Miospores (Spores and Pollens) and Lithofacies of Maastrichtian Sediments of the Benin Flank, South Western Anambra Basin, Nigeria.

Omabehere I. Ejeh, M.Sc.

Geology Department, Delta State University, PMB 1, Abraka, Nigeria.

E-mail: innomaje2002@yahoo.com

ABSTRACT

The study area which is part of the *Nkporo* Group lies within the Benin flank of the Anambra basin. This study is aimed at reconstructing the palaeo-environment of the *Nkporo* shale outcropping in this part of the basin through field relationship, micropalynological, and sedimentological studies.

Palynological analyses of the sedimentary successions revealed 13 species of Miospores, namely: *Retimonocolpiles spp, Monoporites annulatus, Monocolpites marginatus, Fagus spp, Laevigatosporites spp, Belulaepollenites spp, Lycosporites (Lycopodium spp),Monosporites (Asplenium spp),Monosporites (Danallia spp), Tricolporites, Monosulcate pollens, Pteris spp,* and *Araucariacites spp.* Scanning Electron Microscope (SEM) as well as Transmitted Electron Microscope (TEM) were used to study the external and internal features of associated spores and pollens; and through sculptural studies, the miospores found in the shales of *Orhua* and environs have different morphological features such as striate, clavate, psilate, scabrate, and reticulate. Grain size analysis indicated that the sandstones are medium grained, very poorly sorted, near symmetrical and very platy-kurtic.

A close overview of these results revealed that the sediments were deposited in fluvial-beach-shallow marine settings under rainforest vegetal cover. It can also be deduced that the palaeoclimate and palaeo-vegetation has not varied too much since their deposition in Maastrichtian. The field data show that the shales are fissile, light to dark grey with intercalations of fine to medium grained sands. The fissility of the shales suggests that they were deposited in low energy environment, distal to proximal marine environment. The occurrences of these sandy intercalations within the shales are likely indications of fluvial influence during deposition.

(Keywords: pollens, spores*, Lithofacies, Orhua, Maastrichtian,* Anambra basin)

INTRODUCTION

Analysis of palynodebris and palynomorphs content in their stratigraphical context has allowed a detailed understanding of the processes controlling deposition and provides a basis for palaeogeographical reconstruction. Palynofacies represents a geological interpretation of sedimentary dispersed organic material, which together with lithofacies studies can provide the key to identification of depositional environments. Each lithofacies has individual physical characteristics related to factors such as grain size and sorting variations, which are largely dependent upon depositional processes, such as energy conditions and sediment supply. However, similar depositional processes may not always be limited to one palaeoenvironment and can be found, in some cases, in contrasting types of depositional settings (Whitaker, 1992). Thus, from lithofacies alone, it is not always possible to reconstruct precisely the palaeoenvironment. In this respect, a palynofacies approach in conjunction with sedimentology can enable an accurate palaeoenvironmental appraisal and an enhanced analysis of sediment distribution within reservoir sequences.

Foraminiferal assemblages have been used as proxies for palaeoenvironmental determination of the study area (Ejeh, 2011). However, this work is expedient owing to the fact that it corroborates this previous work, at the same time integrates miospores and sedimentology in palaeoenvironmental reconstruction. The sedimentary outcrops of shales and sandstones in *Orhua* and environs (Figure 1) were mapped and fossil content (Miospores) extracted to ascertain their palaeoenvironments of deposition.

The study area is located within the Benin flank (south western part) of the Anambra basin (Figure 1). The primary purpose of the study, however, has been the detailed documentation of palynofacies and lithofacies distributions and their Palaeoenvironmental significance. This work describes palynofacies analyses from outcrop sections which are well documented in terms of sedimentological and microfossil characteristics.

