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Primary and Post Depositional Structures of Cretaceous Succession Around Bambam and Its Environs Part of Yola Sub –Basin, Northern Benue Trough.

Muhammad Abdulrahman, Ibrahim Hamidu, Halidu Hamza, Muhammed Tahir Abubakar, Abubakar Gambo Garkuwa

Department of Geology, Ahmadu Bello University, Zaria, Nigeria

ABSTRACT

Studies of sedimentary structures of the area around Bambam Town part of Yola Sub-basin of the Northern Benue Trough northeastern Nigeria have been carried out. The structures include both primary and post depositional/tectonic structures, the primary structures are; Tabular cross bedding, Trough cross bedding, Tabular oblique cross bedding, Convolute cross bedding Ripple marks, Mud cracks. While the post depositional / tectonic structures include Fold (Anticline), and Recumbent fold. The structures in most outcrops are sandwiched between strata that have no major textural differences with the sediments hosting them. The primary structures include ripple mark, Tabular cross bedding convolute bedding, these occur at the Upper Bima Formation while Trough and Hummocky cross stratification occur in Middle Bima while Pebbles Imbrication occurred at Lower Bima Formation. Post depositional/tectonic structures are features that developed after deposition of the sediment, these include Fold (Anticline), Recumbent Fold and they occurred in Upper Bima Formation. Some of these primary structures of these rocks provide information about the past environment in which the sediment was deposited. While the post depositional structures help provide insight about tectonic history and basin evolution.

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INTRODUCTION

The Benue Trough is the most investigated of all the Cretaceous sedimentary basins in Nigeria (Zaborski 1997). The trough extends northeastward from the Niger Delta of the Equatorial Atlantic into the continental hinterland of Nigeria. This megastructure is approximately 1000 km long and 120-150 km wide, and lies within the Pan African mobile belt of West Africa (Guiraud, 1990b). It contains up to 6000 m of Cretaceous to paleogene sediments and associated volcanics.

The trough is subdivided into three sectors: the southern Benue Trough occupies the region south of an imaginary line through Makurdi-Gboko; the central Benue Trough covers the area between this imaginary line north to the Bashar-Mutum Biyu line; and the Northern Benue Trough extends from Bashar-Mutum Biyu line to the Dumbulwa - Bage High, a structural feature that marks the boundary between this region of the trough and the Chad Basin.

The study area occurs in the eastern Yola sub-basin which is the northeast trending segment of the northern Benue Trough. Geological maps and accounts of its stratigraphy and structure were first provided by Falconer (1911), Carter *et al.* (1963), and then revised by Zaborski *et al.* (1997). Primary sedimentary structures are fundamental features used to interpret environment of deposition of sedimentary rocks that provide the valuable information about the history used to

described features found in sedimentary rocks provide valuable information about the history and process involved in the formation and alteration of these rocks. Primary structures are those that form during or shortly after deposition before lithification of sedimentary rocks. The post depositional /tectonic structures are those that formed as result of deformation caused by movement of tectonic plate.

