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Geological and Petroleum System Insights from the Northern Benue Trough: Implications for Hydrocarbon Potential in the Bornu Basin, Nigeria

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Abstract

This study integrates comprehensive fieldwork conducted in the Gongola Sub-Basin of the Northern Benue Trough with subsurface data from the Bornu Basin to provide a detailed examination of the geological evolution and hydrocarbon potential of these interconnected basins. Due to security concerns limiting direct access to the Bornu Basin and the lack of accessible outcrops, field studies were instead carried out in an analogous region within the Northern Benue Trough, which exhibits similar stratigraphic and structural characteristics. The primary goal was to gather direct evidence of sedimentological and tectonic processes to support the interpretation of hydrocarbon generation in the Bornu Basin. Key stratigraphic units, including the Bima, Yolde, and Kerri-Kerri Formations, were analyzed for their depositional environments, sediment provenance, and diagenetic alterations, with particular emphasis on tectonic features such as normal faults and unconformities. The field investigations revealed critical geological features, such as fractured basement rocks, cross-bedded sandstones, and oil-stained sediments, suggesting active petroleum migration and entrapment in the region. Petrographic analysis of well cuttings and well logs from the Bornu Basin further corroborated these findings, providing evidence of oil-charged intervals and confirming the presence of potential hydrocarbon reservoirs. Additionally, diagenetic processes, including quartz overgrowth and iron oxide cementation, were observed to influence reservoir quality by altering porosity and permeability within the Bima and Kerri-Kerri Formations. The study demonstrates the significant tectonic and paleoclimatic influences that have shaped the geological history of both basins, with particular focus on rifting and faulting during the Cretaceous and Tertiary periods. By utilizing an integrated approach that combines field observations with subsurface data, this research provides a more comprehensive understanding of the petroleum systems in the Bornu and Northern Benue Troughs. The findings suggest that while the Northern Benue Trough has been relatively well-explored, the Bornu Basin remains underexplored and holds substantial untapped hydrocarbon resources. This work also emphasizes the value of analog basin studies in addressing logistical challenges in hydrocarbon exploration, particularly in regions with limited access due to security or terrain constraints.

Keywords

Kerri Kerri Formation
Gombe Formation,
Bornu Basin
Upper Benue Trough,
Quartz Overgrowth

1 Introduction

Due to security constraints that prevented access to the primary study area, specifically the Baga and Maiduguri Sub-basins, as well as the lack of accessible outcrops in the Bornu Basin, fieldwork was conducted in an analogous basin within the Northern Benue Trough. This decision was guided by geological interpretations that suggest the Bornu Basin is not an independent basin but rather an extension of the Northern Benue Trough (Nwajide, 2013). Moreover, Abubakar et al. (2008) highlighted significant similarities between the Cretaceous petroleum system of the Gongola Sub-Basin, a northern segment of the Benue Trough, and other basins such as the Termit, Doba, and Doseo basins of the Central African Rift System. These findings suggest that the geologic processes governing sediment deposition, petroleum system development, and tectonic evolution in these basins are comparable. This approach aligns with established practices in sedimentological and petroleum geology research, where analogue basins are often studied to overcome data inadequacies in the primary area of interest (Genik, 1992; Suleiman et al., 2017b).

Therefore, the Northern Benue Trough, which shares similar structural and stratigraphic characteristics with the Bornu Basin, provided a suitable alternative for investigating the geological and tectonic processes that may have shaped both basins over time.

Overall, this study highlights the importance of using analogous basins to overcome logistical and security challenges in geological research. By integrating field observations from the Northern Benue Trough with subsurface data from the Bornu Basin, this research provides a more comprehensive understanding of the tectonic and paleoclimatic evolution, sedimentary processes, and hydrocarbon potential of these two interconnected basins. The findings contribute to the broader knowledge of the West and Central African Rift System and have implications for future exploration and resource development in the region.

The objective of the geological field study was to gather direct evidence from the Gongola Sub-Basin (Northern Benue Trough) to support the potential for hydrocarbon generation within the primary study area, the Bornu Basin. The study also aimed to document field evidence of tectonic episodes that influenced the basin's evolution, particularly during the Cretaceous and Tertiary periods. Overall, the field study sought to complement findings from subsurface data analyses, including well cuttings and well-log suites. These subsurface investigations have confirmed the presence of oil-charged sediments within the Bornu Basin, and the field study aimed to provide additional surface evidence and insights to enhance the interpretation. This integrated approach strengthens the understanding of the basin's

hydrocarbon potential and tectonic history.

4.1.1 Northern Benue Trough

The Benue Trough is a NE-SW trending rift basin, approximately 800 km long and 150 km wide, filled with up to 6,000 m of Cretaceous-Tertiary sedimentary rocks (Obaje et al., 2004). The trough is subdivided into three segments: The

Southern, Middle, and Northern Benue Trough (Petters, 1982),).

The Northern Benue Trough is further divided into the Gongola and Yola Sub-Basins (Zaborski, 2003; Abubakar, 2014). These two arms are separated by the Zambuk Ridge, a structural inlier that acts as a boundary between the Gongola Arm and the Chad Basin (Burke, 1969; Genik, 1992; Alalade & Tyson, 2010). The Yola Arm, on the other hand, extends into parts of Cameroon.

