BRAIDED RIVER FACIES MODEL OF EARLY CRETACEOUS SEDIMENTS (UPPER BIMA) MEMBER FROM THE YOLA SUB-BASIN, NORTHERN BENUE TROUGH, NE NIGERIA

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ABSTRACT

Facies model was conducted on the Early Cretaceous sediments of Upper Bima Member from Yola Sub-basin of the Northern Benue Trough, northeastern Nigeria with an objective of interpreting the depositional setting and paleoenvironments. The sedimentary logs/sections compriseof the two (2) main facies associations; the pebbly-sandy and the sandy-silty associations. The sediments were interpreted as deposition in channel and floodplain complex of the braided river depositional system. This formed the basis for reconstructing the depositional framework of the Upper Bima Member in Yola Sub-basin as braided river facies model. The findings however, supported the earlier interpretations from the neighbouring sediments of Bima Formation from the Gongola Sub-basin. It also supports the two end-member sub-division for the Cretaceous sequences of Bima Formation.

Keywords: Yola Sub-basin; Bima Formation; Braided river; Facies model; Depositional model

INTRODUCTION

The Early Cretaceous sediments of Bima Formation formed the basal part of sedimentary succession in the Northern Benue Troughof Nigeria (Carter et al., 1963; Nwajide, 2013; Sarki Yandoka, et al., 2014; Tukur et al., 2015; Shettima et al., 2018; Aliyuda, et al., 2019). The Northern Benue Trough is divided into major two basins; the Gongola Sub-basin and the Yola Sub-basin (Figure 1). The Bima Formation was believed as deposition in a continental environment under different conditions which include;alluvial fans, braided river and lacustrine systems (Guiraud, 1993; Samaila et al., 2006; Sarki Yandoka, 2015; Nwajide, 2013; SarkiYandoka et al., 2014 among many others). The Bima Formation have the same age equivalent, origin and paleo depositional setting with the Early Cretaceous sediments within the West and Central Africa Rift System (WCARS); e.g. Chad Basin of Chad Republic, Muglad Basin of Sudan Republic and Termit Basin ofNiger Republic. Commercial hydrocarbons were discovered in the basins within the same rift system. In Gongola Sub-basin, detail studies related to facies analysis was conducted by many authors.

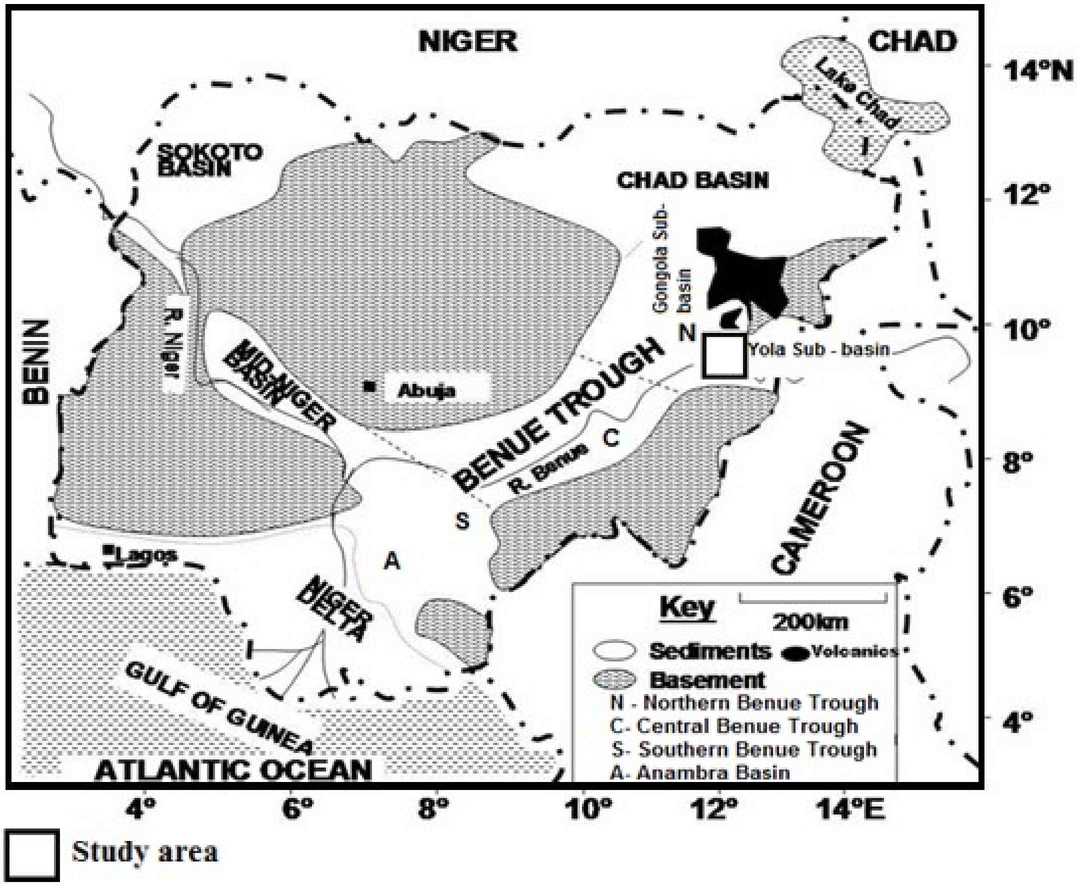

Figure 1: Geological map of Nigeria showing study area (after SarkiYandoka, 2015)

