PALEOENVIRONMENTAL SIGNIFICANCE OF SEDIMENTARY STRUCTURES IN THE CAMPANO-MAASTRICHTIAN SUCCESSION IN THE GONGOLA BASIN NE NIGERIA

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Abstract

The pre and post depositonal sedimentary structures have been examined, recorded and interpreted from the foreshore-shoreface and alluvial facies of the Campano-Maastrichtian succession in the Gongola Basin. Some of these structures seem to be diagnostic of the environment, depositional processes, conditions and direction of the water current which deposited the sediments. The upper Fika Formationis dominantly shale with bioturbatedooidal ironstone toward the top, which indicates deposition mainly from suspension andthe bioturbatedooidal ironstones form in agitated water as water depth decreased, increased agitation formed clay ooids and moderate to intense bioturbation by Thalassinoides, OphiomorphaandSkolithos.as water depths subsequently increased and finaly replacement of kaolinitic precursors with iron oxides/hydroxides.Thetrace fossil assemblage Thalassinoides, Ophiomorpha and Skolithosare consistent with a shallow marine setting.Their presence indicates littoral and shallow sub-littoral environments. The Arowa Formation is made up of cycles that are coarsening-upward and contains channel-filling sandstones in the lower part. The lower shale-dominated part of the cycles contain interbedded sandstones and shales in which hummocky cross stratification, ripples and trace fossils Thalassinoides, Skolithos, Ophiomorpha, and Planolitesoccur. The sandstone-dominated portion of the Arowa Formation are mainly parallel laminatedand dip gently (2^o– 3^o) seaward. The main sedimentary structure of the DuguriFormation, is cross-bedded sandstone overlying a basal conglomerate/pebbly sandstone. The paucity of argillaceous horizons suggests deposition in braided rivers.

Keywords: Campono Maastrichtian, Arowa Formation, thalassinoides, Skolithos, Planolites, Paleoenvironment

Introduction

The Benue Trough, east Niger rift basins and Sudanese rift basins are major elements of the West and Central African Rift System (WCARS) (Fig. 1).

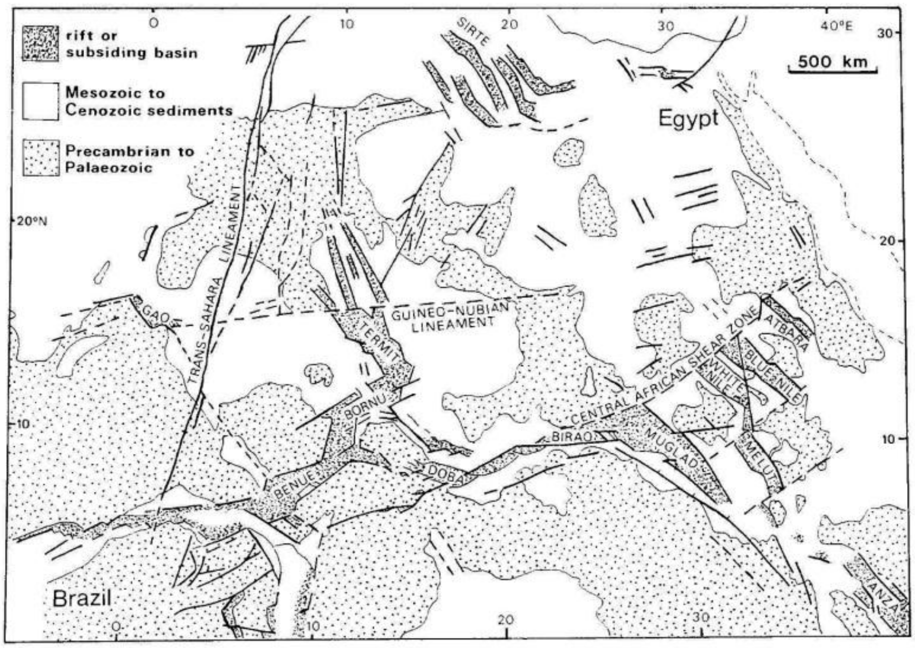

Figure 1. The tectonic configuration of the West and Central African rift system (WCARS) showing the Cretaceous displacement directions. (afterFairhead, 1986)

The Benue Trough is a Cretaceous sedimentary basin in Nigeria. At its northeastern end, an area commonly known as the upper Benue Trough, it bifurcates into an E - W trending Yola Arm and a N - S trending Gongola Arm or Gongola Basin (Fig. 2, 3, 3a).

