SEDIMENTOLOGICAL CHARACTERIZATION AND PETROGRAPHIC ANALYSIS OF A SEDIMENTARY OUTLIER UNIT AT THE OUTSKIRTS OF IKPESHI AREA.

BY

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DEPARTMENT OF GEOLOGY

FACULTY OF PHYSICAL SCIENCES

UNIVERSITY OF BENIN

BENIN CITY

SEPTEMBER, 2023

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF GEOLOGY, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENEIN, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF SCIENCE DEGREE (B.Sc) GEOLOGY

SEPTEMBER, 2023

CERTIFICATION

This is to certify that Precious Solomon EGWULEMU, MAT. NO. PSC1908980 carried out this project in fulfillment for the award of Bachelor of Science (B.Sc.) Degree in Geology.

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(PROJECT SUPERVISOR)	(SIGNATURE)	(DATE)

DEDICATION

I hereby dedicate this work to Almighty God for his provisions of life, unmerited favour and wisdom to accomplish this undergraduate project and; to my parents Mr. and Mrs.Godwin Egwulemu for their unending support, love and encouragement.

ACKNOWLEDGEMENT

My sincere gratitude goes to my supervisor Dr. J. A. EDEGBAI for his guidance, encouragement, thorough supervision and advice through the course of this project.

My profound gratitude also goes to the lecturers and staff of the Department of Geology for their unlimited impartation of sound Knowledge throughout my journey in this department.

Lastly, my utmost gratitude to my colleague and friend Biebele Joy Diri for his timely assistance during the writing of this work.

May God bless you all abundantly.

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ABSRACT

This research is focused on the sedimentological characterization and petrographic analysis of a sedimentary outlier unit at the outskirts of Ikpeshi area.

The sedimentological study of sections of the rock units involved the description, measurements and sampling of various sections and samples broken off from the rock unit in situ. The laboratory studies carried out in this research include petrographic analysis involving thin section petrography.

This rock unit occurs as boulders on a narrow ridge and they are surrounded by basement complex rocks, they have a coarse texture, and contain particle size that range from about 1mm – 15mm with a dominant clast size of 2mm, they are poorly sorted and they range from sub-angular to angular in roundness. They contain about 85% quartz, 10% clay minerals and lithic fragments account for the rest.

The rock unit was observed to be texturally and mineralogically immature. These rock units have been established as sandstones, made up of very coarse sands – small pebbles mineral grains, they are sub-arkosic in nature which is a function of the percentage of the mineral content and the lithic fragments. The sandstone unit consists of series of sedimentary structures which include cross beds, which formed as a result of sudden rise and fall in the depositional energy, the direction of dips of these cross beds indicates the paleocurrent direction of the transporting medium at the time of deposition. The rock unit outcrops in the Benin flank, the sandstone is described as Pre-Santonian due to its age, the sandstone is observed to be older than sandstones that were formed in the Anambra Basin. This is evident in the compaction difference or diagenetic process that occurred between the two, the sediments as well as the depositional processes that make up these sandstones is suggested to have come from the lower Benue Trough this can be said to be true as a result of

the clear distinct lithological and textural characteristics of the sandstones formed in Anambra Basin and the sandstones that is been examined.

CHAPTER ONE

1.1 INTRODUCTION

The study of sedimentary rocks gives us an idea and the opportunity to understand the process in which sediments are deposited, with this we can reconstruct past sedimentary environments and paleo climates. It also provides basic information with which we can re-enact the history of the earth through evolutionary changes of life forms recorded in the form of fossils within sedimentary rocks.

The sediment composition and the textural characteristic of a sedimentary rock gives an indication of the source and maturity of the sediments that make up the rock, the grain size gives an idea of the transport distance while the fossil contents present in the sedimentary rock indicates the age and sequential development of the sediments and the depositional environments.

The sandstone at the outskirts of Ikpeshi area possess specific characteristic features on which descriptions can be made, such descriptions can include the textural maturity, mineralogical analysis, provenance, the ancient depositional environment in which the rock unit was deposited.

The sandstone was observed to be highly lithified; that is, the sandstone has been heavily compacted which indicates that the sandstone was buried at great depth and has undergone a high rate of diagenetic processes.

The rock unit outcrops in the Benin flank, the sandstone is described as Pre-Santonian due to its age, the sandstone is observed to be older than sandstones that were formed in the Anambra Basin e.g., the Ajali sandstone. This is evident in the compaction difference or diagenetic process that occurred between the two, the sandstones at the outskirts of Ikpeshi area are said to be highly lithified and with synonymous characteristics with hard rocks such as the tightly packed sediment grains, On the other hand, sandstones that were formed in the

Anambra Basin are friable and not as compacted as the sandstones in the outskirts of Ikpeshi area.

The sediments as well as the depositional processes that make up these sandstones is suggested to have come from the lower Benue Trough this can be said to be true as a result of the clear distinct lithological characteristics of the sandstones formed in Anambra Basin and the sandstones that is been examined. Hence the name "Pre-Santonian".

The lithostratigraphic observation carried out on the sandstone unit at the location of the study area reveals that this sandstone body is highly lithified to a point at which it is crystallized, the sandstone unit consists of series of sedimentary structures which include cross beds, which formed as a result of sudden rise and fall in the depositional energy, the direction of dips of these cross beds indicates the paleocurrent direction of the transporting medium at the time of deposition.

The history of sedimentation of this sequence is reconstructed from observed physical characteristics inherent in the sandstone body which includes:

1. Beddings
2. Grain sizes, shapes, sorting
3. Sedimentary structures
4. Vertical and lateral facies pattern

Though, some aspects of the sedimentology and stratigraphy of the pre-Santonian siliciclastic sequences within the Lower Benue Trough has been investigated by several authors (Reyment, 1965; Dessauvagie, 1972; Murat,1972; Petters, 1983; Asseez, 1989; Kogbe, 1989; Ben khelil et al., 1989; Amajor, 1990; Obaje et al., 1999; Nton,1999). However, this present study focuses on the comprehensive approach to field observations and sedimentological characterization of outcrop sections of the sandstones at the outskirts of the Ikpeshi area along the Auchi – Igarra express way.

This study provides detailed geology, lithology, and lithologic descriptions of these sections, evaluates the textural and mineralogical characteristics of these sandstone units, and ascertain their depositional environment, provenance and predicting the nature and state of the energy of the medium that transported and deposited them.

It is important to note that this work is one of the very first geological literature that attempts to characterize, analyze and classify these rock units at the outskirts of Ikpeshi area, this will work will form a solid base for other works on this rock units in the near future.

1.2 LOCATION

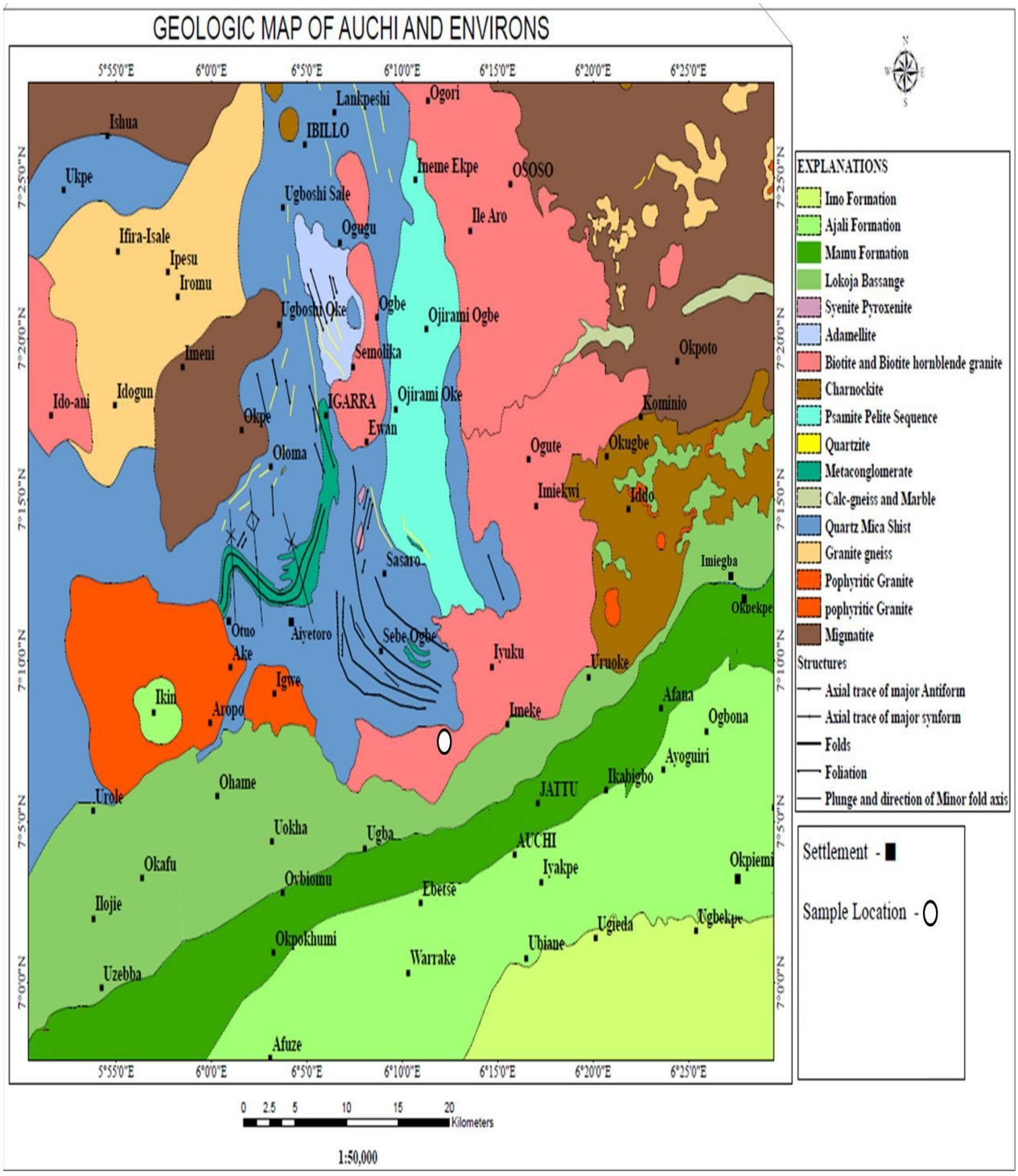


Figure 1: Location of the study area modified by rahaman (1971)

The study area in the outskirts of Ikpeshi along Auchi – Igarra road lies between latitude N 07^0 07’ 41.7’’ and longitude E 006^0 12’ 59.9’’. It is located along Auchi – Igarra road in Akoko-Edo local government area of Edo state. The sandstone body is exposed as huge boulders on farmlands in the area. The sandstone body has an elevation of 210.5m above sea level.