Braided channels consists of a network of river channels separated by small, often temporary, islands called braid bars. Deposits of braided rivers tend to be coarse-grained and contain abundant amalgamated channels (Miall, 1996). Braided river facies models consist of up to three gravel facies, five sand facies and two fine-grained facies. Vertical sequences recorded in modern and ancient deposits are of several types: flood-, channel fill-, valley fill-, channel re-occupation- and point bar-cycles (Miall, 1996, 2010; Nichols, 2009; SarkiYandoka, 2015). The Bima Formation was interpreted as deposition in alluvial, braided and lacustrine environments. The formation was divided into Lower Bima (B1), Middle Bima (B2) and Upper Bima (B3) members by Carter et al., (1963) and Zarborski et al., (1997). Tukur et al., (2015) suggest only two end-member divisions. There are limited facies studies on Upper Bima member from the Yola Sub-basin.

The Upper Bima member (B2), the subject of this study, was unconformably overlying the Lower Bima member (B1) (Guiraud, 1990). The two members were seperated by an angular unconformity (Guiraud, 1990) and the Upper Bima member were considered post-proto rift mega sequences, deposited during rifting phase I and thermotectonic sag stage (Guiraud, 1993). The sediments composed of coarse and medium grained sand-stones having planar, trough and tabular cross stratifications, interbedded with clays and soft sediment deformation structures (Carter et al., 1963;

Samaila et al., 2006; SarkiYandoka et al., 2014). The sandstones are occasionally cross-bedded and may contain some scattered pebbles. The Upper Bima member was conformably overlain by the Cenomanian transgressive (transitional) sequences of Yolde Formation during the rifting Phase II that affected the entire Benue Trough (Guiraud, 1990).

SarkiYandoka et al., (2014) provided the sedimentological and stratigraphical information of Lower Bima Member (B1) from Yola Sub-basin. The study confirmed the presence of lacustrine deposits as identified in the basins of Sudan, Niger and Chad Republics. This study however, present the facies model using sedimentary logging, facies analysis and stratigraphic distribution studies of Upper Bima Member from the exposed sediments of Yola Sub-basin with an objective of interpreting the depositional facies, paleoenvironments and to reconstruct the depositional model within stratigraphic context. The study is important for analog reservoir characterisation for the current hydrocarbon exploration campaigns and resource assessment of the region.

MATERIALS AND METHODS

The Benue Trough is a major rift basin within the West and Central African System (WCARS). It was formed during the Late Jurassic – Early Cretaceous (SarkiYandoka et al., 2014; Tukur et al., 2015; Shettima et al., 2018). The Benue Trough is also filled with approximately 6000 m of Cretaceous to Tertiary sediments with Neogene volcanics (Carter et al., 1983; SarkiYandoka et al., 2014). The trough was sub-divided geographically into Southern (Lower), Central (Middle) and Northern (Upper) Benue (SarkiYandoka et al., 2014) (Figure 1). The Northern Benue Trough is also sub-divided into two; the Gongola Sub-basin and the Yola Sub-basin (Abubakar, 2014; SarkiYandoka et al., 2014; SarkiYandoka, 2015) (Figure 1).

The Yola Sub-basin consist of continental Early Cretaceous Bima Formation, the Cenomanian shallow-marine sequences of Yolde Formation and the coastal-shallow marine sediments of the Late Cenomanian to Santonian age; the Dukul, Jessu, Sekuliye Formations, Numanha Shales and LamjaFormations (Carter et al., 1966; Abubakar, 2014; SarkiYandoka, 2015) (Fig. 3). The Bima Formation is the oldest sedimentary unit (Figure 2). The formation was believed to have been derived from Basement Rocks deposited in a continental environment (Carter et al., 1963; Guiraud, 1990, Guiraud and Maurin, 1992; SarkiYandoka et al., 2014).

Based on recent references, Bima Formation was differentiated into only two members; the Lower Bima (B_1) and Upper Bima (B_2) members (Tukur et al., 2015; SarkiYandoka, 2015). The Lower Bima member (B_1) as the oldest sedimentary unit, consists of conglomeratic, gravels and very coarse to coarse grained sandstone with well-defined fining-upward succession and large scale trough and planar cross stratifications (Guiraud, 1990; SarkiYandoka et al., 2014; SarkiYandoka, 2015), deposited in an alluvial fan, braided river and lacustrine (Kogbe, 1976; SarkiYandoka et al., 2014). The sediments were considered as syn-rift deposits during the Aptian – Albian times (Guiraud, 1993; SarkiYandoka et al., 2014).

