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 13-21
www.iosrjournals.org

Tide Dominated Delta System of the Cretaceous Yolde Formation of the Gongola Sub-basin Northern Benue Trough N.E. Nigeria

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Abstract
The characterization and evaluation of lithofacies of the Yolde Formation at Zambuk village in the Gongola Sub-basin of the Northern Benue Trough indicated occurrences of six lithofacies that comprises of trough crossbeds, planar crossbeds, massive beds, ripple laminations, parallel laminations and mudstone. Resulting facies associations indicated a coarsening and shoaling upward cycles consisting of a mud dominated lower part displaying severe bioturbations transitionally grading into heterolithic interval composed thinly bedded sandstone and mudstones. This succeeded by succession of moderately bioturbated planar crossbedded sandstone with wedged shape geometries. This assemblage account for a deposits of a tide dominated delta with the lower mud dominated zones indicating deposition under low energy fair weather wave base, progressively building intensity to develop tidal ridges that are reflective of mouth-bar sequences. Development of this setting in the Gongola Sub-basin captures scenario of a relatively elevated coastal hinterland paleogeographic relief favorably predisposed humid climatic regime. This feeds vast amount of sediments into the tidally attenuated epicontinental seaway, thereby modifying the fluvially derivative into tidal sand bars superposed on the pro-delta sequences, thus the tide dominated delta.

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

I. Introduction

The Gongola Sub-basin represents the northern tip of the Northern Benue Trough that connects to intracratonic Chad Basin (Fig.1), developing as a result of the separation of the South American plates during the late Jurassic to Early Cretaceous times. The opening of the basin occurred during the late Jurassic, but account of its evolution is highly controversial with two theories adjudged reflective of its development. The rift model theory was proposed at inception by earlier workers and supported to date (Benkhelil, 1989; Likkason et al., 2005; Fairhead 2013). The opening of the trough is accompanied by transgression in the Aptian-Albian and Cenomanian times in the Northern Benue Trough,depositing the Cenomaniantransitional-marine sequences of the Yolde Formation. The product of this sedimentation characterizes much of the mid-Cretaceous globally due to the continuously rising marine sea levels from epicontinental seaways that synonymously developed from the inundation of the Cretaceous rift systems (Shaw, 1964; Haq et al 1987). These seas are generally shallow with low gradient ramp shelve that gently and progressively deepens basin-wards, thus subtly submerging large dimension of the shelf and forcing shoreline migration with slightest marine surge (Midtkandal and Nystuen, 2009). This event largely controls the upward deepening sedimentary facies, with variable depositional packages evolving thereof that reflects complex interactions of sea level changes, inherent coastal topography, sediment supply, basin physiography and hydrodynamic systems (Posamentier and Allen, 1999). The competing interplay of current dynamics particularly tides in oceanographic systems accompanying transgression are usually constricted along narrow epicontinental realms or straits, thereby increasing in magnitude due to resonances and shoaling (Ericksen and Slingerland, 1990). These constrictions are capable of generating highly attenuated and amplified tidal currents relative to wave and fluvial dynamics, imposing strong tidal signatures even in micro tidal setting greatly influencing the development of deltaic sequences feeding in from flanking hinterland when relative sediment supply is high (Correggieri et al, 1996; Longhitano et al, 2012). This researched is aims to evaluate the facies and facies association of the Yolde Formation at Zambuk village that represents one of its major outcrops in the Gongola Sub-basin in order to establish its paleodepositional environment.