1.3 ACCESSBILITY

The study area is accessible with a good network of footpaths that are interconnected. The study area is made up of numerous farmlands which make the road network accessible. The footpath creates a greater part of the accessibility because the topography would have impeded movement.

1.4 CLIMATE

The climate is tropically characterized by wet and dry seasons. However, the seasonal pattern of this area is the wet season dominated by heavy rainfall and high humidity. It starts in March and lasts till July.

The short dry season starts in August and extends to mid – September, this is closely followed by a short-wet season which starts from early October and extends till mid-November. A long dry season known as the harmattan season is characterized by cool and misty mornings as well as hazy afternoons. This begins in late November and extends till mid-March.

1.5 RELIEF AND VEGETATION

The general topography of the study area is rugged with small domes shaped like elongated ridges and steep valleys. This feature is typical of areas with poorly indurated sediments with little cementing materials capped by detrital.

The vegetation is of the guinea savannah vegetation belt of Nigeria. It is made up of tall grasses, shrubs, bushes which are abundantly distributed with concentration of dense vegetation. The canopying shields of the trees help to minimize or prevent the loss of soil

moisture. The loss of water through transpiration is minimized by shedding leaves during the dry season. The grass helps to reduce the leaching rate of the soil in preventing washing away vital nutrients present in the soil. This is why the study area is characterized by farmlands and cattle pens because the soil is rich in organic nutrients which foster agricultural activities in the study area.

1.6 AIM AND OBJECTIVES

1.6.1 AIM

The aim of this work is to have a better understanding of the Geology and Sedimentology of the sandstone in the outskirts of Ikpeshi area. Emphasis is placed on heavy minerals present, sedimentary structures, distribution, mode of occurrence, depositional environment etc.

Geological field study of the sandstone outcrop involved a careful study of the sedimentary sections from which fresh samples were obtained.

The scope of this work includes laboratory analysis carried out on the sample such as heavy mineral analysis etc.

Data interpretation is based on the data obtained from various analysis carried out from which tentative decisions would be made on the source of sediment, mode of transportation and depositional environment.

1.6.2 OBJECTIVES

To describe the sandstone unit based on the:

- Textural maturity
- Mineralogical analysis
- Depositional environment
- Sedimentological framework

To Provide or deduce the provenance and the depositional paleoenvironment of the sandstone unit

1.7 PREVIOUS WORK

Olubunmi et al (2012) published a work on the Sedimentological Characterization of Pre – Santonian Siliclatic Deposits of Lower Benue Trough, Southeastern Nigeria. This work entailed evaluating and characterizing these sediments and carrying out Detailed field studies to establish the lithostratigraphy. Fresh samples were subjected to petrographic, granulometric and heavy mineral analyses.

The study established that the **pre**- Santonian siliciclastic sequences of the Lower Benue Trough are texturally immature to mature and compositionally sub mature to super mature products of a continental block and recycled orogenic provenance under humid climates and deposited in fluvial to tidally influenced fluvial environments with high to moderate energy conditions, humid climates which are deposited under high to moderate energy conditions.

Samuel et al (2017) published an article on the Paleoenvironment and Provenance Studies of Ajali Sandstone in Igbere Area, Afikpo Basin, Nigeria.

The stratigraphy and sedimentology of the Ajali Sandstone successions in Igbere area, Afikpo Basin were studied to determine paleoenvironmental setting and source model of the deposits. The studied deposits consist of five lithofacies namely: pebbly sandstone facies, cross-bedded, laminated, bioturbated sandstone facies and mudstone facies. Paleoenvironmental interpretation based on facies associations and sedimentary structures revealed tide-influenced fluvial deposits, while inferences from bivariate plots of calculated univariate parameters indicated fluvial deposits. The sandstone in the area is essentially quartz sandstone or quartz arenite based on petrographic analysis. The mineralogical and textural maturity of the sandstone therefore indicated a polycyclic deposit.

Adeoye et al (2022) also published a work on the Provenance and Paleoenvironments reconstruction of Sandstones from Onshore Dahomey Basin, Southwestern, Nigeria: Implications for Reservoir Potential.

The aquiferous sandstone units in Daniel-1, Olambe and Yakoyo boreholes located in the onshore part of the eastern Dahomey Basin, Southwestern Nigeria, were investigated through grain size, petrography and geochemical studies to evaluate their provenance, paleoenvironments and the preliminary aquifer or reservoir quality of the sandstones. The sub-mature to mature textures and mineralogy

coupled with their shallow depths of the sandstones at 130 ft – 160 ft are suitable factors that enhance good porosity and permeability in an aquifer or reservoir rock. These are probably the positive attributes favoring the storage and efficient water production of the aquiferous sandstones. They have similar textural and mineralogy features with the Turonian – Coniacian Afowo sandstones reservoir producing oil and gas in the deep subsurface offshore area of the Basin and the onshore Tar sand in Nigeria and part of Benin Republic, West Africa.

These various works were carried out on the solid foundation of Sedimentological analysis such as the well detailed description of the study rock formation, textural analysis, Mineralogical analysis and other Sedimentological tools formed the basis on which these works were done. The same tools will be applied in this work to arrive at geologic conclusions which can characterize and give a detailed explanation and analysis of the study rock formation at the outskirts of Ikpeshi.

CHAPTER TWO

LITERATURE REVIEW AND GEOLOGICAL SETTING OF THE STUDY AREA

The sediments that make up these sandstones is suggested to have come from the lower Benue Trough this can be said to be true as a result of the clear distinct lithological and textural characteristics of the sandstones formed in Anambra Basin and the sandstones that is been examined.

The geology of the study area where the sediments that make up these rock units and as such deposited will be looked at carefully in this chapter, since the sediments were formed in the Lower Benue Trough and then transported and deposited in the Anambra Basin. A proper evaluation of both sedimentary basins will be done.

2.1 STRATIGRAPHIC FRAMEWORK OF THE LOWER BENUE TROUGH

The sedimentary succession in the lower Benue Trough is predominantly Pre – Santonian in age and has been established as the Asu River group, the Eze – aku group and the Awgu formation (Reyment, 1965: Murat, 1972: and Peters, 1978). According to asseez (1989), the oldest sedimentary rocks of southern Nigeria consists of non – fossiliferous, arkosic: gravelly, poorly sorted, commonly cross – bedded sandstones of probable Albian age derived from the Basement Complex and are exposed in Abakaliki and Calabar areas. The Asu River group was the initial clastic fill in the southern Benue Trough. It is about 9800ft (3000m) thick and comprises of basal arkosic sandstones of the Awi and Mamfe Formations; middle marine shales (Abakaliki shales), karstic limestones and upper regressive sandstones (Awi Formation) petters and Ezeokwor(1982) and Petters (1983).

The Awi formation In the Calabar area is made up of continental clastics, consisting of a fluvio – Deltaic sequence of cross bedded

sandstones, siltstones, conglomerates and clay stones (Nton, 1999). This unit overlies the Precambrian massif unconformably. The abakiliki shales in the abakaliki area have been known to not only contain shales but in addition dark micaceous sandy shale, siltstone and fine-grained sandstones with rich ammonite fauna which indicate Albian age (asseez, 1989). Overlying the Asu River group is the Cross-river group which consists of shales, limestones and intertounging sandstones previously assigned to the Eze-aku group and the awgu formation. These sandstones include Makurdi, Agala and Amaseri and Agbani sandstones (Murat, 1972; Offodile, 1976: Hoque, 1977; Banerjee, 1980).

Deposition of the Cross River group is said to have occurred during the late Cenomanian to early Santonian marine transgression.

Amaseri sandstone was deposited as the continental and paralic facies of local Delta complexes, with its sediments derived from the basement complex areas of Ogoja while the Eze-aku may represent the Pro Delta clays and deeper water deposits associated with these complexes (Whitman, 1980). Sandstones ridges of Amaseri sandstone are exposed at Ugep on the eastern side of the Cross river plain and in Amaseri town near Afikpo.

The Eze-aku group grades into the marine Awgu shale which consists of Grey blue shales with subordinate limestone bands and calcareous sandstone. Agbani sandstone, which is the lateral equivalent of the Awgu shales is made up of medium to coarse grained bioturbated and cross bedded sandstones and laminated brownish clays. This deposition cycle was interrupted by the Santonian tectonic movement that folded and faulted the sediments in the Trough. The Santonian folding was faulted by extensive magmatic activity which resulted in the formation of extrusive and intrusive igneous body increases in amount and diversity from the Northeast to the Southwest of the Basin. Based on stratigraphic evidence, the total thickness of the entire sedimentary pile or depth to the basement of the Lower Benue Trough as estimated from the thickness of individual unit is given as 4.8km (Burke et al., 1972; Ofoegbu et al., 1991).

2.2 LOCATION

The Lower Benue Trough lies between Latitudes N6°-7.8°N and Longitudes E6°40’ - 7°30’E. The Benue Trough is a major geological structure underlying a large part of Nigeria and extending about 1000km north east from the Bight of Benin to Lake Chad. It is part of the broader West and Central African Rift system. The Trough has its southern limit at the boundary of the Niger Delta where it dips down and is overlaid with tertiary and more recent sediments it extends in a north easterly direction to the chad Basin, and it is about 150km wide. The Trough is arbitrarily divided into lower, middle and upper regions and the upper region is further divided in to the Gongola and Yola arms. The Anambra Basin in the west of the lower region is more recent than the rest of the Trough being formed during a later period of compression, but is consider ed part of the formation.

