International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2014 Vol. 4 (3) December, pp. 130-137/Odumodu
Research Article

ICHNOLOGY AND LITHOFACIES ANALYSIS OF THE CAMPANO-MAASTRICHTIAN MAMU FORMATION IN THE NORTHERN PARTS OF THE ANAMBRA BASIN, NIGERIA

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ABSTRACT
Lithofacies and Ichnologic study were carried out for the Mamu Formation in the northern part of the Anambra Basin so as to decipher the paleodepositional environment of the formation. Results suggest the presence of eleven lithofacies, which are grouped into five lithofacies association, namely; heterolithic sandstone and shale, heterolithic siltstone and shale, carbonaceous sandstone and shale, massive fine grained sandstone and shale and parallel bedded fine grained sandstone facies associations. The lithology is made up of white and carbonaceous siltstones, gray and white shales, silty shales, fine grained sandstones, carbonaceous and bioturbated mudstones, and black coal. The trace fossils include *Teichichnus, Planolites and Thalassinoides*, These trace fossils belong to one ichnofacies association- the *Cruziana* ichnofacies. On the basis of lithofacies characteristics and trace fossil assemblages, the Mamu Formation in the study area is interpreted as deposited in a shallow marine environment comprising of upper shoreface, foreshore, mixed tidal flats and lagoon / swamp environments.

Keywords: *Anambra Basin, Mamu Formation, Lithofacies, Ichnofacies, Heterolithic, coal, lagoon, swamp.*

INTRODUCTION
The Mamu Formation conformably overlies the Nkporo Group and is the second lithostratigraphic unit in the Anambra Basin. It was previously known as the Coal Measures (Bain, 1925) and Lower Coal Measures (Tattam, 1944; Simpson, 1954; De Swardt and Casey, 1963) until (Reyment, 1965) described it as Mamu Formation with its type locality on outcrops on the banks of Mamu River in southeastern Nigeria. Several studies have been carried out on the Mamu Formation. This includes the stratigraphic / biostratigraphic studies of (Petters, 1978; Ladipo, 1988; Adeniran, 1991; 1995; Gebhardt, 1998), sequence stratigraphic studies of (Nwajide and Reijers, 1996; Onyekuru and Iwuagwu, 2010), palynological studies of (Mebradu, 1982; Ogala *et al*, 2009; Onuigbo *et al*, 2012; Soronnadi-Ononiwu *et al*, 2012), coal characterization studies of (Akande *et al*, 1992) and petroleum potential studies of (Ogala *et al*, 2011). These previous studies are mostly concentrated on outcrops in the southern part of the Anambra Basin. However; very good outcrops also do exist in the northern parts of the basin which have not been well studied. Thus a detailed sampling of the formation was carried out in this study to establish the lithofacies and biogenic characteristics and reconstruct the depositional environments.The study is focused on the outcropping sections of the Mamu Formation at road cuts at Ojodu and Ojuwolijo – Aloji, along Ankpa – Itobe – Abuja road and at Odoba and Okwungaga, along Oturkpa – Ugbokolo – Oturkpo road and at Okaba coal mine (Fig. 1).

Study Area and Geologic Background

The study area is located in the northern parts of the Anambra Basin; bounded by longitudes 6°50′E - 7°46′E and latitudes 7°00′N - 7°30′N (Fig. 1). The Anambra Basin (Fig. 2) lies south - westwards of the NE – SW trending Benue Trough and is a broad synclinal structure containing more than 5,000 m thick sediment of Upper Cretaceous age. The basin evolved during the second sedimentary phase as a result of the Santonian folding and uplifts of the Abakaliki region and displacement of the depocenter into the Anambra platform and Afikpo region (Murat, 1972; Burke *et al*, 1972; Kogbe *et al*, 1976). The stratigraphic succession consists of the Nkporo Formation, Mamu Formation, Ajali Formation & Nsukka Formation, which is the topmost lithostratigraphic unit. The Mamu Formation is Campanian to Lower Maastrichtian in age and overlies the Nkporo Formation as the second lithic fill in the Anambra basin. It

consists of alternating sequences of sandstones, sandy shales and mudstones, with coal seams and carbonaceous shales at various horizons (Simpson, 1954; De Swardt and Casey, 1963; Reyment, 1965 and Kogbe, 1976).

