GEOLOGICAL OF THE AREA AROUND ARAWA PART OF SHEET 152SW GOMBE

BY

ABDULRASHID ABDULKADIR

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JANUARY, 2018.

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10/23740/U/1

A PROJECT SUBMITTED TO THE DEPARTMENT OF APPLIED GEOLOGY, FACULTY OF SCIENCE. ABUBAKAR TAFAWA BALEWA UNIVERSITY, BAUCHI
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF TECHNOLOGY (B. TECH) HONOURS IN APPLIED GEOLOGY.
SUPERVISOR: PROF. A. S MAIGARI

11,843

JANUARY, 2018

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Declaration

I solemnly declare that this work was solely done by me under the guidance of my supervisor and source of info mation is duly acknowledged through references.

.... 2/4/2018 ....

Abdulrashid Abdulkadir

Date

(10/23740/U/1)

The Declaration is confirmed by

.... 2/4/2018 ....

Prof. A. S Maigari

(Project supervisor)

Date

CERTIFICATION

I certify that this report is an original work done by Abdulrashid Abdulkadir (10/23740/U/1) under my supervision and has met the requirement for the award of bachelor of technology (Applied Geology) of Abubakar Tafawa Balewa University, Bauchi.

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Date: 2/4/2018

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Name: Dr. A. I. Haruna

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Date: 3rd/4/2018

External examiner

Name: ....

Signature: ....

Date: ....

DEDICATION

I dedicate this project report to my family, parents; Late Alhaji Abdulkadir Dahuwa Muhammad, Hajiya Bishira Garba. Also my respected brothers and sisters; Basiru, Sadiq, Ghali, Munnira, Aliya, Abida, Sadiya and Fa'iza.

Acknowledgement

All thanks and praises be to almighty Allah for giving me the ability to complete this project report. My special appreciation goes to my parents whose immense contribution cannot be forgotten, and I pray that Allah (S.W.T) will continue to shower His mercy and blessings upon them and grand them Janatul Firdaus. I also pray that Allah (S.W.T) will continue to shower his mercy on my entire family members for their moral and financial support in seeing me through this work.

My deepest gratitude goes to my supervisor in person of Prof. A. S Maigari for his advice, encouragement, help, support, suggestions and assistance which have great influence in this research project. May Allah bless him and his family entirely.

Also tremendous appreciation goes my departmental coordinator in person of Dr. A. I Haruna and to all my lecturers in geology department for their support and assistance in seeing the successful completion of this program.

Lastly, my special regards goes to my collogues and friends for their support in the pursuit of my academic career.

Abstract

The depositional environment of the Gombe Formation around Arawa area was determined using grain size parameters in which nine sandstone samples and three pebbles were subjected to granulometric and pebbles morphometric analysis respectively. The granulometric analysis for the nine (9) samples of the Gombe Formation. The formation is dorminantly composed of fine grained sandstone, and mudstone interbeds. While the granulometric analysis plots showed a dominance of three sand populations indicating influence of transitional environment. The petrographic analysis indicates fluvial environments.

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Introduction

The area of study is located within latitudes 10°19'51"N and 10°17'40"N and longitudes 11°10'20"E and 11°12'20E" in Gombe sheet 152NW within and around Arawa area in the upper Benue Trough which is Gombe sandstone. The study area is located mainly at Gombe sandstone. The purpose of this study is to use granulometric analysis to interpret the depositional environment of Gombe sandstone.

The Gombe formation corresponds to the name "Gombe sandstone "which was proposed by Carter et al. (1963). The Gombe formation is made up of three major lithofacies which may ultimately prove recognizable as separate members. At the base, the Gombe formation consist of rapidly alternating thin beds of silt, and fine to medium grained sandstone with some intercalations of iron stone (Zarborki,1997). Individual beds vary from a few millimeters to few centimeters in thickness. Passing upwards. the sandstone bed becomes mares persistent up to the greater part of the bedded farcies. The lithofacies which is well exposed at Arawa area consist of extremely regular bedded fine to fine grain sand and well sorted quartz wacke. Individual beds vary from a few centimeters to over one meter in thickness but even latter beds are characterized by internal laminations Benkhelil. (1989). The bedded facies also contain channel-fit no sandstones. These sandstones too are fine grain sand and show both cross bedding and internal lamination.

The present study covers an area of about $16km^2$ and is based on a detailed study of nine (9) samples that were taking from the various locations. The sediments of the Gombe Formation are predominantly composed of fine grain sandstones and well sorted.

1.2 Aim and objectives

The aim of this work is to carry out detailed geological mapping of area both within and around the area of Arawa on a scale of 1:25,000.

Objectives:

- Production of a geological map on a scale of 1:25,000.
- Detailed study of the various litho-stratigraphic units occurring in the area, their mode of occurrence, field relationships and geological structures.

- Laboratory analysis of samples collected from the field.

1.3 Location and Accessibility

The area of study is located around Arawa area within latitudes 10°19'51"N and 10°17'40"N and longitudes 11°10'20"E and 11°12'20"E (Fig. 2) in Gombe sheet 152NW.

The area is accessible through numerous interconnected footpaths, motarable roads, a major road.

1.4 Relief and Drainage

The terrain is generally undulating. Outcrops generally consist of rocks that are sandstones. The drainage system in the study area is dendritic. The streams are flowing from northwest to southwest. Most of the streams are seasonal, overflowing their banks during rainy season.

1.5 Climate and Vegetation

The study area falls within the tropical climate zone. It is characterized by two seasons; a rainy season, which starts in May and ends in October and the dry season, which normally spans between the months of October and April (Fig 1). The rainy season is the period when tropical maritime air mass travels northwards over the study area from the Gulf of Guinea. The mean annual rainfall is 1015mm for Gombe where the study area is located while the dry season is characterized by an arid wind or tropical continental air mass originating from the Sahara Desert. During the dry season, there is little cloud cover and the temperature ranges from $14^0C - 32^0C$ (Nigeria Meteorological Agency, Gombe State).

The study area is mainly classified as Sudan savannah region, which is characterized by grasses, shrubs and trees with large trunks. The grasses usually dry and the trees shade off their leaves during dry season and flourish again during the wet season. The vegetation is characterized by occurrence of trees such as baobab, mango, shea butter, and abundant grasses.

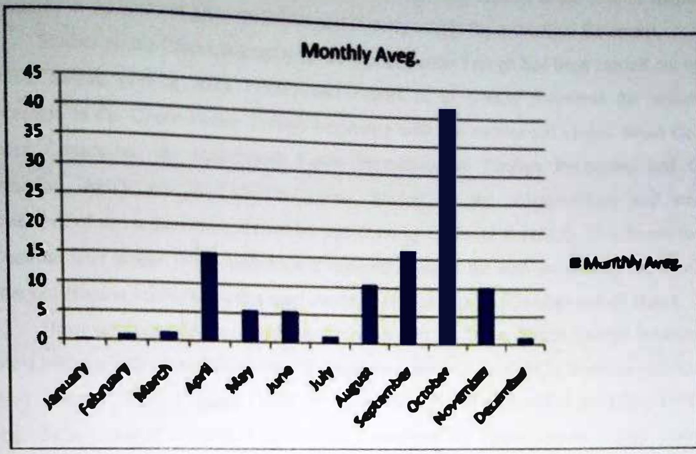

Fig. 1: Showing Average of Temperature Rainfall of Gombe

1.6 Settlement and Land Use

The inhabitants of the study area are mainly indigenous Fulani, Kanuri, Tera and Hausa ethnic groups. The area is sparsely populated. Inhabitants practice farming as their dominant occupation. National integration brought about influx of other ethnic groups from the south and northern parts of the country which ushered in other businesses such as trading and building constructions amongst many others.

