The Reservoir Potentials Of The Bima Sandstone Around Wade Hill, Dadinkowa And Wuyo Areas Of Gombe State Sheets (152NE And 153NW)

Adinye Titus

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THE RESERVOIR POTENTIALS OF THE BIMA SANDSTONE AROUND WADE HILL, DADINKOWA AND WUYO AREAS OF GOMBE STATE SHEETS (152NE AND 153NW).

BY

ADINYE TITUS

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

SEPTEMBER 2010.

DECLARATION

I here by declare that this project was written by me and it is a record of my own research work through the help of God. It has not been presented before in any previous application for a first degree. Reference made to published literature has been duly acknowledged.

STUDENT

NAME:..

SIGN:..

DATE:..

SUPERVISOR

NAME: Isa Mohamed Tahir

SIGN:..

DATE: 21/10/2010

EXTERNAL EXAMINER

NAME:..

SIGN:..

DATE:..

CERTIFICATION

The project entitled "The Reservoir Potential of the Bima Sandstone around Wade hill, Dadinkowa and Wuyo areas of Gombe State" submitted by Adinye Titus, meets the regulation governing the award of the degree of Bachelor of Technology in Applied Geology of the Abubakar Tafawa Balewa University Bauchi and is approved for its contribution to knowledge and literacy presentation.

SUPERVISOR

NAME: Isa Mohammed Tali

SIGN:..

DATE: 21/10/2010

PROGRAMME COORDINATOR

NAME: A. S. Maigari

SIGN:..

DATE: 8/2/11

EXTERNAL EXAMINER

NAME:..

SIGN:..

DATE:..

DEDICATION

This research work is dedicated to Almighty God and to the entire Adinye's family

ACKNOWLEDGEMENT

I acknowledge Almighty God who in his infinite mercy and by his grace has watched over me and directed my footsteps through out the pursuit of my academic goals.

My special thanks goes to my family, my late daddy, my mummy, Mr and Mrs Adinye, my beloved brothers Joseph and Godfrey, God bless you all.

I wish to express my profound gratitude to my supervisor Mallam Isa Mohammed Tahir who through his advice and guidance made this research work a success.

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Finally to all my friends who assisted me during this research work, thank you all.

ABSTRACT

The Bima Sandstone, an entirely continental formation throughout the Upper Benue Trough, is the basal part of the sedimentary succession. The sandstones are interpreted to be of alluvial fan to braided river origin.

Samples of the Bima sandstone around Wade hill, Dadinkowa and Wuyo areas of Gombe state were analyzed to determine their mineralogical composition, grain size distribution, sorting, coefficient of uniformity, permeability and porosity so as to determine its reservoir potential.

Based on granulometric analysis the Bima sandstone is fine, medium to coarse grain and poorly, moderately to very well sorted. Also its coefficient of uniformity is between fair and well graded.

Petrographic studies showed that the sandstone consist of quartz as the dominant mineral with little feldspar and also compaction induced fracturing in the form of micro cracks on brittle quartz grains are evidence of diagenesis and compaction that altered the petrophysical properties of the Formation.

The reservoir potential of the Bima sandstone was inferred to be relatively good as its porosity ranges from 14.9% to26.1% with an average of 21.2% and its permeability ranges from 6.9(D) to 209(D) with an average of 54.4(D) which is in agreement with the values obtained for some giant and super giant silisiclastic reservoir rocks of the world.

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 INTRODUCTION

Sedimentary rocks are formed as a result of weathering and sedimentation processes, originating from older igneous, metamorphic and previously deposited sediments that have been broken down physically and chemically. The weathered material is transported as debris and accumulates at the locus of deposition. One of the most important groups of sedimentary rocks is sandstones. Sandstones frequently form major aquifers and petroleum reservoirs with predictable geometry and reservoir performance compared to carbonates. This is because sandstones are more uniform in their petrophysical properties. Sandstones are very important as reservoirs for oil and gas; about 50% of the worlds petroleum reserve is estimated to occur in sandstones (berg, 1989).

The purpose of this research work is to determine the reservoir potential of the Bima sandstone around Dadinkowa, Wade and Wuyo areas of Gombe state. Knowledge of their properties is essential in the exploration for, and the production of subsurface fluids. Besides that it is also essential to understand the reservoir and its capacity for oil and gas production. The study of porosity and permeability of rocks is of prime importance in relation to the search for oil and underground water since the pore system is the channel for movement as well as the storage of fluids.

Porosity of a rock is defined as the percentage of pore space in the total volume of the rock i.e the space not occupied by solid mineral matter. Primary porosity of a sediment is due to the fact that clastic components at the time of deposition cannot be in continuous contact. Original porosity is usually later changed, to be increased or decreased, due to such causes as fracturing and solution on compaction and cementation. It is then termed secondary porosity.

The original porosity of a sediment is affected by the size and shape of the grains, their sorting and packing and compaction during and after deposition. The highest porosity is reached with good sorting, when all the grains are of the same size, the addition of finer or coarser grains lowers the porosity. In well sorted sediments, the finer have higher porosity than the coarser due to a greater surface area.

Permeability of a rock is the property of allowing the passage of fluids through its pore spaces. The rock is permeable if it permits the passage of an appreciable amount of fluid in a given time, it is impermeable if the rate of passage of fluids is negligible. Permeability is affected by the size and shape of the pores which have to be interconnected. Accordingly any change in packing which increases porosity will increase permeability. Not all porous rocks are permeable. Fine grained rocks though porous are very slightly permeable.

1.2 LOCATION AND ACCESSIBILITY

The research work was carried out around Dadinkowa, Wade and Wuyo areas of Gombe state where the Bima sandstone has been exposed in form of outcrops. The study area is within latitudes $10^0 16'56.7''$ and $10^0 27'26.4''$ and longitudes $11^0 29'1.1''$ and $11^0 40'57.3''$ and is part of sheet 153(Wuyo NE) (Fig 1). The area is accessible by a major road which is the Gombe to biu road and few minor roads (mainly footpaths).

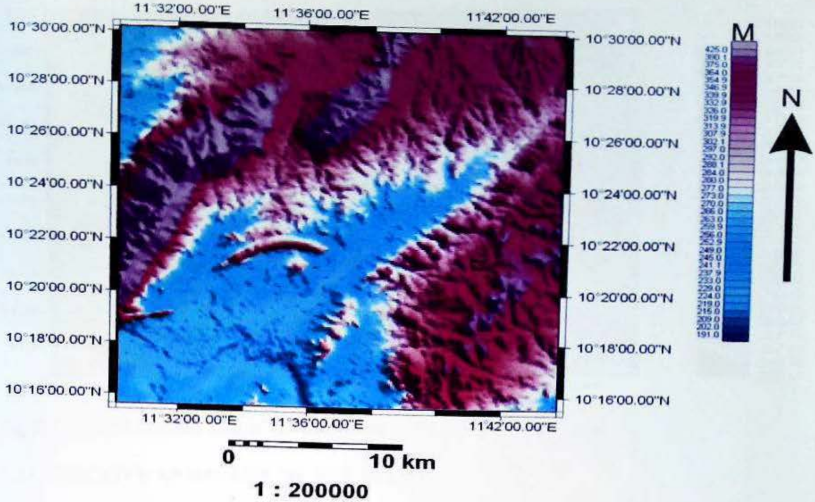


Fig 1:Shuttle Rader Topographic Mission showing Elevation(National Center for Remote Sensing)

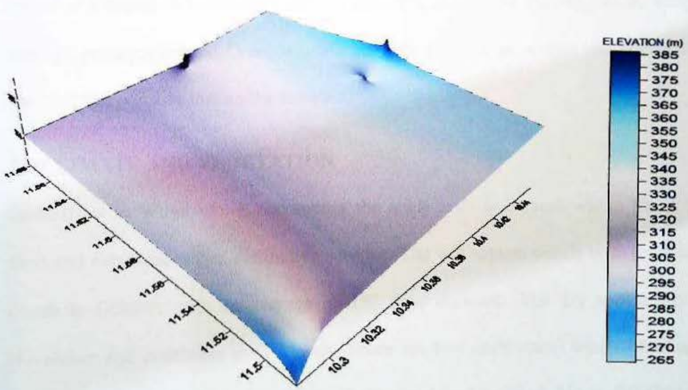


Fig 2: 3D Surface of the study area.

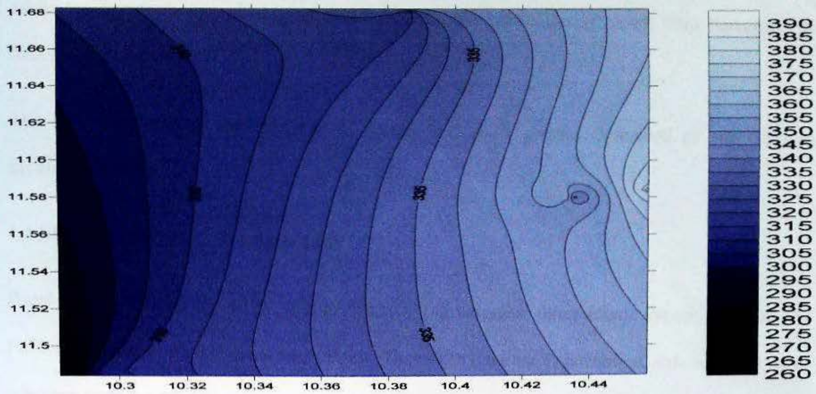


Fig 3: Digitized Contour map of the study area.