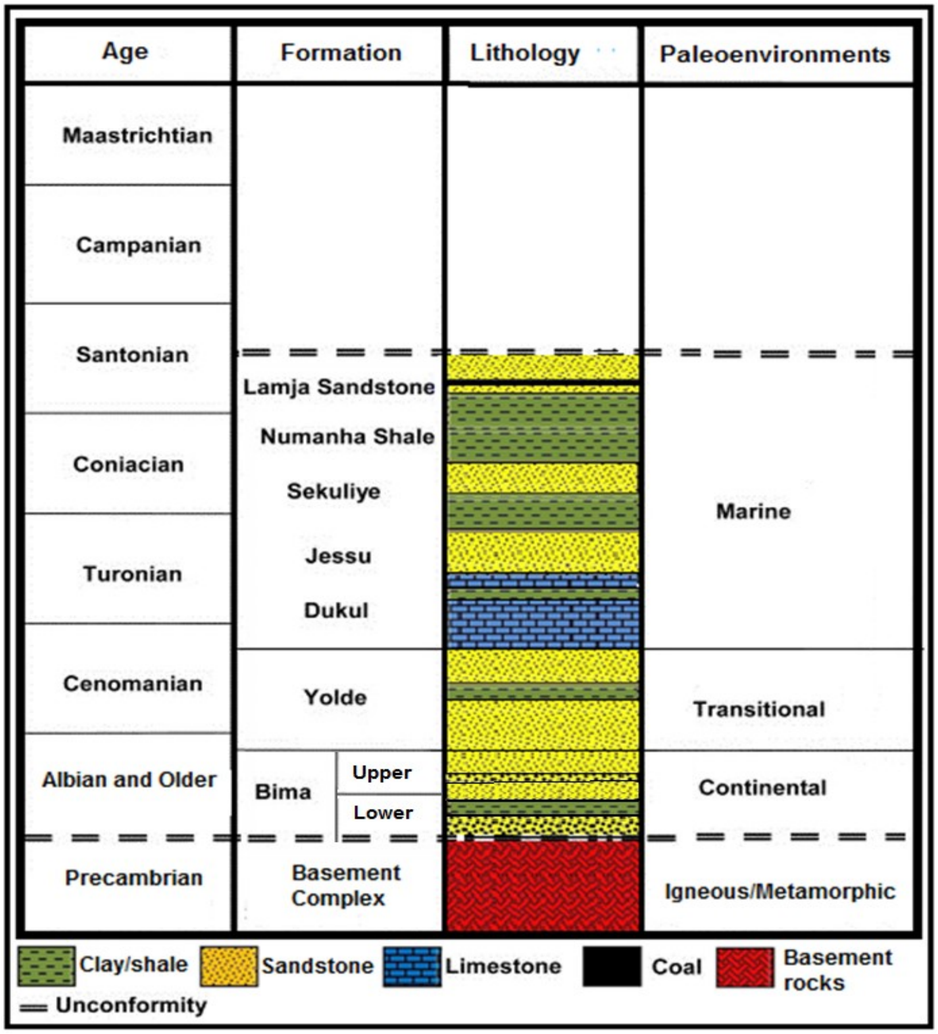

Figure 2: Stratigraphy of Yola Sub-basin (after SarkiYandoka, 2015)

Sedimentology field studies were carried out onthe exposed sections of Upper Bima member in six different localities (Fig. 2) within Yola Sub-basin. The sedimentary sections were described and logged in detail (Fgs. 4 and 5). Each of the studied section display part of a braided river depositional system although, none exhibit complete sequence. The sedimentary logs were recorded using measuring tape and log sheet. Coordinate points and field photographs were recorded from outcrops using camera, compass and GPS. Bed thicknesses, texture and sedimentary structures were measured and recorded in the field. The sedimentary logs however, documented in greater detail the bed-scale sedimentology and internal geometry that allowed detail sedimentary facies analysis and stratigraphical distribution studies. This allows reconstruction of the facies and depositional models of the Upper Bima member (B2).Facies analysis was conducted on the logged sections of Upper Bima member around Tula road, Bolleri and Gundali rivers. The facies are grouped into two facies associations and interpreted based on physical, biological and chemical processes which revealed depositional environments.

RESULTS

Facies Analysis

Theoutcrops of Upper Bima member from Yola Sub-basin composed of pebbles, coarse and medium grained sand stones with cross beddings and soft sediment deformation structures (Figure 3, 4 and 5). The facies were studied based on sedimentary structures and textures and interpreted following the works of Miall, (1996), SarkiYandoka et al., (2014) and others.

Facies Spg: Planar cross stratified sandstone

This is characterised by planar cross stratified, brownish to pinkish colored, pebbles and coarse-grained sandstone. Thickness of beds may reach up to 1.5 – 2 m in total. It is commonly overlain by large scale cross bedded sandstone (Sp) facies (Figure 4). It is laterally entensive displaying fining upward character.The Spg Facies is interpreted as deposits formed due to a migration of point bar in gravel bed stream channels(Miall, 1996, 2010). Similar of this type of facies was interpreted as high-energy braided river channel deposit (Nilsen, 1982).

