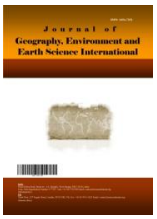

Journal of Geography, Environment and Earth Science International

24(5): 65-72, 2020; Article no.JGEESI.58122
ISSN: 2454-7352

Tidal Rhythmites Depositional System of the Cretaceous Yolde Formation of the Gongola Sub-basin Northern Benue Trough N. E. Nigeria

B. Shettima[1*], B. Shettima[1], M. Bukar[1], B. Shettima[1], H. I. Kamale[1], A. O. Umaru[1] and I. A. Yerima[1]

[1]Department of Geology, University of Maiduguri, Nigeria.

Authors' contributions

All the authors participated in field work where data sets used in producing this research article were generated. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2020/v24i530228
Editor(s):
(1) Kaveh Ostad-Ali-Askari, Najafabad Branch, Islamic Azad University, Iran.
Reviewers:
(1) Mauricio O. Zamponi, Mar del Plata University, Argentina.
(2) Swetalina Parhi, Geological Survey of India, India.
(3) Abbache Abdelkader, Mascara University, Algeria.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58122

Original Research Article

Received 18 April 2020
Accepted 23 June 2020
Published 25 July 2020

ABSTRACT

Facies evaluation carried out on the Yolde Formation at Gabukka locality in the Gongola Sub-basin of the Northern Benue Trough was aimed at enacting its paleo-depositional environment. The formation at this locality revealed an intercalated succession of massive bedded sandstone facies (Sm), planar crossbedded sandstone facies (Sp), ripple laminated sandstone facies (Sr), parallel laminated sandstone facies (Sl) and mudstone facies (Fm). These successions developed a thinning and thickening stratigraphic profile depicting periodic rhythmic signatures indicating deposits of tidal rhythmites. Thickening rhythmic packages are reflective of a spring tide whereas thinning phases are indicative of neap tide. These depositional sequences are genetic to intense tides conditions, thus an indexing a tide dominated oceanographic within the course of development of the Cretaceous Yolde Formation.

Keywords: Tidal rhythmites; depositional system; Yolde Formation; Gongola Sub-basin; Benue trough.

**Corresponding author: E-mail: drsab2010@yahoo.com;*

1. INTRODUCTION

Tidal rhythmicity is typically conditioned to tide dominated oceanographic systems and the mid-Cretaceous marine transgression that inundated the West and Central African Rift System set the template for their evolution. The Gongola Sub-basin forming part of this rift system is the north-south trending arm of the Northern Benue Trough that represent the tip of Benue Trough (Fig. 1), evolving primarily due to of separation of the African plate from the South American plate, occurring during the late Jurassic to early cretaceous times. Current, the evolution is this remained controversial, however the rift and pull-apart theories were considered to be more resounding. The rift model theory was proposed at inception by earlier workers and supported to date [1,2,3,4] indicating initiation through tensional regimes induced by mantle plume convection activities [5,6]. This is opposed to the pull-apart model because of the absences of boundary fault that are proxy to rifting, therefore considered the trough as of strike-slip tectonic origin, as it falls in tune and orientation to the major transcurrent fault systems of the Romanche, Chain and Charcot suture zones [7,8,9]. The opening of the trough is followed by transgressive and regressive phases in the Aptian-Albian times with the Northern Benue Trough characterized by continental depositional regimes. Transgressional activity reached this part of the trough in the Cenomanian, depositing transitional-marine sequences of the Yolde Formation. This researched is aims to evaluate the facies and facies association of this formation at Gabukka stream that represents one of its major outcrops in the Gongola Sub-basin in order to establish depositional model that characterizes its development this locality.