MATERIALS AND METHODS

Five vertical lithologic sections from locations shown in Fig. 1 were systematically logged to obtain sedimentological and ichnological data. Detailed descriptions of the sections were carried out. Sedimentary structures, texture, nature of bedding and bedding contacts, fossil content and lateral variability of the lithofacies were observed and documented. The trace fossils present were systematically described and their distribution recorded.

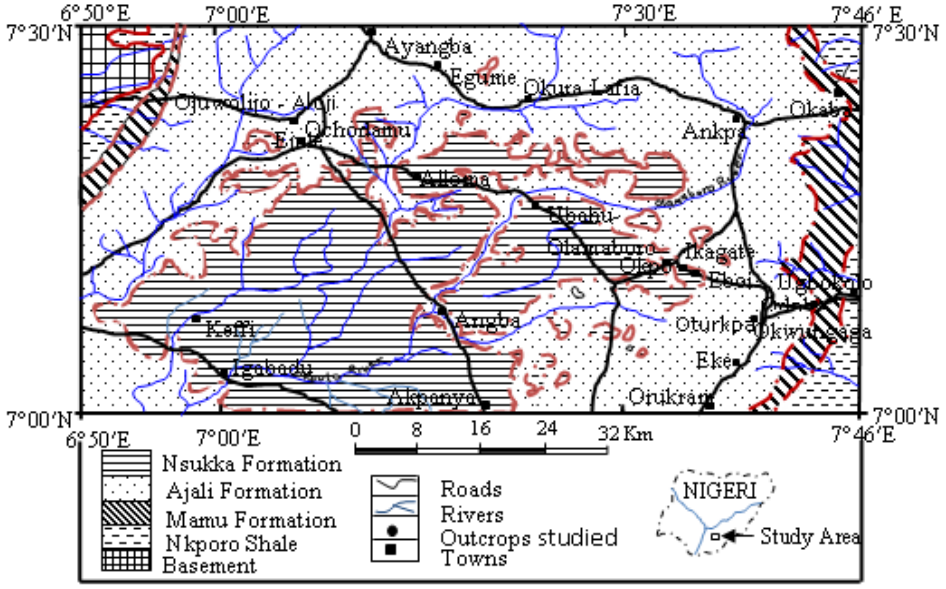

Fig. 1: Geological map of parts of the northern Anambra Basin showing the outcrops locations