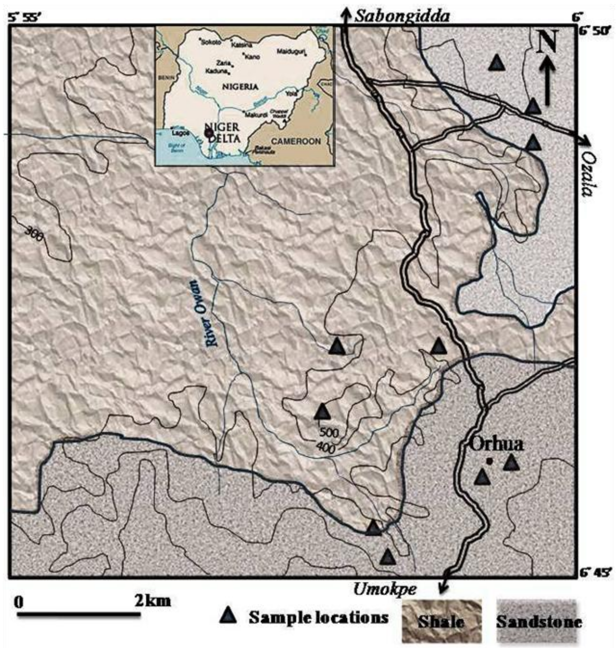

Figure 1: Outline Geologic Map of the Study Area.

GEOLOGIC OVERVIEW

The Anambra Basin is a Cretaceous/Tertiary basin, which is the structural link between the Benue Trough and the Tertiary Niger Delta Basin. Spatially, it is the sedimentary wedge bordered by the Abakaliki anticlinorium to the East, the basement rock and the Benue hinge line to the north and northwest respectively. The formation of this southern sedimentary basin followed the break-up of the South American and African continents in the Early Cretaceous (Murat, 1972; Burke, 1996). Various lines of geomorphologic, structural, stratigraphic and palaeontologic evidence have been presented to support a rift model (King, 1950; Bullard et al., 1965; Reyment, 1969; Burke et al., 1971, 1972; Fairhead and Green, 1989; Benkhelil, 1989; Guiraud and Bellion, 1995).

The stratigraphic history of the region is characterised by three sedimentary phases (Short and Stäuble, 1967; Murat, 1972; Obi et al. 2001; fig.2) during which the axis of the sedimentary basin shifted. These three phases were: (a) the *Abakaliki-Benue* Phase (Aptian-Santonian), (b) the *Anambra-Benin* phase (Campanian-Mid Eocene), and (c) the *Niger Delta* phase (Late Eocene-Pliocene).

The more than 3000 metres of rocks comprising the *Asu* River Group and the *Ezeaku* and *Awgu* Formations, were deposited during the first phase in the *Abakaliki-Benue* Basin, the *Benue* valley and the *Calabar* Flank (Figure 2). The second sedimentary phase resulted from the Santonian folding and uplift of the *Abakaliki* region and dislocation of the depocenter into the *Anambra* platform and *Afikpo* region. The resulting succession comprises the *Nkporo* Group, *Mamu* Formation, *Ajali* Sandstone, *Nsukka* Formation, *Imo* Formation and *Ameki* Group (Figure 2). The third sedimentary phase credited for the formation of the petroliferous *Niger Delta* commenced in the Late Eocene as a result of a major earth movement that structurally inverted the Abakaliki region and displaced the depositional axis further to the south of the Anambra Basin The second sedimentary phase carries the focus of this study.

The formations of the Campanian *Nkporo* Group reflect a funnel-shaped shallow marine shelf setting that graded into channeled low energy marshes. The concave inward shape of the coastline allowed for a gradual filling by minor amount of sediment brought in by short rivers, that were carried along by north-eastward converging lonshore drifts. Extensive coastal swamps developed behind the poorly developed foreshores and shorefaces now known as the *Enugu* shale.