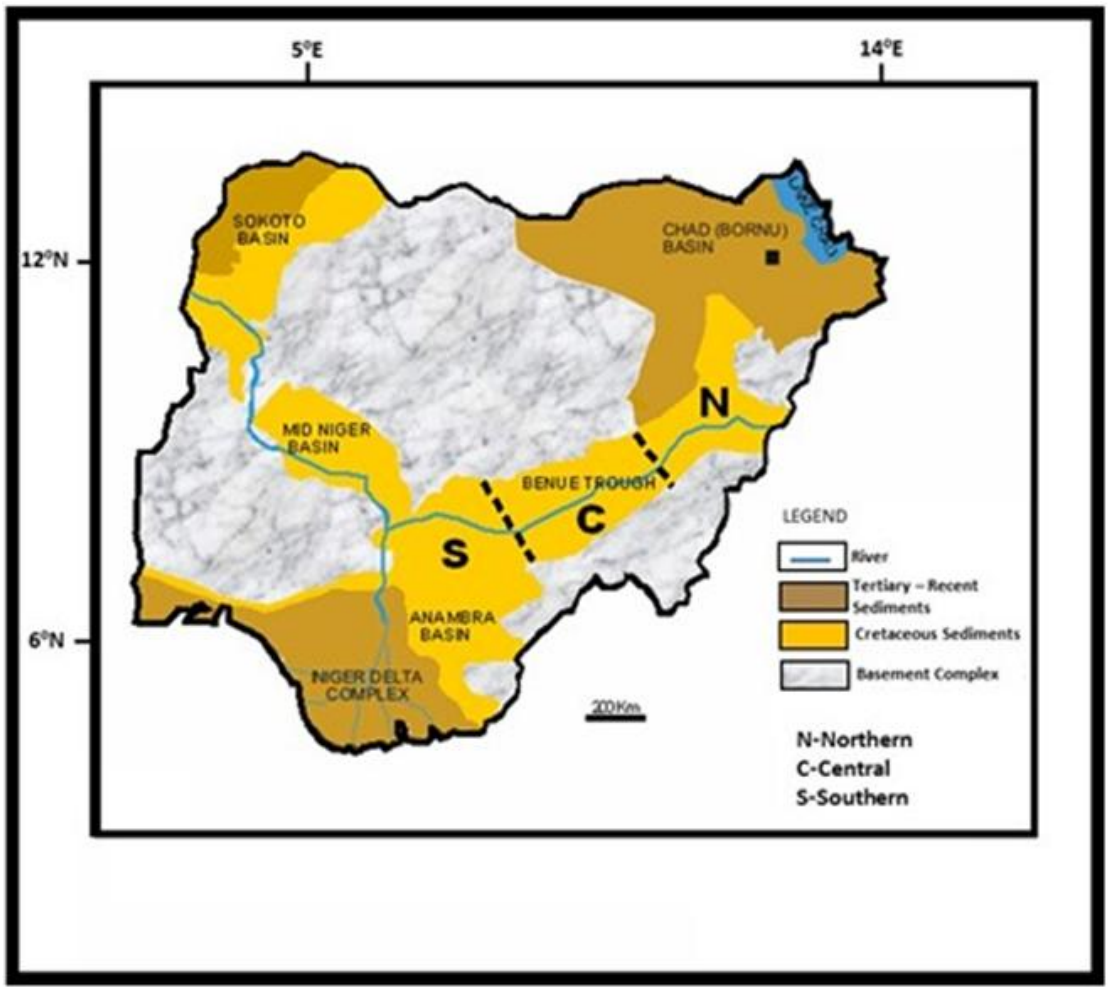

Fig. 1a. Geological map of Nigeria showing the benue trough

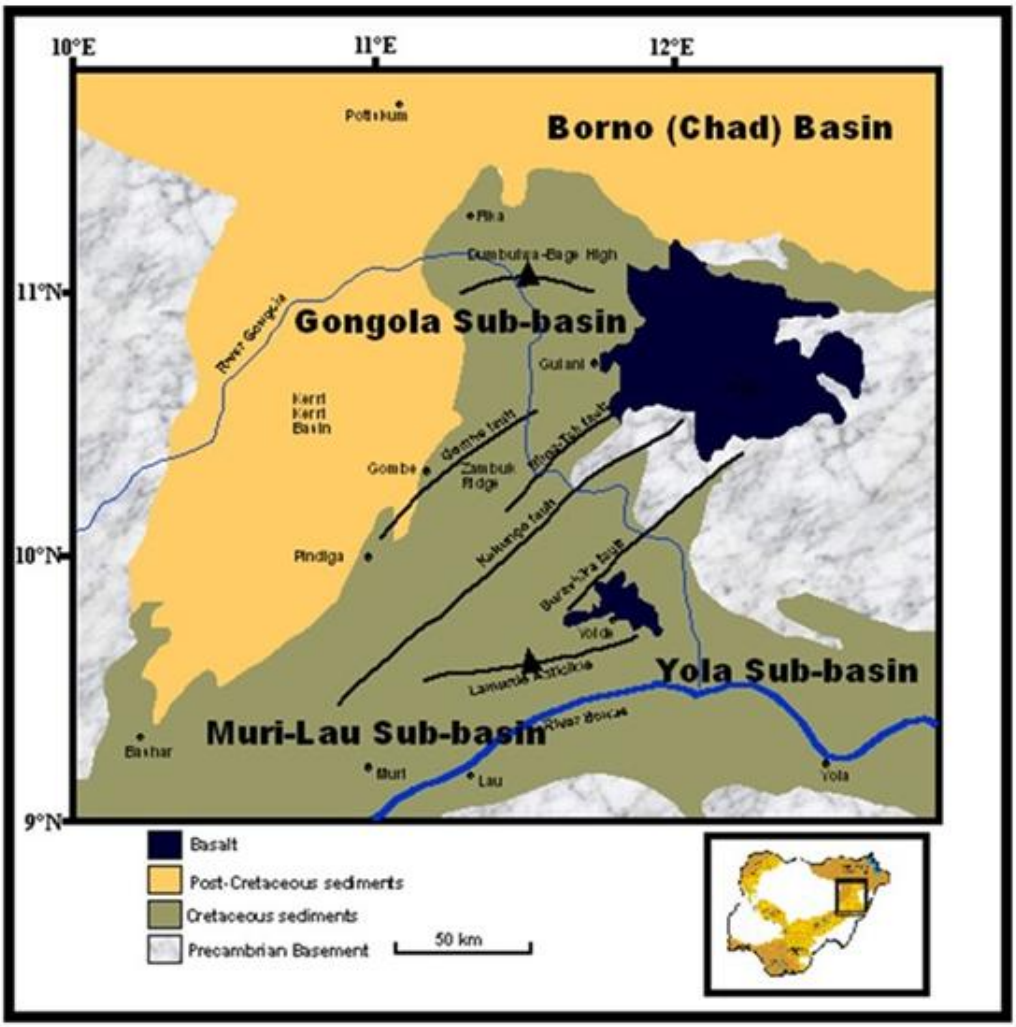

Fig. 1b. Geological map of the Northern Benue Trough

1.1 Geological and Stratigraphic Setting

The Benue Trough of Nigeria is a rift basin in the Central West Africa that extends NNE-SSW for about 1000 km in length and 50-150 km in width [3,10]. The Benue Trough is geographically subdivided into Northern, Central and Southern Benue Trough (Fig. 1). The Northern Benue Trough constitutes of three arms: The N-S striking Gongola Arm, E-W striking Yola Arm and the NE-SW striking Muri-Lau Arm [11]. The Trough contains over 6000 m deep consisting of Cretaceous to Tertiary sediments of which those predating the mid-Santonian have been tectonically deformed, to form major faults and fold systems across the basin. The Bima Group of the Aptian-Albian represents the oldest sedimentary units in the Gongola Sub-basin, conformably overlying the Basement Complex Rocks (Fig. 2) [12,13,14,15]. The deposition of syn-rift sequences thereof is largely controlled by the horst and graben systems and is represented by the alluvial fan-lacustrine deposits of the Bima I Formation, the lowermost in the group, which is unconformably superposed by the post-rift braided river sequences of the Bima II and III Formations [13,14,15]. This is conformably superposed by the Yolde Formation in the Cenomanian, marking a transitional-marin deposits [16]. This representing the onset of the mid-Cretaceous global marine transgression in the basin [17] and reached its acme in the Turonian depositing the shallow marine shale and limestone sequences of the Kanawa Member of the Pindiga Formation [13,18]. Regressive Sandy Members of the Dumbulwa,