Facies Stg: Trough cross stratified sandstones

This is characterised by trough cross bedded, brownish to buff colored, moderately to relatively poorly sorted, pebbles to very coarse-grained sandstones. Thickness of the beds may reach up to 1.5 - 2.5 m. Top of most of the beds are usually erosive with pebble lag (Figure 4). The grain sizes generally decrease upward thereby displaying a fining upward sequence. It is interpreted as deposit that formed by vertically accretion on a longitudinal bar (SarkiYandoka, 2015; Collinson, 1996). Similar facies were interpreted as deposition due to migration of sinuous subaqueous dunes in an out washed braided stream (Nichols, 2009).

Facies St: Trough cross bedded sandstone

This facies is characterised by trough cross bedded, coarse and medium grained, moderately sorted sandstone that reached up to about 1.5 - 3.5 m thick (Figure 4; Table 1). It continuous vertically and laterally.It interbeds with planar cross bedded (Sp) facies, parallel laminated sandstone (Sh) facies and massive bedded sandstone (Sm) facies. Similar of the facies type are interpreted as deposit that formed due to the migration of sandy 3-D dunes (sinuous) in braided river channel (Miall, 1996; Nichols, 2009; SarkiYandoka et al., 2014).

Facies Sp: Planar cross bedded sandstone

The Sp facies composed of a planar cross bedded, coarse and medium grained, that is moderately sorted sandstones. Thicknesses of beds are ranging from 2.5 – 6 m (Figure 4). The facies is commonly interbedded with trough cross bedded and parallel laminated facies. This facies is correspond to the Sp facies of Miall (e.g. Miall, 1977, 1996 and 2010). It is interpreted as deposits produced by the migration of bed forms like sandy or linguoid 2-D dunes (Miall, 1977, 1996, 2010) or transverse bars (e.g. Harms et al., 1995).

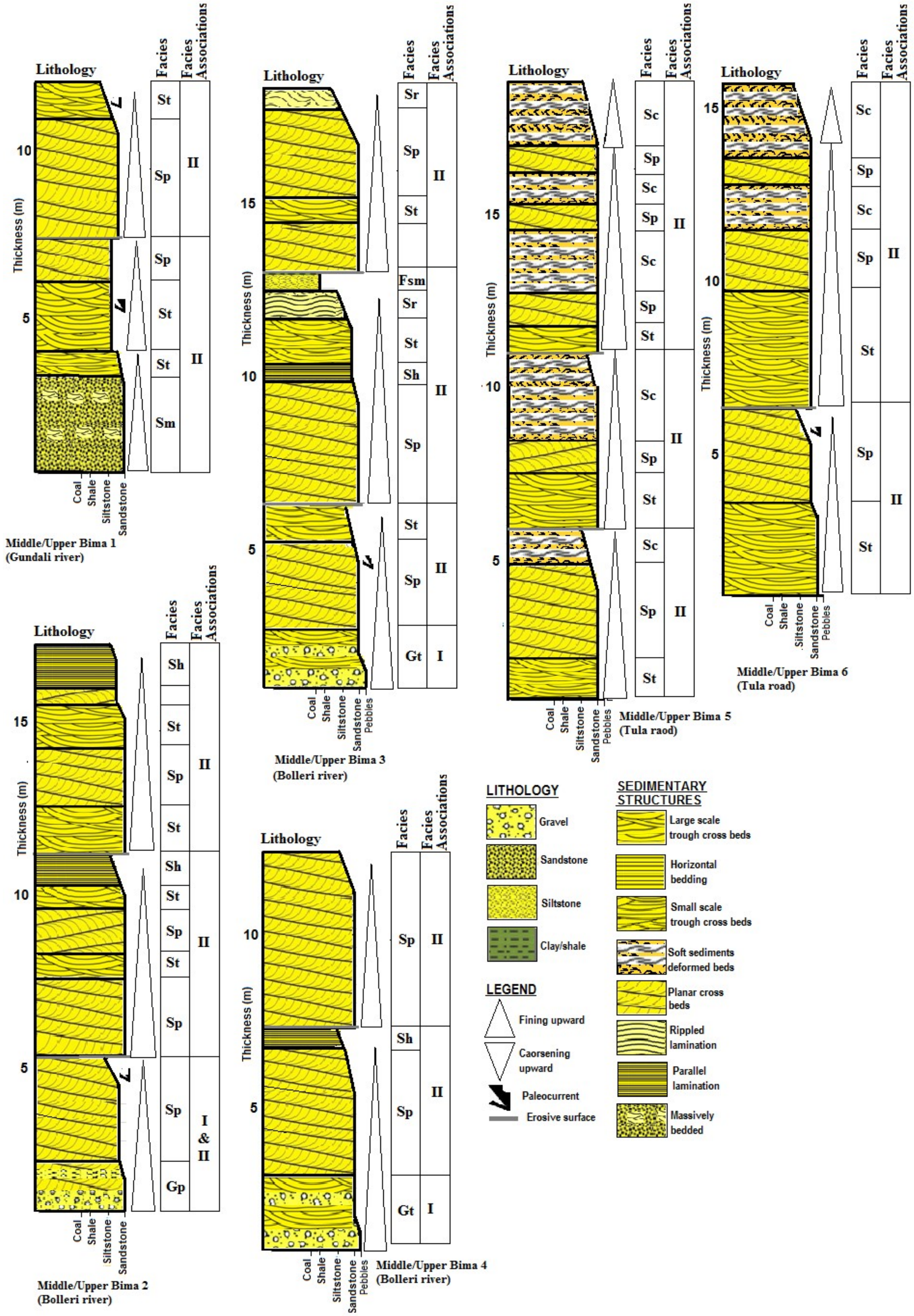

Figure 3: Lithostratigraphic section of Upper Bima Member based on this study

Figure 4: Planar cross-stratified sand and gravels (Spg), parallel laminated sandstone (Sh), trough cross-stratified sand and gravels (Stg), trough cross bedded sandstone (St) and massive bedded sandstone (Sm), planar and trough cross bedded sandstone (St, Sp)