1.2 OBJECTIVE AND SCOPE OF THE STUDY

The aim of the research work is to understand the reservoir potential of the Bima sandstone around Dadinkowa, Wade and Wuyo areas of Gombe state, is also part of the requirement for the award of a degree in technology(applied geology). It involves the analysis of samples in the area through petrography and Granulometric analysis for their porosities and permeabilities, also by carrying out porosity test on the samples.

1.3 CLIMATE AND VEGETATION

Dadinkowa to Wuyo which encompass the study area is located within the subsudan climate zone and experiences two distinctive seasons. The wet season which lasts from about the end of march to October with an average of 152 days duration. The dry season which starts from November and continues until March. There are two continental winds blowing, the moisture laden south west winds that originates from the Atlantic ocean, blows from march to October, while the dry north east winds that originate from the sahara desert blows from November to march.

The vegetation of the area consists of shrubs and short grasses described as sub Saharan savannah.

1.4 SETTLEMENT AND LAND USE

People living around the study area are mostly the tangales, other ethnic groups include, the Fulanis, Hausas, and other ethnic minorities. The major land use is farming. Cattle rearing is also common amongst the Fulanis.

CHAPTER TWO: LITERATURE REVIEW

2.1 GENERAL GEOLOGY OF THE BENUE TROUGH

2.2 INTRODUCTION

The Benue Trough which is located at the gulf of Guinea re-entrant on the west African coast, is a unique Cretaceous rift. The Benue Trough is a sedimentary environment and its trend is in the NE-SW direction. Starting from the southern part of Nigeria near the Niger Delta up to the northern part of the country near the Chad Basin. It is about 800-1000km long and about 50-150km wide, the sediments are of marine and fluvio-deltaic sediments that have been compressed and folded in a non-orogenic shield environment. The Benue Trough is divided into three parts, the Upper Benue Trough, the Middle Benue Trough, and the Lower Benue Trough.

The Upper Benue Trough is divided into a N-S trending Gongola arm and an E-W trending Yola arm (Benkhelil, 1989).

2.3 ORIGIN AND EVOLUTION OF THE BENUE TROUGH

Benkhelil (1982, 1986) Benkhelil and Robineau (1983), Maurin et al (1986) used geology and structural analysis to interpret the evolution of the trough. These authors viewed the Benue Trough as a set of pull apart basins or grabens generated sinistral displacements along pre existing NE-SW transcurrent faults. This led them to conclude that transcurrent currents are the basic tectonic mechanism in the formation and subsequent evolution of the Benue Trough. Guiraud and Maurin (1992) as well as Maurin et al (1986) believed that the orientation of the trough is controlled by the NE-SW dextral shear zones of the late pan African age which were reactivated during the opening of the Benue Trough by the sinistral shear. The evolution of the

Benue Trough is intricately linked with the Atlantic ocean in the early Cretaceous in its shape and is controlled by the pre existing ductile/brittle shear zones periodically reactivated in response to tectonism.

The second model for explaining the origin of the Benue Trough is the Rift System Model. The striking elongated appearance of the Benue Valley suggests some kind of structural control of the sedimentary area and had led to a number of propositions on its origin. In the Rift System Model, the Benue Trough is seen as a direct consequence of the RRR junction beneath the Niger Delta. The earliest model on the origin was proposed by king (1950) who suggested tensional movement resulting in a rift as a controlling factor.

Carter et al (1963) interpreted the origin of the Benue Trough in terms of rifting, folding and faulting associated with basement flexuring. But Burke et al (1970) contended that the Benue rift first opened up in the Cretaceous as a result of a spreading ridge in the region of the present valley.

Cratchley and Jones (1965) and Cractchley et al (1984) based on both geological evidence; gravitational interpretation too support the rift model.

The interpreted and observed axial zone of the positive gravity flanked by linear negative gravity anomaly that resulted from the thinning angle of elevation of the crust mantle boundary beneath the central part of the rift. Burke and Dewey (1974), Olade (1975) and Wright (1976) considered the Benue Trough as the third failed arm of the aulocogene of a three arm rift system related to the development of hot spot. The idea of spreading ridge hypothesis (Burke et al 1970) was dismissed by Wright (1976) as unatenable after comparing the Afar region of the North-East Africa and the Benue valley.

2.4 THE BENUE TROUGH

The Benue Trough is filled with sediments that range from late Aptian to Paleocene Adegoke et al (1978); Alix et al (1981). The environment of deposition also varied over time such that the sediment vary from continental, lacustrine and fluvial sediments at bottom through various transgressive and regressive beds to immature reddish continental sands at the top. The trough contain up to 6000m Cretaceous to Tertiary sediments of which those predating the mid Santonian were compressional folding during the mid Santonian tectonic episode which affected the whole of the Benue Trough and was quite intense producing over 180 anticlines and synclines (Benkhelil, 1986) of which Abakaliki anticlinorium and Afikpo syncline in Lower Benue are examples.

The Trough is thought to have provided a major link between the Tethys ocean and the Gulf of Guinea with the Iullumedden and Chad Basins during the Upper Cretaceous times (Obaje et al 2000). The Benue Trough is arbitrarily and geographically subdivided into a Lower, Middle and Upper portion. No concrete line of subdivision can be drawn to demarcate the individual potions, but major localities, towns, settlements that constitute the depocentres of the different oceans have been well documented peters 1982; Nwajide (1990), Idowu and Ekeolor (1993).

2.5 THE STRATIGRAPHIC FRAME WORK OF THE BENUE TROUGH

In the Benue Trough, the oldest marine deposits are the Albian Asu River group, which includes the shale, limestone and sandstone lenses (Benkhalil 1986) of the Abakaliki shale Formation which are correlative with the Mfomosing limestone Formation in the Lower Benue Trough. In the Middle Benue Trough, the lateral equivalents are the fossiliferous Arufu uomba and Gboko Formations. The Albian Bima sandstone are the oldest deposits in the Upper Benue Trough.

The Cenomanian period is believed to be a minor regressional period in the Lower Benue Trough. During the Cenomanian, there was virtually no deposition, except in the Calabar flank where the Odukpani Formation was deposited.

The regressive Awe and Keana Formations were deposited in The Middle Benue Trough, while the transitional Yolde Formation was deposited in the Upper Benue Trough.

The Turonian period was a period believed to be of a major transgression in the entire Benue Trough, which culminated into possible links between the water to the Gulf of Guinea to the south and the Tethys sea to the north. The transgressive Turonian–Santonian Cross river group in the Lower Benue Trough are siltstones (Carter et al 1960) with regressive sandstones of the Agala and Agbani Formation, which are inter fingered.

The marine Ezeaku and Awgu Formation are the lateral equivalents of the Cross river group in Middle Benue Trough, while the marine Pindiga Formation and the regressive Gulani sandstone were deposited in the Upper Benue Trough during the Turonian-Santonian period.

The shales and limestone of the Dukul Formation, the Mudstones of the Jessu Formation, the Oyster beds of the sukuliye Formation, the Numanah shales and the Lamja sandstone are the lateral equivalent of the Pindiga Formation in the Yola arm of the Upper Benue Trough.

During the Santonian period, all Pre-Santonian sediment in the Lower Benue Trough and part of the Middle Benue Trough were folded and uplifted. The shaly sediments that were less competent in the Abakaliki Trough were intensively folded into the Abakaliki anticlinorium with some minor igneous activities. Due to these processes, depressions were formed on both flanks of the anticlinorium (the small syncline to the SE and the wider Anambra Basin on the NW).

After the Santonian folding, the period turned into a period of regression and the new depo-center became the Anambra basin.

In the Lower Benue Trough, the paralic shales of the Enugu and Nkporo Formations and the Mamu Formation and the fluvio-deltaic sandstone of the Ajali Formation of the Campano-Maastrichtian period were deposited. The regressional period marks the beginning of the proto-Niger Delta in the Lower Benue Trough. The continental fluvial Lafiya Formation in the Middle Benue Trough represent the only lateral facie equivalent of the post Santonian sediments, while in the Upper Benue Trough, the Gombe sandstone is the representative of the Campano-maastrichtian sediment.

In the Tertiary, the sediments deposited are the continental keri-keri Formation which unconformably overlie the Gombe sandstone in the Upper Benue Trough. No sediments were reported to be deposited during the Tertiary in the Middle Benue Trough. During the Paleocene there was a major transgression in the whole of southern Nigeria in the Lower Benue Trough which terminated the advancement of the Upper Cretaceous proto-Niger Delta. Deposition of sediments and sedimentation only occurred in the Anambra Basin where the Imo shales and the Ameke Formation together with their subsurface equivalent, the Agbada and the Akata Formation were represented. The deposition of the Ameke Formation marks the beginning of the main regressional period and the formation of the present Niger Delta during middle Eocene time.

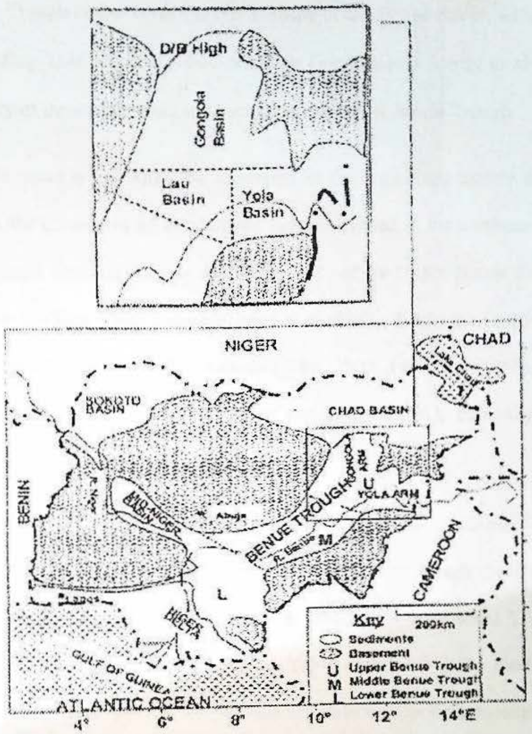


Fig 4: Generalized geologic map of Nigeria showing the Benue Trough, Gongola Basin, and the Dumbulwa Bage High (D/B) (After Abubakar, 2006)

2.6 STRATIGRAPHY OF THE UPPER BENUE TROUGH

The Upper Benue Trough is the North eastern Y shape of the Benue trough which is bifurcated into an E-W trending Yola arm and a N-S trending Gongola arm (carter et al 1963). Fig (5) shows the summary of the stratigraphic successions of the Upper Benue Trough.

