Geology Of Area Around Doho Sheet 152 Gombe North-West Gongola Basin Upper Benue Trough

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OCTOBER, 2012

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GEOLOGY OF AREA AROUND DOHO

SHEET 152 GOMBE NORTH-WEST

GONGOLA BASIN UPPER BENUE TROUGH

BY

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O6/18303U/1

A THESIS SUBMITTED TO THE GEOLOGY PROGRAMME, SCHOOL OF SCIENCE, ABUBAKAR TAFAWA BALEWA UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF TECHNOLOGY (B. TECH) HONOURS IN APPLIED GEOLOGY

OCTOBER, 2012

CERTIFICATION

This thesis entitled: " GEOLOGY OF AREA AROUND DOHO, SHEET 152 GOMBE NORTH-WEST GONGOLA BASIN UPPER BENUE TROUGH" by Abdulmalik Muhammad meets the regulation governing the award of Bachelor of Technology Degree (B.Tech) in Applied Geology of Abubakar Tafawa Balewa University Bauchi, and is approved for its contribution to knowledge and literary presentation.

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Sign.......................... Date:.....................

External Examiner

DECLARATION

I hereby declare that this thesis was written by me. It is a record of my own research; it has not been presented in any previous application for a degree etc to the best of my knowledge.

Sign..................................... Date: 1/11/2012

ABDULMALIK MUHAMMAD

Sign................................ Date:........................

DR. NK Samaila

Project Supervisor

DEDICATION

This project is dedicated to my siblings Umar Muhammad, Abubakar Sadiq Muhammad, Zuwaira Muhammad, and Halima Sadiya Muhammad, then to my father Mallam Muhammad Musa and to the loving memory of my late mum Salamatu Muhammad. I love you all.

ACKNOWLEDGEMENT

First I would acknowledge ALLAH (S.A.W) for bestowing his grace and mercy on me and in seeing through this project. I would also acknowledge the effort of my parents Muhammad Musa and Salamatu Muhammad for their moral and financial support towards my academic carrier. I am highly indebted to them.

My sincere gratitude goes to my supervisor Dr. NK Samaila for his tireless effort in being with me at the field guiding and exposing me to various field mapping techniques. And also for his constructive criticisms, support, advice and useful corrections rendered during the course of this project. I say thank you and God bless you.

I would also acknowledge the effort of all the lecturers of geology program like Professor E.F.C Dike, Professor D.M Orazulike, Dr A.I Haruna, Dr M.B Abubakar, Dr A.S Maigari, Mal M.T Isa, Mal Ahmadu Tukur, and Mal Abdulateef for teaching me the salient part of geology.

My appreciation goes to my friends especially Umar Hassan for working with me at the field, and Musa Akor for his contribution one way or the other towards the success of this work. My gratitude also goes to Engr Sadiq for his moral and financial support towards the success of this project. I will never forget the contribution of Mallam Umar (Baba Amirah) for his financial assistance rendered towards the success of this work.

I would also acknowledge the effort of my well wishers, colleagues like Ameh Peter, Abdulmajid Isa, Nurudeen Abdulhameed and neighbors like Kamal alias Samaru, Olokoba, Aji Muhahammad, Jibo all of Ijetu Villa Sabon Kaura for their assistance in one way or the other towards the success of this project. May Allah reward you all.

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ABSTRACT

The geologic field mapping exercise carried out at Doho reveals that the rock unit exposed in the area are the Gombe Sandstone. Two members of the formation namely: the Lower Gombe and Upper Gombe Sandstone were mapped in detail. The sandstone consists of some sedimentary structures such as cross-bedding and some bioturbations. Petrographic studies shows that the sandstone is mineralogically composed of quartz, feldspars, micas, opaque mineral, with quartz having the largest percentage of the rock composition. Granulometric analysis of the sandstone reveals that the lower member of the Gombe Sandstone are generally fine to medium grained, moderately well sorted, fine skewed, and leptokurtic sandstone. The Upper members are generally coarse to very coarse grained, poorly sorted, near symmetrically skewed and mesokurtic sandstone.

CHAPTER ONE

1.0 INTRODUCTION

HISTORICAL REVIEW OF SEDIMENTOLOGY

Sedimentology is the branch of geology that deals with the study of sediments both lithified (sedimentary rocks) and unlithified, and the processes by which they were formed. The term sedimentology was first used by A.c. Trowbridge in 1925 (Waddell, 1933) but did not come into usage until the 1950s.The word sediment is derived from the Latin word sedimentum meaning settling. An interest in sedimentation and the origin of sedimentary rocks dates back to the very beginnings of geology.

Many scholars have contributed to the foundation of modern sedimentology. Among these scholars are Leonardo Da Vinci, James Hutton and Smith. By the end of the nineteenth century, the principle of uniformitarianism was firmly established in geological thought. The work of Sorby (1853) and Lyell (1850) showed how modern processes could be used to interpret ancient sedimentary textures and structures.

Throughout the 1960's the main focus of research was directed towards understanding of sedimentary processes by studying the bed forms and depositional structures in the field and in the lab.

With the result of field and laboratory analysis, one can accurately interpret the environment of ancient sedimentary rock.

1.1 LOCATION AND ACCESSIBILITY

The study area is located within the Kwami Local Government Area of Gombe State, few kilometers away from Gombe town around Doho village. It covers a land mass of twenty five square kilometers (25) km^2.

The area is bounded by latitude (10^0 25' 0", 10^0 28' 0") N and longitude (11^0 12' 00", 11^0 15' 0") E, sheet 152 Gombe NW map of the geological survey of Nigeria.

The area is easily accessible by foot with a single tarred road through the area. Accessibility through the area is also enhanced by several foot paths and stream channels. Generally accessibility to the outcrops is easy.

1.2 AIMS AND OBJECTIVES

The main objectives of the study include the following:

- To understand the general geology of the area.
- To deduce the mode of deposition of sediment in the area based on sedimentological and petrological analysis.

- To acquire skills and techniques for geological mapping, field data acquisition and interpretation.

1.3 CLIMATE AND VEGETATION

The area like other parts of Nigeria has two (2) different seasons; the rainy seasons and the dry season. The rainy season is usually longer and associated with intermittent heavy down pours in the month of July and August. The season begins around late April and ends around September/October.

The shorter dry season lasts from November to March. It is usually accompanied by cold and dusty harmatan wind. During the period, temperature drops from 31^0 to about 21^0C. This season covers the months of November to early February and sometimes extends till March. The vegetation cover is predominantly made up of short shrubs and short grasses.

1.4 SETTLEMENT AND LAND USE

The people living in the study area are mostly Tera tribe, but other ethnic groups such as Fulani and Hausas also live in and around the study area.

The major land use is farming. The farmers practice maize, groundnut, beans and millet cultivation. Cattle rearing are also very common among the Fulanis.

1.5 SOME PREVIOUS GEOLOGICAL WORK

Carter et al (1963) provided the foundational work on the geology of the Upper Benue Trough. The obvious influence of strike-slip tectonism on its cretaceous history has been reported by Benkhelil (1989) and Guiraud et al. (1989).

Detailed lithostratigraphical and structural study on the cretaceous geology of the Gongola Basin of the Upper Benue Through have been documented by (Zarborski et al 1997; Zarborski 1998). Zarborski (2003) presented a summary of the cretaceous geology of the Upper Benue Through, North-eastern Nigeria.

Abubakar MB (2006) presented a detailed biostratigraphy, paleoenvironment and organic geochemistry of the Gongola basin of the Upper Benue Trough.

Dike (1993) show that there is a rapid change in facies of the Keri-Keri Formation from one Keri-Keri basin to the other.

CHAPTER TWO: LITERATURE REVIEW

2.0 GEOLOGIC SETTING OF THE BENUE TROUGH

The Benue Trough originated from the Cretaceous rifting of the Central West African basement uplift. It forms a regional structure which is exposed from the northern frame of the Niger Delta and runs east-wards for about 1000 km to underneath the Chad basin where it terminates. (Benkhelil, 1989).

Benue Trough is divided into Upper, Middle and Lower. The Upper Benue Trough bifurcates into a S-W trending Yola Arm and N-S trending Gongola Arm (Fig1). Carter et al (1963) produced the foundation on the geology of the Upper Benue Trough.

Zambuk Ridge is referred to the general area between the Yola Arm and Gongola Arm, a zone characterized by a number of important NE – SW trending sinistral strike slip fault. The origin of the formation and evolution of the Benue Trough is related to the opening of South Atlantic Ocean were probably partly controlled by pre-existing structures of the West African Shield, Benkhelil (1989).The Benue Trough lies on the Nigeria Basement Complex that belongs to the rejuvenated Pan-Africa Mobile Belt.

