IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 8, Issue 4 Ser. I (Jul. – Aug. 2020), PP 22-35
www.iosrjournals.org

Sequence Stratigraphic Framework of the Aptian-Albian Bima Formation of the Gongola Sub-basin, Northern Benue Trough, NE Nigeria

Bukar Shettima, Mohammed Bukar, Asabe Kuku and Bintu Shettima
Department of Geology, University of Maiduguri, Nigeria

Abstract: *This study aims to evaluate the sequence stratigraphic framework of the Bima Formation of the Gongola Sub-basin of Northern Benue Trough from its contained facies and facies association. The lowermost Bima Formation (Bima I) is characterized by alluvial fan depositional environment showing spectrum of sub-environments consisting of debris flow and braided river deposits. The Middle and the Upper Bima Formations (Bima II and III) are essentially formed of braided river deposits with the former consisting of deep channel facies while the later of shallow channel sequences. Employing sequence stratigraphic model of high and low accommodation system tracts built on tectonics, subsidence and allogenic controls of sedimentary basins devoid of marine influences,the depositional architecture from the disposition of the sedimentary environments indicated intervals of low and high accommodation in the Lower and Middle Bima Formations. The basal stratigraphic horizons of these formations are characterized by alluvial fans and braided river settings respectively, devoid of mudstone deposits, indicating slow subsidence rate, signaling low accommodation system tract. Whereas the increasing presences of mudstone content in the upper intervals reflected from floodplain and lacustrine settings account for phases of creation of accommodation space through subsidence, hence deposits of high accommodation system tract. The Upper Bima Formation (Bima I) consisting of essentially shallow braided river deposits with complete absences of floodplain mudstone accumulation are reflective of also low accommodation system tract, signifying a regime of damped subsidence conditions in the Gongola Sub-basin.*

Keywords: *Fluvial sequence stratigraphy, Gongola Sub-basin, Benue Trough*

Date of Submission: 26-06-2020 Date of Acceptance: 15-07-2020

I. Introduction

Sequence Stratigraphy is a concept that divides sedimentary deposits into unconformity bound units on a variety of scales as a consequence of variations in the rate of change in accommodation space and sediment supply (Van Wagoner *et al*., 1988; Catuneanu, 2006). This framework ties changes in strata stacking patterns to responses of varying accommodation and sediment supply through time (Van Wagoner *et al*., 1988, 1990; Angela et al., 2003), forming individual sequences that forms the basic building blocks of sequence stratigraphy. Internal packaging of progressively thicker stratal units, representing increasingly greater amounts of time and ultimately defines a chronostratigraphic hierarchy (Van Wagoner *et al.*, 1990; Mitchum and Van Wagoner, 1991; Posamentier and Allen, 1993). Within an overall sequence stratigraphic framework, the smallest scale stratal units including lamina, lamina sets, beds and bed sets are found to progressively form larger-scale stratal units called parasequences (shoaling-upward successions bound by flooding surfaces (Van Wagoner *et al*., 1988; Zaitlin et al., 2002). The lower-order sequences, (parasequences), are found to stack within higher – order sequences in an often repetitive and in predictable pattern (Catuneanu, 2006). The stacking pattern, distribution, and sediment body geometry of lower – order stratal units within a higher – order sequence enables inferences to be made regarding controls operating within a given depositional system (Catuneanu, 2006). The application of sequence stratigraphy to the fluvial rock record is a relatively recent endeavor which started in the early 1990s, with the works of Shanley et al., (1992) and Wright and Marriot (1993), describing changes in fluvial facies and architecture within the context of marine base level changes using the traditional lowstand, transgressive, and highstand system tract nomenclature. Generally, marine base level changes and associated shoreline shifts, may only influence fluvial process within a limited distance upstream from the coeval shoreline. The distance is usually in ranges of tens of kilometers beyond which the rivers responds primarily to the combination of climate and tectonic mechanism (Blum, 1994). Dahle et al., (1997) introduced a conceptual break-through, thereby defining non-marine stratigraphic unit independent of marine base level changes, and this concept was the concept of low and high accommodation system tract. They are the building blocks of a fluvial depositional sequence and they succeed each other in a vertical succession, as being formed during a stage of varying rates of positive accommodation, create by allogenic controls, (Paola et al., 2001). Depositional controls including, eustasy, tectonism, climate, sediment supply dictates base level variability which in turn governs sequence development (Catuneanu, 2009). An understanding of depositional controls and resultant sequence architecture enables the prediction of individual facies within an overall depositional system (Posamentier *et al*., 1988; Catuneanu, 2005). During the Aptian-Albian marine transgression in the Gulf of Guinea, the Benue Trough received marine sedimentation up to the Central Benue, beyond which are essentially continental depositional processes typically characterizing the sedimentations in the Northern Benue Trough (Fig.1a and b). The Aptian-Albian sequences of this basin composes of the Continental Bima Formation and this research is aimed at evaluating sequence stratigraphy of this formation in the Gongola Sub-basin of the Northern Benue Trough.

Stratigraphic and Tectonic Setting

The Gongola Sub-basin is the North-South trending arm of the bifurcated northern Benue trough and host over 6000m of Cretaceous – Tertiary sediments associated with volcanics (Fig.2) emplaced from tectonics that opened the South Atlantic Ocean, consequentially due to the separation of the African and South American Plates during the Jurassic times (Genik, 1992; Guiraud et al., 2005; Fairhead, et al., 2013). The origin and evolution of the basin initiated from pervading rift fault bounded tensional basement flexuring induced by mantle convection around discrete hot spot at RRR tipple junction of the Gulf of Guinea (Farrington, 1952; Cracthley and Jones, 1965; Wright, 1989). This led to the development of a failed arm, an aulocogen and hence, the emergence of the Benue Trough (Grant, 1971; Olade, 1975). Contrary theories considered wrench fault tectonics triggering agent for the evolution, because of the absence of discernable boundary faults that uniquely characterizes rift systems (Benkhelil, 1989; Guiraud and Maurine, 1992; Aribiyi et al., 2004; Likkason et al., 2005). Arbitrarily, the Benue Trough is sub-divided into southern, central and the northern portion which constitutes of the Gongola, Yola and Muri-Lau Sub-basins, forming the main rift arm (Fig.1c) (Nwajide, 2013; Shettima, 2016). The late Jurassic,

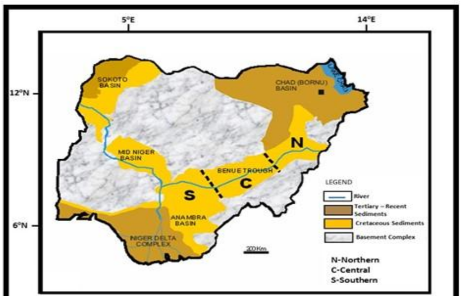

Fig.1a Geological Map of Nigeria showing the Benue Trough

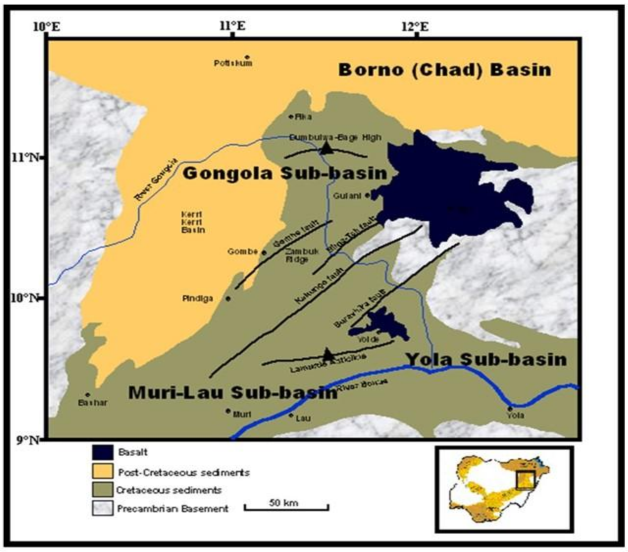

Fig.1b Geological map of the Northern Benue Trough (modified from Zaborski *et al*., 1997)