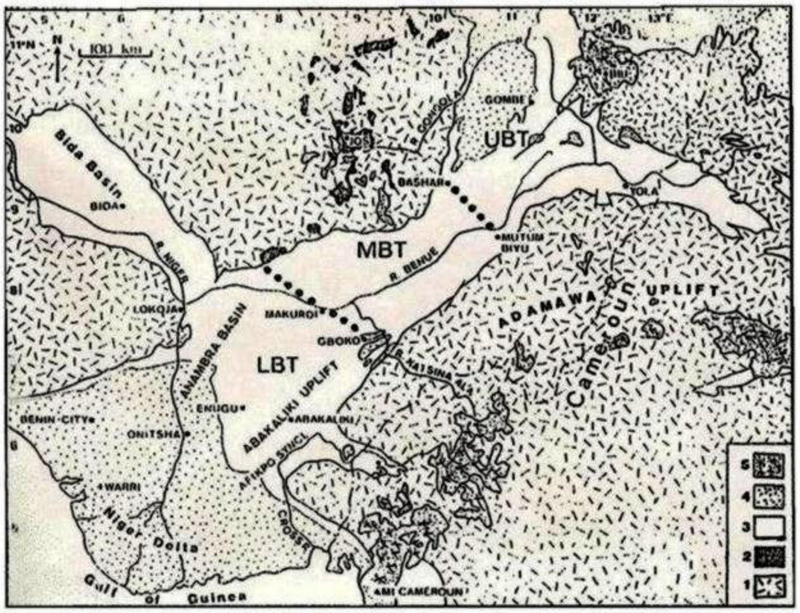

Figure 2. Outline geological map of the Benue Trough and adjcent areas. LBT, Lower Benue Trough; MBT middle Benue trough; UBT, Upper Benue Trough. 1, Precambrian; 2, Jurassic "Younger Granite"; 3, Cretaceous; 4, Post Cretaceous; 5, Cenozoic-Recent Basalt. After Zaborski, 1998

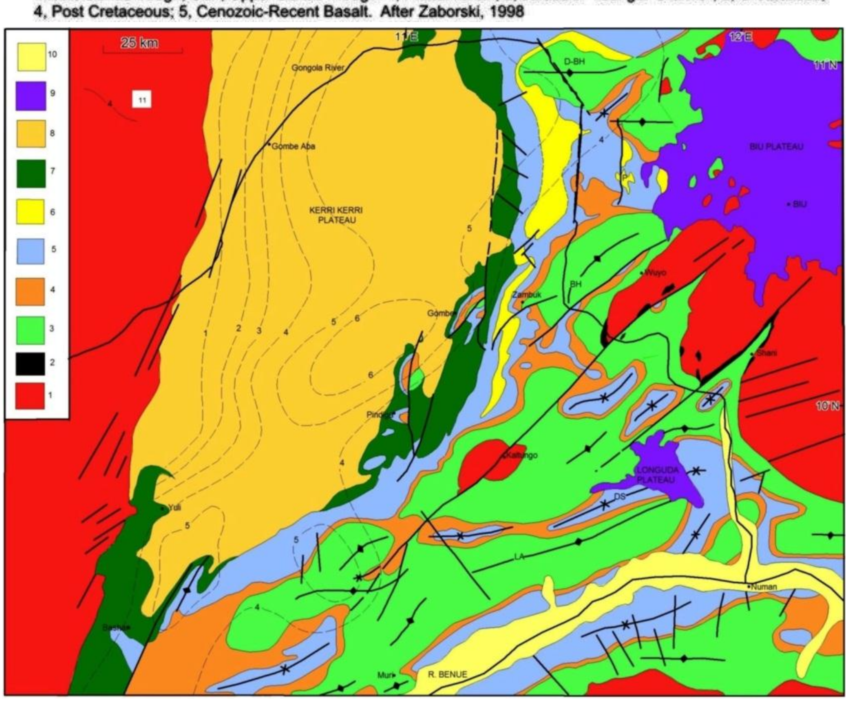

Figure 3. Geological map of the Upper Benue Trough region (Gongola arm) (based on Benkhelil, 1985; Guiraud, 1989; Zaborski*et al*.,1997). 1, Precambrian; 2, Late Jurassic?to Early Cretaceous volcanic; 3, Bima Group; 4, Yolde Formation; 5, Pindiga Formation and lateral equivalents inYola arm; 6, Sandy members of the Pindiga Formation in the Gongola Basin; 7, Gombe Sandstone; 8, Kerri-Kerri Formation; 9, Neogene to Quaternary basalt; 10, alluvium; D-BH, Dumbulwa-Bage high; BH, Bima Hill; DS, Dadiya syncline; LA, Lamurde Anticline.

