STRATIGRAPHY AND STRUCTURE OF DUGURI (YULI) AREA BAUCHI STATE, NORTH-EAST NIGERIA

BY

IBRAHIM, MUYIBAT MODUPE B.Sc
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DECLARATION

I declare that the work in the thesis entitled 'Stratigraphy and Structure of Duguri (Yuli) Area' has been performed by me in the Department of Geology under the supervision of Prof. P. M. Zaborski and Dr. A. E. Ikpokonte.

The information derived from the literature has been duly acknowledge in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

IBRAHIM MUYIBAT MODUPE		JUNE 2011
(Name of Student)	Signature	Date

CERTIFICATION

This thesis entitled "STRATIGRAPHY AND STRUCTURE OF DUGURI (YULI) AREA" by Ibrahim, Muyibat Modupe meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

_____	_____
Prof. P. M. Zaborski Chairman, Supervisory committee	Date
_____	_____
Dr. A. E. Ikpokonte Member, Supervisory committee	Date
_____	_____
Member, Supervisory Committee	Date
_____	_____
Dr. U. A. Danbatta Head of Department	Date
_____	_____
Prof. A. A. Joshua Dean, Postgraduate School	Date

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ABSTRACT

The stratigraphic succession of the Duguri area in Bauchi state North-eastern Nigeria begins with the Precambrian Basement Complex, the Gombe Sandstone was deposited during the Late Campanian to Maastrichtian times as a result of a renewed phase of rifting. The Gombe Sandstone is made up of 2 facies; The pebbly/conglomerate facies and a "Red Sandstone Facies". The "red sandstone facies" makes up a greater part of Gombe Sandstone.

A break in sedimentation, subaerial erosion and ferruginization of Gombe Sandstone gave rise to an unconformity between the Gombe Sandstone and Kerri-Kerri Formation. The Gombe Sandstone in the Duguri area is not folded and only slightly tilted. The palaeocene renewed E – W rifting resulted in the deposition of Kerri-Kerri Formation, unconformably overlying the Cretaceous. The Alluvium and Alluvial fan are of Recent age and were deposited upon the Kerri-Kerri Formation after a break in sedimentation.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 LOCATION AND ACCESSIBILITY

The study area occurs in Alkaleri Local government of Bauchi State, Nigeria. It is located between latitudes 9º45' and 10º00'N and longitudes 10º00' and 10º15'Eº, covering a total area of approximately 50 sqkm. The major rivers in the area are the rivers Yuli, Yashi and Gaji. Access to the area of study is through a tarred road connecting Duguri to Gaji, Yelwa Duguri and the Bauchi – Gombe Road.

1.2 AIM AND OBJECTIVES OF THE PROJECT

The aim of the research is to describe the geology of the area around Duguri and in particular to describe its stratigraphy and structure with emphasis on the sedimentary succession.

1.3 METHDOLOGY

An interpretation of satellite images and aerial photographs covering the area was undertaken, followed by geological mapping. Samples were collected for grain size analysis. Measurement of foreset dips were taken for palaeocurrent determination. The grain sizes, grain mineralogy and grain shapes were studied.

1.4 CLIMATE, VEGETATION AND LANDUSE

The climate of the project area is of the tropical type. There are two distinct seasons, a dry season followed by a shorter wet season. Rain falls between April and October with an annual record varying from 625mm to 875mm. The area is characterized by open savanna woodland, with trees a few metres high. There is abundant farm-land on alluvial plains. Crops grown include groundnuts, cassava and maize.

1.5 TOPOGRAPHY AND DRAINAGE

The Gombe Sandstone in the Duguri area is characterized by elevated tabular hills. The Kerri-Kerri Formation forms an elevated but relatively flat topography. The drainage pattern for the Gombe Sandstone and Kerri-Kerri Formation is dendritic. The basement has a rugged topography. The drainage pattern in the Basement Complex is a trellis drainage system which is structurally controlled by faults and fractures. The Alluvial areas are characterized by flat-low lying plains usually along river channels.

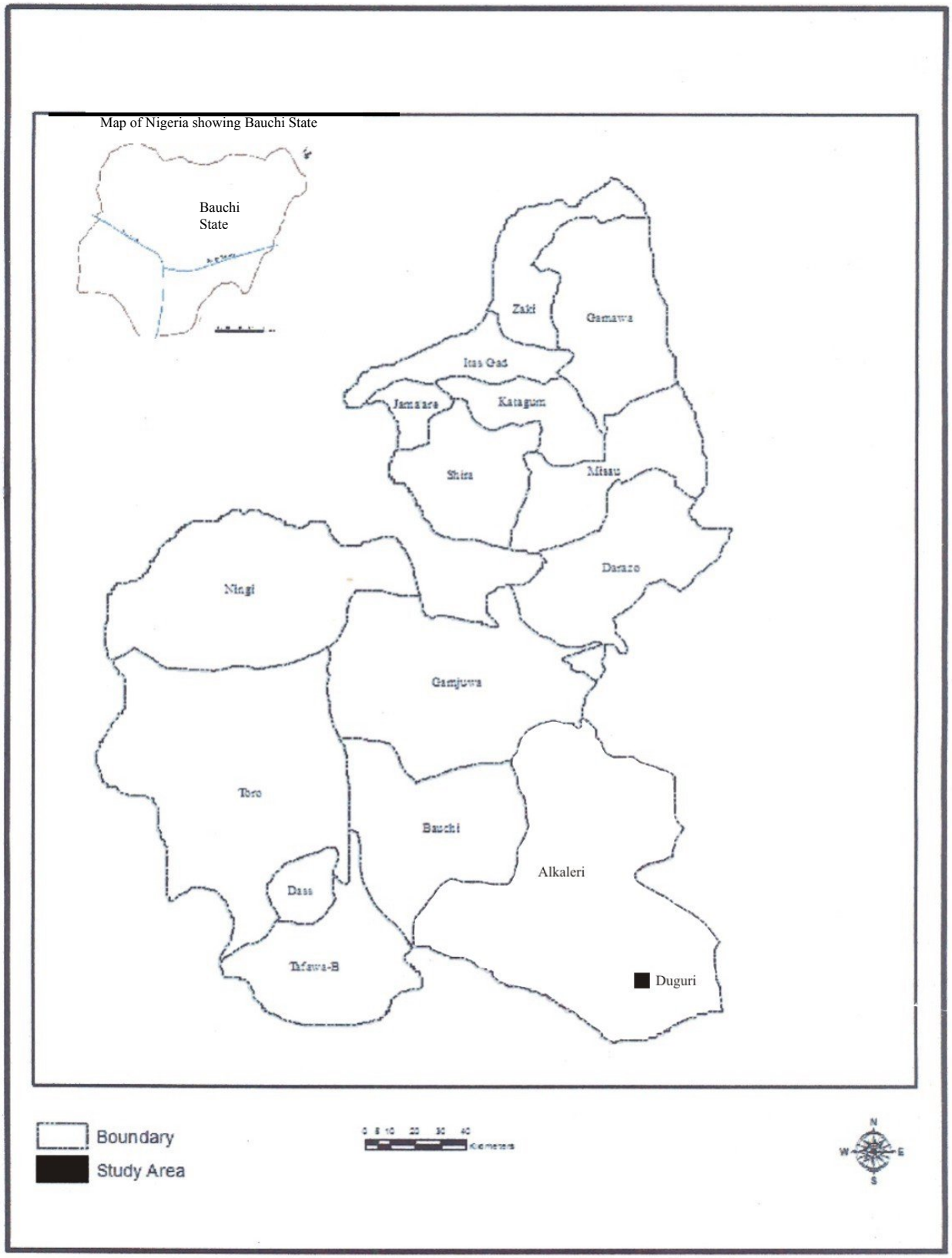


Figure 1 Map of Bauchi State showing study area

CHAPTER TWO

2.0 OUTLINE GEOLOGY OF THE BENUE TROUGH

The Benue Trough originated from Early Cretaceous rifting of the Central West African Basement. It forms a regional structure that extends from the northern frame of the Niger Delta northeastwards for about 1000km. Regionally, the Benue Trough is part of an Early Cretaceous rift complex known as the West and Central African Rift System (Fairhead; 1986; Genik, 1993).

The Benue Trough is filled with a thick accumulation of sediments deposited under changing environments and ranging in age from Early Cretaceous to Paleocene. Late Cretaceous sedimentation within the trough was influenced by a number of transgressive and regressive phases which were the result of combined effects of eustatic rise in sea level and local tectonism (Petters, 1978).

The Benue Trough is subdivided into three region; The Lower, Middle and Upper Benue Trough which correspond to areas of different geologic features.

The Upper Benue is the north-eastern Y-shaped part of the basin and it is subdivided into: to the east-west trending Yola branch; and to the north-south trending Gongola Basin (Benkhelil, 1989, Guiraud, 1990; 1993). The thickest sedimentary successions occurs in the western part of the Gongola Basin. Over 5km of sediments occur in the "Dukku", "Ako" and "Bashar" sub-basins (Benkhelil, 1988; 1989). Thinner successions occur in the "Lau" and "Numan"

sub-basins of the Yola arm Benkhelil (1988, 1989). The two are separated by the Wuyo-Kaltungo high (Zaborski, 1998).

The Middle Benue Trough extends north-eastwards from Makurdi approximately as far as a line joining Bashar and Mutum Biyu (Fig. 2). This boundary marks the southern limits of the outcrops of the Gombe Sandstone and Kerri-Kerri Formation, while the older sediments of the Upper Benue Trough undergo lateral facies changes in this area. The main surface structural feature of the Middle Benue Trough is the NE-SW trending Keana anticline, sedimentary sub-basins were identified by Benkhelil (1988; 1989), on the south-eastern flank, the Wukari sub-basin and Mutum Biyu sub-basin and on the north-western flank a minor Shendam sub-basin and more important Kadarko sub-basin.

The Lower Benue Trough extends roughly as far north as a line running through Makurdi and along the course of the Katsina Ala River (Fig. 2). Murat (1972) subdivided the Lower Benue Trough Cretaceous history into two main phases separated by the Santonian deformation. Prior to the Santonian the main depocentre was the narrow NE-SW trending fault bounded "Abakaliki Trough" to the West. (Murat (1972), identified a broad stable area "the Anambra platform", terminating at the Benin Hinge line. Consequent upon the Santonian folding, the Abakaliki Trough was inverted producing the main surface structure/feature of the Lower Benue Trough, the Abakaliki anticlinorium. The Anambra platform then subsided strongly to become the main depocentre, the "Anambra Basin".

The initial evolution of the Benue Trough was controlled by the opening of the Gulf of Guinea during the Early Cretaceous. The first stage of its evolution started in the Pre-Aptian, forming isolated basin with continental sedimentation.

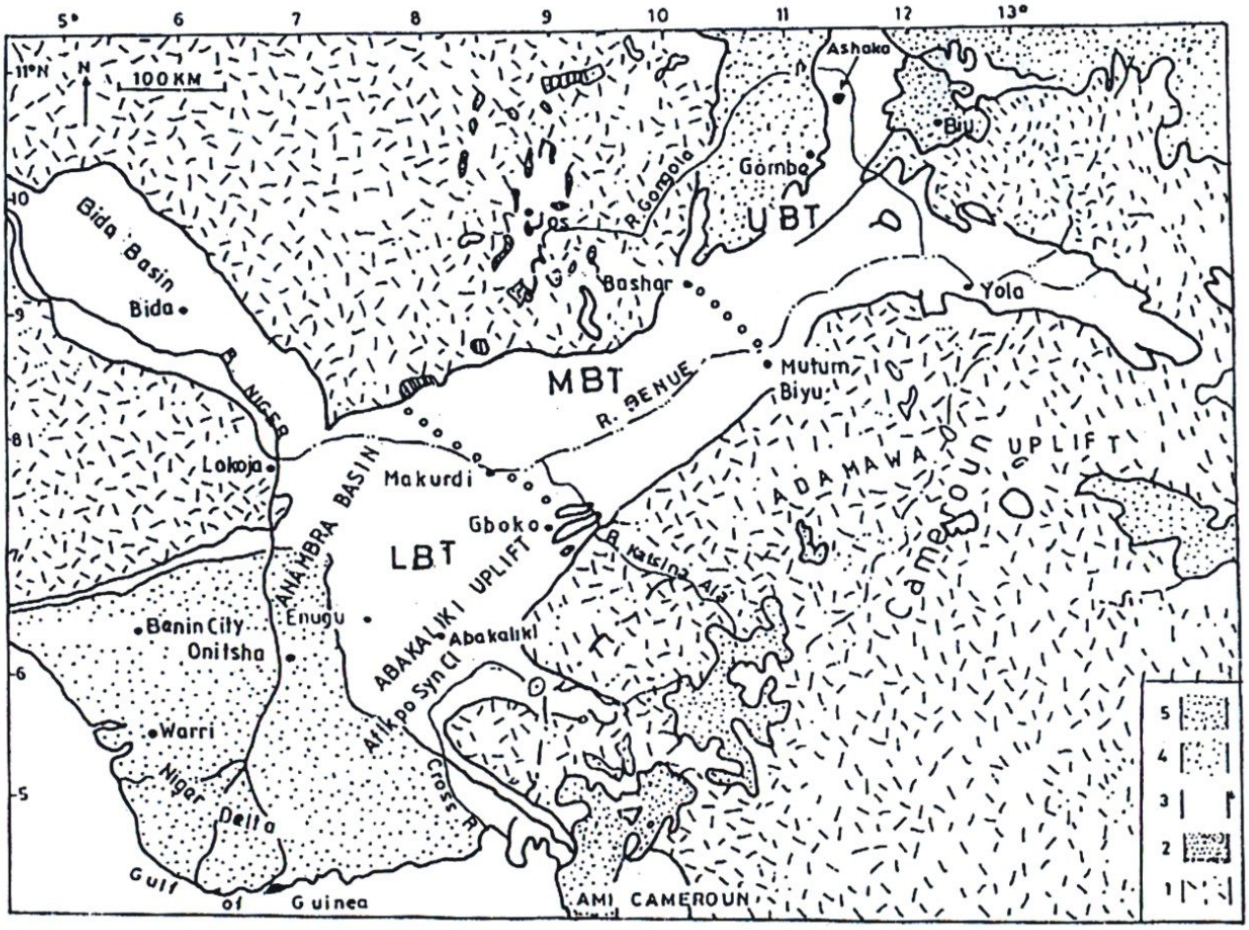


Figure 2 Outline geological map of the Benue Trough and adjacent areas. L BT, lower Benue Trough, M BT, middle Benue Trough, UBT, upper Benue Trough 1. Precambrian 2. Jurassic "Young Granites" 3. Cretaceous, 4. Post-Cretaceous sediments, 5. Cenozoic-Reccant basalts including those of the Cameroun lines (after Zaborski, 1998).

In the Albian, marine transgression from the South Atlantic flooded the Lower and Middle Benue Trough while, a delta developed in the Upper Benue Trough. The Cenomanian stage is represented in the Upper Benue by the Yolde Formation marking a period of transition from continental to marine conditions, (Benkhelil, 1989).

The most extensive transgression occurred at the end of the Cenomanian and connected Atlantic and Tethys waters through the Sahara region, the Niger rift basins and the Benue Trough. A shallow sea was widespread over the Upper Benue Trough. Two paleogeographical domains can be distinguished, the Yola (Dadiya-Lau) and Gongola (Pindiga–Gombe) Basin (Allix, 1983). Regression took place in the Middle Turonian followed by Late Turonian to Coniacian or Early Santonian renewed transgression.

The "Benue Trough proper" was inverted during the Late Santonian. An interval of erosion followed in the Benue Trough where Lower and Middle Campanian beds are unknown. The Santonian is represented in the Lower Benue Trough by the Ogugu Formation (Petters, 1980; Petters *et al*., 1985). Santonian beds have also been identified in the Yola arm of the Upper Benue Trough (Reyment, 1957). A short lived transgression produced Campanian – Maastrichtian sedimentation.