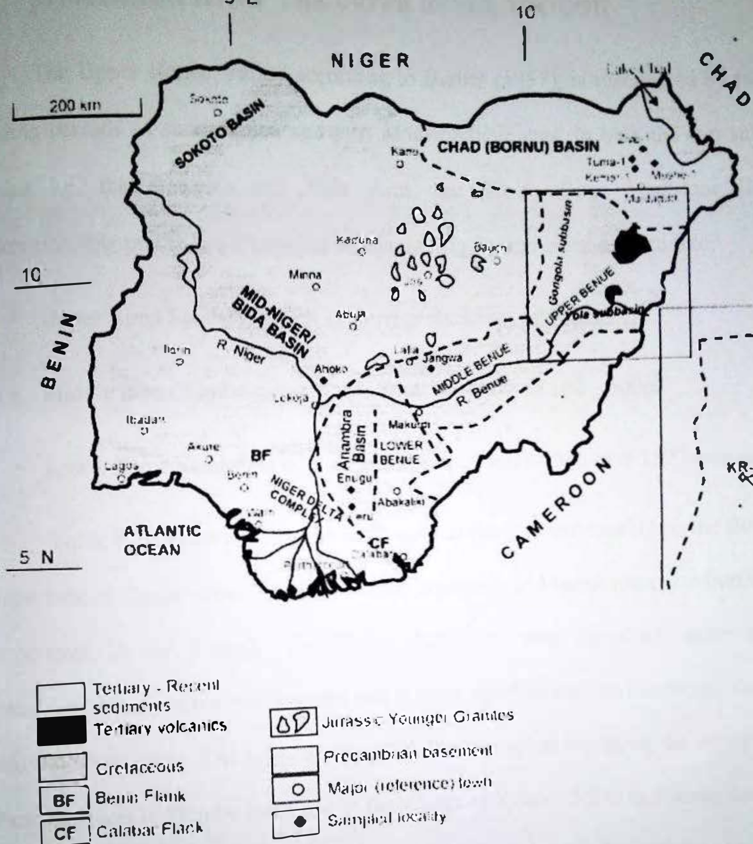


Fig. 1. Sketch geological map of Nigeria showing the inland Basins.

2.1 STRATIGRAPHY OF THE UPPER BENUE TROUGH

The Upper Benue Valley according to Barber (1957), is recognized by two folding periods of cenomanian and post Maastritchian ages, in both the two sub-basins i.e. the Gongola and Yola Arm, the Albian Bima Sandstone lies uncomfortably on the pre-Cambrian basement (Fig. 2) and is subdivided into;

- Upper Bima Sandstone with an average thickness of 500m.
- Middle Bima Sandstone with an overall thickness of 100 – 500m.
- Lower Bima Sandstone with an average thickness of 0 to over 1500 meters.

Yolde Formation is Cenomanian in age and lies uncomformably on the Bima Sandstone of Cenomanian, it represents the beginning of Marine incursion into the uppermost Benue Trough. The Yolde Formation was deposited under the transition/costal marine environment and is made up of sandstone, limestone, shale and mudstone units. The type locality of Yolde Formation are along the valley of Pantami River in Gombe town and in the village of Yolde , 50km to Numan town. In the Yola Arm of the Basin, the Dukkul, Jessu, Sekuleye Formations, Lamja Sandstone and Numanha shales are of the Turonian – Santonian equivalent of the Pindiga Formation.

The Turonian – Santonian deposit of the Yola Arm is lithogically and paleo-environmentally similar to those in the Gongola Arm except Lamja Sandstone, the type locality of the Dukkul Formation is in the village of Lakun.

In the Gongola Arm Sub-basin, the equivalent Gongila and Pindiga Formations plus possibly younger Fika Shales lies uncomformably on the Yolde Formation. These Formations represents fully marine incursion into Upper Benue Trough during Turonian to Santonian age.

Lithologically, these Formations are characterized by dark carbonaceous limestone and shales intercalating with pale coloured limestone, sandstone and shale. The typical locality of Gongila Formation is at the quarry of Ashaka Cement Factory at Ashaka village. Fika shale is composed of bluish-green carbonaceous limestone.

Santonian was a period of deformation and folding in the whole of Benue Trough, post folding sediments are represented by the continental Gombe Sandstone of Maastrichtian age and the Kerri-Kerri Formation of Tertiary age. The type locality of the Gombe Sandstone is along the bank of Pantami River in Gombe town. Good exposures of Gombe Sandstone are found in the study area and also found at Birin Fulani village.

2.2 BASEMENT COMPLEX

The entire sedimentary unit of the Upper Benue Trough lies over the Basement Complex of the Pre-Cambrian age (Fig2). It is also referred to as Older Granite and composed of migmatite, manzonite, chanokite, diorite, gneiss of late Achaen and Pan-African ages of 2.5Gg and 600Ma respectively (Dada 1980, 1983 and 1985). However, the tertiary volcanic intruded Basement Complex in various locations.

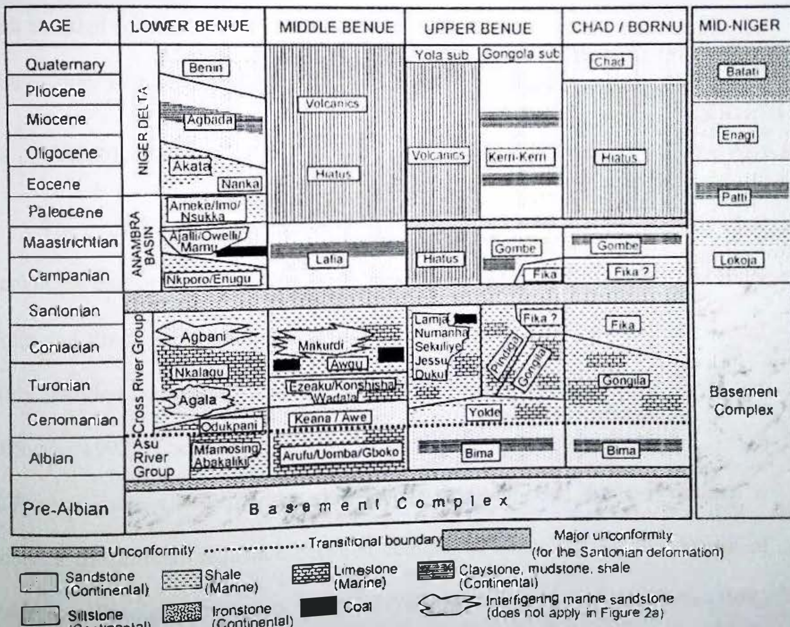


Fig.2. Stratigraphic succession in the Benue Trough, Nigerian sector of the Chad Basin, the Mid Niger Basin and the relationship with the Niger-Delta.

2.3 BIMA SANDSTONE

The Bima Sandstone comprises the oldest sediments in the Upper Benue Trough. It directly overlies the crystalline basement rocks. Its type section is at Bima Hill in the Lamurde anticline, Falconer (1911), Carter et al (1963). Other description of Bima Sandstone were also provided by Popoff (1986, 1989) but the most detailed account of it was provided by Guiraud (1990, 1992) who categorized it into Upper Bima (B3), Middle Bima (B2) and Lower Bima Sandstone (B1).

2.4 YOLDE FORMATION

The name "Yolde" was proposed by Carter et al (1963) for the transition bed recognized earlier by Falconer (1911) and Barber et al (1954) between the Bima group and Pindiga Formation. It directly overlies Bima Sandstone and consists of thinly bedded sandstone followed by alternating mud and shaly limestone (Offodile, 1992). The most complete section of Yolde Formation is found at N – W of Ruwan Kuka village nearly 1500 meters exposed. The Yolde Formation is indeed a transitional sequence between continental Bima and marine deposit of lower part Pindiga Formation, Lawal (1982) with Lawal and Maulade (1986) suggest late Albian to Cenomanian age for Yolde Formation.

2.5 PINDIGA FORMATION

The name "Pindiga" Formation was proposed by Carter et al (1963) for the Calcareous bed and clays and shale previously by Barber et al (1954). It directly overlies the Yolde Formation and make up a greater part of Upper Cretaceous deposit in the Upper Benue Trough, the type section of this Formation is in the Pindiga stream and it is of Turonian-Cenomanina age and in marine sequence consisting of fossiliferous limestone and shale together with sandstone intercalated with siltstone, Benkhelil (1985).

Pindiga Formation is divided into Gongila and Fika Formation by Carter et al (1963) while Zarboski et al (1997) sub-divided it into:

- Kanawa Formation
- Deba-Fulani Formation
- Dumbulwa Formation
- Gulani, and
- Fika Formation.

2.6 GONGILA FORMATION

The Gongila Formation makes up the Marine Upper Creteceous deposit in the Chad Basin of Carter et al (1963). It was first described by Falconer (1911), Reburns and Jones (1934) included in there limestone-shale outcrop group. The base of the formation is defined by the first appearance of real marine sediments conformably above the less developed Yolde Formation.

