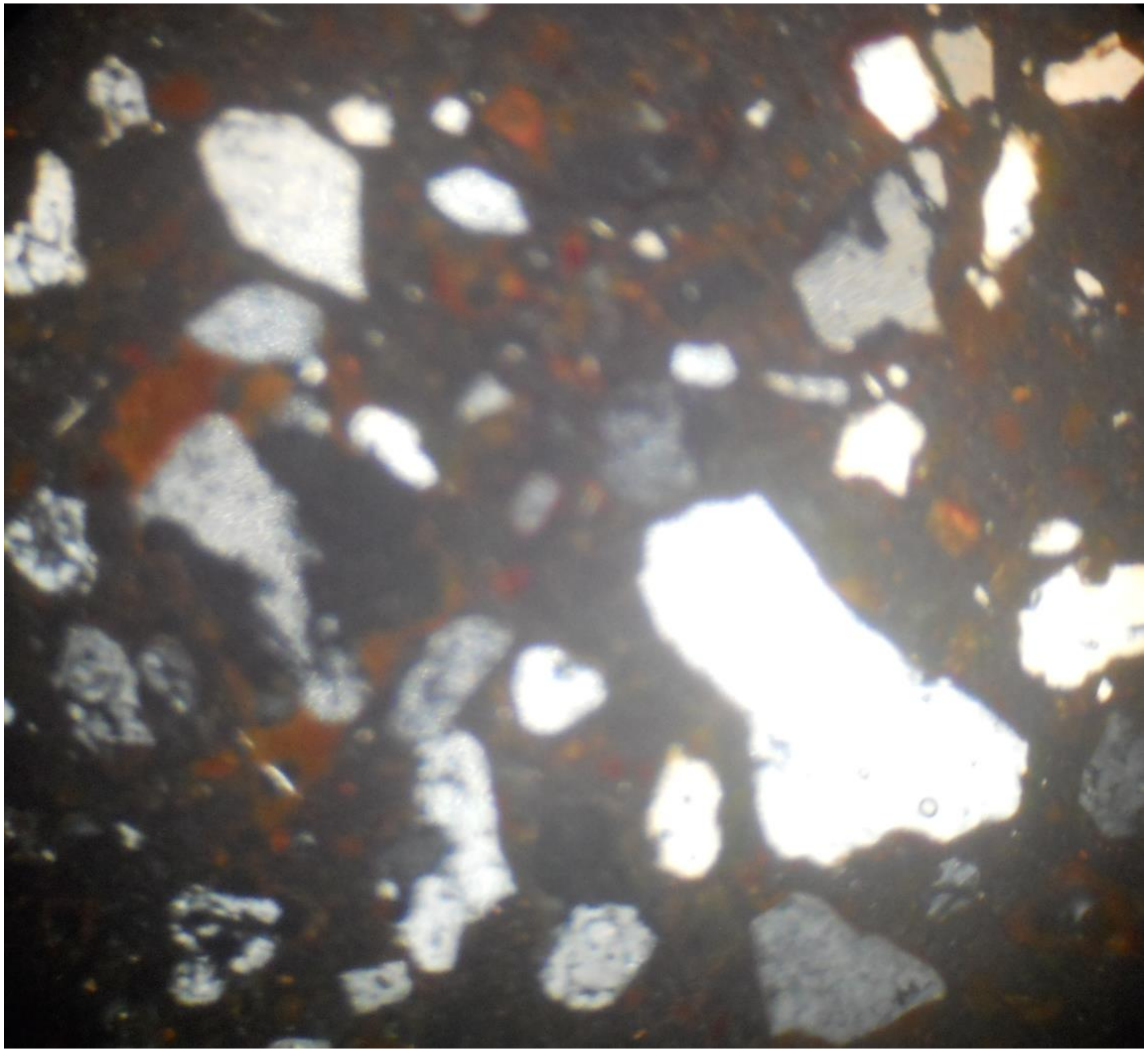


- Figure 4.3a – Photomicrograph of Sample LF5 under Plane Polarized Light (PPL) with interlocking quartz grains.

