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Lithostratigraphy of Sediments in Bashar and Environs, Northern Benue Trough, Northeastern Nigeria.

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ABSTRACT

This study investigates the siliciclastic sedimentary sequences in the Bashar area, located in the Northern Benue Trough, Nigeria. These sequences are critical to understanding the geological history of the region, particularly in terms of sediment provenance, depositional environments, and the diagenetic processes that have affected the rocks since deposition. Through a detailed analysis of lithofacies, this research aims to interpret the paleoenvironmental and geodynamic evolution of the Bashar Formation and correlate it with similar formations across the Benue Trough. The study utilizes fieldwork conducted across eight outcrop sections, covering the Bima Group, Yolde Formation, Pindiga Formation, and Gombe Formation. These sections were meticulously measured and described, with attention paid to lithological variations such as grain size, sediment composition, bedding structures, and the presence of sedimentary and biogenic structures. These characteristics were used to define distinct lithofacies assemblages and reconstruct the depositional environments in the study area, applying Walther's Law of Facies Succession to understand the lateral and vertical facies changes over time. Key findings of the research include the identification of a pronounced angular unconformity between the Pindiga and Gombe Formations in the Bashar area, which is not typically observed elsewhere in the Northern Benue Trough. This unconformity suggests a significant tectonic event that uplifted and eroded parts of the basin before the deposition of the Gombe Formation. Furthermore, the study provides a detailed description of the Gombe Formation, which consists of two main lithofacies: a lower pebbly conglomerate sandstone indicative of high-energy braided river environments and an upper red sandstone facies deposited in more distal, oxygenated settings. The stratigraphic data, combined with geochemical and petrographic analyses, offer a comprehensive picture of the sedimentary processes that shaped the Bashar area. The research highlights the importance of tectonics, sediment supply, and sea-level changes in controlling sediment deposition and basin evolution in the Northern Benue Trough. Moreover, the findings have broader implications for understanding the tectonic evolution of the West and Central African Rift systems and provide valuable insights into the Cretaceous paleogeography of northeastern Nigeria. This study contributes significantly to the lithostratigraphic understanding of the Northern Benue Trough, offering new interpretations of the depositional environments and tectonic history of the Bashar region. It underscores the complex interplay between rifting, subsidence, and sedimentation that has shaped the basin's geological evolution since the Mesozoic era.

KEYWORDS

Benue Trough,
Bima Formation,
Yolde Formation,
Pindiga Formation.

1 Introduction

Siliciclastic sediment sequences preserved within sedimentary basins serve as invaluable forensic records, offering crucial insights into the formation history of these deposits. By analysing these sequences, researchers can interpret the provenance (i.e., the original source area of the sediments), the depositional environment, and the diagenetic history—the physical and chemical changes that occur during the transformation of loose sediments into solid rock (Nesbitt and Young, 1982; Bhatia and Crook, 1986; McLennan et al., 1993; Cullers, 1995). These studies enable a deeper understanding of the geological past, from reconstructing ancient landscapes to tracking tectonic movements that influenced sediment deposition.

In addition to paleo reconstruction, stratigraphic correlation of different sedimentary units can be achieved by studying these sequences. Correlating layers between locations allows geologists to piece together the geological history over a wider region. Furthermore, bulk-rock geochemical analyses, coupled with the study of mineralogical components, offer further insights into sediment provenance, especially in cases where distinct lithologies point to specific source terrains (Bhatia and Crook, 1986; Roser and Korsch, 1986). This information is particularly useful for identifying the type of rocks from which the sediments were derived, the distance they traveled, and the paleocurrents that transported them.

The study of sedimentary rocks reveals key details about the Earth's ancient environments, including the source of the sediment, the nature of the source rocks, and the patterns of sediment transportation. Paleocurrent analysis helps reconstruct the direction of ancient flows and how these currents shifted over time, offering valuable information about past river systems, deltas, and other depositional environments. During the burial of sediments, changes in temperature, pressure, and pore-water chemistry initiate diagenetic processes such as compaction, dissolution, cementation,

replacement, and recrystallization. These processes are responsible for transforming loose, unconsolidated sediments into solid sedimentary rocks.

Diagenesis encompasses all the physical, chemical, and biological changes that occur in sediments after their deposition and before reaching metamorphic conditions (typically below temperatures of 250°C and low pressures). It is a crucial part of the sedimentary rock formation process, affecting porosity, permeability, and overall rock properties. Understanding diagenesis helps in the interpretation of reservoir quality in hydrocarbon exploration, as well as in reconstructing ancient depositional environments.

In this study, the primary aim is to investigate the lithofacies and depositional environments of the Bashar Formation in the study area, and to correlate these findings with other parts of the Benue Trough in Nigeria. To achieve this goal, the objective below was pursued: The production of detailed litho-logs of the formations within the study area to map out the sedimentary sequences and identify key facies changes. These litho-logs will help interpret depositional environments and the geodynamic evolution of the region

2.0 Literature Review

The Benue Trough is an elongated sedimentary basin that plays a significant role in the West and Central African rift system (Binks and Fairhead, 1992; Maurin and Guiraud, 1993). It is the most prominent of the Cretaceous sedimentary basins in Nigeria, dating back to the Mesozoic era. This basin stretches from the Gulf of Guinea in the southwest and extends northeastwards to the Chad (Borno) Basin, marking it as a critical geologic feature in Nigeria's tectonic and depositional history.

The Benue Trough is typically divided into three sub-sections: the Southern Benue Trough, also referred to as the Abakaliki Trough (Murat, 1972; Whiteman, 1982); the Central Benue Trough; and

the Northern Benue Trough (sometimes further subdivided into the Lower and Upper Benue Trough by Whiteman, 1982). The study area for this research is located at the northwestern junction between the Central and Northern Benue Trough.

