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Depositional Patterns of Lamja Sandstone, Northeastern Nigeria

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ABSTRACT: Assessment of bedding relationship, textural characteristics and microfossil analysis were conducted on beds of Lamja Sandstone, which occupy the top of Cretaceous succession in the Upper Benue Trough of Nigeria for the purpose of interpreting environment of deposition. The lithology consists of dominant beds of very fine-grained clean sandstone with clasts having graphic mean (Mz) of 3.87□, standard deviation (□) of 0.44□and graphic skewness (sk) of -0.32□ The beds, about 120m thick are either rippled or horizontally laminated and contains subordinate crystalline limestone and coal seams. Upper beds of dark grey shale and oyster rich limestone (each about 20cm. thick) form the terminal beds of the formation. Petrographically, the sandstone is classified arenite with equant-grained clasts while the limestone bears the strands of the oyster pelecypods within sparitic groundmass. The upper shale bed contains arenaceous foraminifera genera, *Ammobaculites, Ammomarginulina, Ammotium, Haplophragmoides, Saccamina* and *Trochamina* which constitute the Turonian-Lower Senonian *Plaulina biadnelli-Ammoastuta nigeriana* zone. Bed succession and their various attributes depict facies changes from fine-sand particles of a lower shoreface to the upper-bed shale and limestone of the back-barrier brackish sub-environment.

Key words: Lamja Sandstone; lower shoreface; back barrier; Yola Arm.

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INTRODUCTION

Thick beds of clastic sediments occupy the top of the Cretaceous stratigraphic sequence in the Upper Benue Trough. These sediments constitute the Gombe and Lamja Sandstones in the Gongola and Yola Arms respectively. The Lamja Sandstone containing mainly clastic beds, with occasional subordinate clay, shale and coal, is exposed as outcrop sections at Lamja Sanma (Long. 11Ú522 , Lat. 9Ú492) and Chikila Tudu (Long. 11Ú532 , Lat. 9Ú462) in the northeastern Nigeria where their beds wedge against the east facing slope of the Longuda plateau (Fig. 1).

As clast-dominated deposits, fossil remains are scarce such that precise age of the formation remains controversial. Earlier workers (Carter *et al.*, 1963; Reyment, 1965; Whiteman, 1982; Genik, 1992) associated the formation with Maastrichtian Age. They variously arrived at this stratigraphic level based on the presence of abundant mollusc *Pycnodonte vessicularis* and the position of the formation 240m on top of the proven Coniacian – Santonian Formations. They however admitted that mollusc *Pycnodonte vessicularis* has a long ranging lineage that cut across the Cretaceous stages but only reached its acme in the Maastrichtian. Odebode and Enu (1986) through sedimentological and palynological evidences also established the lateral equivalence of the Lamja Sandstone to the Sukuliye and the Numanha Formations thereby regarding their age as Coniacian. Nevertheless, the marine intercalated limestone/ shale beds of the Sukuliye and Numanha Formations contrast the sandstone dominant

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beds of the Lamja Sandstone. The lithologic differences raised curiosity on the environment of deposition of the latter, more so that Whiteman (1982) and Allix (1983) generally referred to it as marine to deltaic deposits. This work therefore examines the bed relationship as well as textural and paleontologic attributes in the Lamja Sandstone, so as to deduce the process of sedimentation in the depositional environment.

Fig. 1: Geological map of Yola Arm of Upper Benue Trough showing location of Lamja Formation

GEOLOGIC SETTING OF THE YOLA ARM

The Benue Trough is an elongate basin that linearly trends NE–SW, forming boundaries with the Niger Delta in the south and the Borno basin in the north. The origin of the Trough is believed to be associated with the separation of the African and South American plates in the Early Cretaceous. Many authors have put forward different models for the evolution of the Trough. These range from aulacogen (Grant, 1971; Burke and Dewey, 1974), through rift (Wright, 1981) to pull apart sub-basins (Benkhelil *et al.*, 1989). A relatively recent model by Guiraud (1993) interpreted the Trough as a complex syn-depositional multiple strike-slip basin along N40°E to N60°E sinistral displacement fault.