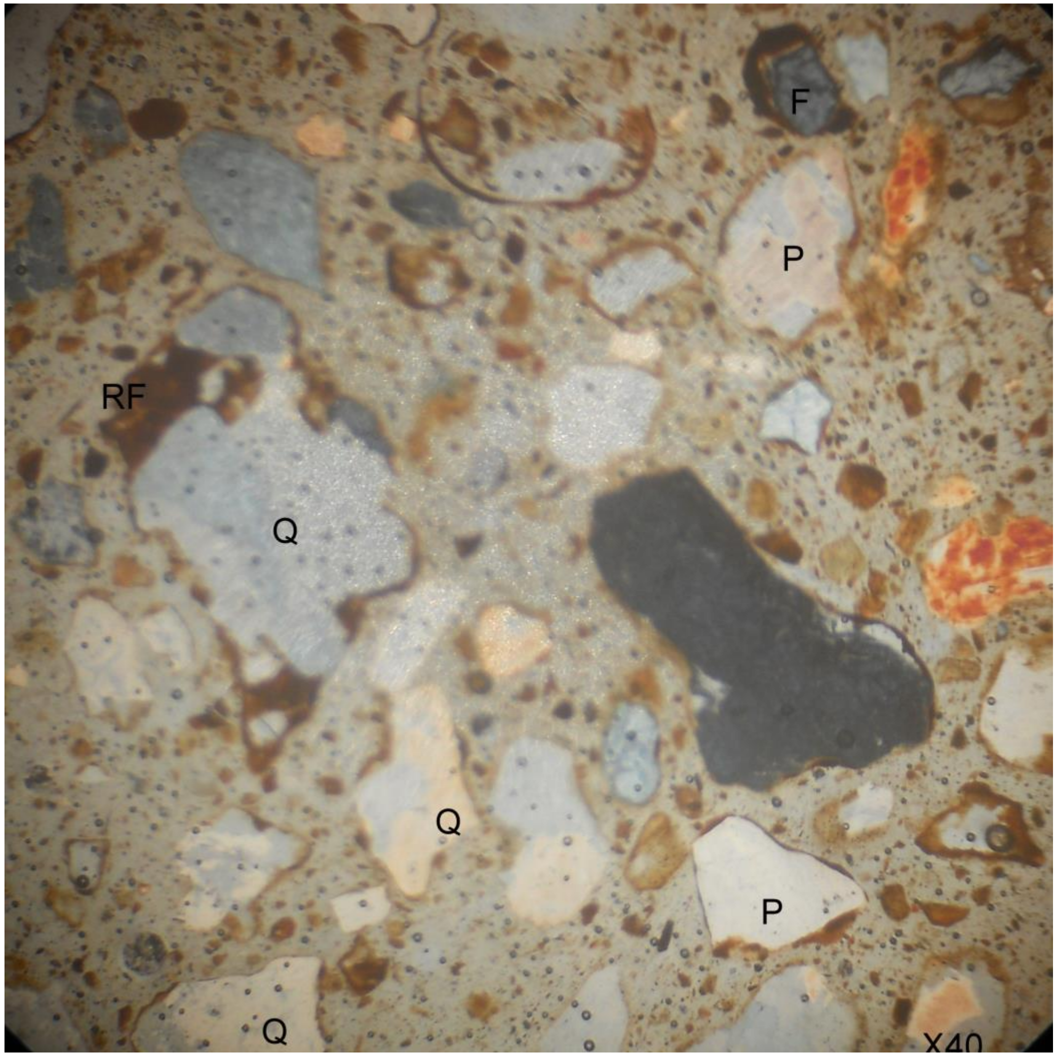


- Figure 4.3b – Photomicrograph of Sample LF5 under Cross Polarized Light (XPL) showing straight extinction and ferruginous cement.

- LF6: Polycrystalline (36), Monocrystalline (19)



- Figure 4.4a – Photomicrograph of Sample LF6 under Plane Polarized Light (PPL) showing angular quartz grains with limited cement.



- Figure 4.4b – Photomicrograph of Sample LF6 under Cross Polarized Light (XPL) showing low interference colors and quartz extinction patterns.

The polycrystalline quartz indicates a significant contribution from high-grade metamorphic rocks, such as schists and gneisses, which are characteristic of the Precambrian Basement Complex that forms the structural foundation surrounding the Bida Basin. Monocrystalline quartz, on the other hand, may have originated from both igneous and low-grade metamorphic sources. The lack of feldspar and lithic fragments in large quantities suggests that the sediments underwent intense chemical weathering, with unstable minerals being removed during prolonged transport or storage in weathering zones.

The angular to subrounded shape of most quartz grains suggests that the sediments did not travel over extremely long distances. Instead, they may have been transported moderate distances by high-energy fluvial systems, consistent with braided river environments common in the Bida Basin during the Late Cretaceous. This moderate maturity also implies that reworking and recycling of older sediments could have occurred.

