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Research Article

PALYNOLOGICAL STUDIES OF THE RECENT SEDIMENT OF PARTS OF BENUE TROUGH, NIGERIA

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ABSTRACT

Palynological analysis was carried out on seventeen samples collected from the North - Central part of the country to the Southern part. The areas in which the samples were collected spanned from Makurdi road, Maraba in Nassarawa state down to Uguwaku village, Umuahia L.G.A (Abia state). The coordinates range from Latitude 08° 35' 2.2" N – 05° 34' 06.6" and Longitude 008° 33' 29.0" E and 007° 18' 30.7" E. The results of palynological analysis shows that the pollen and spores were gradually increasing from the north to south across the latitudial geographic spread with a negligible number of marine representatives, indicating sedimentation in terrestrial environment,.. Five biozones were recognised based on the appearance of new palynomorphs and was named by the most abundant form in the zone; *Elaeis quineensis, ,Psilamonocolporites sp, Polydopopollenites sp, Echitricolporites spinosus, Proteacidites sp and Cycadocolpites sp.* The paleoenvironment ranged from alluvial to transition (tidal zones) and the paleoecology infers fresh water to mangrove swamp vegetation.

INTRODUCTION

Most palynological studies in Nigeria in the past four and a half decades were primarily based on the needs of the oil industry. Because of the occurrence of hydrocarbon in the Niger Delta, oil companies carried out most of the works on the Niger Delta and information from them has remained confidential. Few published studies exist on the Niger Delta, among which are those of Burke 1972 and Avbobo. Most of the above listed studies are largely concerned with systematic descriptions of pollen and spores, or palynological zonations based primarily on foraminiferal assemblages and litho and bio-stratigraph**y**. The reconstruction of past environments is one of the goals of palynological research and this entails the study of the periodic changes in environment over geological time. This offers another way of studying the climatic changes of the past. The changes in climate are most evidently reflected in the vegetation. This is because the vegetation of any area is an integral and basic component of the ecosystem and is sensitive to changes in the ecosystem. According to Ivanor *et al*. (2007), the distribution pattern of vegetation strongly depends on climatic conditions and thus vegetation reconstructions help to understand past climates. Sowunmi (1987) reported that a close relationship exists between vegetation and the rest of the environment, particularly climate and soil. Thus, the flora of an area, generally speaking, provides a good reflection of the major climatic regime of that area. This research work attempt to document the palynomorphs with respect to their Paleoecology of the area.

(a) Aim of the Study: Identify and produce the database of palynomorph assemblage data for the region under study

(b) Location and accessibility of the Study Area: The area of Study covers parts of Nassarawa, Benue, Abia, and Imo States. The Nassarawa State area comprises of Akunza in Maraba L.G.A, Duduguru village, Akanga town and Kadarko village. In Benue State includes Ishere village, Tyo – mu town, Ikpayongo, Igbor and Howe village. Ugwuaku village(Umuahia L.G.A)in Abia State were also studied. It is located between longitudes 8°33′E and 7°18′Eand latitudes5°34′Nand8°35′N. The study areas as mentioned above are accessible through the Nassarawa – Makurdi express way, Makurdi – Yandev road, Abakiliki – Afikpo road expressway, Umuahia – Owerri