The pre Mesozoic rocks which form the Basement in the region are mainly migmatites and gneisses although the complexes of the Jurassic age are located at the northern margin of the Middle Benue Trough. Detailed geology and stratigraphy of the Upper Benue Trough has been presented by many workers which includes carter et al (1963); Benkhelil (1985; 1986; 1988), Offodile (1987), Adegoke et al (1978), Guiraud (1989; 1990; 1991; and 1983), Dike (1993); Zaborsky et al (1997), Obaje (2000), Abubakar and Obaje (2001), Zaborsky et al (2003) Amongst others.

The lithostratigraphic sequence begins with thick lower Cretaceous continental clastics of the Bima sandstone group which comprises of oldest sediments in the trough and directly overlies the crystalline Basement Falconer (1911) Carter et al (1963). The continental Yolde Formation overlies the Bima sandstone group. Overlying the Yolde Formation is the Pindiga Formation which represents the greater part of the dominantly marine upper Cretaceous series. This formation is divisible into three units; the kanawa member, upper Cenomanian to lower Turonian shales and limestones, the laterally equivalent Gulani and Deba Fulani and Dumbulwa members (sandstones deposited mainly during the middle Turonian regression) and Fika member (marine and mainly argillaceous) at the top. The lateral equivalents of the Pindiga Formation are the Dukul, Jessu, Sukuliye and Lamja Formations. The Gombe sandstone, a mainly maastrichtian coarsening upward deltaic unit completes the cretaceous sedimentation in the Upper Benue Trough.

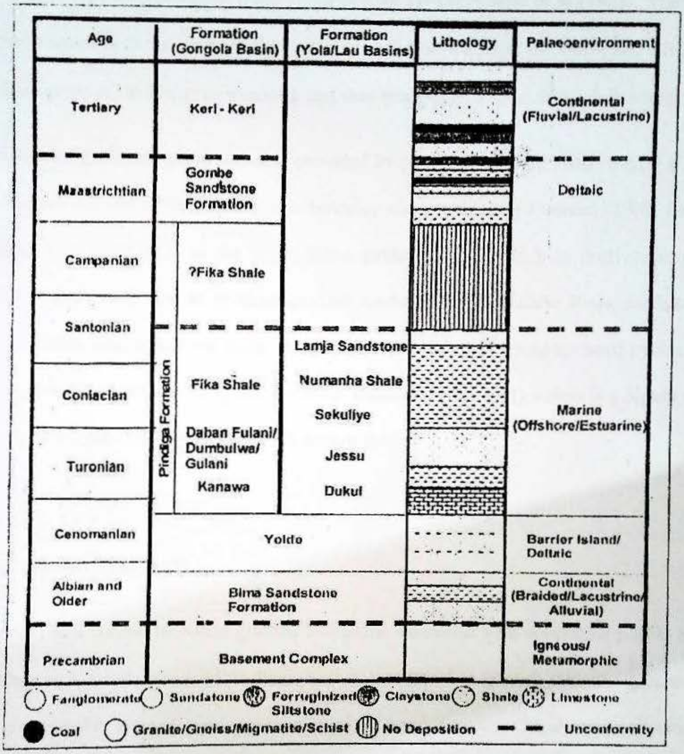


Fig 5 : Stratigraphy of the upper Benue Trough (After Abubakar 2008)

THE BIMA SANDSTONE

The Albain continental Bima comprises of the oldest sediments which unconformably overlie the crystalline Basement rocks both in the Gongola and Yola arms of the Upper Benue Trough. Although the type section is the Bima Hill Falconer (1911); Carter et al (1963). The principal reference section is to the south in the Lamurde anticline. Carter et al (1963) and Allix (1983), gave description of the sequence exposed, and thus recognized a three fold subdivisions.

Description of the Bima group was also provided by popoff et al (1989) and popoff (1988) but most detailed account of the Bima group, however was provided by Guiraud (1990, 1991) who described it in three parts as the upper Bima sandstone (B3) which is fairly homogeneous, relatively mature and fine to medium grained sandstones. The middle Bima sandstone (B2) which is widely distributed and fairly uniform unit consisting of fining up ward cycles each of which is five to ten meters thick and the lower Bima sandstone (B1) which is a highly variable unit with an overall thickness of 0 to 1570 meters thick.

LOWER BIMA MEMBER

The lower Bima consist of coarse grained feldspartic sandstone with occasional pebble horizons alternating with purple and reddish clays, shales, weathered to grayish clay and greenish clays which are probably dirived from the weathering of basaltic rocks. Calcareous sandstones, well bedded medium grained sandstones and thin siltstones also occur within the sequence carter et al; (1963).

THE MIDDLE BIMA MEMBER

A basin wide angular unconformity is present at the top of the Lower Bima Member. The plane of unconformity shows ferruginous crusts and paleosols which can be laterally traced for more than 5km. The paleosols are associated with spectacular solidified tree trunks in the Kaltungo, Kurkurde and Dumme areas.

The Middle Bima Member forms the post proto rift mega sequence along with fine grained sandstones of the Upper Bima Member into which it merges rapidly. It is 50 to 200meters thick and consists of gravel coarse grained sandstone dominated by large scale trough cross beddings. Its sedimentary sequences are very similar to those of the Lower Bima Member.

The braided river system present during the Lower and Middle Bima times are thought to have been characterized by the powerful deep channels, with uneven bed surfaces where they flowed through areas of abandoned channels. The main channels generated pebbly lag deposits and large scale trough stratification at low levels in sedimentary sequences.

THE UPPER BIMA MEMBER

In most part of the Benue Trough, the Middle Bima is overlain by medium to fine grained sandstone of the Upper Bima Member which reaches a maximum thickness of 600meters. The characteristic sedimentary profile of this member is highly homogeneous consisting of a succession of oblique planner cross bedded deposit with only scale trough stratifications. The individual beds are as much as 1-3 meters thick and lack erosive bases pedogenetic features are absent.

This nature of Upper Bima Member was probably due to deposition with large braided stream systems containing very shallow water sand bars in an environment without marked topographic contrast.

THE YOLDE FORMATION

The name Yolde Formation was proposed by Carter et al; (1963) for transitional beds within the Bima and the Pindinga Formation. A type section was designated in the Yolde stream in the western part of the Yola Basin. A new type locality is at Jessu village (Obaje et al; 1999). The Yolde Formation lies conformably on the Bima sandstone. The base of the formation is defined by the appearance of sandstone and the commencement of limestone-shale deposition. The Yolde Formation was deposited under a transitional coastal-marine environment is made up of about 152meters of thin bedded sandstone and shaly limestone. The Yolde Formation is interpreted as fluvial at its base (sandstone and mudstone portions) and shallow marine at its upper portion (Zaborsky et al; 1997) Lawal (1982) and Lawal and maullade (1986) suggested late Albian to late Cenonanain age for the Yolde Formation on the basis of its polynofossils. Lower to Middle Cenomanian age was suggested by popoff et al; (1986).

PINDIGA FORMATION

The Pindiga Formation consist of fossiliferous limestone and shales with interbedded sandstones and siltstones and shaly limestone in the upper part (Carter et al; 1963). The name Pindiga Formation was proposed by Carter et al; (1963) for calcareous beds, clay shales previously described by carter et al; (1954). It makes up for the greater part of the upper cretaceous deposits in the Upper Benue Trough. Its type section is in Pindiga stream in Pindiga, located south-west of Gombe, where about 80 meters of the mudstone are with limestone intercalations overlain by about 160meters of strata consisting almost entirely of shales (zaborsky et al 1997); carter et al (1963) referred to the age equivalent beds in the Gongola Basin as Gongila Formation which is made up of a lower and an upper sandstone member. As a result of a regional regression episode, during the upper Turonian, sandstones where deposited in the middle part of the Pindiga Formation. The sedimentological nature of the Pindiga Formation is best understood by regarding it as consisting of five members which include; Fike, Dumbulwa, Deban Fulani, Gulani and Kanawa members from top to bottom respectively (Zoborsky et al 1997).

Workers have ascribed the pindiga Formation to different ages, Carter et al (1963) suggested a late Cenomanian to Maastrichtian age for the formation late Cenomanian to Turomian age was proposed by Abubakar and Obaje (2001).

THE GOMBE SANDSTONE

The Gombe sandstone is a sequence of estuarine and deltaic sandstone, shales, siltstone and ironstones which overlaid the Pindiga Formation, Gongila and so called Fika shales Formations in the Gongola Basin of the Upper Benue Trough, at its type locality along pantami river south of Gombe with thickness of about 300 meters had been established.

Falconer (1911) termed the Gombe sandstone near Gombe as, the Gombe grits and clays Reaburn and Jorres (1934) included the Gombe sandstone group describing it from country side near fika.