Figure 5: Soft sediment deformation sandstone (Sc) facies.

Facies Sm: Massive bedded sandstone

The facies is characterised by amalgamated massively bedded, light brownish to brownish, pebbles to very coarse and coarse grained, poorly sorted sandstones. Thickness of this facies reached up to 3 m. It is also massively bedded with fining upward trend.However, previous authors such as Miall (1996) identified this lithofacies for the massive bedded sandstones, that are deposited in a small channels resulting from over bank collapse. More so, similar of the facies type were interpreted as depositformed due torapid deposition during waning floods (Harms et al. 1995; Collinson, 1996).

Facies Sh: Horizontally bedded sandstone

The facies consists of parallel or perhaps horizontally bedded, brownish to a pinkish, very coarse to coarse grained, moderately and poorly sorted sandstones. Thickness of the beds is about 0.6- 1 m (Figure 4). There is harp contact at the base, interbedded with trough cross bedded and planar cross bedded sandstones (St and Sp Facies). The Sh Facies is generally interpreted as upper flow bed deposition (Miall, 1977, 1996, 2010; Nichols, 2009) or plane bed deposition under a relatively lower flow regime (SarkiYandoka, 2015; Harms et al., 1995).

Facies Sr: Rippled cross-laminated sandstone

This lithofacies is characterised by rippled cross-laminated, deep brownish medium and coarse grained as well as moderately sorted sandstones. Thickness of beds reached up to 0.5 m. The facies is overlain by fine grained silty clays of the Fm Facies. The facies points to deposition due to migrating of current ripples (ripple cross laminae) under lower flow regime (Table 1 and Miall, 1984, 2010; SarkiYandoka et al., 2014).

Facies Sc: Soft sediments deformed sandstone

This facies is characterised by a soft sediments deformed beds. It consists of reddish to brownish colored, medium and coarse grained, relatively moderately sorted sandstones. The facies is ranging from 2 - 3 m thick (Fig. 5). The sediments hosting the structures are sandwiched between planar cross bedded and trough cross bedded facies with no major textural differences. This facies is generally interpreted as seismic induced fluidization structure in a turbulent flow within the braided river channel system (Boggs, 1987, 2006; Nichols, 2009; SarkiYandoka et al., 2014; Owen, 1995, 1996; Bristow, 1993; Samaila et al., 2006).

Facies Fm: Fine clay and silts

This facies consists of silty clays, comprising of a small thick layers with a maximum thickness of 0.4 m. The facies is overlain by the ripple cross-laminated sandy beded (Sr) facies thereby, ending the fining upward package in the mega sequences. The Fm facies was identified by Miall (e.g. Miall, 1996, 2010) and interpreted as suspension settling deposition produced from weak currents, overbank fines or floodplain deposits (Harms et al. 1995; SarkiYandoka et al., 2014; Miall, 2010).

Table 1: Summary of facies description and interpretation in Upper Bima Member

Lithofacies	**Description**	**Interpretation**
Trough cross stratified sandstones (Stg)	Well-rounded pebbles, very coarse moderately to poorly sorted, pebble rich very coarse grained, about 1.5-2m thick	Deposition by longitudinal bars
Planar cross stratified sandstone (Spg)	Well-rounded pebbles, moderately to poorly sorted, pebble rich very coarse grained, about 1.5 m thick	Migration of transverse bars in braided river channels
Trough cross bedded sandstone (St)	Medium to coarse grained sandstone, moderately sorted, beds ranging 0.5 to 3.5m thick	Linguoid and lobate bars (High flow regime), 3-D dunes
Planar cross bedded sandstone (Sp)	Medium to fine grained sandstones, moderately sorted, 5-6m thick	Transverse bars and sand waves (Lower flow regime), 2-D dunes
Massive bedded sandstone (Sm)	Pebbles to very coarse grained sandstone, poorly sorted, show grading or very faint, patchy lamination, reached up to 1.5m	Rapid deposition from during waning floods
Horizontally bedded sandstone (Sh)	Very coarse to coarse grained sandstones, moderately to poorly sorted, with a thickness of about 0.6m	Upper flow bed deposition under high or low flow regime
Rippled cross-laminated sandstone (Sr)	Medium to coarse grained sandstone, moderately sorted beds reached 0.4m	Migrating current ripples under lower flow regime
Soft sediment deformed sandstone (Sc)	Medium to coarse grained sandstones, abundant soft-sediment deformation structures; convolute bedding, deformed cross-beddings, cusps, droplets and sand volcanoes, 2-3 m thick	Post – depositional soft sediment deformation deposit
Fine clay/silts (Fm)	Silty clays comprising millimeter to centimeter thick layers, attain a maximum of 0.4m.	Overbank or floodplain deposits