1.7 Review of Previous Work

The Benue Trough is the most important of all the Cretaceous sedimentary basins in Nigeria. At its north-eastern end is an area commonly known as the Upper Benue Trough, it bifurcates into an E-W trending Yola arm and N-E trending Gongola arm. The study area falls within the Gongola arm.

The early studies, of the upper Benue Trough and Southern Borno Basin was carried out by Falconer (1911); Jones (1948); and Barber et al (1954); and was later elaborated by Rayment (1965). Falconer (1911) classified the Basement complex as older Granites of Pan-African Orogeny (600 ± 150 Ma) and also was the first person to use the term "Bima sandstone" for beds that occurred at the type locality, The Bima Hill. Carter et al (1963) divided the Bima Sandstones into "upper, middle, and lower". The "Bima sandstone" was formed at the base of sedimentary succession in the cores of great anticlines and directly overly the crystalline Basement.

Studies on the lithostratigraphy of the Upper Benue Trough has been carried out by Enu, (1978); Lawal, (1982); Allix (1983) and Popoff et al (1983) described the sedimentary succession in the Upper Benue Trough beginning with the continental classic Bima Group of Lower Cretaceous, the transitional Yolde Formation the Pindiga Formation and Gombe Formation, which are all Late Cretaceous. Studies on the sedimentology and structural framework of the sedimentary formation was done by Carter et al (1963). This forms the basis for all the later works. They undertook a regional study of the area covered by the Geological Survey of Nigeria 1:250,000 series map sheets 25 (Potiskum), 36 (Gombe) and 47 (Lau).

However, more detailed work has been done on the Upper Benue Trough because it has almost been entirely remapped recently through the work of Allix (1983); Benkhelil (1985, 1986, 1988); Popoff (1988); Guiraud (1989, 1990, and 1993) and Zaborski et al (1997, 1998). The upper Bima member is entirely continental throughout the Upper Benue Trough consists of sandy deposits containing ubiquitous cross - beddings and diversity of soft- sediment sedimentary structures (Samaila et.al. 2005, 2006; Samaila, 2007). Study of porosity loss in the Cretaceous Upper Bima Sandstone of the Upper Benue Trough (Samaila & Singh, 2010) has been done using different parameters.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Geology of the Upper Benue Trough

The Benue Trough is a Cretaceous sedimentary basin in Nigeria. Reviews of the origin and evolution of this linear, NE-SW trending megastructure were provided by Benkhelil (1989) and Freeth (1990). The northeastern endof the Benue Trough is known as the Upper Benue Trough. It bifurcates into an east-west trending Yola Arm and a north-south trending Gongola Arm or Gongola Basin (Fig1). Carteret *al*. (1963) described the geology of the Upper Benue Trough. They referred to the general area between the Yola Arm and the Gongola Basin as the "Zambuk Ridge", actually a zone characterized by a number of important NE-SW trending sinistral strike slip faults.

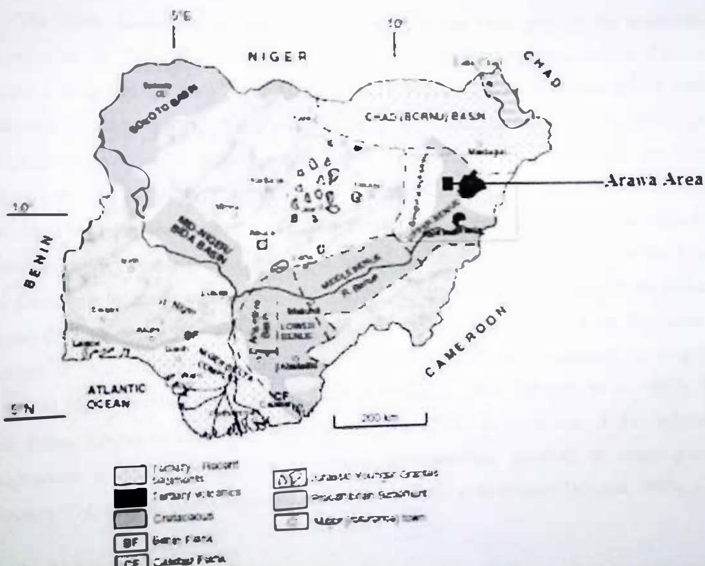

Fig. 2: Geological Map of Nigeria Showing Upper Benue Trough and Location of the Study Area (Obaje, 2009).

The Gongola Basin is separated from the Bornu (Chad) Basin to the north by an anticlinal feature known as the Dumbulwa-Bage High (Zaborski, *et al*. 1997). Concealed beneath the

Cenozoic sedimentary cover of the Bomu Basin are Cretaceous rift- like basins (Avbovo,*et al.* 1986). These in turn form links with those of the West African Rift System in Niger and Chad Republics to the north.

2.2.0 Stratigraphy of the Upper Benue Trough

The basic lithostratigraphical successions for the Upper Benue Trough (Gongola Arm) were established by Carter et al. (1963) and modified by Popoff et al. (1986) Zaborski et al., (1997) considered modification of the stratigraphy by older workers necessary, largely because of the marine sequence making up the greater part of the Upper Createaceous.

2.1.1 The Bima Sandstone.

The Bima Sandstone, a continental formation, is the basal part of the sedimentary successions in the Upper Benue Trough. It lies unconformably on the Precambrian Basement Complex. It ranges in age from Upper Aptian to Lower Albian. The Bima Formation was named by Falconer (1911) after it type locality at Bima Hill. Carter *et al.* (1963), and Allix (1983) gave description of the sequences sub-division, consisting of three siliciclastic members: the Lower Bima (B_1), the Middle Bima (B_2), and the Upper Bima (B_3). The Lower Bima Sandstone which is the oldest has been described in the Lamurde Anticline to consist of red and purple clays with occurrences of very coarse grained feldsphatic sandstone. The most basal sequence of the Lower Bima Sandstone is made up of sands and gravels with poorly defined planar cross bedding believed to have formed in alluvial fans (Guiraud, 1990). The Middle Bima Sandstone is composed of about 400-600m medium to very coarse grained feldspartic sandstone showing both trough and planar bedding with clays and shales (Guiraud, 1993, Zaborski *et al.* 1997). The Upper Bima Sandstone (B_3) may attain more than 1700m in thickness. It has relatively homogeneous appearance consisting of tabular cross-bedding, medium to coarse-grained sandstones. This sequence was deposited in fluviatile braided river system (Guiraud, 1993).