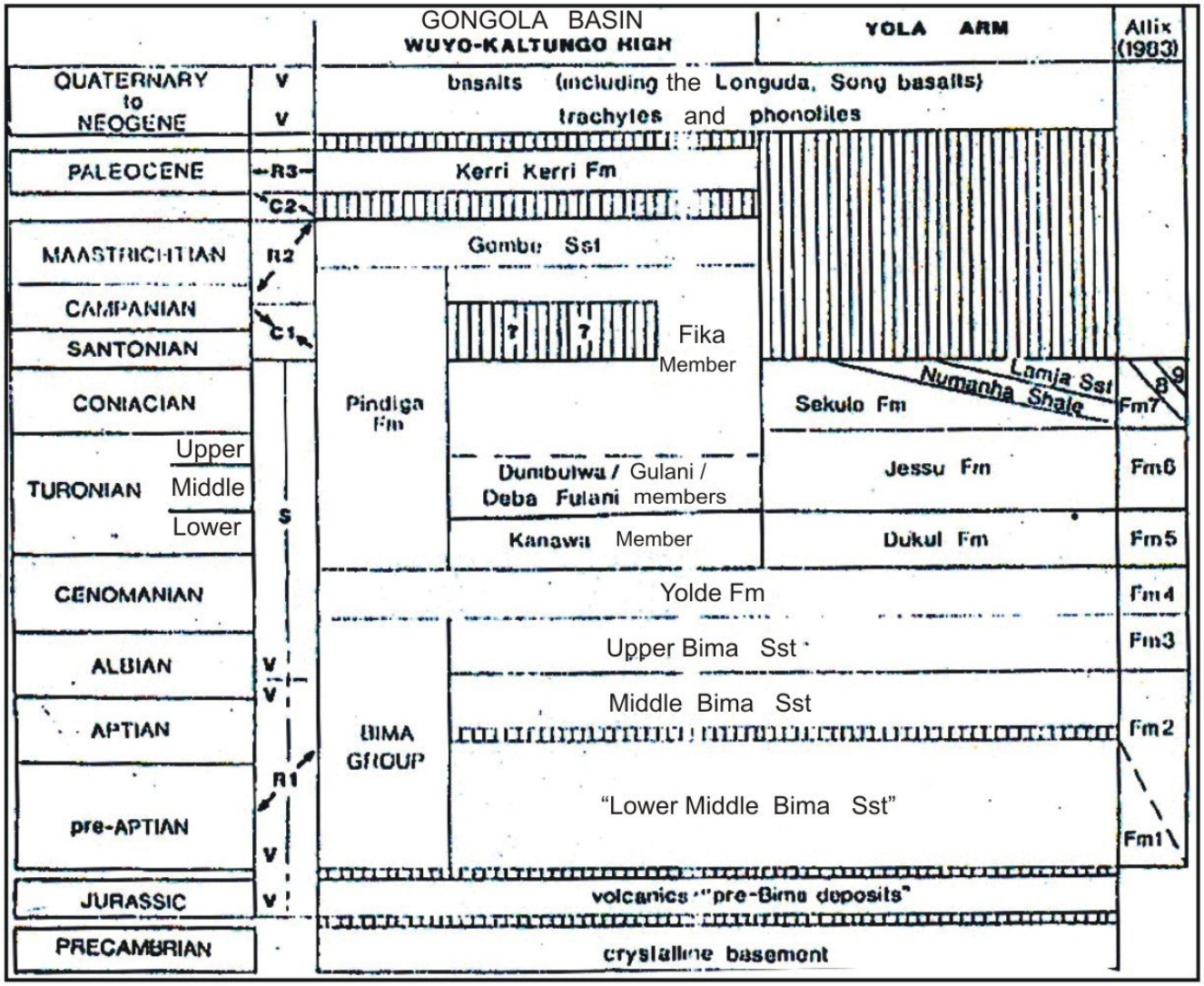
The final transgression which affected Nigeria was of Late Paleocene age. During this event, the Imo shale was deposited in the Anambra Basin and eastern

Benin Basin. Paleocene sediments are unknown from the Middle Benue Trough. In the Gongola basin, the continental Kerri-Kerri Formation represents the Paleocene, at least in part (Adegoke *et al.,* 1978).

2.1 STRATIGRAPHY OF THE UPPER BENUE TROUGH

The lithostratigraphical succession for the Upper Benue Trough has been established by various authors, for example, Carter *et al.* (1963) Popoff *et al.* (1986) and Zaborski e*t al.* (1997), as shown in Table 1.

Table 1 Lithostratigraphical successions present in the Upper Benue Trough region (subdivision of the Bima Group after Guiraud (1990a, 1991a), see text for other sources). V, volcanic episodes; R1 Early Cretaceous strike slip related rifting; S, thermo-tectonic sag, phase; C1, first compressional phase associated with strike-slip movements; R2, Campano-Masstrichtian rifting; C2, terminal Cretaceous compression, associated with strike-slip movements; R3, Paleocene rift stage (After Zaborski *et al*., 1997).



The lithostratigraphical succession begins with thick Lower Cretaceous Continental clastics, the Bima Group. These clastics are divisible into the "Lower", "Middle" and "Upper Bima" Formations (Guiraud 1990, 1991).

The Bima Group is overlain by a dominantly marine Upper Cretaceous succession comprising the Yolde, Pindiga and Gombe Formations.

2.1.1 Bima Group

The Bima Group rests unconformably on the Pan-African basement and forms the basal part of the sedimentary succession. The Bima Group generally make up by far the greatest proportion of the sedimentary succession in the Upper Benue Trough. The Bima Group ranges in ages from Pre-Aptian to Cenomanian. The Lower Bima has been interpreted as alluvial fan and braided river clastic deposits grading into lacustrine deposits (Allix, 1983; Popoff *et al*. (1983), Guiraud, (1990); Zaborski *et al*. (1997); Dike, 2002). The coarse-grained Lower Bima Sandstone is the oldest and thickest sedimentary unit present in the Upper Benue Trough (Guiraud, 1992). It has age limits between terminal Jurassic and Early Aptian. It is composed of arkoses, gravelly sandstone and boulder orthoconglomerates (Guiraud, 1990; 1991).

The Middle Bima Sandstone, is a widely-distributed, fairly uniform unit made up of fining-upwards cycles each 5 – 10m thick. Trough and tabular cross-bedding characterizes the sandstones in the lower part of each cycle, thin clays and paleosols occur above.

These deposits were regarded as of proximal braided river origin by Guiraud (1990; 1991).

The Upper Bima Sandstone consists of tabular cross-bedded, coarse to fine-grained sandstones with horizons showing convolute lamination Guiraud (1990; 1991).

This unit, representing distal braided river environments, is probably of Albian age though there may be Cenomanian beds in its upper part Guiraud (1990; 1991).

2.1.2 The Yolde Formation

The Yolde Formation comprises the transitional beds between the continental Bima Sandstone and the marine Pindiga Formation (Falconer, 1911; Reyment, 1965). It has age limits between Late Albian and Late Cenomanian (Lawal, 1982; Allix, 1983; Lawal and Moullade, 1986). It consists largely of alternations of coarse to fine-grained, cross-bedded or ripple bedded sandstones and grey to greenish shales.

Carter *et al*., (1963) defined the base of the Yolde Formation "by the appearance of marine shales". In the Yola arm, Allix (1983) used the appearance of thick, laterally continuous siltstone or silty shales or the base of a marker horizon comprising greenish fine-grained shales with disturbed cross-bedding found in parts of the Yola arm.

In the Upper Benue Trough as a whole, however, the argillecous deposits in the lower portions of the formation generally represents the upper parts of fining upwards alluvial cycles and frequently show evidence of sub-aerial exposures in the form of mudcracks and petrogenetic features (Zaborski, 2003).

2.1.3 Pindiga Formation

The Pindiga Formation makes up the greater part of the Upper Cretaceous in the Gongola Basin. Its type section is in the Pindiga stream, to the south-west of Gombe. The formation is Late Cenomanian to Campano-Maastrichtian in age. Zaborski *et al*., (1997) regarded the Pindiga Formation as consisting of the Kanawa, the Deba Fulani, the Gulani, the Dumbulwa and the Fika Members.

The Kanawa Member [(Kanawa Formation of Thompson (1958)] ranges in thickness from 120m at Kumo (Lawal 1982) to just a few metres of condensed limestone – dominated beds over the Dumbulwa – Baga high (Zaborski, *et al*., 1998). It corresponds to the Lower "shale-limestone Member" of the Pindiga Formation of Carter *et al.* (1963). The Kanawa Member formed during the Late Cenomanian to Early Turonian transgression which affected the entire Benue Trough and also large parts of the Saharan region to the north (Zaborski *et al*., 1997). The rich ammonite faunas of the Kanawa Member allow its detailed dating (Late Cenomanian to Early Turonian) and correlation (Zaborski *et al*., 1997).

The "Deba Fulani Member" (Zaborski *et al*., 1997) represents variety of fluvial, coastal plain and shallow sub-littoral environments. Coarse-grained,

pebbly tabular cross-bedded sandstones and fining-upwards channel filling sands occurs as well as more thinly bedded sandstone with burrows of *Ophiomorpha* type (Zaborski *et al*., 1997).

The Gulani Member included probably fluviatile sediments with very large-scale tabular cross-bedded coarse-grained sandstones and granulestone (Zaborski *et al*., 1997).

The Dumbulwa Member (Zaborski *et al.,* 1997) is largely made up of fining-upwards fluvial cycles, when complete each about 10m thick. Localized developments of persistent tabular cross-bedded sandstones also occur.

The Fika Member comprises the "Fika shales" and the equivalent of the upper shale, part of the Pindiga Formation (Carter *et al*., 1963; Zaborski *et al*., 1997). In many places, it is concealed by alluvial deposits derived from the overlying Gombe Sandstones and Kerri-Kerri Formation. The Fika Member comprises marine shales of overall Late Turonian to Campanian age. It consists of blue-black shales, occasionally gypsiferous, with thin limestone intercalations. Carter *et al*., (1963) and Lawal (1982) believed that it represented a continuous period of deposition from Turonian to Maastrichtian. Others such as Allix (1983), noted the thinness of the part of the Pindiga Formation dated Late Turonian to Early Campanian by Lawal (1982) and suspected that a hiatus might exist within this interval.

Zaborski *et al*. (1997) presented some evidence for Santonian – Campanian folding including the presence of an angular unconformity between the Pindiga

Formation and the Gombe Sandstone in the Bashar area. Guiraud (1993) believed that the main deformation in the Upper Benue Trough occurred during the Santonian. The Fika Member may represents two distinct depositional phases separated by the Santonian Compression event, one Late Turonian to Early Santonian, representing fairly sustained marine condition, and the other Late Campanian (to Early Maastrichtian ?) and associated with the Gombe Sandstone depositional system.

In the Yola arm, the succession lying above the Yolde Formation is the Dukul Formation, Jessu Formation, Sukule (Sukuliye) Numanha shale and Lamja Sandstone.

The Dukul Formation (Carter *et al*., 1963) comprises shales, thin limestones and sandy and silty intercalation (Allix, 1983).

The Jessu Formation (Carter *et al*., 1963) comprises an alternations of shales, siltstones and subordinate sandstones.

The Sukule (Sukuliye) Formation, consists mainly of grey-green shales but contain numerous hard grey limestone.

The Numanha Shale is dominated by grey-black shales. There are frequent intercalations of green to yellow laminated or bioturbated siltstones.

The Lamja Sandstone (Carter *et al*., (1993) consists of mixed sandstone, siltstones, shales and coal units.

2.1.4 Gombe Sandstone

The Gombe Sandstone is restricted to the western part of the Gongola Basin. In sub-outcrop the Gombe Sandstone extends to west beneath most of the Kerri-Kerri Basin (Dike, 1995).

The Gombe Sandstone was first described by Falconer (1911) as the "Gombe grits and clays" (in part). This included the Gombe Sandstone and part of the Kerri-Kerri Formation. He described it as a well-bedded succession of grits, sandstones, clays and ironstone, usually light coloured below, and dark red and ferruginous above. He assigned an Eocene age to the Gombe Sandstone and suggested an unconformable contact of the Gombe Sandstone with the underlying Cretaceous beds.

Carter *et al*. (1963) proposed the name "Gombe Sandstone" for part of the Gombe grits and clays of Falconer (1911). They interpreted the Gombe Sandstone as a "sequence of deltaic and estuarine sandstone, siltstones, shales and ironstones". Carter *et al.* (1963) assigned a Senonian to Maastrichtian age to the Gombe Sandstone.

Carter *et al*. (1963) gave a detailed description of the Gombe Sandstone. They designated a type section in the Kware stream on the southern outskirts of Gombe town. According to Carter *et al*. (1963), the Gombe sandstone has a thickness of 310 metres.

Adeleye (1975) described the Gombe Sandstone as mainly flaggy sandstones and siltstones, with minor interbeds of shales, lignite and lenticular

oolitic and non-oolitic ironstones yielding a fauna of indeterminate bivalves. He described the Gombe Sandstone as gently warped and locally showing small-scale reverse faults. He also suggested that a poorly exposed angular unconformity may exist at the base of the Gombe Sandstone.

The Gombe Sandstone is made up of three major lithofacies according to Zaborski *et al*. (1997). Its basal part, transitional from the Fika Member, consists of rapidly alternating thin beds of silty shale (Fig. 3a) with fine to medium-grained sandstones with some intercalated thin flaggy ironstone. Individual beds vary from a few millimetres to a few centimetres in thickness. Bioturbation occurs occasionally as do plant remains. This lithofacies is repeated in the Gombe inlier above a few tens of metres of strata belonging to the bedded facies.

The "bedded facies" makes up the greater part of sandstone beds (Fig. 3b). This lithofacies is well exposed in Guiwa (Zaborski, *et al*., 1997). It consists of extremely regularly bedded, fine to medium-grained white and grey quartz arenite (and occasional feldspathic sandstones) with interbedded silts and silty clays. Individual beds vary from a few centimetres to over 10 metres in thickness but even the later beds are characterized by internal laminations. The bedded facies also contains channel-filling sandstones. North of Gombe, the bedded facies makes up the entire outcropping Gombe Sandstone apart from its basal transitional portion.

The third facies outcrops to the south of Gombe, and is termed the "red sandstone facies" (Fig. 3c). This lithofacies increases in importance to the south and west of Gombe.

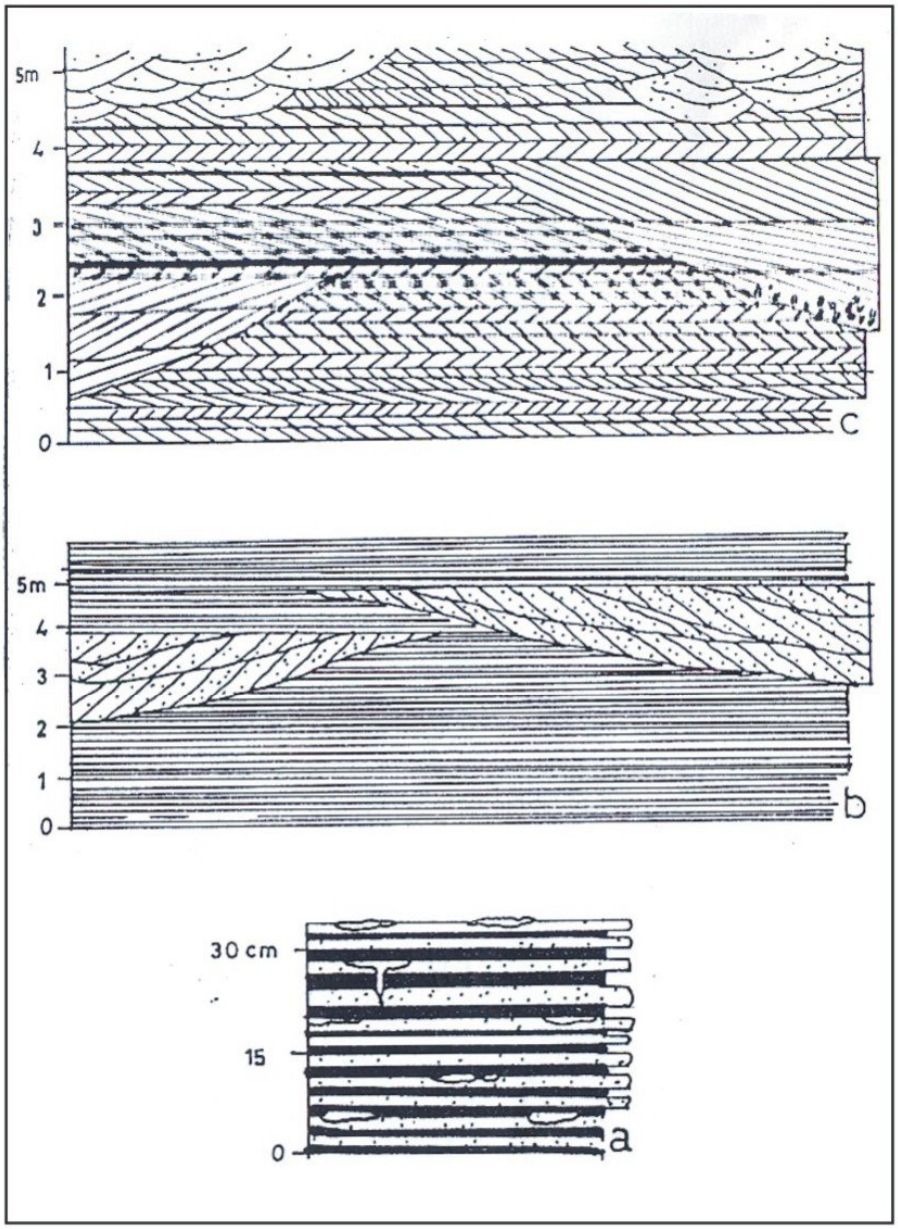


Figure 3 Gombe Formation, Lithofacies recognizable within the formation
a. Basal transitional portion b. Bedded facies c. Red-sandstone facies
(After Zaborski *et al*., 1997).

At Pindiga it makes up the upper two thirds of the formation while around Bashar in the extreme south, almost the entire Gombe Sandstone is made up of the red sandstone facies. The red sandstone facies is mainly composed of brick-red coloured sandstone though they are sometimes grey or white Tabular cross-bedding is common. Higher up in this facies, the sandstones are medium to coarse-grained. The red sandstone facies is believed to be a fluvial deposit. The bedded facies was laid down in a shallow quiet, perhaps hyposaline sea. The basal beds of the Gombe Sandstone probably represent a prodeltaic facies. Allix (1983) and Zaborski (1998) interpreted the Gombe Sandstone as a deltaic deposit as a result of its general coarsening-upwards nature, its lateral facies distribution, the presence of coals and he disappearance of marine microfossils in the upper most Fika Member.

In the Bashar and Yuli (Duguri) area, the Gombe Sandstone rests directly upon the Precambrian basement, there are boulder conglomerates and thick tabular cross-bedded sandstones, alluvial fan and braided river deposits, which represent the extreme proximal parts of this system (Zaborski *et al*., 1997). On the basis of pollens, Allix (1983) suggested a Maastrichtian age for the Gombe Sandstone.

A marked angular unconformaly separates the Gombe Sandstone from the overlying Kerri-Kerri Formation. The Gombe Sandstone was folded, faults and deeply dissected during the terminal Cretaceous compressional episode prior to the deposition of Kerri-Kerri Formation.