The lower part of the Gombe sandstone is composed of thinly bedded mudstone and silt stone. The middle part is composed mainly of well bedded sandstone with occasional coal seams. Unconformity exists between the Gombe sandstone and the overlying Keri-keri Formation. Another unconformity may be present below the Gombe sandstone. An upper maastrichtian age was assigned to it by carter et al (1963), hence representing the youngest cretaceous sediment in the Basin.

THE KERI-KERI FORMATION

The Keri-keri Formation is essentially flat lying, consisting of grits and

ferrugeneous sandstones and claystones that are often kaolinite. It unconformably overlies the Gombe sandstone in the Gongola Basin. The total thickness of the keri-keri Formation is approximately 300meters (dessenvegie; 1975).

The keri-keri Formation was deposited in a wide range of environments including fluviatile, deltaic and marginal marine lacustrine Adegoke et al; (1936), Dike (1993) suggested alluvial fan, fan delta, braided stream and marginal lacustrine environments of deposition for the formation. Based on palynological dating of coaliniferous horizon, the shell BP petroleum Development company's geologist suggested that a tentative palaeocene age which was conclusively proved by Adeyoke et al (1978) on the basis of new palynological data.

2.7 BIMA SANDSTONE IN THE UPPER BENUE TROUGH

The Bima sandstone was first discovered by Falconer (1911). He applied the name Muri sandstone to similar rocks in the muri area. He discovered a Cretaceous sandstone formation which he called the upper grit and he placed those rocks above the Cretaceous marine sediment of the Gongola valley. The upper grit and the sandstone were described chiefly by exposures near Rimi and Bima sandstone of Ture and those of wuyo were also included in the division. Re examination of the sections at Rimi has shown that faulting and slumping disturbed the rocks and the grits and sandstones actually underlie the marine Cretaceous sediments and must accordingly be grouped together with the Bima sandstone cater et al (1963).

Falconer (1911) assigned the Bima sandstone to an Eocene division. The work of carter et al (1963) showed that the Bima sandstone at Lamurde and else where are under the Turonian marine rocks. Carter et al studied the lithology of the Bima sandstone and concluded that it was derived from a granitic terrain and also recognized deltaic and lacustrine depositional environments which was based on structures observed. Allix (1963) gave description of the sequences exposed at the Lamurde anticline and recognized a three fold sub division. Description of Bima was also given by Popoff (1983). The most detailed account was given by Guiraud (1991) who described it as, Lower Bima sandstone B_3, Midle Bima sandstone B_2, Upper Bima sandstone B_1 . Allix 1963 referenced the three parts of the Bima sandstone in the Lamurde area as Formations 1, 2 and 3.

Guiraud (1991) also referred to the lower, middle and upper Bima sandstones as members. The Bima sandstone as a whole is regarded as a group Zaborsky et al (1997). The Bima 1 Member out crops mainly in the core of the Lamurde anticline, south of the Kaltungo inlier (Braide 1992). He also studied middle and upper Bima sandstone at different localities.

The Upper Bima (B3) is fairly homogeneous, relatively mature, fine to course grained sandstone characterized by tabular cross bidding with sets of a few tens of centimeters to a few meters thick, convolute bedding, overturned cross bedding are common. The average thickness is 500 metres with a maximum of 1500 metres.

The Middle Bima (B_2) is fairly distributed and fairly uniform unit that consist of fining upward cycles each of 5 to 10 meters thick trough and tabular cross bedding characterize the sandstone.

2.8 RESERVOIR POTENTIAL OF THE BIMA SANDSTONE

Samaila et al (2008), in the work Microstructures of the Cretaceous Bima sandstone, Upper Benue Trough, N.E Nigeria: Implication for hydrocarbon migration showed that there is a general decrease in the number of deformation bands to less than five deformation bands per meter away from the major fault of the Bima sandstone. This is from measurement of the relative densities of well exposed deformation bands away from the major faults in three localities, making several E-W traverses.

The study also showed that samples of the Bima sandstone collectd from the fault zones and studied under the microscope show highly localized bands of mechanically comminuted grains in a silt and clay matrix in which grain size sorting and porosity are substantially reduced in comparison to the original host sandstone. There is a grain size decrease by up to three size classes from medium to coarse–grained sand to silt, from host rock into the deformation bands. Micro cracks in the quartz grains observed in thin sections studied appeared to be healed. This is an indication that aqueous fluids were present to facilitate the healing process (Engelder 1987).

Earlier workers (carter et al 1963; Offodile, 1976; Guiraud, 1993; Zaborski et al 1997) have expressed doubt on the petroleum prospects of the Upper Benue Trough preliminary analyses carried out on the area considered it high "risk" for exploration. Previous studies also show a large portion of the Upper Benue Trough covered by the cretaceous sandstone to have distinct petroleum exploration problems. Some of these problems include

(i) Geologically persistent high geothermal gradient that promoted source rock maturation into gas phase;

(ii) Intrusive lead-zinc mineralization veins attributed to the santonian igneous and folding event, meteoritic water flushing along the periphery of the basins and

(iii) Exposure of the prospective reservoir rocks in most places as a result of the folding and faulting episodes in the tectonic history of the basin leading to the possible escape of hydrocarbons (Obaje et al 2004). However, Juxtaposition of sandstone facies against the younger shaly and coal source rocks as a result of block faulting produced numerous horst and graben structures, during the early Cretaceous extensional phase, capable of providing good drainage for generated hydrocarbons (Obaje et al 2004). Shelf sandstone members of the Pindinga. Dukul and Gongila Formation might also constitute additional reservoir lithologies (Obaje et al 2004).

Samaila et al (2007), studied porosity loss due to compaction in the cretaceous upper Bima sandstone. The modal study of 17 thin sections shows Quartz, feldspars and rock fragments constituting the main components of the Upper Bima sandstone.

From both perological and petrographical studies, the Upper Bima sandstone is texturally and mineralogical immature (Samaila, 2007). Although development of secondary minerals (Kaolinite, goethite, hematite, gibbsite) in the formation is capable of decreasing the porosity and permeability through pore-space occupancy (Samaila, 2007). Also the drastic decrease in grain size and sorting observed in some thin sections around the extensional fault zones in the formation is an indication that great amount of pressure solution was promoted (Samaila et al, 2008).

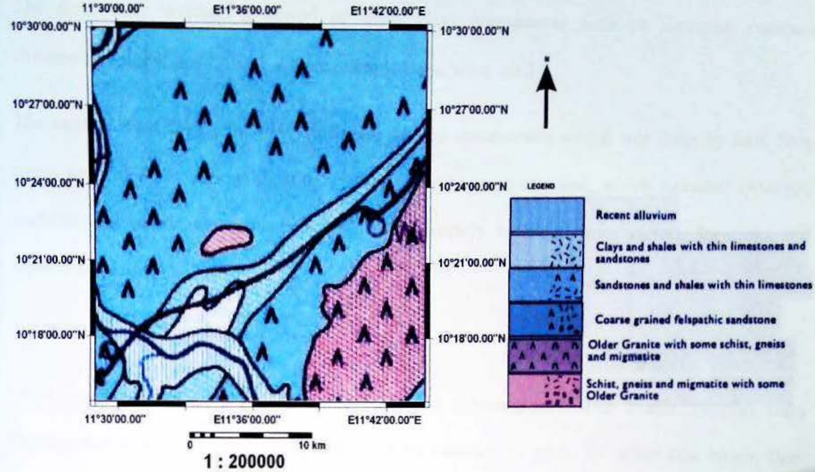


Fig 6: Lithologic map of part of sheet 152 NE and 153 NW showing the study area. Modified after Directorate of Overseas Surveys,(1971)

CHAPTER THREE: METHODOLOGY

3.1FIELD METHODS

The field work covered a period of seven days instruments such as Hammer, compass clinometer, Global positioning system, sample bags, were used.

The method used during the field work was ground transversing which was done by foot. Stop overs were made at various locations where outcrops were exposed, which included erosional surfaces and stream channels. Samples were discretely collected from various locations and labeled accordingly.

3.2 PETROGRAPHIC ANALYSIS

Fresh samples were collected from the field and thin-sectioned. The friable samples were impregnated with epoxy resin and heated on an electric hot plate for some few hours, then allowed to dry. This resulted in highly indurated products that were easily cut into thin sections. The thin sections were mounted on glass slides using araldite and Canada balsam. The slides were then viewed with a standard Zeiss petrographic microscope.

3.3 GRANULOMETRIC ANALYSIS

The theory of mechanical analysis stipulates that the particles of sediments are not spheres; they are seldom irregular in shape and varies greatly from each other. This has made it difficult to determine the sizes of particles of sediments. The method of measurement is based on the assumption that the particles were spheres or that the measurement can be expressed as diameters of equivalent spheres.

The method of sieve analysis depends on the dominant size range of the particles of the sediments. Particles larger than 16mm (pebbles) can be handled easily and may be measured directly, individually. Particles with diameters between 16 and 1/16mm (mainly sand fraction) are usually analyzed by sieving method particles smaller than 1/16mm (silt and day) are analyzed by methods of indirect sedimentation.

SIEVE ANALYSIS

Nine samples was used for sieve analysis. Each of the samples was disaggregated using a ceramic pestle and mortar. 200grams of the disaggregated material was collected and sieved. Ten sieves with meshes ranging from 63µm to 4.75mm were used in sieving the samples in a mechanical sieve shaker. Each sieving lasted for 15 minutes and the material in each sieve was measured on a scale and used for plotting cumulative frequency curves. Graphic mean, standard deviation, coefficient of uniformity and permeability were calculated from the cumulative curves.