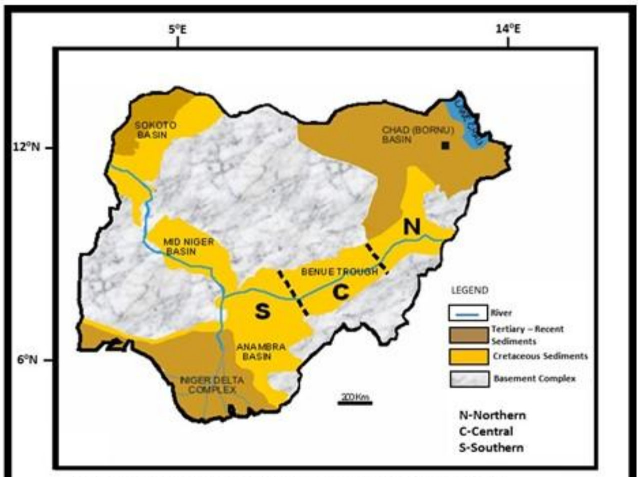

Fig.1a Geological Map of Nigeria showing the Benue Trough

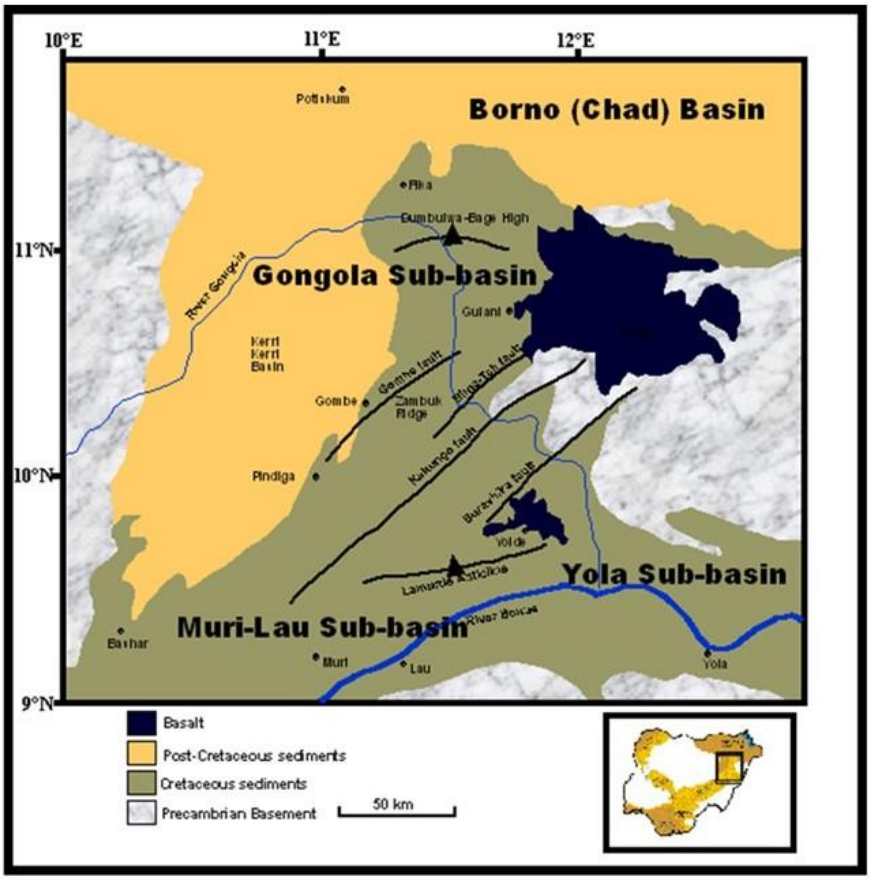

Fig.1b Geological map of the Northern Benue Trough (modified from Zaborski *et al*., 1997)

Geological and Stratigraphic Setting

The Benue Trough of Nigeria is arbitrarily sub-divided into northern, central and southern regoins, forming part of the rift basin in the Central West Africa with NNE-SSW orientation extending for about 1000 km in length and 50-150 km in width (Genik, 1992; Nwajide 2013). The southern limit is the northern boundary of the Niger Delta, while the northern limit is at the Dumbulwa-Bage High, an interphase marking the southern boundary of the Chad Basin (Fig.1) (Zaborski et al., 1997). The Northern Benue Trough is made up of three arms: the N-S striking Gongola Arm, E-W striking Yola Arm and the NE-SW striking Muri-Lau Arm (Dike, 2002) (Fig.2). It evolved as a consequence of separation of the South American from the African plates during the late Jurassic, but account of its evolution is highly controversial with two theories proposed for its origin and evolution. The rift model theory was proposed earlier and supported to date (Kings, 1950; Wright, 1989; Genik, 1992; Fairhead 2013) suggests initiation through tensional regimes induced by mantle plume convection activities (Olade, 1974; Burke, et al., 1971). Owing to the absences of boundary fault that are index to rifting, the pull-apart model was introduced, hence considered the trough as of strike-slip tectonic origin, as it further falls in the same orientation to the major transcurrent fault systems of the Romanche, Chain and Charcot suture zones (Benkhelil, 1989; Likkason et al., 2005; Onyedim, et al., 2005). The Trough is filed with over 6000m 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 constituting of the Aptian-Albian hosts 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). The deposition of syn-rift sequences thereof is largely controlled by the horst and graben network of normal fault and is represented by the alluvial fan-lacustrine deposits of the Bima I Formation, the lowermost in the group. This is unconformably superposed by the post-rift braided river sequences of the Bima II and III Formations (Zaborski et al., 1997; Tukur et al., 2015; Shettima et al., 2018). The Yolde Formation conformably supersedes in the Cenomanian, marked by the deposition of transitional-marine sequences (Shettima et al., 2011), whichaccounts for the relict 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). The middle sandy members of the Dumbulwa, Deba-Fulani and Gulani sandstones conformably followed in the mid-Turonian with falling transgressive surge (Fig.2) (Zaborski et al., 1997; Nwajide, 2013).The late Turonian witnessed another rising relative sea level that continued into the Coniacian and early Santonian, leading to deposition of the deep marine blue-black shales of the Fika Member that represents the youngest units of the Pindiga Formation (Zaborski et al., 1997; Shettima, 2016). The mid-Santonian is characterized by compressional tectonics the resulted due to changing orientation of the displacement vectors between the African plate and European/Tethys plates (Fairhead and Binks, 1991). This led to thrusting of the pre-Maastrichtian sediments westwards of the Gongola Sub-basin, developing adepression for the deposition of the Campano-Maastrichtian regressive deltaic sequences of the Gombe Formation (Dike and Onumara, 1999: Shettima, 2016). The Maastrichtian is characterized by episodes of compressional events, which is followed by the unconformably deposits of the fluvio-lacustrine Kerri Kerri Formation in the Paleogene (Dike, 1993: Adegoke et al., 1978)