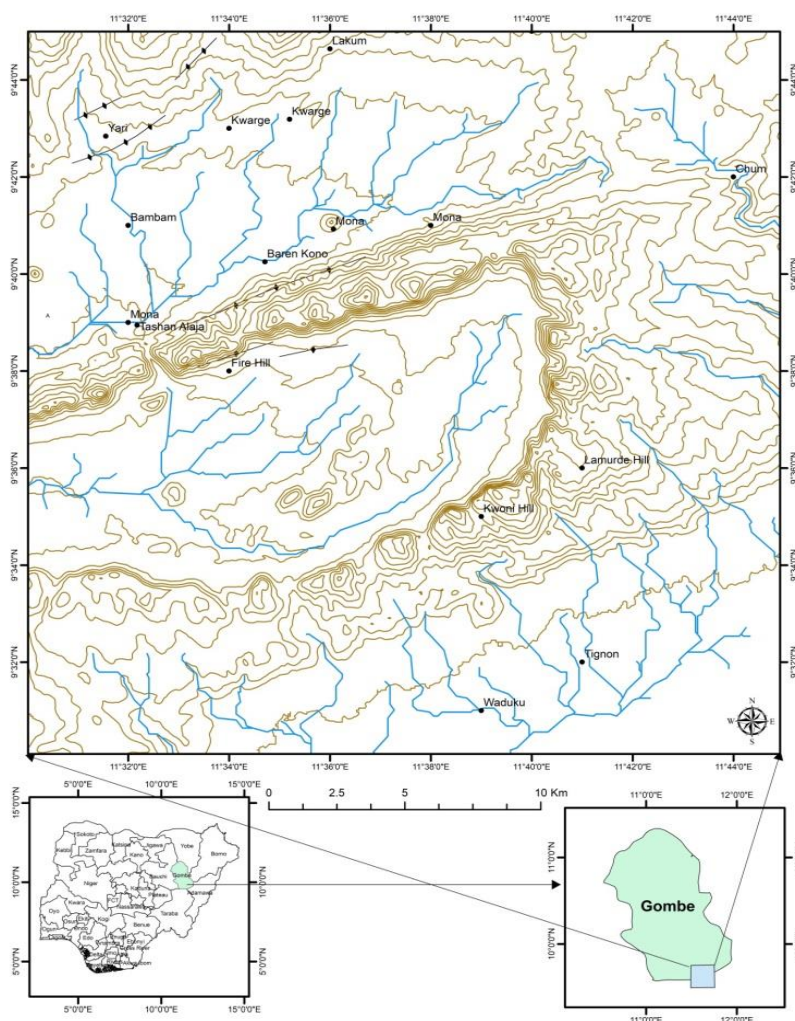


Figure 1: Topographical map showing the location of the study area.

Tectonic structures and stratigraphy of the Yola sub basin of the study area

The Yola Arm (sub- basin) of the Northern Benue Trough developed as a pull-apart basin in line with the model of Benkheilil (1989) for the origin and evolution of the Benue Trough. He had earlier shown that the major NE–SW structural trends in the Benue Trough, formed during the late Pan-African phase of deformation, are aligned and seen to be a continued extension of the oceanic transform faults in the South Atlantic (the Romanche, Charcot, Chain Transform Fault Systems). These structures were reactivated as a set of NE–SW sinistral strike-slip faults during the Early to Mid-Cretaceous time, as a result of which sub-basins of a pull-apart nature in the Benue Trough were formed. Most workers such as Carter *et al.* (1963). Offodile (1976), Benkheilil (1989), Obaje *et al.* (2004), Abubakar (2014), Tukur *et at.* (2015) among many others have

described the stratigraphy of the Northern Benue Trough. The depositional history of the area of study is marked by the deposition of Bima Sandstone which is unconformably overlaid the Precambrian basement during the Aptian/Albian. The Bima Formation has been differentiated into three units: Lower Bima, Middle Bima, and Upper Bima from the oldest to the youngest respectively. The Lower, Bima Formation is alluvial fan deposit which is exposed at Lamurde Anticline. The Middle Bima, which is fluvial, is exposed in, Tashan Alaja and at Lamaurde Anticline. The Upper Bima is braided river deposit and more widely exposed in the study area. The deposition of Bima Formation was followed by the transitional Yolde Formation which inturn was succeeded by marine sequences of Dukul, Jessu Formations, with the Lunguda Basalt capping the sequence in the area.