Aptian-Albian continental sequences designated as Bima Group represents the oldest sedimentary units in the Gongola Sub-basin, conformably overlying the Basement Complex Rocks (Fig.2) (Guiraud,1990; Zaborski et al., 1997; Tukur et al., 2015; Shettima et al., 2018). Syn-rift sedimentation largely controlled by the horst and graben system emplaced the alluvial fan-lacustrine deposits of the Bima I Formation, the lowermost in the group and it is unconformably superposed by the post rift braided river sequences of the Bima II and III Formations, resulting from a probable lower Cretaceous tectonics (Zaborski et al., 1997; Tukur et al., 2015; Shettima et al., 2018). The Cenomanian is marked by the transitional-marine deposits of the Yolde Formation (Shettima et al., 2011), representing the commencement of the mid-Cretaceous global marine transgression in the basin (e.g. Haq et al.,1987). This reached its peak in the Turonian and deposited the shallow marine shale and limestone sequences of the Kanawa Member of the Pindiga Formation (Zarborski et al., 1997; Abdulkarim et al.,2016), and with deaccelerating transgressive conditions, regressive Sandy Members of the Dumbulwa, Deba-Fulani and Gulani sandstones conformably followed in the mid-Turonian (Fig.2) (Zaborski et al., 1997; Nwajide, 2013). Rising relative sea levels in the late Turonian transcending into the Coniacian and early Santonian led to deposition of the deep marine blue-black shales of the Fika Member, representing the youngest units of the Pindiga Formation (Zaborski et al., 1997; Shettima, 2016). This marine inundation is occasioned with a compressional tectonic pulse in the mid-Santonian (Genik, 1993), as consequence of changing orientation of the displacement vectors between the African plate and European/Tethys plates (Fiarhead and Binks, 1991). This tectonics led to thrusting of the pre-Maastrichtian sediments towards the west of the Gongola Sub-basin, correspondingly depositing the Campano-Maastrichtian regressive deltaic sequences of the Gombe Formation (Dike and Onumara, 1999: Shettima, 2016). The mid-Maastrichtian is characterized by another phase of compressional event and thereafter followed unconformably by the deposits of the Paleogene fluvio-lacustrine Kerri Kerri Formation (Dike, 1993: Adegoke et al., 1978) (Fig.2). The Paleogene-Neogene recorded sporadic volcanics which are dominantly emplaced eastern margin of the Gongola Sub-basin along the Nigerian portion of the Cameroonian volcanic line (Wilson and Guiraud, 1992).

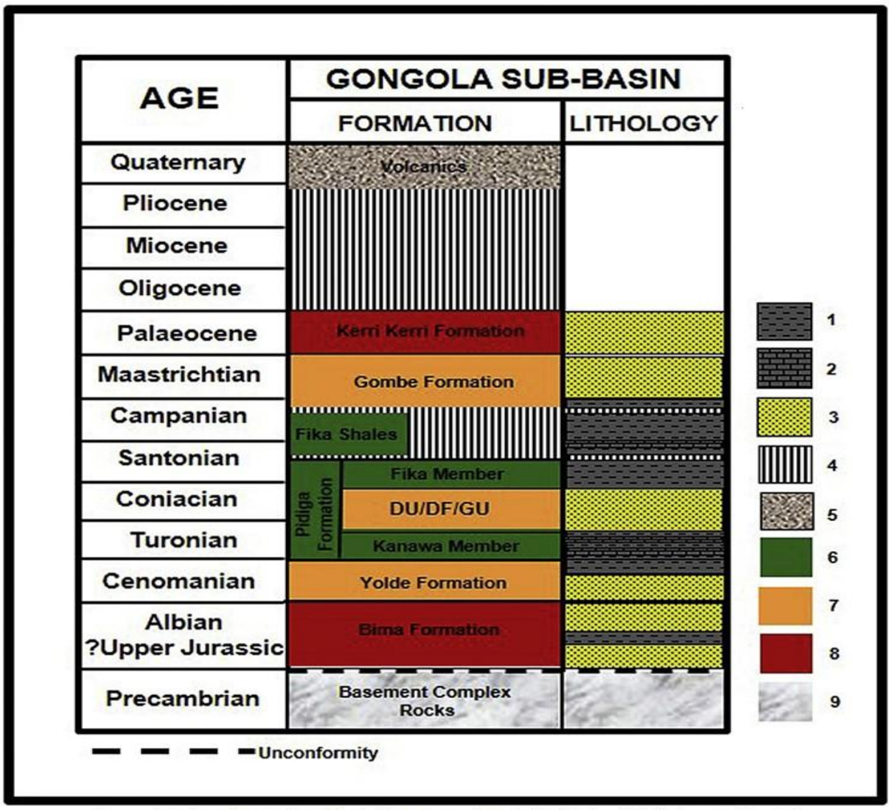

Fig. 2 Showing the stratigraphy of the Gongola Sub-basin (modified from Zaborski et al., 1997). 1-Mudstone, 2-Limestone, 3-Sandstone, 4-Hiatus, 5-Basalt, 6-Marine sediments, 7-Transitional-marine sediments, 8-Continental sediments, 9-Basement Complex (DU-Dumbulwa Member, DF-Deba Fulani Member, GU-Gulani Member).

II. Materials and Methods

Basin inversion experienced during the mid-Santonian tectonics has exposed great thickness of the Bima Formation around the cores of major anticlinal structures and fault escarpments in the Gongola Sub-basin of the Northern Benue. Ten lithostratigraphic sections of the Bima I, II and III Formation in the Gongola Sub-basin of the Northern Benue Trough were analyzed for their lithostratigraphy facies assemblages and depositional association in order to determine the sequence stratigraphic framework of the BimaFormation. The sections were measured and described to detail stratigraphically, taking into account detailed records of thicknesses, grain sizes, sedimentary and biogenic structure and geometry. Paleocurrent measurements were also carried out on the abundant planar and trough crossbedded sandstones and the various orientations determined were used to evaluate provenance and hydrodynamic processes (e.g. Hobbs et al., 1976; Tucker, 2003). The dip and strike as well as the azimuth of the crossbeds were measured using compass clinometers in this analysis, and considering that the regional dip of the beds are generally greater than 100, tilt correction was also carried out on the values using the procedure adopted by (Tucker, 2003).

III. Results

Depositional Facies

Facies assemblages are genetically related association of lithofacies that are definitive of individual depositional environment (Boggs, 1995; Dalrymple, 2010). The facies association studies of the Bima Formation revealed that the Bima I was formed in an alluvial fan – proximal braided river environment, whereas the Bima II and III were exclusively in a braided river depositional environment.

Alluvial Fan Facies Association

The facies succession of the grain supported conglomerate, matrix supported conglomerate and mudstone may represent this environment (Fig.3a-c).

The clast supported conglomerate lithofacies may probably represent sieve deposits in an alluvial fan environment (Selley, 1976; Nilsen, 1992) (Fig.4a). They formed under conditions where the source area supplies mostly gravel size detritus rather than sand, silt or clays. In modern fans, they usually compose of well sorted gravels containing relatively angular monomict clast that forms massive, laterally extensive beds with well-developed imbrications (Nilsen, 1992). Modern sieve deposits are generally formed in proximal areas of alluvial fans (Nilsen and Moore, 1980; Nilsen, 1992) which suggest that the sieve deposit observed at Teli formed in proximal alluvial fan sub – environment.