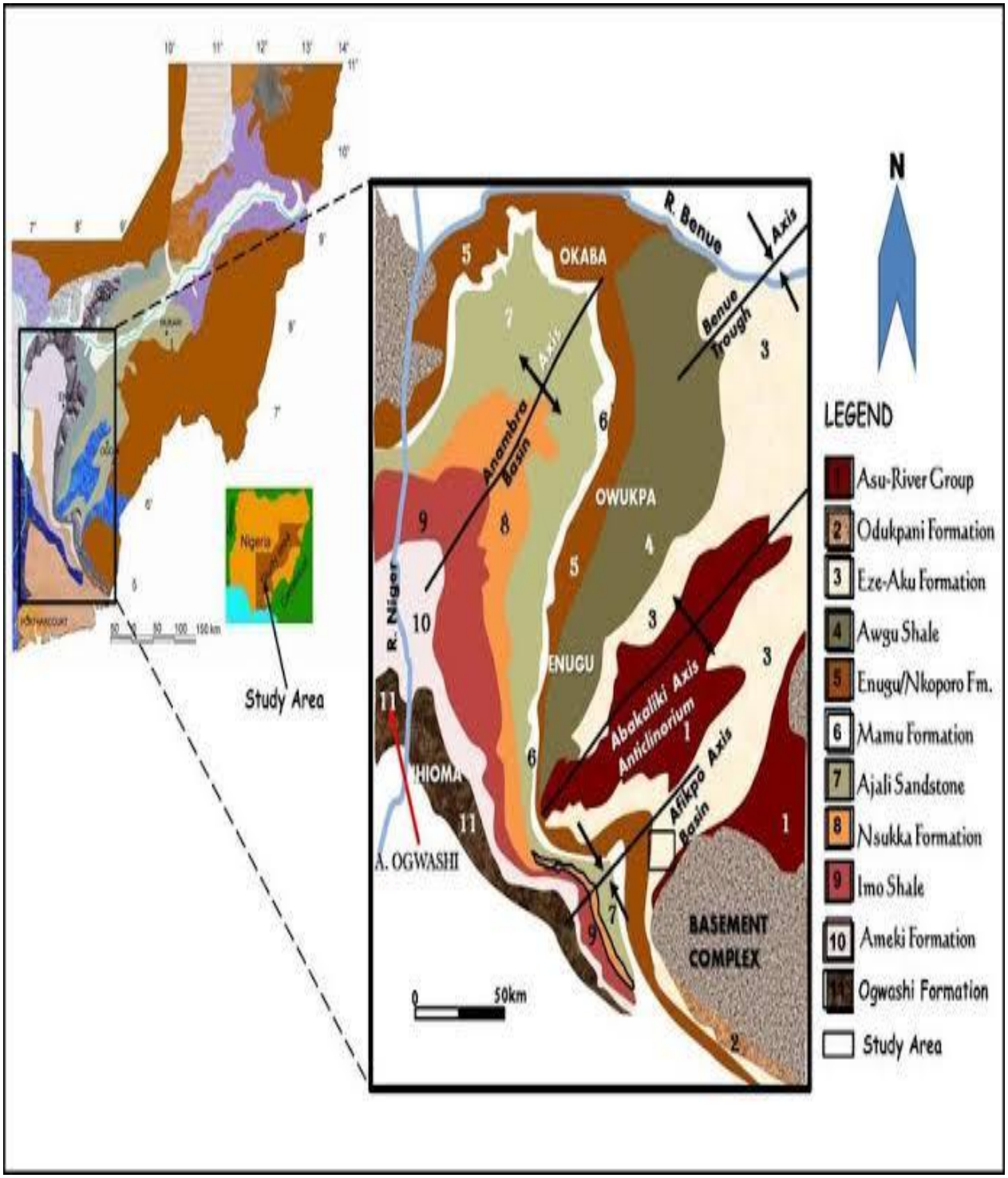


Figure 2: A GEOLOGICAL MAP SHOWING THE STRATIGRAPHY OF THE SOUTHERN BENUE TROUGH (Burke et al 1976)

2.3 TECTONIC HISTORY AND SEDIMENTATION FRAMEWORK OF THE LOWER BENUE TROUGH

The Aptian-Santonian Lower Benue Trough was relatively simple rift comprising a deep southern basinal area located south of Onitsha and a broad shallower platform of the north. Regional stratigraphy and sediment thickness patterns were thereafter strongly modified by the Lower Santonian tectonism in the Lower Benue Trough (Wright, 1968). This movement gave rise to a main axial Abakiliki High that was asymmetrically disposed In the trough to give a wider western complimentary Anambra Syncline and a narrower eastern Afikpo syncline. A tranverse Nsukka High subdivides the Anambra Syncline into a Northern Ankpa and a Southern Onitsha Basins. These tectonic elements were active until the Miocene (Burke et al, 1972).

The Ankpa Basin now has a sediment thickness of about 5000m comprising Pre and Post-Santonian Cretaceous to Paleocene sediments. The Onitsha Basin and the Afikpo Syncline are continuous into the modern Niger Delta where they each have sediments thickness of up to 12000m comprising Pre and Post-Santonian as well as Tertiary sediments (Murat 1965).

The tectonic highs received comparatively thinner sediments and were even non-depostional in places. They, however, constitute favorable regions for developing petroleum entrapment structures and stratigraphic pinch-outs.

2.4 SEDIMENTARY BASIN FILL OF THE LOWER BENUE TROUGH

Lower Benue Trough is a Cretaceous Depo-Centre that received Campanian to Tertiary sediments (Nwajide, 1990 and Obi, 2000). The stratigraphic setting of Southern Nigeria comprises sediments of three major sedimentary cycles. The first two cycles belong to the Pre-Santonian sediments while the third cycle belongs to post-Santonian sediments which are found in the Anambra Basin and Afikpo Syncline (Nwajide, 1990). In Anambra Basin, the strongly folded Albian - Coniacian succession (Pre-Santonian sediments) is overlain

by flat-lying Campanian-Eocene succession. The oldest sediment in the Anambra Basin is Nkporo Group (Nwajide, 1990). It was deposited into the Basin in Late Campanian, comprising Nkporo Shale, Owelli Sandstone and Enugu Shale (Reyment, 1965 and Obi, 2001).

The filling of the Anambra Basin took place within the time interval from Santonian to early Pliocene (Danian) an absolute time of 60 million years.

There are two marine transgressions, a major one, the Okporo transgression, and a less extensive one, the Nsukka transgression.

2.5 PALEOGEOGRAPHY OF THE SOUTHERN BENUE TROUGH

Sedimentary rocks of cretaceous to recent ages outcrop in most parts of Anambra state and further to the western part of the country. South of the basement rocks, sedimentary rocks occur and are composed typically of continental facies, alluvial fans comprising of immature sediments. Younger outcrops successively maintain the same general trend direction implying that these deposits represent products of a regressive condition.

Upper cretaceous sediments in the Lower Benue Trough show a flat to low angle easterly dip direction. This configuration is changed to a westerly dip direction at the cretaceous. The paleogeographic situation of the upper cretaceous would seem to imply that the sand came from the north – west area of the Anambra Basin, with the okitipupa ridge acting as a barrier allowing mainly pellitic sediments to be deposited.

On the western flank, sedimentation rate increased in the Maastrichtian resulting in thick deposition and further westward extension of the paralic to transitional sequence.

2.6 TECTONIC HISTORY AND EVOLUTION OF THE ANAMBRA BASIN

Opinions regarding the tectonic setting and the evolution of the Anambra Basin are rather controversial. The Anambra Basin trends in a NE – SW direction which is one of the same trends as the Benue Trough which suggests that they are tectonically related.

The Anambra Basin is one of the most prominent southern Basins and was believed to have formed in the early Cretaceous with the splitting of the Gondwana land mass and the subsequent development of the Gulf of Guinea and the separation of the African and South American plates (Murat, 1970).

Murat based his presentation of the plate concept on Burke et al (1970). He suggested that it was formed after the Anambra platform subsided contemporaneously with the uplift of Abakaliki high during the Santonian orogeny.

Other works such as (Agagu and Adhigijie, 1983) and (Coker et al 1991) believed that the Anambra Basin, The Benin flank, and the Benue Trough belong to the same tectonic phase of early rifting.

The Anambra Basin directly over lies the facies of the southern Benue Trough and consists of Campanian sediments and younger. It is on record that the Basin was not in existence prior to the Santonian thermo tectonic events. In territorial terms, the outcropping area of the Anambra Basin has a roughly triangular outline with a slightly indented base in the western boundary.

The tectonism in Southern Nigeria started in Early Cretaceous, with the separation of Africa from South American plate and opening of the Atlantic. This resulted in the development of the Benue Trough which stretched in a NE-SW direction and resting unconformably upon the Pre-Cambrian basement complex. It extends from the Gulf of Guinea to the Chad Basin and is thought to have been formed by the Y-shaped (RRR) triple junction ridge system that initiated the breaking and dispersion of the Afro-Brazilian plates in the Early

Cretaceous (Kogbe, 1989). After the evolution of the Benue Trough, sediments started depositing into the Trough with Asu River Group being the oldest sediment followed by Eze-aku Group, and Awgu Group, respectively. (Nwajide, 1990).

Santonian age marked the stage when the Basin experienced another phase of tectonic event that involved deformation, folding, faulting and uplift of the Pre-Santonian sediments leading to the formation of Anambra Basin which evolved as a depression to the west of the uplift (Ben khelil, 1987).