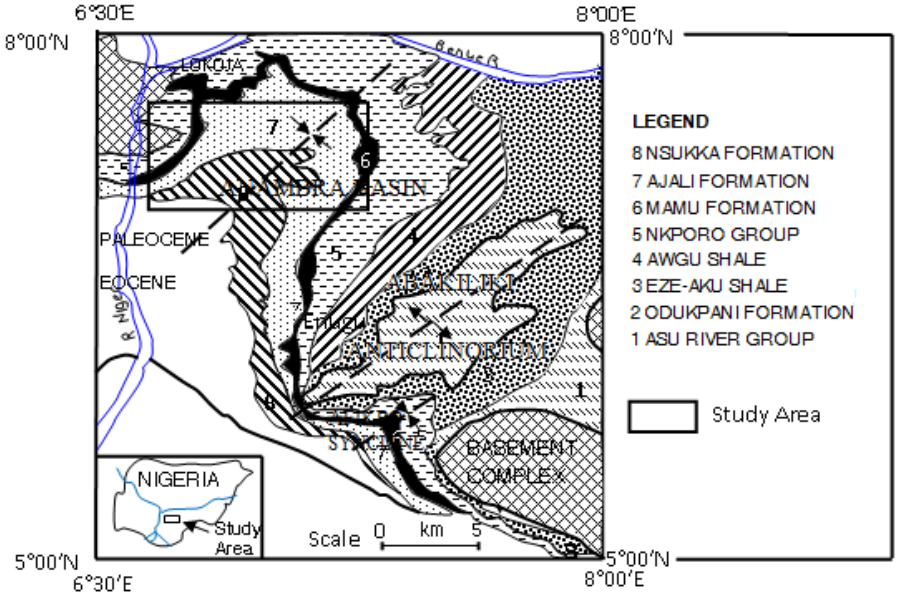

Fig. 2: Geologic map of southeastern Nigeria showing the study area

RESULTS AND DISCUSSION

Lithofacies Association

Ten recurring sedimentary facies (Table 1) were recognized and grouped into five facies associations using sedimentological and ichnological criterion as outlined by Collinson (1969) and Walker and Plint, (1992). The lithofacies associations include;

Heterolithic sandstone and shale facies association Middle to Lower shoreface

The heterolithic fine grained sandstone and shale facies association occurs in the upper part of the formation. It consists of fine grained sandstone / shale heterolith (F4A), white siltstone (F1C), massive fine grained sandstone (F1B), bioturbated mudstone (F1D), and silty shale (F2A) facies. The fine grained sandstone / shale heterolith is thinly laminated, wave rippled to parallel bedded. This facies were observed only at Ojodu. The white siltstone facies are parallel bedded and has a sharp basal contact with the silty shale facies at Okaba. This white siltstone facies were observed at Ojuwolijo – Aloji, Odoba and at Okaba. The massive fine grained sandstone facies were observed only at Odoba and contains no internal sedimentary structures. The bioturbated mudstone (F1D) occurs as two different beds at Ojodu and contains *Teichichnus, Thalassinoides* and *Planolites* Ispp (Fig. 4a and 5a) belonging to the Cruziana ichnofacies. This heterolithic sandstone and shale facies association is overlain by the pebbly and coarse grained sandstone of the Ajali Formation (Fig. 3c).

Interpretation

The heterolithic siltstone and shale facies association is interpreted as middle to lower shoreface deposits. Wave ripple laminated heteroliths usually consists of interbedded ripple laminated mudstones (shale and siltstones) and fine grained sandstone. Wave ripple laminations are storm generated sedimentary structures formed below fair-weather wave but are typical of lower shoreface sequences (Walker and Plint, 1992).

Table 1: Summary of facies used in this study to characterize the strata of the Mamu Formation

Description	Occurrence & contacts	Sedimentology / Accessories	Ichnology / Fossils	Interpretation
F1A Gray shale	Overlies F1B Rare	Horizontally parallel laminated	Rare	Middle shoreface
F2A. Parallel laminated white shale	Underlies a coarse to pebbly sandstone Very rare facies	Horizontally parallel laminated	Rare	Middle to Upper shoreface
F3A. Silty Shale	Overlies F1E	Parallel bedded to lenticular	Rare	Lagoon/ Swamp
F4A Siltstone / Shale heterolith	Overlies F1C Rare	Horizontally laminated Parallel bedded Wave ripple laminated	Rare	Middle to Upper shoreface
F1B. Massive fine grained sandstone	Overlies F1A & F1C	Massive	Trace fossils absent	Middle shoreface
F2B.Parallel bedded fine grained sandstone.	Sharply underlies F4A	Horizontaly parallel lamination Horizontally parallel bedded	Rare	Foreshore – Upper shoreface.
F1C White siltstone	Sharply overlies F1A & F4A Very common facies	Horizontally parallel laminated Horizontally parallel bedded Massive in places	Highly bioturbated Contains *Teichichnus* *Thalassinoides* and *Planolites* burrows	Middle Shoreface
F1D. Carbonaceous mudstone	Overlies F1B & F3A Has an erosional base	Massive	Rare	Lagoon / Swamp
F1E Black coal	Underlies F3A	Massive to thin parallel lamination	Rare	Marsh / Swamp
Carbonaceous siltstone	Overlies F1A	Massive	Rare	Lagoon/ Swamp

Heterolithic Siltstone and Shale Facies Association - Mixed Tidal Flats.