Several theories have been proposed to explain the formation and tectonic evolution of the Benue Trough, based on geomorphological, geophysical, and paleontological evidence. These theories include:

King's Rift Theory

Lee's Compressional Origin Theory

Burke et al.'s Triple Junction Theory

The Aulacogen Theory

Benkhelil's Strike-Slip Model

The Northern Benue Trough extends from the Bashar-Mutum Biyu line northwards to the Dumbulwa Bage High, a feature that separates the Benue Trough from the Borno Basin (Zaborski et al., 1998). The Bashar-Mutum Biyu line demarcates the boundary between the Central and Northern Benue Trough. The study area is located in the northwestern part of this boundary, which also serves as the southern limit of the Gombe and Kerri-Kerri Formations. In this region, older sediments undergo lateral facies changes, marking the transition from one stratigraphic unit The Northern Benue Trough

has been the focus of numerous geological studies over the years. Early foundational work on the region was conducted by Falconer (1911), Jones (1932), Raeburn and Jones (1934), and Barber et al. (1954), with the first comprehensive synthesis of these studies produced by Carter et al. (1963). Since then, the Northern Benue Trough has been more thoroughly investigated and mapped, notably by Allix (1983), Benkhelil (1985, 1986, 1988), Popoff (1988), Guiraud (1989–1993), and Zaborski et al. (1998), contributing to our detailed understanding of its structure and stratigraphy.

Structurally, the Northern Benue Trough is divided into two arms: the E–W trending Yola arm and the N–S trending Gongola arm, also known as the Gongola Basin. These two arms are separated by a structurally complex region dominated by four major NE–SW trending sinistral (left-lateral) strike-slip faults: the Gombe Fault, the Bima-Teli Fault, the Kaltungo Fault, and the Burashika Fault. Associated with these faults are basement inliers, such as the Kaltungo Inlier, which play an important role in the structural framework of the area (Zaborski et al., 1998). These structural features have profoundly influenced sedimentation patterns and basin evolution in the Northern Benue Trough, shaping its complex geological history.

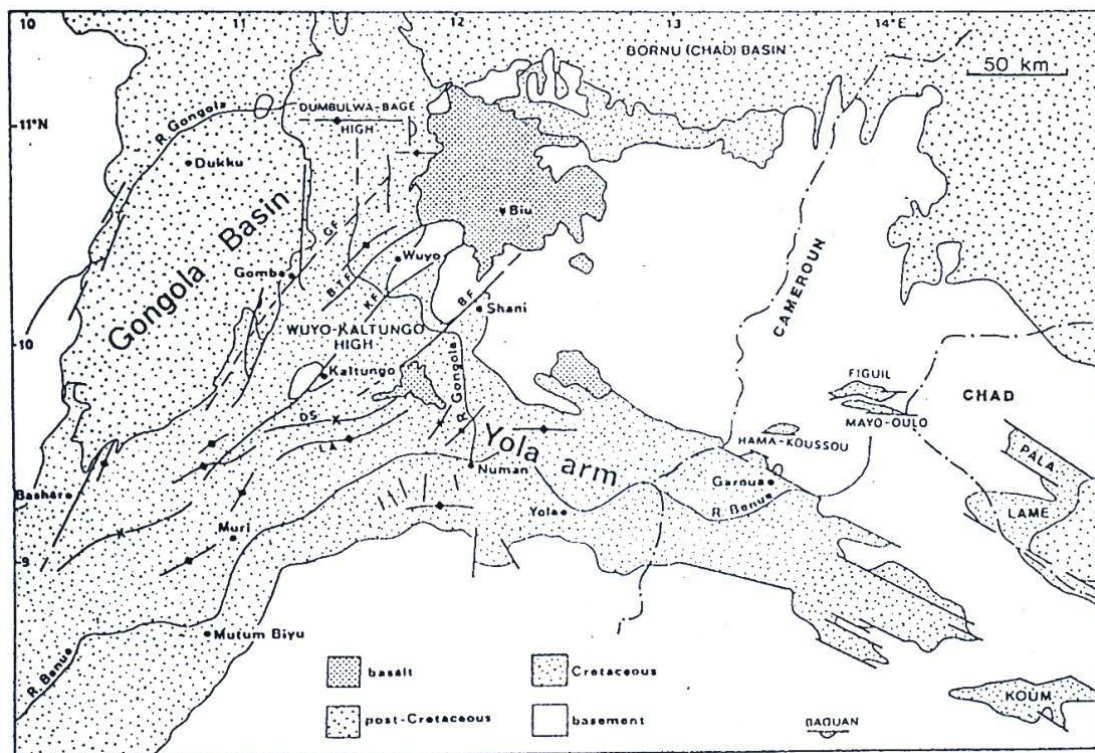


Figure 1: Outline Geological map showing the main features of the Northern Benue Trough region; GF, Gombe Fault; B-TF, Bima-Teli Fault; KF, Kaltungo Fault; BF, Burashika Fault; DS, Dadiya Syncline; LA, Lamurde Anticline. (After Zaborski et al., 1998).

3.0 Materials and Methods

Eight outcrop sections representing the Bima Group, Yolde Formation, Pindiga Formation, and Gombe Formation were carefully measured and recorded in the areas surrounding Jarmai, Bashar, and Zak towns. These sections were examined to capture critical lithological variations, including changes in rock types, textures, and the presence of biogenic and sedimentary structures. Lithological variations such as grain size, composition, and bedding characteristics were assessed in detail, providing a framework for understanding the depositional history of these formations.

Biogenic structures like trace fossils and evidence of biological activity were noted where present, adding insights into the paleoecological conditions at the time of deposition. Sedimentary structures, including features like cross-bedding, ripple marks, graded bedding, and

unconformities, were recorded. These sedimentary structures are essential in interpreting the flow dynamics, energy conditions, and depositional processes that occurred in the past.

The data collected from these outcrops were used to define distinct lithofacies assemblages, which represent particular depositional environments. Lithofacies are critical in identifying sedimentary environments, such as fluvial, deltaic, or marine settings, and can be interpreted based on grain size, sediment composition, and structural features.