3.4 POROSITY TEST

The samples were oven dried at 105^0C for about 24hours (until constant weight was attained), then the dry weight was taken for each of the sample. The samples were then immersed in water for 24hours, the saturated samples were than weighed to give the wet weight. After the saturated samples had been weighed, each of the sample was immersed in water and the volume of displaced water was measured and recorded. The porosity was computed from this test for all the samples using the formula

$$\text{porosity}(n) = Vv/V_T$$

V_V = volume of void ratio

V_T= Total volume of rock.

CHAPTER FOUR: PRESENTATION OF RESULTS

4.1 PETROGRAPHY

A total of eleven samples were thin sectioned. The slides were petrographically studied under plane and crossed polarized light. The photomicrogragh of the slides taken with x40 magnification are shown below; L= location, S= sample

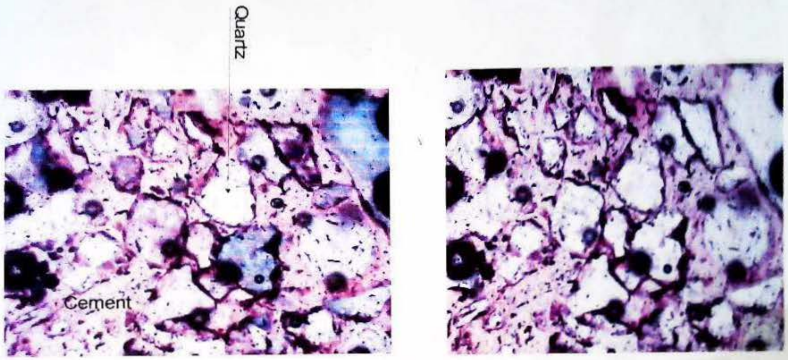
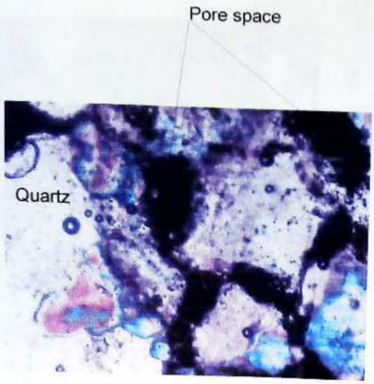


Plate1: Sample L_1S_1(xpl) (ppl)



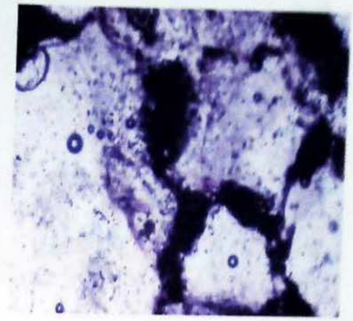
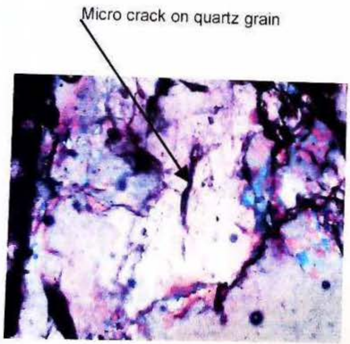


Plate2:Sample L_1S_2 (xpl) (ppl)



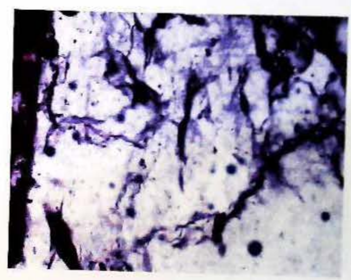


Plate3: Sample L_1S_3 (xpl) (ppl)

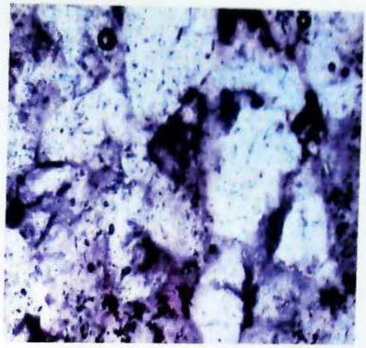
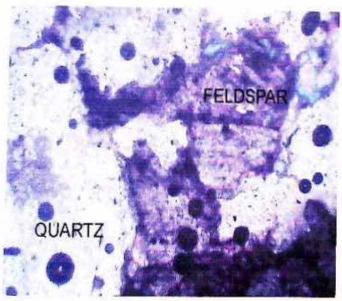


Plate4: Sample L_2S_1(xpl) (ppl)



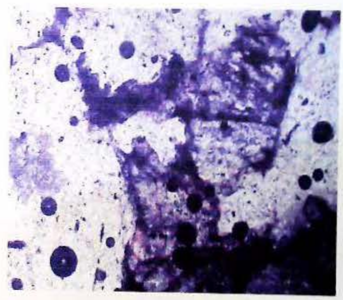
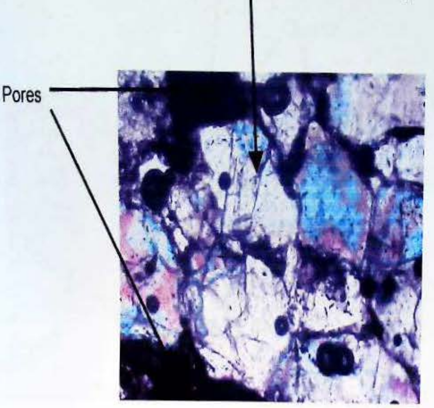


Plate5: Sample L_2S_2(xpl) (ppl)



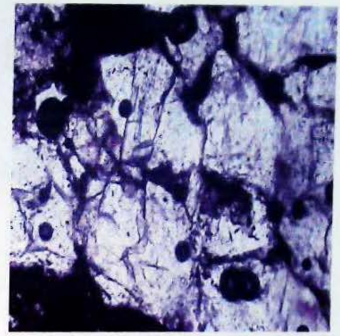
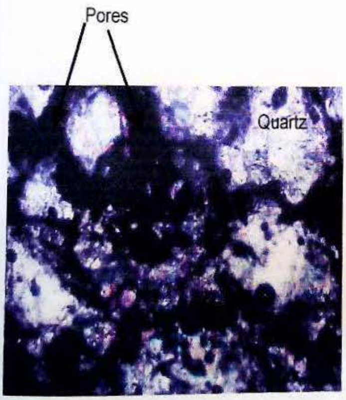


Plate6: Sample L_3S_1(xpl) (ppl)



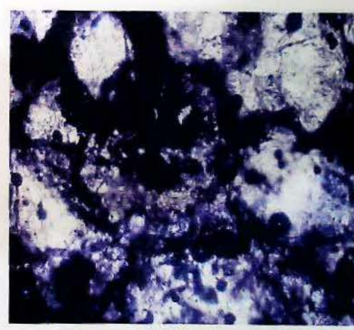
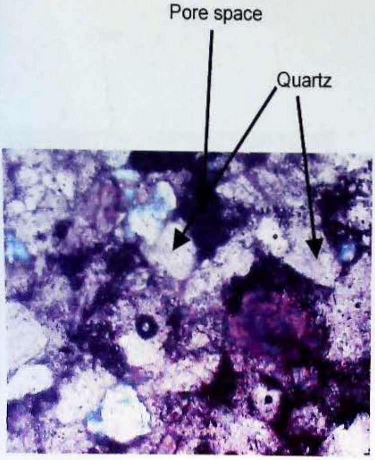


Plate7: Sample L_3S_2(xpl) (ppl)



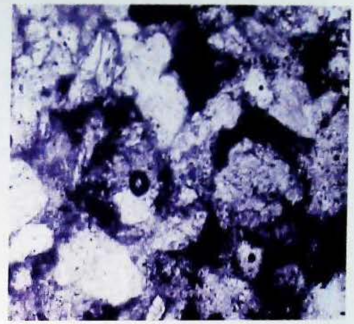
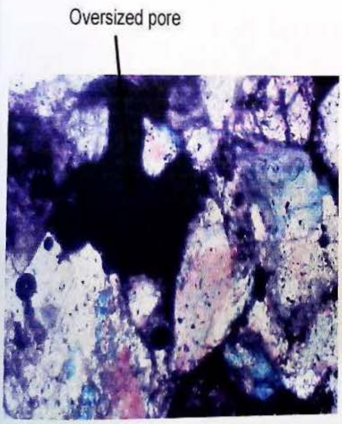


Plate8: Sample L_3S_3(xpl) (ppl)



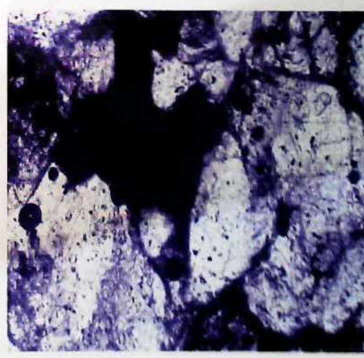
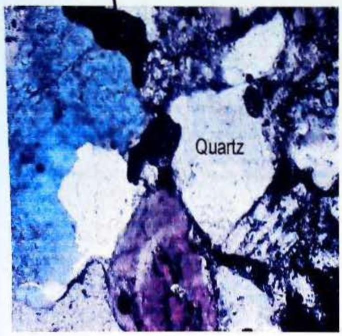


Plate9: Sample L_3S_4(xpl) (ppl)



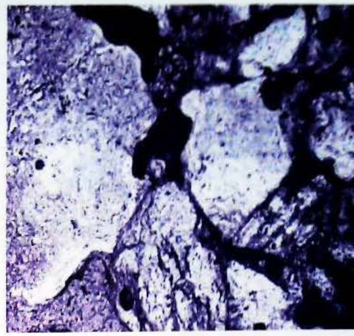


Plate10: Sample L_4S_1(xpl) (ppl)