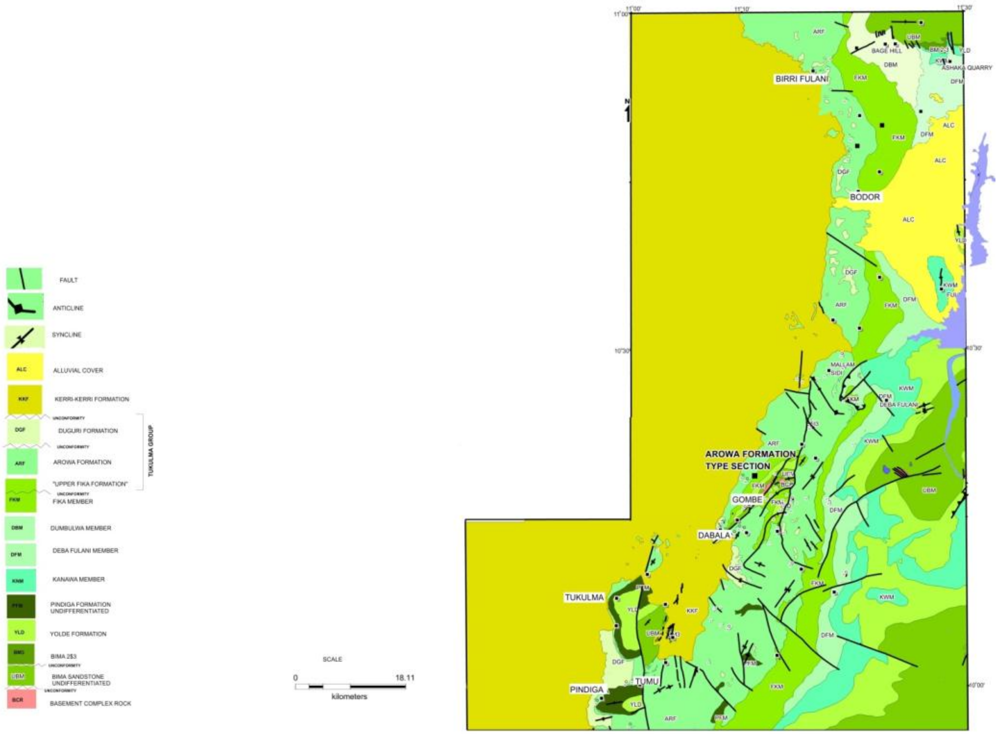

Figure 3a. Geological map of the western part of the Gongola Basin (northern part) (Hamiduetal. 2013)

The present work concerns the environmental significance of sedimentary structures in the Campano-Maastrichtian succession in the Gongola Basin. Geological fieldwork has provided field evidence of these structures, some of these structures seem to be diagnostic of the environment, depositional processes, conditions and direction of the water current which deposited the sediments.The Fika Formation of (Hamiduetal. 2013) is subdivided into upper and lower parts separated by the Santonian unconformity, while the Campano-MaastrichtianGombe Sandstone is subdivided into two Formations (Arowa and DuguriFormation of Hamiduetal. 2013) separated by an erosional surface at least in places (Fig.4).

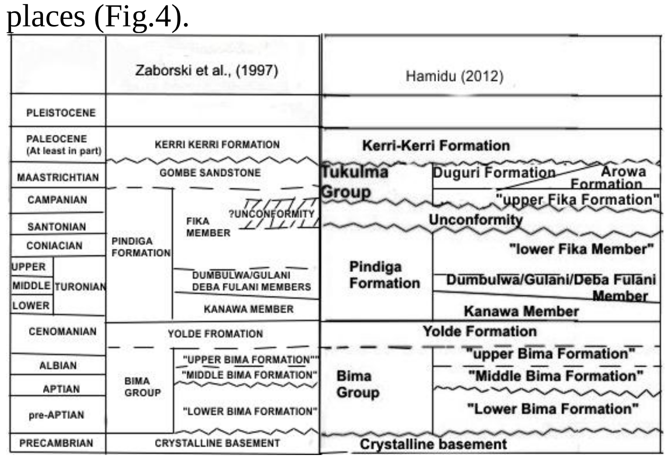

Figure 4: lithostratigraphical subdivision for the Campano-Maastrichtian succession in the Gongola Basin(Hamiduetal. 2013)

Environment of deposition of the upper FikaFormation

The dominantly shale nature of the upper FikaFormation(Fig.5) indicates deposition mainly from suspension.The ooidal ironstones is formed as a result of agitated water, as water depth decreased, increased agitation formed clay ooids.Therefore the formation of the ooidal ironstones can be summarized as follows.

i) Deposition of kaolinitic clays from suspension.

ii) Formation of ooids under agitated low salinity conditions as water depth decreased.

iii) Moderate to intense bioturbation by *Thalassinoides*, *Ophiomorpha*and*Skolithos*as water depths subsequently increased (Fig. 6).

iv) Replacement of kaolinitic precursors with iron oxides/hydroxides.

Figure 5.upperFika Formation", stream section south of Gombe by-pass N 10º 15' 10.7'' E 011º 08' 56.0''. Photograph showing cycles of silty shale and bioturbatedooidal ironstones

Figure 6.upperFika Formation", stream section south of Gombe by-pass N 10º 15' 10.7'' E 011º 08' 56.0''. Photograph showingbioturbatedooidal ironstones(*Ophiomorpha)*

The presence of *Thalassinoides*and *Skolithos*indicates littoral and shallow sub-littoral environments. Frey and Howard (1970) reported that *Thalassinoides*and*Ophiomorpha* are reliable indicators of littoral and shallow sublittoral environments.

The presence of low diversity arenaceousforaminiferal faunas and scarcity of planktonics, suggests a shallow marine environment.Petters (1978a; 1978b; 1979; 1982) reported assemblages of arenaceous foraminifers from the upper part of the Pindiga Formation and inferred their environment to be brackish water. Olaleye (1983) recognized the abundance of arenaceous benthonic foraminifers within the "FikaMember" and they inferred anearshore environment of deposition.Gebhardt (1997) noted that dysaerobic conditions can be identified by the absence of calcareous benthic foraminifers while arenaceousforaminifers may survive under dysoxic to anoxic conditions, such conditionsbeing characterized by the absence of a macrofauna. Thetrace fossil assemblage (*Thalassinoides*, *Ophiomorpha* and *Skolithos*) is consistent with a shallow marine setting.

Environment of deposition of theArowa Formation

The cycles in the ArowaFormation have a coarsening-upward nature and can be recognized in all the studied sections. Channel-filling sandstones are found in the lower part of the Arowa Formation where the "a" and "b" portions of the cycles are dominant (Fig.7).