2.1.2 The Yolde Formation

The Yolde Formation (Cenomanian in age) marks the transition between the continental environment and the major Turonian transgression. It was first recognized by Falconer (1911) and later by Barber *et al.* (1954). The type Locality was designated in Yolde stream in the western part of Yola Arm. It consists of a variable sequence of thinly bedded sandstones, sandy mudstone and Shelly limestone. The formation overlies the Bima Sandstone (Fig 2) in both Gombe and Numan-Muri areas.

The Yolde Formation gives rise to a subdued topography often with a sparse vegetation cover. It is poorly exposed in most parts of the Gongola Basin east of the Gongola River however, between Kubtogana, Alhaji Ruhu and Ruwan Kuka it occupies the core of a gentle anticlinorial structure in which good exposures occur (Zaborski et al., 1997).

The most complete section in the Yolde Formation has been found northwest of RuwanKuka (Zarboski et al., 1997). Adjacent to the RuwanKuka fault, the feldspathic Yolde Sandstones contain siliceous cements in contrast to their poorly consolidated nature elsewhere. Nearly 150 meters of the Yolde Formation is exposed, though its uppermost and lower portions are not seen. The lower part of the formation consists of alternating sandstones and dark grey mudstones. The latter frequently display prominent desiccation cracks on their upper surfaces. The sandstones are variable, mostly coarse-grained, trough cross-bedded sandstones reaching a thickness of over5m occur in the middle part of the section. Above, the formation consists of regularly bedded sandstones with argillaceous intercalations. Bioturbation (planolites) is common towards the top while groove marks are present on some beds (Zaborski et al., 1997).

2.2.3.0 The Pindiga Formation

The Pindiga Formation, according to Carter *et al.*, (1963) and Barber (1957) is the lateral equivalent of the Gongila and Fika Formations in the Fika area and the Chad Basin and the marine sequence (Dukul, Jessu, Sekule, Numanha, and Lamja Formations) in the Yola Arm. Dukul Formation is the earliest of the marine deposits in the Yola Arm whose ammonite fossils (the Vascoceratids) was identified as a lower Turonian unit. The ferruginous Jessu Formation succeeds it. Another sets of limestone and shale intercalated beds succeeded the Jessu Formation. They are identified as the Sekule and the Numanha Formations. The Sekule Formation consists of thin to medium bedded limestone and grey fissile shale while the Numanha Formation has a more pronounced black shale beds. The stratigraphic succession of the Yola Arm terminates with the deposits of the clastic Lamja Sandstone (Fig. 2). It consists of fine grained parallel laminated sandstone with interbeds of thin limestone, coal seams and fossiliferous shale.

The Pindiga Formation, consisting of thick marine shale, with limestone beds toward the base ranges in age from Turonian to Santonian (Fig. 5) (Zaborski *et al.*, 1997; Obaje et al., 1999). It overlies the Yolde Formation in Gombe area. Zaborski*et al*. (1997) subdivided the formation into five members (Kanawa, Gulani, Deba Fulani, Dumbulwa and Fika members).

2.2.3.1 The Kanawa Member

The name Kanawa Formation was proposed by Thompson, for a sequence of shales and intercalated limestone outcropping around Kanawa to the east of Gombe (Zaborski et al. 1997). The Kanawa Formation corresponds to the (shale-limestone) member of the Pindiga Formation. The most complete section occur in the Pindiga stream (the type section of the Pindiga Formation) and in the Ashaka quarry.

The Kanawa Member provides an excellent stratigraphical marker horizon between the sandy unit above and the Yolde Formation below. It produces a low featureless topography and weathers to a distinctive black cotton soil which is heavily cultivated in the study area and in the few remaining virgin areas. It is formed during the Late Cenomanian to Early Turonian transgression, which affected the entire Benue Trough and also the Sahara region to the north (Zaborski et al., 1997).

The greater part of the Kanawa Member consist of a shaly mudstone, dark grey in color when fresh but showing much lighter blue to green-grey colors in the weathered zones, which typically extends to depths of about 20 m. The limestones have thicknesses varying from a few centimeters to a maximum of 2 m. The limestone is grey in color when fresh, and white, cream, orange to red when weathered. Individual limestone beds are laterally non-persistent crystalline. These marly and shelly varieties most commonly occur as wackestones. Biostromal limestone less than 1 meter thick, composed of bivalve *Picatula* and bryozoans occur at Pindiga. The upper surfaces of the limestone sometimes show thalassinoides burrows and often represents a minor discontinuity surfaces with reworked fossils, epifaunas, phosphatic matter, glauconite concentrations and occurrences of exo-ammonites such as *Pseudaspidoceras* and *Watinoceras*. These horizons mark level of water deepening. Glauconite concentrations sometimes persist into the few centimeters of shales directly overlying such horizons (Zaborski et al. 1997).

2.2.3.2 The Gulani Member

The Gulani Member consists of three units. The top unit is characterized by grey, white-orange-grey, coarse–grained, tabular cross-bedded sandstones. The middle unit is fine to medium grained sandstone, grey and purple siltstones and a grey hard shelly limestone. The bottom unit is characterized by siltstone and thin sandstones. The Gulani Member has an estimated thickness of about 230 m occurring at the Dogon Zaga area (Zaborski *et al.*, 1997).

2.2.3.3 Deba Fulani Member

The name "Deba Fulani Member" is proposed herein for the mainly sandy beds occuring in the middle part of the Pindiga Formation over most of it outcrops. The unit has not been previously differentiated by the Geological Survey of Nigeria. Maps [sheets 36 (Gombe) and 47 (Lau)] indicated it as part of the Gombe Formation and "Gongila Formation". The Deba Fulani Member appears to pass laterally into the Dumbulwa Member south of the Dumbulwa-Bage High (Zaborski et al. (1997).

The outcrop of the Deba Fulani Member south of Deba Fulani is expressed topographically by a low ridge of undulating hills. it weathers to produce a thin. red lateritic soil with regolith composed of some boulders but mostly pebble-sized fragments of dense and flaggy or vesicular ironstone (Zarboski et al.. 1997).

Exposures in the Deba Fulani Member are rare and no complete section has been found. Limited sections showing sequences of sandstones and siltstones in beds of 5 to 15 centimeters thick are present in streams around the study area and especially to the west of Deba Fulani (Zaborski et al., 1997).

The basal part of the Deba Fulani Member can be seen at the Ashaka quarry. Its boundary with the Kanawa Member is transitional. occurring through a sequence of glauconic, feldspathic, calcareous sandstone, sandy shelly limestone and shales. An alternating sandstone-shale sequence occurs above, including thin laminated sandstones and thicker through cross-bedded sandstones with erosional bases.

2.2.3.4 The Dumbulwa Member

The Dumblwa Member represents the upper sandstone–shale portion of "Gongila Formation" of Carter *et al.*, (1963). The unit consists of sequence of coarse-grained, feldspartic, tabular cross- bedded sandstone. It reaches a thickness of about 200 m in Dumbulwa and Bage Hills and apparently passes laterally into the Deba Fulani Member (Zaborski *et al.*, 1997). Zaborski *el al.*, (1997) interpreted this member as fluviatile deposits.