The Upper Benue Trough, which contains the Lamja Sandstone as one of the formations, is the northern section of the elongate trough consisting of the Gongola and the Yola Arms which are oriented north-south and east-west respectively. A structural element in the latter, the Dadiya Syncline, consists of the entire stratigraphic succession whose initial sediments were fanglomerates. The sediments were derived from continental fragmentation of the basement by rifting and later graded into braided stream deposits. Both fanglomerates and braided stream deposits collectively form the Bima Sandstone that non- conformably overlies the basement during the Aptian-Albian Age. The Bima Sandstone is succeeded by Cenomanian Yolde

Formation whose sedimentologic characteristics are transitional between marine and continental environment. The beds are dominated by well sorted fine to medium grained clean sandstone of beach environment. They are mainly medium bedded in thickness with subordinate limestone, shale and mudstone.

The post Cenomanian deposits are marine sediments laid down by paleo-sea inundation of the rifted Trough as it continued to founder. The deposits in the order of succession are Dukul, Jessu, Sukuliye, Numanha and Lamja Formations. The Dukul reflects the peak of marine transgression as its lithologic and fossil contents particularly the abundance of the ammonites and pelecypod molluscs depict deposition in a full marine environment. Dukul Formation was succeeded by sediments of Jessu Formation which is dominated by ferruginous and rippled fine to medium grained sandstone and mudstone typical of enclosed marginal marine environment. The successively overlying Sukuliye and Numanha Formations consist of interbedded limestone and shale, signifying an environment of increase marine influence. Although the beds of the formations do not contain ammonites like the similar fully marine Dukul Formation, occurrence of rich assemblages of foraminifera and ostracods reveal fully marine paleo-sea condition during deposition (Opeloye, 2002). The stratigraphic succession of the Yola Arm terminates with the thick sandstone and coal seam deposits of Lamja Sandstone (Table 1).

Table 1: Stratigraphic units in the Dadiya syncline of the Upper Benue trough

METHODS OF STUDY

Bedding characteristics of outcrop sections of the Lamja Sandstone at both Lamja Sanma and Chikila Tudu areas of the Upper Benue Trough were recorded, described and sampled. Spot sampling procedure was adopted in collecting a handful of sample each, from selected beds along the vertical sections. Sandstone samples, which form the dominant lithology, as well as those of the limestone, shale and coal, were labeled as LS1 to LS18 at Lamja Sanma (Fig. 2). Labelled samples were also derived from Chikila tudu sections. The samples were subjected to granulometric, petrographic and microfossil analyses.

Granulometric analysis of the sandstone was by point count method on the slides produced, on account of the particles being indurated, using ocular micrometer gauge attached to UNICO microscope. Mineral analysis was also carried out for the purpose of sandstone classification while thin sections of the limestone were also petrographically studied for textural characteristics.