Facies codes are slightly modified from Miall (1996, 2010) and SarkiYandoka et al. (2014)

Paleocurrent Analysis

Palaeocurrents are used with facies analysis to make palaeogeographic reconstructions. The data are collected during logging of a sedimentary section from localities in order to increase the size of the data set. Paleocurrent readings were recorded from Upper Bima Member mainly from sedimentary structures such as cross beddings and current ripples that indicate direction of sediments transportation. The paleocurrent trends in the outcrops are generally towards NNW and NW directions as shown in Figure 6.

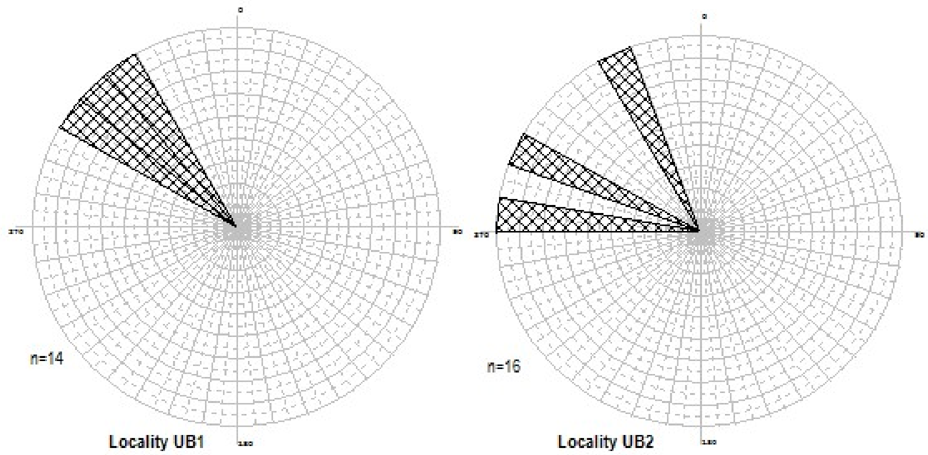

Figure 6: Paleocurrent flow direction of Upper Bima Member from Yola Sub-basin

DISCUSSION

Facies Associations and Succession

Facies association represent facies that are genetically related in terms of depositional environments (Nichols, 2009). The eight (8) identified facies formed two main facies associations; the pebbly-sandy and sandy-silty associations. The pebbly-sandy dominated facies association consists of trough cross stratified sand-stones (Stg) facies and planar cross stratified sandstones (Spg) facies (Table 1). The sandy-silty dominated association constitute five major facies association, namely; trough cross bedded (St) facies, the planar cross bedded (Sp) facies, the massive bedded (Sm) facies, parallel laminated (Sh) facies and the soft sediment deformed (Sc) facies (Table 1). The two facies associations formed one major facies succession.

Facies succession however, represents the depositional environment of sedimentary sequences. Figure 7 shows a summary of the braided river facies succession (facies model) of the Upper Bima Member from Yola Sub-basin.The facies succession of the braided river is made up of the gravelly-sandy and the sandy-silty dominated facies associations. The predominance of the moderately and poorly-sorted, cross-bedded, pebbles to coarse grained sandstones with fining-upward packages and a well-rounded clast indicates deposition within the braided river channels (Miall, 2010). The upward transition from the massive sandstone (Sm) to cross bedded sandstone (St and Sp facies) is modelled as a product of waning flow in a relatively braided river facies system (Blair and McPherson, 1994; Miall, 1996, 2010). However, Sc Facies are deposited due to seismic shocks and pressure in a braided river system (SarkiYandoka et al., 2014) whereas the fine-grained silty clays (Fm) are over bank deposit accumulated by the settling of suspended load in a flooded area of braided channel (Miall, 1996, 2010).