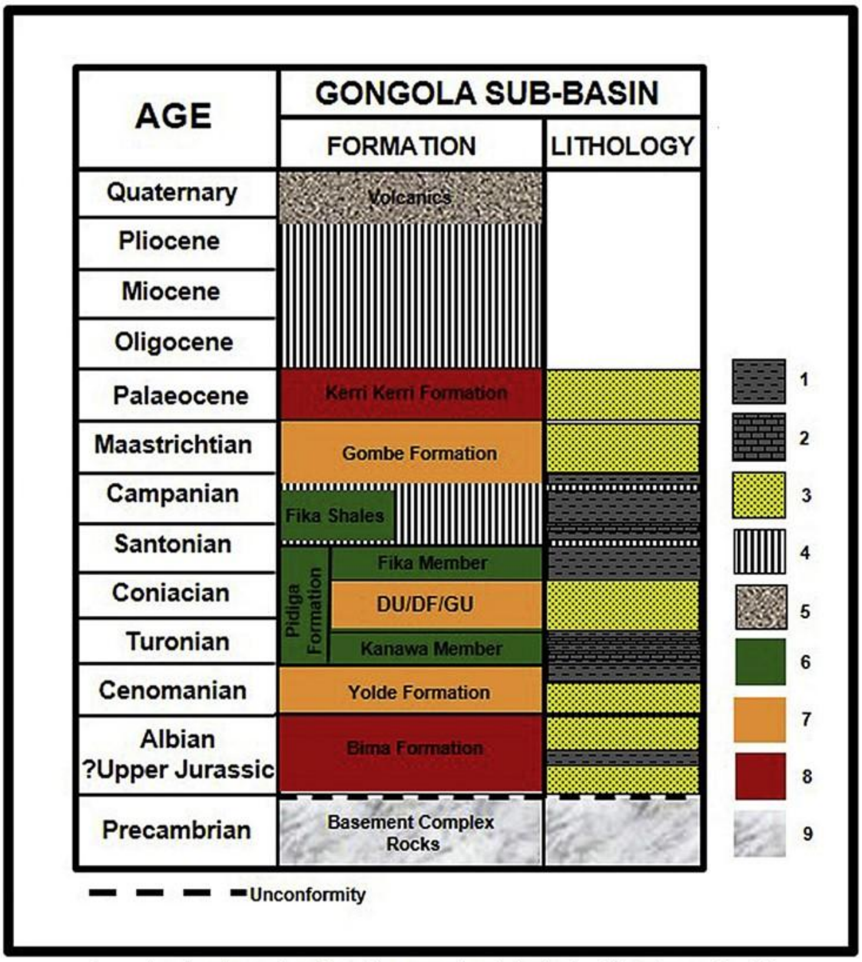

Fig. 2 Showing the stratigraphy of the Gongola Sub-basin (modified from Zaborski et al., 1997). 1-Mudstone, 2-Limestone, 3-Sandstone, 4-Hiatus, 5-Basalt, 6-Marine sediments, 7-Transitional-marine sediments, 8-Continental sediments, 9-Basement Complex (DU-Dumbulwa Member, DF-Deba Fulani Member, GU-Gulani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

(Fig.2). Volcanics typically define the Neogene, emplaced in an NNE-SSW orientation along the eastern margin of the Gongola Sub-basin (Wilson and Guiraud, 1992).