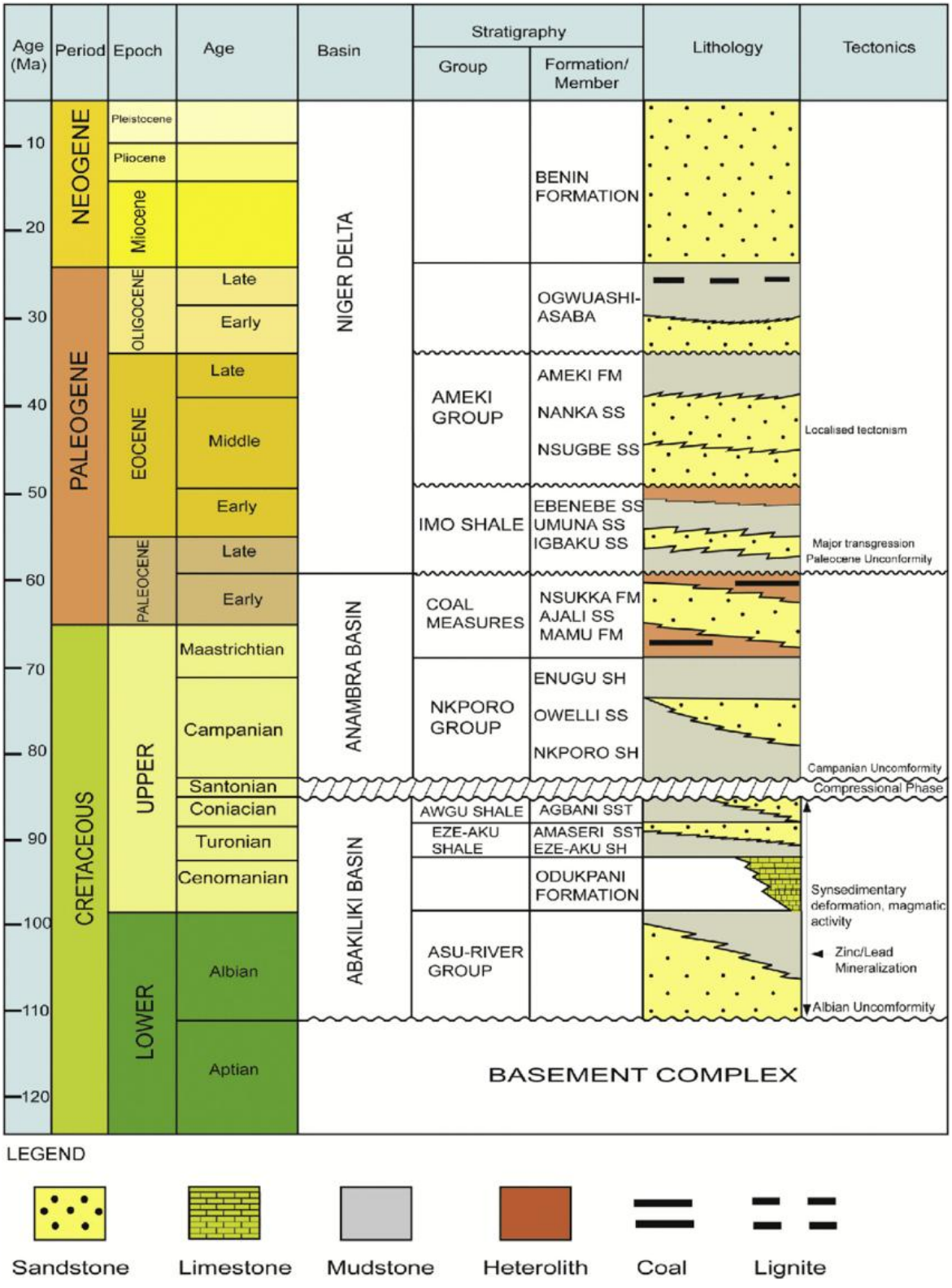


Figure 3: Stratigraphic succession of the Basins in southeastern Nigeria (Ofoegbu, 1999)

CHAPTER THREE

MATERIALS AND METHODOLOGY

The methodology adopted in this work is divided into two sections; field observations and laboratory analysis.

3.1 FIELD OBSERVATION

Samples were collected from the sandstone outcropped on the outskirts of the Ikpeshi area.

Detailed description, measurements, and sampling of profiles of the sandstone were done. A Garmin handheld global positioning system (GPS) was used to determine and Geo – reference the positions of the outcrop. Sedimentological study of sections of the sandstone involved the description and sampling of various sections and samples broken from the sandstone in situ, appraisal of the physical and biogenic sedimentary structures, and textural characterization of the exposed unit.

3.2 LABORATORY ANALYSIS

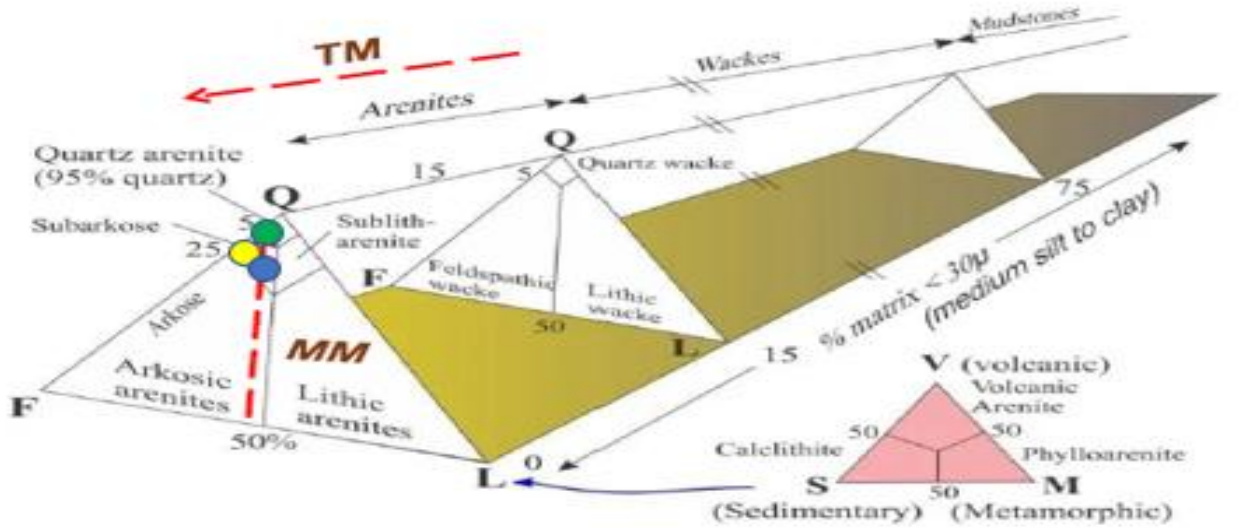
The laboratory studies carried out in this work include petrographic analysis involving thin sections petrography.

3.2.1 THIN SECTION PETROGRAPHY

Three samples were selected from the arsenal of samples for the thin section petrography, they are referred to as; Sample A, Sample B, and Sample C under the context of this work.

The samples were analyzed thoroughly using a petrographic microscope. The petrographic analysis of the samples was done using a petrographic microscope.

Classification and further description of the samples collected were done based on specific lithologic characterization of sandstones by (Pettijohn, Potter and Siever, 1951).



Classification of terrigenous sandstone, from Pettijohn, Potter and Siever, 1973, who in turn modified a diagram from R.H. Dott, 1964 (see text for references). Q = quartz, F = feldspar, L = lithics

	Sample A
	Sample B
	Sample C

Figure 4: Classification of Terrigenous Sandstone (Pettijohn, 1973)

The classification of the sandstone maturity, depositional process, depositional energy was done based on folk classification (Folk, 1951).

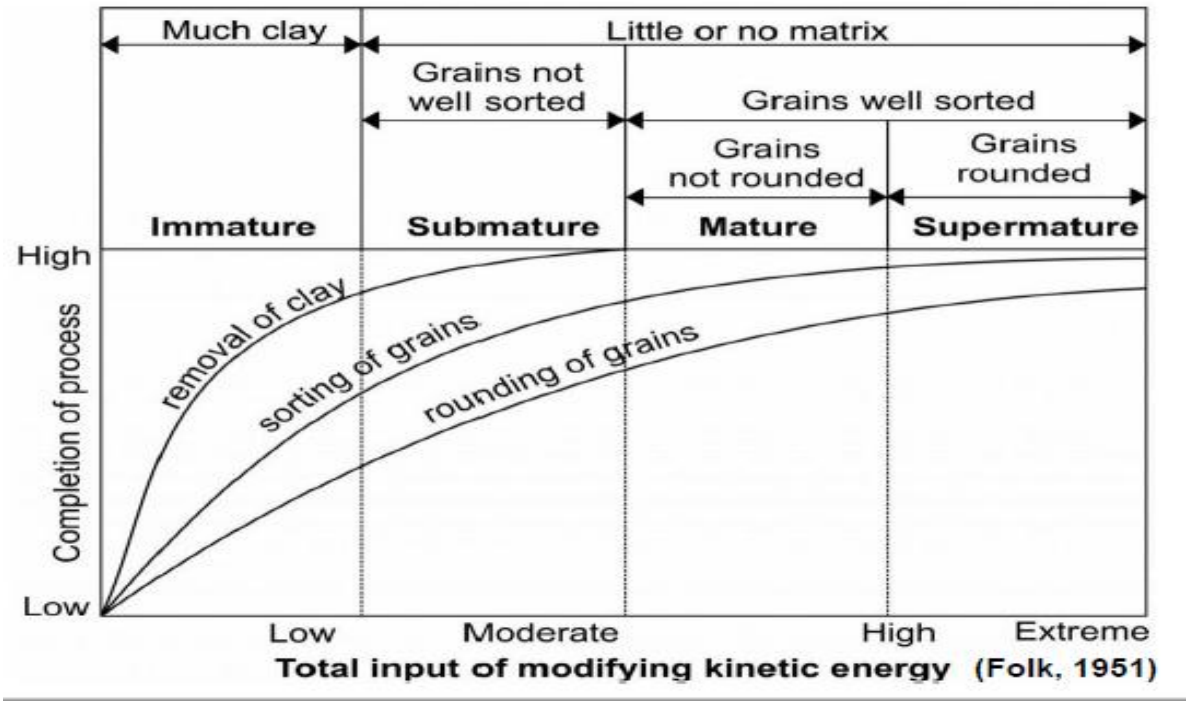


Figure 5: Sandstone Classification (Folk, 1951)

A comparator was also used to analyze and classify the samples based on the grain size, grain shape, grain arrangement (sorting) etc.

Classification of the sediment particle sizes was done based on the UddenWentworth particle size classification.