In analysing these lithofacies, Walther's Law of Facies Succession played a crucial role. This law states that the vertical succession of facies reflects lateral changes in depositional environments over time. The facies identified in these outcrop sections were analysed to

determine how different sedimentary environments migrated across the area through time due to shifting sea levels, tectonic activity, and sediment supply. This facies analysis allowed for the reconstruction of the past depositional environments in the study area and provided insights into the paleogeographic evolution of the region.

Additionally, concepts from sedimentological studies were applied to establish relationships between the facies. These relationships helped to better understand the stratigraphic architecture and spatial distribution of the sediments. By identifying the various lithofacies and their depositional contexts, the study offers a detailed interpretation of how the different formations were deposited in response to regional and local geological processes.

During the fieldwork, a total of samples was collected from these outcrops for further laboratory analysis. These samples were subjected to a range of analytical techniques, including grain size analysis, petrographic studies, and geochemical tests, to further characterize the lithologies and validate field interpretations. The combination of field observations and laboratory results enabled a comprehensive understanding of the stratigraphy, depositional environments, and diagenetic history of the formations.

The detailed stratigraphic sections and sample locations are illustrated in Figures 2–9, providing a visual representation of the spatial relationships and vertical stratigraphic profiles of the different formations. These figures serve as a key resource for correlating lithofacies and understanding the depositional sequences that shaped the geological history of the study area.

4.0 Results and Discussion

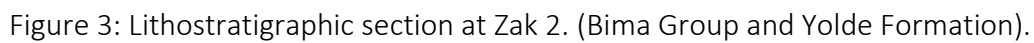
The lithostratigraphic results for the study area are comprehensively illustrated in **Figures 2-9**,

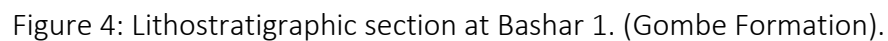
highlighting the spatial distribution of various geological formations. These sections were carefully chosen to represent different parts of the study area, ensuring that a variety of lithological units were covered.

- **Sections Zak 1 and Zak 2** were sampled approximately 1 km southeast of **Zak town**. These sections provide insights into the stratigraphy of the area and capture transitions between key formations, including the Bima Group and the Yolde Formation. The Zak sections are critical in understanding the local depositional environment and its relationship to the broader Northern Benue Trough. Detailed observations from these sections include sedimentary structures like cross-bedding and facies changes that reflect shifts in depositional environments over time.
- **Bashar Sections 1 through 4** were measured and sampled from locations about 500 meters east of **Government Secondary School in Bashar**. These sections offer a detailed look at the lithostratigraphy of the Gombe and Pindiga Formations in the Bashar area. Each section captures key lithological features, such as grain size, sediment composition, and bedding thickness, allowing for precise interpretation of the depositional environment. For instance, Bashar 1 and 3 predominantly show coarse-grained sandstone, while Bashar 2 and 4 have finer-grained sediments, indicating variations in energy levels during deposition. The proximity of these sections allows for high-resolution lateral correlation and identification of subtle facies changes within the formations.



Figure 2: Lithostratigraphic section at Zak 1. (Bima Group and Yolde Formation).