According to Reijers (1996) the shallow open marine shelf sea was alternatively storm- and tide-dominated and in many respects comparable to that prevailing on the Nigeria's southwest coast. The Maastrichtian coal-bearing *Mamu* and the *Ajali* Formations formed during the overall regression of the *Nkporo* Group with associated progradation. The *Nsukka* Formation, which overlies the *Ajali* Sandstone, begins with coarse- to medium-grained sandstones and passes upward into well-bedded blue clays, fine-grained sandstones, and carbonaceous shales with thin bands of limestone (Reyment, 1965; Obi *et al*., 2001).

m.y	AGE	ABAKALIKI – ANAMBRA BASIN	AFIKPO BASIN
30	Oligocene	Ogwashi-Asaba Formation	Ogwashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/ Nsugbe Sandstone (Ameki Group)	Ameki Formation
65	Palaeocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83	Campanian	Npkoro Oweli Formation/Enugu Shale	Nkporo Shale/ Afikpo Sandstone
87.5	Santonian		Non-deposition/erosion
88.5	Coniacian	Agbani Sandstone/Awgu Shale	
93	Turonian	Eze Aku Group	Eze Aku Group (incl. Amasiri Sandstone)
100	Cenomanian – Albian	Asu River Group	Asu River Group
119	Aptian Barremian Hauterivian	Unnamed Units	
	Precambrian	Basement Complex	

Figure 2: Correlation Chart for Early Cretaceous-Tertiary Strata in Southeastern Nigeria (Modified after Nwajide, 1990).

Obi *et al*. (2001) used sedimentological evidence to suggest that the *Nsukka* Formation represented a phase of fluvio-deltaic sedimentation that began close to the end of the Maastrichtian and continued during the Paleocene. The *Nsukka* Formation (Paleocene) marks the onset of another her transgression and documents the return of paludal conditions. Sedimentation was mainly of fluvial origin though punctuated at the height of transgressive phases by marine flooding.

The *Imo* shales reflect shallow-marine shelf conditions in which foreshore and shoreface sands are occasionally preserved. The *Imo* Formation consists of blue-grey clays and shales and black shales with bands of calcareous sandstone, marl, and limestone (Reyment, 1965). Ostracode and foraminiferal biostratigraphy (Reyment, 1965), and microfauna recovered from the basal limestone unit (Adegoke *et al*., 1980; Arua, 1980) indicate a Paleocene age for the formation. Lithology and trace fossils of the basal sandstone unit reflect foreshore and shoreface (Reijers *et al*., 1997) The Eocene *Ameki* Group marks the return to regressive conditions.

Local Geologic Setting

Orhua and environs is a sedimentary terrain with two major lithologies namely: shales and sandstone units interbedded with occasional sandy-shale units (Figure 3). Of these two, the sandstone unit is younger. The underlying shales are usually dark brown to dark grey in color, thickly to thin laminated, and fissile. The field relationship is that of a sharp contact and mode of occurrence is low-lying outcrops buried by thick overburden and exposed by the erosive effects of springs and streams.

A number of fresh water springs sourced within the sharp contacts between underlying shale, overlying sandstone, and the water table are prominent hydrogeological features in the study area (Figure 3). The younger Lithologic unit sandstone is either ferroginized or non-ferroginized. The ferroginized sandstone ranges in color from reddish brown to yellow, and black to grey. Intercalations of carbonaceous shales occur in some cases. Grain sizes of sandstones ranged from fine to medium, and rounded to sub-angular. The non-ferroginized sandstone ranges in color from white to yellowish coloration with angular to sub-angular in shape. It comprises of quartz, feldspar, and mica. It occurred as a low lying outcrop exposed by river channel.

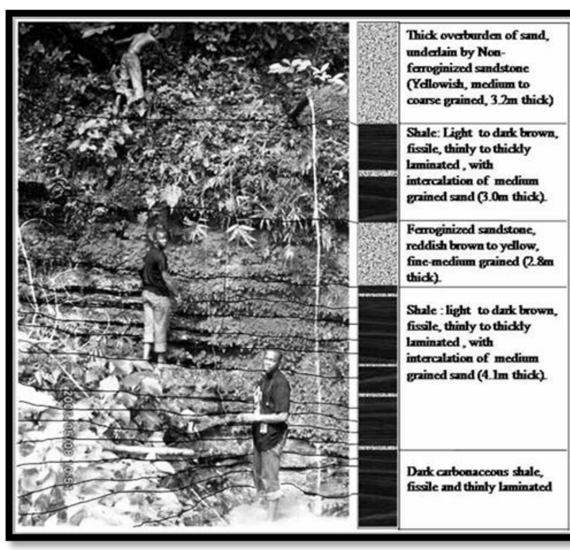

Figure 3: Outcrop of Sedimentary Succession at *Orhua*.