Deba-Fulani and Gulani sandstones conformably followed in the mid-Turonian with decelerating transgressive conditions (Fig. 2) [13,10]. Renewed rising relative sea levels in the late Turonian transcending into the Coniacian and early Santonian set in the deposits of the deep marine blue-black shales of the Fika Member, representing the youngest units of the Pindiga Formation [13,19]. This marine transgression is accompanied by compressional tectonics in the mid-Santonian [20], which resulted from changing orientation of the displacement vectors between the African plate and European/Tethys plates [21]. This event led to thrusting of the pre-Maastrichtian sediments towards the west of the Gongola Sub-basin, creating an accommodation for the deposition of the Campano-Maastrichtian regressive deltaic sequences of the Gombe Formation [22,19]. The mid-Maastrichtian is also characterized by another phase of compressional event and thereafter followed by the unconformably deposits of the Paleogene fluvio-lacustrine Kerri Kerri Formation [23,24] (Fig. 2). The Paleogene-Neogene is notable for volcanics, emplaced along the eastern margin of the Gongola Sub-basin [25].

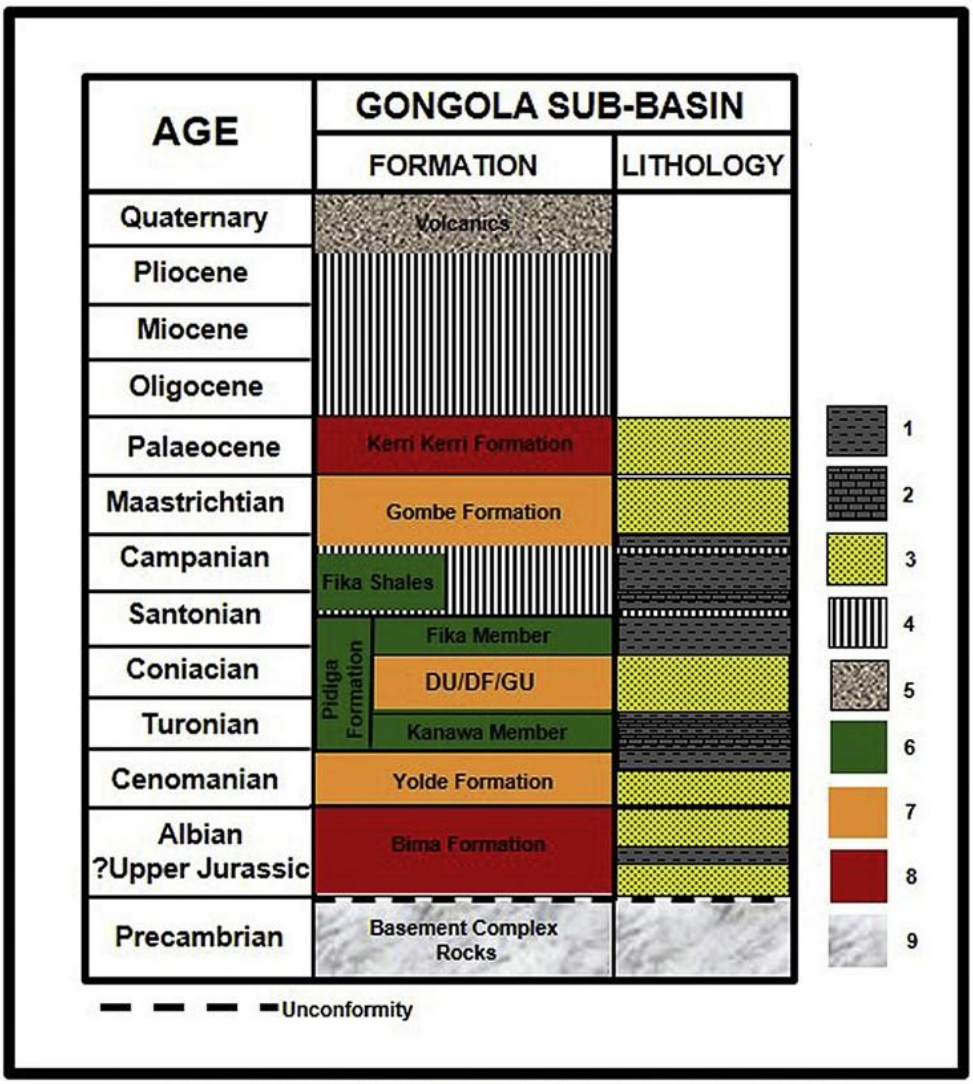

Fig. 2. Showing the stratigraphy of the gongola sub-basin
1-mudstone, 2-limestone, 3-sandstone, 4-hiatus, 5-basalt, 6-marine sediments, 7-transitional-marine sediments, 8-continental sediments, 9-basement complex (du-dumbulwa member, df-deba fulani member, gu-gulani member

2. MATERIALS AND METHODS

Topographic and structural maps of Gombe town and environs were employed in the fieldwork of this research to identify potential areas where Yolde Formation are well exposed. Along these well exposed outcrops identified, lithostratigraphic sections of this Formation outcropping around Gabukka stream (Fig. 3) were systematically logged to record data on lithologic variations, texture, bed geometry, paleocurrents, sedimentary structures and fossil content. Based on facies concept and application of Walters law in conjunction with facies relation provided by sedimentologic studies on ancient and modern environment, these data were utilized in designating lithofacies assemblages representing particular depositional environment. 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 [26]. The dip and strike -plus the azimuth of the crossbeds were measured using compass clinometers in this analysis, and furthermore subjected to tilt correction using the procedure of [26].