The matrix supported conglomerate lithofacies (Fig.4b) characteristically forms in proximal alluvial fan sub- environment and is generally generated where sediment source provides abundant muddy material in steep slope terrains, and vegetation is scarce and rainfall is either seasonal or irregular (Bull, 1977; Nilsen, 1992; Allen and Hovius, 1998). Bull (1963) indicated that proximal debris may show sub – horizontal orientation of megaclast, whereas distal flows tends to have larger clast in predominantly vertical position due to the matrix support. The sub – horizontal orientation of the megaclast have been observed at the Teli section (Fig.3b), hence this

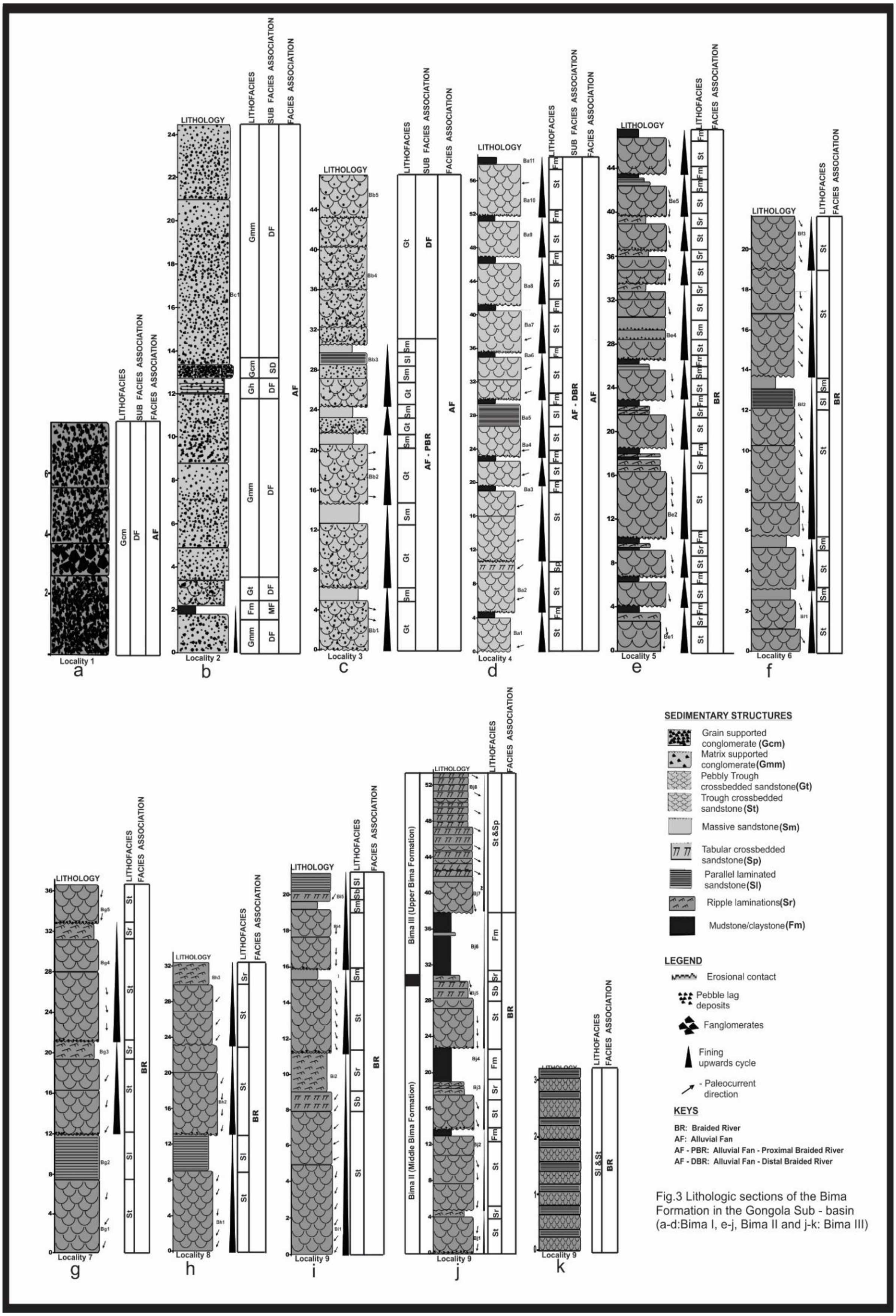

Fig.3 Lithologic sections of the Bima Formation in the Gongola Sub - basin (a-d:Bima I, e-j, Bima II and j-k: Bima III)

lithofacies is considered to have formed in a proximal alluvial fan sub – environment. Debris flow can either be channelized or non – channelized (Gloppen and Steel, 1981). When confined to channel poorly developed sedimentary structures can be formed, whereas when unconfined to channel the deposits spread out laterally as sheets or lobes in interchannel or lower fan areas (Nilsen, 1992; Collinson, 2002). All these conditions are supported on the Teli section (Fig.3b), and shows graded or ungraded beds as the most predominant. Therefore, the generality of the debris flow deposition at Teli may possibly be non – channelized.The mudstone observed towards the base of the section (Fig.3b) may represent mud flow deposits.

Schumm (1977) and Nilsen (1992) suggested that humid alluvial fans characteristically defined by dominant fluvial processes are usually devoid of debris flow deposits. Therefore, the presence of debris flow deposits in the Bima I may probably suggest that the formation most have been formed in arid to semi – arid climatic conditions. The presence of the sieve deposits may further confirm this suggestion (see Nilsen, 1992).

Proximal Braided River Facies Association

Proximal braided river environment was suggested at the Bima hill valley section (Fig.3b) where it composes of gravelly trough crossbedded and massive sandstone facies fining upward to mudstone facies. At the Wuyo village (Fig.3c), the trough crossbedded sandstone facies is composed of cobbles at base that fines upward to mudstone facies (Fig.4c).

At the Bima Hill valley, these cycles may typically represent different regimes of stream flow deposits formed in relatively well channelized distal part of an alluvial fan. Considering the absence of mudstones and presence of gravelly trough crossbedded sandstones facies in these cycles, they may represent proximal braided river systems of Scott – type (Miall, 1977); an inference earlier drown by Carter et al. (1963), Allix (1983), Guiraud (1990) and Abubakar (2006). Furthermore, alluvial fans forming in arid or semi – arid regions are most commonly defined by braided river systems at their lowermost part (Nilsen, 1992), and since the proximal portion of the alluvial fan in the Teli section has been established to have formed in arid to semi – arid conditions, the braided river system interpretation for these cycles may be quite plausible.

The overlying succession of gravelly to pebbly trough crossbedded sandstone lithofacies may represent a sheet flood deposits, which results from the spreading out of sediment – laden flood water from channels (Nilsen, 1992) (Fig.4c).

At the Wuyo village (Fig.3d), the thin nature of the mudstonee facies, well rounded cobbles and local occurrence of planar crossbedded facies in these cycles, may probably suggest more distal portion of alluvial fan environment, where it interfingers with braided river systems of basin – floor (alluvial plain). Though, these braided river cycles do not conform to the classical braided river model of Miall (1977), the presence of mudstone and tabular crossbedded facies may make them conformable to the unique South Saskatchewan braided river system model (Cant and Walker, 1978).

Deep Channel Braided River Facies Association

The succession of these facies association gave rise to fining upward packages, and similarity in the lithofacies distribution may suggest that these cycles were genetic and probably