MATERIALS AND METHODS

Field Study, Sample Collection and Processing

The field study involved a detailed geologic mapping on a scale of 1:10,000. Ten composite sedimentary successions outcropping (one shown in Figure 3) in *Orhua* and environs of Edo State, Southwestern Nigeria (fig.1) were measured, to gather data on the textural and Lithologic variations. Twenty samples from shale and sandy shale horizons were collected and processed for fossil (pores and pollens) contents. The samples each weighing about 150g was prepared for palynological analyses. Sandstone samples were collected from outcrops with good exposure patterns. Sandstone samples were subjected to granulometric analysis.

The standard sample preparation method for palynological studies is outlined in Table 1. The proportions of the different palynological constituents were estimated semi-quantitatively using a purely visual assessment. Their proportions were considered in transmitted light using a non-oxidized slide sieved at 15 µm. Slides made of residues prior to sieving proved impractical to count, since the dominance of fine organic and mineral particles effectively diluted the coarser (structured) fraction. The palynomorphs were counted in detail using the oxidized and swirled slide.

17g of each sample was weighed out and crushed into 2-5mm fragment. The measured quantity was placed on aluminum foil and oven dried for 20 minutes at a temperature of about 40˚C. Dried samples were placed in a beaker containing HCl acid overnight to dissolve the carbonates. Decant from HCl solution was soaked in concentrated hydrofluoric acid for 2 hours to dissolve silicates from the samples. If the sample was clean of mineral matter (palyno-debris) it was then soaked in nitric acid for 1.5 hours, decanted, and soaked in 10% HCl three times. If sample still contained mineral matters, it was soaked in zinc bromide for 4 hours, decanted, and soaked finally in 15% HCl three times.

The treated sample is swirled in a centrifuging machine to separate organic matter from any remaining mineral matter. The treated sample is then washed through acid resistant sieve gauze of a set of mesh size able to retain pores and pollens (15µm). The sieved fractions are oven dried for 3 hours. The various fractions are then viewed under M_8 *Wild* binocular microscope with oil immersed objective lenses. In order to properly examine the internal structures, the picked samples were stained with a particular color depending on the natural color of the spores and pollens.

Table 1: Sample Preparation Method.

Stages	Procedures
1	Rock material cleaned and then crushed to 2-5 mm fragments
2	HCl 10% conc., 20 minutes
3	HF 40% conc., 120 minutes
4	HC1$^1/_2$% conc., washing
5	Heavy liquid separation in Zinc Bromide solution (Specific Gravity: 2.2)
6	15 micron sieve -- slide prepared
7	HNO_3 90 minutes
8	Swirled
9	15µm sieve -- slide prepared

Sandstone intervals were sampled and subjected to grain size analysis. Following the air-drying of samples, about 200g of each sample was weighed out and disaggregated and thereafter 50g of which poured into a set of sieves already arranged in decreasing order of mesh sizes from top to bottom and mechanically shaken for 15minutes. Samples retained in each sieve were collected, weighed and tabulated. Sieve sizes in mm were converted to *phi* (Φ) using the formula proposed by Folk and Ward (1957).

RESULTS AND DISCUSSION

Palynology

Results of palynological analysis (abundance and diversity population of spores and pollens) are presented in Table 2 with 13 species identified. Scanning Electron Microscope (SEM) as well as Transmitted Electron Microscope (TEM) was used to study the external and internal features of associated spores and pollens (Figure 4). Through sculptural studies, the miospores found in the shales of *Orhua* and environs have different morphological features such as: striate, clavate, psilate, scabrate, and reticulate (Table 3 and Figure 4). Orientation of spores and pollens under the microscope stems from high to low focusing.

Table 2: Abundance and Diversity Population of Spores and Pollens.