This type section of the Gongila Formation is a small hill side near Gongila village, carter et al (1963). However, the better developed section of this very formation is seen in the limestone quarry of the Ashaka Cement Factory at Ashaka village (Obaje et al 1999).

2.7 GOMBE SANDSTONE

Gombe Formation was proposed by Carter et al (1963) for the Gombe grits and clays previously identified by Falconer (1911). It varies from few millimeters to few centimeters in thickness. It overlies the Pindiga Formation in the stratigaphic sequence and it is a flat lying alternating thinly bedded fine to medium grained ferrogenised sandstone. Thin coal beds occur in localized areas and this has been dated as Campanian – Maastritchian. The depositional environment of this Formation is Deltaic to continental (Offodile, 1975).

There is a marked angular unconformity between Gombe Sandstone and Kerri-Kerri Formation and underlained by Fika Formation.

In outcrops many of the sandstone and mudstone are extensively ferruginised and the highly indurated beds form low grade iron stones which is responsible for the rugged and hill topography characterizing most of the outcrops (Zaborsky et al. 1997). In the Sub-surface, the Gombe Sandstone extends to the west beneath most of the Kerri-Kerri Basin (Dike, 1995).

Zaborsky et al (1997) differenciated the Gombe Sandstone into three lithofacies. These facies are:

- At the base the Gombe Sandstone consist of rapidly alternating thin beds of silty shales and fine to medium grained sandstone with some intercalated thin flaggy iron stone with individual bed thickness varying from few millimeters to centimeters. Bioturbation is common in this facies, mainly horizontal feeding *Thalassinoides* type, though rare vertical burrows also exist.
- Going upward, the sandstone bed become more consistent and constitute what is termed "the bedded facies". This second lithofacies consist of regularly bedded, fine to medium grained quartz arenites with interbedded with silty clays and flaggy iron stones. Individual beds vary from few centimeters to over

one meter in thickness. The latter beds are characterized by internal lamination. Occasional horizontal burrows are found in this lithofacies.

- The upper part of the Gombe Formation is termed "the red sandstone facies". It is composed of brick red coloured sandstone, though sometime grey or white. In the lower part of the facies the sandstones are fine to medium grained and generally show tabular cross-bedding. Higher up in the facies, the sandstones are medium to coarse-grained and show large scale tabular cross-bedding. Pebbly lags frequently occur along forsets and bottom sets. Purple and light grey shaley mudstones are interbedded.

The Gombe Sandstone was interpreted by carter et al (1963) as a sequence of estuarine and deltaic sandstones. This was further supported by Ojo et al (1999) where high diversity of Nypo-like pollen of *Echimonocolpites* and *Spinizocolpites* type of pollen and spore suggest estuarine conditions similar to mangrove , swamps.

Zarbosky et al (1997) interpreted the basal transition facies as probably prodeltaic facies the red sandstone facies as fluvial while the bedded facies are shallow marine perhaps deposited in hypersaline sea.

An Upper Maastritchian age first attributed to the Gombe Sandstone by Carter et al (1963) has been confirmed by Lawal (1982) who found a marked decrease in marine micro-fossils (foraminifera, dinoflagellates, and arcritarchs) at the boundary of Pindiga Formation and the Gombe Sandstone. The pollen of the later indicated Mastritchian age.

Coals are intercepted at shallow depth of about 15-35m in Gombe area. The seams are generally thin, though one seam was reported to be up to 2m thick (Offodile, 1979; Obaje et al, 1999) thus confirming earlier claims by Carter et al (1963) on the occurrence of coal within the Gombe Sandstone. The Sandstone dips to the North-west with varying amount of dip from 7° to 12° (Thompson, 1958).

2.8 KERR-KERRI FORMATION

The Keri-Keri Formation unconformably overlies Gombe Sandstone with an estimated thickness ranging from few meters to about 300meters. (Dessanvasic, 1975) and Dike (1993), the depositional environment of the Keri-Keri Formation is fluviatile to lacustrine.The Ker-Keri Formation is made up of whitish grey sandstone, siltstones and clay stones with the clay stones dominating the lithology in most places. Typical sections are exposed in Gombe Abba, in Duku and Alkaleri.

CHAPTER THREE

3.0 METHODOLOGY

A dual phase data acquisition methodology was adopted. These methods are the mapping and laboratory techniques.

3.1 FIELD METHOD

The field method is a geological work that is targeted at describing the rock types and other structural features. The field methods was carried out in two ways.

- A reconnaissance survey was done to establish the extent of the study area and strategy to be employed during the field study.
- A detailed geological field mapping along streams channels, road cuts, and on outcrops.

Observations and description were made on the rock types in terms of colour, grain sizes, mineral composition, sedimentary structures and fossil content. The global positioning system (GPS) was used to determine accurate sample location. Orientation of structural features such as fracture and jointing were systematically measured and mapped with the aid of the compass clinometers. Representative sample of Gombe Sandstone at different locations were collected and labeled for laboratory analysis.

Good exposures were logged and drawn to scale. The field equipment used were hammer, compass, hand lens, G.P.S. and measuring tape.

3.2 LABORATORY METHODS

The representative samples obtained from the field were subjected to both granulometric and petrographic analysis.

3.2.1 GRANULOMETRIC ANALYSIS

Granulometric analysis was conducted only on the sandstones collected during the field work. This was used to determine their grain size distribution.

A total number of five (5) samples were selected and were carefully disaggregated using a mortar and a pestle. Initial weight of 100g of each disaggregated samples was placed in a standard set of sieves arranged in an increasing mesh size from bottom to top. The mesh sizes of sieves used from top to the bottom respectively are; 4.75mm, 3.35mm, 2.36mm, 1.18mm, 0.850mm, 0.425mm, 0.300mm, 0.212mm, 0.106mm and 0.063mm. Each sample was sieved for a period of 15 minutes using a mechanical shaker after which the individual weight retained on each of the sieves was obtained using a highly sensitive digital balance. The values of individual weight and cumulative weight percent were computed and tabulated.

Cumulative frequency curve and histograms were plotted for each sample. The values of standard deviation, graphic mean, kurtosis and skewness were calculated from the cumulative frequency curves.

3.2.2 PETROGRAPHY

A total of four (4) rock samples were selected from the samples obtained in the field and thin sectioned for petrographic studies in the laboratory.

The thin section preparation of the samples was based on the method described by Ireland (1971). Both friable and consolidated sample was used.

The friable samples were initially impregnated prior to cutting, in order to harden the sample. The samples were each mounted with the polished side on a glass slide using Canada balsam. The mounted sample was ground initially with a coarse abrasive and later with sludge of fine abrasive on a glass until the slide was fine or thin enough for individual mineral identification. The prepared thin sections were then examined under a flat stage petrographic microscope under both plane and cross- polarized light. Modal compositions of the mineral were determined by point counting. Mineral identification was based on the optical properties of the mineral.

Photomicrographs of the slides were taken to clearly show the mineralogical composition of the rock samples.

CHAPTER FOUR: PRESENTATION OF RESULT

4.1 LITHOFACIES

The Gombe Sandstone is typically fine to medium and coarse grained with colours ranging from brown, red, brick red whitish and purple. The lithologic units recognized in the study area are basically the Red Sandstones, Fine Grained Sandstones, Coarse Grained and the Pebbly Coarse- Grained Sandstones. Within the Pebbly Coarse Grained Sandstone are interbedded purple mudstones.

Bioturbation is very prominent especially in the fine grained sandstones. Bioturbation also occurs in the Red Sandstone Facies and the Coarse Grained Sandstone Facies. These bioturbations are mostly horizontal burrows of *Thalassinoides* type. Vertical burrows of *Skolithos* also occur but not as frequent as the horizontal burrows.