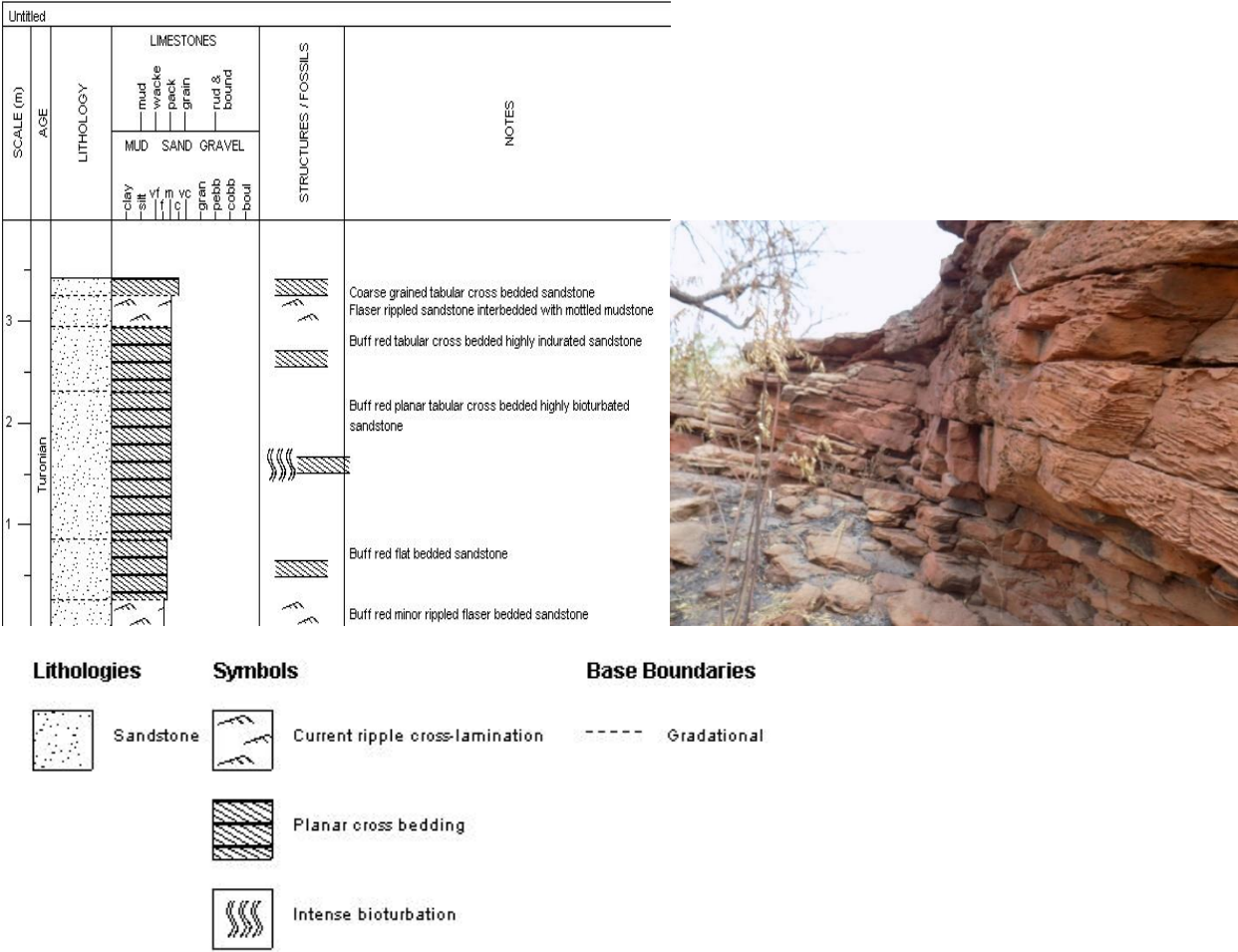


Figure 5: Lithostratigraphic section at Bashar 2. (Pindiga Formation).

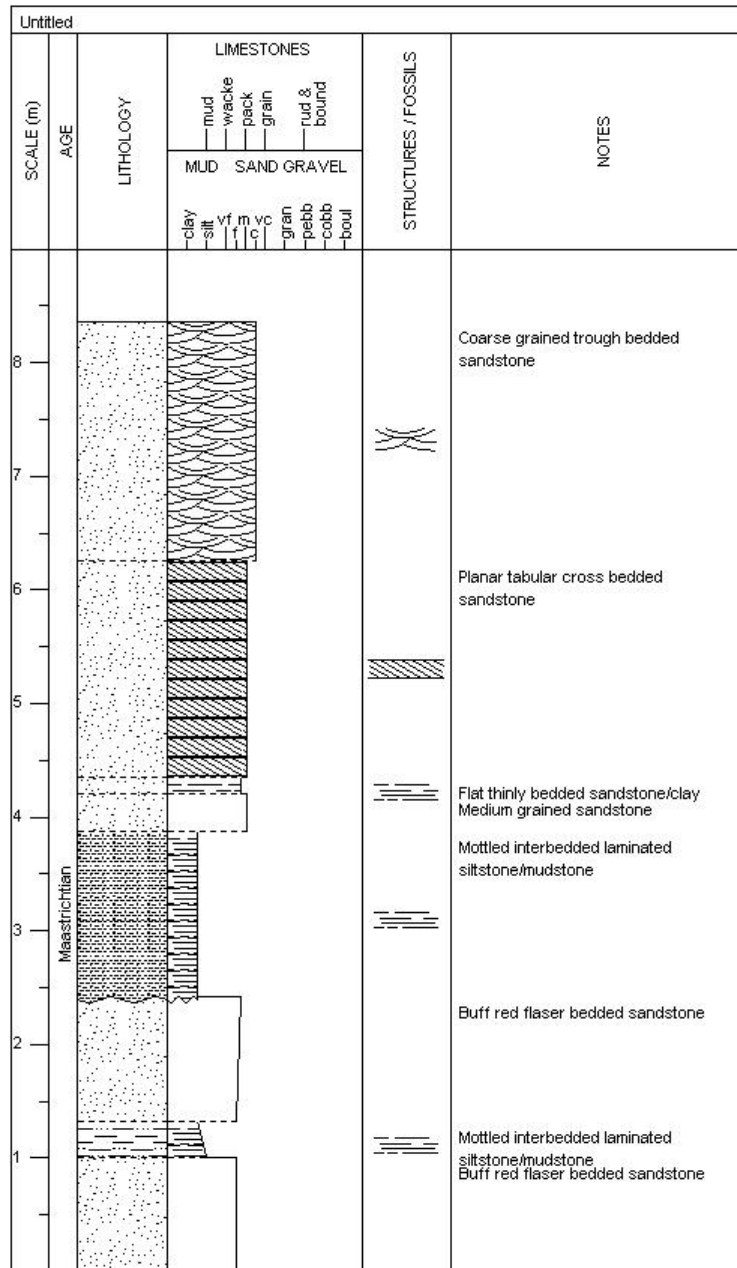


Figure 6: Lithostratigraphic section at Bashar 3. (Gombe Formation).

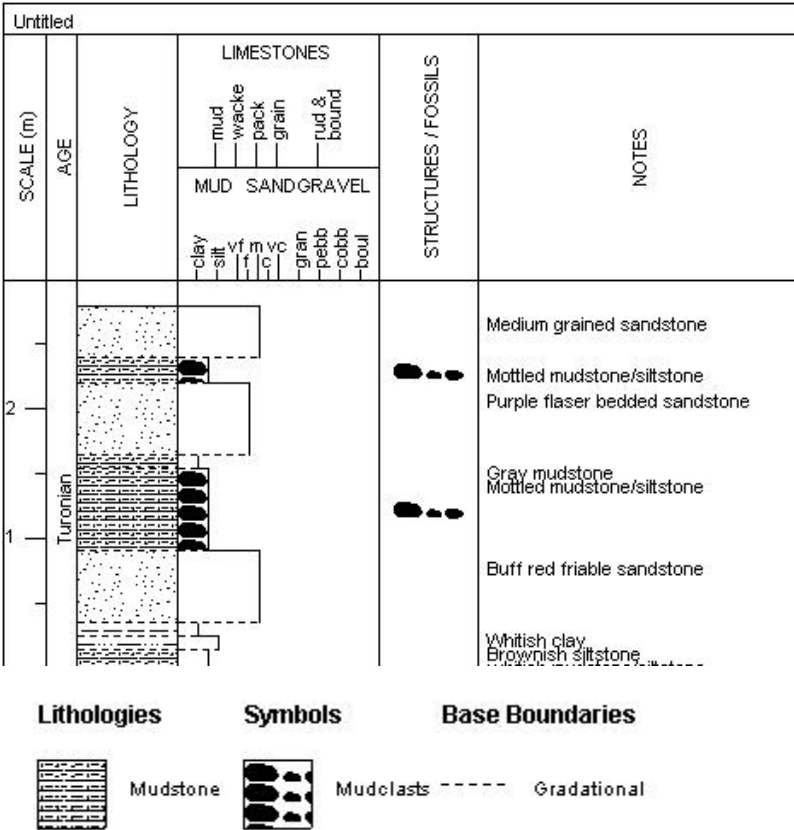
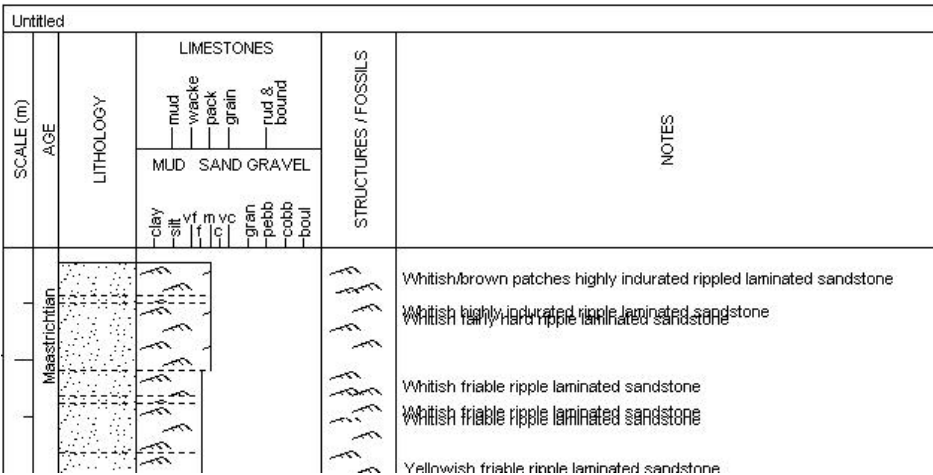