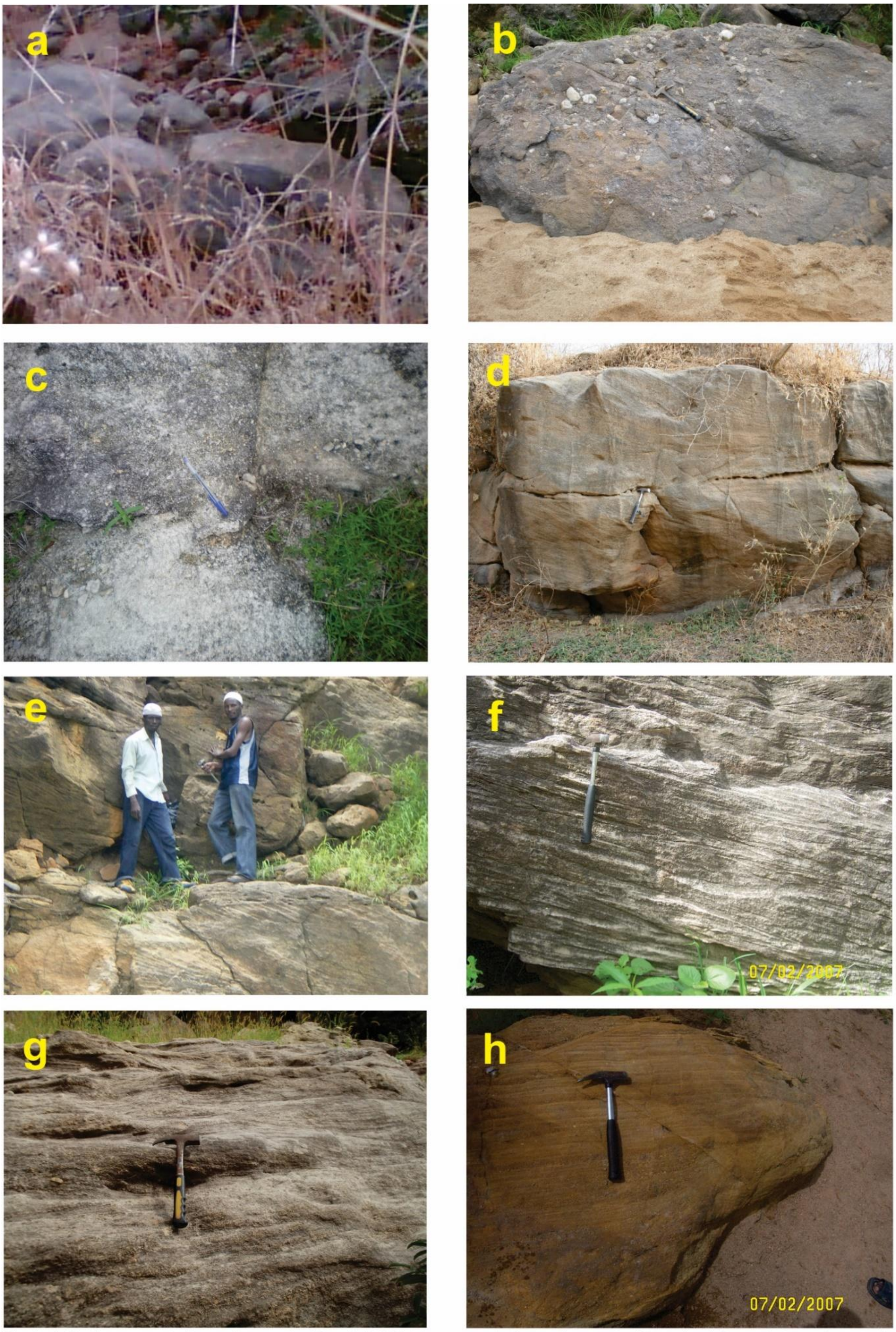

Fig.4 a) Grain supported conglomerate (Gcm), b) Matrix supported conglomerate (Gmm), c) Gravely trough crossbedded sandstone (Gt), d) Trough crossbedded sandstones (St), e) Planar crossbedded sandstone (Sp), f) Climbing ripple laminated sandstone (Sr), g) Asymmetrical ripple laminated sandstone (Sr) and h) Parallel laminated sandstones (Sl) formed under similar hydrodynamic conditions (Figs.3g-j, 5d). These fining upward cycles may suggest a fluvial system considering the lack of marine indicators, in which the mudstone may represent floodplain deposits formed as a consequence of vertical accretion during flooding, while the sandstone may indicate in – channel deposit. Considering the thin mudstone that are occasionally associated with ripple laminations (Fig.4f and g) defining the upper part of almost all of the cycles and infrequent occurrence of tabular crossbeds (Fig.4e), these cycles may probably represent braided river system, because braided river have relatively very thin floodplain (Miall, 1977; Cant and Walker, 1978). This interpretation is in line with earlier interpretations (Carter et al. 1963; Allix, 1983; Guiraud, 1990; Dike, 2002; Abubakar, 2006). The channel deposits in most of these cycles are represented by single or multistory units of trough crossbedded sandstone facies (Fig.4d), usually formed from migration of sinuous crested dunes (Miall, 1977, 1978). Tabular crossbedded facies rarely occur except at the Dadinkowa hill and the Wuyo village (Fig.3g-i). This generally suggests that the braided river channels are relatively deep (Miall, 1977; Cant and Walker, 1978) and the Wuyo village section may represent distal portion of the braided river complex of the Bima II.

Shallow Channel Braided River Facies Association

In the Bima III, multiple occurrences of tabular crossbedded sandstone (Fig.5b) units above the basal trough crossbedded sandstone (St) indicate the occurrence of braid bars in these channels and such multistory succession of bars are termed as sandflats (Cant and Walker, 1978) (Fig.3k and 5b). During waning flow stages, upper flow regime structures e.g. parallel laminated sandstone (Fig.5h) can develop upon these bars as observed in the section (Collinson, 1970).

Aggradation and accretion of braid bar complexes generally occur in shallow channels with depth range of 1–2m (Smith, 1970; Miall, 1977; Blodgett and Stanley, 1980; Walker and Cant, 1986; Collinson, 2002). Therefore, the lithofacies association of the Bima III suggested formation in braided river complexes of shallow channels depth.

IV. Discussion

The Bima Formation is a purely continental formation and it forms the base of the sedimentary succession in the Northern Benue Trough lying conformably on the Pre-Cambrian Basement Complex (Cater et al., 1963). The formation is of Aptian – Albian age (Cater et al., 1963) and it is syn-depositionally formed under the tectonic event the led to origin of the Benue Trough. It has attained a maximum thickness of over 3300 meters and was sub-divided into three members on basis of their contained distinctive characteristic facies assemblage (Bima I, Bima II and Bima III) (Guiraud, 1990). The Bima I was believed to have been formed under alluvial fan setting, whereas Bima II and Bima III were exclusively formed under braided river environment (Allix, 1983; Guiraud, 1990; Zaborski et al., 1997). The Bima I which is the lowermost Bima was studied at Telli village, Wuyo village and Bima hill (Fig.3a-d). The facies packages of this formation at Teli village consists of a succession of debris flow deposits defined by gravels imbricated in vary coarse grained sandstone, and these facies association are generally indicative of proximal alluvial fan environment. The outcrop at Bima hill also composes of very coarse grained trough crossbedded sandstones associated with cobbles and gravels, fining upwards to