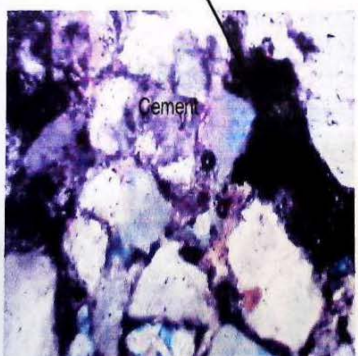


Plate11; Sample L_4S_2(xpl) (ppl)

4.2 GRANULOMETRIC ANALYSIS

A total of nine samples were subjected to sieve analysis. The individual weight percent of the material retained in each sieve was determined for each of the sample and their cumulative percent finer and coarser was calculated. This was carried out to aid in the determination of the permeability of the samples of the sediment. The result of the sieve analysis is as shown below;

Table1: sieve analysis result of sample L_1S_1

Sieve Opening	phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25	0.83	0.83	0.41	0.42	99.58
3.35mm	-1.75	1.63	2.46	1.23	0.82	98.77
2.36mm	-1.25	6.81	9.27	4.64	3.41	95.36
1.18mm	-0.25	55.57	64.84	32.50	27.79	67.55
850µm	0.25	41.93	106.77	53.44	20.97	46.56
425µm	1.25	56.43	163.20	81.68	28.22	18.32
300µm	1.75	14.83	178.03	89.10	7.42	10.90
212µm	2.25	5.97	184.00	92.09	2.99	7.91
106µm	3.25	0.90	184.90	92.54	0.45	7.46
63µm	4.75	11.87	196.77	98.48	5.92	1.52
Pan		3.04	199.81	100	1.52	0

Table2: sieve analysis result of sample L_1S_2

Sieve Opening	phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25	1.11	1.11	0.56	0.56	99.44
3.35mm	-1.75	6.57	7.68	3.84	3.29	96.17
2.36mm	-1.25	18.10	25.78	12.90	9.05	87.10
1.18mm	-0.25	79.06	104.84	52.46	39.53	47.54
850µm	0.25	35.23	140.07	70.09	17.62	29.91
425µm	1.25	31.16	171.23	85.68	15.58	14.32
300µm	1.75	6.73	177.96	89.05	3.37	10.95
212µm	2.25	4.57	182.53	91.34	2.29	8.66
106µm	3.25	5.62	188.15	94.15	2.81	5.85
63µm	4.75	7.34	195.49	97.82	3.67	2.18
Pan		4.35	199.84	100	2.18	0

Table3: sieve analysis result of sample L_1S_3

Sieve Opening	phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25					
3.35mm	-1.75					
2.36mm	-1.25	0.15	0.15	0.07	0.08	99.93
1.18mm	-0.25	10.30	10.45	5.22	5.15	94.78
850µm	0.25	16.31	26.76	13.38	8.16	86.62
425µm	1.25	88.81	115.57	57.76	44.41	42.24
300µm	1.75	37.53	153.10	76.52	18.77	23.48
212µm	2.25	13.25	166.35	83.15	6.63	16.85
106µm	3.25	2.59	168.94	84.44	1.30	15.56
63µm	4.75	19.1	188.04	93.99	9.55	6.01
Pan		12.03	200.07	100	6.02	0

Table4: sieve analysis result of sample L_2S_1

Sieve Opening	Phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25					
3.35mm	-1.75	0.1	0.1	0.05	0.05	99.95
2.36mm	-1.25	0.48	0.58	0.29	0.24	99.71
1.18mm	-0.25	7.93	8.51	4.27	3.97	95.73
850μm	0.25	17.33	25.84	12.97	8.67	87.03
425μm	1.25	65.66	91.50	45.93	32.83	54.07
300μm	1.75	32.39	123.89	62.19	16.20	37.81
212μm	2.25	23.13	147.02	73.80	11.57	26.20
106μm	3.25	12.14	159.16	79.89	6.07	20.11
63μm	4.75	23.99	183.15	91.93	12.00	8.07
Pan		16.07	199.22	100	8.04	0

Table5: sieve analysis result of sample L_2S_2

Sieve Opening	Phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25	0.35	0.35	0.17	0.75	99.83
3.35mm	-1.75	0.56	0.91	0.45	0.28	99.55
2.36mm	-1.25	2.23	3.14	1.57	1.12	98.43
1.18mm	-0.25	30.53	33.67	16.83	15.27	83.17
850μm	0.25	30.73	64.40	32.20	15.37	67.80
425μm	1.25	71.06	135.46	67.72	35.53	32.28
300μm	1.75	26.62	162.08	81.03	13.31	18.97
212μm	2.25	10.62	172.70	86.34	5.31	13.66
106μm	3.25	5.49	178.19	89.08	2.75	10.92
63μm	4.75	14.45	192.64	96.31	7.23	3.69
Pan		7.39	200.03	100	3.70	0

Table6: sieve analysis result of sample L_3S_1

Sieve Opening	Phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25					
3.35mm	-1.75	0.46	0.46	0.23	0.23	99.77
2.36mm	-1.25	2.28	2.74	1.38	1.14	98.62
1.18mm	-0.25	24.97	27.71	14.00	12.49	86.04
850μm	0.25	22.99	50.70	25.55	11.50	74.45
425μm	1.25	70.27	120.97	60.95	35.14	39.05
300μm	1.75	26.14	147.11	74.12	13.07	25.88
212μm	2.25	11.15	158.26	79.74	5.58	20.26
106μm	3.25	5.75	164.01	82.64	2.88	17.36
63μm	4.75	22.69	186.70	94.07	11.35	5.93
Pan		11.77	198.47	100	5.89	0

Table7: sieve analysis result of sample L_3S_2

Sieve Opening	Phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25					
3.35mm	-1.75	0.44	0.44	0.22	0.22	99.78
2.36mm	-1.25	1.42	1.86	0.94	0.71	99.06
1.18mm	-0.25	12.04	13.90	7.02	6.02	92.97
850μm	0.25	16.44	30.34	15.34	8.22	84.66
425μm	1.25	58.30	87.64	44.31	29.15	55.69
300μm	1.75	37.85	125.49	63.44	18.93	36.56
212μm	2.25	21.88	147.37	74.50	10.94	25.50
106μm	3.25	16.52	163.89	82.85	8.26	17.15
63μm	4.75	22.68	186.57	94.32	11.34	5.68
Pan		11.24	197.81	100	5.62	0

Table8: sieve analysis result of sample L_3S_4

Sieve Opening	Phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25	8.67	8.67	4.35	4.34	95.65
3.35mm	-1.75	2.15	10.82	5.42	1.08	94.58
2.36mm	-1.25	3.95	14.77	7.40	1.98	92.60
1.18mm	-0.25	33.34	48.11	24.12	16.67	75.88
850µm	0.25	26.83	74.94	37.57	13.42	62.43
425µm	1.25	54.38	129.32	64.83	27.19	35.17
300µm	1.75	23.08	152.40	76.40	11.54	23.60
212µm	2.25	15.21	167.61	84.03	7.61	16.00
106µm	3.25	3.89	171.50	85.98	1.95	14.02
63µm	4.75	24.53	196.03	98.28	12.27	1.72
Pan		3.44	199.47	100	1.72	0

Table9: sieve analysis result of sample L_4S_2

Sieve Opening	phi	Weight Retained(g)	Cumulative Weight(g)	Cumulative % Coarser	Individual Weight %	Cumulative % Finer
4.75mm	-2.25					
3.35mm	-1.75	0.57	0.57	0.29	0.29	99.71
2.36mm	-1.25	0.41	0.98	0.49	0.21	99.51
1.18mm	-0.25	3.45	4.43	2.22	1.73	97.78
850µm	0.25	6.75	11.18	5.61	3.38	94.39
425µm	1.25	51.44	62.62	31.42	25.72	68.58
300µm	1.75	51.58	114.20	57.30	25.79	42.70
212µm	2.25	30.70	144.90	72.70	15.35	27.30
106µm	3.25	9.37	154.27	77.41	4.69	22.59
63µm	4.75	36.50	190.77	95.72	18.25	4.28
Pan		8.53	199.30	100	4.27	0