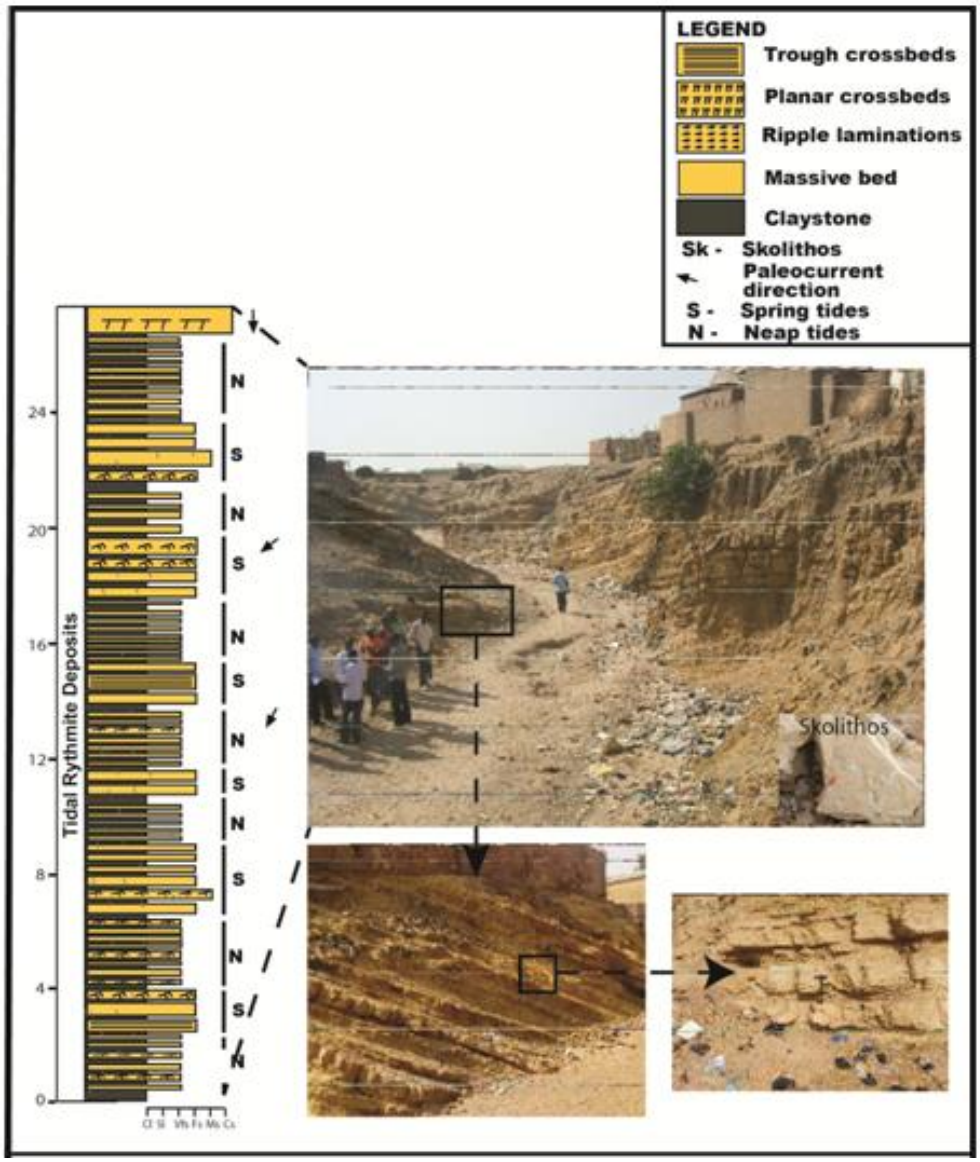

Fig. 3. Showing lithostratigraphic section of the yolde formation at gabukka locality

3. RESULTS

3.1 Sedimentary Facies Characterization

This facies association is formed of successive sequence of horizontally bedded sandstones 2-40 cm interbedded with mudstones of 2-10 cm amalgamating to build succession of over 20 m thick. This package typically displays very fine – fine grained sandstones dominantly of parallel laminated (Sl), ripple laminated (Sr) and massive bedded (Sm) sandstone facies (Fig. 3). Uncommonly, coarser units and planar crossbedded sandstone facies (Sp) are also noticeable often bearing soft sediment deformational structure. The stacked succession of these units are characterized with systematic packages of thickening and thinning clusters of horizontally stratified sandstone units showing marked differentiations in grain sizes, predominantly of fine grained texture in thickening sequences and very fine to siltstones in the thinning packages. Boundaries are generally sharp and bioturbation are scarce, but records of Skolithos ichnofacies are common. Paleocurrent evaluation from the few planar crossbeds and relatively inclined horizontal stratification indicate a southwestern trend.

4. DISCUSSION

These stratigraphic packages displaying sandstones-mudstones symmetry arranged in a relatively predefined harmonic pattern, scarcely bioturbated by Skolithos ichnogenera are indications of a tidal rhythmites deposits [27,28]. These alternations between sand-mud accounts for interchanging dynamics of high and low tide energy and the periodic rarefaction and compression of thicknesses configured to reflect neap-spring tidal sedimentation cycles [29,30]. The mudstone units are product of slack-water periods, appearing as thicker couplets interbedded with thinner plane horizontal sandstone, suggesting deposition during neap tides, commonly occasioned with weak tidal current, thus promoting maximum mud deposition. Contrarily, generation of thicker sandstone beds interbedded with less mudstones packages are skewed to spring tides which is typically accompanied by strong tidal currents [31]. Presences of coarse grained units in these packages are probable indication of attenuated tidal regime deposits, likely driven by superposed wind processes [32], whereas the less common planar crossbedded units are functions of re-circulatory flow from tidal flow separation associated with large dune migration [33]. The vertical burrows of the low diversity Skolithos ichnofacies consisting of Skolithos is reflective of tidal agitations [34]. Rarity and absence of bioturbations at several intervals are account of high sedimentation rate or changing salinity conditions, most probably induced by high flux of fresh water [35,36].