Figure 7: Lithostratigraphic section at Bashar 4. (Pindiga Formation).



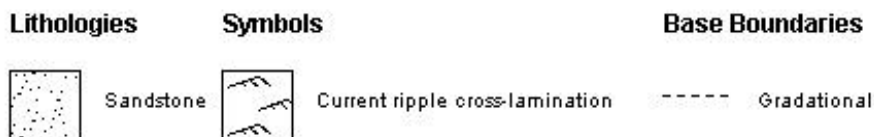


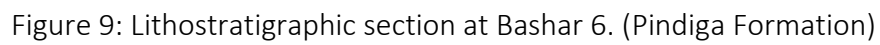
Figure 8: Lithostratigraphic section at Bashar 5. (Gombe Formation).

- Bashar 5**, collected 1.5 km south of **Bashar town**, represents a slightly different depositional setting compared to the previous Bashar sections. This location is situated further from the central outcrop cluster, providing important data on how the formations vary both laterally and vertically over a larger area. Bashar 5 captures the transitional nature of the Gombe Formation, with evidence of sedimentary structures that suggest deposition in a high-energy fluvial environment. This section is key for understanding the broader depositional patterns in the region, as it marks the transition between different sedimentary environments.
- Bashar 6**, located about 500 meters south of Bashar 5, further refines the stratigraphic profile of the area. This section complements the information obtained from Bashar 5, providing continuity in the geological record. The lithologies here also show finer details of the Pindiga Formation, especially in terms of the intercalation of sandstone and mudstone layers. This section aids in delineating the contact between

formations and identifying any unconformities or major sedimentary breaks.

Overall, the sections from **Zak** and **Bashar** cover a significant spatial range, capturing various depositional environments and lithofacies transitions. The careful selection of these outcrops enables a thorough examination of both lateral and vertical facies changes within the Bima, Yolde, Pindiga, and Gombe Formations. Each section contributes uniquely to the overall stratigraphic framework of the study area, offering insights into the depositional processes that shaped the Northern Benue Trough and its sedimentary record.

These sections also help in correlating lithostratigraphic units across different parts of the region, enabling a broader understanding of the sedimentary history and paleogeography of the area. The detailed litho-logs and field observations from these sections are essential for reconstructing the geological history and identifying potential variations in depositional environments across the basin.



5.0 Summary and Conclusion

Bashar is one of the significant sedimentary sub-basins within the Northern Benue Trough, as described by Benkhelil (1988; 1989). It is located in the northeastern part of the Northern Benue Trough and has a complex geological history shaped by rifting and tectonic processes. The evolution of this area was initiated by rifting, accompanied by normal faulting that controlled the deposition of the Bima Group. This early rifting phase was followed by a thermotactic sag stage, a period of subsidence during which the basin continued to develop and accumulate sediments. Various other depositional and tectonic events then contributed to the area's geological complexity.

Compared to other parts of the Northern Benue Trough, the Bashar area displays some distinct geological characteristics:

1. Pindiga/Gombe Contact:

In much of the Northern Benue Trough, the contact between the Pindiga Formation and the Gombe Formation is transitional, reflecting a gradual shift from one depositional environment to another.

However, in the Zak area, near Bashar, a marked angular unconformity separates these formations, indicating a significant break in sedimentation. This unconformity suggests that tectonic activity may have uplifted and eroded part of the basin before the deposition of the Gombe Formation, which is a feature not commonly seen elsewhere in the region. The presence of this unconformity provides insights into localized tectonic events and variations in depositional processes in the Bashar area.

2. Nature of the Gombe Formation:

The Gombe Formation around Bashar shows distinct characteristics that differentiate it from its expression elsewhere in the Northern Benue Trough. In the Bashar area, the Gombe Formation has a continuous presence from east to west and consists of two main lithofacies:

Lower Pebbly Conglomerate Sandstone: This facies is indicative of a high-energy, braided river depositional environment, often referred to as a braided bar deposit. These coarse-grained sediments suggest a dynamic river system with strong currents, likely

representing proximal river channels or bars within the braided system.

Upper Red Sandstone Facies: This overlying facies reflects a more distal depositional environment, with evidence pointing towards the downstream migration of braided bars. The red coloration is often indicative of oxidation, suggesting that the sediments were deposited in a more oxygenated, terrestrial environment, possibly during a period of lower energy deposition compared to the lower conglomerates.