2.2.4 The Gombe Formation

The Gombe Sandstone is of Maastrichian age (Fig. 2) and it is the youngest member of the Cretaceous series in Fika and Gombe areas. It consists of the sequence of estuarine and deltaic sandstones, siltstone, shales and ironstones. The sediment is well-bedded sandstones, grits, siltstone, flaggy sandstone and clays. Coal beds have been reported locally (Carter *et al.*, 1963). The siltstone and flaggy sandstones from the greater part of the formation occur in Gombe area. The formation rests unconformably on the older Cretaceous strata (Carter *et al.*, 1963). It overlies the Pindiga Formation (Upper Part) and it is overlain by the Kerri – Kerri Formation.

2.2.5 Stratigraphic Sections in the Area of Study

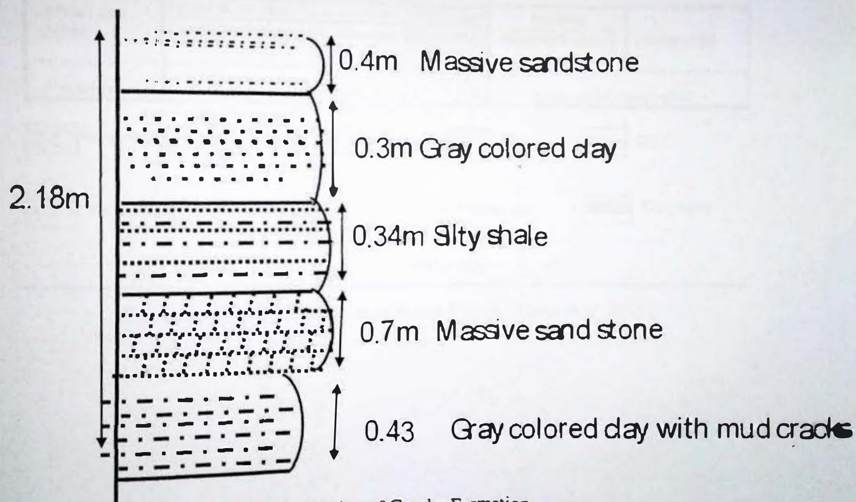

Fig. 3: Section of Gombe Formation

2.2.6 The Kerri Kerri Formation

The Kerri – Kerri Formation of Paleocene age (Adegoke *et al.*, 1978) is a continental series, consisting of loosely cemented sandstones, siltstones and claystones lying unconformable on the folded Cretaceous strata in Fika and Gombe areas (Adegoke *et al.*, 1986).

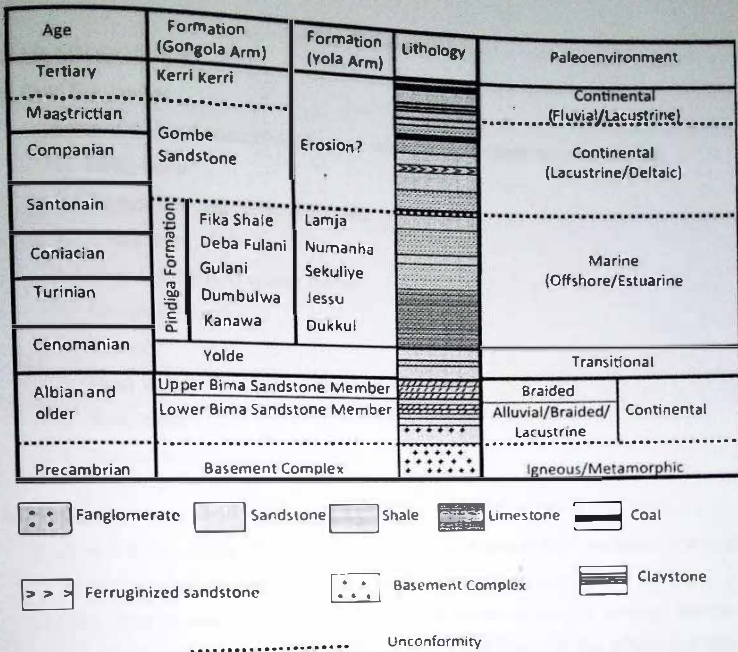

Fig. 4: Stratigraphy Succession of Benue Trough (Tukur et al. 2015).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Field Equipment

Some of the field materials/equipment used during the field mapping include;

1. Safety boots
2. Topographic map of the study area
3. A base map
4. Global positioning system (GPS)
5. Compass Clinometers
6. Hammer
7. Hand lens
8. Sample bag
9. Measuring tape

3.2 Field Method and Sample Collection

- A reconnaissance survey was done to establish the extent of the study area and strategy to be employed during the field study.
- The samples were collected along the areas traversed using a geologic hammer at various locations and at random due to the rugged nature of the terrain and also the extensiveness of some rock types.
- Each location where sampling was carried out was located in a topographical map using G.P.S.
- Each of the samples collected was well labeled using masking tape for proper identification.
- Only fresh samples of the various rock types were selected for granulometric and petrographical analysis

3.3.0 Laboratory Analysis

3.3.1 Procedure for Thin Section Preparation

Samples brought from the field were cut using cutting machine. Samples were gumed on the glass slide using Canada balsam and also the samples were polished to 2mm on the glass slide, and grind and polished with carborundum powder of 0.6mm, 0.4mm and 0.2mm simultaneously to make it thin and clear. The polished surface was covered with a thin glass cover slip using the same gum (Canada balsam). The glass slide was then placed on a heater at low temperature of 35^0 - 40^0C overnight and all the air bubbles was expelled and dried properly. The glass slide was then allowed to cool for sometime and ready for petrographic studies. The glass slide helped in identifying the minerals by the use of a microscope, and also photographs of the slide were taken.

Precaution

- When thinning and grinding, care must be taken not to break the glass slide. Overheating was avoided in order not to course cracks and it was ensured that bubbles were expelled.

3.3.2 Granulometric Analysis

Standard mechanical sieving method was used for the granulometric analysis. The samples were first disaggregated using a mortar and pestle. 200g of each sample was placed in the uppermost sieve of the stacked set of sieves. The sieve were arranged with mesh sizes decreasing from top to bottom in the following order: 4.75mm, 3.35mm, 2.36mm, 1.18mm, 0.850mm, 0.425mm, 0.300mm, 0.212mm, 0.106mm, 0.0063mm, and the pan (<0.063mm). The sieves were then covered and fastened against the Endicott sieve shaker and allowed to run for 5 minutes. Weight of the materials retained in each sieve was measured and recorded.

The statistical measures of frequency distribution were determined graphically. The phi (Φ) values were obtained using the formula $\Phi = -\log_2 D$ where D is grain diameter (mm). The individual weight percentages were obtained by dividing the weight (g) of each retained material by their total and multiplying it by 100. Whereas, the cumulative weight percentage were obtained by adding the individual weight percentage of the first sieve to the next, and the answer obtained is added to the subsequent weight percentage, continuously to the end.