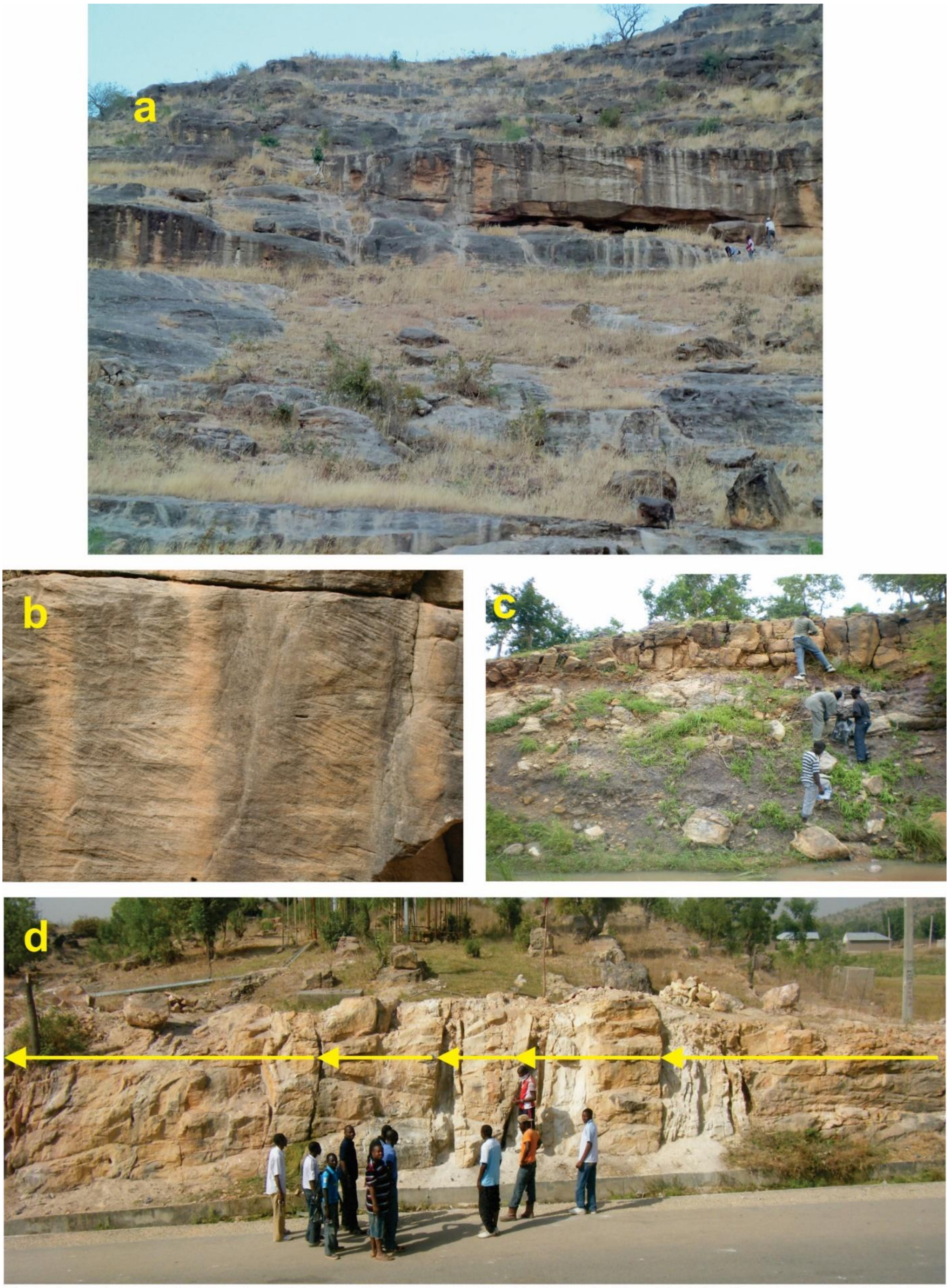

Fig.5 a) Amalgamated channel sandstones of deep channel braided river in Bima II, b) Shallow channel braided river In Bima I, c) Thick mudstones of Bima II d) Fining upwards cycles of deep braided river channels

coarse sandstone. This facies association typically defines proximal braided river deposits of distal alluvial fan environment. These two localities display a contrastingly similar gravely coarse grained lithology, in view of this, the Bima I at these localities may represent low-accommodation depositional sequence (Fig.6), because Catuneanu (2006) indicated that the low accommodation system tracts typically contain the coarsest sediments in the fluvial depositional sequence. Is was further suggested that these lithological feature may reflect early and slow base level rise conditions, leading to absence or restricted occurrence of flood plain deposits (Catuneanu, 2006). The absence of this floodplain facies at these locations may indicate low rate of creation of accommodation space, suggesting a very slow subsidence rate for the basin at that point in time. Sweet et al.(2005) and Catuneanu (2006) indicated that low amount of available accommodation space also control high channel fill to overbank deposit, the facies packages of the Bima I at Wuyo village displayed strikingly similar signatur,e having thick braided in-channel facies and thin overbank deposit. The Bima I Formation at this locality represents its topmost section stratigraphically, and it is the most distal part of the alluvial fan environment, where it interfingers with basinal facies. Therefore, it could be suggested that at this point of the basins development, there could have been a relative increase in subsidence rate, in the overall realm of the low accommodation system tract established for the Bima I Formation because of the relative occurrence of floodplain deposits at the Wuyo village section (Fig.3d). On the overall, the Bima I Formation may generally represent a low accommodation depositional sequence by the virtue of its relative position stratigraphically, lying unconformable on the Pre-Cambrian Basement Complex, because Remaekers and Catuneanu, (2004) indicated that low accommodation system tracts typically forms on top of subarial unconformity. The middle and Upper Bima Formation (Bima II and III) unconformably overlies the lower Bima Formation (Bima II) and composes of sediments ranging from medium- very coarse grand sandstones with thickness varying between 400-600m (Guiraud and Maurin, 1992). The facies association of this formation were studied at five (5) different localities in the Gongola Basin (Fig.3e-i). The association of the lithofacies in all the study locations gave rise to a fining upwards cycle, typically composes of trough cross bedded sandstone having erosion contact and mudclast at base, fining upwards to claystones and mudstones and they are interpreted as braided river channel and overbank facies deposits. Another conspicuous facies that occurs together with these cycles are the thick mudstone facies (Fig.5c), and this facies were interpreted as lacustrine facies (Guiraud, 1993).

The paleogeography of the middle and Upper Bima shows that its depositional profile has graded into transitional environment, because it has clearly been observed that its facies succession has been overstepped conformably by the Cenomanian Yolde Formation at Gabukka and Pantami stream in the Gongola Sub-basin. Therefore, the application of continental sequence stratigraphy in this context was view in terms of both marine influenced base level changes and allogenic controlled base level changes. Shanley and McCabe (1994) indicated that application of sequence stratigraphic concept to fluvial system also changes with location within the basin, pending on the dominance of the agent controlling the fluvial processes i.e. marine or allogenic influenced base level changes. Marine base level changes may only influence fluvial process within limited