The Gombe Formation is further subdivided into three parts:

Basal Transitional Portion: This part represents the gradual change from the underlying Pindiga Formation into the Gombe Formation, marked by variations in sediment size and depositional energy.

Bedded Facies: This portion consists of well-developed bedding, indicating a relatively stable depositional regime. The bedding may reflect periodic shifts in sediment supply or environmental conditions.

Red Sandstone Facies: The uppermost part of the Gombe Formation, as mentioned earlier, consists of fine- to medium-grained red

sandstones, representing a fluvial or deltaic environment with lower energy conditions.

Deltaic Deposition and Progradation:

Zaborski et al. (1998) described the sandstones around Bashar as part of a coarsening-upward deltaic-like deposit that prograded from the southwest and west into a sea open to the north. This type of deposit typically forms as a delta advances, with coarser materials deposited in more proximal settings (closer to the shoreline) and finer materials laid down further offshore. The sandstones in the Bashar area, therefore, represent the proximal part of a fining-upward sequence, meaning that as one moves vertically through the sequence, the grain size decreases, indicating a shift from higher energy fluvial environments to lower energy marine or deltaic conditions.

This pattern reflects the progradation of the delta system, with coarser sediments (such as the pebbly conglomerates) laid down in nearshore environments and finer sediments (like the red sandstones) deposited further offshore as the delta built out into the basin. The interpretation of this sequence suggests that the area experienced significant changes in sea level or sediment supply, driving the

progradation of the delta from the southwest into a shallow sea that opened towards the north.

The Bashar area's geological history, particularly the unique Pindiga/Gombe contact and the characteristics of the Gombe Formation, highlights the complex interplay between tectonics, sedimentation, and sea-level changes in this part of the Northern Benue Trough. The continuous and well-preserved nature of these formations provides a valuable record of the depositional processes and tectonic influences that shaped the basin during the Cretaceous period.

The lithostratigraphy of the Bashar area in the Northern Benue Trough offers a detailed and layered record of the region's tectonic and sedimentary evolution. Each stratigraphic unit, from the oldest **Bima Group** to the more recent **Gombe Formation**, provides evidence of distinct depositional environments, reflecting significant changes in the geological landscape over time. These changes are directly tied to broader tectonic events, including rifting, subsidence, and

uplift, which have shaped the Benue Trough since the Mesozoic.

The **Bima Group**, for example, consists of coarse-grained sandstones and conglomerates, indicative of high-energy fluvial systems. These sediments were likely deposited during the early stages of the rifting process, when faulting and uplift provided significant topographic relief, driving the accumulation of sediments in river channels. The energy associated with these fluvial systems points to a dynamic environment, with fast-moving water capable of transporting large sediment loads. This unit represents the initial phase of basin development, capturing the transition from continental to a progressively more marine-influenced setting.

As the basin evolved, the **Yolde Formation** records a shift towards deltaic or marginal marine environments, with alternating periods of fluvial and marine influences. This transition reflects changes in sea level and sediment supply, as well as the progressive subsidence of the basin. The interbedding of sandstones, siltstones, and shales in the Yolde Formation demonstrates the interplay between terrestrial and marine processes,

which is critical for reconstructing the paleogeographic evolution of the region.

The **Pindiga Formation** marks the peak of marine influence, characterized by finer-grained sediments such as shales and mudstones. This formation reflects a period of relatively calm, low-energy deposition in a shallow marine setting, signifying a transgressive phase when sea levels rose and the basin was flooded. The occurrence of limestone interbeds also suggests periodic carbonate deposition, which may have been influenced by variations in water chemistry or sediment input. The Pindiga Formation provides valuable clues about the regional marine incursions and the broader paleoclimatic conditions that affected sedimentation during this time.

One of the most significant stratigraphic features in the Bashar area is the **angular unconformity** between the Pindiga and Gombe Formations. This unconformity marks a major tectonic event that caused uplift and erosion, disrupting the otherwise continuous sedimentary record. Such an unconformity indicates a period of deformation, when regional forces resulted in the tilting or folding of earlier strata, followed by a phase of erosion before the deposition of younger

sediments. The presence of this unconformity in the Bashar area offers important insights into the timing and extent of tectonic activity in the Northern Benue Trough, highlighting the region's complex structural evolution.

The **Gombe Formation**, which overlies this unconformity, represents a return to continental conditions, characterized by braided river deposits and red sandstones. The transition from marine to continental environments signifies a regressive phase, when sea levels dropped, and fluvial processes dominated once again. The red coloration of the sandstones is indicative of oxidizing conditions, suggesting that these sediments were exposed to the atmosphere for prolonged periods, likely in an arid or semi-arid climate. The Gombe Formation thus provides evidence of the later stages of basin development, when tectonic uplift and changes in climate led to the re-establishment of fluvial systems.

By studying the lithostratigraphic sections in detail, geologists can reconstruct the sequence of events that shaped the Benue Trough over millions of years. The identification of key stratigraphic contacts, such as the unconformities and facies

transitions, helps to define the timing of tectonic events and the nature of the depositional environments. This analysis contributes to a broader understanding of the basin's geodynamic evolution, offering insights into how rifting, subsidence, and uplift have influenced sedimentation patterns across the region.

Furthermore, the data derived from the Bashar area has implications beyond local stratigraphy. It provides a window into the tectonic processes that affected the West and Central African Rift system, as well as the paleoenvironmental conditions that prevailed during the Cretaceous period. This knowledge is crucial for geologists seeking to understand the broader tectonic framework of Africa and the mechanisms that controlled the opening of the Atlantic Ocean. In

particular, the Benue Trough serves as a key example of how continental rifting can lead to the formation of major sedimentary basins, which in turn record the complex interplay between tectonics, sedimentation, and climate.