II. Materials And Methods

Geologic and topographic maps of Gombe town and environs that falls within the Gongola Sub-basin were used in the fieldwork exercise of this research to identify favorable areas where Yolde Formation is well exposed. From these well exposed outcrops identified outcropping around Gabukka stream (Fig. 4) lithostratigraphic sections of this Formation were systematically logged to record data on lithologic attribute that includes; texture, bed geometry, paleocurrents, sedimentary structures and fossil content. Based on facies concept and application of Walters law in connection with facies relation provided by sedimentologic studies on ancient and modern environment, these data were utilized in defining lithofacies assemblages representing particular depositional environment. Paleocurrent evaluations were also carried out on crossbedded units that composes of planar and trough crossbedded sandstones, and the various orientations determined were deployedin evaluating provenance and hydrodynamic processes (e.g. (Tucker, 2003). Dip and strike values as well as azimuth of crossbeds were measured using compass clinometers in this analysis, and considering that the regional dip of the beds are generally greater than 10^o, tilt correction was also carried out on the values using the procedure adopted by (Tucker, 2003).

Facies Analysis

Facies St: Trough crossbedded sandstone facies

This lithofacies composes of fine – medium grained sandstone, dominantly well sorted with rounded grains, ranging in thickness from 0.5 – 1m. They commonly compose of sharp basal boundaries, occasionally associated with mud streaks, mildly bioturbated (Fig.3a). This lithofacies was interpreted to have formed from migrating sinuous 3-D dunes that stack up to generate bar forms in channel (Plint, 1983; Boggs 1995; Miall, 1978, 1996, 2010).

Facies Sp: Planar crossbedded sandstone facies

This lithofacies composed of fine – medium grained sandstone with sub – rounded to well-rounded grains and typically occurs above trough crossbedded sandstone facies with thicknesses in the range of 20cm – 60cm, individual foresets ranged from 1mm – 2mm. They mostly appear bioturbated with local mud parting occurring along corset and forest planes (Fig.3c). This lithofacies was interpreted to have been produced from migration of 2-D dunes or sheet loading and/or interpreted as transverse bars formed under lower flow regime (Tucker, 2003; Miall, 2010).

Facies Sr: Ripple laminated sandstone facies

The ripple laminated sandstone facies compose of fine–very fine grained sandstone that are well sorted with rounded grains. Thicknesses ranges from 5–15cm, mostly associated with parallel lamination (Sl) and mudstones (Fm) (Fig.3e). Asymmetrical forms dominant and they are commonly bioturbated. This facies forms either when the water surface show little disturbance, or when water waves are out of phase with bedforms during lower flow regime, or forms through migrating current ripples, under lower flow regime (Miall, 1996; 2010).

Facies Sm: Massive sandstone facies

The massive sandstone facies are well – moderately sorted with fine – medium grained sandstone that are mostly bioturbated. It ranges between 20– 40m in thickness and commonly amalgamates to form thicker units ofteny overlain by trough crossbedded sandstone (St) or parallel laminated sandstone facies (Sr) (Fig.3b). This facies is generally deposited as plane beds in lower flow regime and/or rapid sedimentation due to high deposition rates with no preservation of sedimentary structures. It is commonly deposited on bars by stream floods and mostly associated with channelized flood flows around bars (Miall, 1978, 2010).