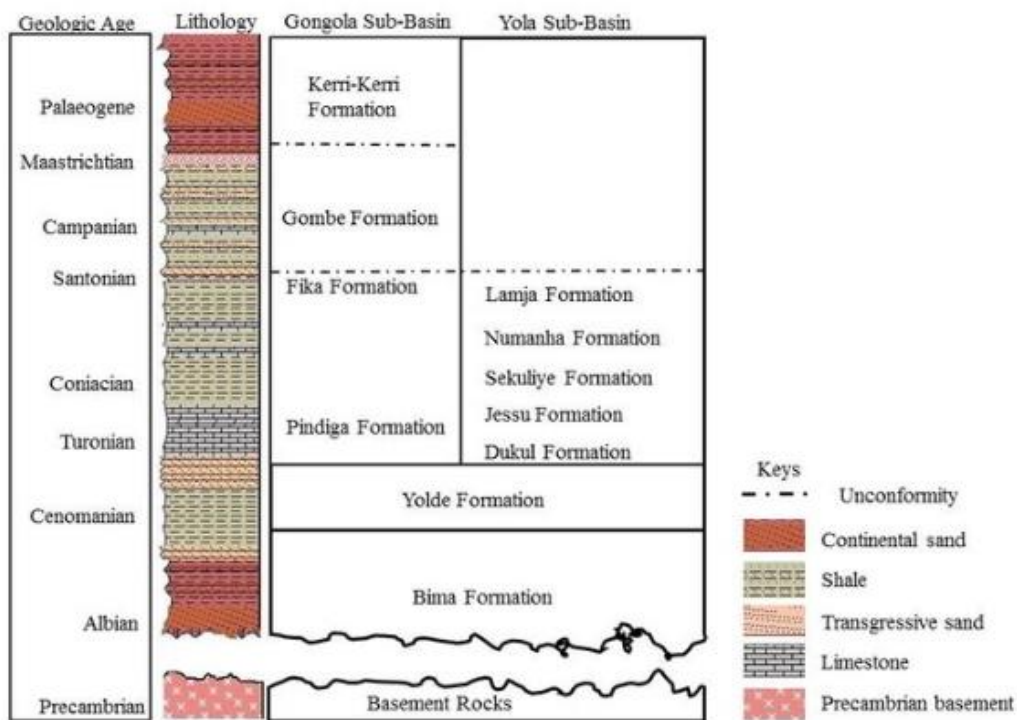


Figure 1: Simplified stratigraphy of the Northern Benue Trough (Bata et al., 2018).

In the Gongola Sub-basin, where the field study area is located, the stratigraphy is characterized by a succession of lithostratigraphic units as depicted in Figure 1. The oldest and thickest unit is the Aptian-Albian continental Bima Formation, which

unconformably overlies the Precambrian crystalline basement. The Bima is succeeded by the transitional Yolde Formation (a stratigraphic equivalent of the Gongola Formation in the Bornu Basin), which marks the onset of marine influence. Above this lies the Pindiga

Formation, a fully marine sequence that reflects deposition in deeper environments during the Cenomanian to Santonian. The Fika Formation primarily consists of dark grey shales interspersed with occasional sandstone layers. In the Gongola Basin, it is regarded as a member of the Pindiga Formation, dating from the Upper Turonian to Coniacian age, and is overlain by the Gombe Sandstone. The Campano-Maastrichtian deltaic Gombe Formation, representing regressive sedimentation marks the final Cretaceous deposition in the Gongola Sub-basin (Zaborski et al., 1997; Yandoka et al., 2014). The Kerri-Kerri Formation, a Tertiary unit, marks the youngest sediments in the basin.

During the field study in the adjoining Northern Benue trough, different

locations were visited, such include Kwayakusar, Biryel, Yaranduwa and the Gombe-inlier localities in Borno state where fractured basements, Formations of Bima and Yolde outcropped, while in Yobe state the Kadi-Gooya escarpment was visited.

During the field investigations, particular attention was given to key outcrops that expose significant stratigraphic units, including the Bima Formation, Kerri-Kerri Formation, and transitional deposit of the Yolde Formation. These outcrops offer insights into the depositional environments, sediment provenance, and tectonic controls that have shaped the basin over millions of years (e.g., Bata et al, 2015, 2024).