In conclusion, the lithostratigraphy of the Bashar area not only records the geological history of the Northern Benue Trough but also serves as a valuable case study for understanding the processes that govern basin formation and evolution in rift settings. By examining the various formations and their depositional environments, geologists can gain deeper insights into the tectonic and environmental forces that shaped the region and contributed to its current geological configuration.

REFERENCES

- Allix P., 1983. Environment mesozoique de la partie nordorientale du fosse de la Benoue (Nigeria) stratigraphie-Sedimentologie Evolution geodynamique; Journal Travaux de laboratoire de I Sciences de Terre, St-Jerome, Merseille, France. B21, p. 200.
- Barber et al. 1954. Facies and Facies Architecture and Depositional Environment of the

Cretaceous Yolde Formation in the Gongola Basin of the Upper Benue Trough, North-Eastern Nigeria.

- Bhatia, M.R. and Crook, K.A.W. (1986) Trace Element Characteristics of Greywackes and Tectonic Setting Discrimination of Sedimentary Basins. Contributions to Mineralogy and Petrology, 92, 181-193.

- Benkhelil, J., 1985.** Geological map of part of the Upper Benue Valley (scale 1:100,000) (with explanatory note). Elf Nigeria Ltd., Lagos, Nigeria.
- Binks, R. M. and Fairhead, J. D., 1992.** A plate tectonic setting for Mesozoic rifts of West and Central Africa Tectonophysics. V. 213, p. 141 – 151.
- Burke, K. C., and Whiteman, A. J., 1973.** Uplift, rifting and the breakup of Africa: In Tarlin, D. H, and Runcon, S. K. (eds). Implications of continental drift to Earth Sciences: Academic Press London. p. 735-755.
- Carter, J. D., Barber, W., Tait, E. A. and Jones, G. P., 1963.** The geology of parts of Adamawa, Bauchi and Borno provinces in north-eastern Nigeria. Bulletin Geological Survey Nigeria. V. 30, p. 1 – 99.
- Cullers, R.L. (1995)** The Controls on the Major and Trace Element Evolution of Shales, Siltstones and Sandstones of the Ordovician to Tertiary Age in the Wet Mountain Region, Colorado, U.S.A. Chemical Geology, 123, 107-131.
- Falconer, D. J., 1911.** The geology and geography of Northern Nigeria Macmillan London. p. 295.
- Guiraud, M., 1990a.** Tectonic sedimentary framework of the early Cretaceous Continental Bima Formation (Northern Benue Trough, NE Nigeria). Journal of African Earth Sciences. V. 15, p. 275-234.
- Guiraud, M., 1990b.** Mécanismes de formation du bassin sur de crochements multiples de la Haute-Benue (Nigeria). Facies et géométrie des Corps Sédimentaires. Mémoire d'Habilitation Université des Sciences et Techniques du Languedoc Montpellier. p. 444.
- Guiraud, M., 1991.** Tectono-sedimentary framework of the Early Cretaceous continental Bima Formation (Northern Benue Trough): Jour. Of African Science. V. 15, p. 275-344.
- Guiraud, M., 1993.** Late Jurassic rifting – Early Cretaceous rifting and Late Cretaceous transpressional inversion in the Upper Benue Basin (NE Nigeria). Bulletin Centre's Recherches Exploration-Production Elf-Aquitaine. V. 17, p. 371 – 383.
- Jones, B., 1932.** The geology of southern Bornu. Annual Report Geological Survey Nigeria. 1931, p. 9 – 14.
- Maurin, J. C. and Guiraud, R., 1993.** Basement control in the development of the Early Cretaceous West and Central African Rift System Tectonophysics. V. 228, p. 81 – 95.
- McLennan, S.M., Hemming, S., McDaniel, D.K. and Hanson, G.N. (1993)**

- Geochemical Approaches to Sedimentation, Provenance and Tectonics. In: Johnsson, M.J. and Basu, A., Eds., Processes Controlling the Composition of Clastic Sediments: Geological Society of America, Special Papers, 285, 21-40.
- Murat, R. C., 1972.** Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in southern Nigeria, in: African Geology (Edited by Dessauvage, T.F.J. and Whiteman, A. J.), p. 251 – 266. Ibadan University Press, Ibadan, Nigeria.
- Nesbitt, H.W. and Young, G.M. (1982) Early Proterozoic Climates and Plate Motions Inferred from Major Element Chemistry of Lutites. *Nature*, 299, 715-717.
- Popoff, M., Wiedmann, J., and Klasz, D. E., 1986.** The Upper Cretaceous Gongila and Pindiga Formations, Northern Nigeria: subdivisions, age, stratigraphic correlations and paleogeographic implications: *Eclogae Geologica Helvetiae*. V. 79, p. 343-363.
- Raeburn, C. and Jones, B., 1934.** The Chad Basin: geology and water supply. *Bulletin Geological Survey Nigeria* 15, 1 - 61.
- Roser, B.P. and Korsch, R.J. (1986) Determination of Tectonic Setting of Sandstone-Mudstone Suites Using SiO₂ Content and K₂O/Na₂O Ratio. *The Journal of Geology*, 94, 635-650.
- Whiteman, A. J., 1982.** Nigeria: its petroleum geology resources and potential. V. 1, p. 176., V. 2, p. 238. Graham and Trotman, London, U.K.
- Zaborski, P., Ugodulunwa, F., Idornigre, A., Nnabo, P. and Ibe, K., 1997.** Stratigraphy and Structure of the Cretaceous Gongola Basin, north east Nigeria. *Bulletin centres Recherches Exploration-Production Elf-Aquitaine*. V. 21 (for 1997). p. 153 – 185.
- Zaborski, P. M., 1998.** A review of the Cretaceous System in Nigeria. *African Geoscience Review* 5, p. 385 – 483.

APPENDIX



Plate 1: Angular Unconformity at Location 1 (ZAK). **Plate 2.** Grey/buff-mottled siltstone with trace fossils(planolites) at location 3.