Thus, the provenance of the sandstones from Lafiagi is confidently interpreted as being from a metamorphic-dominated terrain, most likely the Nigerian Basement Complex, with sediments transported by rivers into a stable, intracratonic basin (the Bida Basin). The results further imply that tectonic uplift and erosion of older continental crust occurred during the Campanian to Maastrichtian, supplying sediment to the depositional system.

4.2.2 TEXTURAL AND COMPOSITIONAL MATURITY INTERPRETATION

Understanding the textural and compositional maturity of sandstones is essential in sedimentological studies because it provides insight into the extent of sediment transport, weathering, and reworking, as well as the reservoir quality of the rock. In this study, thin section petrography of four sandstone samples (LF1, LF3, LF5, LF6) from the Lafiagi area has been used to assess their maturity levels.

Textural maturity refers to the degree of sorting, roundness, and matrix content in the sandstone. These characteristics indicate how much abrasion and sorting the grains experienced during transportation.

The analyzed samples exhibited:

- Angular to subangular polycrystalline quartz
- Rounded to subrounded monocrystalline quartz
- Moderate to good sorting
- Very low matrix content

These features suggest that the sandstones are texturally mature to supermature. The presence of rounded quartz grains indicates that the sediments underwent substantial mechanical abrasion and reworking, likely within high-energy fluvial systems such as braided rivers. However, the coexistence of some angular grains, particularly among the polycrystalline quartz, suggests that the sediments were not transported over excessively long distances and may include some primary or first-cycle detritus.

Well-sorted grains and minimal matrix indicate consistent hydraulic energy during deposition and winnowing of finer particles. This also reflects prolonged weathering and transportation under oxidizing, humid conditions typical of tropical environments.

Compositional maturity is determined by the relative abundance of stable and unstable minerals. Quartz is the most stable mineral, whereas feldspar and lithic fragments are less stable and break down more easily dlring weathering.

In all four samples, quartz content exceeded 92%, with feldspar and lithic components being either minor or absent. This dominance of quartz, especially monocrystalline and polycrystalline types, points to an extremely compositionally mature sandstone. The maturity reflects extensive chemical weathering in the source area—likely a high-standing, tectonically stable terrain composed predominantly of granite gneiss, quartzite, and other resistant metamorphic rocks.

This high compositional maturity suggests:

- A stable continental craton as the sediment source
- Intense tropical weathering, which eliminated feldspars and unstable rock fragments
- Possible recycling of older sedimentary rocks previously enriched in quartz.

Texturally and compositionally mature sandstones often exhibit high porosity and permeability, especially if diagenetic alterations (e.g., cementation, compaction) are minimal. The observed maturity in the Lafiagi samples implies a favorable reservoir rock with good fluid storage and flow characteristics. These properties are significant for groundwater aquifers and hydrocarbon reservoirs within the Bida Basin.

Therefore, based on petrographic evidence, the Lafiagi sandstones can be described as both supermature texturally and supermature compositionally, placing them in the category of quartz arenites.

4.2.3 DEPOSITIONAL ENVIRONMENTS INTERPRETATION

Interpreting the depositional environment of sedimentary rocks involves analyzing grain size, sedimentary structures, texture, composition, and fossil content (if present) to reconstruct the physical conditions under which the sediments were deposited. For the sandstone units studied in the Lafiagi area of the Northern Bida Basin, a combination of field observations, petrographic analysis, and grain characteristics supports a well-defined interpretation of the depositional setting.

Sedimentary Structures and Field Features

During fieldwork, the exposed sandstone units displayed features such as:

- Large-scale planar and trough cross-bedding
- Ripple marks
- Fining-upward sequences
- Variable grain size (coarse to medium)
- Ferruginous cementation and iron nodules

These sedimentary structures are indicative of high-energy, unidirectional current systems, commonly associated with fluvial environments. Cross-bedding and ripple marks suggest sediment transport by water, likely in braided or meandering rivers, where flow direction and energy fluctuate over time. The presence of fining-upward sequences supports deposition in a river channel where waning energy leads to the settling of progressively finer sediments.

The color and ferruginous character of the sandstones further suggest oxidizing conditions, typically found in subaerial continental settings with episodic wetting and drying cycles. Such environmental indicators align with deposition under continental fluvial conditions.

Petrographic Support for Depositional Interpretation

Thin section analysis of samples LF1, LF3, LF5, and LF6 revealed:

- High quartz content (92–94%)
- Moderate sorting
- Angular to subrounded grains
- Low matrix and minimal feldspar or lithic fragments

These features are consistent with fluvial-dominated depositional systems, particularly braided rivers, which tend to deposit sand with a high quartz fraction due to reworking and winnowing of unstable minerals. The moderate sorting and mixed grain roundness reflect variable flow energy and intermittent reworking, typical of rivers influenced by seasonal or tectonic pulses.