Sample Number	Spores and Pollens Species 1	2	3	4	5	6	7	8	9	10	11	12	13	Species Abundance	Species Diversity
L13A	-	-	□	□	-	-	-	□	-	-	□	-	-	11	4
L13B	-	-	□	-	□	-	□	-	□	□	-	□	□	12	7
L13C	□	-	□	-	-	□	□	-	□	-	□	-	□	14	7
L13D	-	-	□	-	□	□	-	□	□	-	-	-	□	16	6
L13E	-	-	□	-	□	-	□	-	□	-	□	-	-	10	5
L13F	-	-	-	□	-	-	-	-	□	-	-	□	-	8	3
L13G	□	□	-	-	-	□	□	-	□	-	□	-	-	9	6
L13H	-	-	□	□	-	-	□	□	-	□	-	-	-	13	5
L13I	-	□	□	□	□	□	□	-	□	□	□	□	□	20	11
L13J	-	□	□	-	□	□	-	□	-	□	-	□	□	15	8
L13K	□	□	□	-	□	-	-	□	□	□	-	-	□	18	8
L13L	-	-	□	□	-	□	-	□	-	-	-	-	□	16	6
L13M	□	-	□	□	-	-	□	-	□	□	□	□	□	17	9
L13N	□	-	-	-	-	□	-	-	-	-	□	-	-	12	2
L14A	-	-	□	-	-	-	□	-	-	-	-	-	□	8	3
L14B	-	-	-	-	-	□	-	-	□	-	□	-	-	10	3
L14C	□	-	□	□	-	-	-	□	□	-	□	□	-	12	7
L14D	□	-	-	-	-	□	□	□	□	-	-	-	-	9	5
L14E	-	-	□	□	-	-	□	-	-	-	-	□	-	12	4
L14G	-	-	-	□	□	-	-	-	-	□	-	-	□	9	4

Species 1= *Retimonocolpiles spp*
Species 2= *Monoporites annulatus*
Species 3= *Monocolpites marginatus*
Species 4= *Fagus spp*
Species 5= *Laevigatosporites spp*
Species 6= *Belulaepollenites spp*
Species 7= *Lycosporites (Lycopodium spp)*
Species 8= *Monosporites (Asplenium spp)*
Species 9= *Monosporites (Danallia spp*
Species 10= *Tricolporites*
Species 11=*Monosulcate pollens*
Species 12= *Pteris spp*
Species 13= *Araucariacites spp*

The sizes of the identified spores under the microscope are also given in Table 3.

Palaeoclimatic Reconstruction

From the palynological analysis, several species of plants were recovered from the shales of the study area amongst which are *Fagus spp.* and *Araucariacites spp.* The plant *Fagus spp.* is of the phylum *Anthophyta.* They have double fertilization and development of endosperm-characteristics that distinguished the phylum from others. The modern *Anthophyte* flora is primarily terrestrial. On the distribution of the pollen, *Fagus spp.* tree grow in upland area, dispersed by insects and deposited on nearby areas (Delevoryas, 1962). The plant *Araucariacites* is of phylum *Coniferophyta,* Class *Gymnospermae*, Order *Coniferales* and Family *Araucariaciteae*. They are trees of over 30m in height and are characterised by more or less symmetrical and whorled branches.

On the basis of their distribution, this species grows in upland area, produces pollen grains which are dispersed by wind and deposited in nearby area (Hedgepeth, 1957). Pollens which accumulated in place in terms of abundance and type may reflect the most important plant that constitutes the vegetation of the region. The two species aforementioned show characteristics which can be correlated to the rainforest vegetation belt of Nigeria. According to *Koppen's* classification of climate based on rainfall and temperature, the rainforest vegetation belt is grouped under equatorial climate.

Ecological Relationships

Diversity can be related to the palaeoenvironment of deposition. Observations by the author suggest that low diversity, or predominance of one or two types, indicates either an extreme form of sorting, or an association of sporomorphs indigenous to the palaeoenvironment. Some types, irrespective of their morphology, may be locally limited due to the poorly drained nature of the coastal plain area or the low frequency of their parent plant. Sporomorphs found in high numbers and dominating assemblages from the *Orhua* sediments include *Pteris spp* and *Araucariacites spp*. Marine and fluvial sediments are generally characterized by moderate or low diversities. Sporomorphs such as *Araucariacites* spp, may represent local swamp vegetation.