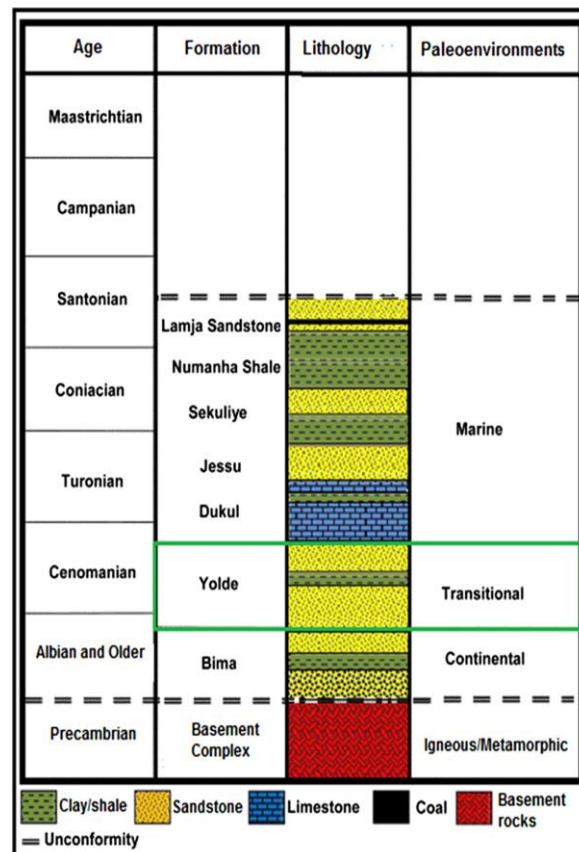


Fig. 2. Stratigraphic sequence of the Yola Sub-basin (Sarki Yandoka *et al.*, 2015).

Description of primary structures: Bed form (Ripple marks)

These are formed as result of unidirectional current, like in the case of river or wind in the desert. These create ripple marks with pointed crests and rounded trough. Asymmetrical ripple

marks were observed on the bedding planes of fine-medium grained sandstone at the Upper Bima Formation. Measurements show that the orientation of the ripples is 044° NE strike as shown below in Plate I.



Plate I: Exposure of Upper Bima Formation showing Asymmetrical ripple marks exposed East of Yiri village
 $11^{\circ} 31' 56''$ N, $9^{\circ} 44' 10''$ E

Pebbles imbrication: this is form during or shortly after deposition of sediments and its related to the sedimentary processes. This occur when pebbles or larger particles within the

sedimentary layer become aligned or oriented to the specific direction due to the flow of water or any other transporting agents.



Plate I. Lower Bima Formation with conglorometic Sandstone at Boller river ($N9^{\circ} 38' 24.8''$ and $E11^{\circ} 32' 22.2''$).

Mud crack: this is the Clay-rich sediment that is cohesive and the individual particles tend to stick to each other as the sediment dries out. As water is lost the volume reduces and clusters of clay

minerals pull apart developing cracks in the surface. Under subaerial conditions a polygonal pattern of cracks develops when muddy sediment dries out completely:



Plate III: photograph of polygonal mudcracks within Dukul Formation at Lakun Village (N 9° 44' 53.3" E11° 37' 43.8")

Convolute cross-beddings: This is the type of soft sedimentary structure that is developed in response to vertical stresses on massively bedded to parallel-laminated sediments during partial liquefaction (Owen, 1995). The origin of the convolute lamination is not fully understood but probably the causes are differential

liquefaction and lateral-vertical intrastratal flow (dewatering processes) and shearing of the sediment surface by currents. Convolute lamination is common in turbidite beds but it also occurs in fluvial, tidal-flat and other sediments (Adam *et al.*, 1984).



Plate:IV field photograph of Convolute cross-bedded sandstone Upper Bima Formation at Bambam stream (9° 42' 17.5"N, 11° 32' 12.1"E).

Tabular Cross bedding: is formed by asymmetrical migration of dunes under low energy regime flow due to wave swash process in the upper shore face (Mial 1978, Souza *et al* 2012). Sandstone were formed during deposition

in desert, river, deltas, lakes, beaches, and shallow sea, they are formed based on specific environment. The presence of the cross-beddings in the study area is an indication of deposition by river.