The heterolithic siltstone and shale facies association were observed at Okaba coal mine. It consists of parallel and ripple laminated heteroliths of siltstone and shales.

Interpretation
This facies association is interpreted as a mixed tidal flat deposit based on Dalrymple (1992) model. Reading and Collinson (1996) suggests that the interbedded siltstones and shales indicate equal periods of suspension and bedload deposition with bedload deposition increasing seaward.
Carbonaceous mudstone and shale facies association – Lagoon / Swamp
This facies association underlies the heterolithic siltstone and shale facies. It consists of carbonaceous mudstone (F2D), silty shale (F3A), and black coal (F1E) facies. The carbonaceous mudstone consists of very thin brownish carbonaceous mudstone bed with an erosional basal contact, occurring at Okaba. The silty shale (F3A) occurs as two beds at Okaba with a thickness of about 1 to 2 meters. Sedimentary structures include parallel and lenticular lamination. The black coal is sub – bituminous in character. This facies association was observed only at Okaba and at Odoba.
Interpretation
The interbedded and interfingering carbonaceous shale, sandstone and siltstone are interpreted as lagoonal sequences based on Reinson (1992) model. The black coal is suggestive of deposition in a swamp / lagoon environment. They are usually very thin having been formed on sands and mudflats on the lagoonal margins (Reinson, 1992).
Fine grained sandstone and shale facies association – Middle shoreface
The fine grained sandstone and shale facies association consists of parallel laminated gray shale (F1A) and massive fine grained sandstone (F1B). The parallel laminated gray shale occurs only at Odoba and is about 1.2 meters thick. The massive fine grained sandstone facies were also observed only at Odoba.
Interpretation
The massive fine grained sandstone and the parallel laminated dark gray shale suggest deposition in a low energy shallow marine environment. This facies association is interpreted as a middle shoreface environment following Walker and Plint (1992) model
Parallel bedded fine grained sandstone facies association – Upper shoreface to foreshore
This facies association consists only of parallel bedded fine grained sandstone facies (F2B). The parallel planar beds often resembles planar cross – bedding. The facies association was observed only at Odoba.
Interpretation
This facies association is interpreted as upper shoreface to foreshore deposits because of the planar lamination and bedding, as well as the lack or low diversity of trace fossils in the deposit. MacEarchern and Pemberton (1992) attributed the low diversity of trace fossils to harsh environmental conditions, continuously shifting substrates and low preservation potentials.

Ethology
The three trace fossils described in this study can be assigned to one ethological category – fodonichnia. Fodonichnia refers to deposit feeding burrows and include all burrows made through the combined activities of feeding and dwelling in sediments. It is constructed by some endobenthic deposit feeders living in the burrows; through the systematic mining of sediments for food. It includes *Teichichnus rectus*, *Planolites montanus* and *Thalassinoides suevicus*.

Systematic Description of Trace Fossils
The trace fossils observed in the study area include *Teichichnus*, *Thalassinoides* and *Planolites* belonging to the *Cruziana* ichnofacies. The description of ichnofossil taxa is given below.
Ichnogenus *Teichichnus* Seilacher, 1955
Teichichnus rectus, Figs. 4a and Fig 5a.
Description: *Teichichnus* consists of curved, unbranched, horizontal or inclined spreiten tunnels, stached in a sub-vertical plane at various angles to bedding; preserved in full relief or hyporelief.
Diameter: 1.5 – 2.5, Height: 20 cm.

Discussion: *Teichichnus* burrows occurs mainly in subtidal areas with reduced sedimentation rates, low turbulence and generally stable substrates, and characterized by deposit feeding and shallow burrowing traces.

Ichnogenus *Planolites* Nicholson, 1873
Planolites isp, Figs. 4a and 5b.
Description: *Planolites* consists of unlined, unbranched and unwalled, straight to gently curved and smooth burrow formed generally parallel to bedding.
Diameter: 1cm , Maximum length: 25 cm
Discussion: Planolites are made by sediment ingesting deposit feeding.