3.3.3 Cumulative Frequency Curves

In the cumulative curve the weight percentage of the material retained on the largest sieve is recorded first. The position of the next point to be recorded will be fixed by the sum of the preceding percentage plus that of the material retained on the next (finer) sieve, and so on. Cumulative curves can be drawn using either an arithmetic ordinate or a probability ordinate

3.3.4.0 Interpretation of Cumulative Curves

In cumulative frequency curves, the method most commonly used involves plotting the cumulative curve and reading the diameter represented by various percentages. The various statistical parameters used as proposed by (Folk, 1957) are:

1. Graphic Mean (M_Z)
2. Graphic Kurtosis (KG)
3. Inclusive Graphic Skewness (SK_I)
4. Inclusive Graphical Standard Deviation (δ_I)

3.3.4.1 Graphic Mean (M_Z)

Graphic Mean (M_Z): This statistical measures reflects the overall average grain size of studied samples was calculated using the formula below.

$$M_Z = \frac{\Phi 16 + \Phi 50 + \Phi 84}{3}$$

A description scale corresponding to the value of graphic mean as defined by Folk (1975) is given in Table 1.

Table 1: Descriptive Scale of Graphic Mean

GRAPHIC MEAN (Φ) M_Z	GRAIN SIZES
<0	Very coarse sand
0 to 1.0	Coarse sand
1.0 to 2.0	Medium grained sand
2.0 to 3.0	Fine grained sand
3.0 to 4.0	Very fine grained sand
4.0to6.0	Coarse silt

3.3.4.2 Graphic Kurtosis (K_G)

This is the measured of degree of peakedness of the distribution curve. Graphic Kurtosis is given by the formula.

$$K_G = \frac{\Phi 95 + \Phi 5}{3}$$

A description scale given by Folk (1975) for Kurtosis is given in Table 2.

Table 2: Descriptive Scale of Graphic Kurtosis

GRAPHIC KURTOSIS (K_G)	DEGREE OF PEAKEDNESS
<0.67	Very Platykurtic
0.67 to0.90	Platykurtic
0.90 to1.11	Mesokurtic
1.11 to 1.50	Leptokurtic
1.50 to 3.0	Very leptokurtic
>3.00	Extremely leptokurtic

3.3.4.3 Inclusive Graphic Skewness (SK_I)

This is the measure of the degree of asymmetry of the distribution curve. When sediment has more materials in the coarse tail (coarse skewed) the skewness in negative while if there are more materials in the fine tail (fined skewed) it is positive, and it is given by the formula of Folk and Ward (1975) below. The interpretations of the values of Inclusive Graphical Skewness were given in Table 3.

$$SK_I = \frac{\Phi 84 + \Phi 16 + \Phi 50 + \Phi 95}{2(\Phi 84 - \Phi 16)} + \frac{\Phi 5 - 2\Phi 50}{\Phi 84 + \Phi 16}$$

Table 3: Descriptive Scale of Inclusive of Graphic Skewness (SK_I)

INCLUSIVE GRAPHIC SKEWNESS	DESCRIPTION TERM
+1.0 to 0.3	Very fine skewed
+0.3 to 0.1	Fine skewed
+0.1 to -0.1	Near Symmetrical
-0.1 to -0.3	Coarse skewed
-0.3 to -0.1	Very Coarse skewed

3.3.4.4 Inclusive Graphic Standard Deviation (δ_I)

This is the measure of degree of sorting or uniformity of the particles size distribution about the mean in a normal distribution. It is given by the formula below. The interpretations of these values were given in Table 4.

$$\delta_I = \frac{\Phi 84 + \Phi 16 +}{4} \quad \frac{\Phi 95 + \Phi 5}{6.6}$$

Table 4: Descriptive Scale of Inclusive Standard Deviation (δ_I)

INCLUSIVE STANDARD DEVIATION	DESCRIPTION TERM
<0.350	Very well sorted
0.35 to 0.50	Well sorted
0.50 to 0.71	Moderately well sorted
0.71 to 1.00	Moderately sorted
1.00 to 2.00	Poorly sorted
2.00 to 4.00	Very poorly sorted
>4.00	Extremely poorly sorted

CHAPTER FOUR

4.0RESULTS AND INTERPRETATION

4.1 Geological of the Study Area

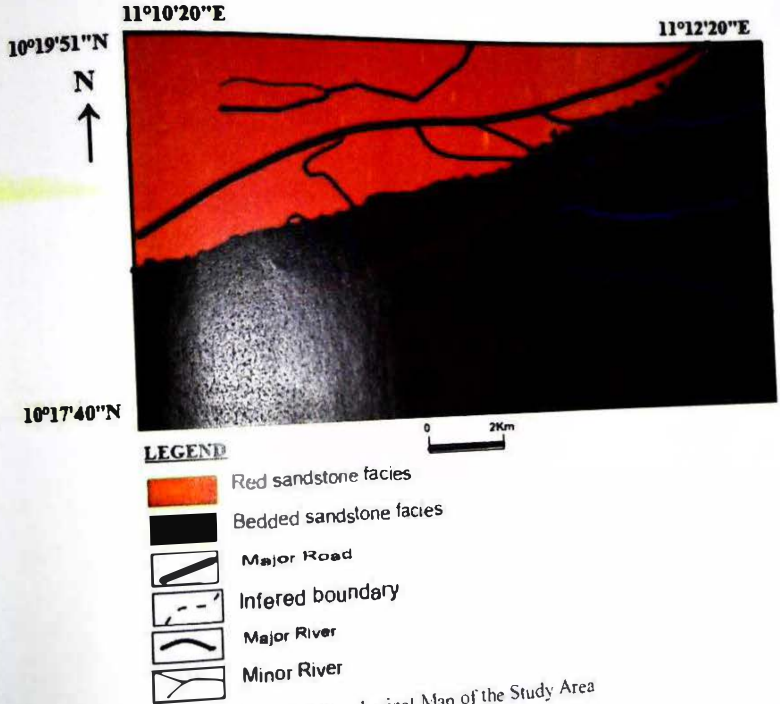

Fig. 5: A Geological Map of the Study Area

4.2.0 Sedimentary Structur s

These are internal structures of sediments that are formed before, during or shortly after deposition and are classified into erosional, depositional, post-depositional and biogenic structures (Tuker, 2003). They are very important for the interpretation of depositional environment and for determining the way of rock sequence in an area of complex folding, and for deducing paleocurrent direction and paleogeography. The sedimentary structures observed in the mapped area are, cross stratification (strough cross- bedding), graded beddings and ripple marks.

4.1.1 The Gombe Formation

The Gombe sandstone occupied the North and South-western part of the study area (Arawa), the sandstones comprises of white-grey, red sandstones, siltstones, silty clays and bioturbations.