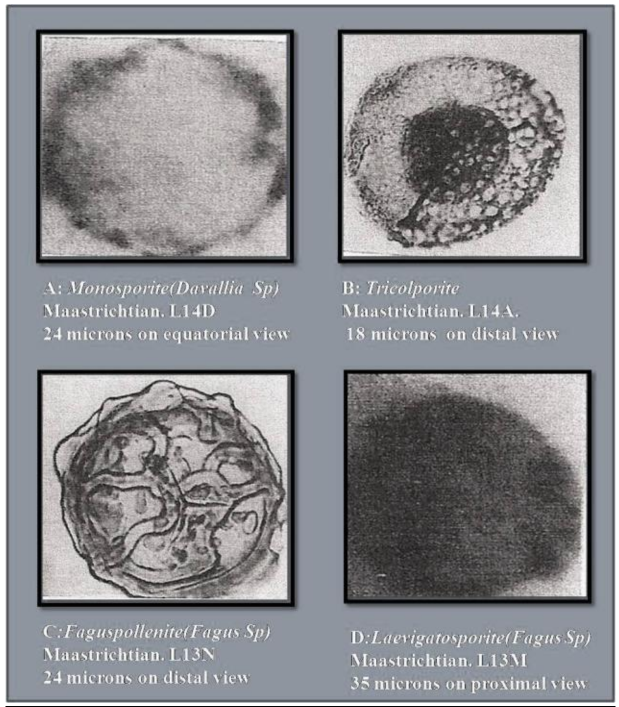

Figure 4: Some Identified Spores and Pollens recovered from Shales at *Orhua* and Environs.

Table 3: Spores and Pollens Sculptural Types and Size Ranges.

Spores and Pollens	Sculptural Types	Size Ranges (µm) <6	7-12	13-18	19-30	25-30	31-36	37-42
Pteris sp	Striate	-	☐	☐	-	-	-	-
Tricolporites	Clavate	☐	☐	☐	☐	☐	-	-
Monosulcate pollens	Psilate	-	-	☐	☐	-	-	☐
Monosporites (Davallia sp)	Scabrate	☐	☐	☐	☐	☐	-	-
Monosporites (Asplenium sp)	Scabrate	-	☐	☐	-	-	-	☐
Araucariacites sp	Reticulate	-	☐	☐	-	☐	-	☐
Lycosporites (Lycopodium sp)	Psilate	☐	☐	-	☐	☐	-	-
Betulaepollenite sp	Reticulate	☐	☐	☐	-	-	-	☐
Laevigatosporites sp	Clavate	☐	☐	-	☐	☐	☐	-
Fagus sp	Striate	☐	☐	☐	☐	-	-	-
Monocolpites marginatus	Scabrate	☐	☐	-	-	-	☐	☐
Retimonocolpites sp	Reticulate	☐	☐	☐	☐	☐	☐	☐
Monoporites annulatus	Psilate	-	-	☐	☐	-	-	-

Table 4: Results and Interpretation of Grain size Analysis of Selected Sandstone Samples.

Sample Location	Simple Sorting Measure (Φ)	Simple Skewness Measure (Φ)	Graphic Mean	Standard Deviation	Skewness	Kurtosis	Interpretation
L17	0.90	0.10	0.46	6.31	0.18	0.45	Coarse grained, very poorly sorted, fine skewed and very platykurtic sandstone.
L15	1.10	-1.50	1.23	1.03	-0.11	0.60	Medium grained, poorly sorted, coarse skewed, and very platykurtic sandstone.
L14	1.15	-0.05	0.75	1.17	0.24	0.63	Coarse grained, poorly sorted, fine skewed and very platykurtic sandstone.
L16	1.25	-1.35	1.30	0.85	-0.019	0.79	Medium grained moderately sorted, strongly coarse skewed and platykurtic sandstone.
L18	1.30	-1.80	1.45	1.00	-0.19	0.89	Medium grained, poorly sorted, coarse skewed, and platykurtic sandstone.
Average	1.14	-0.92	1.04	2.07	0.02	0.67	Medium grained, very poorly sorted, near symmetrical and very platykurtic sandstone.