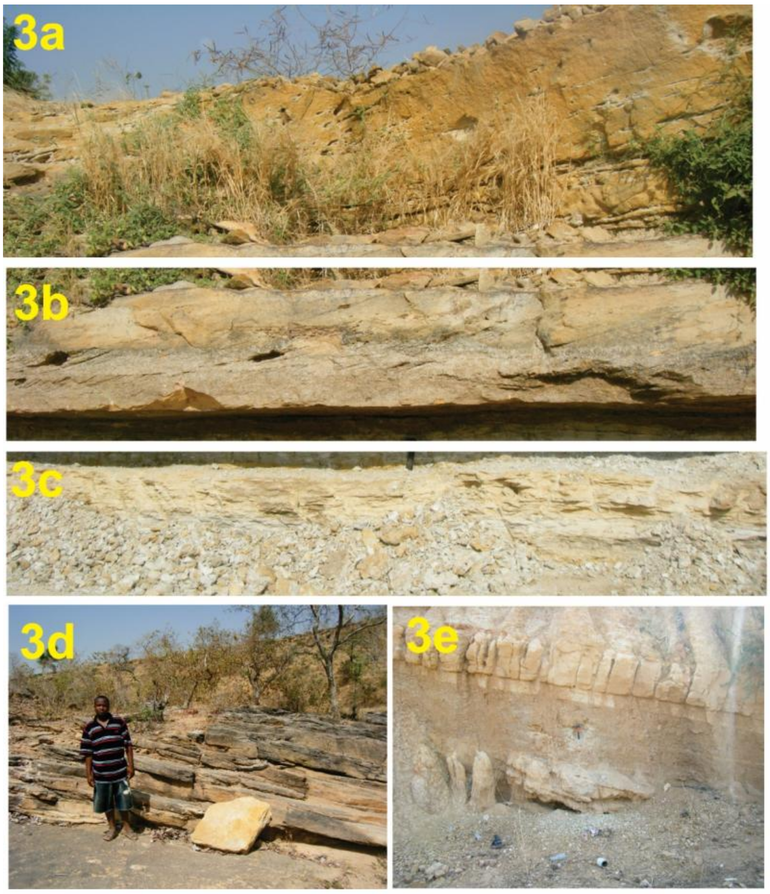

Fig.3a) trough crossbedded sandstone, b) planar crossbedded sandstone, c) ripple laminated sandstone, d) massive bedded sandstone and e) mudstone

Facies Fm: Mudstone facies

This lithofacies is dominantly grey coloured and commonly bioturbated with thicknesses ranging from 20cm – 1.6m. It is usually interbedded with ripple laminated sandstone facies (Sr) and massive sandstone facies (Sm) or define the base of trough crossbedded sandstone facies (Fig.3f). This facies forms under environmental conditions where sediments are abundant and water energy is sufficiently low to allow settling of suspended fine silt and clay. They are characteristic of marine environment where seafloor lies below the storm base, but can form in lakes and quite part of rivers, lagoons, tidal flat and deltaic environment (Tucker, 2003; Boggs, 2006).

Sedimentary Facies Associations

This facies association constitutes of stacked succession of fine–medium grained, well sorted lenticular sand bodies constituting dominantly of planar crossbedded facies (Sp), ripple cross laminations and low angle trough crossbedded sandstone facies (Sr and St) with interval of heterolithic beds and mudstone organized into coarsening upwards cycles of 7-11 m thick (Figs.3a-c). Lower sequences of these packages are characteristically densely bioturbated, dark grey mudstone facies (Fm) with upper horizons consisting of thin interbedded of sandstone and mudstones (5-10 cm), displaying parallel, ripple laminated and/or massive bedded sandstone facies (Sl, Sr and Sm) (Fig.3e). This continually grows into thicker heterolithic assemblage with an upwardly thickening trends of lenticular to lensiod beds, generally displaying planer cross-strata with wavy geometries that are sparely bioturbated, but shows presences of bivalve molds (Fig.4). This gradually changes to thick lenticular sandstone units having disseminated mud-drapes trapped within packages of compound cross-strata that are mostly tabular and planar crossbedded units. Locally, the heterolithic beds building into trough crossbedded sandstone facies (St) intercalated with thick mud-drapes or otherwise (Fig.13k). Foreset most often exhibits reactivation surfaces with the containing cosets bundles thickening upwards and bioturbation are generally moderate. Bioturbation indexes are moderate-dense (BI:3-5). Trace fossils assemblage relatively decreases away from the heterolithic intervals, particularly in the overlying lenticular and tabular sandbodies, where it is scarce, marked by low diversity assemblage of, bivalves and skolithos. Paleocurrent measurements indicate dominant unidirectional trajectory pattern trending south-west, ranging between 270- 290^{o}, associated subordinate field trending in northeastern directions of 100-135^{o} (Fig.4)