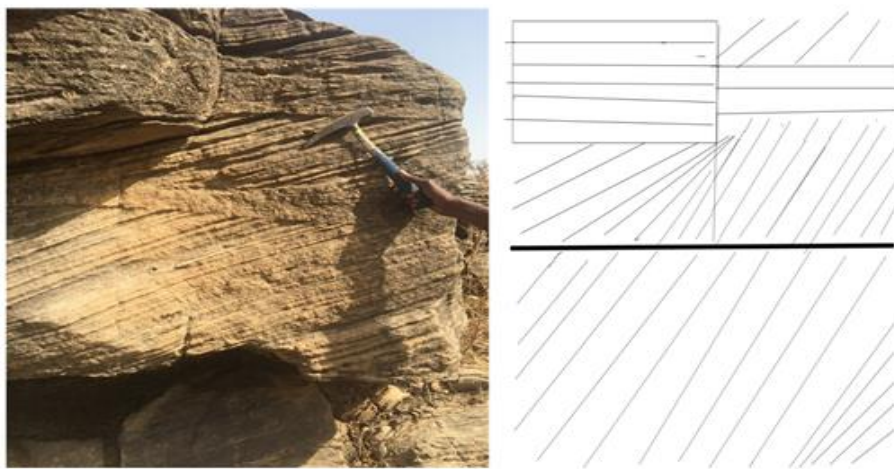


Plate V: Tabular cross-bedded sandstone with foresets in the Upper Bima Formation exposed at Yiri village (9° 44' 20.1" N 011° 34' .42.6"E)

Tabular oblique cross bedding: Tabular oblique cross bedding is a type of bedding that is inclined at an angle less than 90° to the horizontal.

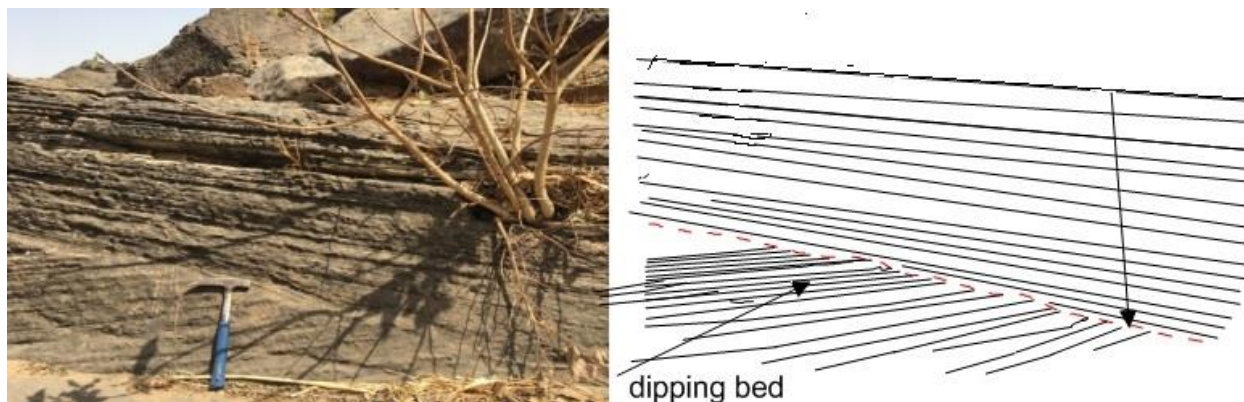


Plate VI: Field Photograph of Tabular oblique cross bedding in Upper Bima Formation at (Kwarge village)

Trough Cross Bedding: is formed by downstream migration of curved crest bed or forms through migration of sinus and lunate dune bed forms where there is change of flow velocity or are

layers of sediment that are inclined relative to the base and top of the beds, they have lower surfaces which are curved and merged tangentially with lower surface.