From the lithofacies studies in the area, the following facies were recognized:

i. The Medium to Coarse Grained Red Sandstone Facies

ii. The Fine Grained Sandstone Facies

iii. Inter-bedded Fine Grained Sandstone with Shales Facies

iv. The Pebbly Coarse Grained Sandstone Facies.

v. Fine Grained Siltstone Facies

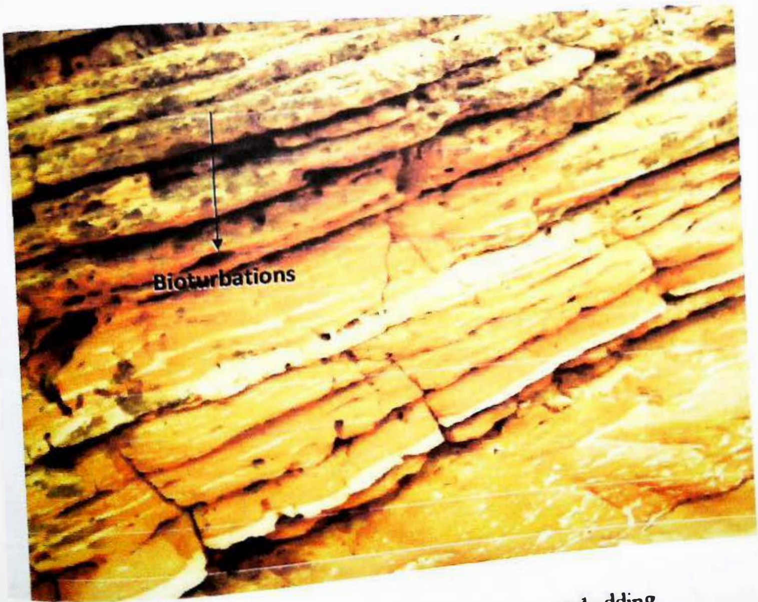
4.11 The Medium to Coarse Grained Red Sandstone Facies

These facies is reddish in colour and is highly bioturbated. It is usually associated with highly weathered cobles and boulders. These highly weathered rocks constitute the rugged hilly topography of the study area. The bedding surfaces of the Red Sandstone Facies are hardly exposed in most areas, but where they are exposed, their dipping amount rarely exceed 8^0. This facies is illustrated in Fig.3 below.

Fig.3 Medium to Coarse Grained Red Sandstone Facies.

4.12 The Fine Grained Sandstone Facies

This facies is brick red in colour, fine grained and is highly bioturbated. The bioturbations of this facies is basically horizontal burrows of organisms. The Fine Grained Sandstone Facies show a large scale planar cross bedding and constitute the major outcrop exposed in the Doho stream. This facie is illustrated in the Fig.4 below.



F ig.4 Fine Grained Sandstone Facies showing planar cross-bedding.

4.1.3 Interbedded Fine Grained Sandstone with Shale Facies

This facies is also exposed in the Doho stream. The shales are highly fissile. They are whitish, purple or pinkish and occur either as thin beds or massive beds within the fine Grained Sandstones. These facies are illustrated in the fig.5, fig.6, fig.7 and fig.8 below.

Fig.5 Thin shales interbedded with fine grain

Fig6. Thin shale bed

Fig.7 Thick shale bed within fine grained sandstone

Fig 8. Thick shale bed

4.1.4 Fine Grained Siltstone Facies

This facies is brick in colour with a thickness of about 1.2 meters. This facies is also moderately well sorted and shows little bioturbations. Also the Fine Grained Siltstone Facies are horizontally bedded and often shows erosional surfaces. This facies is illustrated in the Fig 9 below.

Fig 9. Fine Grained Silstone Facics, showing some erosional surfaces.

4.1.5 Pebbly Coarse Grained Sandstone Facies

This Facies are brownish to pinkish in colour with intercalation of mud stones in some part. The Pebbly Coarsed Grained Sandstone Facies is often associated with clay clast. (paraconglomerate). The thickness of this facie is over 3 meters. This facies are exposed along major road cut in the study area. It is characterized by planer cross bedding, and are siliciclastic and poorly sorted. Bioturbations rarely occur in this facies. This facies is illustrated in the Fig 10 below.

Fig 10. Pebbly Coarse Grained Sandstone

4.2 Sedimentary structures

The sedimentary structures observed in the study area are mainly primary sedimentary structures that are formed during the deposition of the sediments. The primary sedimentary structures are the variety of cross-beds that include: through cross-bedding and planar cross-bedding. Other structures include: fractures, convolute lamination and bioturbations which are mainly dwelling traces of organisms. These various kinds of sedimentary structures are described below.

4.2.1 Convolute Lamination

This structure is a soft sediment deformation structure that forms when folding and crumpling of lamination occur. This structure are mostly exhibited by the Interbedded Fine Grained Sandstone Facies. This is illustrated in fig.11 below

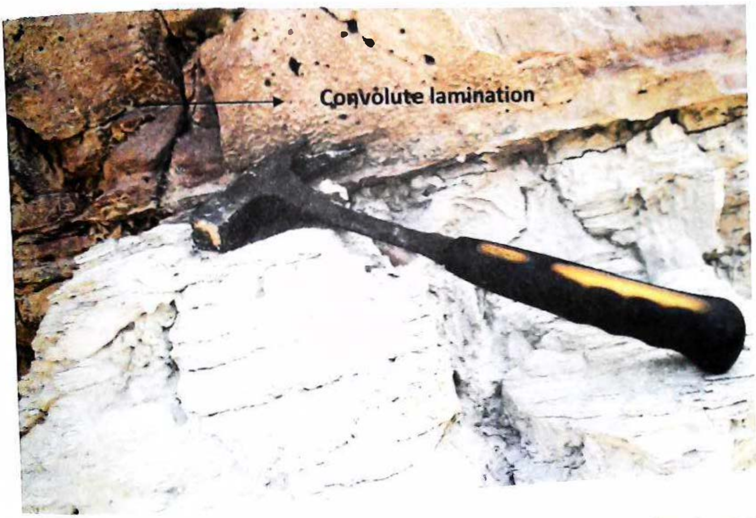


Fig.11 Fine Grained Sandstone Interbedded Facies showing convolute laminations on the sandstone bed.

4.2.2 Trough Cross-bedding

This structure are mostly found in the Fine Grained Sandstone Facies, consisting of cross-bedding unit in which the bounding surfaces are bowed. It is shown in fig.12 below.

Fig.12 Trough cross-bedding in Fine Grained Sandstone Facies.

4.2.3 Planar Cross-bedding

Planar cross-bedding occurs in both Fine Grained Sandstone Facies an Pebbly Coarse Grained Sandstone Facies. This is shown in the fig13 below.

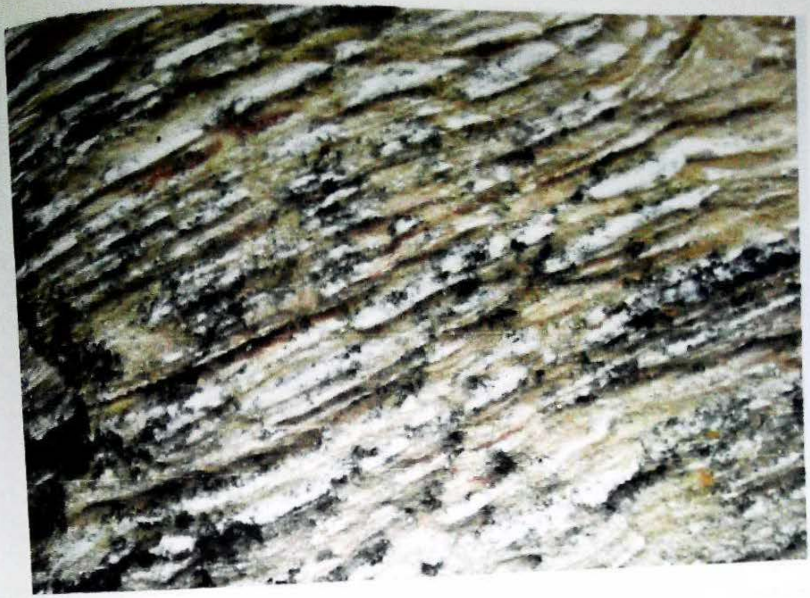


Fig.13 Planar Cross-bedding very coarse grained sandstone.

4.2.4 Fractures

Fractures are also found associated with the Fine Grained Sandstone Facies. This fracture trends in the north-west and south-eastern directions respectively. This is illustrated below.

Fig.14. Fractured cross-bedded rock

4.2.5 Bioturbations: These are mainly horizontal borrows of organisms and characterizes the Fine Grained Sandstone and Siltstone Facies. This is illustrated in the fig.15 below

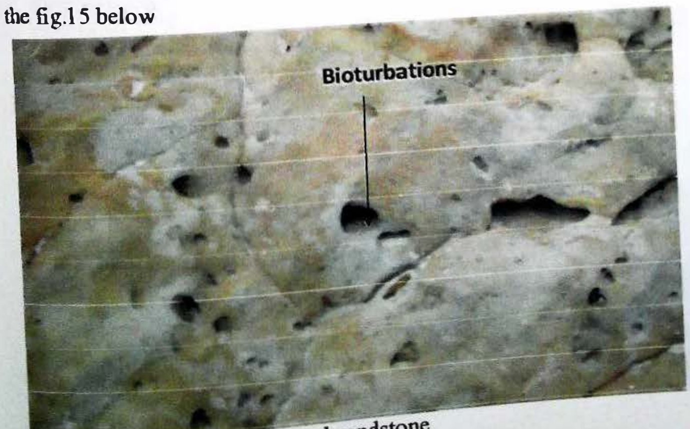


Fig.15. Bioturbated fine grained sandstone

4.2.6 Clay Clast (Para conglomerate)

These are found on the Pebbly Coarse Grained Sandstone facies. It is illustrated in the fig.16 below