III. Discussion

The lithostratigraphic succession of the tide dominated delta facies association are sutured with increasing abundances of current ripple cross-laminations bottom-wards and temporally dominating presence of planar cross-stratification within the thickening sandstone upwards, suggesting a progressively shoaling sequences (Fielding et al., 2005; Hampson et al., 2011), evolving in a subaqueous predominantly current driven setting to a more tidally influenced dynamics, typically of tide influenced delta (Dalrymple et al., 2014). Fair weather wave base induced depositional controls typifies basal bedsetsdeveloping thick mudstone units of these coarsening upwards packages, whereas the intercalated upper intervals with current ripple cross-lamination are shear product of relatively weak oscillatory flows due to damped wave actions (Boyd, 2010). Succession of cross-stratified sandstone assemblage are products of 2D and 3D dune fields migration generated from tidal reworking of deltaic fed sediments derived from relatively elevated hinterland adjacent to the epicontinental passage way (Longhiteno and Steel, 2016). Assemblage of low diversity Cruziana (thalassiniodes) and Skolithos (skolithos and diplocraterion) ichnofaciesare an account of a chemically stressed marine depositional conditions, a probable interaction of marine and fresh water sources in a delta setting (Pemberton, 1998; MacEachen and Bann, 2008). The perpendicular interaction between the axially flowing tidal current within this realm and prograding delta front emplaces successive cross-strata with greater abundances of tidal imprints than river attributes, spatially aligned to the coastal margin (Huang and Bhattacharya, 2017). Longhiteno and Steel (2016) indicated that these deflected delta deposits which display a gradual upward differentiation in paleocurrents, are clearly reflected herein by a dominantly south-western paleocurrent packages marking the tidal modulation pathway and the north-eastern minor trajectory trends reflecting fluvial contributions, characteristically revealing perpendicular orientation geographically, similar to the tide dominated delta system of the Serdina strait (Rossi et al., 2017).