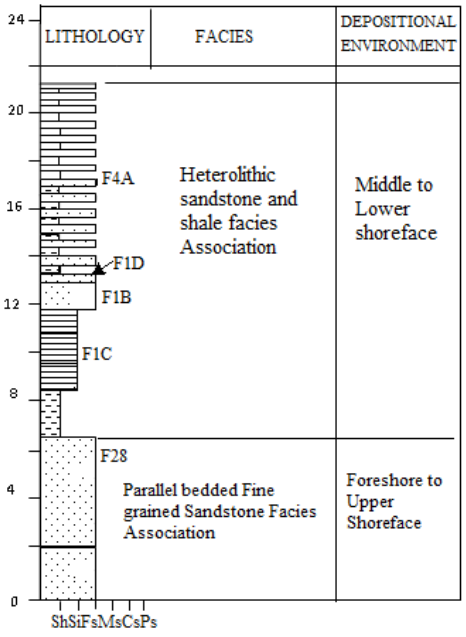

Fig. 3a: Litholog of Mamu Formation at Ojodu, along Anyangba - Itobe Road

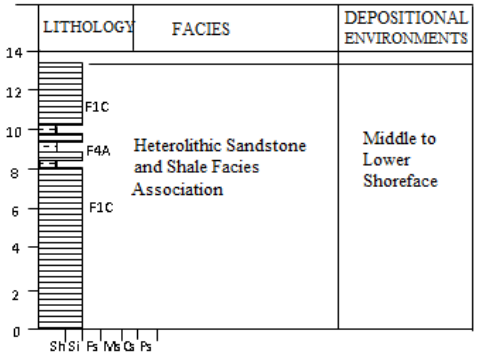

Fig. 3b: Litholog of Mamu Formation at Okwungaga.