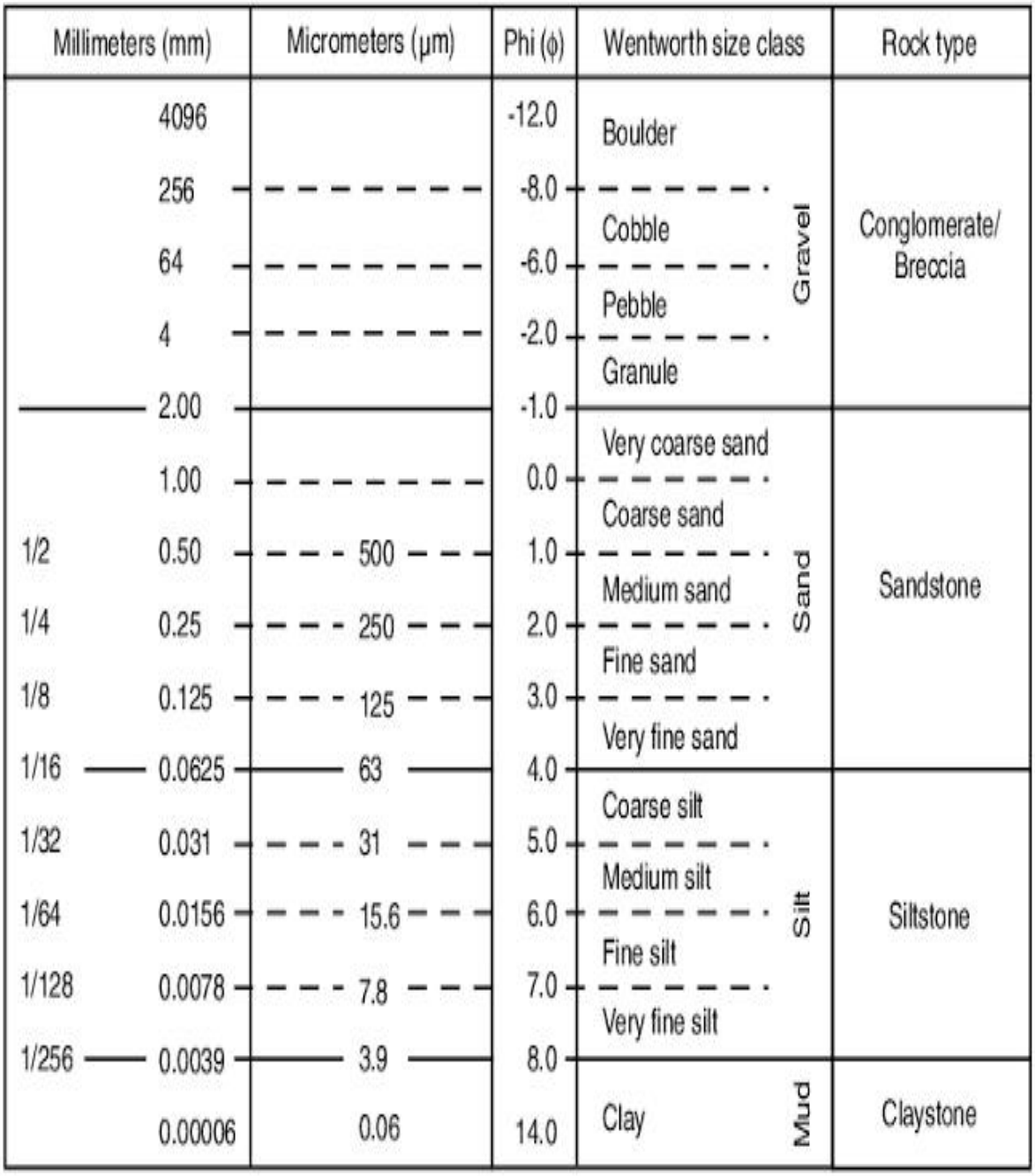


Figure 6: UddenWentworth particle size classification

CHAPTER FOUR

INTERPRETATION OF RESULT AND DISCUSSION

4.1 GENERAL DESCRIPTION OF THE STUDY ROCK FORMATION

The sandstone at the outskirts of Ikpeshi area possess specific characteristic features on which descriptions can be made, such descriptions can include the textural maturity, mineralogical analysis, provenance, the ancient depositional environment in which the rock unit was deposited.

A careful field observation and analysis was carried out on the rock units at the site of occurrence, several inferences as well as observation which was observed at the site will be discussed in details subsequently.

The rock units were observed to have been highly lithified; that is, the rock units were greatly compacted which indicates the diagenetic process which the rock must have undergone, the rock unit must have been buried at great depths and a high diagenetic process must have acted on it.

The rock units were observed to be coarse in texture, the particle size ranges from about 1mm-15mm with a dominant particle size of 2mm, under the uddenwentworth grain size classification, these particle size can be classified as coarse sands, very coarse sands, granules and even small pebbles.

The rock units was also observed to be poorly sorted, this indicates that sediments were texturally immature and have not travelled very far from their source, the grain shapes are sub-angular to angular, this also indicates the duration of sediment transport and the maturity of the sediments.

The rock units was observed to have been made up predominantly of quartz, it contains about 85% quartz 10% clay minerals and lithic

fragments account for the rest, the rock units can be termed as subarkosic which is a function of the percentage of quartz and clay minerals present in the rock units.

And finally sedimentary structures were observed to have been present in the rock units. The sedimentary structures present in this rock units include cross beddings and graded beds.

The cross beds have a thickness that ranges from about 3cm to about 5cm in thickness, the cross beds indicate the paleocurrent direction of the transporting medium which deposited the sediments.

4.2 MODE OF OCCURRENCE

The study rock formation outcrops at the outskirts of the Ikpeshi area along Benin-Auchi Road. They occur as boulders in low ridges, they appeared to have been broken up and weathered, they were found on a farmland in the area.

Figure 7: Mode of Occurrence of the rock units

4.3 TEXTURAL CHARACTERISTICS AND SEDIMENT FRAMEWORK COMPONENT

The sandstone at the outskirts of the Ikpeshi area possess specific features on which description can be made, such descriptions can include textural maturity, mineralogical analysis, provenance, and the depositional environment in which the rock unit was deposited.

4.3.1 Particle size

The particle size of the sediments was observed with the help of a hand lens and a comparator during the field observation, further physical analysis was carried out during the thin section petrography. The rock unit has a clast size ranging from about 1mm – 15mm, with a dominant clast size of 2mm, under the udden wentworth grain size classification, these particles sizes are regarded as coarse sands – very coarse sands or even small pebbles.

Figure 8: A clear photo of the rock units showing the particle size

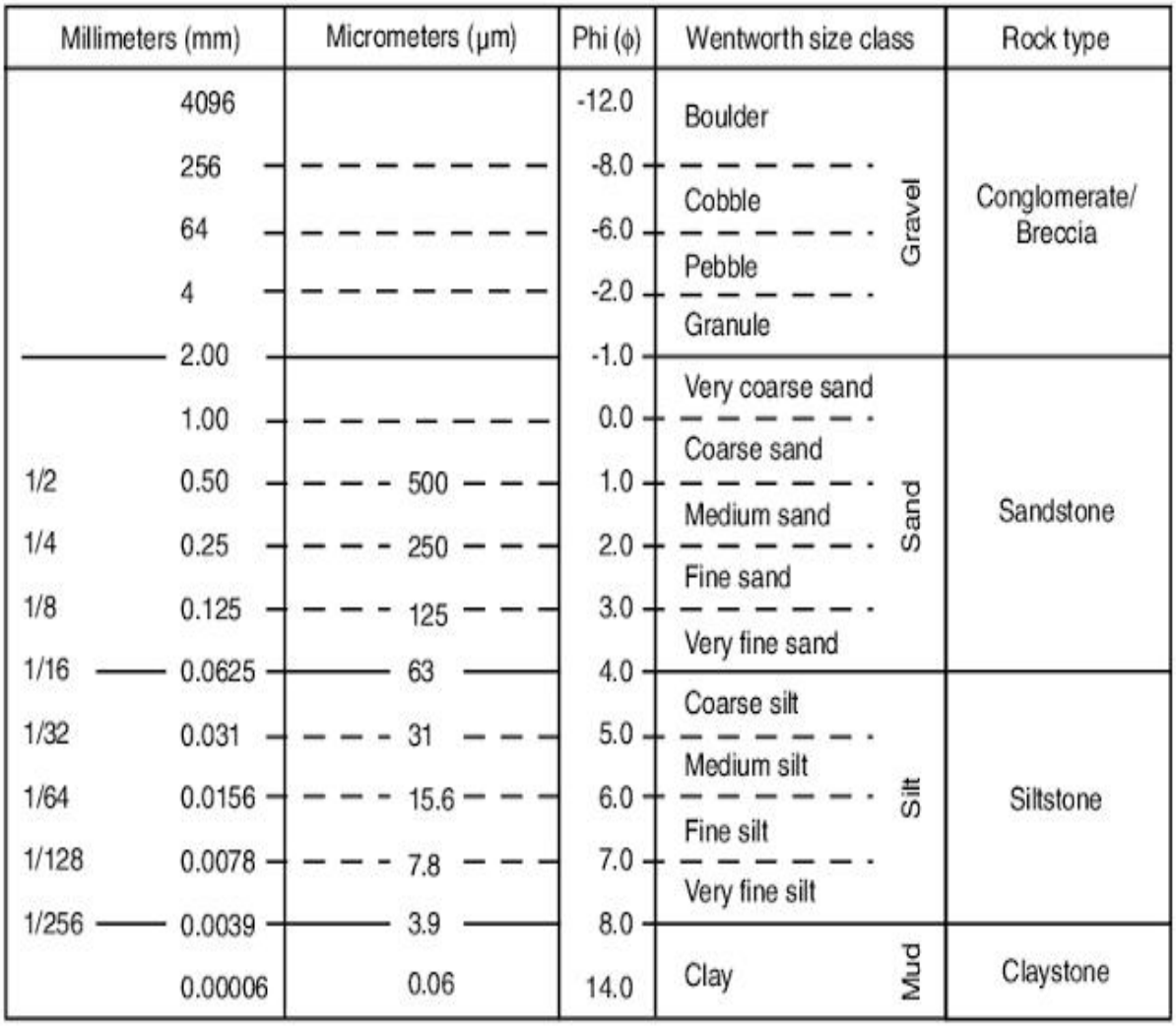


Figure 9: Uddenwentworth grain size classification

Using this particle size classification, we can infer that the rock units can be classified as sandstone which is a function of the grain size and also the grain type (sands).