Plate VI: Field photograph of Trough cross and Hummocky cross bedding in Middle Bima Formation at Bambam stream ($09^{\circ} 42' 17.5''\text{N}$, $011^{\circ} 32' 12.1''\text{E}$)

Description of tectonic/post depositional structures

Fold: is a stack of originally planar surface, such as sedimentary strata, that are bent or curved during permanent deformation, caused by temperature and pressure triggered by tectonic

activities. Along Boller River towards Maitunku, a border village between Gombe and Adamawa State Lamurde anticline was encountered, which is the complementary structure to the Dadiya Syncline according to (Chukwu-Ibe 1981; Benkhelil, 1986; Braide, 1992).

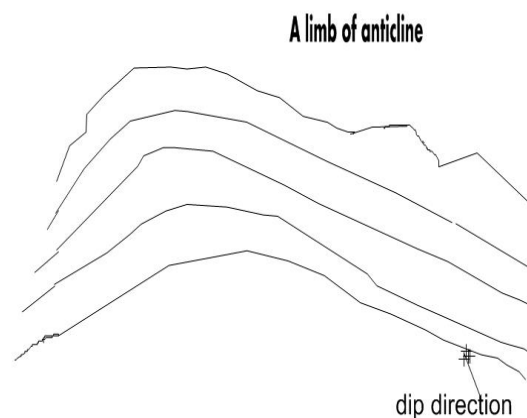


Plate VII: A limb of Lamurde anticline along Boller river off Mai-tunku ($N9^{\circ} 37' 33.1''$ $E11^{\circ} 31' 45.8''$)

Recumbent fold: is type of soft sedimentary deformation that is formed as a result of horizontal stress during liquefaction and this triggered by tectonic activity. Is the one with axial plane essentially horizontal, with the limit of

variation of axial – planar dip, and the resulting limit of plung, being 10° (Turner and Weiss, 1963; Fleuty, 1964). It sideways – closing neutral structure that is neither a synform nor antiformal fold



Plate II: Recumbent Fold in the Upper Bima Formation. ($9^{\circ} 31' 45''\text{N}$, $11^{\circ} 34' 27''\text{E}$)

Paleocurrent Analysis

Cross beddings and asymmetrical ripples were used in determination of Paleocurrent direction and the result of the measurement Shows Bimodal pattern. The major direction of flow is NE –SW, with the NE, being more prevalent (Figure 3)A bimodal pattern in Paleocurrent

measurements suggest that there were two distinct directions of water or sediment transport during the deposition of the sandstone and can be explained in the context of environment of deposition, in a fluvial (river) environment. For example one direction could represent the dominant flow of the river while the other could be related to meandering or changing channels within the river system.