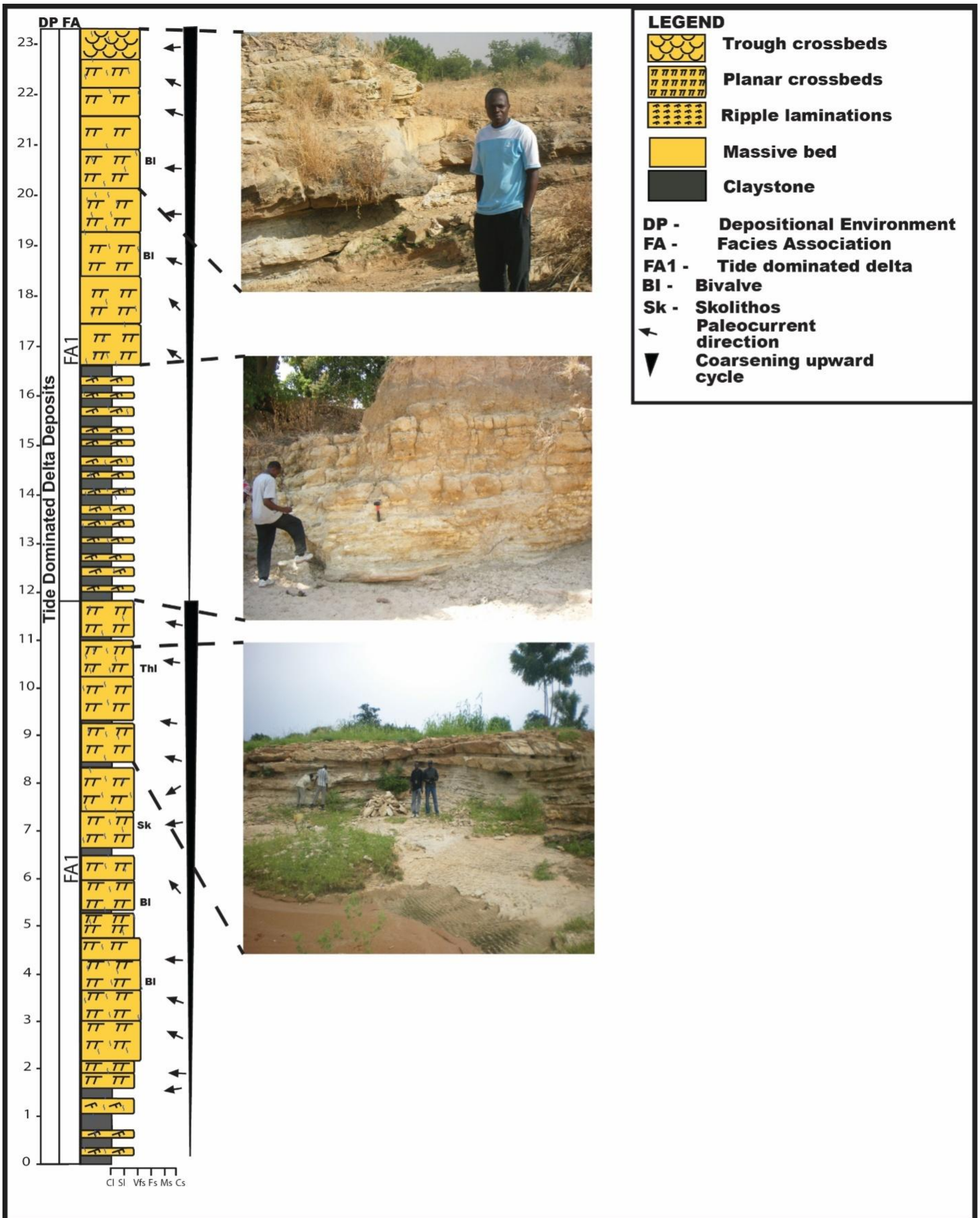

Fig.4 Showing lithostratigraphic section of the Yolde Formation at Zambuk village

IV. Conclusion

Facies analysis of the lithologic section of the Yolde Formation at Zambuk village in the Gongola Sub-basin presented six lithofacies comprising of trough crossbedded sandstones, planar crossbedded sandstone, ripple laminated sandstones, parallel laminated sandstones massive bedded sandstones and mudstones. Association of these lithofacies formed coarsening upward cycles that are definitive of tide dominated delta with marked differentiation of energy regime, where the lower mud dominated interval depicted low energy conditions, evolving through fair weather wave base and an upper sand dominated zone generated under turbulent regime indicted by the succession of planar crossbedded sandstones representing tidal ridges of mouth-bar sequences. Tidal dominance in the Gongola Sub-basin part of the trans-saharan epicontinental seaway is considered to be product of tidal attenuation resulting from constrictions of cross-sectional area of the sub-basin. Hence, the modification of this sediment fetch from relative elevated coastal morphology evolving at the flanks of the sub-basin by this oceanographic current created the template for the development of this tide dominated delta.

References

[1]. Abdulkarim H. Aliyu, Y.D. Mamman, M.B. Abubakar, Babangida M. SarkiYandoka, John ShirputdaJitong& 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

[2]. 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.

[3]. Benkhelil, J. (1989). The origin and evolution of the Cretaceous Benue Trough (Nigeria). Journal of AfricanEarth Sciences, 8: 251 – 282.

[4]. Boggs, S. Jr. (1995). Principle of Sedimentology and Stratigraphy. New Jersey, Prentice Hall, 109p.

[5]. Boggs, S. Jr. (2006). Principles of Sedimentology and Stratigraphy. Upper Saddle River, New Jersey, Prentice Hall,129p.

[6]. Boyd, R. (2010). Transgressive wave dominated coast. In N. P. James & R. W. Dalrymple (Eds.); Facies Model 4 (pp 265 – 294). St John's, Geological Association of Canada Publication.

[7]. Burke, K., Dessauvagie, T. F. G. & Whiteman, A. J. (1971). The opening of Gulf of Guinea and geological history of the Benue depression and Niger delta. Nature Physical Science, 233: 51 – 55.

[8]. Correggiari, A., Cattaneo, A., and Trincardi, F., 2005, The modern Po Delta system: Lobe switching and asymmetric prodelta growth: Marine Geology, v. 222–223, p. 49-74.

[9]. 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.

[10]. 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.

[11]. 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.

[12]. Ericksen, M.C. and Slingerland, R. (1990) Numerical simulations of tidal and wind-driven circulation in the Cretaceous Interior Seaway of North America. Geol. Soc. Am. Bull., 102, 1499–1516.

[13]. 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.

[14]. 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.

[15]. Fielding, C.R., Trueman, J.D., and Alexander, J., 2005. Sharp-Based, Flood-Dominated Mouth Bar Sands from the Burdekin River Delta of Northeastern Australia: Extending the Spectrum of Mouth-Bar Facies, Geometry, and Stacking Patterns: Journal of Sedimentary Research, v. 75, no. 1, p. 55-66.

[16]. 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.

[17]. 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.

[18]. Hampson, G.J., Gani, M.R., Sharman, K.E., Irfan, N., and Bracken, B., 2011, Along-Strike and Down-Dip Variations in Shallow-Marine Sequence Stratigraphic Architecture: Upper Cretaceous Star Point Sandstone, Wasatch Plateau, Central Utah, U.S.A.: Journal of Sedimentary Research, 81, 3, 159-184.