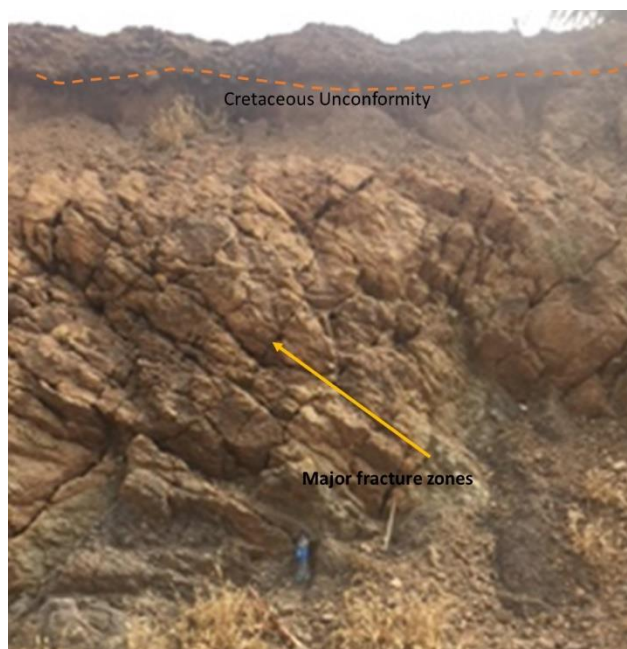


Figure 2: Fractured Basement Rocks at Gombe Inlier with Bima Formation Unconformably Overlying (Dotted Line Marks the Cretaceous Unconformity).

The fractured basement rocks at the Gombe Inlier, with the Bima Formation resting unconformably above, are shown in Figure 2, where the dotted line indicates the Cretaceous unconformity. This unconformity represents a key boundary that reflects shifts in tectonic regimes and depositional environments. Fractures and the unconformity itself serve as evidence of past tectonic activity, particularly the normal faults trending NE-SW (Fairhead & Okereke, 1990; Suleiman et al., 2015). This NE-SW fault regime, which delineated the boundaries of cratonic horsts and grabens, played a significant role in controlling the evolution, deformation, and deposition of sedimentary sequences within the Benue Trough and the Bornu Basin

The exposed basement rocks (Figure 2) exhibit a highly fractured zone, indicating intense tectonic activity and faulting. The diverse fracture orientations suggest a complex fault network formed under varying stress regimes. The primarily brittle fractures reflect shallow crustal deformation where the confining pressure is relatively low and the temperature is not high enough to promote ductile flow (Twiss & Moores, 1992). These fractures are likely associated with the transtensional tectonic forces that influenced the basin formation when rifting coupled with sinistral wrenching separated Africa and South America at the beginning of the Cretaceous (e.g. Benkhelil, 1989).



Figure 3: Field Photographs showing the Bima Formation at Kwaya Kusar, Northern Benue Trough



Figure 4: Field Photographs showing the Bima Formation at Kwaya Kusar Northern Benue Trough

Figures 3 and 4 show the characteristics of the Bima Formation which is the oldest sedimentary unit in the Benue Trough, deposited during the Early Cretaceous. This formation is of significant geological importance as it represents the initial phase of sedimentation in both the Benue Trough and the Bornu Basin. The Bima Formation was deposited in a continental fluvial environment, characterized by high-energy river systems that transported and deposited sediments across the basin. These sediments have since been preserved as a record of the tectonic and climatic conditions that prevailed during the Early Cretaceous.

The field photographs in Figures 3 and 4 depict exposures of the Bima Formation at Kwaya Kusar, located within the Northern Benue Trough. These

exposures reveal several key lithological features, including cross-bedded sandstones with fine- to medium-grained textures. The sandstones exhibit a distinct reddish-brown coloration, indicative of ferruginous cementation, which is a common diagenetic feature in fluvial deposits. The cross-bedding structures, which are not prominently visible in the photographs, are a result of the migration of sand dunes or bars within a high-energy fluvial system. Additionally, the presence of channel-like structures further supports the interpretation of a dynamic depositional environment, likely dominated by braided river systems. These rivers would have been characterized by multiple, interconnected channels that shifted frequently due to variations in water flow and sediment supply.

The depositional environment inferred from these features aligns with the broader understanding of the Bima Formation as a product of fluvial processes. The high-energy nature of the braided river system would have facilitated the transport and deposition of coarse-grained sediments, which are now preserved as cross-bedded sandstones. The ferruginous cementation observed in the outcrops is likely the result of post-depositional diagenetic processes, where iron-rich fluids percolated through the sediments, precipitating iron oxides that cemented the grains together. This process has implications for the reservoir quality of the Bima Formation, as the presence of iron oxide cement in sandstones significantly impacts porosity and permeability. It reduces porosity by filling pore spaces and cementing grains, thereby decreasing permeability by reducing pore throat size and creating a barrier to fluid flow.

From a reservoir perspective, the Bima Formation is recognized as a significant reservoir rock within the Benue Trough. The cross-bedded sandstones observed in Figures 3 and 4 suggest the potential for variable porosity and permeability,

which are critical factors in hydrocarbon storage and flow. The fine- to medium-grained textures indicate that the sandstones may have good initial porosity, but the extent of diagenetic alteration, particularly the iron oxide cementation, could reduce pore space and hinder fluid flow. Understanding these diagenetic processes is essential for evaluating the reservoir potential of the Bima Formation, as they directly impact the economic viability of hydrocarbon exploration and production in the region.

In summary, Figures 3 and 4 provide a window into the geological history and reservoir characteristics of the Bima Formation at Kwaya Kusar. The cross-bedded sandstones, fine- to medium-grained textures, and ferruginous cementation observed in the outcrops provide clues into the depositional environment and diagenetic evolution of this Early Cretaceous unit. The Bima Formation's potential as a reservoir rock warrants further investigation, including detailed petrographic and geochemical analyses, to comprehensively assess its reservoir quality and hydrocarbon potential in the region.