Interpretation of the Shale-dominated portion of the cycles

The lower shale-dominated ("a") part of the cycles contain interbedded sandstones in which hummocky cross stratification, and ripples are the dominant sedimentary structures, while the trace fossils *Thalassinoides*, *Skolithos*, *Ophiomorpha*, and *Planolites*occur here.

Figure.7: Log of Arowa stream

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Figure.8: Tukulma Group, Gombe Sandstone, Arowa Formation, roadcuttingalongBirri Fulani road to WuroBapparo road, N10º 55′ 9.3″ E11º 17′ 31.8″. Photograph showing fine to medium-grained quartz arenitesinterbedded with siltyshales and containing*Skolithos* and *Ophiomorpha* with chevron structures. Note greater thicknesss of sandstones overlying terminated *Ophiomorpha*.

Figure.9: Tukulma Group, Gombe Sandstone, Arowa Formation,Arowa stream, N10º 18′ 41.5″, E11º10′17.8″. Detail of "a" portion of a cycle showing hummocky cross- stratified fine-grained sandstones alternating with silty-shale.

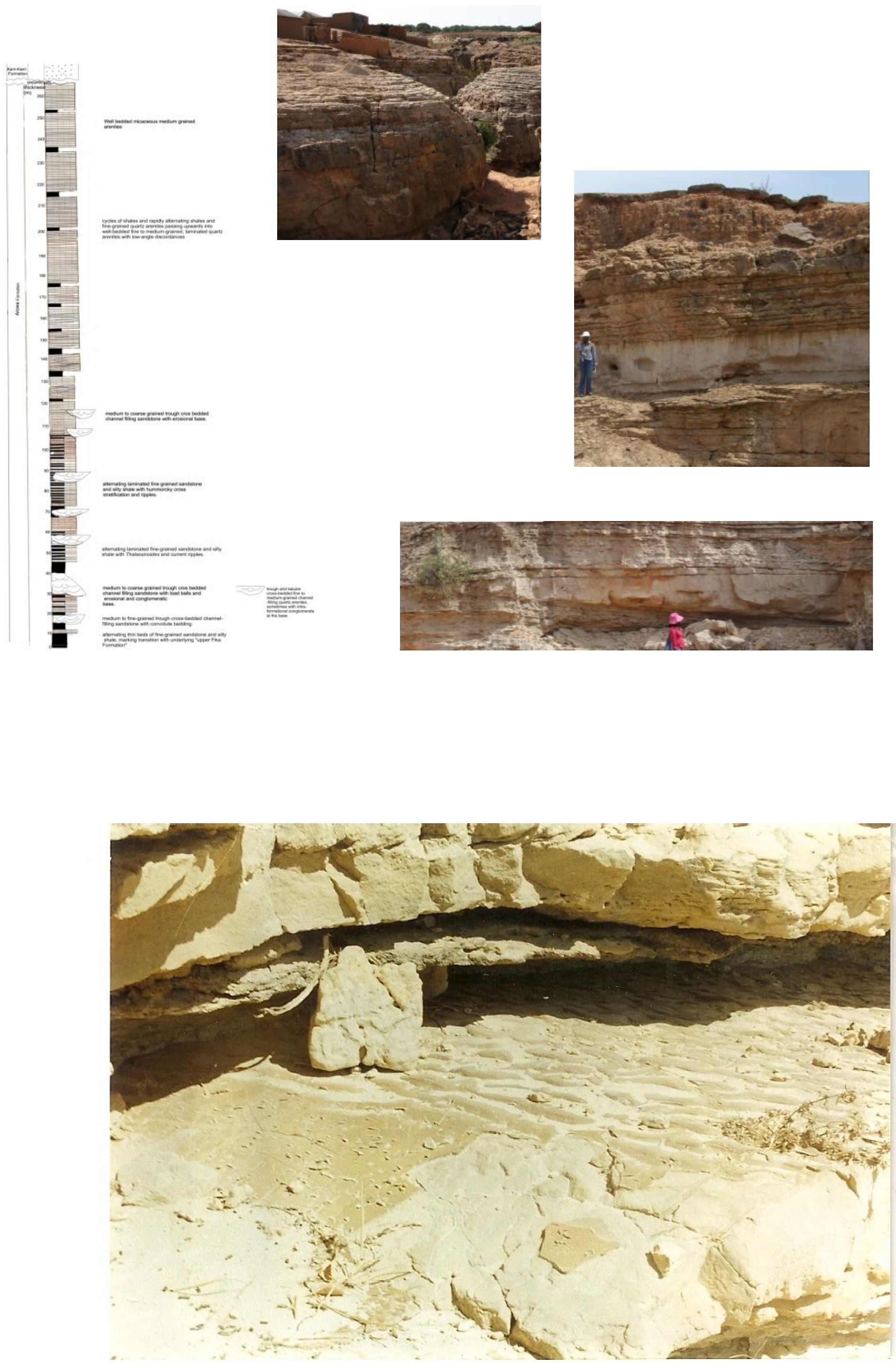

Figure.10: Tukulma Group: Arowa Formation, Dabala stream. N10º 13' 57.3'' E 11º 08' 21.4''.

Channel-filling sandstone showing a sub-aqueous dunewith current ripples and *Planolites.* Above is thin shale with further cross-bedded sandstone on top produced by similar NNW-flowing paleocurrent.