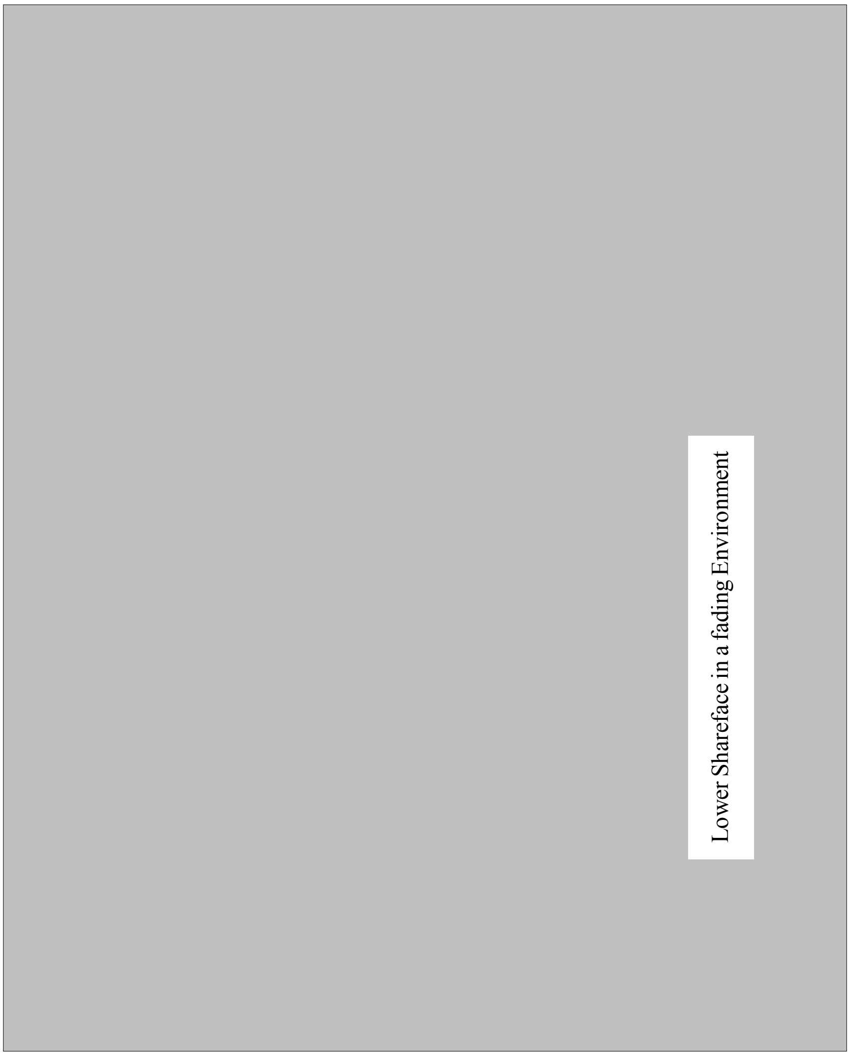
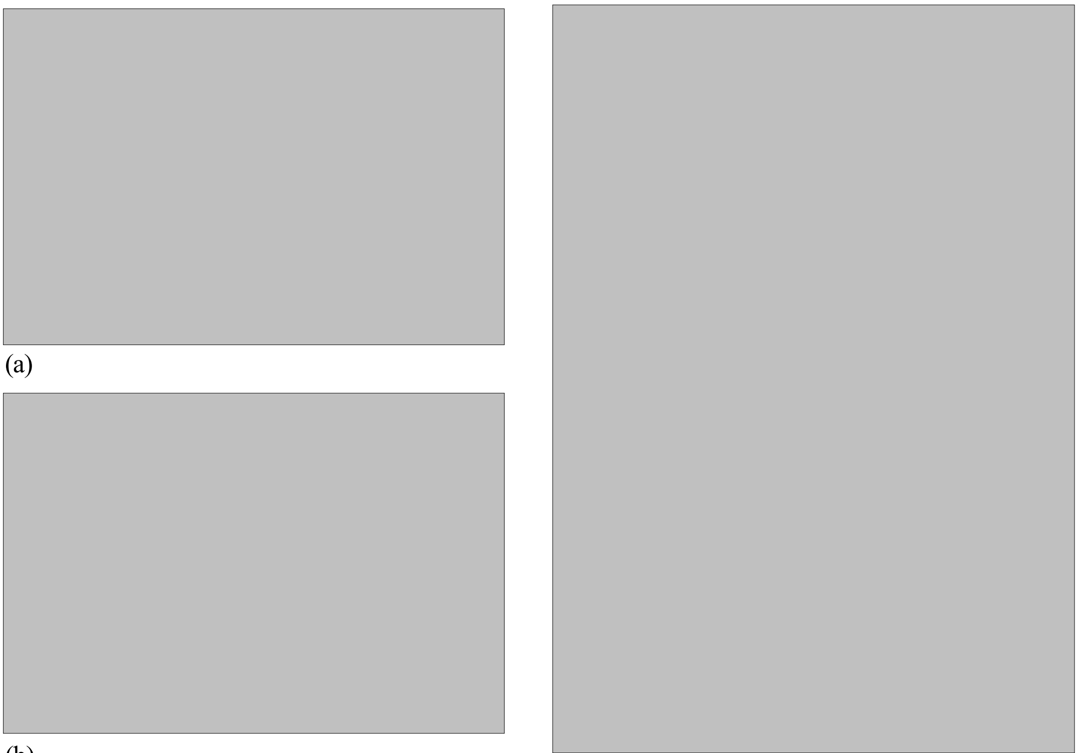


Fig. 2: Lamja Sandstone Litholog section at Lamja Sanma showing sample points and paleoenvironmental depositional patterns

Paleontological study was by foraminifera analysis. The shale samples, having been soaked in solution of 0.50g of Na_2CO_3 and washed through 230 mesh sieve was allowed to air-dry. The shale was in portion spread over black paper under OLYMPUS binocular microscope for picking of foraminifera.