Ayoola (1981) identified an (angular) unconformable relationship between the Gombe Sandstone and Tertiary Kerri-Kerri Formation in the Bashar area. Based on paleocurrent directions interpretation of the Bashar area, Ayoola suggested that beds referred to as the Kerri-Kerri formation has a westerly source and the Cretaceous sediments were derived from the east, this paleocurrent direction interpretation indicates the unconformity between the Kerri-Kerri Formation and Cretaceous sediments. He suggested that the basement complex was the source of the Kerri-Kerri Formation" and pointed out that the petrographic characteristic of the Gombe Sandstone and Kerri-Kerri Formation suggests a recycled nature.

Zaborski *et al*; (1997) interpreted the sandstones around Bashar area as the proximal part of a coarsening-upward deltaic-like deposit prograding from the south-west (and west ?) into a sea open only to north (Fig. 4).

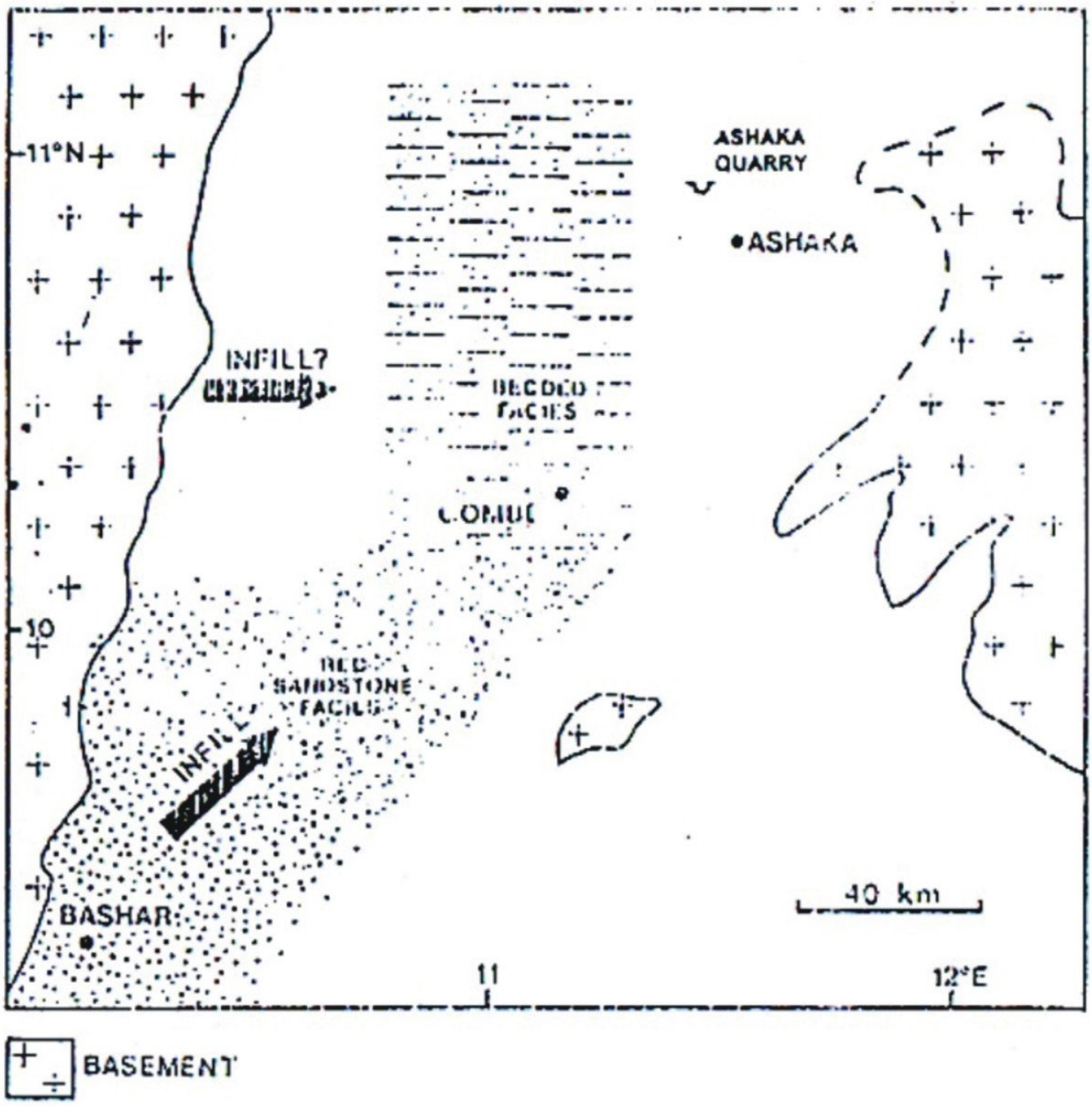


Figure 4 Map showing lateral facies relationships within the Gombe Formation. (After Zaborski *et al*., 1997).

Benkhelil (1988) interpreted the Gombe Sandstones as fluvial-deltaic deposit filled from the east and localized along the Western edge of sedimentary basin (Fig. 5).

2.1.5 Kerri-Kerri Formation

The Kerri-Kerri Formation occurs in the western part of the Gongola Basin and was first named and dated as Eocene by Falconer (1911). He described the beds directly underlying the Kerri-Kerri Plateau *sensu stricto* in the north-central part of the outcrop as the Kerri-Kerri Formation. Falconer (1911) described a characteristic section at Gombe Aba hill. A white clay with gritly and sandy bands in its upper part and some what stained with iron forms the lower slopes of the hill, while above are dark red sandstones and pebbly grits passing in places into flaggy or oolitic ironstone. Falconer (1911) correlated the Kerri-Kerri Formation with Eocene Sandstones in the Lokoja and Sokoto Basins. Shell B.P. Petroleum Development Company Palynologists, based on carbonaceous material from a borehole at Dukku dated the Formation as Paleocene. Adegoke *et al*. (1978), based on palynomorphs, confirmed a Paleocene age for the formation and identified a regional fault along the formation's western boundary with the basement complex.

Carter *et al*. (1963) and Wright (1976) suggested derivation of the Kerri-Kerri deposits from older sedimentary beds after the end of Maastrichtian folding, uplift and erosion.

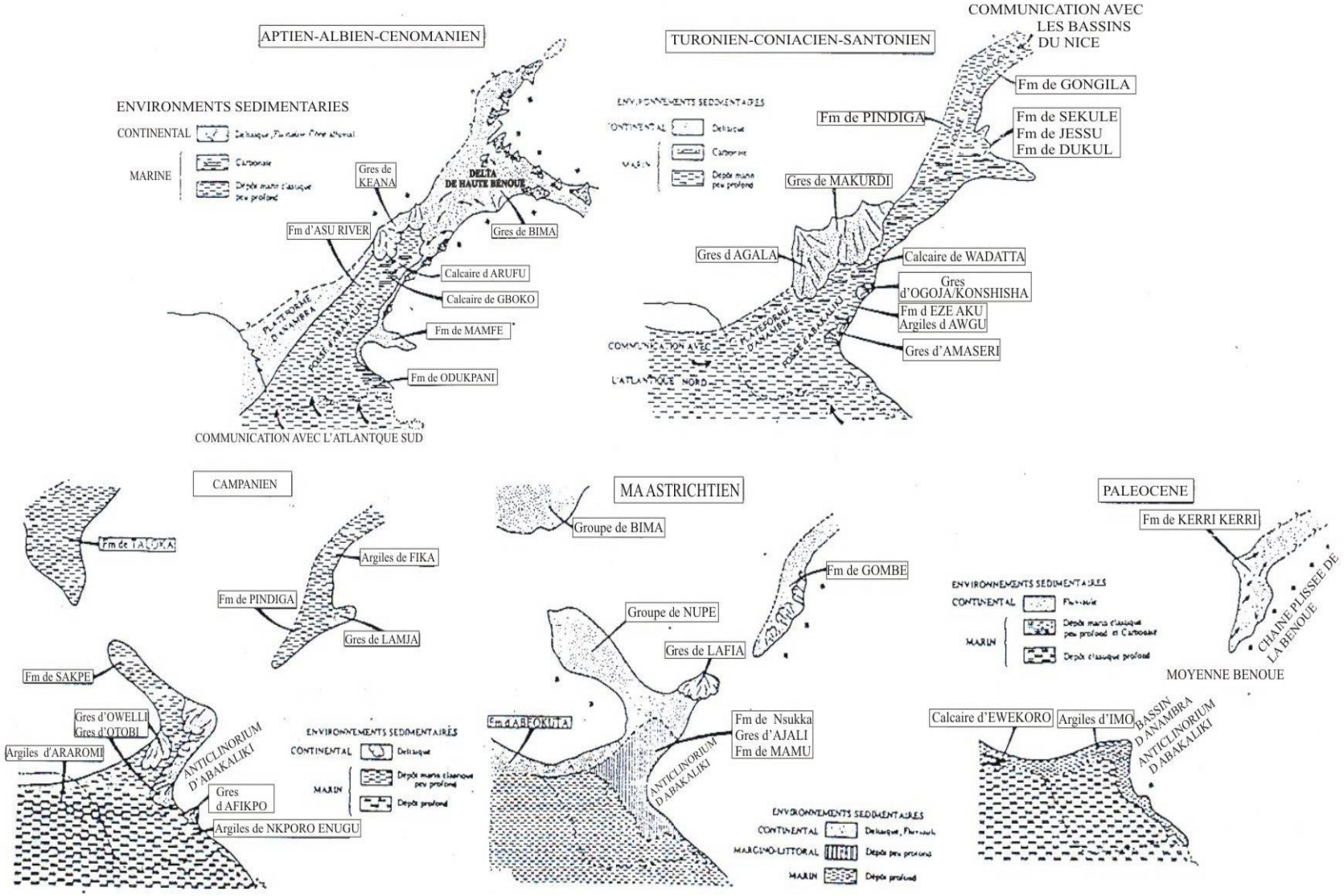


Figure 5 Palaeogeographic reconstitutions and facies distribution during the Cretaccous and the Early Tertiary in the Benue Trough (After Benkhelil, 1986)

Burke (1972) however, attributed their origin to materials derived from the Neogene uplift of Jos Plateau. Dessauvagie (1975) described the Kerri-Kerri Formation as lying unconformably on folded Cretaceous sediments of the Upper Benue Trough and itself being mainly underformed.

Benkhelil (1989) indicated that the Kerri-Kerri Basin was controlled by a set of NNE-SSW trending faults occurring along its western margin which separates it from the Basement Complex of the Jos Plateau. Based on sub-surface data, Okafor (1982) suggested that the Kerri-Kerri basin was bounded in its western and eastern margin by two parallel faults trending N15ºE. The fault in the west is said to pass through Alkaleri.

According to Adegoke *et al*; (1986) and Zaborski *et al*. (1997) the Kerri-Kerri Formation exhibits N – S trending faults to the east. According to Dike (1992) structurally, the Kerri-Kerri basin is an elongate slightly asymmetrical graben characterized on both the western and eastern margin by a system of N15ºE to N30º normal faults. The fault zone which controls the deposition and the structure of the Kerri-Kerri Formation, at least along its western margin, belongs to an inherited fault system of the Basement Complex. The greater thickness of sediments along the western margin was related to presence of an active fault zone during sedimentation (Adegoke *et al*., 1986). The Kerri-Kerri Formation generally is undeformed with flat-lying beds. However, broad synclinal and anticlinal warps have been suggested by Adegoke *et al*. (1986).

Compressional deformation represented by folds located along the main western fault zone are particularly well expressed at the southern end of a fault zone near Ganjuwa south of the study area. Dike and Egbuniwe (1993) recognized a non-conformity between the Kerri-Kerri Formation and the Basement Complex along its western margin. The Kerri-Kerri Formation oversteps the Late Cretaceous Gombe Sandstone to overlie the Cretaceous Fika Member at Damagum in Yobe State. Dike (1993) recognized alluvial fans, braided stream, marginal lacustrine and central axial fluvial-plain environments of deposition for the Kerri-Kerri Formation. The Kerri-Kerri Formation is characterized by medium to coarse-grained sands, pebbly coarse sands and coarse grits, as well as interbeddings of sandy gravels, medium to fine-grained sands, siltstones and clays. The Kerri-Kerri Formation reaches a thickness of over 320m (Adegoke *et al*., 1986; Dike, 1995).

CHAPTER THREE

FIELD GEOLOGY AND STRATIGRAPHY OF DUGURI AREA

3.0 INTRODUCTION

The Duguri area is located in Bauchi state and form part the Upper Benue Trough. The Duguri area has been worked on in the past to determine its stratigraphy and structure.

3.1 PREVIOUS WORK ON THE DUGURI AREA

Falconer (1911) referred to the sandstones around Duguri as the "Duguri Sandstones and grits" (which refers to parts of the Gombe Sandstones and Kerri-Kerri Formation herein); He described the sediments as a well bedded succession of grits, sandstones, clays and ironstones, usually light coloured below and dark red and ferruginous above. According to Falconer (1911) these beds were of Eocene age. Falconer (1911) suggested that their contact with the underlying basement was unconformable, but the actual contact was not found by him.

Falconer (1911) described the basal beds around Duguri in the cliffs behind Tongolan A "400 feet" section of white and purple grits capped by hard red ferruginous sandstone, and banked against the crystalline rocks was described. West of Duguri Falconer (1911) described a series of white sandstone and clays overlain by red sandstones and grits exposed in the cliffs which bound the valley

of the Yuli River. South of Duguri, the white grits appeared to be replaced by ferruginous sandstone.

On the Plateau at Katana a thin series of red sandstone with bands and streaks of flaggy limonite, underlain by white sandstone, pebbly grits and conglomerates, rests directly upon the crystalline rocks.

Dessauvagie (1975) also recognized the Gombe Sandstone and Kerri-Kerri Formation in the Bashar area and also suggested an unconformity between the Gombe Sandstone and the Kerri-Kerri Formation. Dessauvagie (1975) recognized beds referred to as Gombe Sandstone by Zaborski *et al*; 1997 as in part, Kerri-Kerri Formation and the Bima Sandstone. In Bashar he suggested that the Bima Sandstone and Kerri-Kerri Formation overlie the basement directly (Fig. 6). Dessauvagie (1975) drew a cross-section across the Yuli area (Fig. 7a) and obtained a section which showed (i) an unconformity between the Precambrian basement complex and Gombe Sandstone and (ii) an unconformity between the Bima Sandstone and Kerri-Kerri Formation (Fig. 7b). The 1:2,000,000 scale Geological Survey Map of Nigeria (1975) showed the Basement Complex, Migmatite Gneiss and Granite Gneiss overlain by Kerri-Kerri Formation (Fig. 8).

Zaborski *et al*. (1997) recognized three litho units (Fig. 9) in the Bashar-Yuli area. The Basement Complex, overlain by the Gombe Sandstone and the Kerri-Kerri Formation overlying the Gombe Sandstone. In the Bashar and Yuli Duguri) areas, the basal Gombe Sandstone was described as consisting of white to grey, coarse-grained pebbly sandstone, with indistinct cross-bedding, but the

greater part of Gombe Sandstone was made up of tabular cross-bedded grey or brick red sandstone. They also presented some evidence for Santonian-Campanian

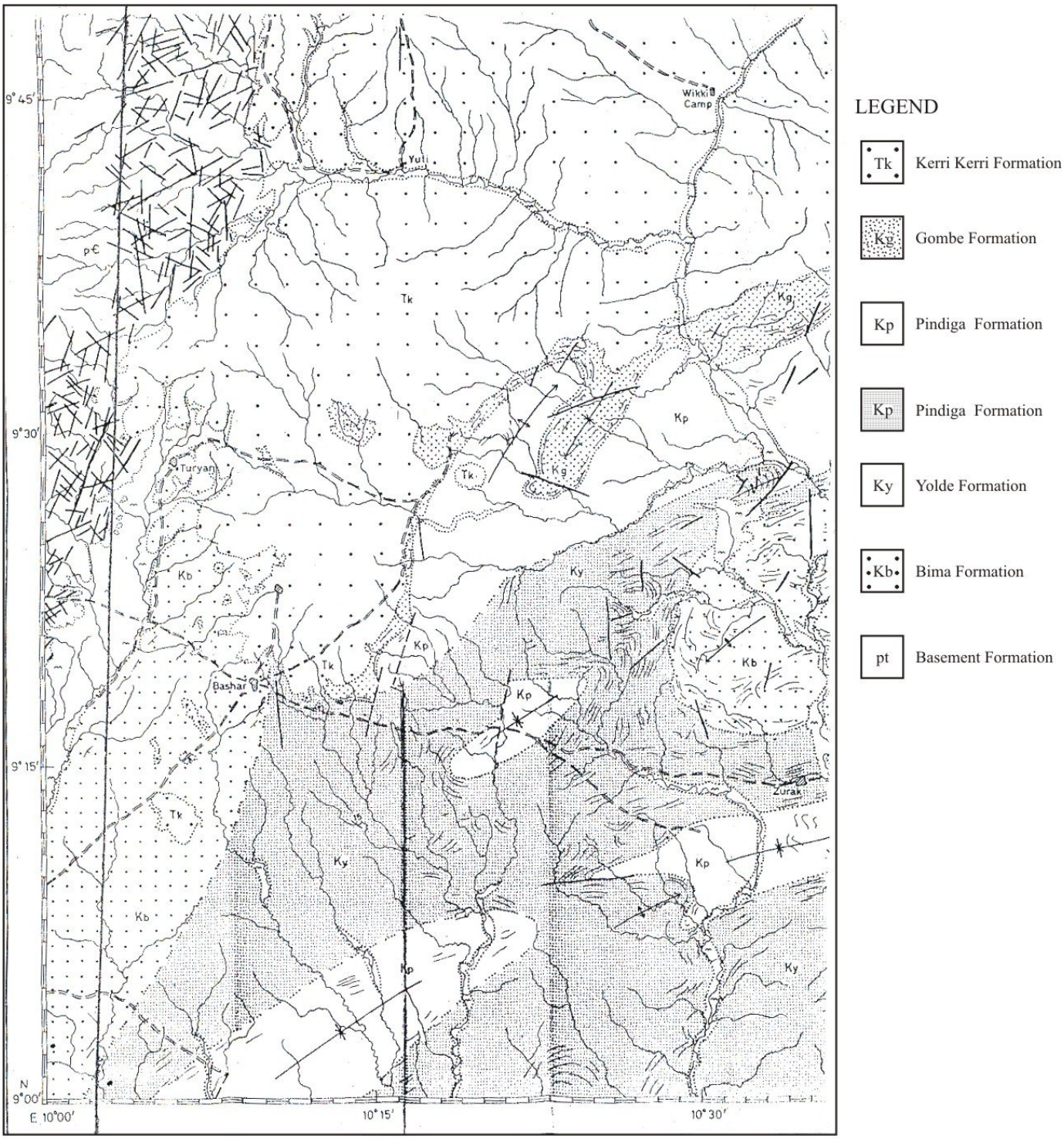


Figure 6 Geological Survey and photo interpretation of sheet 46 (Futuk) (After T.F.J. Dessauvagie 1969).