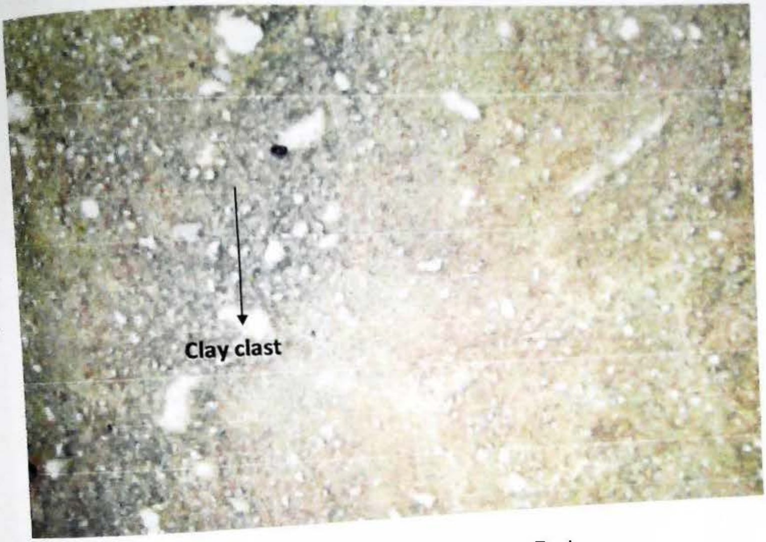


Fig.16 Clay clast in Pebbly Coarse Grained Sandstone Facies

4.3 LITHOSTRATIGRAPHY

Two lithosratigraphic sections of the Gombe Sandstone were drawn to scale one each for Lower Gombe Sandstone member and the Upper Gombe Sandstone member. These sections are illustrated below.

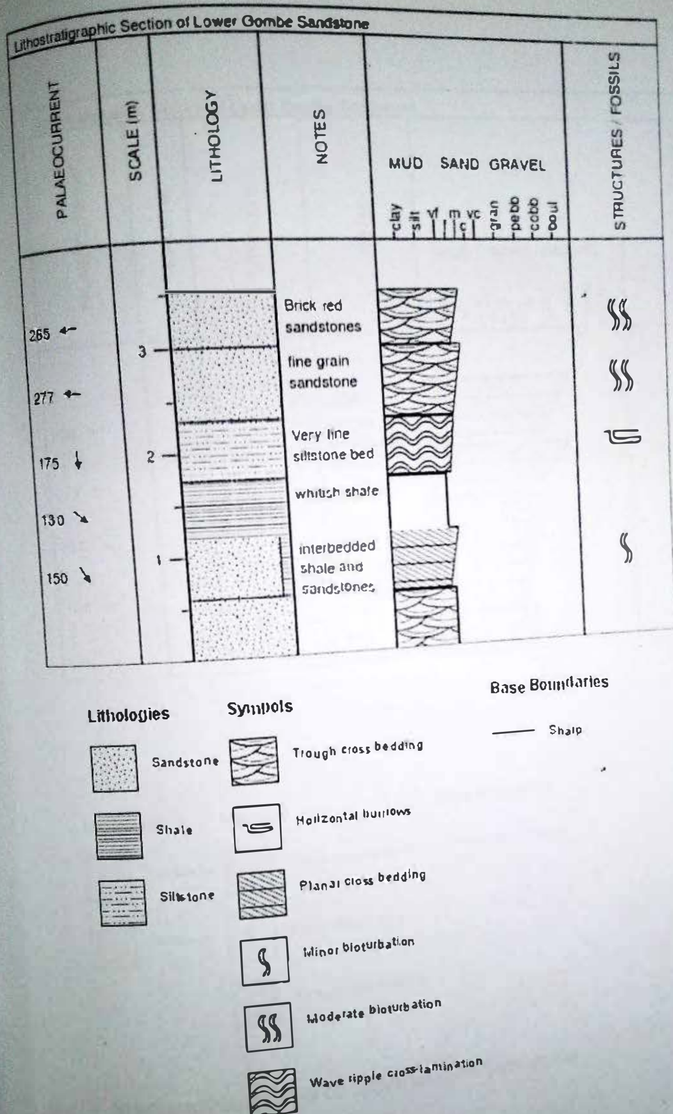

Lithostratigraphic Section of Lower Gombe Sandstone
PALAEOCURRENT
SCALE (m)
LITHOLOGY
NOTES
MUD SAND GRAVEL
clay
silt
vf
f
m
c
vc
gran
pebb
cobb
boul
STRUCTURES / FOSSILS
265
277
175
130
150
3
2
1
Brick red sandstones
fine grain sandstone
Very fine siltstone bed
whitish shale
interbedded shale and sandstones
Lithologies
Sandstone
Shale
Siltstone
Symbols
Trough cross bedding
Horizontal burrows
Planar cross bedding
Minor bioturbation
Moderate bioturbation
Wave ripple cross-lamination
Base Boundaries
Sharp

Fig.17

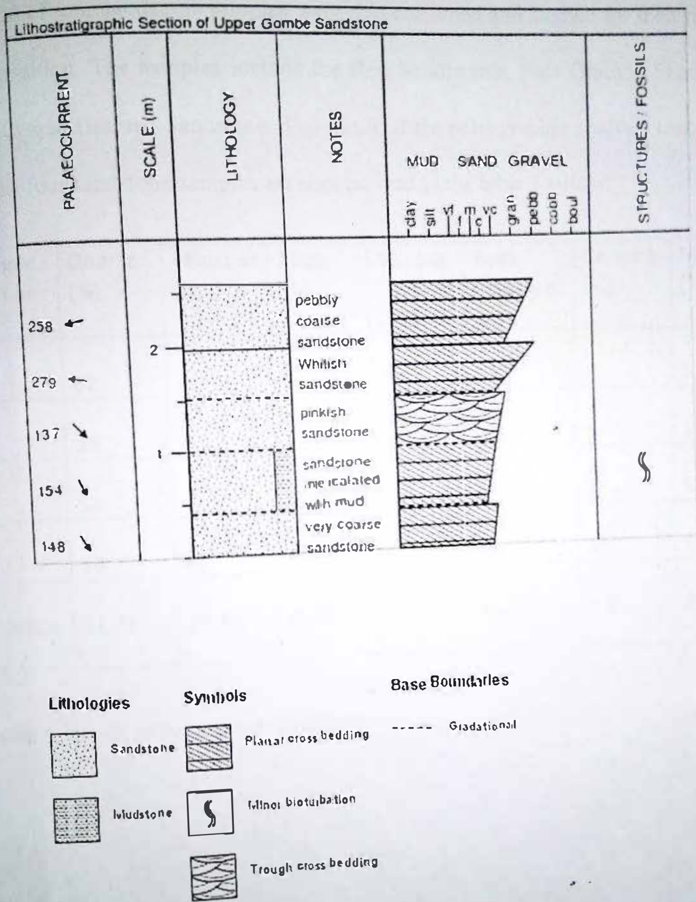


Fig18. Stratigraphic section of upper Gombe Sandstone

4.4 PETROGRAPHY

A total of four sandstone samples were thin sectioned and studied for their mineral composition. The samples include the Red Sandstones, Fine Grained Sandstones and Coarse Grained Sandstone. The result of the petrographic analysis carried out on the four sandstone samples are summarized in the table 1 below.

Sample Number	Quartz (%)	Feldspar (%)	Mica (%)	opaque mineral (%)	Rock Fragment (%)	Cement (%)	Matrix (%)
A	62	15	2	8	3	5	5
B	65	23	1	3	-	5	1
C	54	17	5	4	8	7	5
D	50	22	4	7	6	10	4
Average	57.75	19.25	4.00	5.5	4.25	6.25	3.75

Table 1: Result of Petrographic Analysis

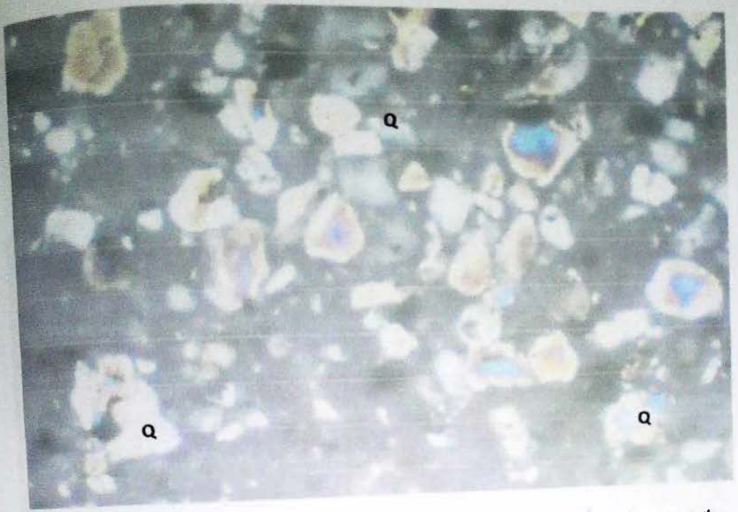


Fig.19 Photomicrograph of sample A under cross nicols showing poorly sorted sediments. Quartz is represented as (Q).