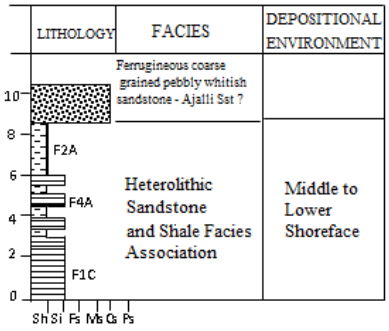

Fig. 3c: Litholog of Mamu Formation at Ojuwolijo-Aloji, 33 kms to Ajaokuta

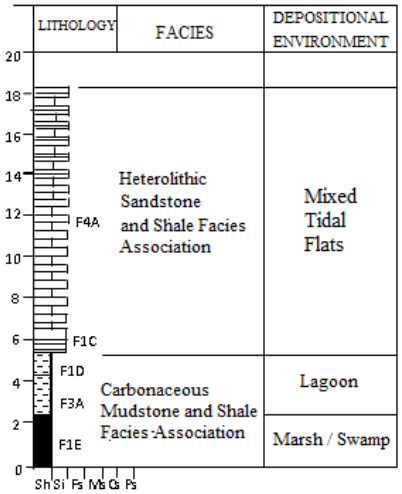

Fig. 3d: Litholog of Mamu Formation at Okaba coal mine

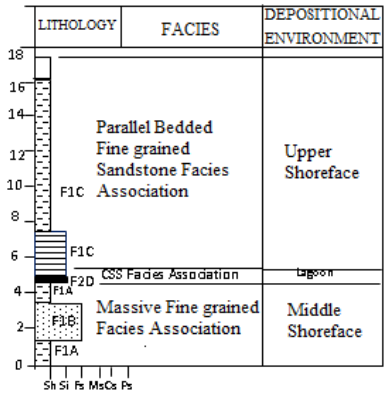

Fig. 3e: Litholog of Mamu Formation at Odoba

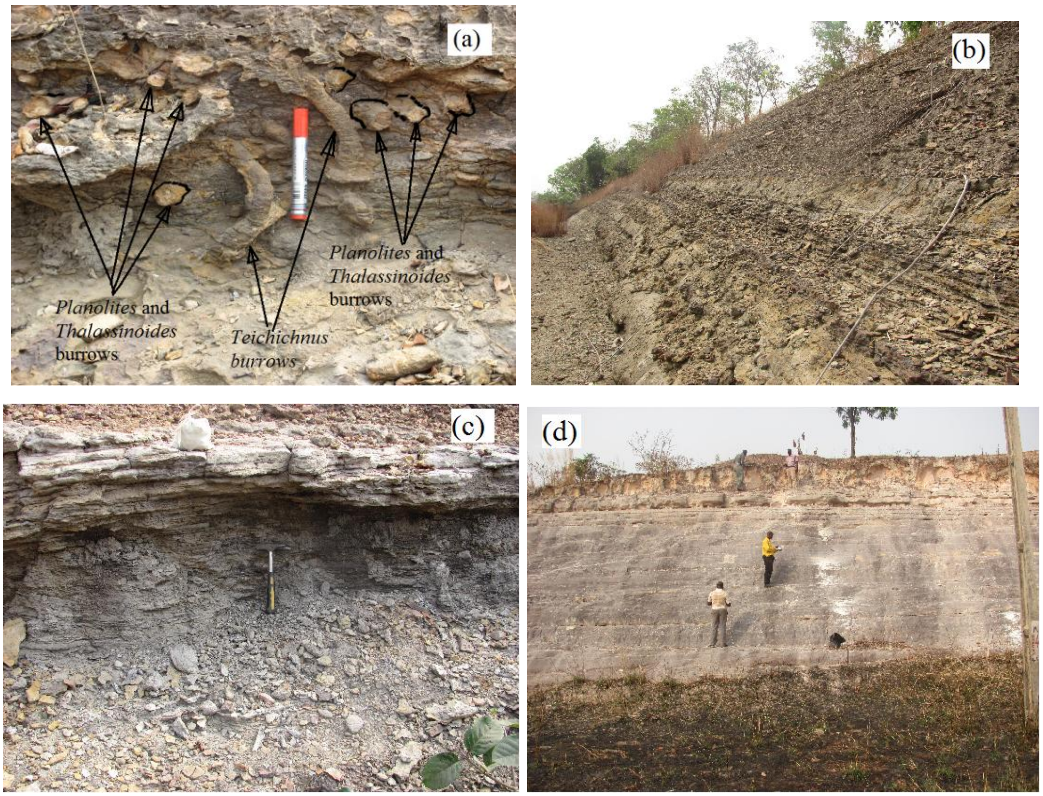

Fig. 4. {a)Trace fossils from the Mamu Formation {*Teichichnus*, *Thalassinoides* and *Planolites*) .at Ojodu. Wave ripple and parallel laminated siltstones and shales at (b) Odoba (c) Ojodu and (d) Ojuwolijo – Aloji

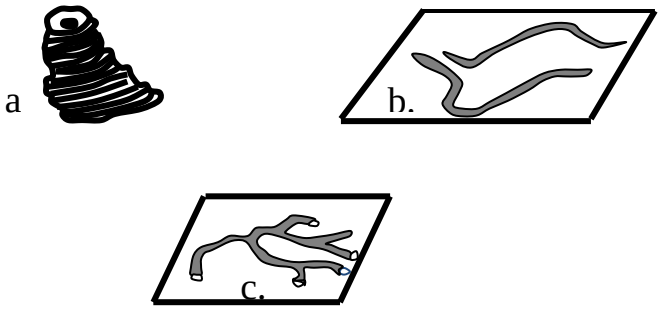

Fig. 5. A sketch of biogenic structures from the Mamu Formation (a) *Teichichnus rectus* (b) *Planolites montanus* and (c) *Thalassinodes suevicus*

Ichnogenus *Thalassinoides* Ehrenberg, 1944
Thalassinoides suevicus
Figs. 4a and 5c

Description: They consists of cylindrical to elliptical burrows which form a 3 – dimensional to horizontal branching polygonal network with vertical shafts connected to the surface (Myrow, 1995). These burrows show a regular branching with Y – or T shaped bifurcations. Most of the specimens swell at branches and elsewhere on superimposed tunnels.
Diameter: 0.9 – 1.6 cm Length: 4 – 10 cm
Discussions: *Thalassinoides* are most probably produced by arthropods. They are feeding and dwelling burrows of decapods crustaceans or some other kind of arthropods.