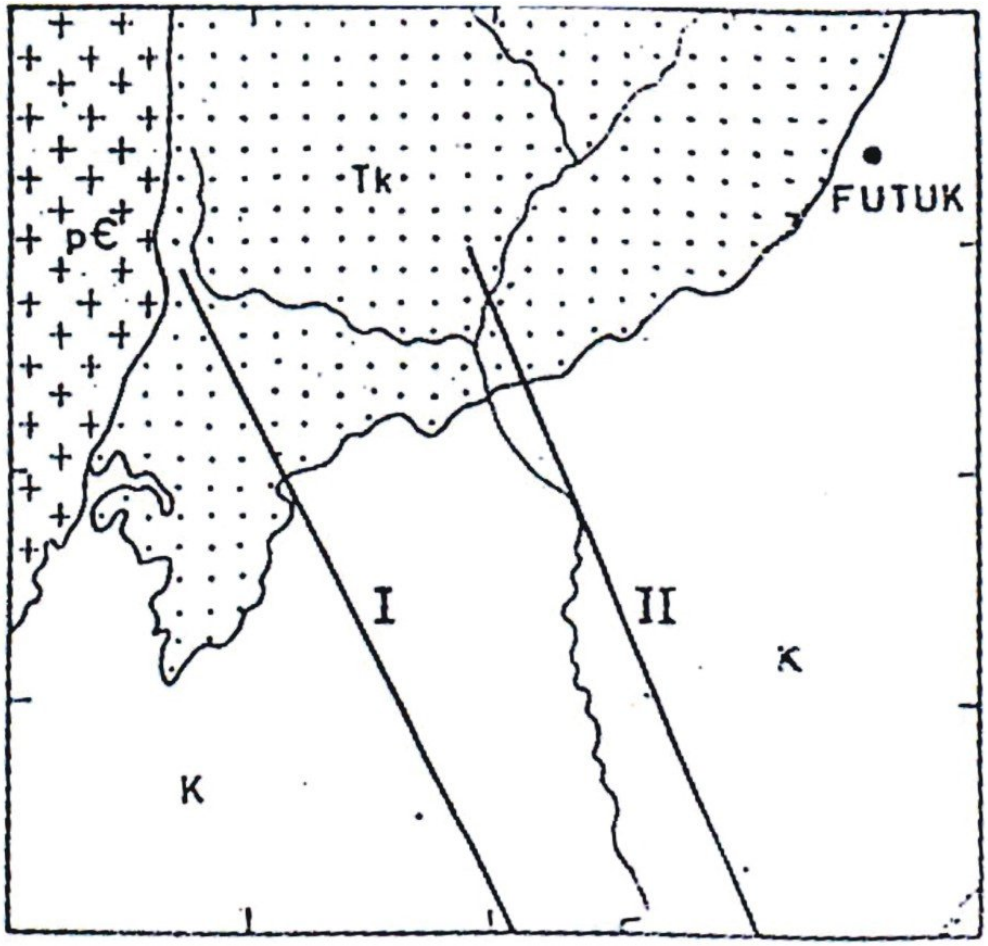


Figure 7a Sketch of sheet 46 (Futuk) showing the location of cross-section I (After Dessauvagie 1969).

Legend

Kk	Kerri Kerri Formation
K	Bima Sandstone
PE	Basement complex

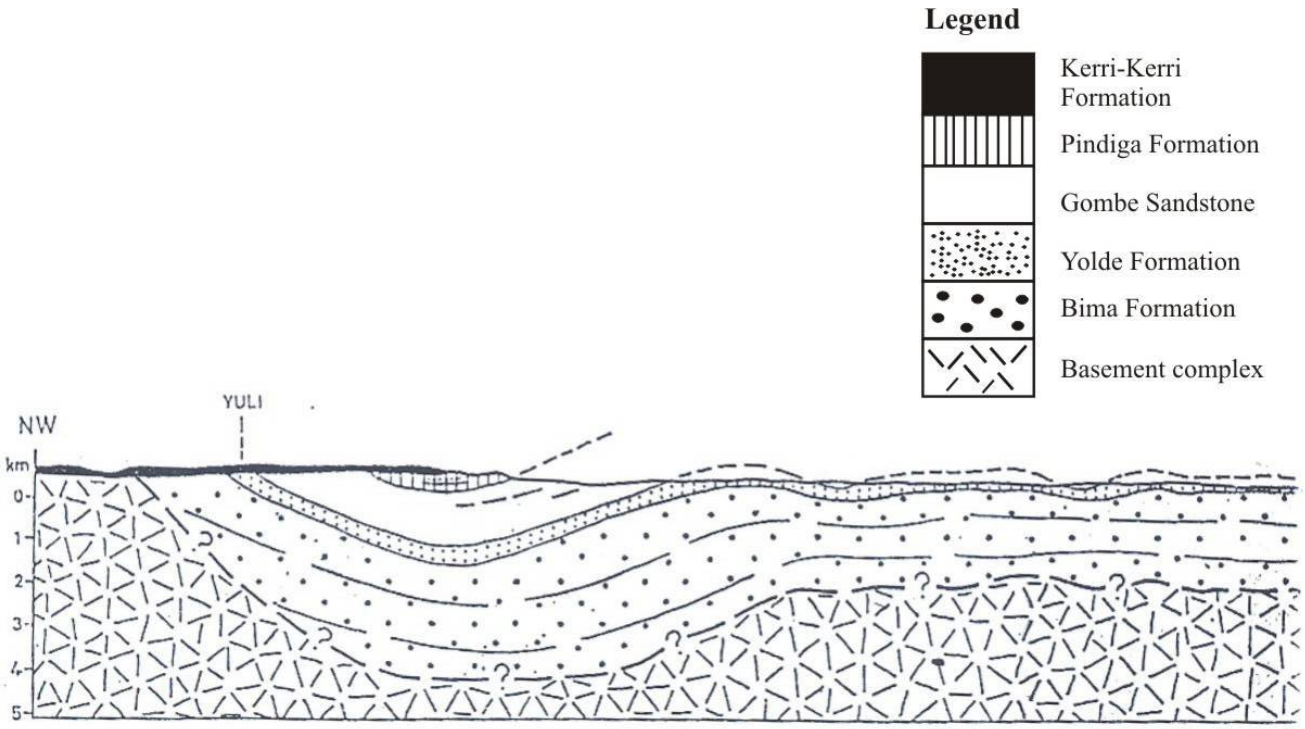


Figure 7b Sketch section across sheet 46. Futuk (After Dessauvagie 1969).

Legend:

GG Granite Gniess MG Migmatite Gniess Kerri Kerri Formation

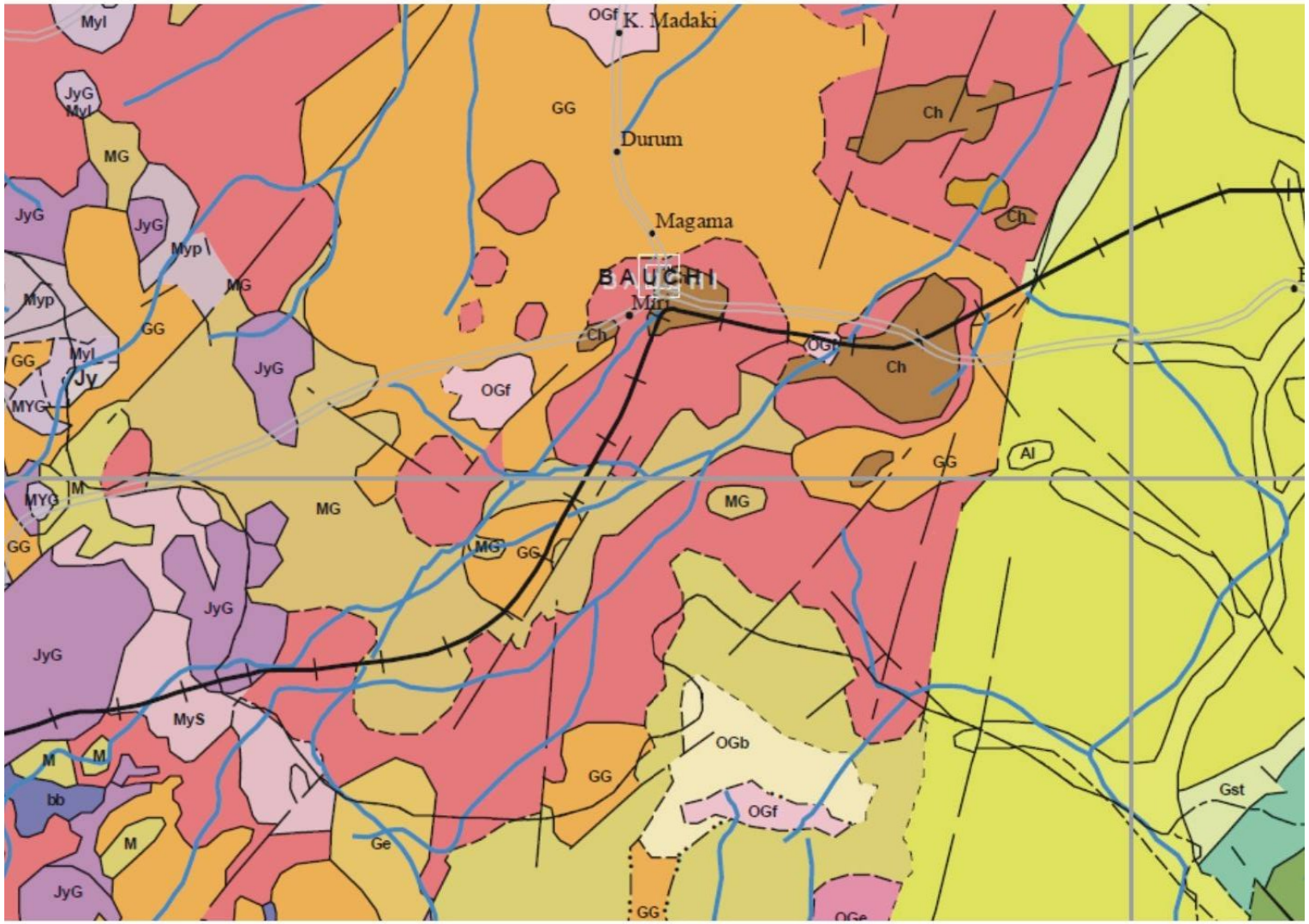


Figure 8: Geological Survey map of Nigeria (1974) showing Basement complex, overlain by Kerri Kerri Formation. Scale 1:2000,000

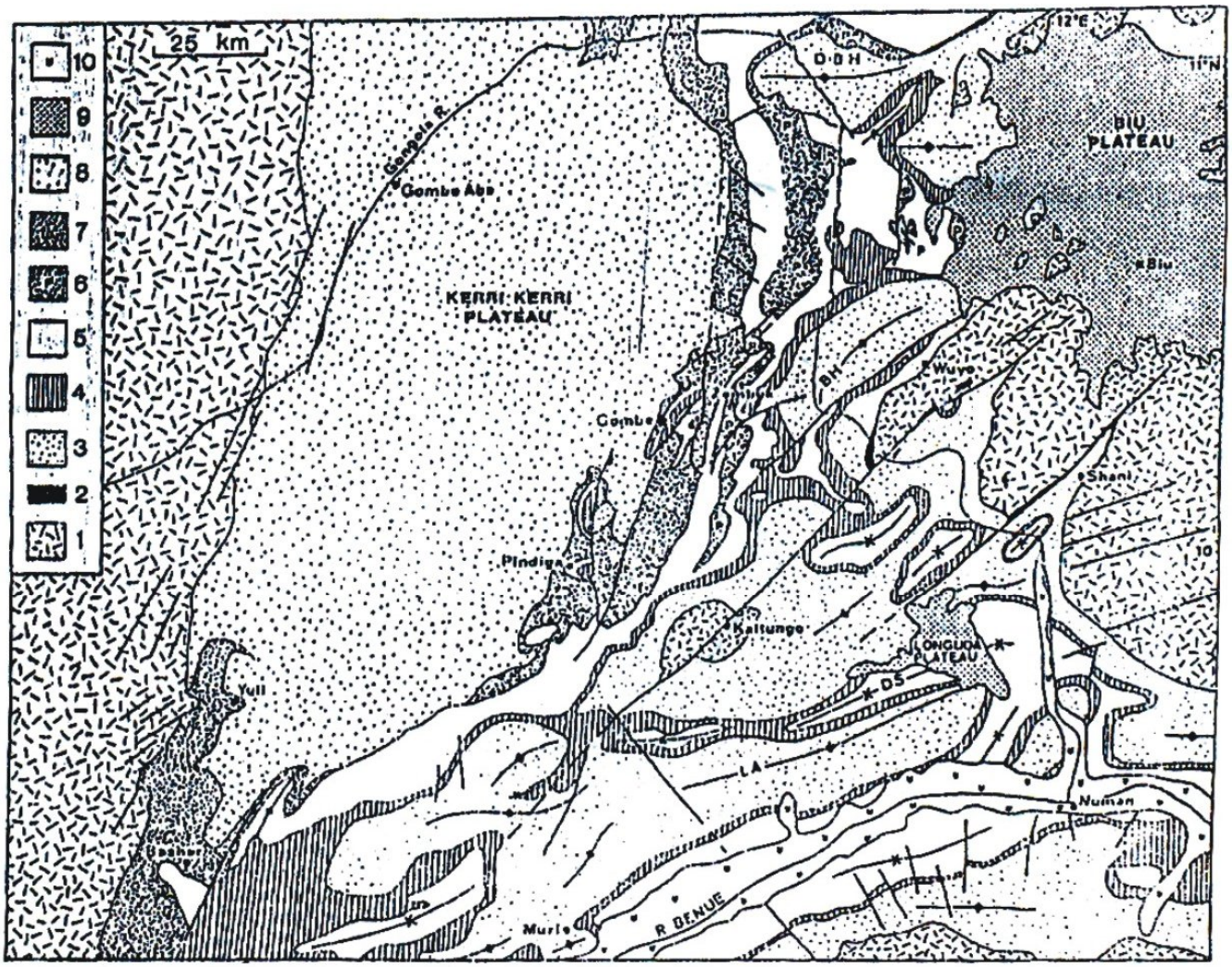


Figure 9 Geological map of the upper Benue Trough region (based on Benkhelil; 1985; Guiraud, 1989; Zaborski *et al.,* 1998), 1, Precambrian; 2, Late Jurassic? To Early Cretaceous volcanies, 3, Bima Group; 4, Yolde Formation; 5, Pindiga Formation and lateral equivalents in the Yola arm; 6, sandy members of the middle part of the Pindiga Formation in the Gongola Basin, 7, Gombe Sandstonep; 8, Kerri Kerri Formation; 9, Neogene to Quatenary basalt; 10, alluvium; D-BH, Dumbulwa-Bage high; BH, Bima Hills DS, Dadiya syncline; LA, Lamurde anticline (After Zaborski *et al*., 1998).

folding including the presence of an angular unconformity at the base of the Gombe Sandstone in the Bashar area. Around Bashar the Gombe Sandstone is separated from the Pindiga Formation by an angular unconformity.