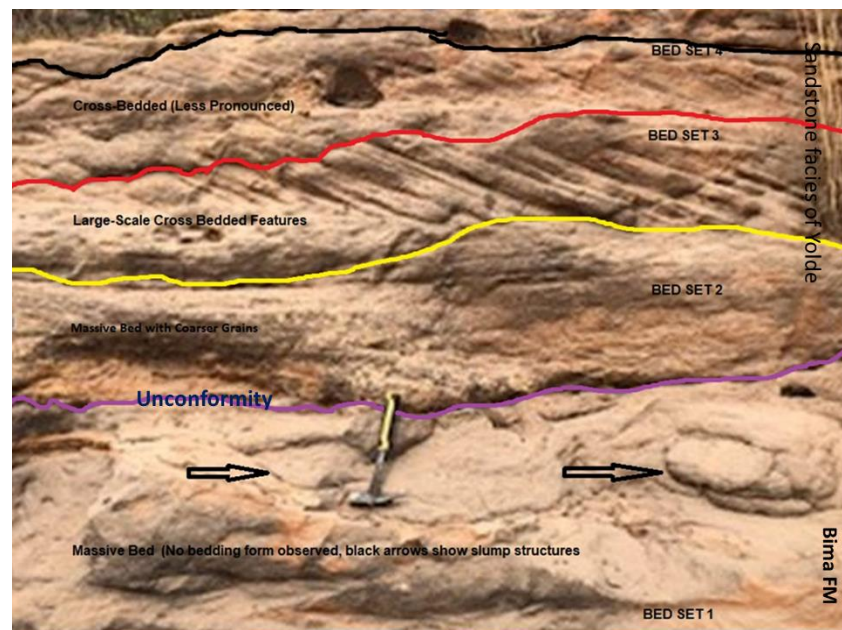


Figure 5: Unconformable contact between the Yolde Formation sandstone facies and the underlying Bima Formation, exposed at Yaranduwa, Dadin-Kowa Road.

The outcrop in figure 5 exhibits four distinct bed sets, varying in texture and structural features. Notably, bed sets 2, 3, and 4, which comprise sand facies of the Yolde Formation, display either tabular stratification (bed-set 2) or cross-bedding lithofacies (bed sets 3 and 4). These bed sets unconformably overlie a massive bed of the Bima Formation; bed Set 1.

The Bed Set 1 is a massive bed-set of approximately 0.5-0.8 m in thickness of Bima Formation, it's below the unconformity and the purple Line. The black arrows point to Soft-sediment deformation structures (SSDS). They display distorted, bulging bedding patterns in ellipsoidal to circular shapes, forming during or shortly after sediment deposition when sediments are unconsolidated. (SSDS) structures are

associated with rapid sedimentation events, such as delta-front deposition. According to Del Valle et al. (2021), overloading and fluidization drive deformation, triggered by gravitational instability caused by steep slopes and density gradients. Observations from the Gombe Formation (Shettima et al., 2017) reveal similar structures, including simple internal cusps, slumps, and concave-upward features, attributed to high-energy syn-depositional processes in a deltaic environment.

Bed Set 2, a 0.7-1.0 m thick massive bed with slightly coarser grains compared to the lower bed (Bed Set 1) indicates a shift towards more proximal (upslope) depositional settings, such as a delta front or higher-energy channel fill, with grain coarsening suggesting upward shallowing or progradation.

Bed Set 3, a 1.2-1.5 m thick unit with prominent large-scale tabular cross-bedding, suggests deposition in a high-energy, shallow marine or coastal environment, such as a tidal channel, where strong unidirectional currents, possibly longshore or tidal currents, formed the cross-bedding. Bed Set 4, estimated to be 1.0-1.3 m thick, exhibits cross-bedding similar to Bed Set 3, but with less pronounced structures, indicating a slightly lower energy environment, possibly marking a transition towards a more distal setting within a channelized environment.

The sedimentary features observed within the Yolde Sandstone facies, including large- to medium-scale cross-stratification and moderate grain sorting, are indicative of deposition within a shallow marine environment influenced by tidal and fluvial processes. Cross-stratification, a diagnostic feature of both fluvial and deltaic systems, results from the migration of bedforms such as sand bars under unidirectional water flow. The moderate sorting of sediment, reflecting a range

of grain sizes, suggests fluctuating energy conditions typical of tidal zones and deltaic systems, where variations in water flow and sediment transport are driven by tidal cycles and fluvial discharges.

The alternating succession of massive stratification and cross-bedded units within the bed-set indicates episodic shifts in depositional energy. These fluctuations were likely governed by periodic changes, such as tidal cycles, seasonal floods, or variations in sediment supply. The vertical facies trend reflects a dynamic energy gradient, transitioning from finer-grained sediments deposited in lower-energy environments to coarser, cross-bedded deposits formed under higher-energy conditions.