Figure.11Tukulma Group, Gombe Sandstone, Arowa Formation, Photograph showing Ichnofossil *Thalassinoides* burrows

The shales are suspension deposits. Current ripples are downstream migrating bed forms produced by unidirectional flows.According to Harms *et al*. (1982), hummocky cross-stratification is a structure commonly preserved between fairweather and storm wave base produced by a combination of unidirectional and oscillatory flow related to storm activity.Richard and Dale (1993) noted that hummocky-cross stratification (HCS) associations occur as discrete sandstone beds interbedded with mudstones and generally produce the hummock and swale structures similar to those found in the Arowa stream section (fig.9), and amalgamated massive sandstones (up to several tens of metres) thick. They occur above the discrete HCS beds in regressive shoreline successions and are representative of sedimentation in the lower shoreface (Fig. 8). They also noted that the trace fossils associated with progradational successions containing HCS sandstone are *Skolithos*and *Ophiomorpha.Skolithos*and *Ophiomorpha* are characteristic of high energy settings, and represent colonization by opportunistic or resilient organisms of a substrate which has been rapidly deposited. Vertical escape burrows represent organisms suddenly buried by sand attempting to rise to the new substrate following storms.The *Ophiomorpha* at Birri Fulani is found in the "b" portion of the cycle. It shows chevron structures, resulting from burrow collapse and the settling downward of superjacent sediment. Continous slumping of sediment surrounding the burrow collapse of a vertical component results in a cylindrical structure resembling nested funnels. The massive sandstoneoverlying and terminating*Ophiomorpha*in Birri Fulani section (Fig. 8) is probably an amalgamated HCS formed during storm activity, creating winnowing and rapid deposition of thick sandstones and abrupt termination of the burrows.

The trace fossils *Thalassinoides*, *Skolithos,Ophiomorpha*, and *Planolites* indicate shallow water depths.Gunver and Richard (2006) carried outecological studies along the southeast Atlantic coast of the USA and found them extremely useful in indicating the depositional environments. Cretaceous and Tertiary sediments containing *Ophiomorpha* in wellsorted, massive sandstone indicated wave-agitated littoral or shallow neritic conditions. *Ophiomorpha*is extremely important in establishing shoreline position and in reconstructing shoreline trends.Gunver and Richard (2006) reported*Ophiomorpha*in the Black Hawk and Starpoint formations (Lower Campanian) in the Book Cliffs, Utah. They occur as ovoid, sinous, branching and horizontal galleries in fine-grained to muddy, organic-rich sandstones interpreted as middle to lower shoreface deposits. *Ophiomorpha* was also associated with *Skolithos* and *Planolites*. According to Robert *et al*. (1978) *Ophiomorpha*occurs frequently in beaches. Gunver and Richard (2006) reported that *Ophiomorpha* is an indicator of nearshore/shoreface environments. The same associations are found in theArowaFormation, and indicate that the ‘a” and “b” portions of the cycles are sublittoral to middle shoreface deposits.

Interpretation of the Sandstone-dominated portion of cycle

The sandstone-dominated “c” portion of the ArowaFormation cycles are well-sorted sands and very negatively skewed sands reflecting high reworking of the sediment during transport and in these respects most agreeing with beach sands (Fig. 12). Tucker (1988) proposed that beach sands are well sorted and negatively skewed. Pedro and Antonio (2007) described Pliocene to Pleistocene nearshore marine sediments from central Portugal which consist of fine to medium-grained, well sorted sands as shoreface deposits, and laminated fine to medium-grained sands with low-angle discordances as foreshore/beach deposits. They interpreted the superposition of shoreface below and foreshore/beach deposits above as a prograding beach sequence. They suggested that sediment of the foreshore consists predominantly of fine to medium sand but may also include scattered pebble layers or lenses. Sedimentary structures are mainly parallel laminations(formed during swash-backwash flow) that dip gently (2^o– 3^o) seaward, and heavy mineral-rich laminae are commonly present.

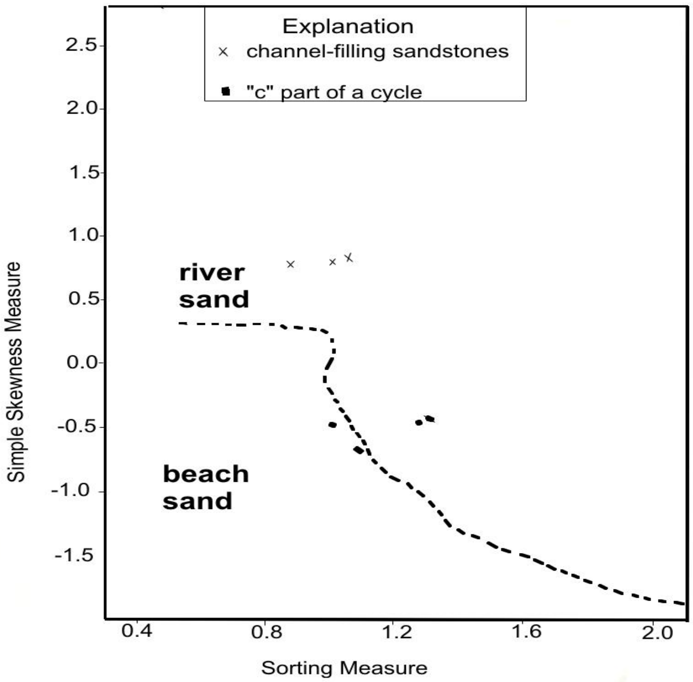

Figure 12. A plot of sorting versusskewnessfor sands from the "c" parts of Arowa member cycles and channel-filling sandstones as compared with modern beach/river sand adapted after Friedman and Sanders (1978).