5. CONCLUSION

The stratigraphic architectural packages of the Yolde formation outcropping at Gabukka locality in the Gongola Sub-basin is composed of five lithofacies that comprises of massive bedded sandstone facies (Sm), planar crossbedded sandstone facies (Sp), ripple laminated sandstone facies (Sr), parallel laminated sandstone facies (Sl) and mudstone facies (Fm). These sandstones facies interbedded with mudstones facies are organized into thickening and thinning packages that reflects spring and neap tides. This implies an intense tide conditions, invariably indicating tide dominated oceanographic regimes, thus the development of the tidal rhythmite stratigraphic architecture in the Cretaceous Yolde Formation at Gabukka locality Gongola Sub-basin of the Northern Benue Trough.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. King LC. Outline and distribution of Gondwanaland. Geol. Mag. 1950;87:353-359.
2. Wright JB. Review of the origin and evolution of the benue trough. In Kogbe CA, (Eds.); Geology of Nigeria. Jos, Rock view (Nigeria) Ltd. 1989;125–173.
3. Genik GJ. Regional framework, structural and petroleum aspects of rift basin in Niger, Chad and Central African Republic (CAR). In Zeigler PA. (Eds.); Geodynamics of rifting, Volume II, Case History Studies on Rift: North and South America and Africa.1992;213:169 –185.
4. Fairhead JD, Green CM, Masterton SM. Guiraud R. 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. 2013;594:118–127.
5. Olade MA. Evolution of Nigerian's Benue Trough (aulacogen): A tectonic model. Geological Magazine. 1974;112:575–583.
6. Burke K, Dessauvagie TFG, Whiteman AJ. The opening of Gulf of Guinea and geological history of the Benue depression and Niger delta. Nature Physical Science. 1971;233:51–55.
7. Benkhelil J. The origin and evolution of the Cretaceous Benue Trough (Nigeria). Journal of African Earth Sciences. 1989;8:251–282.
8. Likkason OK, Ajayi CO, Shemang EM, Dike EFC Indication of fault expressions from filtered and Werner deconvolution of aeromagnetic data of the Middle Benue Trough, Nigeria. Journal of Mining and Geology. 2005;41(2):205–227.
9. Onyedim GC, Arubayi JB, Ariyibi EA, Awoyemi MO, Afolayan JF. Element of wrench tectonics deduced from SLAR imagery and aeromagnetic data in part of the middle Benue Trough. Journal of Mining and Geology. 2005;41:51–56.
10. Nwajide CS. Geology of Nigeria's sedimentary basins. Lagos, CCS Bookshop Ltd. 2013;45-89.
11. Dike EFC. 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. 2002; 45.
12. Guiraud M. Tectono-sedimentary framework of the Early Cretaceous continental Bima Formation (Upper Benue Trough N.E. Nigeria). Jour. Afr. Earth Sci. 1990;10:341-353.
13. Zaborski P, Ugodulunwa F, Idornigie A, Nnabo P, Ibe K. Stratigraphy, structure of the cretaceous Gongola Basin, Northeastern Nigeria. Bulletin Centre Researches Production Elf Aquitatine. 1997;22:153–185.
14. Tukur A, Samaila NK, Grimes ST, Kariya II, Chaanda MS Two member subdivision of the Bima Sandstone, Upper Benue Trough, Nigeria: Based on sedimentological data. J. Afr. Earth Sci. 2015;104:140-158.
15. Shettima B, Abubakar MB, Kuku A, Haruna AI. 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. 2018;137:193-207.
16. Shettima B, Dike EFC, Abubakar MB, Kyari AM, Bukar F. 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. 2011;10(1):67.
17. Haq BU, Hardenbol J, Vail PR. Chronology of fluctuating sea levels since the Triassic (250 million years ago to present). Science. 1987;235:1156–1166.
18. Abdulkarim H, Aliyu YD, Mamman MB, Abubakar, Babangida M, Sarki Yandoka, John Shirputda Jitong, Bukar Shettima. 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. 2017;134:345-351.
19. Shettima B. 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. 2016;267.
20. Genik GJ. Petroleum Geology of the Cretaceous – Tertiary Rift Basin in Niger, Chad and Central African Republic. American Association of Petroleum Geologists Bulletin. 1993:77(8):1405–1434.
21. Fairhead JD, Binks RM. Differential opening of the Central and South Atlantic Oceans and the opening of the west African rift system. Tectonophysics. 1991; 187:181–203.
22. Dike EFC, Onumara IS. Facies and facies architecture, and depositional environments of the Gombe Sandstone, Gombe and Environs, NE Nigeria. Science Association of Nigeria Annual Conference, Bauchi. 1999;67.
23. Dike EFC. The Stratigraphy and structure of the Kerri-Kerri Basin Northeastern Nigeria. Journal of Mining and Geology. 1993;29(2):77–93.
24. Adegoke OS, Agumanu AE, Benkhelil J, Ajayi PO. New stratigraphic sedimentologic and structural data on the Kerri-Kerri Formation, Bauchi and Borno States, Nigeria. Journal of African Earth Sciences. 1986;5:249–277.
25. Wilson M, Guiraud R. Magmatism and rifting in Western and Central Africa, from