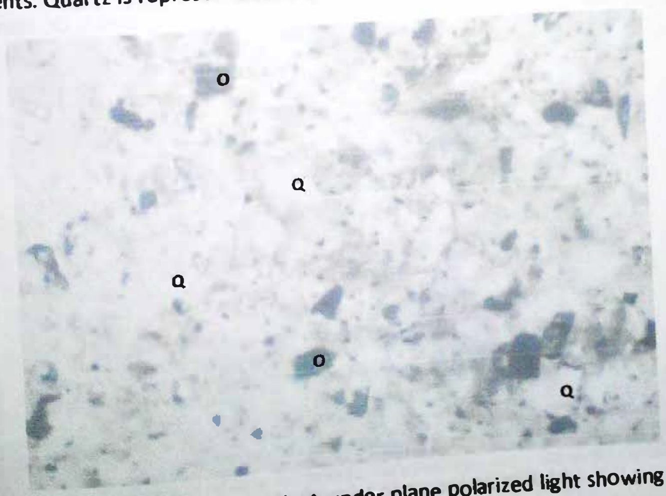


Fig.20 Photomicrograph of sample A under plane polarized light showing opaque minerals (O) and quartz (Q)

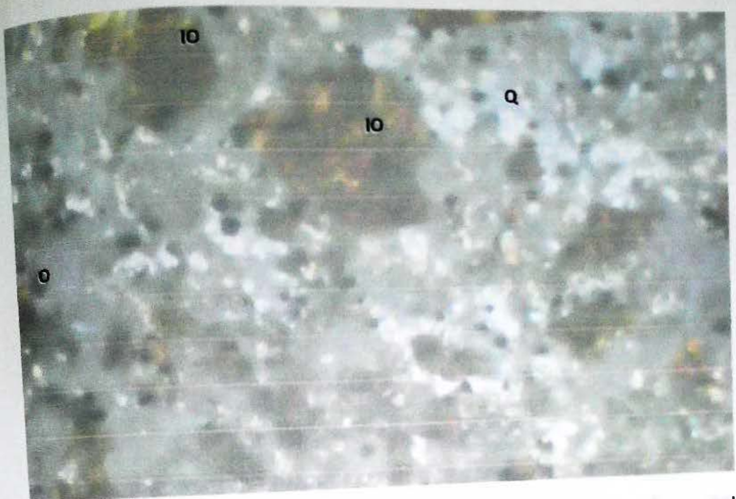


Fig 21 Photomicrograph of sample B under cross nicols showing poorly sorted sediments. IO stands for iron oxide, O stands for opaque minerals and Q is quartz

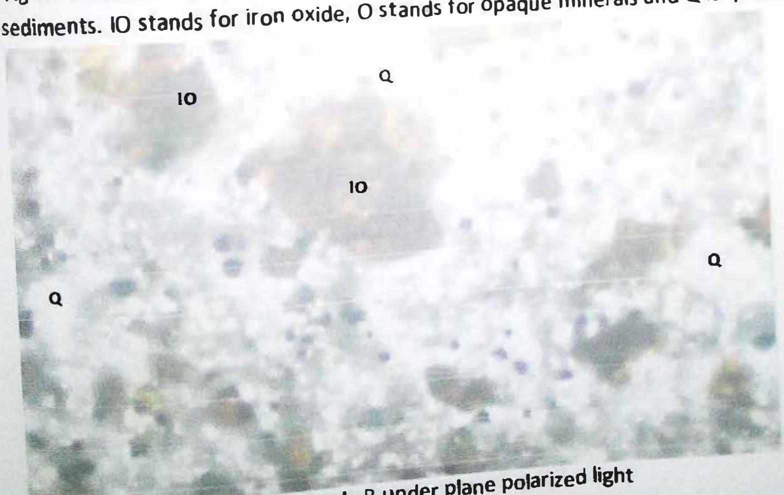


Fig 22 Photomicrograph of sample B under plane polarized light

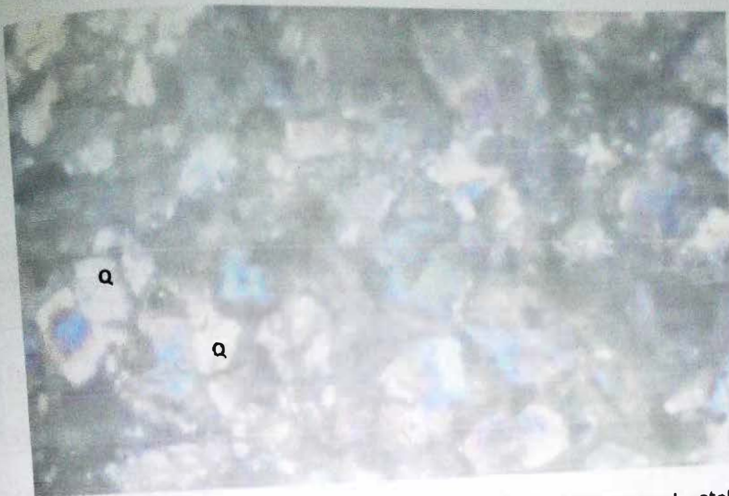


Fig.23 Photomicrograph of sample C under cross nicols showing moderately well sorted sediments.

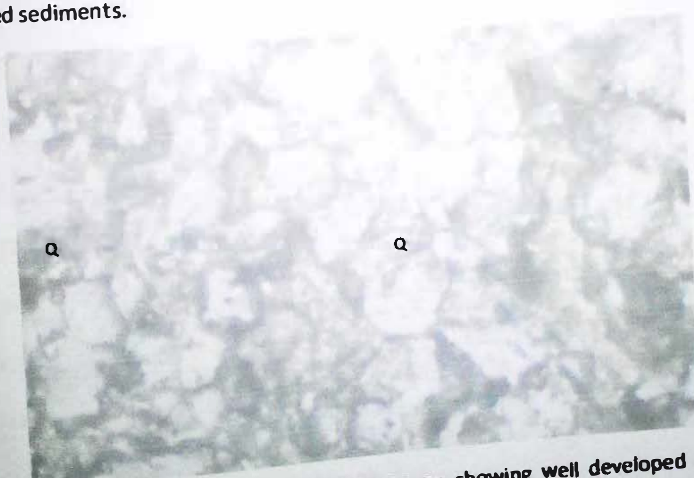


Fig.24. Photomicrograph of Gombe Sandstone showing well developed crystals under plane polarized light. Quartz is represented as (Q)

4.5 GRANULOMETRIC ANALYSIS

The results of four samples selected for granulometric analysis are presented in the tables 1, 2, 3 and 4 below.

Mesh Size (mm)	Mesh Size (PHI)	Weight Retained (g)	%Weight Retained	Cumulative Weight %
4.75	-2.26	10.90	9.12	9.12
3.35	-1.75	7.93	6.61	15.7
2.68	-1.43	8.12	6.75	22.48
1.18	-0.25	28.38	23.67	46.15
0.850	0.25	22.28	18.57	64.72
0.425	1.24	30.66	25.55	90.27
0.300	1.74	3.70	3.08	93.35
0.212	2.24	2.44	2.03	95.38
0.106	3.25	3.91	3.26	98.64
0.063	4.00	1.48	1.34	99.98
TOTAL		119.5		

TABLE 2: Sieve Analysis Result for Sample A

Mesh Size (mm)	Mesh Size (PHI)	Weight Retained (g)	%Weight retained	Cumulative Weight %
4.75	-2.26	11.31	8.21	8.21
3.35	-1.75	8.51	6.18	14.39
2.68	-1.43	9.59	6.96	21.35
1.18	-0.25	27.90	20.25	41.60
0.850	0.25	25.40	18.44	60.04
0.425	1.24	37.67	27.35	87.39
0.300	1.74	6.81	4.94	92.33
0.212	2.24	3.90	2.83	95.16
0.106	3.25	4.07	2.95	98.11
0.063	4.00	2.57	1.86	99.97
TOTAL		137.73		

TABLE 3: Sieve Analysis Result for Sample B

Mesh Size (mm)	Mesh Size (PHI)	Weight Retained (g)	%Weight Retained	Cumulative Weight %
4.75	-2.26	-	-	-
3.35	-1.75	-	-	-
2.68	-1.43	-	-	-
1.18	-0.25	-	-	-
0.850	0.25	-	-	-
0.425	1.24	6.16	4.00	4.00
0.300	1.74	3.31	2.15	6.15
0.212	2.24	4.61	2.99	9.14
0.106	3.25	116.47	75.58	84.82
0.063	4.00	23.33	14.95	99.77
TOTAL				

TABLE 4: Sieve Analysis Result for Sample C

Mesh Size (mm)	Mesh Size (PHI)	Weight Retained (g)	% Weight Retained	Cumulative Weight %
4.75	-2.26	0.00	0.00	0.00
3.35	-1.75	0.00	0.00	0.00
2.68	-1.43	0.00	0.00	0.00
1.18	-0.25	0.00	0.00	0.00
0.850	0.25	0.00	0.00	0.00
0.425	1.24	10.32	8.26	8.26
0.300	1.74	7.41	5.93	14.19
0.212	2.24	8.23	6.59	20.72
0.106	3.25	79.54	63.67	84.45
0.063	4.00	19.43	15.55	100
TOTAL		124.93	100	

TABLE 5: Sieve Analysis Result for Sample D

The results of the granulometric analysis are presented in the charts below.