Reineck and Singh (1980) suggested that surf zone, swash zone and beach sediments contain heavy minerals, present in the suspended sediments, they settle rapidly to generate thin heavy mineral laminae. Thompson (1937) has demonstrated that the presence of low angle cross stratification is characteristic of the beach-foreshore environment. McKee (1957) reported that the upper foreshore deposits of Mustang Island beach Texas, consists of strata that are regular, even and have a gentle dip. Tucker (1996) reported that low angle discordances suggest deposition in beach-foreshore environments. Ghibaudo*et al*. (1974) studied the Cretaceous Aren Sandstone in the Spanish Pyrenees Seaward-dipping sets of parallellaminated sandstones with low angle discordances between overlie highly bioturbatedsandstones with reminant patches of hummocky cross-stratification. Below are fossiliferous marls and siltstones with thin storm-generated beds. This succession is very similar to that shown in the cycles in the ArowaFormation (Figs.13, 14).

Figure. 13. Tukulma Group, Gombe Sandstone, Arowa Formation, Dabala stream. N10º13′ 59″ E11º 08′ 02.2″ Grey, fine to medium-grained, laminated, micaceous quartz arenites, with low angle discordances in "c" portion of a cycle.

The succession in each complete cycle from bottom to top represents offshore to foreshore/backshore to shoreface environments respectively.Overall the nature of cycles in the ArowaFormation is dominantly shale-rich at the base, toward the middle the proportion of sand and shale are almost equal, while the upper part of the cycle is dominated by sandstone. This indicates a coarsening- upward succession with a sustained supply of sediments. The ferruginized top of the ArowaFormation cycle indicates sub-aerial exposure and weathering while the shale-rich "a" part of the cycles lacks body fossils possibly due to hyposalinity. In these respects the cycle differs from the Aren Sandstone cycle where deposition terminated with aeolian dunes at the top while the lower part contains body fossils indicating normal salinities (Fig. 14).

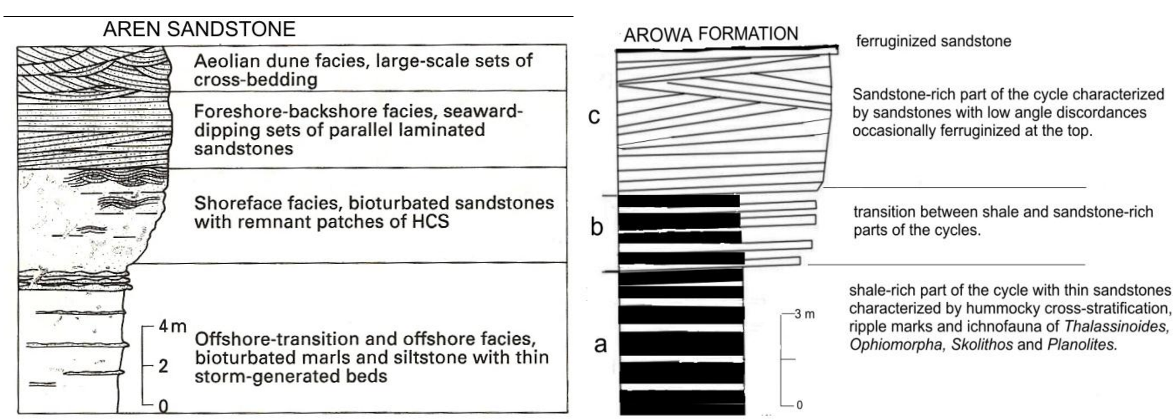

Figure 14: Coarsening-upwards cycle in the Cretaceous Aren Sandstone in the Spanish Pyrenees (after Ghibaudo*et al.* 1974), compared to the Arowa Member cycle.

Interpretation of the channel-filling sandstone

The channel-filling sandstones occur cutting through the more shale-rich portions of the lower Arowa Formation. Channels are formed by erosion andare commonly filled with sediment that is texturally different from the beds they truncate. Channel-fillings in marine environments may bethe result of tidal current or turbidity flows. The channel-fillings in the ArowaFormation are unlikely to be the result of tidal currents since the channels do not cut through all subfacies, being concentrated in the sublittoral zone. They are unlikely to be a result of turbidity flows since the palaeoenvironment was too shallow and the characteristic sedimentary structures of such flows are not manifested. Another possibility ishyperpycnal flows. The effluent behavior and depositional pattern of a river flowing into a basin depends upon the relative importance of: (i) the inertia of the inflowing water as it enters the basin and its diffusive mixing with basin water; (ii) the friction of the inflow at basin-ward of the river mouth; and (iii) the buoyancy process at the river mouth. The main consideration is the density contrast between river and basin waters.Wright (1977) suggested that the hyperpycnal flows occur mainly during floods and pass beneath the basin water as density currents causing sediments to bypass the shoreline andbe deposited on the lower delta front or on the prodelta. Hyperpycnal flows are again unlikely since the channels do not cut through all subfacies.