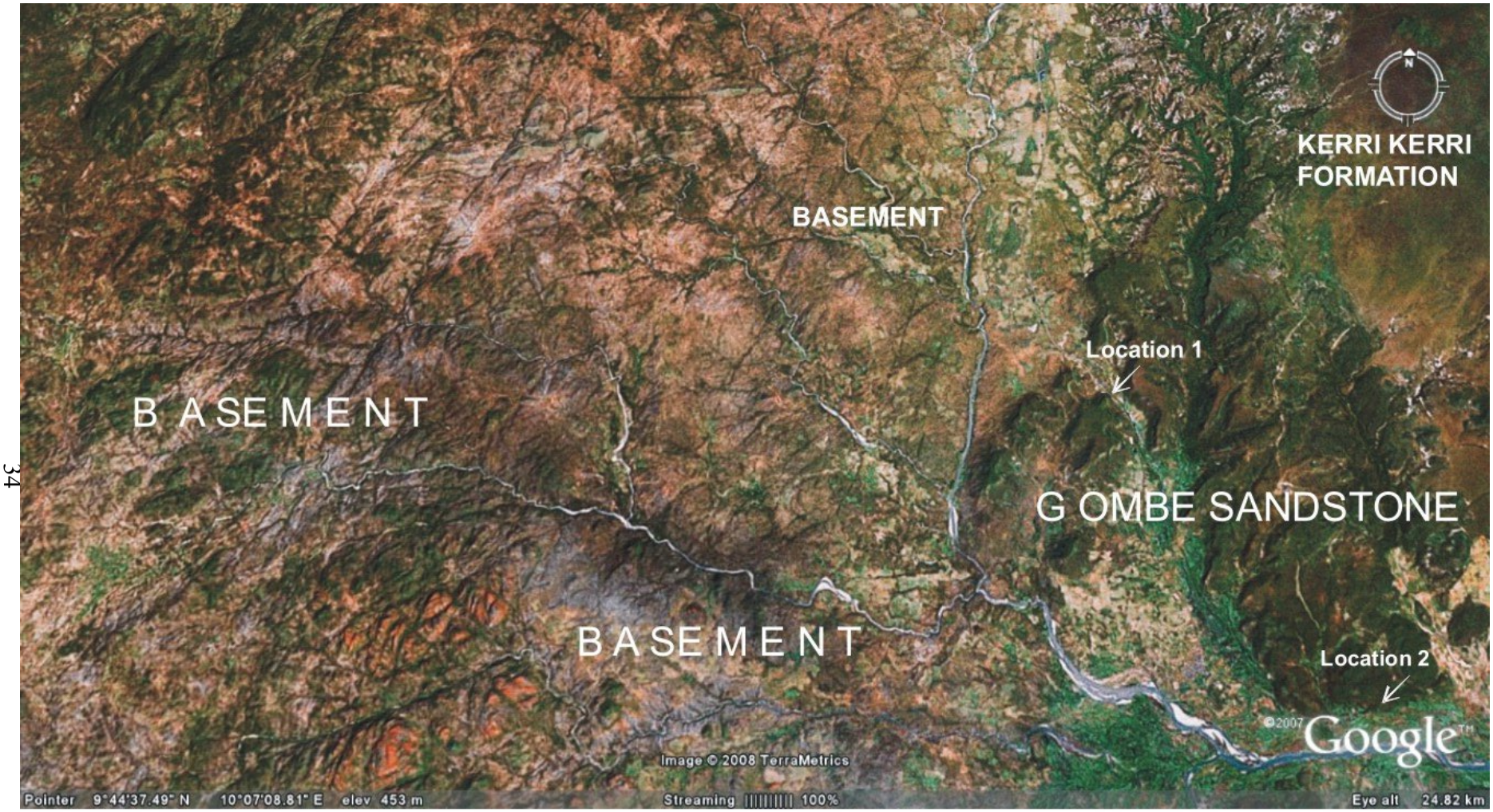


FIGURE 10: Satellite Image of Yuli– Vertical View. Gombe Sandstones Overlies the basement complex.

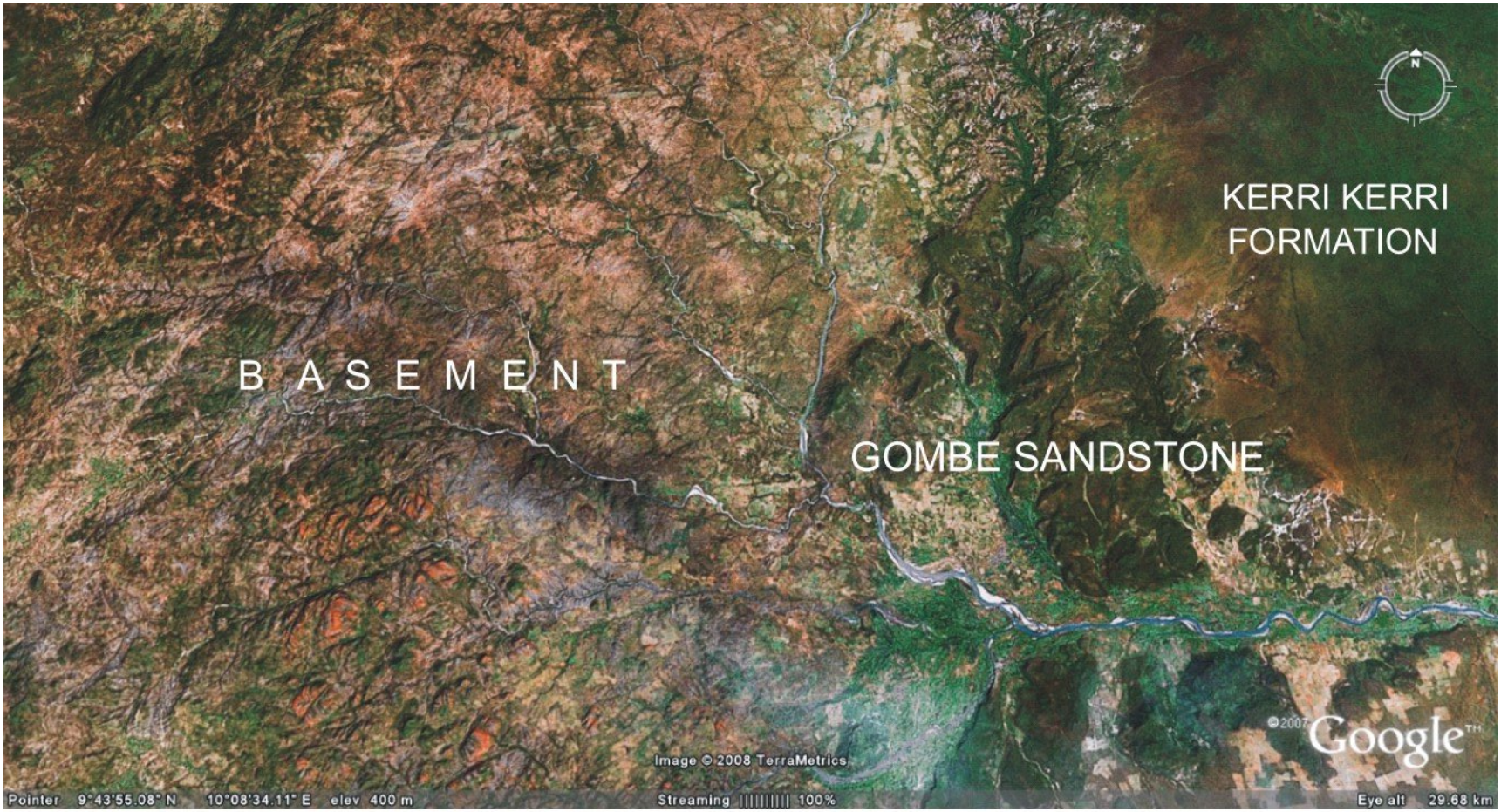


Figure 11: Satelite Image of Yuli-Vertical View. Kerri Kerri overlies the Gombe Sandstone



FIGURE: 12 Satellite Image of Yuli-Oblique view. Showing Gombe Sandstone overlying Basement Complex

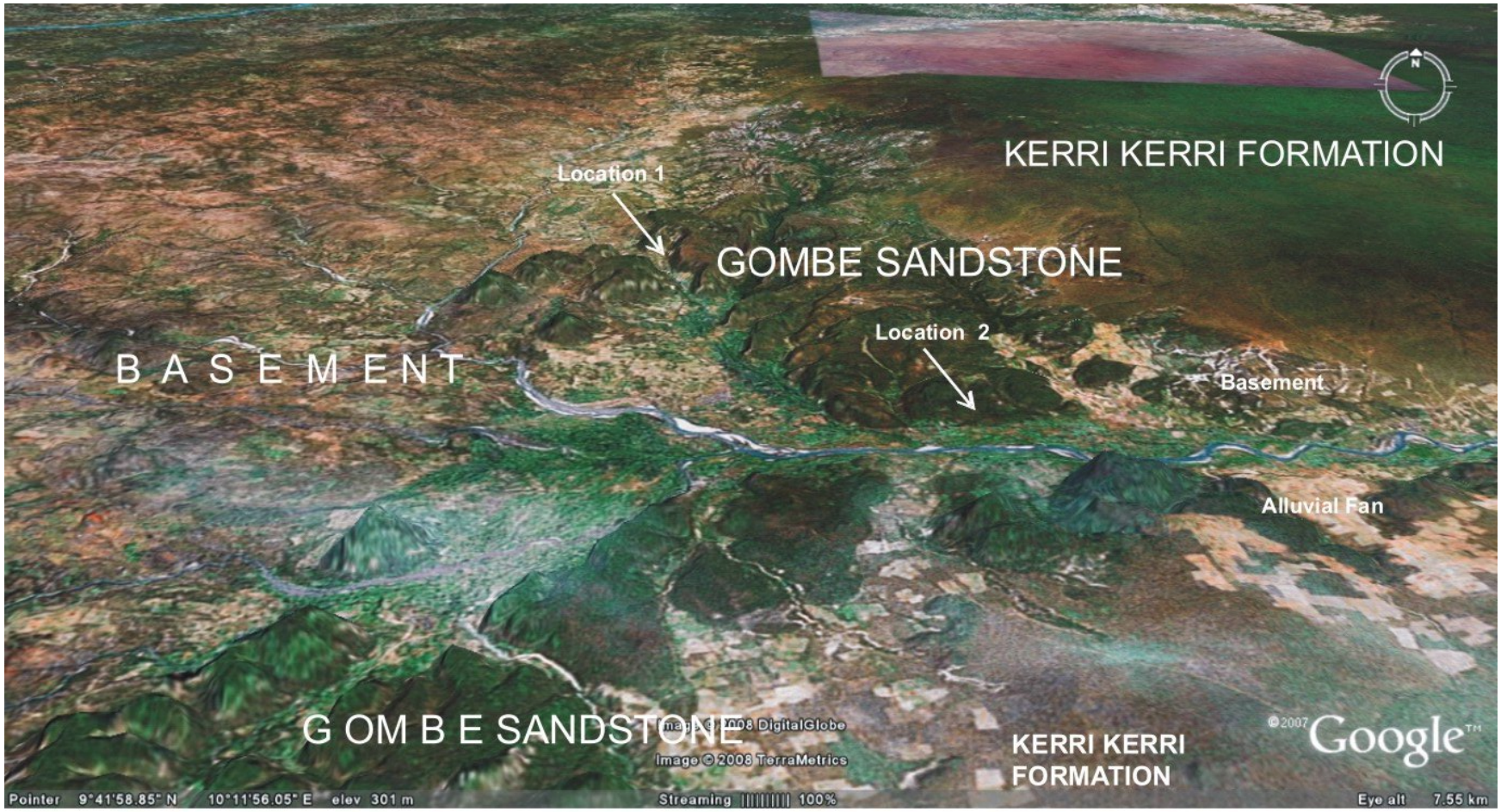


FIGURE 13: Satellite Image of Yuli – Oblique View.
Showing Kerri Kerri Overlies Gombe Sandstone

3.2 THE GEOLOGY OF DUGURI AREA

3.2.1 Stratigraphy

The Duguri area is characterized by sedimentary rocks and the Precambrian Basement Complex.

The lithostratigraphical units identified in the Duguri area are from youngest to oldest.

v) River alluvium

iv) Neogene alluvial fan

iii) Kerri-Kerri Formation

ii) Gombe Sandstone

i) Precambrian Basement Complex

3.2.2 The Precambrian Basement Complex

In the Duguri area the Precambrian Basement Complex is restricted to the western part of the study area. The basement rocks seen in the area of study are mainly granites and gneiss. They have a rugged topography with isolated hills. Pegmatites and veins were observed.

The gneisses, are intruded by pegmatites (Plate ia, b and c) Minerallogically the pegmatites are composed of very coarse grains of quartz, feldspar and muscovite (mica). (Plate ia) shows modern physical weathering of pegmatites, quartz, feldspar and muscovite appear unaltered; they appear fresh, weathering is slow. (Plate ib and c) shows chemical weathering of pegmatites, the

feldspar crystals have been altered to kaolinite during chemical weathering leaving patches of whitish material. Chemical weathering is as a result of a warm/humid climate.

These pegmatites are very recently exposed, through removal of the overlying Gombe Sandstone. The grain size of quartz vary from less than 1.0mm to 50mm. The quartz are spherical (Plate ib) vein fracture fillings also occur, mostly in the gneiss and are mostly made up of quartz and quartz/feldspar. The study of satellite images - annotated reveal a pattern of lineaments interpreted as fractures and joint (Fig. 10). The major trend of fractures is NE-SW and NW-SE typical of the Pan-African Basement terrain. The drainage is largely structurally controlled by the joints and fractures.

3.2.3 The Gombe Sandstone

The Gombe Sandstone directly overlies the Basement Complex. The Gombe Sandstone in the Duguri area is made up of a basal conglomerate/pebbly sandstone facies and an upper "red sandstone facies".

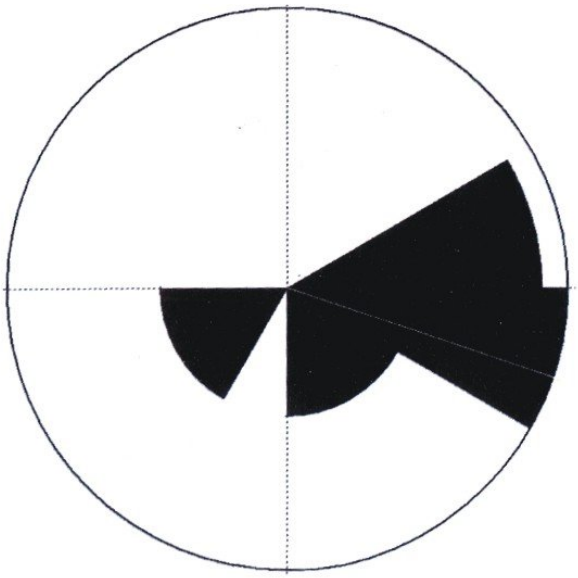
3.2.3.1 Basal Conglomerate/Pebbly Sandstone

This facies lies unconformably on the basement complex. The Basal conglomeratic sandstone facies shows a maximum clast size of about 22cm with modal pebble diameter of 4cm (Plate iib). It is poorly bedded, clasts are mainly quartz with some fragments of acidic Basement Complex rocks.

The basal conglomeratic facies in the Duguri area is mainly matrix supported (Plate iia) by smaller clasts, granules and sand-sized grains. The grains were transported through traction currents as Bed-load and were rounded during transportation. The sedimentary structure exhibited by the pebbly sandstone facies is cross-bedding. The source is probably from pegmatites. The overall thickness of the basal conglomerate facies is about 15 metres. Its contact with basement is undulating. The contact is well exposed at Location 1. 8.6km NW of Gaji. The Rose diagram plots (Fig. 14a-b) shows easterly paleocurrent trends.

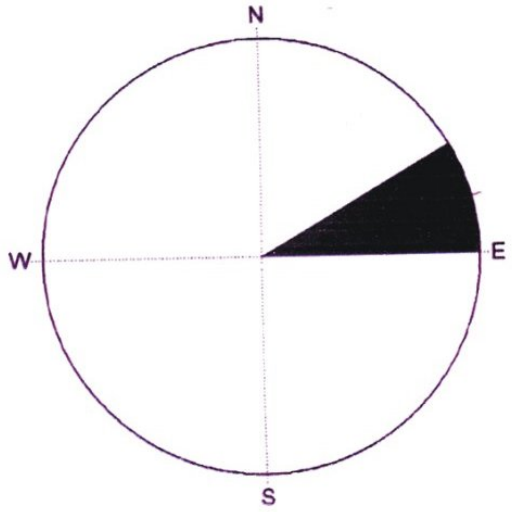
3.2.3.2 "Red Sandstone Facies"

This facies in the Duguri area weathers to a reddish colour as a result of the presence of ferric ion Fe^{3+}. When fresh, however, it is frequently white in colour due to a primary matrix of kaolinite. The rocks are thickly bedded. The quartz grain sizes in the "red sandstone facies" are medium grain sand to granulestone to fine pebbles. Mineralogically, they are composed of quartz, muscovite (mica) and clay matrix (kaolinite). The "red sandstone facies" in the Duguri area comprises quartz arenites and quartz wackes. The muscovite was broken and kaolinite transported in suspension. They are matrix-supported by kaolinite in some cases. They exhibit mostly tabular cross-beddng (Plate iv) but trough cross-bedding also occurs (Plate v). Graded foresets also occur (Plate vi); coarser grains occur at the bottom showing greater permeability. They are moderately sorted (Table 4). The red sandstone facies makes up the greater part of the Gombe Sandstone in the



LOCATION 1: **N**09^{0} 44^{1} 55^{11}
E10^{0} 10^{1} 55^{11}

ROSE PLOT 1: Paleocurrent Data from Gombe Sandstone
Figure 14a: Paleocurrent is Bimodal, Dominant Trend SE



LOCATION 2: **N**09^{0} 44^{1} 835^{11}
E10^{0} 10^{1} 595^{11}

Duguri area, and forms flat topped hills. The upper most few metres of the red sandstone facies are strongly ferruginized. Ferruginization occurred during sub-aerial weathering. The elevation of the top of Gombe "red sandstone facies" is 460m, while, at the base it averages 330m. The overall thickness of red sandstone facies is 130 metres, since there is no appreciable tectonic dip. The "red sandstone facies" is well exposed south-east of Gaji.

3.2.4 Kerri-Kerri Formation

The Kerri-Kerri Formation outcrops in the eastern part of the study area. It unconformably overlies the Gombe Sandstone. The Kerri-Kerri Formation occurs as elevated, flat-lying outcrops. The Kerri-Kerri Formation in the study area is made up of fine to medium grained ferruginous sandstone and kaolinitic sandstone.

On the aerial photographs no structural features are visible on the Kerri-Kerri Formation. The formation is easily recognized by a change in topography and vegetation.

3.2.5. Alluvial Fan

An alluvial fan is a fan-shaped body of usually coarser detrital sediments which is poorly sorted, built up by a stream at the base of a mountain front, fault scraps and valley sides where a steeper slope passes abruptly into a more gentle slope. The alluvial fan in the Duguri area is characterized by thick sediments of

coarse sands derived from erosion of Kerri-Kerri Formation upper-slope. The alluvial fan is recognized on the aerial photographs by a fan shape and convex top.

3.2.6 River Alluvium

In the Duguri area, the alluvium is of Recent age and made up of sands deposited along the existing river channels notably the valleys of Yuli and Gaji rivers. The alluvium is made of fine sands and pebbles.