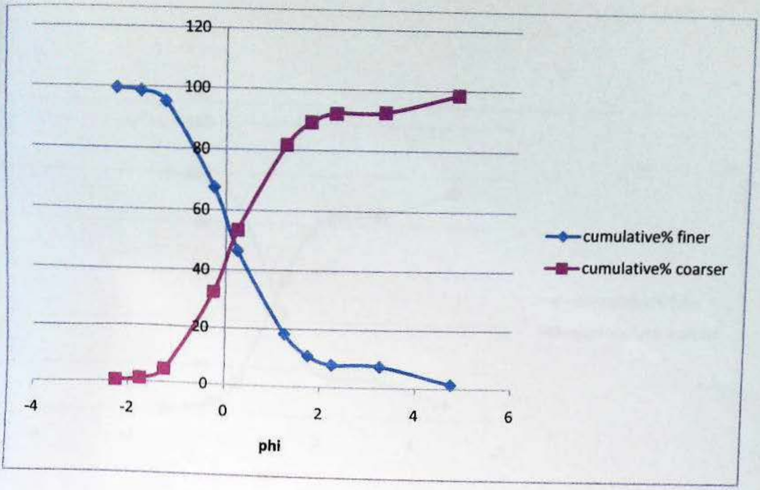


Fig 7 : cumulative curve for sample L_1S_1

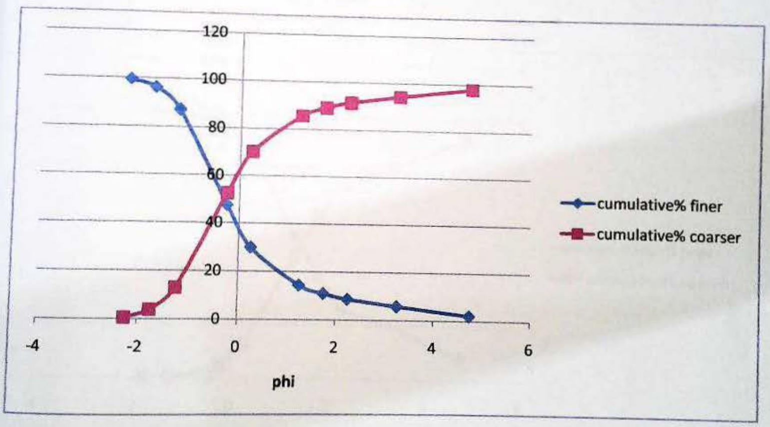


Fig 8 : cumulative curve for sample L_1S_2

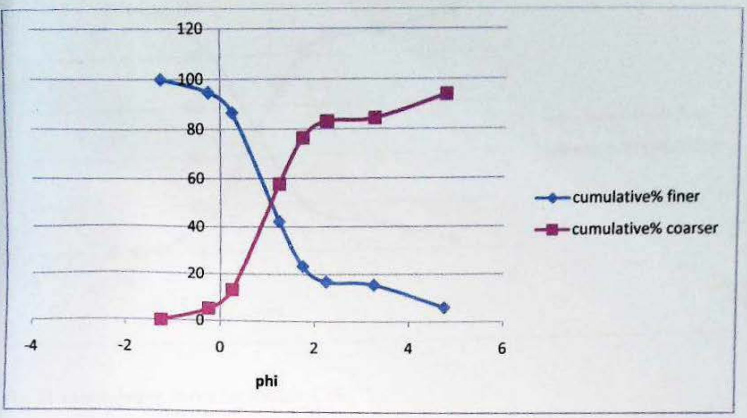


Fig 9 : cumulative curve for sample L_1S_3

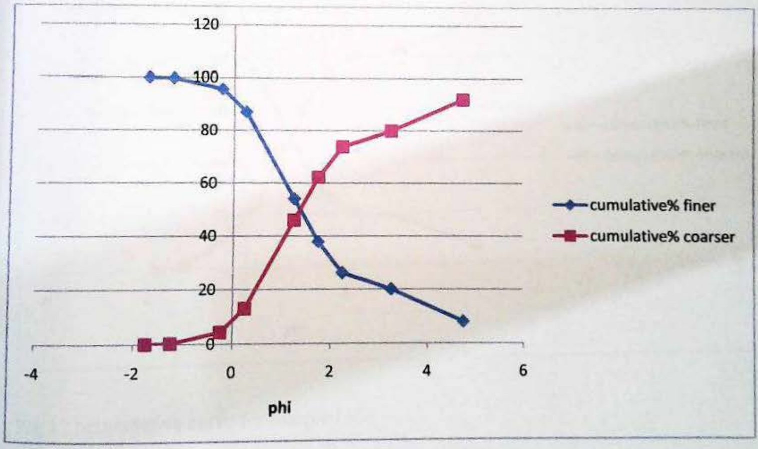


Fig 10 : cumulative curve for sample L_2S_1

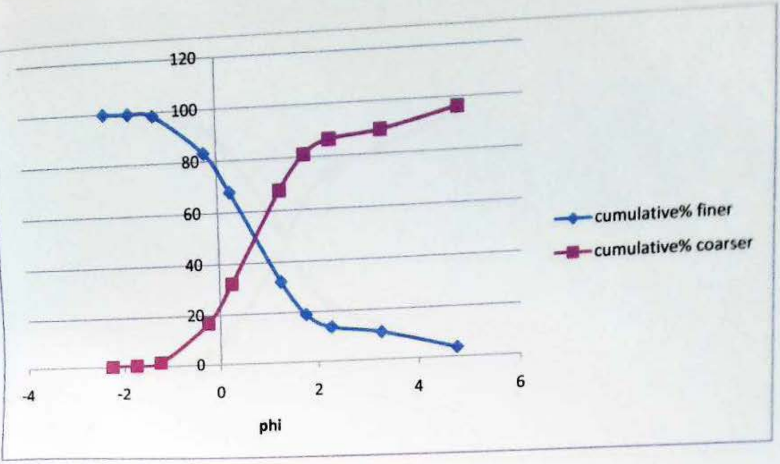


Fig 11 : cumulative curve for sample L_2S_2

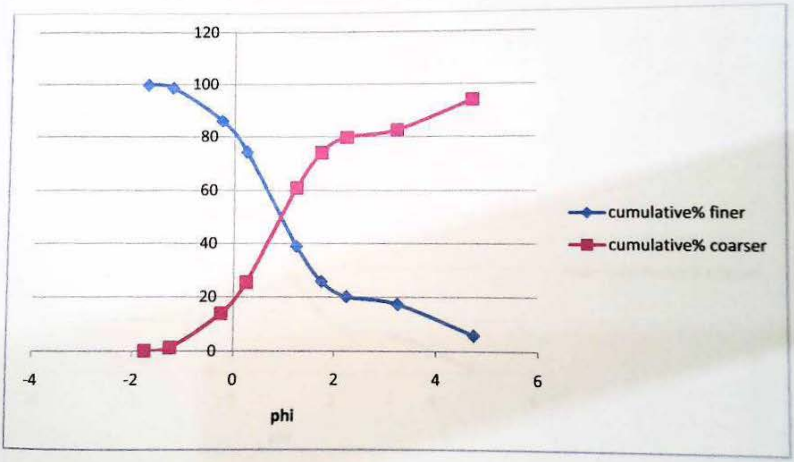


Fig 12 : cumulative curve for sample L_3S_1

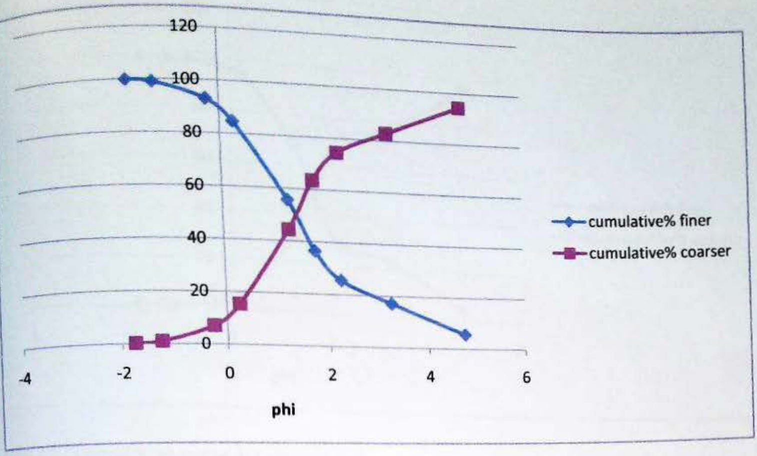


Fig 13 : cumulative curve for sample L_3S_2

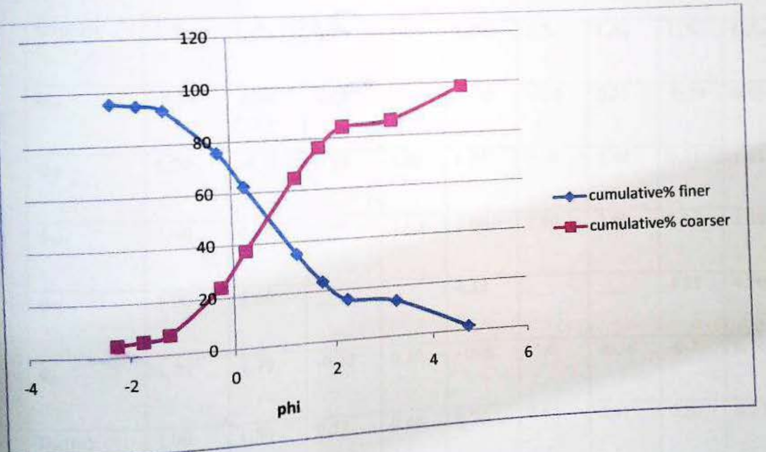


Fig 14 : cumulative curve for sample L_3S_4

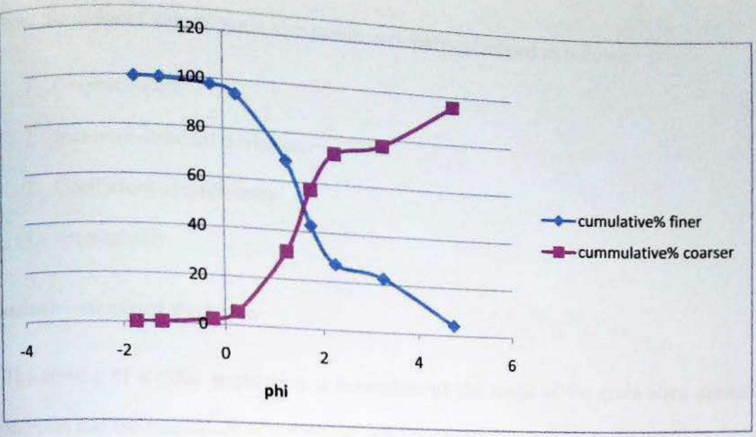


Fig 15 : cumulative curve for sample L_4S_2

TABLE10: Percentile Deductions from Cumulative Curve.