Alternatively, the Arowa Formation channel-filling sandstones may be the result of rip-currents which comprise, narrow, high velocity, storm-generated seaward-directed currents that start in the surf zone (Gruszczynski*et al*., 1993). The currents that produced the channel-fillings flowed intermittently. The clasts of ferruginized sandstones that they contain were derived from the enclosing coarsening-upwards cycles and were not transported from far as would be the case with river flows. The channel-fillings from the lower portion of the ArowaFormation are comparable to those from the modern barred coastline of Oregon where a series of obliquely oriented nearshore bars is separated from the shore by a trough that curves seaward into a rip channel. The channel sands in Oregon occur below foreshore sands in a similar position to that of the channels in the ArowaFormation cycles.

Paleocurrent measurements were obtained from asymmetrical ripples, cross bedding and dune bedforms (Fig.10) within the channel-filling sub facies of the ArowaFormation. Anorth-westerly to northerly directed paleocurrent was determined for the ArowaFormation, indicating that the open sea was located to north-north-west. The presence of slump folding around Maiduguri (Fig. 15) and soft sediment deformationelsewhere in the lower part of the ArowaFormation(Fig.16) indicates deformation shortly after deposition. Allen (1977; 1984) proposedthat structures such as convolute lamination, loadcasts and recumbent folds are due to liquefaction. The present features are probably the result of hydroplastic behavior triggered by seismicityalong nearby faults active during sedimentation.

Guiraud and Jean (1993) stated that convolute bedding/lamination may be a result of sediment deformation by hydroplasticity, liquefaction and fludization. Hydroplastic behavior corresponds to the deformation of grain-supported unlithified sediments in which the water film lubricating the grain contacts and the pore fluid pressure do not permit true liquefaction but favour plastic deformation, the folding and stretching may result from the efficient application of a local or regional driving stress on the weak but not liquefied sediment. In this area the probable cause for convolute bedding is seismic activity associated with synsedimentaryfaulting along the Gombe fault which also probably produced the minor angular unconformities.

Figure.15 Tukulma Group, Gombe Sandstone, ArowaFormation, Maiduguri village.N 10º 47′ 54.8″, E 11 º19′ 47″.Photo showing a slump structure.

Figure.16 Tukulma Group, Gombe Sandstone, ArowaFormation, Yalo village.Photo showing a slump structure.

The channel-filling sandstones are found through most of this section being especially common in the lower part (Fig. 17). They are several metres thick, have erosional bases and flat tops and are internally cross-bedded. Theyaremicaceous, poorly sorted (1.07ϕ) negatively skewed (0.097ϕ) andleptokuritic (1.32ϕ).One of such channel-filling sandstones comprises several internally cross-bedded sub-aqeous duneseach some tens of centimeters thick separated by thin shales. On theferruginizedstoss side surface of one dune are transverse becoming lingoiddowncurrentripples. The lee side surface shows *Planolites*(Fig.10).The cross-bedding, lee faces and ripples all indicate a NNW flowing paleocurrent direction similar to that recorded from ripples in the Arowasection. The presence of intervening shales suggests that the currents that produced the dunes flowed intermittently.

Figure. 17. Tukulma Group, Gombe Sandstone,Arowa Formation, Dabala stream. N 10º 14'01'' E11º08' 22.5''. Photograph showing typicalchannel-filling sandstones within 'a' portion of a cycle.

Interpretation of the DuguriFormation

The main features of the DuguriFormation, include the following: i) an unconformable/erosional base; ii) aroundDuguri and Bashar, cross-bedded sandstone overlying a basal conglomerate/pebbly sandstone; iii) the dominance of coarse to very coarse-grained cross-bedded sandstone and granulestone in all or the greater part of the unit; iv) the presence around Bashar, Yuli and Jarmai of a pervasive primary kaolinitic matrix; v) lack of a fauna/flora; vi) unimodalpaleocurrent patterns.

The absence of marine indicators, the relatively mature sediment texture and broadlyunimodalpaleocurrents,suggest an alluvial environment of deposition. The sandstones are dominantly negatively skewed and moderately to poorly sorted reflecting high reworking of the sediment during transport and in these respects agree with river sands (see Fig. 12). The paucity of argillaceous horizons suggests deposition in braided rivers, similar to those proposed for the Upper Bima Sandstone by Guiraud (1991).The "Upper Bima Sandstone" closely resembles the greater part of the Duguri Formation but differs petrologically being a feldspathic sandstone; the Duguri Formation lacks feldspar.

The primary kaolinitic matrix indicates intense chemical weathering of source area. The basement rock around Yuli now being exposed due to erosion of the DuguriFormation, shows total degradation of feldspar to kaolinite. The grain size variation shows coarser mean grain sizes in the west and south-west, and in the area between Dagudi and Gudus, suggesting a greater proximity to the source area.

References

Allen, J. R. L. (1984). Sedimentary structures, their character and physical basis, Volumes 1 and 2, *Developments in Sedimentology*, 30. Elsevier Scientific Publ. Co, Amsterdam.

Benkhelil, J. (1985). Geological Map of part of the Upper Benue Valley (Scale 1:100,000 with explanatory note). Elf Nigeria Ltd, Lagos.