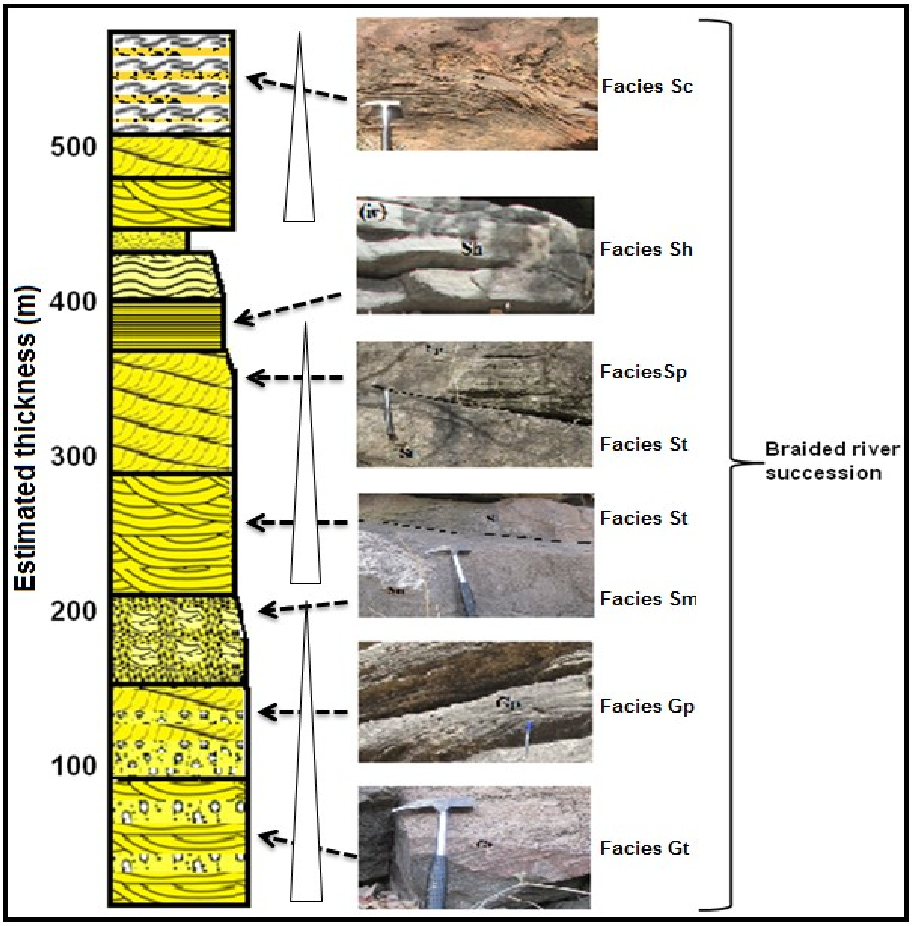

Figure 7: Facies model of Upper Bima member showing inferred depositional environment

Paleodepositional Environment

Facies model using sedimentary logging, facies studies comprising of facies, facies associations, facies succession and stratigraphical distribution relationships was conducted. The model summarised the concept of depositional framework for the Cretaceous successions of Upper Bima Member which reflect a braided river facies model. The depositional model is based on a braided river system (Fig. 8). The gravelly-sandy cross stratified beds were inferred to be deposited in the braided river channels by either transverse bars, longitudinal bars or sandy dunes. Sandy-silty cross stratified sandstone beds were deposited on bar tops in an upstream portion of the braid bars. The channel deposits generally fine upwards. Upstream parts of sand channels contain deposits of a smaller unit bars. The small scale cross bedded sandstones generally decreases upwards, to a relatively parallel and ripple cross-laminated sandstone beds as channel fills.

The various sandstone channels had experienced deformation from seismic shocks and soft sediments deformed sandstone beds have been deposited in an entrenched braided river system. The fine clay silts occur mostly as over-bank or floodplain deposits. The deposits capped channel-belts and form drapes in major troughs of channel bars and dunes within the braided river complex. Facies analysis of Bima Formation have permitted the generalized determination of paleodepositional facies as progradational and retrogradation successions. In general, the Bima Formation was deposited in a continental environment (alluvial fans, braided river and lacustrine) as ?pre-rift and syn-rift (Lower Bima member) and perhaps, post-rift (Upper Bima member) sequences during the Early Cretaceous (Guiraud, 1993).

CONCLUSION

Facies model using facies analysis and stratigraphical distribution studies on the exposed sediments of Upper Bima member from Yola Sub-basin allows overall identification of depositional processes, environments and reconstruction of depositional models and stratigraphic development for the successions. The sedimentary structures, textures and other field features revealed nine (9) facies which constitute the gravelly sandy dominated and the sandy silty dominated facies associations. The facies associations represent the braided river facies succession. The Upper Bima Member however, indicates a retrogradation and fining upward motif of a braided river deposits (channel and floodplain), dominated by sandy dunes associated with deeply entrenched channels of braided river, channels aggraddations, sand flat formation and post-depositional soft sediments deformation structures. Soft-sediment deformed structures in the Upper Bima member could have been generated due to the earlier reported syn-depositional Mesozoic volcanism (Jurasic-Albian times) that affected the Northern Benue Trough. The braided river facies model could be use as ingredient for analog hydrocarbon reservoir modeling.

REFERENCES

Abubakar, M.B., 2014. Petroleum Potentials of the Nigerian Benue Trough and Anambra Basin: A Regional Synthesis. Natural Resources, 5(1), 25–58.

Aliyuda, K., Howell, J., Usman, M.B., Bello, A.M., Maina, B., Abubakar, U., (2019) Depositional variability of an ancient distributive fluvial system: The upper member of the lower cretaceous Bima Formation, Northern Benue Trough, Nigeria. Journal of African Earth Sciences. 159, Article 103600

Bata, T., Parnell, J., Samaila, N.K., Abubakar, M.B., Maigari, A.S., (2015). Geochemical evidence for Cretaceous oil sand (Bima oil sand) in the Chad Basin, Nigeria. Journal of African Earth Sciences 111, 148 – 155.