This depositional framework has critical implications for petroleum geology, as the presence of large-scale cross-bedding within the bed-set suggests enhanced reservoir potential due to the development of primary porosity and permeability associated with well-sorted, cross-bedded sandstone units.



Figure 6: Field evidence of hydrocarbon presence in the Yolde Formation. a) Limestone block with patches of bitumen, b) Fossil ammonite, a characteristic fauna of the Yolde Formation.



Figure 7: Oil Bleeding Bima sand stone-Gongola Basin, Northern Benue Trough

Figures 6 and 7 present field study findings of bitumen patches within the Yolde limestone facies—comparable to the Gongola Formation in the Bornu Basin—along the Yaranduwa/Dadin Kowa road, as well as oil-wet Bima Sandstone around the Gombe Inlier. These observations provide direct evidence of hydrocarbon presence, offering significant implications for the petroleum system of the Bornu Basin. Specifically, the field observations offer direct evidence of oil-charged intervals within the Bima Formation,

confirming hydrocarbon migration and entrapment in the region. The visible oil infillings documented within the Bima and Yolde formations align with earlier reports by Bata et al. (2015) and Lar et al. (2018). These occurrences suggest that the Bima Sandstone has functioned as a viable reservoir, supporting the broader petroleum system framework of the basin. The presence of bitumen patches further indicates the potential for hydrocarbon generation and migration, reinforcing the basin's significance in petroleum exploration.

Kadi-Gooya Escarpment in Yobe State

The Kadi-Gooya escarpment; a tectonically induced feature is a prominent geological feature located at the southern foot of the Kerikeri Plateau in Yobe State. It is a long moderately sloping cliff with an inclination of about 30 to 45 degrees that rises to an elevation of about 470 meters above sea level.

Although its precise dimensions were not obtained during the field study, observational estimates suggest that the escarpment's width spans a few kilometers, while its length extends significantly beyond the visible horizon. This structure serves as a geological microcosm and natural laboratory of the Tertiary tectonic deformation framework that shaped the geological history of the Northern Benue Trough and the Bornu Basin.

This escarpment is of significant geological interest as it offers a unique opportunity to study the interplay between different sedimentary facies and the tectonic processes that have shaped the region over millions of years. The rock type within the escarpment consist essentially of Keri-Keri Formation, here is where the best of the Kerri-Kerri Formation is exposed and the geological structures well reveal the characteristic depositional facies of the Formation.

The Kerri-Kerri Formation's depositional environment is interpreted as fluvial to deltaic (Adegoke et al., 1983),

characterized by varying energy conditions as evidenced by grain size distribution. The Formation is predominantly composed of sandstones, with minor interbeds of claystone and siltstone, reflecting a dynamic depositional environment that evolved over time (e.g. Odedede et al., 2005; Bello et al., 2025).

The Kadi-Gooya Escarpment serves as a critical boundary where younger Tertiary sediments of the Kerri-Kerri Formation overlie older Cretaceous deposits, providing an insight into the geological evolution of the area.

From the escarpment, this Paleogene Formation unconformably overstep the Fika Shale to the north while to the east it oversteps the Maastrichtian Gombe Sandstone (Adegoke et al., 1986; Okosun, 1995). The exposure of the horizon allows for detailed stratigraphic analysis, which can shed light on the processes that governed the transition from Cretaceous to Tertiary sedimentation.

Figure 8 below provides a compelling view of the Kadi-Gooya Escarpment, where distinct sedimentary facies of the Kerri-Kerri Formation are exposed. The outcrop in the picture reveals a basal layer of kaolinitic sandstone, characterized by its whitist to purplish coloration. Overlying this is a ferruginous sandstone layer with conglomeritic textures, indicative of an upward abrupt coarsening sequence. The sudden change of depositional material from fine to coarse and even

coagulometric can be explained in the light of rapid increase in the intensity of depositional energy. The topmost layer is a hardened lateritic cap with occasional ironstones, reflecting prolonged weathering and iron enrichment. This vertical succession illustrates the lithological and facies variability within the Kerri-Kerri Formation, reflecting

the complex interplay of depositional and diagenetic processes that have shaped this sedimentary sequence. The weathering patterns observed in the outcrops, such as differential erosion and the development of surface textures, provide clues about the post-depositional exposure of these rocks to atmospheric conditions