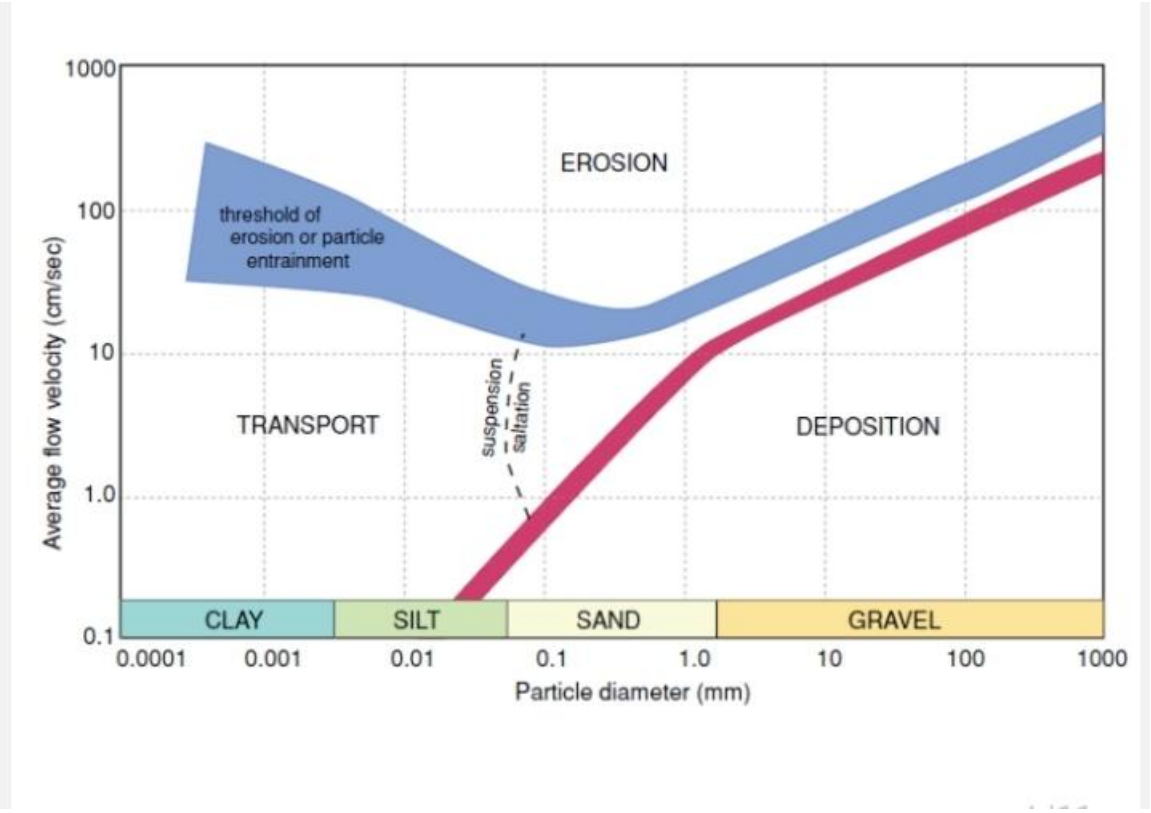


Figure 10: relationship between the particle size and the flow velocity of the transporting medium (folk, 1951)

This chart gives us an idea of the particle size in relation to the flow velocity of the transporting medium that deposited it, using data from our physical evaluation we noted that the dominant particle size in the rock unit is 2mm with this we can establish the relationship between the rock units and the flow velocity using the particle size.

4.3.2 Degree of Sorting

Sediments exposed to longer transport and weathering activities of current and waves tend to be more sorted by shape and size. The degree of sorting is dependent on the energy conditions, distance travelled and the period the weathering agents have worked on the sediments. For instance, particles of the same mineral composition that are more rounded and well sorted have travelled farther. It is important to note that in sorting of sediments, beach sands are very

well sorted, river sands are moderately sorted, and deep ocean turbidity current sediments tend to be poorly sorted.

The sorting regime of the sandstone at the outskirts of Ikpeshi area is poorly sorted.

Figure 11: A clear picture showing the sorting of the grains in the rock unit

4.3.3 Degree of Roundness

The greater the degree of roundness the farther the sediments have travelled, as sediments travel, they grind and rub against each other this result in the roundness of sediment particles. This characteristic can be used to delineate the textural maturity of the sediments or sandstone in general. The degree of roundness also infers the distance at which sediments that make up the rock unit have travelled and also their distance from the source.

The sample collected from the sandstone showed a degree of roundness ranging from sub-angular to angular.

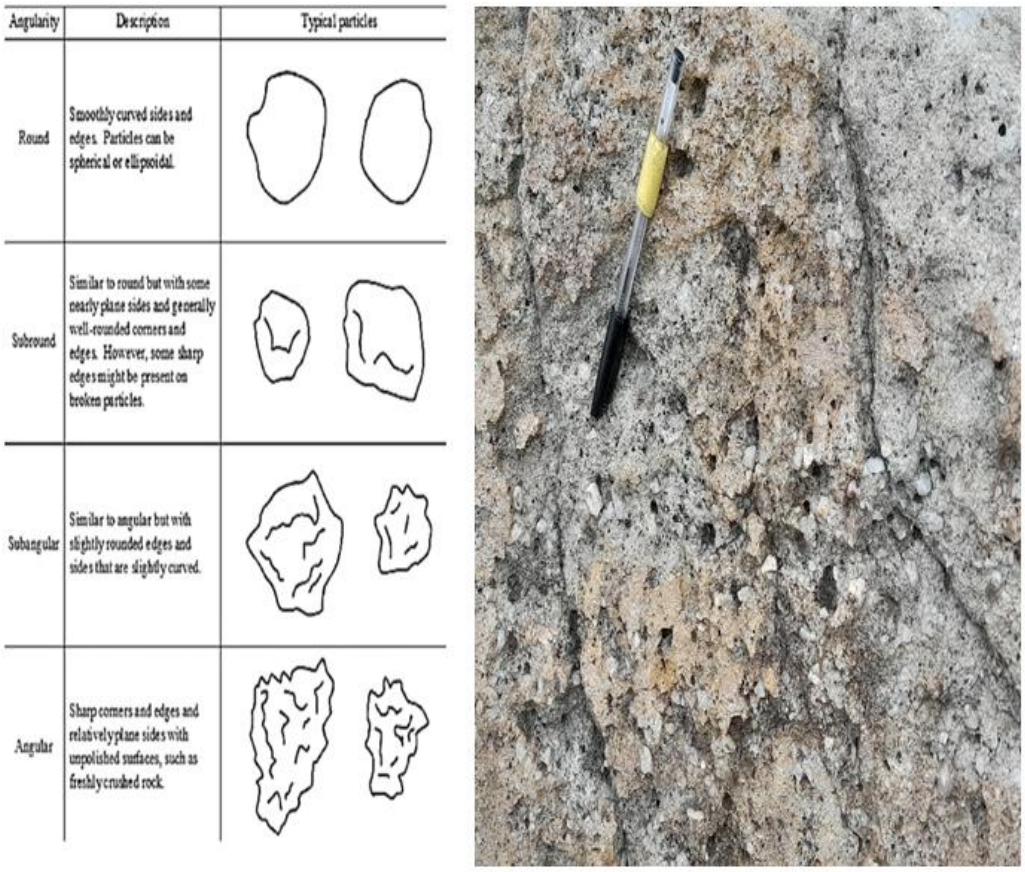


Figure 12: A clear picture showing the particle shape of the rock unit

4.3.4 Diagenetic process

The diagenetic process that occurred during the formation of these rock units resulted in the lithification of the rocks, evidence of this process can be observed in the grain contacts of the rocks, the rock units were observed to be highly compacted or lithified such that they appeared like they were crystallized hard rocks, this observation is evidence of the diagenetic process that acted on the rock. This infers that the rocks were buried at deep depths and were uplifted during major tectonic activities that occurred during the Santonian.

Figure 13: A picture showing the lithification of the rock unit

4.3.5 SEDIMENTARY STRUCTURES

Sedimentary structures reflect the depositional process associated with specific sedimentary environments (Friedman and Visher, 1975).

The sedimentary structures observed in the rock units include:

Cross Beds: the cross beds indicate the paleocurrent direction of the transporting medium that deposited the sediments, cross beds observed in this rock unit ranges from about 3cm to about 5cm in thickness.

Figure 14: A photo showing well highlighted cross beds present in the rock unit.

The rock unit was also observed to contain graded beddings which gives an idea of the sedimentation pattern of the rock unit.

4.3.6 Textural Maturity

Textural maturity refers to the length of time that sediments that make up the sandstone have been in the sedimentary cycle, sediments that have been transported farther and more frequently are termed as texturally matured. The textural maturity is determined using data from sorting, degree of roundness and feldspar content.

Table 1: Result of Textural Maturity Parameter

Result Of Textural Maturity Parameter			
Samples	Sorting	Degree of roundness	Feldspar content
Sample A	Poorly – Moderately sorted	Sub angular – angular	< 10% feldspar
Sample B	Poorly sorted	Sub angular – angular	< 15% feldspar
Sample C	Poorly sorted	Sub angular – angular	< 10% feldspar

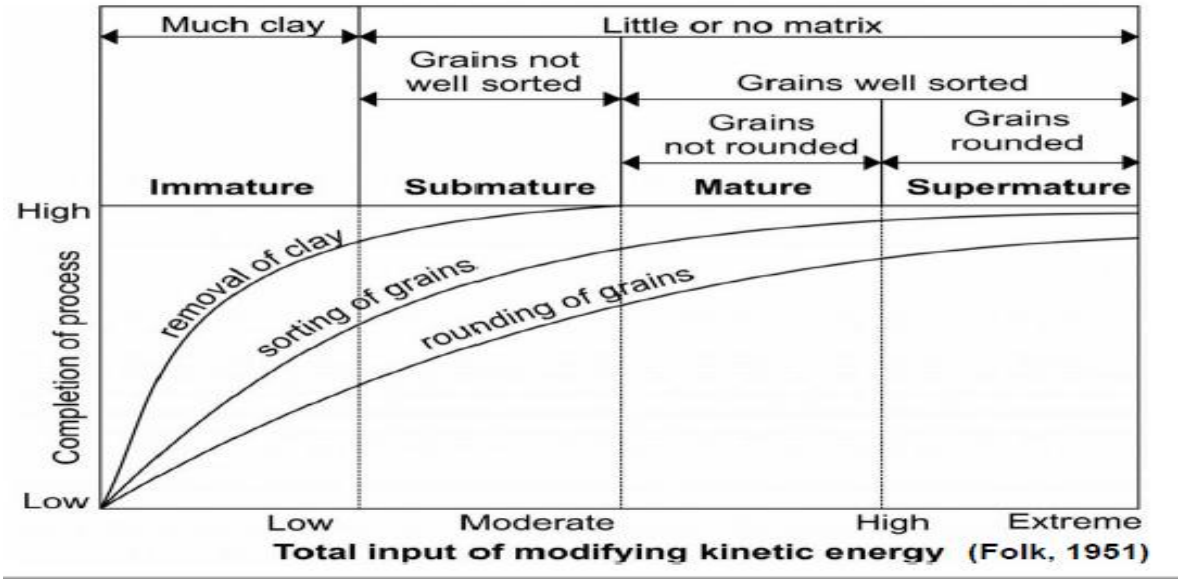


Figure 15: sandstone classification (textural maturity) modified by Folk (1951).