Plate 1: Gombe Sandstone Formation

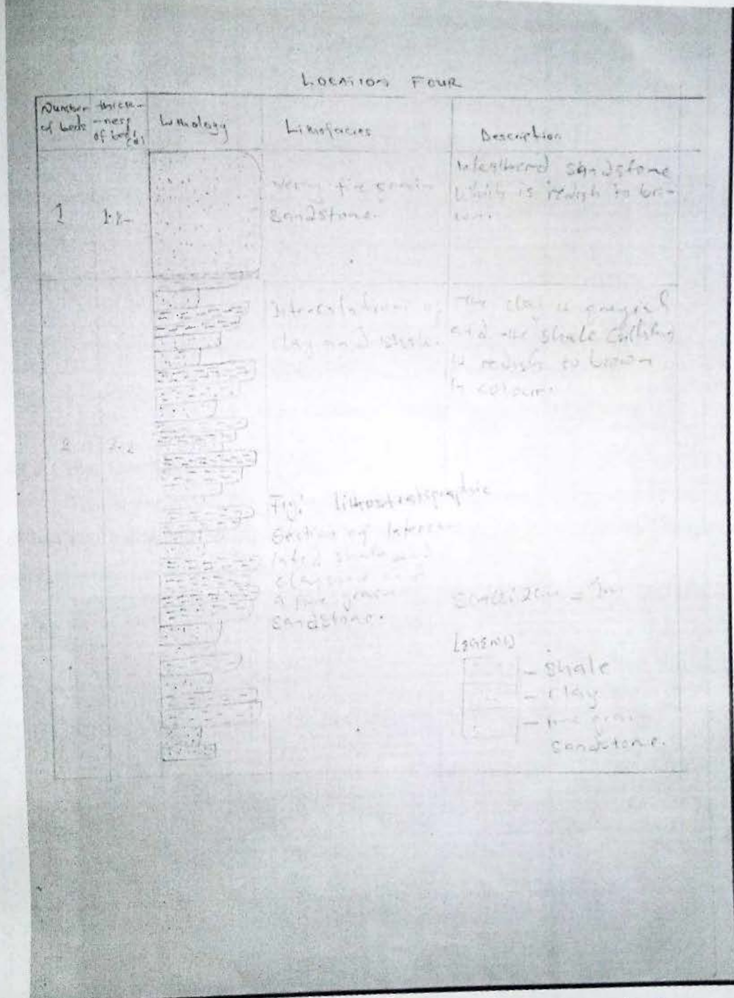

Fig. 6: Lithologic Section of Gombe Formation at Location 4

Plate 2: A Planer Bedding of Gombe Formation at location 5

4.1.2 Cross Bedding

This is one of the most oblivious sedimentary structures in the study area consist of sets of bed that are inclined relative to one another. The beds are inclined in the direction that the wind or water was moving at the time of deposition.

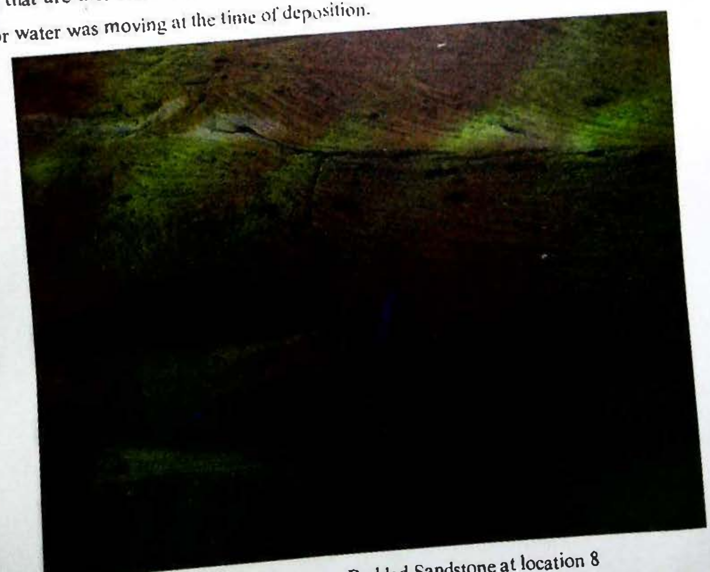

Plate 3: Troughs Cross Bedded Sandstone at location 8

4.2.0 Data Presentation

4.2.1 Interpretation and Discussion of Results

Statistical measures of frequency distribution were determined graphically. The cumulative frequency curve was used to determine the phi values of various percentile points.

Phi (ϕ) values were obtained using formula

$\phi = \log_2 D$

Statistical percentile ϕ 5, ϕ 16, ϕ 25, ϕ 50, ϕ 75, ϕ 84 and ϕ 95 determine from cumulative curves were used in calculating various parameters (after Folk and Ward, 1957).

4.2.2 Grain Size Data Table

Table 5: Raw data for granulometric analysis for location 1 Gombe sandstone.

Location 1

Sieve size(mm)	Phi(□)	Weight retained(g)	Weight %	Cumulative weight %
			0	0
4.75	-2.25	0	0	0
3.35	-1.74	0	0	0
2.36	-1.24	0	0	0
1.18	-0.24	0.67	0.34	0.34
0.85	0.23	1.10	0.55	0.89
0.43	1.22	2.53	1.27	2.16
0.30	1.74	1.50	0.75	2.91
0.21	2.25	2.58	1.29	4.20
0.11	3.18	163.47	81.77	85.97
0.08	3.64	19.57	9.79	95.76
0.06	4.06	2.97	1.49	97.25
Pan		5.53	2.77	100.02
Total		199.92		

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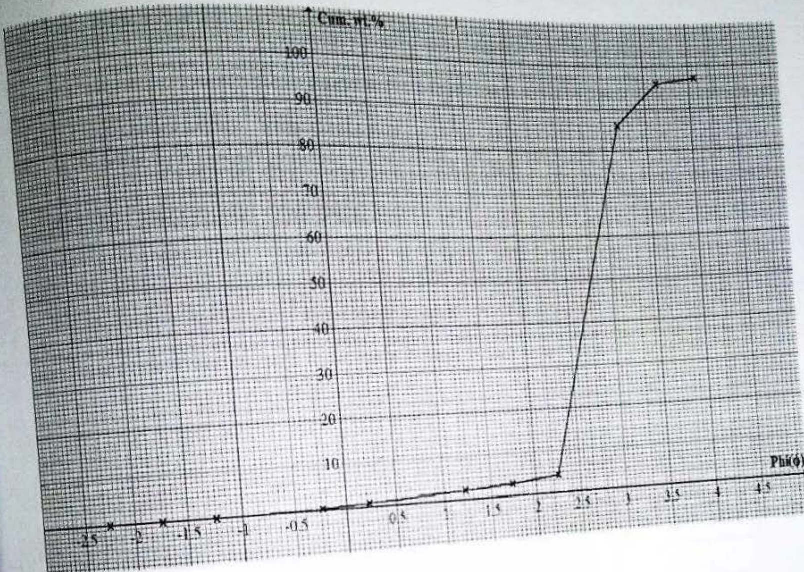


Mean [illegible]

The mean is 2.8 and therefore the sample is a fine grain sand size particle.

Standard deviation (D) [illegible]

The standard deviation is 0.46 and therefore the sample is well sorted.

Skewness [illegible]

[illegible]

[illegible]

[illegible]

The skewness is 0.13 and therefore the sample is fine skewed.