Summary and Conclusion

Using sedimentological and ichnological criterion, five lithofacies association were distinguished for the Mamu Formation in the northern part of the Anambra Basin. The lithofacies associations include; heterolithic sandstone and shale facies association – lower to middle shoreface, heterolithic siltstone and shale – mixed tidal flats, carbonaceous sandstone and shale – lagoon / swamp, massive fine grained and shale – middle shoreface, and parallel bedded fine grained sandstone and shale facies association – upper shoreface to foreshore. The trace fossil assemblage in this formation belongs entirely to the Cruziana ichnofacies comprising of *Teichichnus rectus, Planolites montanus* and *Thalassinoides suevicus*. This study has thus revealed that the paleodepositional environment of the Mamu Formation in the northern part of the Anambra Basin ranges from the shoreface to foreshore, mixed tidal flats to lagoons / swamps.

ACKNOWLEDGMENT

The present study has been carried out in the Department of Geology of Anambra State University, Uli. The author also wishes to thank an anonymous reviewer for reviewing this work and for his constructive criticisms which greatly improved this paper.

REFERENCES

Adeniran BV (1991). Maastrichtian tidal sequences from the northern Anambra Basin, southern Nigeria. *Nigerian Association of Petroleum Explorationists Bulletin* **6** (1) 56 – 66.
Adeniran BV (1995). Transitional deposits of the Maastrichtian Mamu Formation, southeastern Nigeria: *Nigerian Association of Petroleum Explorationists*. 13th Annual International Conference, Abstracts 26 – 27.
Akande SO, Hofftnecht A and Erdtmann BD (1992). Rank and Petrographic composition of selected Upper Cretaceous and Tertiary coals of southern Nigeria. *International Journal of Coal Geology* **20** 209 – 224.
Bain ADN (1925). The Nigerian Coalfield. Section 1, Enugu Area. Bull. Geol. Surv. Nigeria **6** 81.
Burke KG, Dessauvagie TFJ and Whiteman AJ (1972). Geological History of the Benue valley and adjacent areas. In: *African Geology* edited by Dessauvagie, T.F.J. and Whiteman, A.J (University of Ibadan Press, Ibadan, Nigeria) 187–206.
Collinson JD (1969). The sedimentology of the Grindslow Shales and the Kinderscout Grit: a deltaic complex in the Namurian of northern England. *Journal of Sedimentary Petrology* **39** 194 – 221.
Dalrymple RW (1992). Tidal depositional systems. In: *Facies models: response to sea level change* edited by Walker, R.G. and James N.P. (Geol. Assoc. Canada) 195–217.
De Swardt AMJ and Casey OP (1963). The coal resources of Nigeria. *Bull. Geol. Surv. Nigeria* **28**.
Ekdale AA, Bromley RG and Pemberton SG (1984). *Ichnology; Trace fossils in sedimentology & Stratigraphy*: SEPM short course **15** 317.
Gebhardt H (1998). Benthic Foraminifera from the Maastrichtian Lower Mamu Formation near Leru (Southern Nigeria): Paleoecologic and Paleogeographic significance. *Journal of Foraminiferal Research* **28** 76 – 89.
Kogbe CA (1976). Paleogeographic history of Nigeria from Albian times. In: *Geology of Nigeria* edited by Kogbe, C.A. (Elizabethan Publishers, Lagos) 237 – 252.