Samples	L_1S_1	L_1S_2	L_1S_3	L_2S_1	L_2S_2	L_3S_1	L_3S_2	L_3S_2	L_4S_2
ϕ_{16}	-0.80	1.20	0.31	0.34	-0.30	-0.20	0.27	-0.74	0.65
ϕ_{50}	0.20	-0.31	1.10	1.40	0.75	0.94	1.40	0.71	1.61
ϕ_{84}	1.40	1.14	3.00	3.60	2.00	3.40	3.40	2.25	3.79
ϕ_{95}	3.90	3.60	—	—	4.48	—	—	4.35	4.70
ϕ_5	1.20	1.70	-0.29	0.30	-1.00	-1.0	-0.58	-0.2	0.20
D_{60}(m)	1.00	1.50	0.55	0.48	0.70	0.63	0.47	0.80	0.37
D_{10}(m)	2.00	0.25	0.06	0.04	0.09	0.05	0.05	0.75	0.05

From the deduced values, grain size parameters were calculated as follows;

1. Graphic mean
2. Inclusive standard deviation
3. Coefficient of uniformity
4. Permeability

Inclusive standard deviation

The sorting of a grain population is a measure of the range of the grain sizes present in the samples and the magnitude of the spread or scatter their sizes around the mean.

Sorting can be estimated in the field or in the laboratory by using hand lenses or microscope. More accurate determination of sorting requires using the formula below.

$\delta = \phi_{84} - \phi_{16}/4 + \phi_{95} - \phi_{5}/6.6$

verbal interpretation

<0.35---------------------------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

Mean grain size

This is the arithmetic average of all the particle sizes in a sample. The true arithmetic mean size of the sediment samples cannot be determined because it is impossible to count the total number of grains of the samples.

Verbal interpretation

$-\infty$ to -1-------------------Gravel

-1 to 0-------------------Very coarse sand

0 to 1.00----------------------Coarse sand

1.0 to 2.00--------------------Medium sand

2.00 to 3.00------------------------Fine sand

3.00 to 4.00----------------Very fine sand

4.00 to >8.00--------------------------Silt

8.00 to $+\infty$----------------------------Clay.

Coefficient of uniformity

The distribution of particles is characterized by the uniformity coefficient (U_C) expressed

as: $U_C = D_{60}/D_{10}$

Where:

D_{60} and D_{10} in the formula above represents the grain diameter in mm, for which, 60% and 10% of the samples are finer than. The smaller the value of U_C the more uniform is the grading. The larger the value of U_C the better is the grading.

$U_C=1$--------- Soil of one grain size is said to be poorly graded

$U_C=2$ or 3---------Fairly graded, $U_C \geq 15$------------Well graded

Permeability

The Krumbein and Monk equation was used to estimate the permeability (in Darcie) of the samples from grain size analysis. This equation was empirically developed using very well sorted sediment samples ranging -0.75 to 1.25ϕ in mean grain size, and standard deviations ranging from 0.04 to 0.80 ϕ. The Krumbein and Monk equation is expressed as follows:

$K=760(Gm_e)^2 e^{(-1.31\delta_\phi)}$

Where:

K= intrinsic permeability in darcies

Gm_e= geometric mean grain diameter(in mm)

δ_ϕ= standard deviation (phi scale)

Table 11: Results from cumulative curve

Samples	L_1S_1	L_1S_2	L_1S_3	L_2S_1	L_2S_2	L_3S_1	L_3S_2	L_3S_4	L_4S_2
M_Z(in ϕ)	0.25	0.67	1.46	1.78	0.82	1.40	1.68	0.74	2.02
M_Z(in mm)	0.84	0.63	0.36	0.29	0.57	0.38	0.31	0.60	0.25
δ	1.34	0.28	0.72	0.78	1.41	1.00	0.87	1.7	1.47
U_C	4.2	6.00	10.0	11.0	8.00	12.0	9.00	11.0	7.30
K(Darcy)	92.7	209	38.4	23.0	38.9	27.7	23.4	29.5	6.9

4.3 POROSITY TEST RESULT

A total of fifteen samples were subjected to porosity test and the result is as shown in the table below;

Table 12: Porosity test result

Samples	Dry Weight of sample(g)	Saturated weight of sample(g)	Volume of water Before Immersion(ml)	Volume of water After Immersion(ml)	$V_T(cm^3)$	$V_V(cm^3)$	Porosity (n)%
L_1S_1	395.4	426	400	580	180	30.6	17
L_1S_2	478	508.5	400	605	205	30.5	14.9
L_1S_3	317.1	352.6	400	565	165	35.5	21.5
L_2S_1	269.3	299.2	400	525	125	29.9	23.9
L_2S_2	307.3	333.1	400	540	140	25.8	18.4
L_3S_1	307.6	333.2	400	550	150	25.6	17.1
L_3S_2	218.5	237.6	400	500	100	19.1	19.1
L_3S_4	244.9	265.2	400	515	115	20.3	17.7
L_4S_1	151.1	165.6	400	475	75	14.5	19.3
L_4S_2	183.6	209.7	400	500	100	26.1	26.1
L_4S_3	312.1	349.4	400	550	150	37.3	24.9
L_4S_4	167.5	188.9	400	485	85	21.4	25.2
L_4S_5	117.7	130.8	400	455	55	13.1	23.8
T	134.4	149.9	400	465	65	15.5	23.9
QD_2	212	237.7	400	505	105	25.7	24.5

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 PETROGRAPHY

Thin section analysis indicates that quartz is the principal mineral component, with evidence of diagenesis supported by the presence of little feldspars. From the visual and microscopic observation of the slides quartz grains are angular, sub-angular to sub-rounded with low sphericity (Powers 1953). The monocrystalline quartz with undulose extinction suggests the derivation of the sediments from an igneous terrain. While the sub-rounded nature of some of the grains is suggestive of derivation from an older sedimentary sequence (Blatt 1967).

The criteria for the classification of porosity was adopted from Schmidt, Mc Donald and Platt (1977) coupled with Choquette and Pray (1970) modifiers. Primary porosity in the sediment is mainly inter granular. Secondary porosity ranges from elongate pores (plate2) which are narrow but highly interconnected pore spaces to oversized pores (plates 9&11) formed as a result of secondary leaching. Micro fracture porosity in the form of micro cracks on brittle quartz grain observed by Samaila et al (2008) was also seen in this study (plates 3&6).These phenomenon of brittle deformation is strongly associated with grain size as coarser grains show moderate fracturing while very coarser grains shows extensive fracturing and it varies with proximity to faults, joints or within intensively folded units. It can therefore be inferred that Wade hill and Wuyo areas are adjacent to the extensional fault zone in the Formation.

5.2 GRANULOMETRIC ANALYSIS

The result of sieve analysis are interpreted in the table below;

Table 13 Interpretation of granulometric analysis result

Samples	Mean size	Standard Deviation
L_1S_1	Coarse sand	Poorly sorted
L_1S_2	Coarse sand	Very well sorted
L_1S_3	Medium sand	Moderately sorted
L_2S_1	Medium sand	Moderately sorted
L_2S_2	Coarse sand	Poorly sorted
L_3S_1	Medium sand	Moderately sorted
L_3S_2	Medium sand	Moderately sorted
L_3S_4	Medium sand	Poorly sorted
L_4S_2	Fine sand	Poorly sorted

The result of sieve analysis shows that the sample of the sediment range in grain size from coarse through medium to fine sand. While in terms of sorting, they range from very well sorted through moderately sorted to poorly sorted. The uniformity coefficient of the sediment is above fair grading but not up to well graded sediment.

5.3 POROSITY TEST RESULT

The Bima Sandstone, an entirely continental formation throughout the Upper Benue Trough, is the basal part of the sedimentary succession. The sandstones are interpreted to be of alluvial fan to braided river origin (Benkhelil,1989; Guiraud, 1990).Braided fluvial reservoirs for some of the worlds giant oil fields were discussed by Martin(1993).The porosity of the sediments in the study area ranges from 14.9% to 26.1% with an average of 21.2% (Table 12). Although the sediments are poorly, moderately to very well sorted, the porosity is relatively good and is in the range of values for some giant and super giant oil and gas silisiclastic reservoir rocks of the world (14-32%)(Morse,1994).The relatively good porosity can be attributed to the presence of fractures and empty pore spaces within the sediments or as a result of secondary porosity.

5.4 PERMEABILITY

The permeability of the sediments in the study area has a minimum of 6.9(D) and a maximum of 209(D) with an average of 54.4(D) (Table11). The permeability of the sediment can be said to be fair to good. According to Krumbein and Monk, permeability decreases with increase in standard deviation. This is reflected in the result as the maximum permeability is seen in the sample of the sediment with the least value of sorting (very well sorted sediment).

CHAPTER SIX: SUMMARY AND CONCLUSION

6.1 SUMMARY

Sandstones is one of the most important group of sedimentary rock. Sandstones frequently form major aquifers and petroleum reservoirs with predictable geometry and reservoir performance compared to carbonates. This is because sandstones are more uniform in their petrophysical properties. The study of porosity and permeability of rocks is of prime importance in relation to the search for oil and underground water since the pore system is the channel for movement as well as the storage of fluids.

Based on petrographic analysis, evidence of diagenesis on the reservoir quality of the Bima sandstone is shown by the presence of little feldspar and dominance of quartz. Also compaction induced fracturing in the form of micro cracks was observed.

From the results of porosity test and grain size analysis(permeability), the reservoir quality of the Bima sandstone is relatively good and is in agreement with some of the giant and super giant oil and gas silisiclastic reservoirs of the world.

6.2 CONCLUSION

Though the analysis carried out was not a detailed one due to time constrain and equipment limitation, it can be inferred that the reservoir potential of the sediments of the Bima sandstone around Wade hill, Dadinkowa and Wuyo areas of Gombe state is relatively good.

More research should be carried out on the Bima sandstone sediment to study the reservoir potential.

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