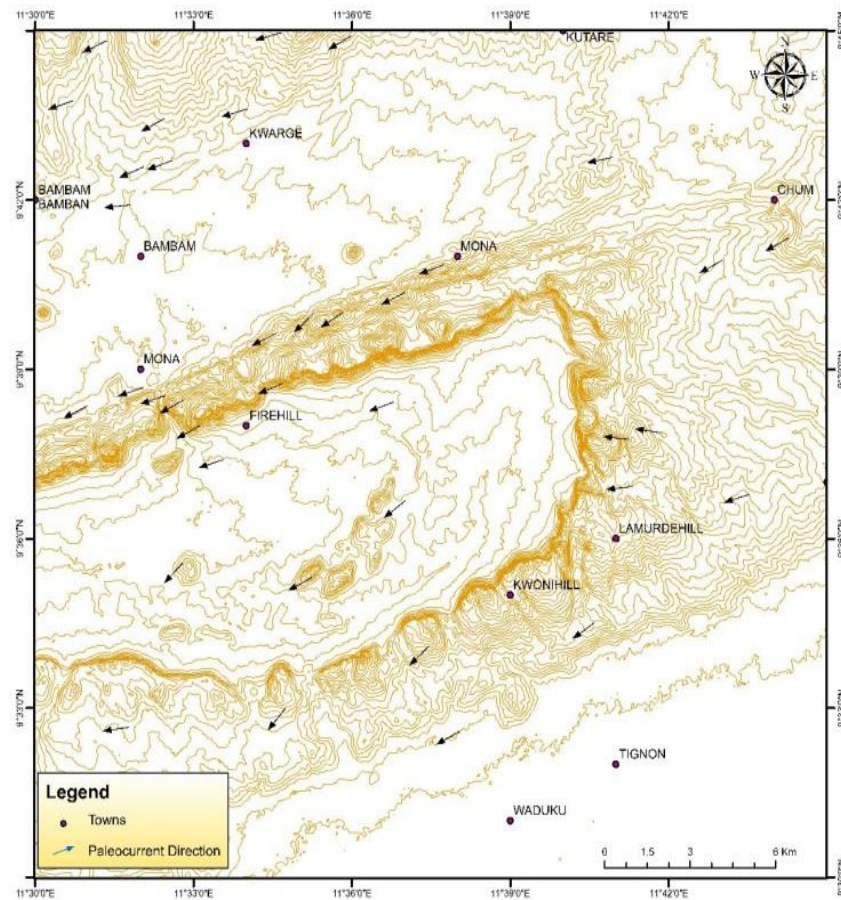


Figure 3: Paleocurrent map of the Bima Group in the study area.

Discussion and Conclusion

Both primary and post depositional/ tectonic structures have been observed and studied in the study area the primary structures are formed during deposition before lithification, the presence of bed forms in the study area suggest that sedimentary deposition was under fluvial influence and this can provide information about the direction and the intensity of the current and the environment at the time of deposition. Cross bedding is structures often form in environment with the migrating dunes or ripples. It indicates the direction of sediment transport and can help reconstruct ancient depositional environment. Some primary structures such as pebbles

Imbrications helps in understanding the direction and the intensity of the transporting agents that influenced the sedimentation process since it point to the sorting and alignment of larger particles within sedimentary layers. The presence of fold (anticline) in the study area suggests that it has undergone tectonic compression, causing rock layers to bend and fold. The observation of recumbent folds can provide clues about the magnitude and the direction of tectonic forces that have affected the study area over geological time. Therefore, the sedimentary structures such as Recumbent fold and convolute bedding within the Upper Bima Formation may have originated from the impact of crustal stress that was

transmitted through incompetent sediments that might have resulted from the major tectonic activity of the underlying basement. Jones (1962) has earlier associated the mechanism responsible for the soft-sediment deformation in the Yola Arm to liquefaction-induced slope collapse triggered by the Cameroon volcanic line. Braide (1991, 1992), on the other hand related it to the syndepositional tectonics at the margins of the Yola sub-basin.

These authors therefore, suggest that the seismic shocks responsible for the soft-sediment deformation structures in the Northern Bima Formation might have been generated by the widely reported episodic syndepositional Mesozoic volcanism of the Jurassic to Albian times in the Upper Benue Trough, however the Compressional events such as the one in the Santonian (80Ma) that reactivated preexisting shear zones in the Northern Benue Trough (Benkelil *et al*; 1989) led to the formation of NNW – SSE, trend observed within the sediments as well as the folds observed in the study area. By studying both primary and post depositional / tectonic structures together a geological history of the study area can be reconstruct comprehensively because they can provide together information about the ancient environment, sedimentary processes, tectonic event and basin evolution.

However, there is correlation between primary sedimentary structures and depositional environment, because the presence of tabular cross bedded sandstone indicates that the environment associated with fluvial (river) processes. in a fluvial setting such as river systems, tabular cross bedding can form as a result migrating of sand dunes or ripples within the riverbed. A Ripple mark is inferred to be generated by waves is interpreted to represent

low energy wave deposition in shallow marine settings (Walker and Plint 1992).

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