RESULTS AND INTERPRETATION

Lithologic Observation and Descriptions: Prominent sections of Lamja Sandstone extend from its base at Lamza village to the top of the section at Lamja Sanma. The section is represented by the log profile in Figure 2. The basal bed is a thin crystalline limestone (LS 1) overlain by a 25m thick ripple laminated sandstone. The bed is terminated by another thin crystalline limestone (LS 4) with about 30m massive sandstone bed (LS 5 and 6) overlying it. The massive bed, at intervals of its thickness, consists of stringers and wavy streak of carbonaceous materials (LS 7). The massive bed is succeeded by about 40m parallel laminated sandstone (LS 8, 10-13) with thin fossiliferous oyster shell limestone at its base (LS 9). Another10m ripple bedded sandstone overlies it. It is terminated by a 25cm coal seam and separated from the overlying 7m thick parallel laminated sandstone. The succeeding 10cm fissile dark grey shale and 20cm oyster rich limestone beds form the terminal topmost beds. The fossiliferous limestone extends throughout the entire Lamja Sanma village where it truncates into basaltic lava. Figure 3 shows the encountered oyster rich limestone, the basal coal seam as well as the rippled sandstone bed. A less prominent section of Lamja Sandstone about 7m thick is also exposed at Chikila Tudu village.



(a) (b) (c)

Fig. 3: Lithologies of limestone, coal seam within bed of sandstone and rippled laminated sandstone bed

The base of the section consists of 1m thick fireclay succeeded by 50cm thick limestone bed. Another 1m of fissile grey shale overlies the limestone with a 20cm thick bituminous coal forming a sharp contact on top of the shale bed. About 3m thick indurated and parallel laminated sandstone terminate the section. The lithologic observations indicate that Lamja Sandstone with component beds having dominance of white, clean fine grained sandstone overlain by limestone and shale is a marginal marine deposits reflecting a shore complex.

Granulometric study

All the sandstone beds consist of clast particle sizes whose majority of grains range between 0.125mm and 0.083mm (3□and 3.6□) as measured through the aid of ocular micrometer. Five selected samples from both Lamja Sanma and Chikila Tudu are represented in Figure 4. The clasts are enmeshed within ca 35% silty matrix and calcareous cementation with a unimodal distribution. Graphic means (Mz) is 3.87□, standard deviation (□) is 0.44□while skewness (sk) is 0.32□, depicting a well sorted distribution. The sandstone of the formation is therefore texturally classified as fine to very fine.

Fig. 4: Granulometric data and Grain size cumulative plot of some sandstone samples of the Lamja Formation

Petrographic Study

Sandstone: The grains are composed entirely of quartz with siliceous matrix (Fig. 5). The sandstone is classified as quartz arenite as feldspars and any form of rock fragments were not identified. Porosity is very poor on account of the grains being well sorted as well as its siliceous cementation. Both the quartz grains and the matrix are of low undulatory extinction.

Limestone: Limestone beds of the Lamja Sandstone are of two types; the fossiliferous and the hard non-fossiliferous limestone. Texturally, the crystalline limestone is composed of crystal grains with sutured margins reflecting grain dissolution. The fossiliferous limestone is biomicrite with interlocking allochem-bioclasts of bryozoans, bivalves and ostracod cemented by sparite crystals (Fig. 5).

(a) (b)

Fig. 5: Photomicrographs of the sandstone and the limestone of the Lamja Sandstone

Foraminifera Assemblage:

The analysed upper shale bed (sample LS 17) yields 15 species of foraminifera with *Ammobaculites* and *Ammotium* species constituting the most abundant forms. The foraminifera species are as follows: i) *Ammobaculites amabensis*, ii) *A. bauchensis, iii) A. benuensis, iv) A. corprolithiformis v) A. dilatatus, vi) A. irregulariformis vii) Ammomarginulina* sp. *viii) Ammotium nkalagum, ix) A. nwalium, x) Haplophragmoides bauchensis, xi) H. hausa , xii) H. talokaensis, xiii) H. sahariense, xiv) Saccamina* sp. and xv) *Trochamina* sp. (Fig. 6). Planktonic forms are however not found in the assemblage.

DISCUSSION

Clean, fine grained sandstones exposed either as massive, rippled or laminated beddings form the major lithology of the Lamja Sandstone, reflecting a shore environment. The sandstone is well indurated and composed entirely of quartz. As intergranular pore volume depends mostly on compaction and lithifaction by cementation (Makowitz, 2006), Lamja Sandstone porosity is very poor. Nevertheless, absence of cross bed-sets suggests that the deposition occurred within a fair weather wave base devoid of storm events. Shale, coal, crystalline and fossiliferous limestone variously constitute subordinate beds of the formation. Grain size distribution reveals that the majority of the clast size falls between 3□and 3.6□ It classifies the Lamja Sandstone as well-sorted, very fine grained silisiclastics whose negative skewness indicates more of fine sands than silty grains. Histogram of the clast size distribution is unimodal suggesting a single source or similar form of sedimentation.