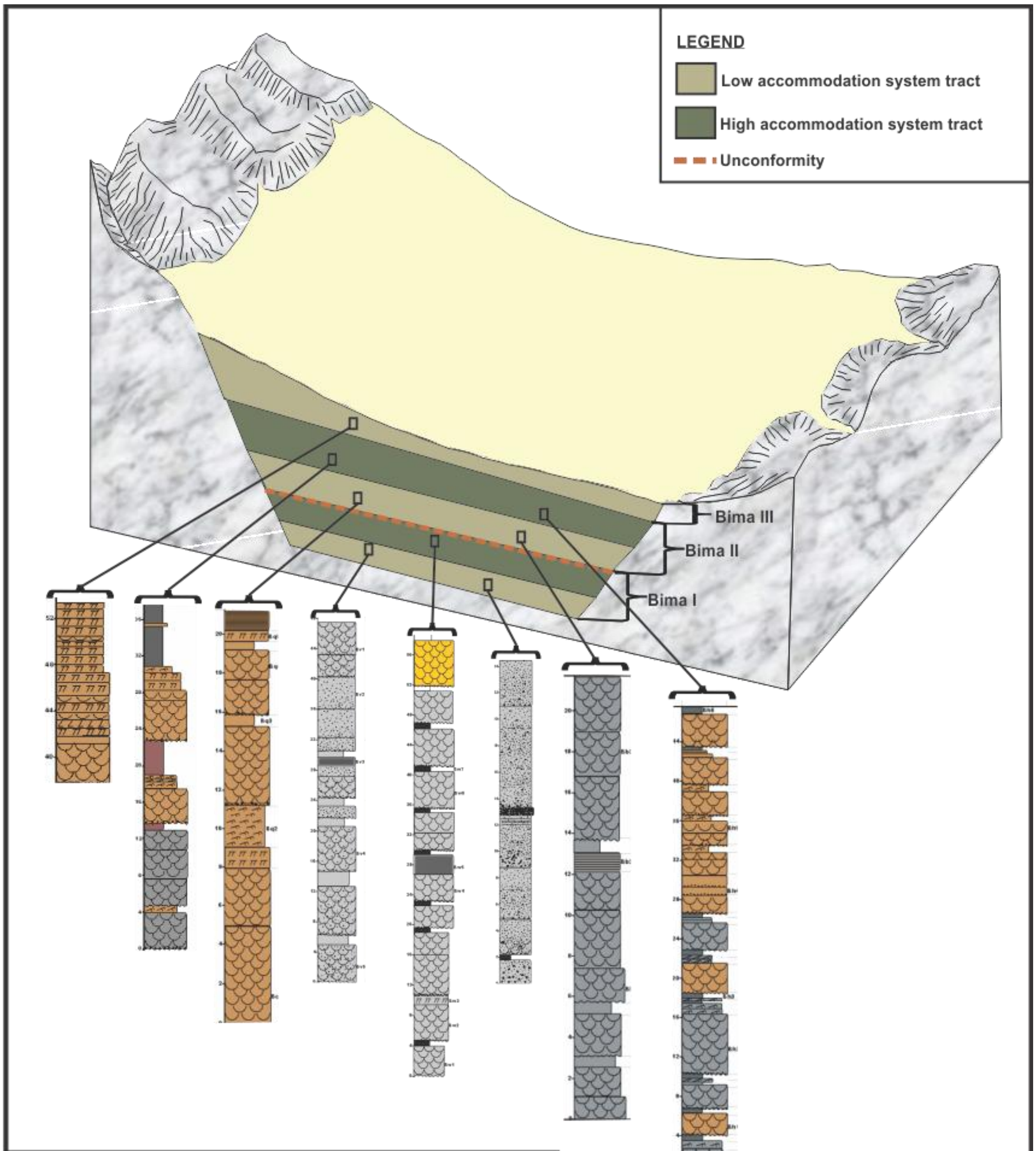

Fig.6 Sequence stratigraphic frameWork of the Bima Formation

distance upstream, in which case the fluvial sequence stratigraphy will be interpreted in term of the traditional nomenclature of lowstand, highstand and transgressive system tract (Posamentier, 2001). Considering the relative position of the Bima II with respect to Yolde Formation representing the onset of marine transgression in the Gongola Basin, it may be suggested that the base level changes in the Bima II was pure controlled by allogenic agents, because its thickness is over 600m, therefore, its horizontal profile is far beyond the reaches of the marine influence of its age equivalent marine deposits of the Asu River Group of the Central Benue Trough. In any case, the limited distance to which marine base level shift can influences fluvial processes is in the range of 200km ((Blum and Price, 1998; Posamentier, 2001), and from arbitrarily evaluation, the distance between the study area and the northern boundary of the Central Benue Trough is over 300m, hence devoid of marine influence. In view of this, the relative increase in the ratio of overbank deposits to channel facies when compared with that of the preceding lower Bima Formation (Bima I) may probably suggest a regime of positive accommodation (Catuneanu and Elago 2001; Remaekers and Catuneanu, 2004), developed as a consequence of improved subsidence rate and other allogenic agents (Catuneanu, 2006). Therefore, the succession of the Bima II may represent high accommodation system tract (Fig.6).

The accommodation of fluvial facies under high accommodation conditions continues during a regime of declining depositional energy, which results in overall fining upwards profile (Boyd et al., 1999; Catuneanu, 2006). The variation of grain size from very coarse to medium grained sandstone to claystone facies in the Bima

II may reflect these conditions, because fall in grain size is indicative of dissipation of deposition energy (Abdel-Wahab, 1992).

The lacustrine deposits are devoid of deep lacustrine facies and they rarely exceed 6m in thickness. Farrell (1987) indicated that semi-arid and arid region where vegetation is less prolific, more sediments can accumulate in the floodplain, in which lakes and swamps can develop. Therefore, this facies most have developed from depression adjacent to floodplain environment. These depressions are indicative of positive accommodation space, and this coupled with the fine grained nature of the sediments accumulating there, it could be suggested that the Bima II represents a high accommodation depositional sequence.

The Bima III unconformably overlies the Bima II and it is of 1700 thick consisting of fine to coarse grained sandstone (Carter et al., 1963). The facies architecture of this formation was studied at Wuyo village and it show a fining upwards cycle defined by a coarse trough crossbedded at base passing upwards to a succession of tabular crossbedded sandstone associated with ripple and parallel lamination (Fig.5b). This facies association represents braided river channel deposit overlain by bar aggradation often referred to as sands flats (Cant and Walker, 1978). The base of the Bima III is defined by an angular unconformity (plate g), and by the virtue of this its relative position, it could be suggested that it was formed under a low accommodation system tract, because this tract typically forms on subarial unconformities reflecting an early stage of renewed sediment accumulation within non marine depozone, owing to rejuvenation of the sediment source area (Catuneanu and Sweet, 2005). Such conditions generally result in a multistory channel fills and a generally lack of floodplain deposits (Catuneanu, 2006), and this is reflected in the section under study, having multistory bar complexes devoid of floodplain materials (Fig5a) (Fig.5c). This facies architecture is underlain by a thick mudstone and their association gave rise to coarsening upwards profile. This signature is very common in low accommodation system tract, because it reflects a gradual spillover of coarse terrigenous sediments from source area into developing basins, on top of fine grained floodplain or lacustrine facies (Rameaker and Catuneanu, 2005; Sweet et al, 2003, 2005; Catuneanu and Sweet, 2005). Considering this facts, it could be suggested conclusive that the Bima III may probably represent low accommodation depositional sequence.

V. Conclusion

Sequence stratigraphic architecture of the Benue Trough developed on the basis of non-marine influenced sedimentation indicated succession of low and high accommodation system tracts. The occurrence of alluvial fans composed of debris flow and braided river facies at the lowermost part of the Bima I Formation presents records of low accommodation system tracts indicative of a slow subsidence rate, whereas the development of floodplains imprinted on braided river deposits at the upper stratigraphic horizons indicate deposition in a high accommodation system tract. Amalgamated channel succession at the base of the Bima II Formation likewise reflect low accommodation system tract which at the upper intervals evolve into high accommodation system tract because of the dominant presences of lacustrine to palustrine setting. The Bima III Formation exclusively composes of shallow channels braided river systems complete devoid of mudstonesfloodplain accumulates signify development under low accommodation system tract.

References

[1]. Abdel-Wahab, A., Kholief, M. & Salem, A. (1992). Sedimentological and Palaeoenvironmental studies on the clastic sequence of Gebel El-Zeit area, Gulf of Suez, Egypt. Journal of African Earth Sciences, 14(1): 121 – 129.

[2]. Abdulkarim H. Aliyu, Y.D. Mamman, M.B. Abubakar, Babangida M. Sarki Yandoka, John Shirputda Jitong & Bukar Shettima (2017), Paleodepositional environment and age of Kanawa Member of Pindiga Formation, Gongola Sub-basin, Northern Benue Trough, NE Nigeria: Sedimentological and palynological approach. Journal of African Earth Sciences, vol.134, 345-351

[3]. Abubakar, M. B. (2006). Biostratigraphy, paleoenvironment and organic geochemistry of the Cretaceous sequences of the Gongola Basin, Upper Benue Trough, Nigeria. Unpublished doctoral dissertation, Abubakar Tafawa Balewa University, Bauchi, Nigeria, 294p.

[4]. Adegoke, O. S., Agumanu, A. E., Benkhelil, J. & Ajayi, P. O. (1986). New stratigraphic sedimentaologic and structural data on the Kerri-Kerri Formation, Bauchi and Borno States, Nigeria. Journal of African Earth Sciences, 5: 249 – 277.

[5]. Allen, P. A. & Hovius, N. (1998). Sediment supply from landslide dominated catchments: implications for basin margin fans. Basin Research, 10: 19 – 35.

[6]. Allix, P. (1983). Environments mesozoiques de la paritc nord-orientale du fosse de la Benue (Nigeria), stratigraphic sedimentologic, evolution goodynmique. Traraux Laboratoire Sciences terre St. Jerome Marselle, (B), 21: 1 – 200.

[7]. anomalies of the Benue valley, Nigeria. Overseas geological Survey Geological paper 1, 1-26.

[8]. Ariyibi, E. A., Onyedim, G. C. & Ayuk, A. M. (2004). Use of magnetotelluric method in structural analysis of part of the middle Benue Trough. Journal of Mining and Geology, 40: 151 – 157.

[9]. Bima Formation (Upper Benue Trough N.E. Nigeria). Journal of African Earth Sciences, 10: 341 – 353.

[10]. Blum, M. D. & Price, D. M. (1998). Quaternary alluvial plain construction in response to glacio-eustatic and climatic controls, Texas Gulf coastal plain. In Relative Role of Eustasy, Climate, and Tectonism in Continental Rocks (K. W. Shanley and P. J. McCabe Eds.), pp. 31–48. SEPM (Society for Sedimentary Geology) Special Publication 59.

[11]. Blum, M. D. (1994). Genesis and architecture of incised valley fill sequences: a Late Quaternary example from the Colorado River, Gulf Coastal Plain of Texas. In P. Weimer & H. W. Posamentier (Eds.); Siliciclastic sequence stratigraphy: recent developments and applications vol 58(pp 259 – 283). Tulsa, American Association of Petroleum Geologists Publication.