Plate 1a: Location 1
N 09° 44′ 55.″1
E 10° 10′ 55.″0
Crystalline basement complex pegmatites. Recent physical weathering. Made up of fresh coarse grains of quartz, feldspar and muscovite.



Plate 1b: Location 1
N 09° 44′ 55.″1
E 10° 10′ 55.″0
Crystalline basement complex pegmatites. Recent chemical weathering in pegmatites. feldspar crystals have been altered to kaolinite.
Note: whitish material



Plate 1c: Location 1
N 09° 44′ 55.″1
E 10° 10′ 55.″0
Crystalline basement complex pegmatites. Recent chemical weathering in pegmatites. made of coarse grains of quartz, feldspar and muscovite



Plate 2a: Location 1, 8.6km N of Gaji
N 09°44′ 55.″1
E 10°10′ 55.″0
Gombe Sandstone, basal conglomerate facies.



Plate 2b: Location 1, 8.6km N of Gaji
N 09°44′ 55.″1
E 10°10′ 55.″0
Gombe Sandstone basal conglomerate facies. Clasts are made up of quartz and polycrystalline quartz and rock fragments.



Plate 3:
N 09°44′ 835″
E 10°10′ 595″
Gombe Sandstone, "red sandstone facies". Made up of angular quartz, kaolinite and muscovite.



Plate 4: Location 2, 4.8km S of Gaji Gombe Sandstone "red sandstone facies" showing large-scale tabular cross bedding.

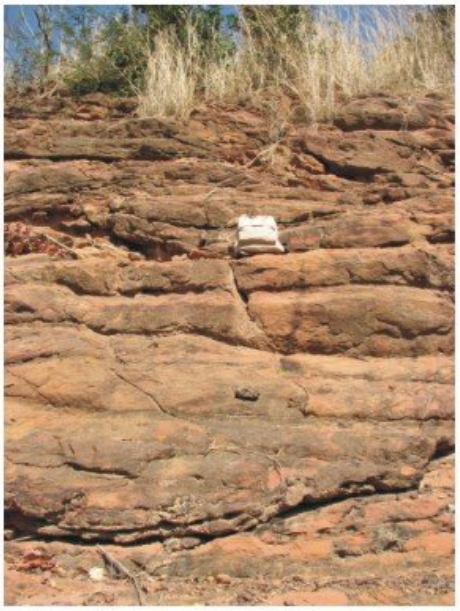


Plate 5: Location 2, 4.8km S of Gaji
N 09° 41′ 620″
E 10° 12′ 823″
"red sandstone facies" showing trough cross bedding.



Plate 6: Graded foresets with oxidation along more permeability in Gombe Sandstone.



Plate 7: Location 1, 8.6km N of Gaji
N 09° 44′ 55″.1
E 10° 10′ 55″.0
Gombe sandstone "red sandstone facies" ferruginized flat top hills.

CHAPTER FOUR

STRUCTURS AND GEOLOGICAL HISTORY OF DUGURI AREA

4.0 INTRODUCTION

The structures observed in the Duguri area are fractures, joints and unconformities.

4.1 STRUCTURE OF DUGURI AREA

4.1.1 FRACTURES AND JOINTS

The fractures and joints are restricted to the Basement Complex in the Duguri area. A study of satellite Images (Figure 10) shows most of the tributaries of the Yuli rivers are controlled by these fractures and joints. These fractures and joints dominantly show NE-SW and NW and SE trends (Fig. 16).

4.1.2 UNCONFORMITIES

A non-conformity separates the Basement Complex rocks from the basal Gombe Sandstone. The basal Gombe Sandstone is formed as a result of the erosion of the Basement Complex. The nature of the plane of contact between the basement and the Gombe Sandstone is irregular/undulating.

A gentle angular unconformity separates the Gombe Sandstones from the overlying Paleocene Kerri-Kerri Formation. Gombe Sandstone dips slightly about 3º below the Kerri-Kerri Formation.

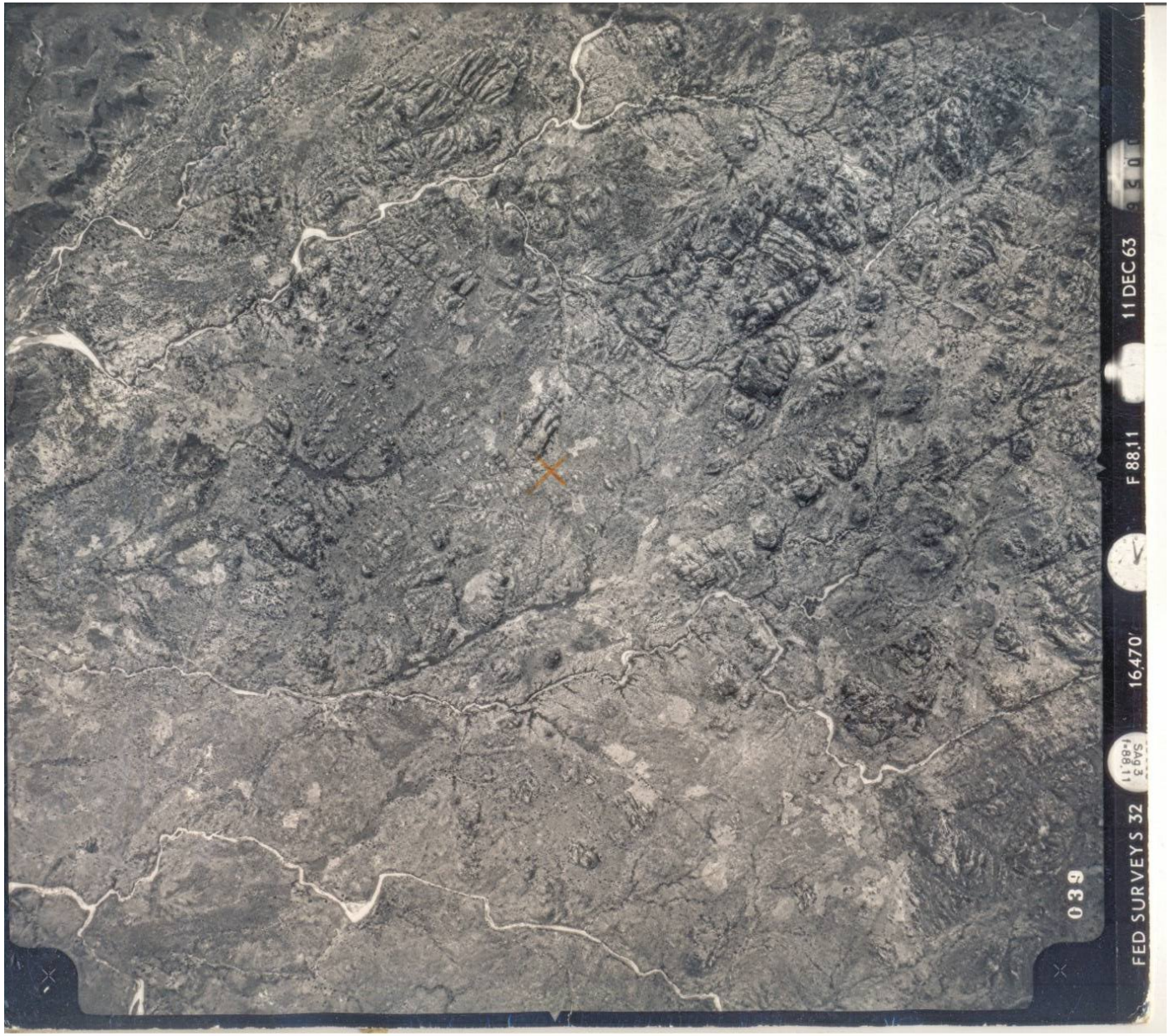


Figure 16 Aerial photograph showing fractures and joint in the Yuli Area

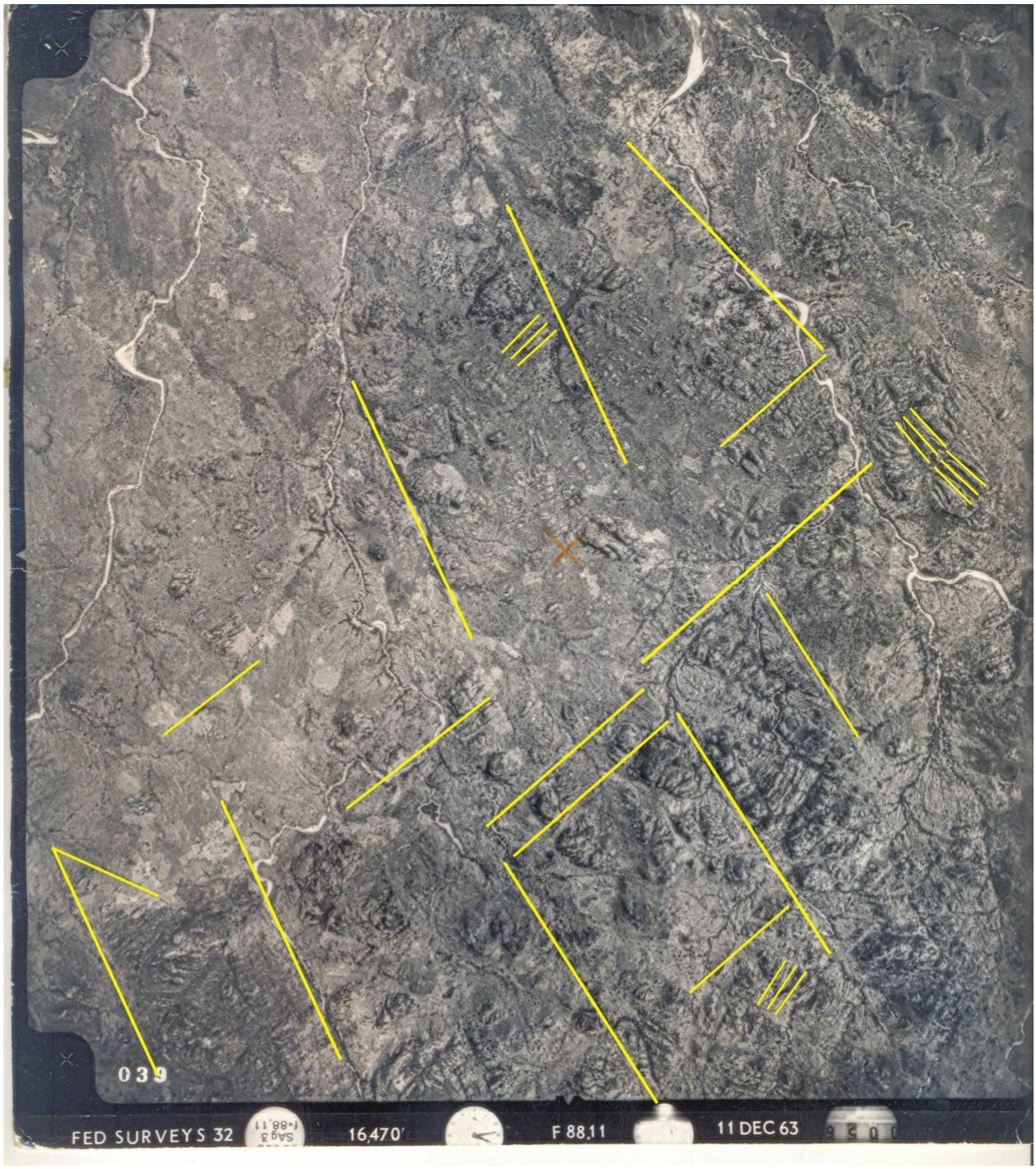


Figure 16: Aerial photograph showing fractures and joint in the Yuli Area

4.2 GEOLOGICAL HISTORY OF DUGURI

1. During the Late Campanian to Maastrichtian times renewed phase of rifting occurred which led to the deposition of the Gombe Sandstone. Paleocurrent determination shows that the Gombe Sandstone sediments were transported from the Basement rocks (west direction). This is shown by an easterly direction as indicated by paleocurrent data (Fig. 14a & 14b). From the Aeromagnetic data, Benkhelil (1998; Fig. 17), the magnetic anomaly corresponds to depth of basement in metres. The paleocurrent direction is in the direction of the deeper magnetic bouger anomaly and so the sediments were deposited in the same direction into the Bashar sub-basin from the basement.
2. During the Late Maastrichtian to Pre-Paleocene times there was a break in sedimentation, subaerial erosion and ferruginization of the Gombe Sandstone.
3. During the Paleocene renewed E – W rifting occurred resulting in the deposition of Kerri-Kerri Formation, unconformably overlying the Cretaceous.
4. After the deposition of Kerri-Kerri Formation there was a break in sedimentation and the deposition of Alluvium and Alluvial fan.

Compared with the Upper Benue Trough, the Geological history of Duguri (Yuli) differs in:

i) The Gombe Sandstone in the Duguri (Yuli) is not folded and, only slightly tilted. The faults and folds are not visible in Duguri (Yuli). A thrust/reverse fault affects the Gombe Sandstone. It extends from Bashar to Garga (Fig. 18).

During terminal cretaceous the Garga fault was reactivated and caused the folding of the Gombe Sandstone around Gwagen and Gir (Fig. 18).

Folds are also located along the main western fault zone are well exposed at the southern end of a fault zone near Ganjuwa south of study area (Fig. 19).

ii) In the Duguri (Yuli) area, the unconformity is identified by the sub-aerial erosion and ferruginization. Elsewhere, there is a marked angular unconformity between the Gombe Sandstone and Kerri-Kerri Formation (Zaborski, *et al*., 1998).

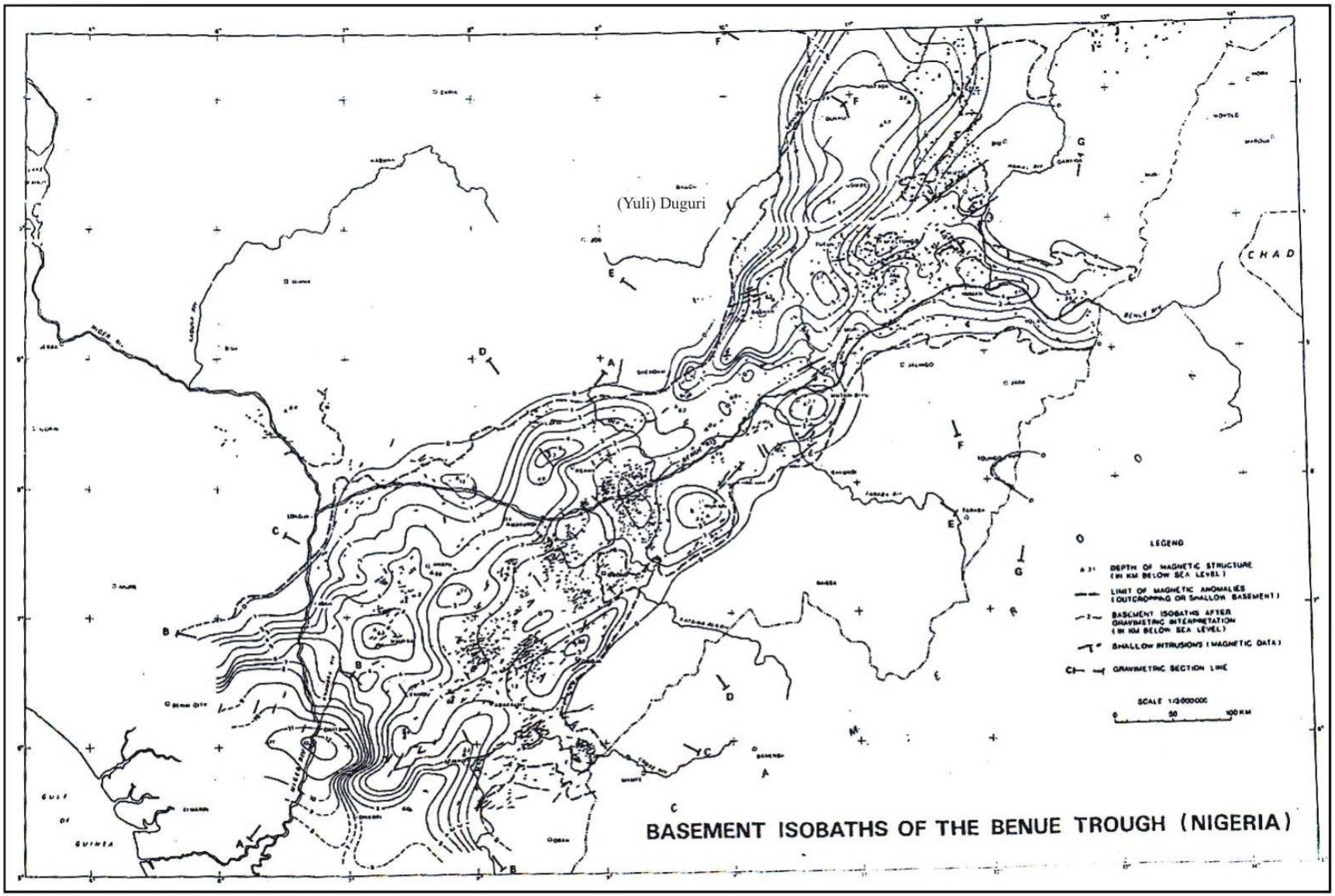


Figure 17 Basement isobaths of the Benue trough (Nigeria). The map results from the plotting and the interpretation of 704 magnetic indexes and 23 gravimetric profiles. Because of its final reduced size, the man is simplified from an original document in which the contour interval of isobaths is 500m. After Benkhelil (1998).