[19]. 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

[20]. Huang, C. and Bhattacharya, J.P. (2017) Facies analysis and its relation to point-sourced growth faults in river-dominated prodeltaic delta front deposits of the Cretaceous Ferron Notom Delta, Utah, USA. Marine and Petroleum Geology, 81, 237-251

[21]. King, L.C., 1950. Outline and distribution of Gondwanaland. Geol. Mag., 87, 353-359.

[22]. 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.

[23]. Longhitano, S.G., Chiarella, D., Di Stefano, A., Messina, C., Sabato, L., Tropeano, M., 2012a. Tidal signatures in Neogene to Quaternary mixed deposits of southern Italy straits and bays. Sediment. Geol. 279, 74 -96

[24]. Longhitano, S.G., Steel, R.J., 2016. Deflection of the Progradational axis and Asymmetry in Tidal Seaway and Strait Deltas: Insights from Two Outcrop Case Studies. Paralic Reservoir. Geological Society - Special Publication, London.

[25]. MacEachern, J.A., and Bann, K.L., 2008, The role of ichnology in refining shallow marine facies models, in Hampson, G.J., Steel, R.J., Burgess, P.M., and Dalrymple, R.W., eds., Recent Advances in Models of Shallow-Marine Stratigraphy: SEPM, Special Publication 90, p. 73–116.

[26]. MacEachern, J. A., Brian A Zaitlin, B. A. and Pemberton, G. (1998), High-resolution sequence stratigraphy of early transgressive deposits, Viking Formation, Joffre Field, Alberta, Canada. American Association of Petroleum Geologists, 82, 5, 729-756.

[27]. Miall, A. D. (1978). Lithofacies types and vertical profile models of braided river deposits, a summary. In A. D. Miall (Eds.); Fluvial Sedimentology vol 5 (pp 597 – 604). St Johns, Newfoundland, Canadian Society of Petroleum Geologists Publication.

[28]. Miall, A.D., (2010). Alluvial deposits. In: James, N.P., Dalrymple, R.W. (Eds.), Facies Models 4. Geological Association of Canada, St. John's, Newfoundland, pp. 105-137. GEO text 6.

[29]. Miall, A.D., 1996. The Geology of Fluvial Deposits. Springer, Berlin.

[30]. Midtkandaland, I and Nystuen, J.P. (2009) Depositional architecture of a low- gradient ramp shelf in an epicontinental sea: the lower Cretaceous of Svalbard. Basin Research, 21, 655–675.

[31]. Nwajide, C. S. (2013). Geology of Nigeria's sedimentary basins. Lagos, CCSBookshop Ltd,

[32]. Olade, M. A. (1974). Evolution of Nigerian's Benue Trough (aulacogen): a tectonic model. Geological Magazine, 112: 575 – 583.

[33]. Onyedim, G. C., Arubayi, J. B., Ariyibi, E. A., Awoyemi, M. O. &Afolayan, J. F. (2005). Element of wrench tectonics deduced from SLAR imagery and aeromagnetic data in part of the middle Benue Trough. Journal of Mining and Geology, 41: 51 – 56.

[34]. Plint, A. G. (1983). Facies, environment and sedimentary cycles in the Middle Eocene, Bracklesham Formation of Hamshire Basin: evidence for sea-level change? Sedimentology, 30: 625 – 653.
[35]. Posamentier, H. W. & Allen, G. P. (1999). Siliciclastic sequence stratigraphy: concepts and applications. SEPM Concepts in Sedimentology and Paleontology, 7: 210p.
[36]. Shaw, D.P. (1964) Time in Stratigraphy. McGraw-Hill, New York.
[37]. 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
[38]. 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.
[39]. 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
[40]. Tucker, M. E. (2003). Sedimentary Rocks in the field. West Sussex, John Wiley & Sons Ltd, 83 – 158p.
[41]. 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.
[42]. Wilson, M., & Guiraud, R., (1992). Magmatism and rifting in Western and Central Africa, from Late Jurassic to Recent times. Tectonophysics 213, 203–225
[43]. 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.
[44]. 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.

Bukar Shettima, et. al. "Tide Dominated Delta System of the Cretaceous Yolde Formation of the Gongola Sub-basin Northern Benue Trough N.E. Nigeria."*IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 8(4), (2020): pp 13-21.