Using the classification above we can delineate that the rock units at the outskirts of Ikpeshi are texturally ‘immature –sub mature' and were formed as a result of low-moderate (kinetic) energy processes.

4.4 MINEROLOGICAL ANALYSIS

The mineralogy of this sandstone is peculiar, this also gives us an insight to the sedimentary processes which the sandstone has undergone over the course of its deposition. The mineral content

present in the rock serves as a guide to understanding the geology of the sandstone better. The sandstone at the outskirts of Ikpeshi are made up predominantly of quartz, minute feldspars and other minerals.

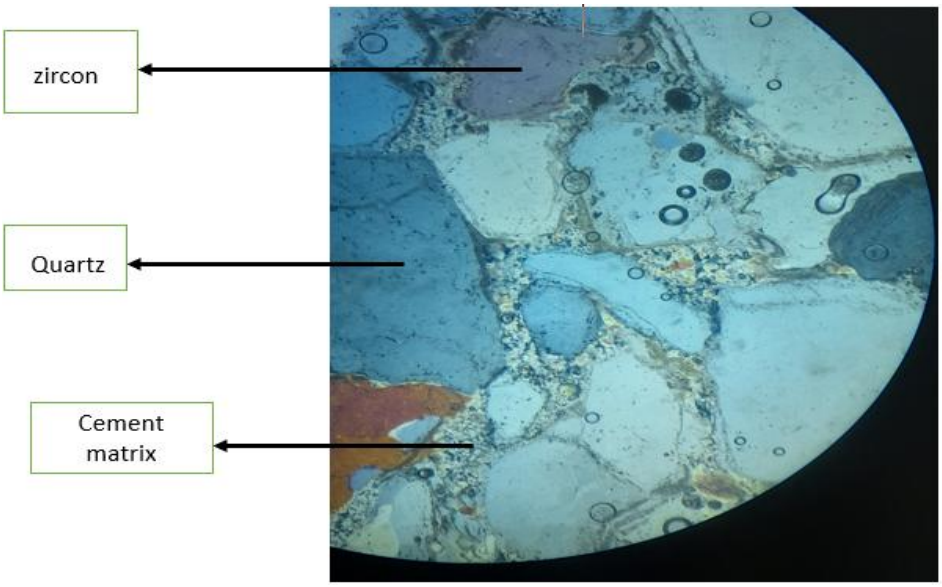


Figure 16: Photomicrograph of Sample A

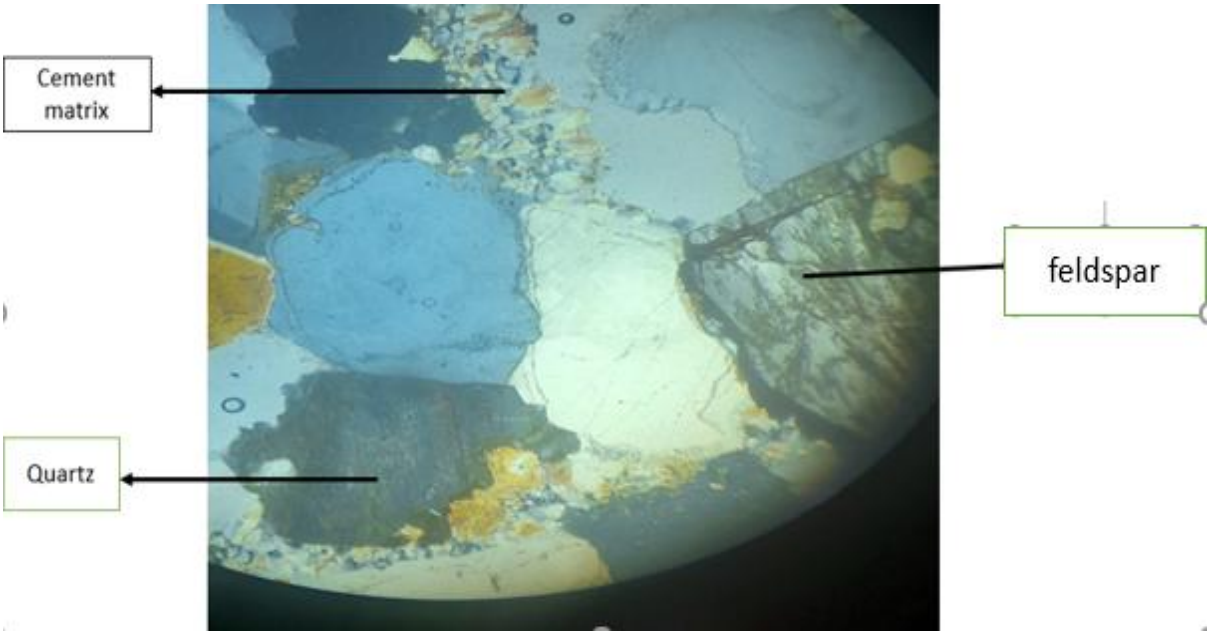


FIGURE 17: photomicrograph of Sample B

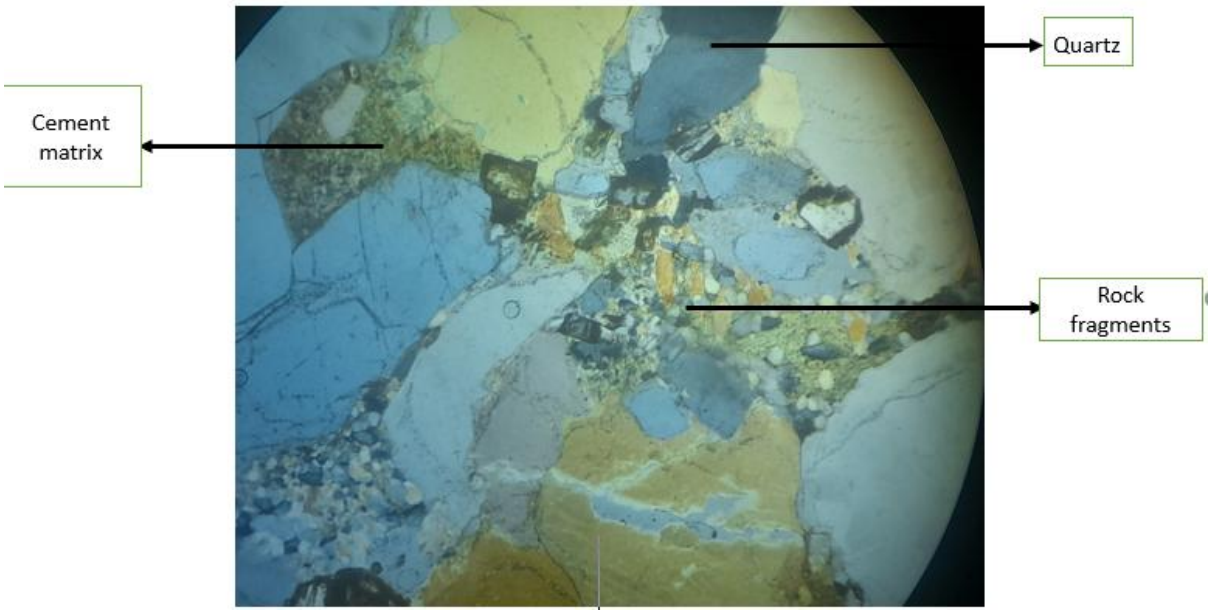


FIGURE 18: Photomicrograph of Sample C

Table 2: Mineral Composition Percentage

Framework minerals	Sample A	Sample B	Sample C
Quartz	90%	88%	85%
Feldspars	3%	8%	10%
Lithic fragments	7%	4%	5%

4.4 DEPOSITIONAL ENVIRONMENT

Lithofacies interpretation forms the basic tool for identifying the depositional condition under which the sediments were deposited and preserved.

The samples of the sandstone are observed to have been made up predominantly of sands, with little amounts of clay. The depositional

environment history of this sandstone can better be told by the textural analysis of the samples.

Textural analysis is significant in the reconstruction of the depositional environment, this is due to the distinct textural characteristics that are peculiar to specific environments this enables the formation of textural parameters which deduce change in the environment and energy conditions present at the time of deposition.

The result of the textural analysis gives an insight on the type of environment and energy conditions in which they were formed.

The sand particles present in the sandstone are described as coarse sands, very coarse sands and even small pebbles, this information tell us that the sediments were deposited in a fluvial setting, most likely carried downstream or transported by a river at high energy deposition conditions, The degree of sorting and roundness of the particle grains also support this insight.