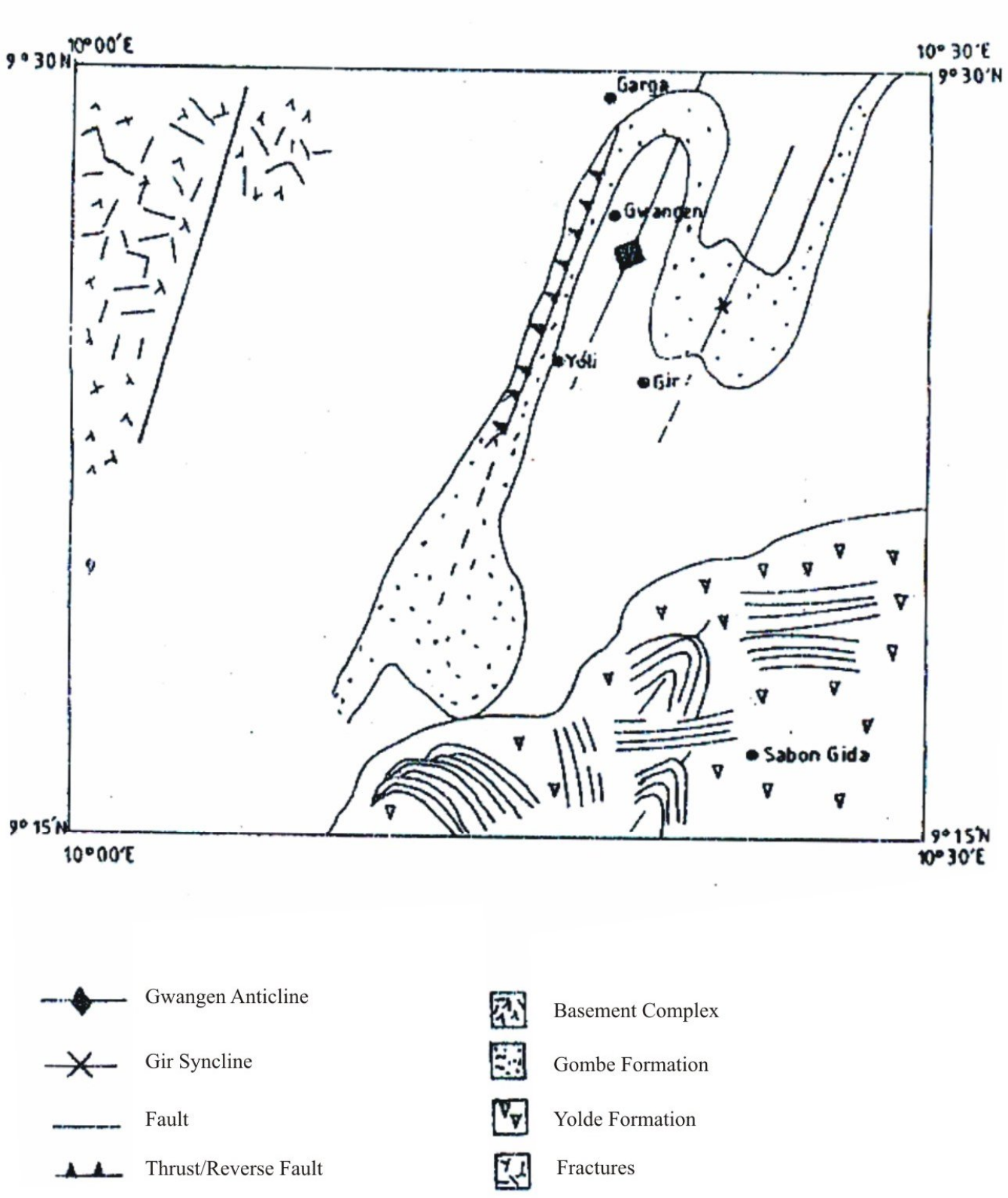


Figure 18 Structural map of Bashar Area (after Zaborski *et al*., 1997))

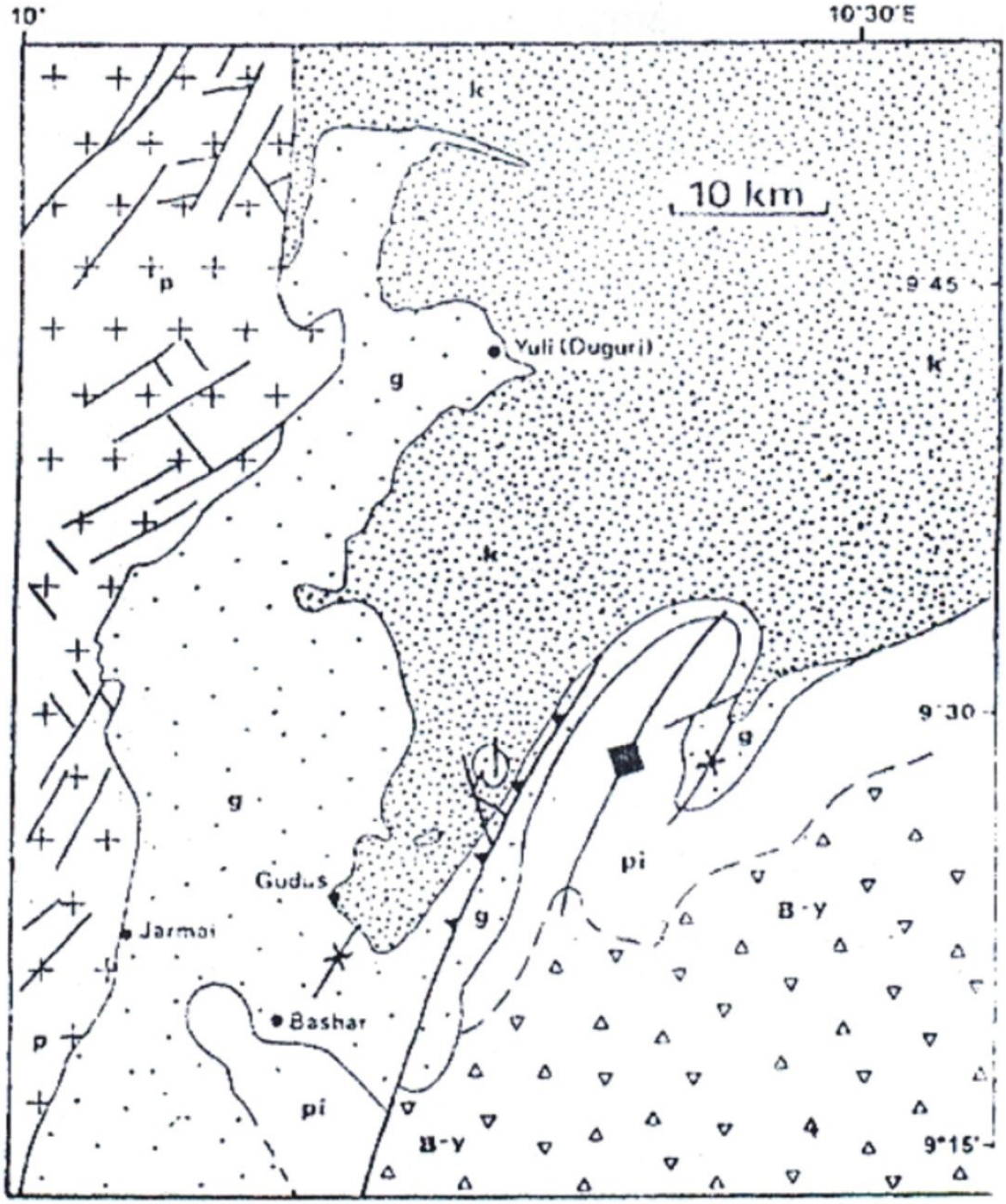


Figure 19 Geological map of the Bashar-Yuli area in the south western part of the Upper Benue Trough (after Zaborski *et al*., 1997)

p. Crystalline basement: B-y Bima Group and Yolde Formation pi, Pindiga Formation. g, Gombe Formation, k, Kerri Kerri Formation.

anticlinal axis; X Synclinal axis; fault;

thrust/reverse.

4.3 GRAIN SIZE ANALYSIS

Grain size analysis is used to determine particle size distribution in sands. The statistical parameters of grain size frequency distribution, the mean, skewness and kurtosis were obtained.

METHOD OF ANALYSIS

The samples were first disaggregated in a mortar using a pestle to obtain 200 grams of the loose samples. Each of the samples was then put in a beaker, and soaked with water for about one hour. This was done to help further in disaggregating the sample. The samples were dried, then placed in a sieve shaker, and sieved for 10 minutes.

Appendix 1.4 shows sieve analysis results obtained from Cumulative frequency curves.

Appendix 1.2:

$$\text{Mean } (\mu) = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

$$\text{Skewness (Ski)} = \frac{\phi_{84} + \phi_{16} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_{95} + \phi_{5} - 2\phi_{50}}{2(\phi_{95} - \phi_{5})}$$

$$\text{Kurtosis (KG)} = \frac{\phi_{95} - \phi_{5}}{2.44(\phi_{75} - \phi_{25})}$$

(Adopted from Folk and Ward, 1957).

Vertical Scales and Terms for textural parameters by Folk and Ward (1957)

Sorting	Verbal Term	
<0.35	very well sorted	(V.W.S)
0.35 – 0.050	Well sorted	(W.S)
0.50 – 1.00	Moderately sorted	(M.S)
1.00 – 2.00	Poorly sorted	(P.S)
2.00 – 4.00	Very poorly sorted	(V.P.S)
>4.00	Extremely poorly sorted	(E.P.S)

Skewness	Verbal Term	
-1.0 to -0.30	Very negatively skewed	(V.N.S)
-3.0 to 0.10	Negatively skewed	(N.S)
-0.10 to 0.10	Nearly Symmetrical	(N.S)
0.10 to 0.30	Positively Skewed	(P.S)
0.30 to 1.00	Very positively skewed	(V.P.S)

Kurtosis	Verbal Term	
<0.67	Very Platykurtic	(V.P)
0.67 – 0.90	Platykurtic	(P)
0.90 -1.11	Mesokurtic	(M)
1.11 – 1.50	Leptokurtic	(L)
1.50 – 3.00	Very leptokurtic	(V.L)

Table 2a:

Sample x_1, (Brick red, Gombe Sandsone in Yuli - Duguri)

Sieve Size	Phi Scale (ϕ)	Weight of Sample (g)	% Weight of Sample	Cumulative Weight %
2mm	-1	1.00	0.5	0.5
1mm	0	14.58	14.08	14.58
500μm	1	56.09	55.59	70.17
250μm	2	18.38	17.88	88.05
125μm	3	5.00	4.50	92.55
63μm	4	6.45	5.90	98.50
Pan		1.72	1.25	99.75

Table 2b:

Sample x_2 (Gombe Sandstone in Yuli – Duguri)

Sieve Size	Phi Scale (ϕ)	Weight of Sample (g)	% Weight of Sample	Cumulative Weight %
2mm	-1	3.71	3.40	3.40
1mm	0	27.76	27.45	30.85
500μm	1	43.36	43.05	73.90
250μm	2	17.5	17.19	91.09
125μm	3	1.00	0.69	91.99
63μm	4	8.06	7.75	99.74
Pan		0.78	0.67	100.2

Table 2c:

Sample x_4 (Kerri-Kerri Sandstone) Yuli-Duguri

Sieve Size	Phi Scale (ϕ)	Weight of Sample (g)	% Weight of Sample	Cumulative Weight %
2mm	-1	1.00	0.69	0.69
1mm	0	11.86	11.55	12.24
500μm	1	27.36	27.05	39.29
250μm	2	24.5	24.19	63.48
125μm	3	16.26	15.95	79.43
63μm	4	19.20	18.89	98.32
Pan		2.00	1.69	100.01

Table 2d:

Sample x_4 (Gombe Sandstone) Yuli-Duguri

Sieve Size	Phi Scale (ϕ)	Weight of Sample (g)	% Weight of Sample	Cumulative Weight %
2mm	-1	6.26	5.96	5.96
1mm	0	20.57	26.27	26.23
500μm	1	29.36	29.06	55.29
250μm	2	21.63	21.33	76.62
125μm	3	13.00	12.70	89.32
63μm	4	8.20	7.90	97.22
Pan		3.14	2.84	100.00

TABLE 3: CRITICAL STATISTICAL PARAMETERS OBTAINED FROM CUMULATIVE FREQUENCY CURVE

Sample	ϕ_5	ϕ_{16}	ϕ_{50}	ϕ_{84}	ϕ_{95}	ϕ_{25}	ϕ_{75}
x_1	-0.7	0.1	1.1	1.7	3.2	0.5	1.1
x_2	-0.9	-0.45	0.5	1.4	2.5	-0.2	1.1
x_3	-0.6	0.2	1.4	3.3	3.9	0.6	2.7
x_4	-1.1	-0.5	0.85	2.6	3.8	-0.1	1.9

Table 4: Computed Results of Graphic Measure and Descriptive Terms

Sample Number	Graphic Mean (Mz)	Skewness (Sk_1)	Kurtosis (K_G)	Graphic Sorting
Sample x1	0.5 Coarse Sand	-0.09 Nearly Symmetrical	2.67 Very Leptokurtic	0.99 Moderately sorted
Sample x2	0.71 Coarse Sand	-0.22 Nearly Symmetrical	1.07 Mesokurtic	0.98 Moderately sorted
Sample x3	0.30 Medium sand	0.17 Positively skewed	0.88 Mesokurtic	1.46 Poorly sorted
Sample x4	0.50 Coarse sand	0.16 Positively skewed	1.0 Mesokurtic	1.52 Poorly sorted

Sample x_1: Graphic Mean

$$M_z = \frac{\phi_{16} + \phi_{50} + \phi_{64}}{3}$$

$$= \frac{0.1 + 1.1 + 1.7}{3}$$

$$= \frac{2.9}{3} = 0.96\phi$$

$$= 0.5\text{mm}$$

Skewness

$$Sk_1 = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

$$= \frac{0.1 + 1.7 - 2(1.1)}{2(1.7 - 0.1)} + \frac{-0.7 + 3.2 - 2(1.1)}{2(3.2 - -0.7)}$$

$$= -0.09$$

Kurtosis

$$K_G = \frac{(\phi_{95} - \phi_5)}{2.44(\phi_{75} - \phi_{25})}$$

$$K_G = \frac{3.2 - (-0.7)}{2.44(1.1 - 0.5)} + \frac{3.9}{1.46}$$

$$K_G = 2.67$$

Graphic Sorting

$$= \frac{(\phi_{84} - \phi_{16})}{4} + \frac{(\phi_{95} - \phi_5)}{6.6}$$

$$= \frac{1.7 - 0.1}{4} + \frac{3.2 - -0.7}{6.6}$$

$$= 0.99$$

Sample x_2

Graphic mean

$$M_z = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

$$M_z = \frac{-0.45 + 0.5 + 1.4}{3} = \frac{1.45}{3}$$

$$M_z = 0.48\phi = 0.71\text{mm}$$

Skewness

$$Sk_1 = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

$$= \frac{0.45 + 1.4 - 2(0.5)}{2(1.4 - -0.45)} + \frac{-0.9 + 2.5 - 2(0.5)}{2(2.5) - -0.9)}$$

$$= \frac{1.05}{3.7} + \frac{0.4}{6.8}$$

$$= \text{-0.28 + 0.06} = \text{-0.22}$$

Kurtosis

$$K_G = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

$$= \frac{2.5 - -0.9}{2.44.(1.1 - -0.2)}$$

$$K_G = 1.07$$

Graphic Sorting

$$= \frac{(\phi_{84} - \phi_{16})}{4} + \frac{(\phi_{95} - \phi_5)}{6.6}$$

$$= \frac{1.4 - (-0.45)}{4} + \frac{2.5 - (-0.9)}{6.6}$$

$$0.46 + 0.52$$

$$= 0.98$$

Sample x_3

Graphic Mean

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

$$M_Z = \frac{0.2 + 1.4 + 3.3}{3} = \frac{4.9}{3} = 1.63$$

$$= 1.63\phi = \quad 0.3\text{mm}$$

Skewness

$$S_{K1} = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

$$= \frac{0.2 + 3.3 - 2(1.4)}{2(3.3 - 0.2)} + \frac{0.6 + 3.9 - 2(1.4)}{2(3.9 - -062)}$$

$$\frac{0.7}{6.2} + \frac{0.5}{9} = 0.17$$

Kurtosis

$$K_G = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

$$= \frac{3.9 - (-0.6)}{2.44(2.7 - 0.6)} \qquad \frac{4.5}{5.12}$$

$$K_G = 0.88$$

Graphic Sorting

$$= \frac{(\phi_{84} - \phi_{16})}{4} + \frac{(\phi_{95} - \phi_5)}{6.6}$$

$$= \frac{3.3 - -0.2}{4} + \frac{3.9 - (-0.6)}{6.6)}$$

$= \quad 0.78 + 0.68$

$= \quad 1.46$

Sample x_4

Graphic mean

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

$$= \frac{-0.5 + 0.85 + 2.6}{3} = \frac{2.96}{3} = 0.986$$

$= \quad 0.98\phi = 0.5\text{mm}$

Skewness

$$S_{K1} = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

$$= \frac{-0.5 + 2.6 - 2(0.85)}{2(2.6 - -0.5)} + \frac{-1.1 + 3.8 - 2(0.85)}{2(3.8 - -1.1)}$$