Proximity to coastal conditions also allows a proportion of sporomorphs more commonly associated with lagoonal and marine palaeoenvironments to be incorporated. Occasional influxes of *Araucariacites* spp. suggest periodic swamp development.

Sedimentology

Results of sieve analysis of sandstones are presented in Table 4. The percentage weight retained for each sample was obtained by dividing the value of the weight retained by the total weight of the sample multiplied by 100. The

cumulative weight retained in percentage and textural parameters were computed for each sample (table 4). The following textural parameters were computed: graphic mean, standard deviation, skewness, kurtosis, simple skewness measures, and simple sorting measures; using formulae proposed by Folk and Ward (1957). Textural parameters computed for samples collected indicated a graphic mean range of 0.66-1.5Φ (coarse to medium grained) with an average of 1.04Φ (medium grained). Standard deviation ranges form 0.85-6.31Φ (moderately sorted to very poorly sorted) with an average range of 2.07Φ (very poorly sorted), Skewness ranges from -0.017-0.024Φ (strongly skewed to fine skewed) with an average value of 0.02Φ (near symmetrical) and kurtosis ranges from 0.45-0.89Φ (very platykurtic to platykurtic) with an average value of 0.67Φ (very platykurtic).

Comparative plots of simple skewness measure versus simple sorting and skewness versus standard deviation indicate that the ancient sandy sediments were deposited in fluvial-beach-shallow marine settings. This is supported by field relationships.

CONCLUSIONS

The sedimentary successions outcropping at *Orhua* subjected to micropalynological and sedimentological analyses revealed that the sediments were deposited in fluvial-beach-shallow marine settings under rainforest vegetal cover. It can also be deduced that the palaeoclimate and vegetation has not varied too much since their deposition in Maastrichtian. The field data shows the shales are fissile, light to dark grey with intercalations of fine to medium grained sands. The fissility of the shale suggests that it was deposited in low energy environment, distal to proximal lagoon environment. The occurrences of these sandy intercalations within the shales are likely indications of fluvial influence during deposition

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of Mr. L.E. Ugboro and J.O. Umukoro during the course of the field mapping exercise.

REFERENCES

1. Adegoke, O.S., Arua, I., and Oyegoke, O. 1980. "Two New Nautiloids from the Imo Shale, (Paleocene) and Ameki Formation (Middle Eocene), Anambra State, Nigeria". *Journal of Mining and Geology*. 17:85–89.

2. Arua, I. 1980. "Paleocene Macrofossils from the Imo Shale in Anambra State, Nigeria". *Journal of Mining and Geology*. 17:81– 84.

3. Benkhelil, J. 1989. "The Origin and Evolution of the Cretaceous Benue Trough (Nigeria)". *Journal of African Earth Sciences*. 8:251–282.

4. Bullard, E.C., Everett, J.E., and Smith, A.G. 1965. "Fit of the Continents around the Atlantic". *Philosophical Transactions of the Royal Society London A*. 258:41–51.

5. Burke, K.C. 1996. "The African Plate". *South African Journal of Geology*. 99:341–409.

6. Burke, K.C., Dessauvagie, T.F.J., and Whiteman, A.J. 1971. "The Opening of the Gulf of Guinea and the Geological History of the Benue Depression and Niger Delta". *Nature Physical Science*. 233: 51–55.

7. Burke, K.C., Dessauvagie, T.F.J., and Whiteman, A.J. 1972. "Geological History of the Benue Valley and Adjacent Areas". In: Dessauvagie, T.F.J., Whiteman, A.J. (eds.). *African Geology*. University of Ibadan Press: Ibadan, Nigeria. 187–218.

8. Delevoryas, T. 1962. *Morphology and Evolution of Fossil Plants*. Holt Rinehart and Winston Inc.: New York, NY. 65-90.

9. Ejeh, O.I. 2011. "Foraminifera Assemblages: Proxies for Palaeoenvironmental Determination - An example from Maastrichtian Sediments of Orhua and Environs". *Continental Journal of Earth Sciences*. 6(1):8-17.