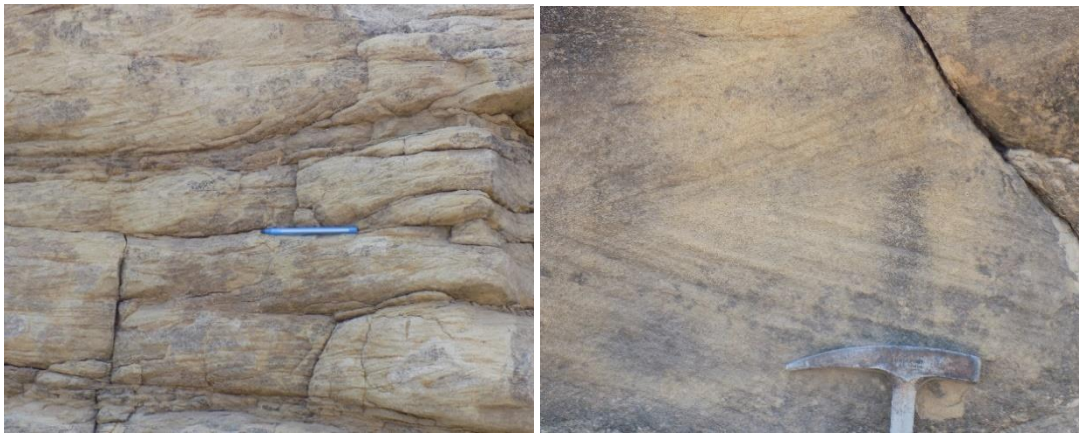


Plate 3. Medium grained sandstone at 2. **Plate 4.** Sandstone at ZAK showing Herring bone cross bedding.

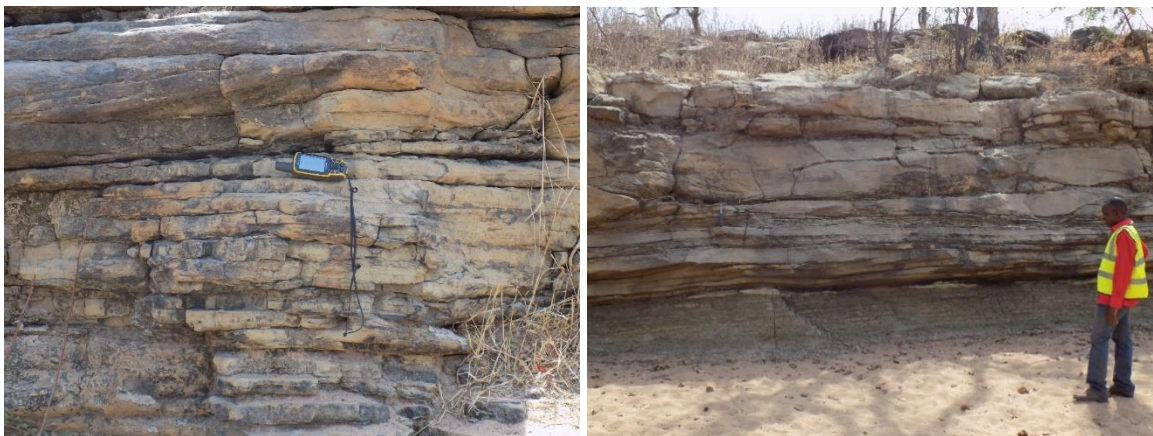


Plate 5. Medium grained sandstone beds thickening upward at location 5. **Plate 6.** Sandstone with thin beds of brownish iron oxide cemented siltstone at ZAK.



Plate 7. Sandstone beds thickening upward at ZAK along river channel. **Plate 8.** Buff-red planar cross beds sandstone at Bashar.



Plate 9. Medium-fine grained purple kaolinitic sandstone at Bashar. **Plate 10.** Iron rich sandstone cap with trace fossils at Bashar.



Plate 11. Planar cross bedded sandstone at Bashar. **Plate 12.** Mudstone intercalated with iron oxide cemented siltstone at Bashar.

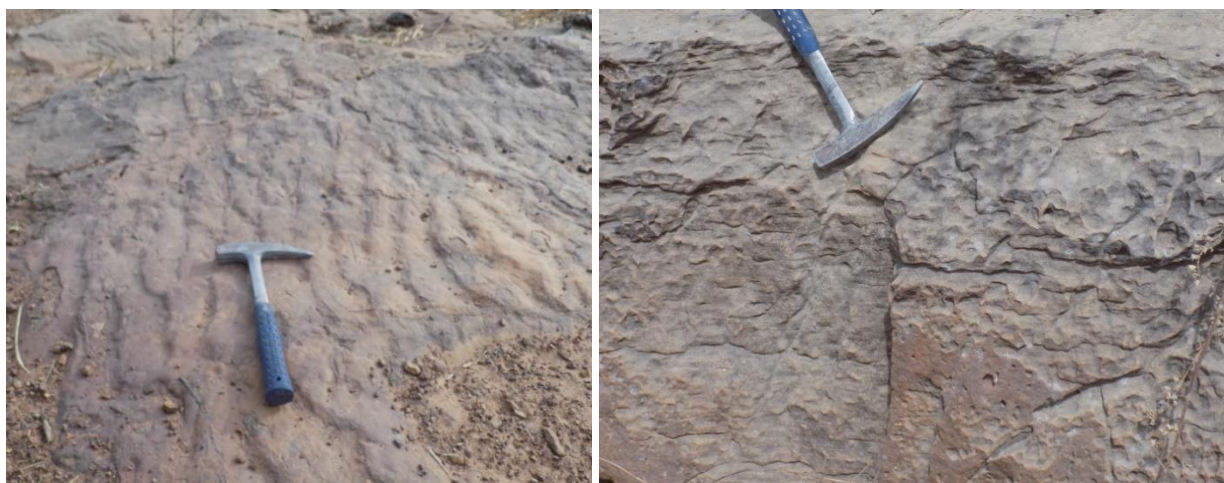


Plate 13. Sandstone at Bashar showing Paleocurrent direction. **Plate 14.** Bioturbated Sandstone at Bashar.