Three major sub-environments normally characterize the proximal region of the shore complex to the sea; the shoreface, the foreshore and the backshore. The foreshore and the backshore extend landward from the low tide level to form the beach, while the shoreface is constantly under water, extending from mean low tide level down to the lower limit of fair weather wave base (Boggs, 1987). The dominant clasts of the formation with clean, fine to very fine particles and horizontally laminated facies, depict deposition in the lower shoreface sub-environment. The Lower shoreface sub-environment is a section of the shore complex that is generated by marine wave processes leading to accretion of well sorted sand body parallel to the shoreline.

Fig. 6: Foraminifera of the topmost shale beds of the Lamja Formation.

Shoreline deposits, according to Dickinson (1988), is tectonically associated with downward flexing of the lithosphere along rifted continental margin due to continual sediment loading. The resulting subsidence not only allowed for thick bedded depositions that form in a continental margin basin. It also argues for occurrences of thin beds and stringers of crystalline and fossiliferous limestone, coal and shale during shoreline migration, in relation to pattern of eustatic changes. The dominant sandstone beds of the formation are interpreted to have been deposited from suspension in the shoaling wave zone. This is on account of their very fine grained nature and horizontally laminated/rippled beds. The interlayered massive beds reflect occasional stormy conditions. In a typical transitional environment, massive sandstone beds are usually attributed to both tidal and wave activities. However it is the opinion of Ramos *et al* (2006) that massive sandstone of tidal influence is additionally associated with post depositional process of dewatering and partial fluidization which was not identified in the Lamja beds. On the contrary the model of Reinson (1984) that the influence of wave, reaching the shoal from the breaker/surf zone, can lead to re-sedimentation fits the depositional pattern of the massive beds. The wave might have scoured already deposited sediments of the shoal into suspension. Such occasional stormy conditions also pave ways to reduced water pressure (Boggs, 1987) giving rise to loss of carbon dioxide and eventual precipitation of the carbonates within such enhanced high pH environment. The thin bedded crystalline limestone might have been deposited in this way. Equally associated with stormy condition of sedimentation are detrital vegetal materials and hydraulically light particles which McCubin (1982) associated with the origin of organic and argillaceous stringers within clastic beds. Occurrences of fossiliferous limestone and shale, prominent at the topmost layer of the formation, however indicate a shift to brackish environment. The densely packed oyster shells in the limestone, as well as the enriched arenaceous foraminifera in the shale, support the evidence of the brackish environment typical of the back-barrier of the shore complex. Identified foraminifera that are entirely arenaceous are more ecologically significant than denoting stratigraphic position. They are detritivores indicating habitat in muddy restricted lagoonal brackish environment. The entire forms however, constitute the major assemblage of the *Plannulina beadnelli-Ammoastuta nigeriana* zone of Petters (1982, p.17) which range from Turonian to Lower Senonian (Early Santonian). Since the Lamja Sandstone occupies the topmost stratigraphic sequence of the Yola Arm overlying a proven Turonian stages and was also affected by the Santonian folding, a Coniacian age is assigned to it. This age is in assertion made by Odebode (1987) based on palynological study.

The succession of the Lamja Sandstone therefore depicts gradation from fair weather wave sedimentation of fine grained particles of a lower shoreface in a shoaling environment, to a back-barrier brackish environment which must have resulted from waning sea influence (Fig. 2). This succession fits into the model of regressive barrier bar sedimentation of Galloway and Hobday (1983), in which back-barrier lagoonal/brackish deposits overlaps the sea proximal environments of backshore, foreshore and shoreface deposits in the Galveston Barrier Island complex of southeast Texas, U.S.A.

CONCLUSION

Thick-bed sections of Lamja Sandstone overlie the shaly and limestone- intercalated beds of Numanha Formation at both Lamja Sanma and Chikila Tudu near Guyuk in the northeast of Nigeria. Lithologies of the sections are dominated by clean white sands, laminated and rippled with occasional stringers and thin bedded crystalline limestone, interpreted as lower shoreface deposit. The prominence of fossiliferous shale, oyster limestone bed and coal seam at the upper beds of the succession reflects overlap of brackish sediments on the shoreface deposit signifying a waning sea influence. A regressive barrier bar sedimentation is inferred while the arenaceous foraminifera in the shale of the upper beds, constitutes forms within the Turonian-Lower Senonian assemblage zone.