Late Jurassic to Recent times. Tectonophysics. 1992;213:203–225.
26. Tucker ME. Sedimentary Rocks in the field. West Sussex, John Wiley & Sons Ltd. 2003;83–158.
27. Driese SG An analysis of large-scale ebb-dominated tidal bedforms: Evidence for tidal bundles in the Lower Silurian Clint Sandstone of east Tennessee: Southeastern Geology. 1987;27:121–140.
28. Wells MR, Allison PA, Hampson GJ, Pig Gott MD, Pain CC. Modelling ancient tides: the Upper Carboniferous epi-continental seaway of Northwest Europe. Sedimento-logy. 2005;5 (4):715–735.
29. Boerma JR, Terwindt JHJ. Neap-Spring tide sequences of intertidal shoal deposits in a mesotidal estuary. Sedimentology. 1981;28:151-170.
30. Jensen M, Larsen E, Demidov IN, Funder S, Kjær KH. Depositional environments and sea-level changes deduced from Middle Weichselian tidally influenced sediments, Arkhangelsk region, northwestern Russia. BOREAS. 2006;35: 521-538.
31. Dalrymple RW, Rhodes RN. Estuarine dunes and barforms. In: Geomorphology and Sedimentology of Estuaries. (Eds. G.M. Perillo). Dev. Sedimentology. 1995; 53:359–422.
32. Yang B, Dalrymple RW, Chun S. The significance of hummocky cross-stratification (HCS) wavelengths: Evidence from an open-coast tidal flat, South Korea. Journal of Sedimentary Research. 2006; 76:2-8.
33. Tape CH, Cowan CA, Runkel AC. Tidal bundle sequences in the Jordan Sandstone (Upper Cambrian), southeastern Minnesota, U.S.A.: Evidence for tides along inboard shorelines of the Sauk epicontinental sea. Journal of Sedimentary Research. 2003;73:354–366.
34. Gingras MK, Mac Eachern JA. Tidal ichnology of shallow-water clastic setting. Principle of Tidal Sedimentology. 2012; 57-77.
35. Martino RL, Sanderson DD. Fourier and autocorrelation analysis of estuarine tidal rhythmites, lower Breathitt Formation (Pennsylvanian), eastern Kentucky, USA. Journal of Sedimentary Petrology. 1993; 63:105-119.
36. Mac Eachern JA, Bann KL. The role of Ichnology in refining shallow marine facies models. In: Recent Advances in Models of Siliciclastic Shallow-Marine Stratigraphy (Eds Hampson GJ, Steel RJ, Burgess PM, Dalrymple RW), SEPM Spec. Publ. 2008; 90:73-116.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/58122