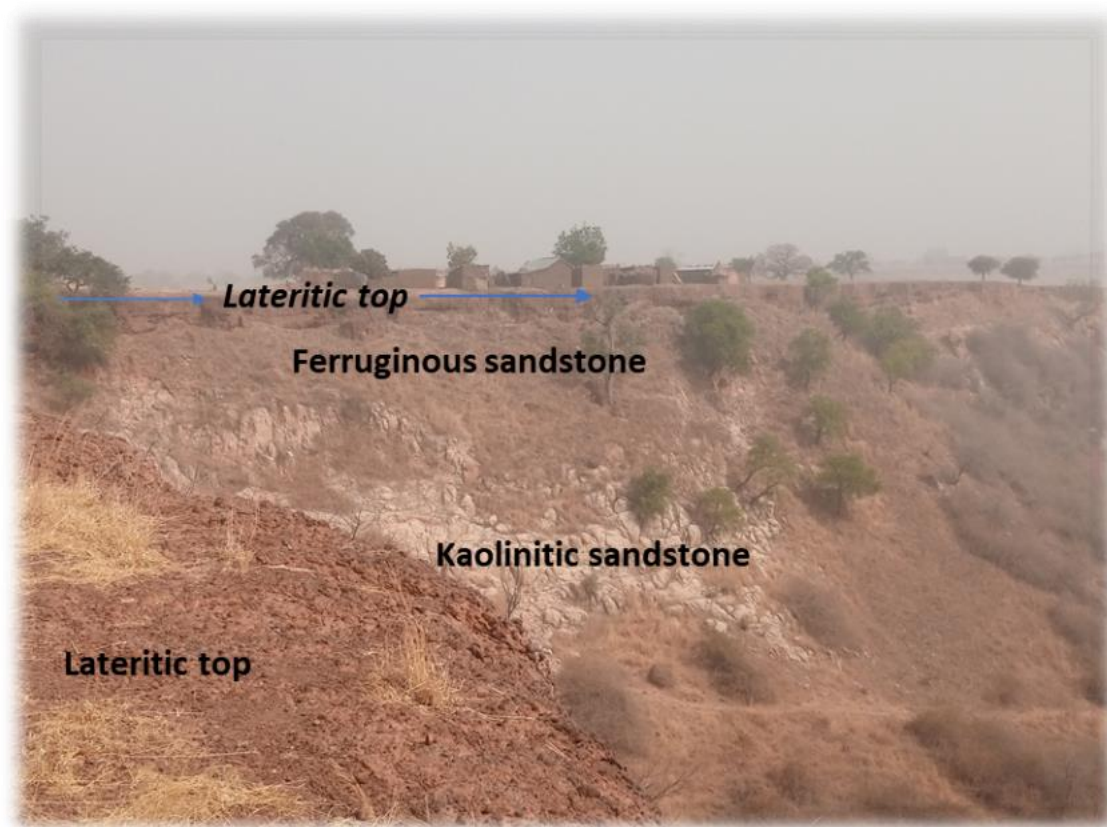


Figure 8: Field photographs of the Kadi-Gooya Escarpment, exposing sedimentary facies within the Kerri-Kerri Formation.

Differential erosion, driven by variations in the resistance of the sedimentary units to weathering, may have played a significant role in shaping the escarpment and the type of sedimentary facies. The softer, less resistant rocks of the Kerri-Kerri Formation would have eroded more rapidly than the underlying, more durable Cretaceous formations.

creating the pronounced topographic contrast observed today (Obaje, 2009; Falconer & Woods, 1911).

Additionally, faulting likely played a significant role in the formation of the escarpment. Tectonic activity during the Tertiary period probably triggered displacement along fault lines, leading to the development of the gorge. This

process can be attributed to the effects of tensional stress, characterized by the bilateral pulling of rock blocks, culminating in a normal fault. The associated strain led to the stretching and thinning of the rock, ultimately sculpting the escarpment's morphology.

Lithological variations between the younger and older sedimentary units also likely influenced the escarpment's formation, as differences in rock composition and structure can affect how erosion and weathering processes operate. In humid climates the high precipitations combined with high temperature intensify deep chemical weathering and strong leaching in the soil primary minerals such as feldspars may be transformed into kaolinite while silicates may produce dissolved silica.

The Kerri-Kerri Formation is characterized by tilted bedding, reddish-hued sand/siltstones, and a

universally lateritic ironstone capping. These lithological and geomorphological features suggest that the formation's development was influenced by both tectonic processes and climatic conditions. The reddish colouration and ironstone capping are indicative of prolonged subaerial exposure and intense chemical weathering, consistent with tropical or semi-arid paleoenvironmental conditions (e.g., Tucker, 2003). These sediments reveal the paleogeography and sedimentary processes that shaped the area during the Tertiary period. These insights are not only valuable for reconstructing the geological history of the area but also for understanding the broader tectonic and sedimentary evolution of the Benue Trough and its surrounding regions especially during the Tertiary.



Figure 9: Field photographs of the Kerri-Kerri Formation at the Kadi-Gooya Escarpment, illustrating its distinctive reddish hue and massive tilted-bed.



Figure 10: Field photographs at the Kadi-Gooya Escarpment, illustrating key geological features: a) Fractured fault damage zone; b) Fault scarp, with a person standing on it for scale.

The massive bedding depositional disposition of the Kerri-Kerri Formation may signal periods of sustained sediment accumulation likely in a relatively low-energy and stable environmental conditions.

Figure 10 captures key structural features of the Kadi-Gooya Escarpment, highlighting a fractured fault damage zone and a well-defined fault scarp. The presence of the fault damage zone, characterized by intense fracturing, indicates brittle deformation associated with tectonic stress. The well-defined fault scarp marks the surface expression of fault displacement, providing evidence of vertical movement along the fault plane. Together, these structural features reflect tectonic processes that have influenced the region's geological evolution.