REFERENCES

ALLIX, P. (1983)**.** Enviroments mesozoiques de la parte nord-orental du fosse de la Benoue (Nigeria).Stratigraphie, sedimentologie, evolution geodynamique. These trieme cycle, Univ. Marseille. Trav. Lab. Sci Terre St. Jerome, Marseille 21, 200p.

BENKHELIL, J., GUIRAUD, M., PONSARD, J. F and SAUGY, L., (1989)**.** The Borno-Benue Trough, the Niger Delta and its offshore tectonosedimentary reconstruction during the Cretaceous and Tertiary from geophysical data and geology. In: Kogbe C.A (ed) Geology of Nigeria. Abiprint and Pak Ltd Ibadan. pp. 277-309.

BOGGS, S; Jr., (1987). Principles of Sedimentology and Stratigraphy. Macmillan, New York pp. 77-99.

BURKE, K. C. and DEWEY, J. F., (1974). Two plates in Africa during the Cretaceous? *Nature* **249**:313-316

CARTER, J. D., BARBER, W., TAIT, E. A. and JONES, G. P., (1963). The Geology of parts of Adamawa, Bauchi, Bornu Provinces in northeastern Nigeria. Geological Survey of Nigeria Bulletin **30.** 109p.

DICKINSON, W. R. (1988), Provenance and sediment dispersal in relation to paleotectonics and paleogeography of sedimentary basin. In: Kleinsphen, K.L. and Paola, C. (eds). Frontiers in sedimentary Geology. New York pp. 3-25.

GALLOWAY, W. E; and HOBDAY, D. K. (1983). Terrigenous clastic depositional systems. Springer Verlag, New York, 423p.

GENIK, G. J., (1992). Regional framework, structural and petroleum aspects of rift basins in Niger, Chad and the Central African Republic (C.A.R). *Tectonophysics* **213**:169-185.

GRANT, N. K., (1971). South Atlantic, Benue Trough and Gulf of Guinea Cretaceous triple Junction. *Bulletin Geological Society of America* **82**: 2295-2298

GUIRAUD, M. (1993). Late Jurassic Rifting- Early Cretaceous Transpressional inversion in the Upper Benue Basin (NE Nigeria) *Bull. Elf Aquitaine* **17**:371-383.

MAKOWITZ, A. LANDER, R. H. and MILIKAN, K. L. (2006). Diagenetic modeling to assess the relative timing of quartz cementation and brittle grain processes during compaction. *American Assoc. Petrol. Geol. Bull.* **90**(6) 873-885.

McCUBIN, D. J., (1982). Barrier island and strand plain facies. In: Scholle, P.A and Spearing, D. (eds), Sandstone depositional Environments. *American Assoc. Petrol. Geol. Mem.* **31**: pp. 247-279.

ODEBODE, M. O. and ENU, E. I. (1986). Evidence of lateral equivalence of terminal Cretaceous formations in the Upper Benue Basin, Nigeria. *Newsl. Statigr.* **17**: pp 45-55

ODEBODE, M. O. (1987). Palynological dating of the Lamja Sandstone (Benue Basin, Nigeria) and its geological significance. *Jour Afr. Earth Sci.* **6**:421-426.

OPELOYE S. A. (2002). Some aspects of Facies architecture, Geochemistry and Paleoenvironment of Senonian formations in the Yola Arm, Upper Benue Trough (Nigeria). Unpublished Ph.D Thesis, Abubakar Tafawa Balewa University, Bauchi. 160p.

PETTERS, S. W. (1982). Central West African Cretaceous – Tertiary benthic foraminifera and stratigraphy. *Paleontographica.* 104p.

RAMOS, E., MARZ, M., deGILBERT, J. M., TAWENGI, K. S., KHOJA, A. A. and BOLATTI, N. D. (2006). Stratigraphy and sedimentology of the Middle Ordovician Hawaz Formation (Murzuq basin, Libya) *American Assoc. Petrol. Geol. Bull.* **90**(9):1309-1336

REINSON, C. E. (1984). Barrier Island and associated strand plain systems. In: Walker, R.G.(ed). Facies models: Geosc. Canada, Reprint ser.1 2nd ed. pp.119-140.

REYMENT, R. A., (1965). Aspect of the Geology of Nigeria. Univ. Ibadan Press, Ibadan. 133p.

WHITEMAN, A.J., (1982**).** Nigeria-Its petroleum Geology resources and potential. Graham and Trotman, London.394p.

WRIGHT, J.B., 1981, Review of the origin and evolution of the Benue Trough in Nigeria. *Earth Evolution Science* **1**:98-104.