Blair, T.C., McPherson, J.G., (1994). Alluvial fan and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes and facies assemblages. Journal of Sedimentary Research A64, 450–489.

Boggs, S., (1987). Principles of Sedimentology and Stratigraphy, Maxwell Macmillan International Publication Company, New York, p. 784.

Boggs, S. Jr., (2006). Principles of Sedimentology and Stratigraphy, 4th edition, Prentice Hall, 662 p.

Bristow, C.S., (1983). Sedimentary structures exposed in bar tops in the Brahmaputra River, Bangladesh, in: Best, J.L., Bristow, C.S. (Eds.), Braided Rivers. Geological Society Special Publication 75, pp. 277–289.

Carter, J.D., Barber, W., Tait, E.A., Jones, G.P., 1963. The geology of parts of the Adamawa, Bauchi and Bornu Provinces in Northeastern Nigeria. Geological Survey Nigerian Bulletin 30, 53–61.

Collinson, J.D., (1996). Alluvial sediments, In: Reading, H. G. (Ed.), Sedimentary environments and facies. Blackwell Scientific Publications, Oxford, pp. 20 – 62.

Dalrymple, R.W., (2010). Interpreting sedimentary successions: facies, facies analysis and facies models, in: James, N.P., Dalrymple, R.W. (Eds.), Facies Models 4. Geological Association of Canada, St. John's Newfoundland, pp. 3-18.

Falconer, J.D., (1911). The Geology and Geography of Northern Nigeria. Macmillian: London, UK. 147- 154.

Friend, P.F., (1966). Clay fractions and colours of some Devonian red beds in the Catskill Mountains, USA. Journal of Geological Society London 122, 273–292.

Guiraud, R., Maurin, J. E., 1992. Early Cretaceous rifts of Western and Central Africa: an overview, in: P.A., Ziegler, (Eds.), Geodynamics of Rifting, Volume II. Case History Studies on Rifts: North and South America and Africa. Tectonophysics, 213, 153–168.

Guiraud, M., 1990. Tectono-sedimentary frameworks of the Early Cretaceous continental Bima Formation (Upper Benue Trough, NE Nigeria). Journal of African Earth Sciences 10, 341 –353.

Harms, J.C., Southard, J.B., Spearing, D.R., Walker, R.G., (1995). Depositional environments as interpreted from primary sedimentary structures and stratification sequences. SEPM Short Course 2 (161 pp.).

Kogbe, C.A., 1976. Paleogeographic history of Nigeria from Albian times, in: Geology of Nigeria, Kogbe, C.A., (Eds.). Elizabethan Publishers, Lagos, Nigeria, pp: 237-252.

Miall, A.D., 1996. The Geology of Fluvial Deposits, Sedimentary Facies, Basin Analysis, and Petroleum Geology: New York, Springer, pp. 582.

Miall, A.D., 2010. Lithofacies classification, in: Noel P. James, and Robert W. Dalrample, (Eds.), Facies Models 4, Canadian Sedimentology Research Group, pp. 111 -119.

Nichols, G.J., 2009. Sedimentology and stratigraphy. John Wiley and Sons, New York, 452p.

Nilsen, T.H., (1982). Alluvial fan deposit, in: Sholle, P. A., Spearing, D., (Eds.), Sandstone Depositional Environments, Volume 31 American Association of Petroleum Geologist Memoir, pp. 49 – 86.

Nwajide, C.S., 2013. Geology of Nigeria's Sedimentary Basins.CSS Bookshops Ltd., Lagos, Nigeria, 565pp.

Owen, G., (1995). Soft sediment deformation in Upper Torridonian Sandstones, Northwest Scotland. Journal of Sedimentary Research A65, 495 – 504.

Owen, G., (1996). Experimental soft sediment deformation structure formed by the liquefaction of unconsolidated sands and some ancient examples. Sedimentology 43, 279 – 293.

SarkiYandoka B.M., Abubakar M.B., Abdullah, W.H., Amir Hassan M.H., Adamu, B.U., Jitong, J.S., Aliyu, A.K., Adegoke, K.A., (2014). Facies analysis, palaeoenvironmental reconstruction and stratigraphic development of the Early Cretaceous sediments (Lower Bima Member) in the Yola Sub-basin, Northern Benue Trough, NE Nigeria. Journal of African Earth Sciences 96, 168–179.

SarkiYandoka, B.M., (2015). Sedimentary and organic facies characterisation of the Cretaceous sequences, Yola Sub-basin, Northern Benue Trough, NE Nigeria.

Unpublished PhD thesis, University of Malaya, Kuala Lumpur, Malaysia.

Samaila, N.K., Abubakar, M.B., Dike E.F.C, Obaje N.G., 2006. Description of soft-sediment deformation structures in the Cretaceous Bima Sandstone from the Yola Arm, Upper Benue Trough, Northeastern Nigeria. Journal of African Earth Sciences 44, 66–74.

Zarboski, P.F.,Ugodulunwa, A., Idornigie, P.,Nnabo, K., Ibe, (1997). Stratigraphy and structure of the CretaceousGongola Basin, Northeast Nigeria. Bulletin des Centres Research Exploration and Production Elf Aquataine21(1), 154–185.