[12]. Boggs, S. Jr. (1995). Principle of Sedimentology and Stratigraphy. New Jersey, Prentice Hall, 109p.
[13]. Boyd, R., Diessel, C. F. K., Wadsworth, J., Chalmers, G., Little, M., Leckie, D. & Zaitlin, B. (1999). Development of a nonmarine sequence stratigraphic model. American Association of Petroleum Geologists Annual Meeting, San Antonio, Texas, USA. Official Program, p. A15.
[14]. Bull, W. B. (1963). Alluvial fan deposits in western Fresno County, Califonia. Journal of Geology, 71: 243 – 251.
[15]. Bull, W. B. (1977). The alluvial fan environment. Progress in physical geography, London, Arnold, 222p.
[16]. Cant, D. J. & Walker, R. G. (1978). Fluvial processes and facies sequences in the sandy braided South Saskatchewan River, Canada. Sedimentology, 25: 625 – 648.
[17]. Carter, J. D., Barber, W., Tait E. A & Jones, G. P. (1963). The geology of parts of Adamawa, Bauchi and Borno provinces in north-eastern Nigeria. Bulletin of Geological Survey of Nigeria, 30: 1– 99.
[18]. Catuneanu, O, Abreu, V., Bhattacharya, J. P., Blum, M. D., Dalrymple, R. W., Eriksson, P. G., Fielding, Christopher R., Fisher,W. L., Galloway, W. E., Gibling, M. R., Giles, K. A., Holbrook, J. M., Jordan, R., Kendall, C. G. St.C., Macurda, B., Martinsen, O. J., Miall, A. D., Neal, J. E., Nummedal, D., Pomar, L., Posamentier, H. W., Pratt, B. R., Sarg, J. F., Shanley, K. W., Steel, R. J., Strasser, A., Tucker, M. E. & Winker, C. (2009) Towards the Standardization of Sequence Stratigraphy. Papers in the Earth and Atmospheric Sciences. 238.
[19]. Catuneanu, O. (2006). Principles of Sequence Stratigraphy. Amsterdam, Elsevier, 234p.
[20]. Catuneanu, O. & Elango, H. N. (2001). Tectonic control on fluvial styles: the Balfour Formation of the Karoo Basin, South Africa. Sedimentary Geology, Vol. 140, pp. 291–313.
[21]. Catuneanu, O.& Sweet, A. R. (2005). Fluvial Sequence Stratigraphy and Sedimentology of the Uppermost Cretaceous to Paleocene, Alberta Foredeep. American Association of Petroleum Geologists Annual Convention, Calgary, 23–25 June 2005, Field Trip Guidebook, p. 68.
[22]. Collinson, J. D. (1970). Bedforms of the Tana river, Norway. Geography Annaler, 52: 31–56.
[23]. Collinson, J. D. (2002). Alluvial sedimentation. In H. G. Reading (Eds.); Sedimentary Environments, Process, Facies and Stratigraphy (pp 37 – 82). London, Blackwell.
[24]. Cratchley, C.R. and Jones, G.P. 1965. An interpretation of the geology and gravity anomalies of the Benue valley, Nigeria. Overseas geological Survey Geological paper 1, 1-26.
[25]. Dahle, K., Flesja, K., Talbot, M. R., & Dreyer, T. (1997). Correlation of fluvial deposits by the use of Sm-Nd isotope analysis and mappingof sedimentary architecture in the Escanilla Formation (Ainsa Basin, Spain) and the Statfjord Formation (Norwegian North Sea). Abstracts, Sixth International Conference on Fluvial Sedimentology, Cape Town, 1997, South Africa, pp. 46.
[26]. Dalrymple, R. W. (2010). Introduction to siliciclastic facies models. In N. P. James & R. W.
[27]. Dalrymple (Eds.); Facies Model 4 St John's, Geological Association of Canada Publication.59 – 72.
[28]. Dike, E. F. C. & Onumara, I. S. (1999). Facies and facies architecture, and depositional environments of the Gombe Sandstone, Gombe and Environs, NE Nigeria. Science Association of Nigeria Annual Conference, Bauchi, 67p.
[29]. Dike, E. F. C. (1993). The Stratigraphy and structure of the Kerri-Kerri Basin Northeastern Nigeria. Journal of Mining and Geology, 29(2): 77 – 93.
[30]. Dike, E. F. C. (2002). Sedimentation and tectonic evolution of the Upper Benue Trough and Bornu Basin, Northeastern Nigeria. Nig. Min. Geosci. Soc. 38th Annual and international confer., Port Harcourt, 45p.environments of the Gombe Sandstone, Gombe and Environs, NE Nigeria. Science Association of Nigeria Annual Conference, Bauchi, 67p.
[31]. Fairhead, J. D. & Binks, R. M. (1991). Differential opening of the Central and South Atlantic Oceans and the opening of the west African rift system. Tectonophysics, 187: 181 – 203.
[32]. Fairhead, J.D., Green, C.M., Masterton, S.M., & Guiraud, R., (2013). The role that plate tectonics, inferred stress changes and stratigraphic unconformities have on the evolution of the West and Central African Rift System and the Atlantic continental margins. Tectonophysics, 594, 118–127.
[33]. Farrell, K.M. (1987) Sedimentology and facies architecture of overbank deposits of the Mississippi River, False River region, Louisiana. In: Ethridge FG, Flores RM, Harvey MD (eds) Recent developments in fluvial sedimentology, vol. 39. Society of Economic Paleontologists and Mineralogists, Special Publication, pp 111–120
[34]. Farrington, J. L. (1952). A preliminary description of the Nigerian Lead-Zinc field. Journal of Economic Geology, 42: 583 – 608.
[35]. Genik, G. J. (1992). Regional framework, structural and petroleum aspects of rift basin in Niger, Chad and Central African Republic (CAR). In P. A. Zeigler (Eds.); Geodynamics of rifting, Volume II, Case History Studies on Rift: North and South America and Africa vol 213 (pp 169 – 185). Amsterdam, Elsevier.
[36]. Genik, G. J. (1993). Petroleum Geology of the Cretaceous – Tertiary Rift Basin in Niger, Chad and Central African Republic. American Association of Petroleum Geologists Bulletin, 77(8): 1405 – 1434.
[37]. Gloppen, T. G. & Steel, R. J. (1981). The deposits, internal structure and geometry in six alluvial fan-fan delta bodies (Devonian Norway): a study in the significance of braiding sequence in conglomerates. In F. G. Ethridge & R M. Flores(Eds.); Recent and ancient non-marine depositional systems: models for exploration vol 31 (pp 49 – 69). Tulsa, Society of Economic Palaeontology and Mineralogy Special Publication.
[38]. Grant, N.K., (1971). The south Atlantic Benue Trough and Gulf of Guinea Cretaceous Triple Geol. Sci. of American. Bull. 82, 2295-2298.
[39]. Guiraud, M., (1993). Late Jurassic rifting–Early Cretaceous rifting and Late Creaceous transpressional inversion in the upper Benue Basin (NE Nigeria). Bull. Centres Rech. Explor.—Prod. Elf Aquitaine 17, 371–383
[40]. Guiraud. M., (1990). Tectono-sedimentary framework of the Early Cretaceous continental Bima Formation (Upper Benue Trough N.E. Nigeria). Jour. Afr. Earth Sci., 10, 341-353.
[41]. Haq, B. U., Hardenbol, J. & Vail, P. R. (1987). Chronology of fluctuating sea levels since the Triassic (250 million years ago to present). Science, Vol. 235, pp. 1156–1166
[42]. Hobbs, B.E., Means, D.W.&William, F.P.,(1976). An outline of structural geology: John Wiley and Sons, New York, 384p.
[43]. Likkason, O. K., Ajayi, C. O., Shemang, E. M. & Dike, E. F. C. (2005). Indication of fault expressions from filtered and Werner deconvolution of aeromagnetic data of the Middle Benue Trough, Nigeria. Journal of Mining and Geology, 41(2): 205 – 227.
[44]. Miall, A. D. (1977). A review of braided river depositional environment. Earth Science Review, 13: 1 – 16.
[45]. Mitchum, R. M. Jr. & Van Wagoner, J. C. (1991). High-frequency sequences and their stacking patterns: sequence stratigraphic evidence of high-frequency eustatic cycles. Sedimentary Geology, Vol. 70, pp. 131–160
[46]. Nilsen, T. H. & Moore, T. E. (1980). Selected list of references to modern and ancient alluvial fan deposits. U.S. Geological Survey Open file report, 53: 80 – 658.
[47]. Nilsen, T. H. (1992). Alluvial Fan Deposits. In P. A. Scholle & D. Spearing (Eds.); Sandstone depositional environments vol 38 (pp 49 – 86). Tulsa, American Association Petroleum Geologists Publication.