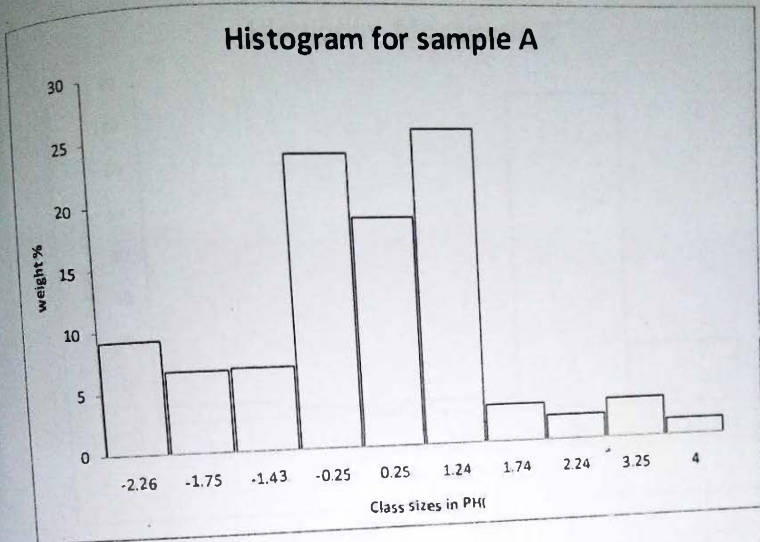


Fig.25 Histogram for sample A

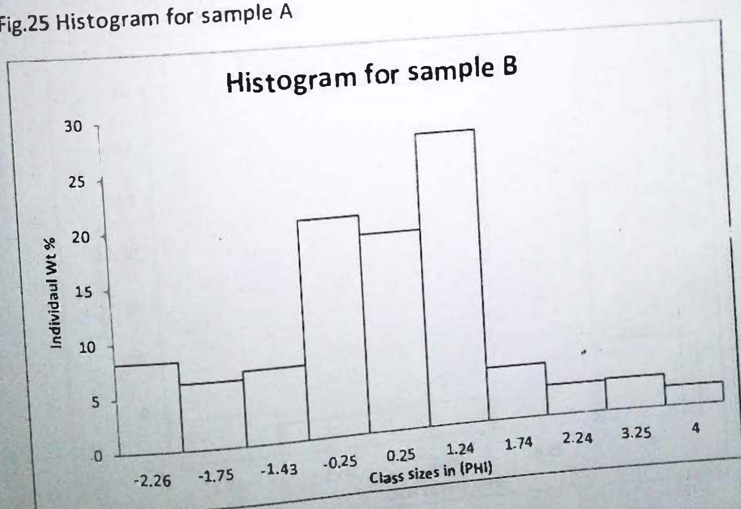


Fig 26 Histogram for Sample B

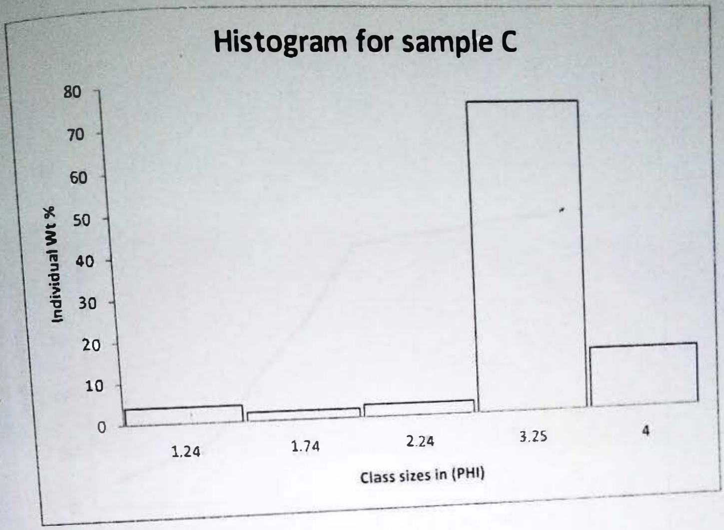


Fig.27. Histogram for Sample C

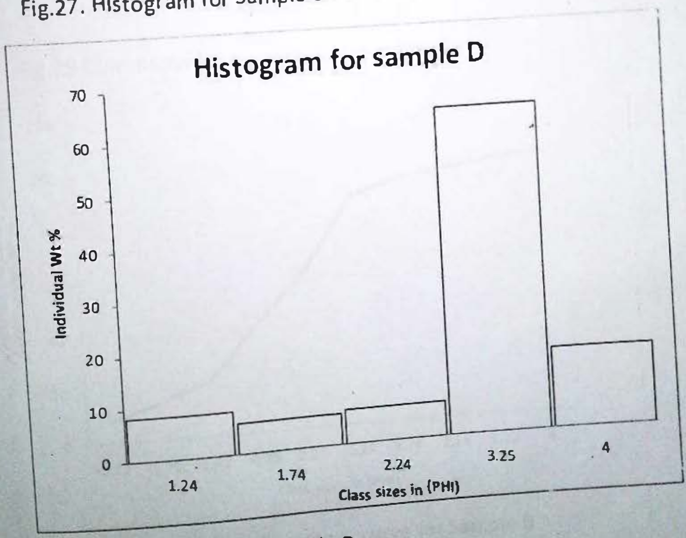


Fig.28 Histogram for Sample D

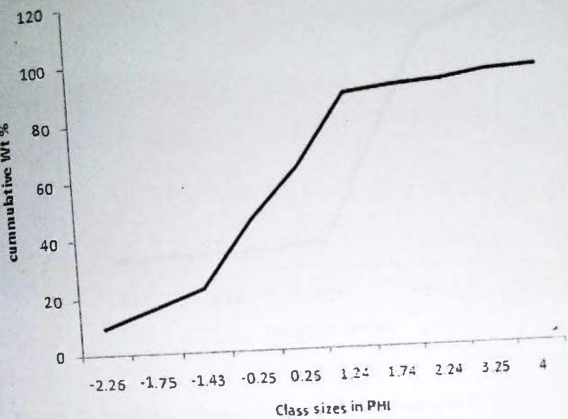


Fig.29 Cumulative frequency curve for Sample A

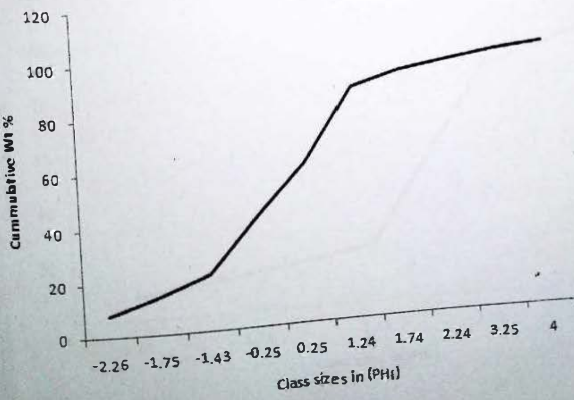


Fig.30 Cumulative frequency curve for Sample B

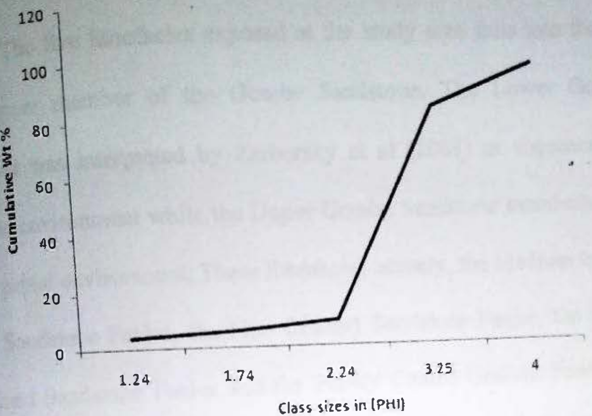


Fig.31 Cumulative frequency curve for Sample C

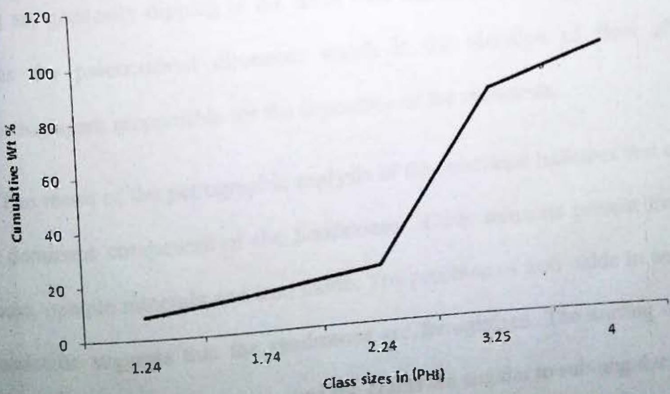


Fig.32 Cumulative frequency curve for Sample D

4.6 INTERPRETATION OF RESULT

The five lithofacies exposed at the study area falls into the lower member and upper member of the Gombe Sandstone. The Lower Gombe Sandstone member was interpreted by Zarborsky et al (2003) as sequence deposited in a marine environment while the Upper Gombe Sandstone members are deposited in continental environment. These lithofacies namely, the Medium to Coarse Grained Red Sandstone Facies, the Fine Grained Sandstone Facies, the Interbedded Fine Grained Sandstone Facies and the Pebbly Coarse Grained Sandstone Facies are similar to three lithofacies described by Zarborsky et al (1997).

The various cross-beddings namely the trough cross-bedding and planar cross bedding are generally dipping in the north west and south eastern directions. This indicates the paleocurrent direction, which is the direction of flow of the transporting agent responsible for the deposition of the sediments.

The result of the petrographic analysis of the sandstone indicates that quartz is the dominant component of the Sandstones . Other minerals present includes feldspars, opaque minerals and iron oxide. The presence of iron oxide in some of the sandstone suggests that the sandstones are ferroginised. The sorting of the mineral grains is moderate to poor, and the grains are angular to sub-angular.

The result of the granulometric analysis from the statistical charts in fig.26 and fig27 (histograms) indicates that sample A and Sample B are polymodal with the dominant grain sizes falling under 1.24Φ. This indicates in samples A and B, the dominant grain sizes are coarse grained sandstone. Samples C and D from the histograms in fig.28 and fig.29 indicates that these samples are unimodal with the dominant grain sizes falling under 3.24Φ implying that the samples are fine grained.

General interpretation of textural parameters such as graphic mean sizes, standard deviation, skewness and kurtosis are summarized in table 6 below.

Sample Number	Graphic mean	Standard Deviation	Skewness	Kurtosis	Interpretation
A	0.142	1.15	0.017	1.04	Coarse grained, poorly sorted, near symmetrical, mesokurtic sandstone.
B	0.136	1.12	0.15	1.02	Coarse grained, poorly sorted, near symmetrical, mesokurtic sandstone.
C	2.67	0.53	0.38	1.366	Fine grained moderately well sorted, fine skewed, leptokurtic sandstone
D	2.35	0.51	0.31	1.23	Fine grained moderately well sorted, fine skewed, leptokurtic sandstone.
Average	1.325	0.827	0.214	1.16	Medium grained, moderately sorted, fine skewed, leptokurtic sandstone.

Table 6: Interpretation of textural parameters from Granulometric Analysis

4.7 Discussion of Result

All sedimentary rocks carry an inprint of the physical processes that resulted in their deposition and later alteration. Understanding of these inprints in the field lead to proper interpretation as regards to how the sediment were deposited and subsequent event that happened to them after their deposition.

Based on the facie characteristics, petrographic and granulometric analysis carried out on the sandstones, two depositional environments where interpreted as the possible depositional environments for the Gombe Sandstones. These environments are discussed below.

4.7.1 Lower Gombe Sandstone

The fine to medium grained sandstone, the interbedded fine grained sandstone with shale and the horizontal burrows of *Thalassinoides* that characterized these facies suggest that these facies were deposited in an environment where there is little or no existence of tidal or wave action i.e. quiet environment where low energy favored the deposition of fine to very fine grained sediments. The lower shoreface is suggested as the possible depositional environment for the Lower Gombe Sandstone. This observation agrees with similar observation made by Zarborsky (2003) when he suggested that the bedded facies of the Gombe Sandstone where deposited in a shallow, quiet, marine environment.