Fairhead, J. D. (1986). Geophysical Controls on Sedimentation within African Rift systems. *Geological Societyof London Special Publication,*25: 19 – 27.

Frey, R. W and Howard, J. D. (1970).Comparison of Upper Cretaceous ichnofaunas from siliceous sandstones and chalk, Western Interior, U.S.A. In: Crimes, T. P. and Harper, J. C. (Eds), Trace fossils. *Geological Journal Special Publication.* 3: 141-166.

Friedman, G. M. and Sanders, J. E. (1978).*Principles of sedimentology*. John Wiley and Sons, New York, PP. 792.

Gebhardt, H. (1997).Cenomanian to Turonian Foraminifera from Ashaka (NE Nigeri).Qualitative analysis and paleoenvironmental interpretation.*Cretaceous Research*, 18: 17 – 36.

Ghibaudo, G., Mutti, E. and rossell, J. (1974). Le Spiagge fossils delleavenarie de Aren (CretacicoSuperiore) Nella Valle NogueraRibagorzana (Pirenel Centro-Meridionali province di lerida E. HuescaSpagna). *MemoriedellasocietaGeologicaItaliana*, 13: 497 – 537.

Guiraud, M. (1989).Geological Map of the part of the Upper Benue Valley, 1:50,000 (with explanatory note). Elf Nigeria Ltd, Lagos.

Guiraud, M. (1991).Mechanisme de formation du basin Crétacésurdécrochement.Un examples des décrochementssenestres NE – SW du bassindela Haute-Bénoué (Nigeria). *Bulletin de Centres des Recherches Exploration—Production Elf-Aquitaine,*15: 11 – 67.

Gunver, K.P. and Richard, G.B. (2006).*Ophiomorphairregulaire*, rare trace fossil in shallow marine sandstones, Cretaceous Atane Formation, West Greenland. *Cretaceous Research*, 27: 964-972.

Gruszczynski, M., Rudowski, S., Semil, J., Skominski, J. and Zrobek, J. (1993).Rip currents as a geological tool.*Sedimentology,*40: 217 – 236.

Hamidu, I., Zaborski, P. M and Hamza, H. (2013).A Review of the Campanian to Maastrichtianlithostratigraphic succession in the Cretaceous Gongola Basin of North-east Nigeria.*Journal of Mining and Geology*.49(2), 145-160.

Harms, J. C., Southard, J. B., and Walker, R. G. (1982). Structure and Sequence in Clastic rocks. Lecture notes Society of Economic Paleontology and Mineralogy Short Course No. 9. Calgary.

McKee, E. D. (1957). Primary structures in some recent sediments. *American Association of Petroleum Geologists Bulletin*, 41(8): 1704 – 1747.

Pedros, A.D and Antonio, F.S. (2007). Stable and ultrastable heavy minerals of alluvial to nearshore marine sediments from central Portugal: facies related trends. *Sedimentary Geology*, 201: 1-20.

Petters, S. W. (1978).Mid-Cretaceous paleoenvironments and biostratigraphy of the Benue Trough, Nigeria.*Bulletin of the Geological Society of America*,89: 151–154.

Petters, S. W. (1978a).Stratigraphic evolution of the Benue Trough and its Implications for the Upper Cretaceous paleogeography of West Africa.*Journal of Geology*, 86: 311–322.

Petters, S. W. (1979a).Nigerian Paleocene benthonic foraminiferal biostratigraphy, paleoecology and paleobiogeography.*Marine Micropaleontology*, 4: 85–85.

Petters, S. W. (1982).Central West African Cretaceous Tertiary benthic foraminifera and stratigraphy.*Paleontographica*,(A) 179: 1–104.

Richard, J. C and Dale, A, L. (1993).Hummocky cross-stratification. In: V. P, Wright (Ed). *Sedimentology Review/1*.Blackwell, Oxford, PP.142.

Robert, W. F., James, D. H and Wayne, A. P. (1978).Ophiomorpha: Its morphologic, taxonomic and environmental significance. *Palaeogeography, Palaeoclimate, Palaeocology*. Elsevier Scientific Publication, Amsterdam. 23: 199-229.

Reineck, H. E. and Singh, I. B. (1980).*Depositional sedimentary environments with reference to terrigenousclastics*. Springer-Verlag, Berlin,PP.439.

Records of the Geological Survey of Nigeria, 1956, 46 – 65.

Thompson, W. O. (1937). Original structures of beaches, bars and dunes.*Bulletin of the Geological Society of America*, 48: 732 – 752.

Tucker, M. E. (1988). *Sedimentary Petrology*.An Introduction. Blackwell, Oxford, PP. 252.

Tucker, M. E. (2001). *Sedimentary Petrology (third edition).Blackwell,* Oxford, PP. 262.

Wright, L. D. (1977). Sediment transport and deposition at river mouth.A synthesis.*Bulletin of the Geological Society of America*, 88: 857 – 868.

Zaborski, P. M. (1998). A review of the Cretaceous System in Nigeria.*Africa Geoscience Review,* 5: 385 – 483.

Zaborski, P. M., Ugoduluwa, F., Idornigie, A., Nnabo, P. and Ibe, K. (1997).Stratigraphy and structure of the Cretaceous Gongola Basin, north eastern Nigeria.*Bulletin des Centres des Recherches Exploration–Production Elf-Aquitaine*, 21:153 – 185.