$$= \frac{0.4}{6.2} + \frac{1}{9.8}$$

$= \quad 0.06 + 0.10$

$= \quad 0.16$

Kurtosis

$$K_G = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

$$= \frac{3.8 - (-1.1)}{2.44(1.9 - -0.1)} \qquad \frac{4.9}{4.88}$$

$= \quad 1.00$

Graphic Sorting

$$= \frac{(\phi_{84} - \phi_{16})}{4} + \frac{(\phi_{45} - \phi_{5})}{6.6}$$

$$= \frac{2.6 - (-0.5)}{4} + \frac{3.8 - (-1.1)}{46.6}$$

$$= \frac{3.1}{4} + \frac{4.9}{6.6}$$

$$0.78 + 0.74 = 1.52$$

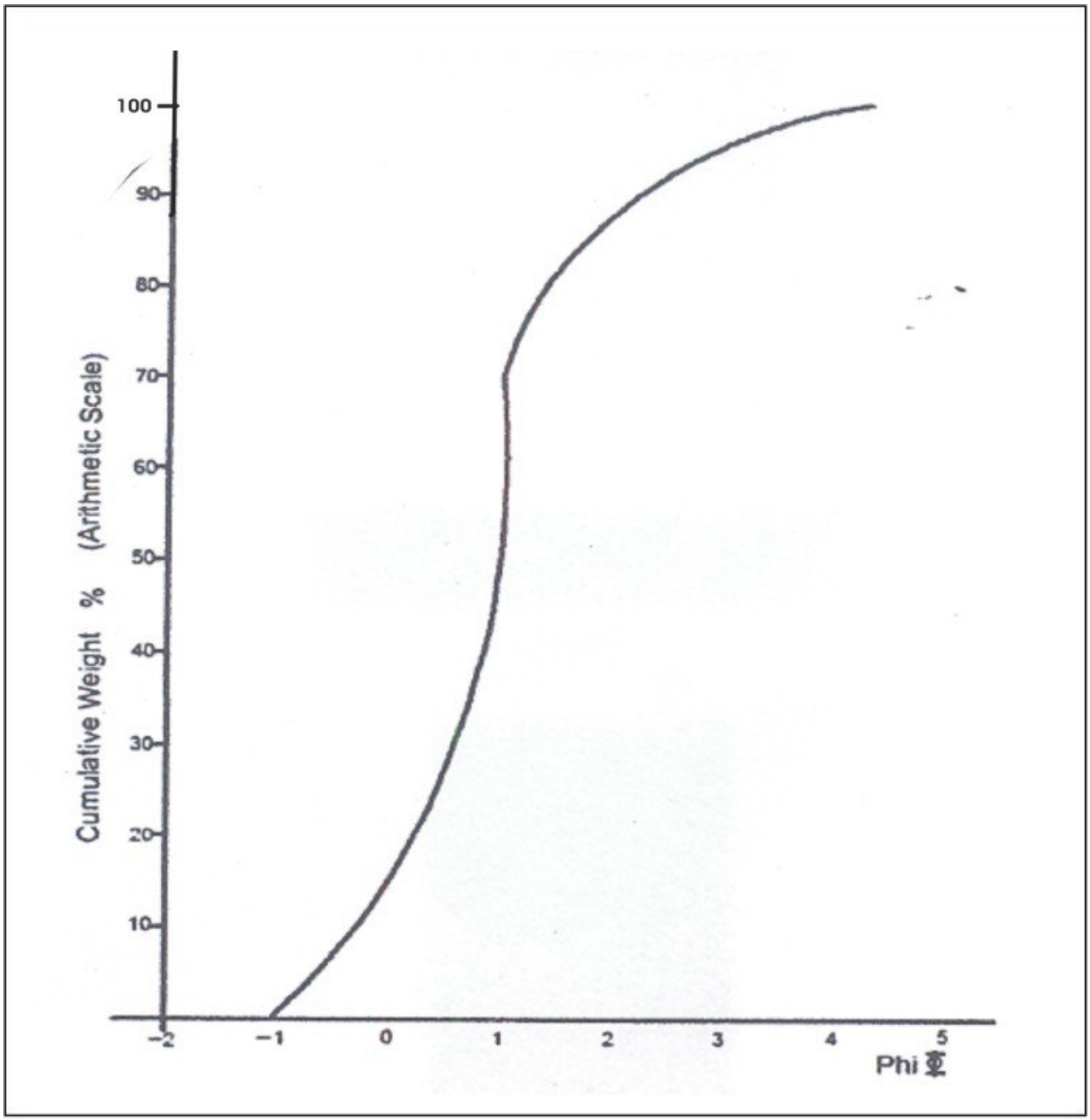


FIG: 20a Cumulative frequency curve for sample x1
(Brick red Gombe Sandstone) in Yuli (Duguri)

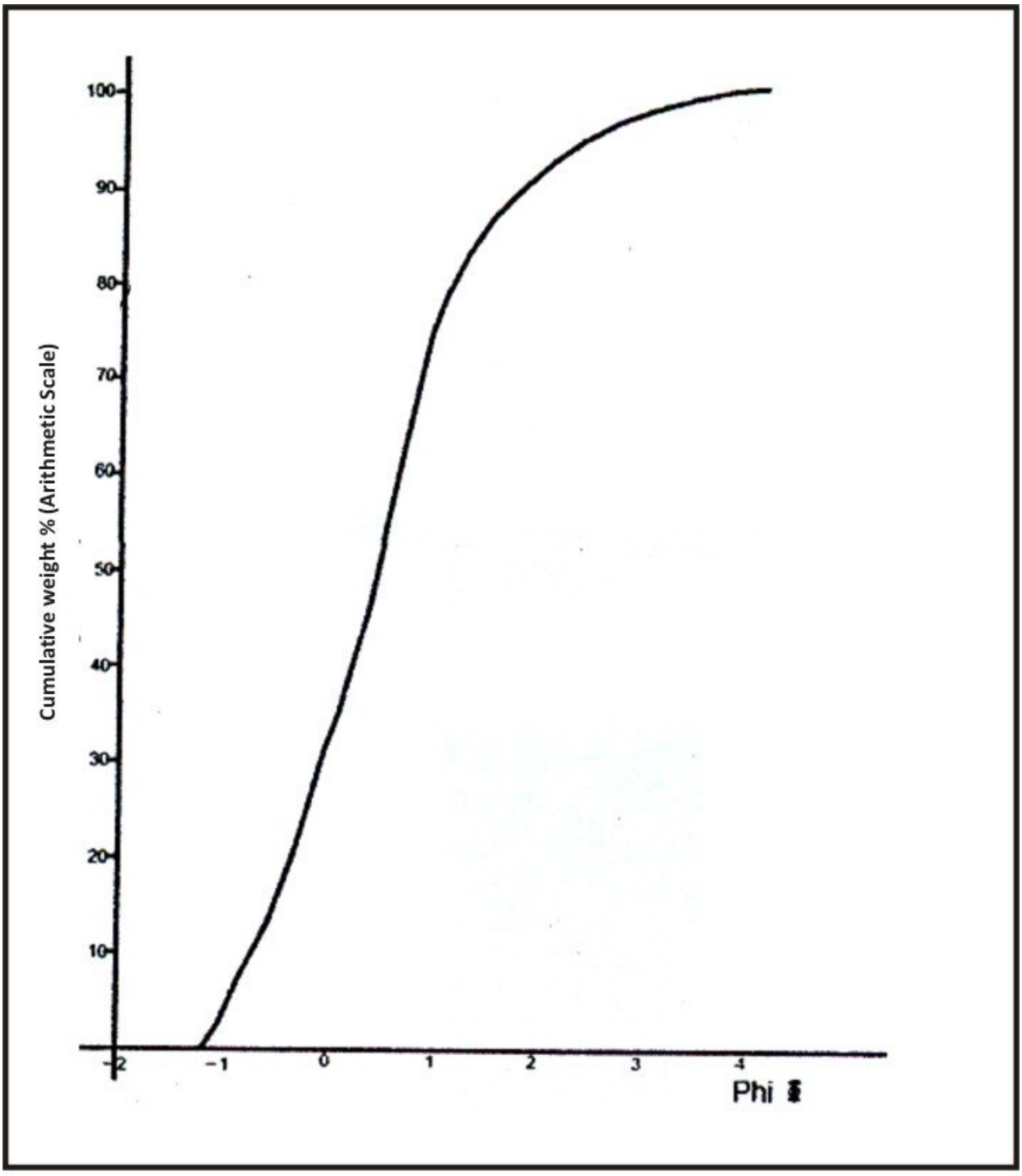


FIG: 20b Cumulative frequency curve for sample x2
(Gombe Sandstone) in Yuli (Duguri)

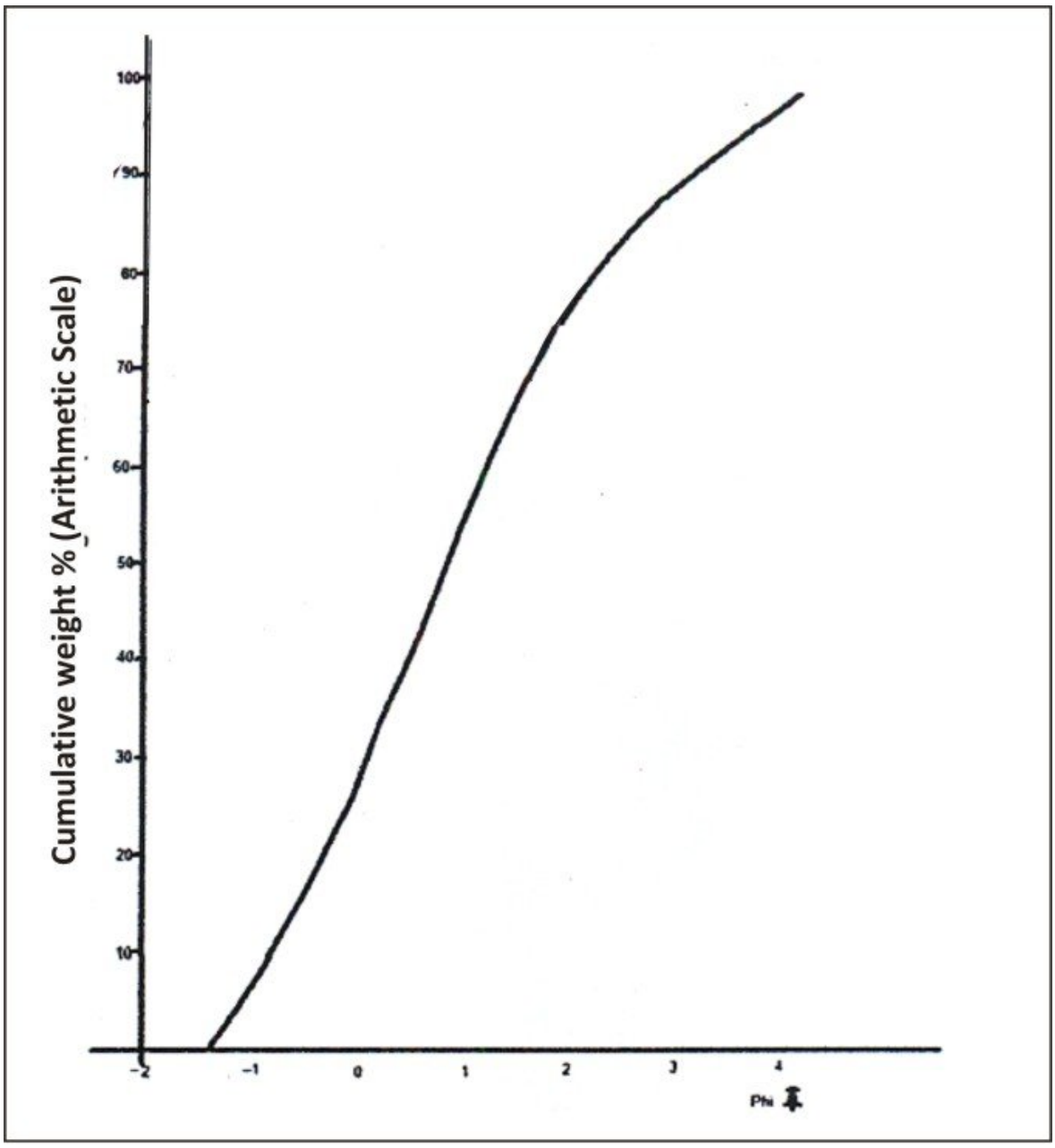


FIG: 20d Cummulative frequency curve for sample x4
(Gombe Sandstone) in Yuli (Duguri)

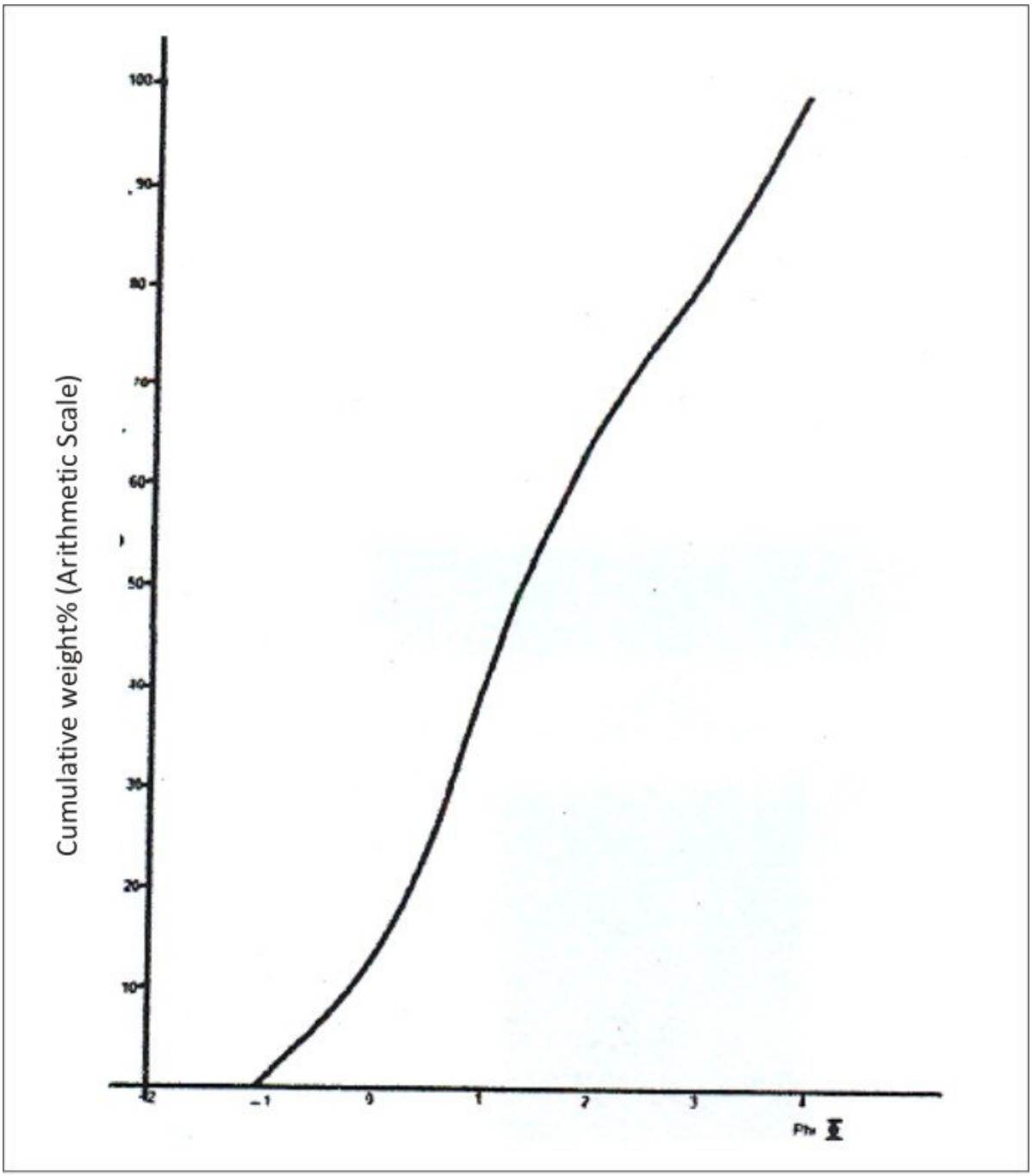


FIG: 20c: Cummulative frequency curve for sample x3
(Kerri Kerri Sandstone) in Yuli (Duguri)

CHAPTER FIVE

5.0 CONCLUSION AND SUMMARY

The Duguri (Yuli) area is characterized by a Cretaceous to Recent sedimentary succession. The Gombe Sandstone was deposited during the Late Campanian to Maastrichtian times. During the Late Maastrichtian to Pre-Paleocene times there was a break in sedimentation, sub-aerial erosion and ferruginization of Gombe Sandstone. The Paleocene Kerri-Kerri Formation, unconformably overlies the Cretaceous. The Alluvial fan and Alluvium are of Recent age and were deposited after a break in sedimentation of Kerri-Kerri Formation.

The Gombe Sandstone in the Duguri area is made up of 2 facies; the pebbly/conglomerate facies and a "red sand stone facies". The "red sandstone facies" makes-up a greater part of Gombe Sandstone. It is thickly bedded, moderately sorted coarse sands. The "red sandstone facies" in the Duguri area comprises quartz arenites and quartz wackes. Paleocurrent analysis shows that the Gombe Sandstone sediments were transported from the Basement Complex rocks.

The Paleocene Kerri-Kerri Formation in study area is made-up of fine to medium grained ferruginous sandstone and kaolinitic sandstone. The Alluvial fan is characterized by thick sediments of coarse sands derived from erosion of Kerri-Kerri Formation upper slope. The Alluvium is made-up of fine sands and pebbles.

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APPENDIX 1.0

PALAEOCURRENT DETERMINATION

A wide distribution of palaeocurrent directions determined from the analysis of cross bedding sheds light on the ways in which varying kinds of basins receive their sediments. The foreset of the beds containing the cross beds were measured.

Appendix 1.1: Location 1: N09º44'55" Class size – 30º

E10º10'55"

Foreset readings for Gombe Sandstone

160º, 120º, 110º, 100º, 096º, 220º, 115º, 240º, 080º, 075º

070º, 095º.

Location 2: N09º44'835" Class size – 30º

E10º10'595"

Foreset readings for Gombe Sandstone (Basal conglomerate)

070º, 080º.