The moderately well sorted Lower Gombe Sandstone is also an evidence of quiet environment with very low energy of deposition.

4.7.2 Upper Gombe Sandstone

These members are very coarse, poorly sorted, nearly symmetrically skewed, mesokurtic, planar cross-bedded sandstone. Bioturbations are less prominent in members of these facies. The coarsening upward sequence of the Upper Gombe Sandstone deposit accompanied by a pebble composition suggests a fluctuating energy of deposition. The siliciclastic nature of the sediments and almost complete absence of marine trace fossils suggests that the Upper Gombe Sandstones were deposited in a continental environment.

A generally high energy fluvial depositional agent such as storm activities was suggested as the agent of deposition of the pebbly coarse grained sandstone. The presence of clay clast (para conglomerate) in the pebbly sandstone suggests that this sequence marks the end of a sequence and the beginning of another sequence.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The field mapping exercise carried out at Ḋoho reveals that Gombe Sandstone is the Formation that characterized the area. The two members of the Gombe Sandstone namely; the Lower Gombe and Upper Gombe Sandstones are well exposed in the study area. Five lithofacies were mapped. These facies are: Medium to Coarse Grained Red Sandstone; Fine Grained Sandstone; Interbedded Fine Grained Sandstone; Fine Grained Siltstone Facies and Pebbly Coarse Grained Sandstone. The lower Gombe Sandstones are generally medium to fine grained, trough cross bedded, bioturbated sandstones. While the Upper Gombe Sandstone members are generally very coarse grained pebbly, planar cross-bedded sandstones with no bioturbation.

The Granulometric analysis of the sandstone reveals that the sandstones are generally poorly sorted but the Lower member of the Gombe Sandstone is moderately well sorted. The colors of the sandstone range from red to reddish brown and from pinkish to whitish.

Petrographic analysis shows that the sandstone is mineralogically composed of mainly quartz, feldspar, mica, opaque minerals and iron oxide.

The depositional environment of the Gombe Sandstones based on facie characteristics reveals that the sandstones are deposited in shallow marine (lower shoreface) to continental (fluvial) environment.

5.2 RECOMMENDATIONS

Several depositional environments have been proposed for the Gombe Sandstone. These environments are fluvial, beach, estuary, and shoreface respectively. In order to settle these controversies as regards to the depositional environment of the sandstone, it is recommended that further research should be carried out on the Gombe Sandstone so as to come up with a single depositional environment particularly for the lower member of the Gombe Sandstone.

REFERENCE

Abubakar MB (2006) Biostratigraphy, Paleoenvironment and Organic Geochemistry of the Cretaceous Sequence of the Gongola Basin, Upper BenueTrough Nigeria. P 49-57.

Adegoke O.S Agumanu A.E Benkhelil M.J and Ajayi P.O (1986) New Stratigraphic, Sedimentological and Structural data on the Kerri-Kerri formation, Bauchi and Borno State Nigeria. Journal of Africa Earth Sciences vol.5 pp 249-227

Allen (1965). A review of the characteristics of resources alluvial sediment. Sedimentology vol.5 pp 89-191.

Benkhelil J. (1989) The Origin and Evolution of Benue Trough Nigeria. Journal of African Earth Science vol.8 pp 281-282.

Benkhelil J (1992) Workshop on the Cretaceous Geology of the Upper Benue Trough and Field trip 16-20 April 1992. The University of Jos.

Dike E.F.C (1993) Statigtaphy and Structure of the Kerri-Kerri Basin North Eastern Nigeria, Journal of Mining Geology vol. 29 pp 77- 93.

Falcorner J.B (1911) The Geology and Geography of Northern Nigeria. Macmillan London p29

Folk R.L (1951) Stages of textural maturity in sedimentary rocks. Journal of sedimentary petrology, vol 21

Friedman G.M (1961). Distinction between dune beach, river sand from textural characteristics, journal of sedimentary petrology, vol31 p 514-529

Kogbe C.A Geology of Nigeria Elizabeth Publishing Company Lagos.

Offodile M.E. 1989 A review of the Cretaceous sediments of the Benue Trough In: Kogbe, CA. (Ed) Geology of Nigeria. Rock View Nigeria L.t.d Pp 365-374

Zarbosky (1997) Stratigraphy and structure of the Cretaceous Gongola Basin N-E Nigeria. ELF Exploration production. Vol 21, No 1, p 153-185.