Two distinct types of concretionary structures were identified within the Kerri-Kerri Formation:

(a) Probable Goethite-Rich Concretions:

These iron oxide concretions appear as spherical to rounded, nodule-like bodies with a lumpy surface texture and no discernible internal structure (Figure 11a). Their formation may be attributed to the precipitation of iron oxides, chiefly goethite, which typically exhibits a reddish-brown to yellowish-brown colouration. The nodules likely developed through a replacement process in which iron oxides substituted detrital minerals within the host rock, rather than precipitating directly into primary pore spaces. The reddish-to-brownish discolouration surrounding the nodules indicates localized geochemical alteration, reflecting diagenetic processes influenced by groundwater movement and iron mobilization.

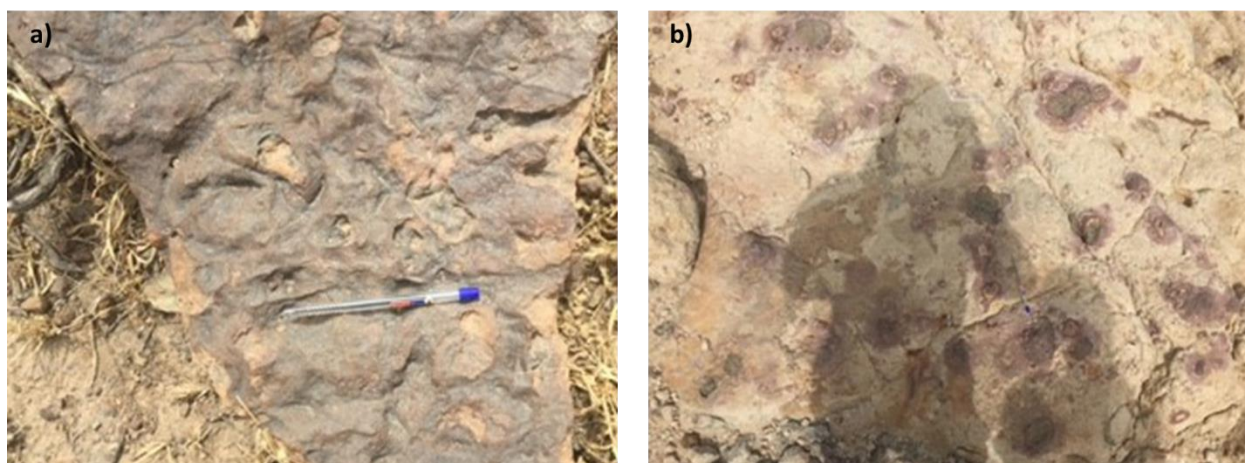


Figure 11 (a & b): Concretionary structures observed within the Kerri-Kerri Formation.

(b) Iron Oxide Concretions (Likely Hematite):

Purplish, rounded, and flat concretions were also observed within the rock matrix (Figure 11b). Their distinct purplish hue is characteristic of hematite, an iron-rich mineral that can exhibit purple to purplish-red colouration, sometimes influenced by trace elements such as manganese or titanium. The concentric or zonal pattern observed, with a central nucleus surrounded by ring-like structures, suggests formation through mineral precipitation around a nucleus, consistent with hematite's typical concretionary growth patterns.

The presence of these iron oxide concretions has important implications for the diagenetic history within the Kerri-Kerri Formation. The goethite-rich nodules indicate oxidizing conditions and localized iron enrichment during early diagenesis, while the hematite-rich concretions suggest variations in redox conditions that influenced mineral precipitation. Diagenetic process such as a such as mineral replacement or

alteration, significantly influence reservoir quality.

Further analysis, such as X-ray diffraction (XRD) for mineral identification and scanning electron microscopy (SEM) for textural and morphological examination, could provide additional insights into the mineralogical composition and formation processes of these concretions. Recent advancements in the field can offer deeper insights into the in studying diagenetic alterations. For example, Li et al. (2022) utilized cathodoluminescence microscopy to investigate diagenetic alterations in sandstone reservoir.

Figure 12 below presents a backscattered scanning electron microscope (SEM) image of a sample from the Kerri-Kerri Formation, collected at the Kadi-Gooya Escarpment. The image reveals a significant diagenetic feature: quartz overgrowth over detrital grain, as highlighted by the red arrow. Quartz overgrowth is a critical petrographic and diagenetic indicator that provides insights into the burial history and post-depositional processes that have affected the Kerri-

Kerri sandstones. This feature occurs when silica-rich fluids precipitate and crystallize over existing quartz grains, forming additional layers of quartz that grow outward from the original grain boundaries. Bjørlykke (2010) suggests that quartz overgrowth can occur at burial depths of 1-3 kilometers, where temperatures range from 60°C to 120°C.

The presence of well-developed quartz overgrowth in the sample therefore suggests that the Kerri-Kerri Formation underwent deep burial at some point in its geological history, exposing the sediments to high temperatures and pressures conducive to such diagenetic modifications.