Braided river systems are known for:

- Coarse, poorly to moderately sorted sands
- Episodic flooding and sediment pulses
- Multiple, shifting channels
- Common cross-bedding and channel lag deposits

The characteristics observed in the Lafiagi sandstones match these attributes, indicating that sedimentation likely occurred in a proximal fluvial system, possibly near the sediment source terrain (Precambrian basement rocks).

Previous research (e.g., Ojo, 2012; Akande et al., 2005) has documented that the Bida Basin sediments, especially in the Lokoja and Bida formations, were deposited in fluvial to deltaic environments. The data from this study align with these findings, strengthening the conclusion that the Lafiagi sandstone units formed in a continental fluvial depositional setting, with some minor overbank and floodplain influences.

This environment suggests active sediment supply, rapid deposition, and limited marine influence during the Campanian to Maastrichtian, consistent with the tectonically stable but gradually subsiding intracratonic nature of the Bida Basin.

4.2.4 IMPLICATIONS FOR PETROLEUM EXPLORATION

The petrographic and textural maturity of the sandstone samples analyzed from the Lafiagi area suggests excellent reservoir potential for petroleum exploration. The high quartz content, low matrix, moderate sorting, and fluvial depositional setting point to good porosity and permeability conditions. These characteristics support the role of these sandstones as potential reservoir rocks in the Northern Bida Basin.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has provided a comprehensive sedimentological analysis of sandstone units exposed in the Lafiagi area of the Northern Bida Basin, Nigeria. Through integrated field investigations, petrographic thin section analysis, and interpretations of grain size and sedimentary structures, the depositional environments and provenance of the sandstones have been effectively reconstructed.

The sandstone units are dominantly composed of quartz (over 92%), with both polycrystalline and monocrystalline varieties indicating derivation from metamorphic terrains—most likely the surrounding Nigerian Basement Complex. Textural features such as angular to subrounded grains and moderate sorting further confirm that the sediments underwent moderate transport under high-energy fluvial conditions, typical of braided and meandering river systems.

Sedimentary structures, including cross-bedding, ripple marks, and fining-upward sequences, suggest deposition in a dynamic fluvial environment influenced by episodic flow energy. Ferruginous cementation and weathering rinds observed in the outcrops also imply subaerial exposure and post-depositional alteration in oxidizing conditions.

Collectively, the sandstones studied in Lafiagi are classified as supermature quartz arenites and exhibit good reservoir qualities—such as high compositional purity, moderate to good sorting, and potential porosity—making them suitable for groundwater aquifers and possibly hydrocarbon reservoirs. These findings fill significant gaps in the sedimentological framework of the northern Bida Basin and support regional interpretations of Late Cretaceous fluvial deposition in an intracratonic tectonic setting.

5.2 Contribution to Knowledge

This research contributes to knowledge by providing detailed petrographic data and depositional interpretations of sandstones in the underexplored Northern Bida Basin. It integrates field-based sedimentological observations with laboratory thin section analysis to better understand the provenance, maturity, and reservoir quality of the studied formations. These findings offer new insights into the petroleum potential and sedimentary evolution of the Bida Basin.

5.3 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Extended Grain Size Analysis:

   A detailed granulometric study using both sieve and laser diffraction methods is recommended across a wider range of exposures to improve understanding of spatial variability in textural parameters.

2. Hydrogeological Testing:

   Given the reservoir potential suggested by the high quartz content and textural maturity, aquifer tests and hydraulic conductivity measurements should be conducted to assess groundwater potential quantitatively.

3. Geochemical and Heavy Mineral Studies:

   Further studies involving whole-rock geochemistry and heavy mineral analysis would provide more definitive provenance indicators and help constrain tectonic settings using discrimination diagrams.

4. Subsurface Investigation:

   To enhance stratigraphic correlation and assess reservoir continuity, shallow drilling or geophysical methods (e.g., resistivity, seismic refraction) should be employed in conjunction with surface mapping.

5. Comparative Studies:

   It is recommended that similar sedimentological studies be conducted in adjacent areas such as Share, Pategi, and Lokoja to build a broader depositional model for the entire Bida Basin.

6. Collaborative Research and Funding:

   Academic and governmental institutions should collaborate to expand research into inland basins like Bida. Improved funding and access to laboratories will help produce high-quality, integrated geological data.

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