Ladipo KO (1988). Paleogeography, sedimentation and tectonics of Upper Cretaceous Anambra Basin, southeastern Nigeria. *Journal of African Earth Sciences* **7** (5/6) 865 – 871.
MacEachern JA and Pemberton SG (1992). Ichnological aspects of Cretaceous shoreface successions and shoreface variability in the Western Interior Seaway of North America. In: *Applications of Ichnology to Petroleum exploration: A Core Workshop. Society of Economic Paleontologists and Mineralogists* edited by Pemberton, S.G. (Core Workshops, Tulsa, Oklahoma) **17** 57 – 84.
Mebradu SJ (1982). Palynofacies of Enugu / Iva valley shales, Enugu State, Nigeria. *Journal of Mining & Geology* **26** (1) 5 – 11.
Murat RC (1972). Stratigraphy and paleogeography of Cretaceous and Lower Tertiary in southern Nigeria. In: *African Geology* edited by Dessauvagie T.F.J and Whiteman A.J. (University of Ibadan, Nigeria) 251–266.
Myrow PM (1995). Thalassinoides and the Enigma of Early Paleozoic Open – Framework burrow systems: *Palaios* **10** 58 – 74.
Nwajide CS and Reijers TJA (1996). The Geology of the southern Anambra Basin, In: *Selected chapters in Geology, sedimentary geology and sequence stratigraphy of the Anambra Basin* edited by T.J.A. Reijers (SPDC publication) 133–148.
Ogala JE, Ola-Buraimo AO and Akaegbobi IM (2009). Palynological and Paleoenvironmental study of the Middle – Upper Maastrichtian Mamu coal facies in the Anambra basin, Nigeria. *World Applied Science Journal* **7**(12) 1566 – 1575.
Ogala JE (2011). Hydrocarbon potential of the Upper Cretaceous coal and shale units in the Anambra Basin, southeastern Nigeria, *Petroleum and Coal* **53** (1) 35 – 44.
Onuigbo EN, Etu-Efeotor JO and Okoro AU (2012). Palynology, paleoenvironment and sequence stratigraphy of the Campanian – Maastrichtian deposits of the Anambra Basin, southeastern Nigeria. *European Journal of Scientific Research* **78** (3) 333 – 345.
Onyekuru SO and Iwuagwu CJ (2010). Depositional environment and sequence stratigraphic interpretation of the Campanian – Maastrichtian Nkporo Shale Group and Mamu Formation exposed at Leru – Okigwe axis, Anambra Basin, southeastern Nigeria. *Australian Journal of Basic and Applied Science* **4** (12), 6621 – 6640.
Petters SW (1978). Stratigraphic evolution of the Benue Trough and its implications for the Upper Cretaceous paleogeography of West Africa: *Journal of Geology*, **86** 311 – 322.
Reading HG. & Collinson JD (1996). Clastic coasts. In: *Sedimentary Environments: Processes, Facies & Stratigraphy edited by* Reading, H.G. (Blackwell Science Ltd, Oxford, London) 154 – 231.
Reinson GE (1992). Transgressive Barrier Island & estuarine systems. In: *Facies models: Response to Sea level change* edited by Walker, R.G. and James, N.P. (Geological Association of Canada) 179 -194.
Reyment RA (1965). *Aspects of the Geology of Nigeria*. University of Ibadan Press, Nigeria, 145.
Simpson A (1954). The geology of parts of Onitsha, Owerri and Benue Provinces: the Nigerian Coalfield: *Geological Survey of Nigeria Bulletin* **24** 1 -40.
Sorannadi – Ononiwu CG Omoboriowo AO and Chukwujekwe NV (2012). Palynological and paleoenvironmental studies of the Mamu Formation, Enugu Area, Anambra Basin, Nigeria. *International Journal of Pure and Applied Science and Technology* **10** (2) 1-11.
Tattam CM (1944). A Review of Nigerian stratigraphy. *Report of the Geological Survey of Nigeria* **13** 61.
Walker RG and Plint AG (1992). Wave & storm – dominated shallow marine systems. In: *Facies models: Response to Sea level change* edited by Walker, R.G. and James, N.P. (Geological Association of Canada) 219 – 238.