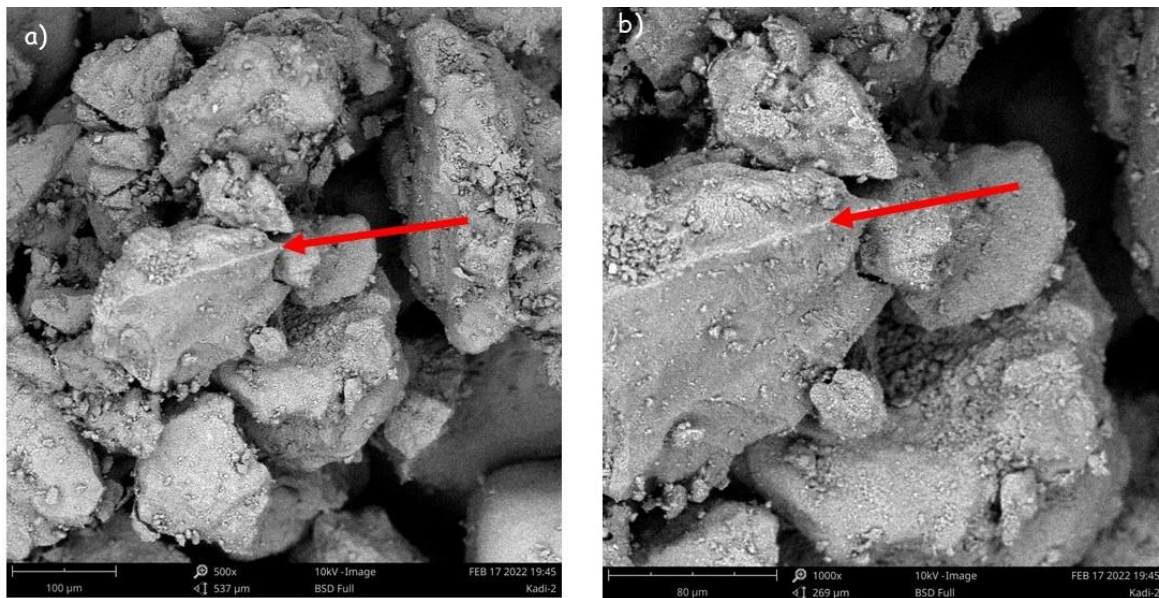


Figure 12: Backscattered SEM image of a sample of the Kerri-Kerri Formation from the Kadi-Gooya Escarpment Showing evidence of Quartz Overgrowth (Red Arrow).

Quartz overgrowth impacts reservoir quality by reducing porosity through silica precipitation while enhancing mechanical strength via grain cementation (e.g. Bata et al., 2017). This dual effect is crucial in assessing the Kerri-Kerri Formation for hydrocarbon exploration and groundwater storage. The extent of overgrowth reveals burial history, indicating deep compaction followed by uplift and erosion, as seen at the Kadi-Gooya Escarpment. Understanding this diagenetic history aids in reconstructing regional tectonic and sedimentary evolution and refining resource assessments.

Field observations in the Northern Benue Trough confirm its geological links to the Bornu Basin, with evidence of stratigraphic continuity between the two basins. Their petroleum systems share similarities due to their common geological setting within the West African Rift System (WARS) (Petters & Ekweozor, 1982; Abubakar, 2014). Both regions contain comparable source rock formations, such as the Fika Shale, and display similar structural features, including horsts and grabens. Their rift-related depositional environments—comprising alluvial fans, fluvial systems, and deltaic systems—have resulted in

analogous hydrocarbon generation potential and reservoir characteristics, with Cretaceous source rocks being the primary contributors to oil and gas generation.

The Bima and Kerri-Kerri Formations exhibit similarities indicative of an interconnected depositional system during the Cretaceous and Tertiary periods. While both formations hold reservoir potential, diagenetic processes, such as quartz overgrowth and iron oxide cementation, influence porosity and permeability, thus affecting hydrocarbon migration and storage. The Bima Formation's high-energy fluvial sandstones suggest favorable reservoir quality, whereas diagenetic alterations in the Kerri-Kerri Formation may reduce its storage capacity. Tectonic activity has further shaped the region's sedimentary framework, with the Kadi-Gooya Escarpment marking a transition between Cretaceous and Tertiary sequences, likely resulting from fault reactivation. Post-depositional faulting has influenced sediment distribution and may have impacted hydrocarbon migration pathways. Oba et al. (2004) suggest the potential for shallow hydrocarbon prospects within the Paleocene Kerri-Kerri Formation in the Northern Benue Trough. However, they propose that hydrocarbon losses may have occurred in the Bornu Basin due to the Paleogene hiatus.

While the Northern Benue Trough has undergone more extensive exploration, including confirmed hydrocarbon discoveries such as the Kolmani Prospect, the Bornu Basin remains underexplored and may hold substantial untapped

resources. Lessons learned from exploration in the Northern Benue Trough should be applied to the Bornu Basin to optimize hydrocarbon exploration strategies. This field study enhances the understanding of the geological, stratigraphic, and diagenetic evolution of the Northern Benue Trough, providing insights into the geological history and resource potential of the Bornu Basin. Future research should focus on petrophysical, geochemical, and structural analyses to refine the understanding of the Bornu Basin's evolution and hydrocarbon viability, supporting both academic advancements and sustainable resource exploration in the region.

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