Kurtosis (K)[illegible]

[illegible]

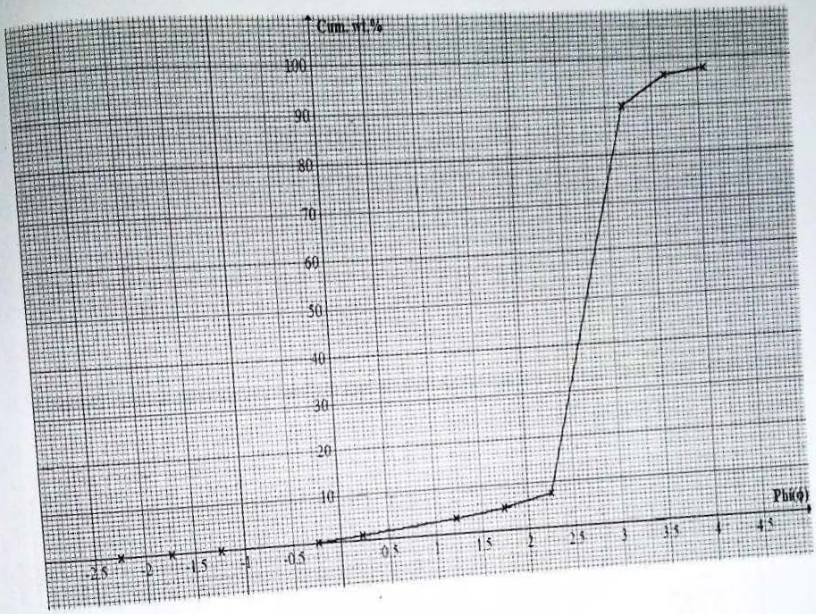
[illegible]

The kurtosis is 1.10 and therefore the sample is Mesokurtic

Table 6: Raw data for granulometric analysis for location 3 Gombe sandstone.

Location 3

Sieve size(mm)	Phi(□)	Weight retained(g)	Weight %	Cumulative weight %
4.75	-2.25	0	0	0
3.35	-1.74	0	0	0
2.36	-1.24	0	0	0
1.18	-0.24	0.46	0.23	0.23
0.85	0.23	1.88	0.94	1.17
0.43	1.22	4.55	2.28	3.45
0.30	1.74	2.96	1.48	4.93
0.21	2.25	4.74	2.37	7.30
0.11	3.18	165.86	82.95	90.25
0.08	3.64	12.25	6.13	96.38
0.06	4.06	2.87	1.44	97.82
Pan		4.38	2.19	100.01
Total		199.95		



Mean [illegible]

The mean is 2.7 and therefore the sample is a fine grain sand size particle.

Standard deviation (D) [illegible]

The standard deviation is 0.46 and therefore the sample is well sorted.

Skewness [illegible]

[illegible]

[illegible]

[illegible] = 0.52

The skewness is 0.52 and therefore the sample is strongly fine skewed.

Kurtosis (K) [illegible]

[illegible]

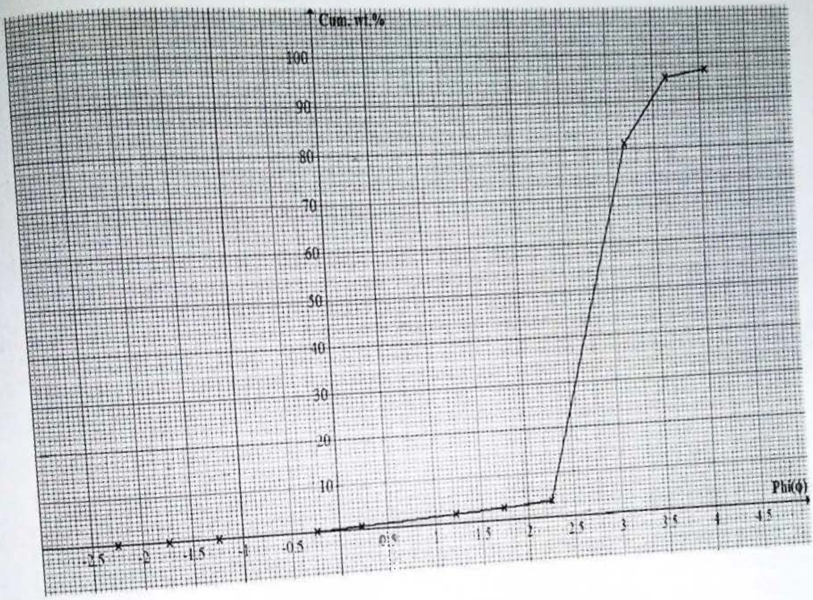
[illegible]

The kurtosis is 1.30 and therefore the sample is Leptokurtic

Table 7: Raw data for granulometric analysis for location 5 of Gombe sandstone.

LOCATION 5

Sieve size(mm)	Phi(ϕ)	Weight retained(g)	Weight %	Cumulative weight %
			0	0
4.75	-2.25	0	0	0
3.35	-1.74	0	0	0
2.36	-1.24	0	0.21	0.21
1.18	-0.24	0.41	0.49	0.70
0.85	0.23	0.97	1.36	2.06
0.43	1.22	2.72	0.71	2.77
0.30	1.74	1.42	0.78	3.55
0.21	2.25	1.56	77.52	81.07
0.11	3.18	154.99	13.75	94.82
0.08	3.64	27.49	1.67	96.49
0.06	4.06	3.34	3.75	100.24
Pan		7.49		
Total		199.94		



Mean [illegible]

The mean is 2.8 and therefore the sample is a fine grain sand size particle.

Standard deviation (D) [illegible]

The standard deviation is 0.41 and therefore the sample is well sorted.

Skewness [illegible]

[illegible]

[illegible]

[illegible]

The skewness is 0.14 and therefore the sample is fine skewed.

Kurtosis (K) [illegible]

[illegible]

[illegible]

The kurtosis is 1.0 and therefore the sample is Mesokurtic

4.3.0 Data Interpretation

Table 8 data interpretation

S/N	LOCATION NAME	GRAPHIC MEAN (MZ)	STANDARD DEVIATION (SD)	GRAPHIC INCLUSIVE SKEWNESS (SKI)	GRAPHIC INCLUSIVE SKEWNESS (SKI)
1	Sample 1	2.8	0.46	0.13	1.10
2	Sample 2	2.7	0.46	0.52	1.30
3	Sample 3	2.8	0.41	0.14	1.0

4.3.1 Sample Description

Table 9: the interpreted result of individual sample analysed were presented in the table below.