10. Fairhead, J.D. and Green, C.M. 1989. "Controls on Rifting in Africa and the Regional Tectonic Model for the Nigeria and East Niger Rift Basins". *Journal of African Earth Sciences*. 8:231–249.

11. Folk, R.I. and Ward, W. 1957. "Brazos River Bar. A Study in the Significance of Grain Size Parameters". *Journal of Sedimentary Petrology*. 27:3-26.

12. Guiraud, R. and Bellion, Y. 1995. "Late Carboniferous to Recent Geodynamic Evolution of the West Gondwanian, Cratonic, Tethyan Margins". In: Nairn, A.E.M. et al. (eds.). *The Ocean Basins and Margins (8), The Tethys Ocean*. 101–124.

13. Hedgepeth, J.W. 1957. "Sandy Beaches". In: *Treaties on Marine Ecology and Palaeoecology. Vol.1 Ecology*. J.W. Hedgepeth (ed). Memoir Geological Society of America. 67:587-608.

14. King, L.C. 1950. "Outline and Disruption of Gondwanaland". *Geological Magazine*. 87:353–359.

15. Murat, R.C. 1972. "Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria". In: Dessauvagie, T.F.J., Whiteman, A.J. (eds.). *African Geology*. University of Ibadan Press: Ibadan, Nigeria. 251–266.

16. Nwajide, C.S. 1990. "Cretaceous Sedimentation and Palaeogeography of the Central Benue Trough". In: Ofoegbu, C.O. (ed.). *The Benue Trough Structure and Evolution*. Friedr. Vieweg and Son: Braunchweig/Wiesbaden, Germany. 19–38.

17. Obi, G.C., Okogbue, C.O., and Nwajide, C.S. 2001. "Evolution of the Enugu Cuesta: A Tectonically Driven Erosional Process." *Global Journal of Pure Applied Sciences*. 7:321–330.

18. Reijers, T.J.A. 1996. *Selected Chapters on Geology: With notes on Sedimentary Geology, Sequence Stratigraphy and Three Case Studies and a Field Guide*. S.P.D.C. Corporate Reprographic Services: Warri, Nigeria. 197.

19. Reijers, T.J.A., Petters, S.W., and Nwajide, C.S. 1997. "The Niger Delta Basin". In: Selley, R.C. (ed.). *African Basins*. Elsevier: Amsterdam, The Netherlands. 151–172.

20. Reyment, R.A., 1965. In: *Aspects of the Geology of Nigeria*. University of Ibadan Press: Ibadan, Nigeria. 145.

21. Reyment, R.A. 1969. “Ammonite Biostratigraphy, Continental Drift and Oscillatory Transgressions”. *Nature*. 224:137–269.

22. Short, K.C. and Stäuble, A.J. 1967. “Outline of Geology of Niger Delta”. *American Association of Petroleum Geologists Bulletin*. 51:761–779.

23. Whitaker, M. F., Giles, M.R., Cannon, S.J.C., and Morton, A.C. 1992. “Palynological Review of the Brent Group, UK sector, North Sea”. In: Haszeldine, R.S., Giles, M.R. and Brown, S. (eds.). *Geology of the Brent Group.* Geological Society Special Publication 61. 169-202.

ABOUT THE AUTHOR

Omabehere Innocent Ejeh, holds the degree of Masters of Science (M.Sc.) in Petroleum Geology/Sedimentology from the University of Ibadan, Ibadan, Nigeria. He is currently a doctoral student of the University of Ibadan, with research interests in petroleum geology, facies characterization, and computer applications especially in solving geological problems such as stratigraphic forward modeling of fields within the Niger Delta basin. He is a Lecturer I in Geology Department, Delta State University, Abraka, Nigeria.

SUGGESTED CITATION

Ejeh, O.I. 2012. “Miospores (Spores and Pollens) and Lithofacies of Maastrichtian Sediments of the Benin Flank, South Western Anambra Basin, Nigeria”. *Pacific Journal of Science and Technology*. 13(1):652-660.