[48]. Nwajide, C. S. (2013). Geology of Nigeria's sedimentary basins. Lagos, CCSBookshop Ltd, Olade, M. A. (1974). Evolution of Nigerian's Benue Trough (aulacogen): a tectonic model. Geological Magazine, 112: 575 – 583.

[49]. Paola, C. J., Mullin, C. Ellis, D. C. Mohrig, J. B. Swenson, G. Parker, T. Hickson, P. L. Heller, L. Pratson, J. Syvitski, B. Sheets, N. &Strong, B. (2001). Experimental stratigraphy. GSA Today, Vol. 11 (7), pp. 4–9.

[50]. Posamentier, H. W. (2001). Lowstand alluvial bypass systems: incised vs. unincised. American Association of Petroleum Geologists Bulletin, Vol. 85, no. 10, pp. 1771–1793.

[51]. Posamentier, H. W.& Allen, G. P. (1993). Variability of the sequence stratigraphic model: effects of local basin factors. Sedimentary Geology, Vol. 86, p. 91–109.

[52]. Posamentier, H. W., Jervey, M. T. & Vail, P. R. (1988). Eustatic controls on clastic deposition I – conceptual framework. In Sea Level Changes–An Integrated Approach (C. K. Wilgus, B. S. Hastings, C. G. St. C. Kendall, H. W. Posamentier, C. A. Ross and J. C. Van Wagoner, Eds.), pp. 110–124. SEPM Special Publication 42.

[53]. Ramaekers, P. & Catuneanu, O. (2004). Development and sequences of the Athabasca Basin, Early Proterozoic, Saskatchewan and Alberta, Canada. In P. G. Eriksson, W. Altermann, D. Nelson, W. Mueller & O. Catuneanu (Eds.); The Precambrian Earth: Tempos and Events vol 12 (pp 705 – 723). Amsterdam, Elsevier.

[54]. Schumm, S. A. (1977). The fluvial system. New York, John Wiley and Sons, 338p.

[55]. Schumm, S. A. (1993). River response to baselevel change: implications for sequence stratigraphy. Journal of Geology, Vol. 101, pp. 279–294.

[56]. Selley, R. C. (1997). The basins of Northwest Africa: Stratigraphy and sedimentation. In R. C.

[57]. Selley (Eds.); "African Basins" (pp 3 – 16). Amsterdam, Elsevier.

[58]. Shanley, K. W. & McCabe, P. J. (1994). Perspectives on the sequence stratigraphy of continental strata. American Association of Petroleum Geologists Bulletin, Vol. 78, pp. 544–568

[59]. Shanley, K. W., McCabe, P. J. & Hettinger, R. D. (1992). Significance of tidal influence in fluvial deposits for interpreting sequence stratigraphy. Sedimentology, Vol. 39, pp. 905–930.

[60]. Shettima, B. Dike, E.F.C. Abubakar, M.B., Kyari, A.M. & Bukar, F. (2011). Facies and facies architecture and depositional environments of the Cretaceous Yolde Formation in the Gongola Basin of the Upper Benue Trough, northeastern Nigeria. Global Journal, Vol.10, No.1, 67p

[61]. Shettima, B., (2016). Sedimentology, Stratigraphy and Reservoir Potentials of the Cretaceous Sequences of the Gongola Sub – basin, Northern Benue Trough, NE Nigeria. PhD Thesis Abubakar Tafawa Balewa University, Bauchi, 267p.

[62]. Shettima, B., Abubakar, M.B., Kuku, A & Haruna, A.I. (2018), Facies Analysis, Depositional Environments and Paleoclimate of the Cretaceous Bima Formation in the Gongola Sub - Basin, Northern Benue Trough, NE Nigeria. Journal of African Earth Sciences, vol. 137, 193-207

[63]. Smith, N. D. (1970). The braided stream depositional environment: comparison of Platte River with some Silurian clastic rocks. Geological Society of American Bulletin, 81: 2993 – 3014.

[64]. Sweet, A. R., Catuneanu, O. & Lerbekmo, J. F. (2005). Uncoupling the position of sequence-bounding unconformities from lithological criteria in fluvial systems. American Association of Petroleum Geologists Annual Convention, 14: 136p.

[65]. Sweet, A. R., Long, D. G. F. & Catuneanu, O. (2003). Sequence boundaries in fine-grained terrestrial facies: biostratigraphic time control is key to their recognition. Geological Association of Canada–Mineralogical Association of Canada joint annual meeting, Vancouver, May 25–28, Abstracts Volume 28, p. 165.

[66]. Tucker, M. E. (2003). Sedimentary Rocks in the field. West Sussex, John Wiley & Sons Ltd, 83 – 158p.

[67]. Tukur, A., Samaila, N.K., Grimes, S.T., Kariya, I.I.& Chaanda, M.S., (2015). Two member subdivision of the Bima Sandstone, Upper Benue Trough, Nigeria: based on sedimentological data. J. Afr. Earth Sci. 104, 140 e158.

[68]. Van Wagoner, J. C., Mitchum, R. M. Jr., Campion, K. M. & Rahmanian, V. D. (1990). Siliciclastic sequence stratigraphy in well logs, core, and outcrops: concepts for high-resolution correlation of time and facies. American Association of Petroleum Geologists Methods in Exploration Series 7, p. 55.

[69]. Van Wagoner, J. C., Posamentier, H. W., Mitchum, R. M. Jr., Vail, P. R., Sarg, J. F., Loutit, T.

[70]. S.& Hardenbol, J. (1988). An overview of sequence stratigraphy and key definitions. In Sea Level Changes–An Integrated Approach C. K. Wilgus, B. S. Hastings, C. G. St. C. Kendall, H. W. Posamentier, C. A. Ross and J. C. Van Wagoner, Eds.), pp. 39–45. SEPM Special Publication 42.

[71]. Wilson, M., & Guiraud, R., (1992). Magmatism and rifting in Western and Central Africa, from Late Jurassic to Recent times. Tectonophysics213, 203–225

[72]. Wright, J. B. (1989). Review of the origin and evolution of the Benue Trough. In C. A. Kogbe (Eds.); Geology of Nigeria (pp 125 – 173). Jos, Rock view (Nigeria) Ltd.

[73]. Wright, V. P.& Marriott, S. B. (1993). The sequence stratigraphy of fluvial depositional systems: the role of floodplain sediment storage. Sedimentary Geology, Vol. 86, pp. 203–210.

[74]. Zaborski, P., Ugodulunwa, F., Idornigie, A., Nnabo, P. & Ibe, K. (1997). Stratigraphy, Structure of the Cretaceous Gongola Basin, Northeastern Nigeria. Bulletin Centre Researches Production Elf Aquitatine, 22: 153 – 185.

[75]. Zaitlin, B. A., Warren, M. J., Potocki, D., Rosenthal, L. & Boyd, R. (2002). Depositional styles in a low accommodation foreland setting: an example from the Basal Quartz (Lower Cretaceous), southern Alberta. Bulletin of Canadian Petroleum Geology, Vol. 50, no. 1, pp. 31–72.

Bukar Shettima, et. al. "Sequence Stratigraphic Framework of the Aptian-Albian Bima Formation of the Gongola Sub-basin, Northern Benue Trough, NE Nigeria."*IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 8(4), (2020): pp 22-35.