S/N	LOCATION NAME	GRAPHIC MEAN (MZ)	GRAPHIC KURTOSIS (KG)	GRAPHIC INCLUSIVE SKEWNESS (SKI)	STANDARD DEVIATION (SD)
1	Sample 1	Fine grain sand	Mesokurtic	Fine skewed	Well sorted
2	Sample 2	Fine grain sand	Leptokurtic	Strongly fine skewed	Well sorted

3	Sample 3	Fine grain sand	Mesokurtic	Fine skewed	Well sorted

4.4.0 Petrographic Analysis

4.4.1 Microscopic Study of sample 1

Plate 4: Under plane polarized light

Plate 5: Under crossed polarized light

Statistical Computation of Sample 1

Table 10: showing the count from the various slide positions of sample 1

Slide position	**1**	**2**	**3**	**4**	**Total**
Quartz	17	20	21	20	78
Feldspar	4	4	6	7	21
Rock Fragment	10	13	10	10	43
					$\sum 142$

Quartz = $^{78}/_{142} \times 100 = 55\%$

Feldspar = $^{21}/_{142} \times 100 = 14.8\%$

Rock Fragment = $^{43}/_{142} \times 100 = 30\%$

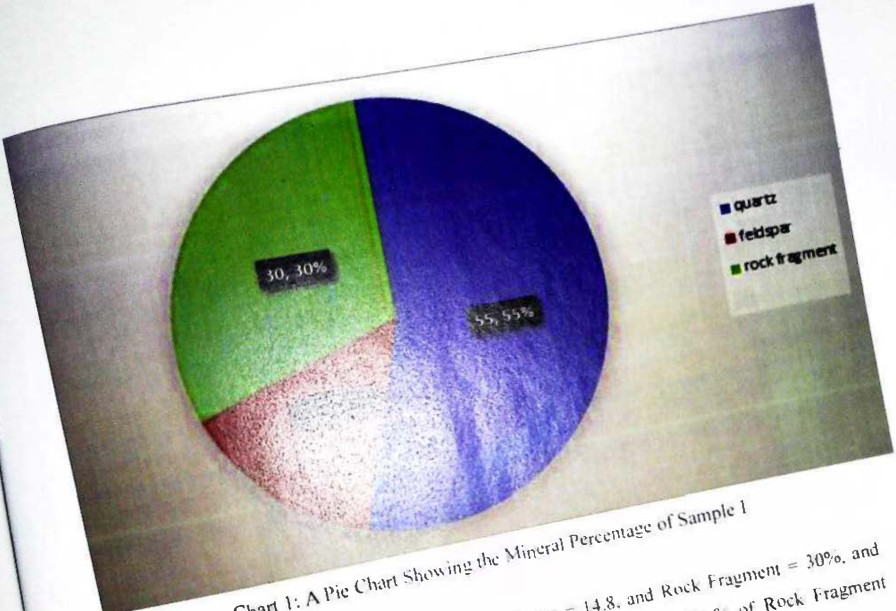


Chart 1: A Pie Chart Showing the Mineral Percentage of Sample 1

Relating to QRF the initial Quarts = 55.55, Feldspars = 14.8, and Rock Fragment = 30%, and respectively. Normalizing it to 100% we have 55.1% of Quartz, 14.8 % of Rock Fragment and30.1 % of Feldspars and is presented in the QRF diagram below:

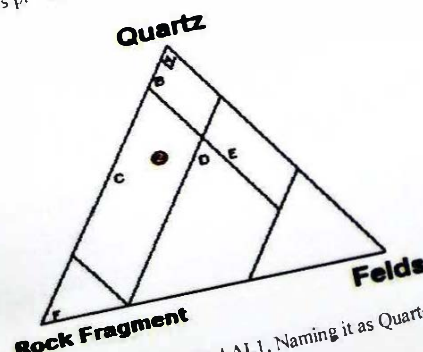


Fig 7: QRF Diagram of Sample AAL1. Naming it as Quartz Wacke

4.4.2 Microscopic study of Sample 2

Plate 5: Under plane polarized light

Plate 6: Under crossed polarized light

Statistical Computation of Sample 2

Table 11: showing the count from the various slide positions of sample 2

Slide position	1	2	3	4	Total
Quartz	18	20	19	20	77
Feldspar	4	5	7	8	24
Rock Fragment	7	10	10	11	38
				$\sum 139$	

Quartz = $^{77}/_{139} \times 100 = 55.5\%$

Feldspar = $^{24}/_{139} \times 100 = 17.2\%$

Rock Fra ment = $^{38}/_{139} \times 100 = 27.3\%$

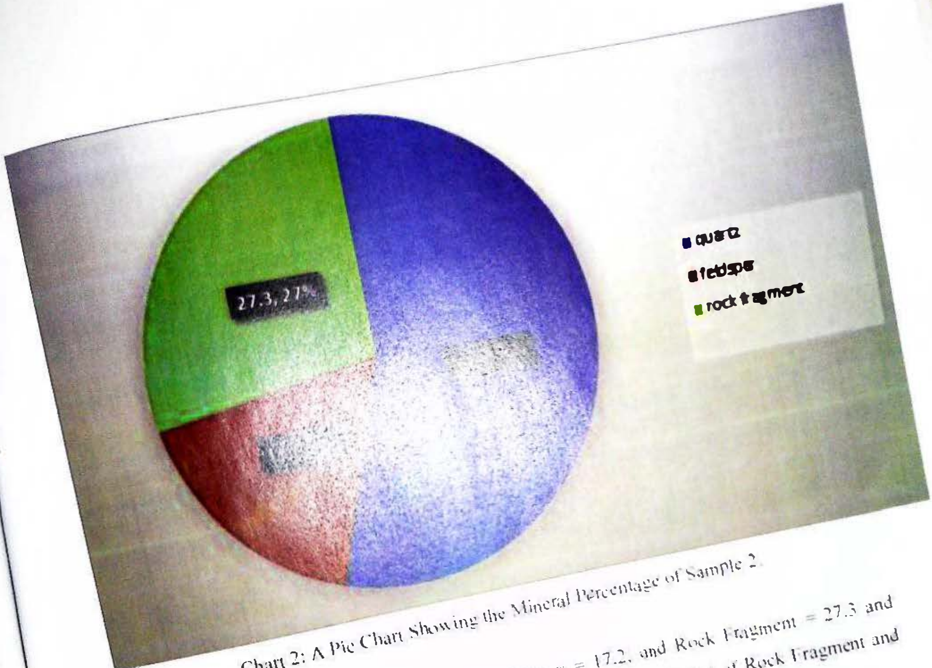


Chart 2: A Pie Chart Showing the Mineral Percentage of Sample 2.

Relating to QRF the initial Quarts = 55.5, Feldspars = 17.2, and Rock Fragment = 27.3 and respectively. Normalizing it to 100% we have 55.5% of Quartz, 17.2 % of Rock Fragment and 27.3 % of Feldspars and is presented in the QRF diagram below.

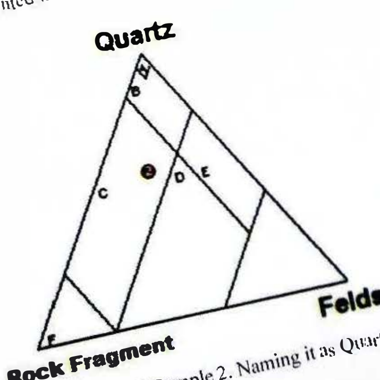


Fig 8: QRF Diagram of Sample 2. Naming it as Quartz Wacke

4.4.3 Microscopic study of sample 3

Plate 7: Under plane polarized light

Plate 8: Under crossed polarized light

Statistical Computation of Sample 3

Table 12: showing the count from the various slide positions of sample 3

Slide position	**1**	**2**	**3**	**4**	**Total**
Quartz	15	20	17	20	72
Feldspar	4	8	7	8	27
Rock Fragment	9	10	9	10	38
					$\sum 137$

Quartz = $72/_{137} \times 100 = 53.2\%$

Feldspar = $27/_{137} \times 100 = 19.7\%$

Rock Fragment = $38/_{137} \times 100 = 27\%$

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