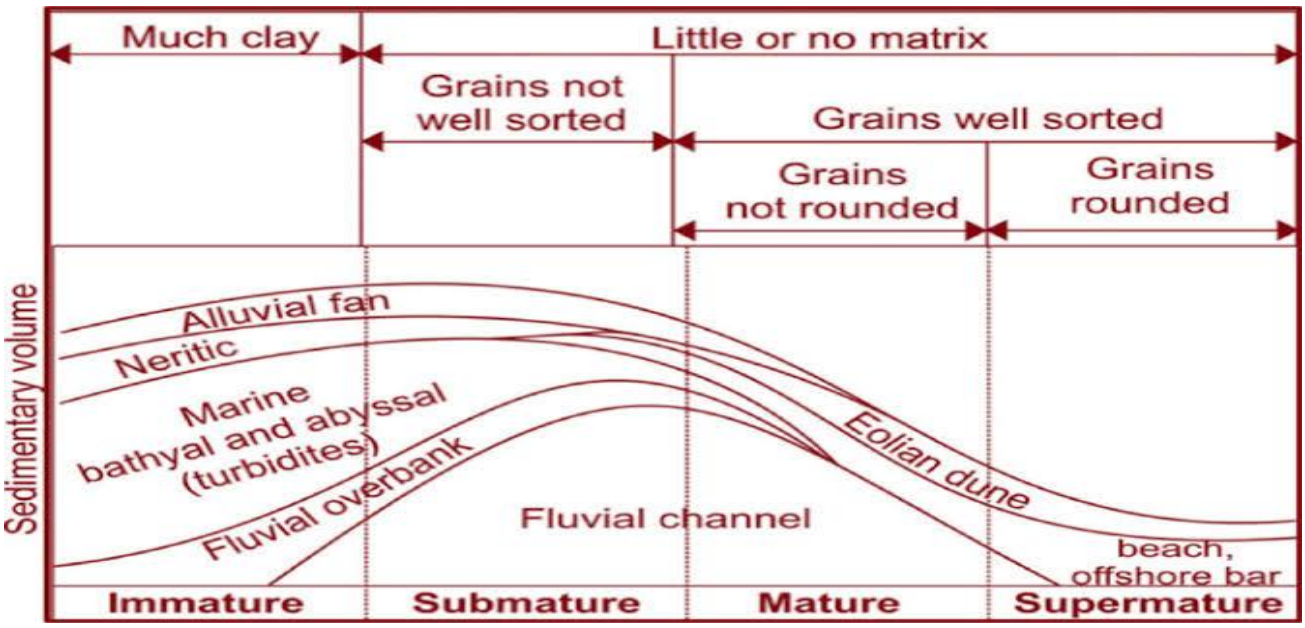
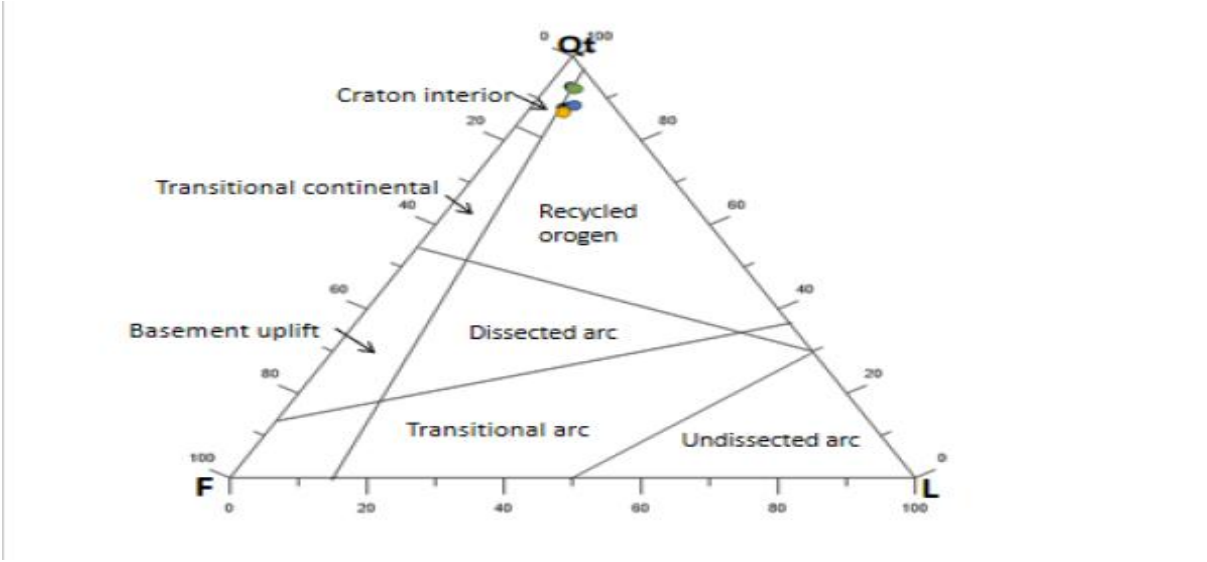


Figure 19: maturity of sandstones and their sedimentary environments modified after Folk (1951)

4.5 PROVENANCE AND PALEOCLIMATIC RECONSTRUCTION

The composition of sedimentary rocks can be used to explain the history of provenance and tectonic setting and it is a significant source of knowledge about earlier orogenic settings the mineralogical and geochemical properties of the sediment can be utilized to decipher its geologic history as the sediment composition evolves overtime.

The scope of study includes the location and characteristics of sediments source regions, the route by which sediment is carried from source to the Basin of deposition and the variables influencing the composition of sedimentary rocks (e.g., relief, climate, tectonic setting).



Q- Quartz, F- Feldspar, L- lithic rock fragment

Figure 20: QtFL ternary provenance discrimination diagram of the sandstone after Dickinson et al. (1988).

Result of the ternary plot shown above shows the sandstone having a recycled orogeny, these forms of sediments occur in a variety of tectonic environments where stratified rock are deformed, uplifted, and eroded. These environments are formed from different tectonic settings and depositional processes including the suture belts, these are zones where physically opposed sequences of both oceanic and

continental types can serve as sources of sediments for longitudinal dispersal systems that feed neighboring remnant ocean Basins as well as transverse dispersal system that feed nearby periphery foreland Basins.

Orogenic highlands also give birth to major river systems that can transport recycled orogenic sediments across the surfaces of adjacent continental blocks and into distant Basins having a variety of tectonic settings (Potter, 1978).

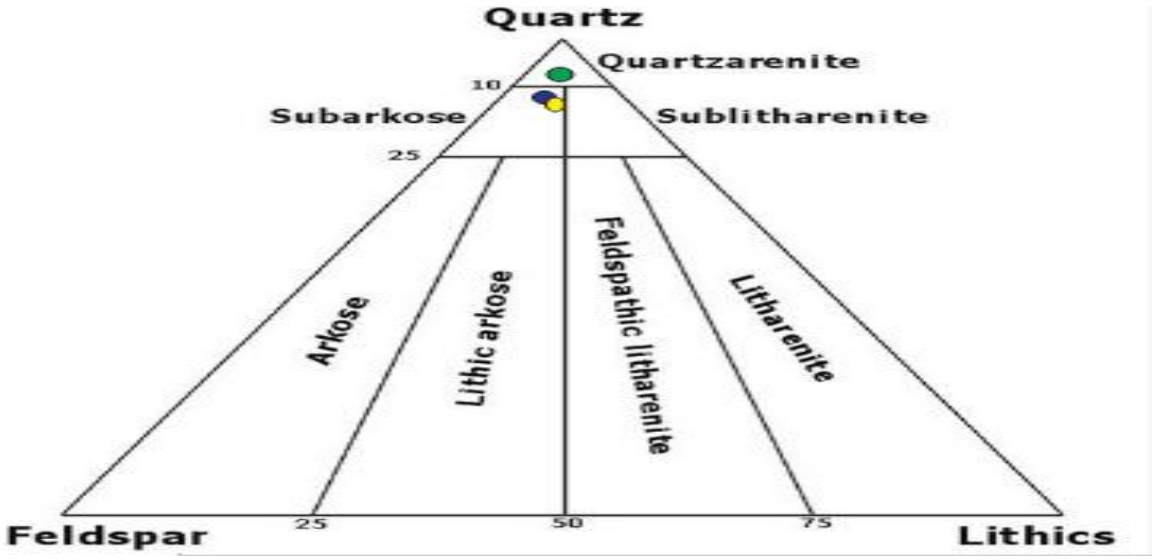
4.6 SANDSTONE CLASSIFICATION

Since it has been established that the rock unit at the study area is a sandstone, further analysis is carried out in order to classify the sandstone.

Many schemes for sandstone classification have been drawn up, some based on theoretical principles, some emphasizing on the mineral composition, and others devised empirically for convenience in field and laboratory description.

Current tendencies are to subdivide sandstones based on their mineral content, or mineral and textural attributes. None of the proposed schemes is used universally, so that care is needed when interpreting the nomenclature used by various authors. Some of the attributes of sandstone may be easily recognizable in the field, but most invariably, require confirmation by petrographic and other means.

In this work, the classification adopted is the folk sandstone classification. The amount of quartz grains, feldspars and lithic material (rock fragments) is considered.



●	Sample A
●	Sample B
●	Sample C

Q- Quartz, F- Feldspar, Lithic fragment

FIGURE 21: sandstone classification modified by Folk et al (1970)

The ternary diagram above depicts that Sample A is quartz arenite in nature while Sample B and C are sub arkosic in nature.

CHAPTER FIVE

CONCLUSION

5.1 CONCLUSION

In conclusion, this study provides a detailed analysis of the textural characteristics, mineralogical characteristics and an understanding of the other sedimentary processes such as the depositional environment and the provenance of these rock units. This work provides a well detailed insight concerning the particle size, particle shape, minerals present e.t.c.

The rock units have been established as a sandstone, containing coarse sands – very coarse sands and even small pebble sediments, the sandstone is said to be poorly sorted with a sub angular- angular degree of sorting, they were also said to be texturally and mineralogically immature, they contain about 85% quartz, about 10 % clays and lithic fragments account for the rest, this rock units were said to be sub-arkosic, that is, the rock unit is a sub-arkosic sandstone.

The sandstone outcrops in the Benin flank and it is described as “Pre-Santonian” due to its age. The sediments that make up these sandstones is suggested to have come from the Lower Benue Trough, this supported by the clear distinct textural characteristics of the sandstones in the Anambra bas in and the sandstone that is been examined.

5.2 SUGGESTION FOR FURTHER STUDIES

Series of analysis such as the Geochemical analysis, Heavy Mineral analysis should be looked at in other works, as they will further provide detailed explanation and characterization of this rock units.

More lights should be shed on the heavy mineral present in the rock, the geochemical characteristics of the rock and also the economic importance of this rock unit.

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