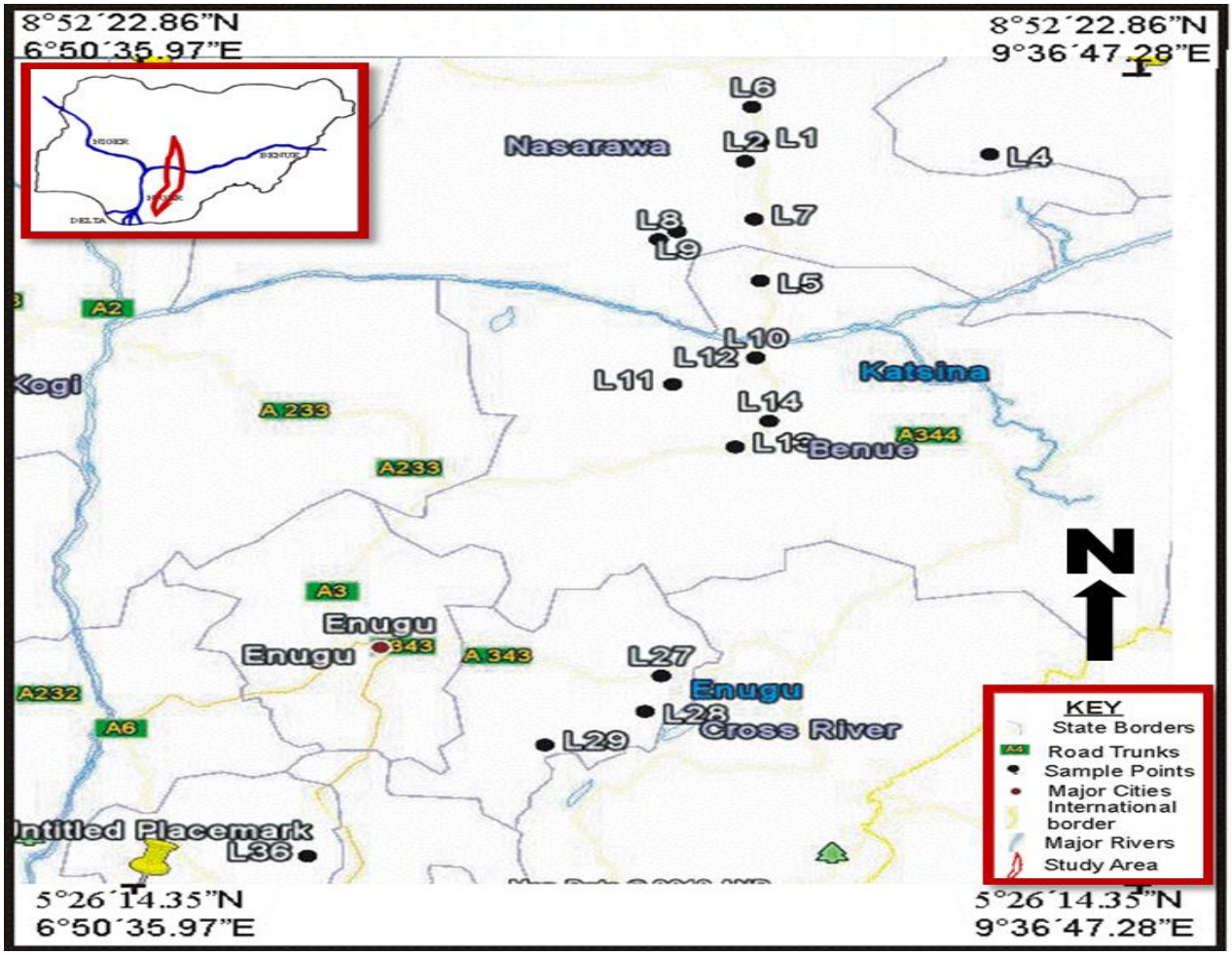

Figure 1: Location map of the study area showing the sampled points.

LITERATURE REVIEW

Several authors have made various studies on the Benue Trough and Niger Delta among which are those of Zaborski (1983) on the Chronostratigraphic paleoecologic studies that have been carried out on various Cretaceous sequencess of the Benue Trough using ammonites. Oloto (1984) described the late Cretaceous and Tertiary sediments from the Gbekebo – 1 well making use of dinoflagellates cysts with pollen and spores assemblage encountered for the dating. Oyelaran (1991) reported that paleoenvironmental reconstruction has so far made modest progress in Nigeria. Elsewhere in Africa, several studies exists documenting vegetation and climatic changes at various geologic periods especially in the Holocene (Sowunmi, 1981a, 1981b; Jahns *et al*., 1998; Salzaman, 2000; Marchant and Taylor, 2000). Omoboriowo and Oloto (2014), Omoboriowo and Soronnadi-Ononiwu (2012) also studies and documented variety of palynomorphs in Middle and Lower Benue Trough and Mamu Formation Enugu Area Respectively

However, very few palynological studies have been carried out detailing Tertiary palynological and

paleonvironmental changes especially in Nigeria.

PLATE 1:

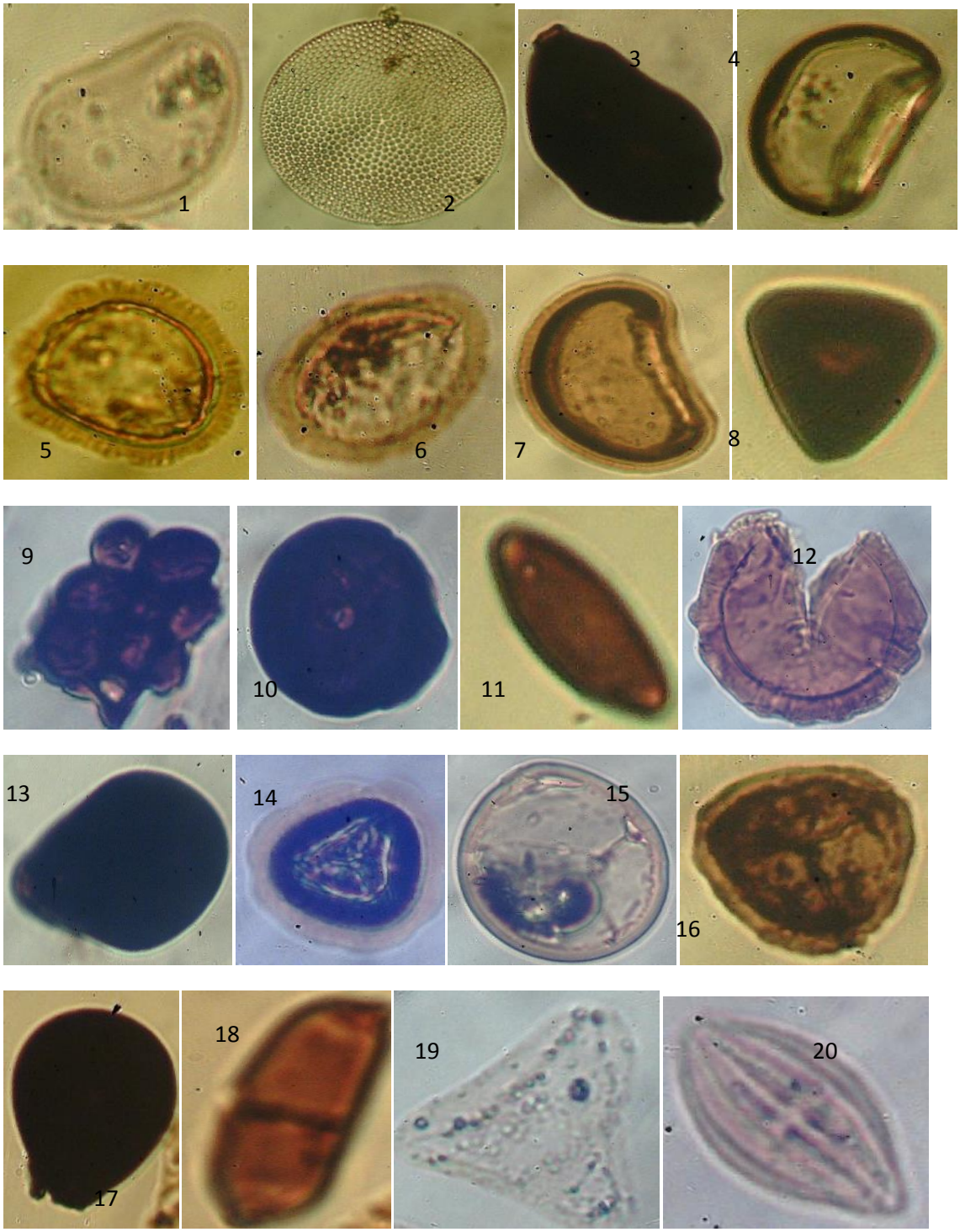

Plate 1: showing some of the palynomorphs in the Study Area

1. *Laevigatosporites discordatus*
2. *Diatom sp*
3. *Striadiporites reticulatus*
4. *Laevigatosporites discordatus*
5. *Selaginella myosurus*
6. *Monoporisporites lagenarius*
7. *Laevigatosporites discordatus*
8. *Matonisporites sp*
9. *Polyaposporites sp*
10. *Exisisporites annulatus*
11. *Hypoxylonites xylarioides*
12. *Psilatricolporites sp*
13. *Didymoporisporonites poratus*
14. *Deltoidspora minor*
15. *Anthoceros psilate*
16. *Lycopodiumsporites sp*
17. *Monoporisporites lagenarius*
18. *Fusiformisporites sp*
19. *Syncolporites sp*
20. *Psilatricolporites sp*

METHODOLOGY

Field work and laboratory study approach was carried out for this research work. The samples obtained from the field were subjected to laboratory analysis and interpretation.

(a) SAMPLE COLLECTION: A total number of seventeen control samples were collected using the "pinch" method (Adams and Mehringer, 1975): collecting 10 pinches of soil throughout each sampled locationsof about 50 to 100 square meters. These pinches were combined into a single, sterile, plastic bag and then sealed. Multiple pinches from each sample area were combined to prevent the possibility of over-representation of a single pollen type. The samples collected from different locations were well-labelled with

sample and location number,then kept in a sample bag and stored in a dry place. The hand auger and hand trowel were washed thoroughly with water to ensure samples were not contaminated (Bryant *et al*., 1990) through all stages of collection and storage until the analysis are over. It is also necessary to note that samples were collected from fresh and undisturbed vegetation that has not experienced bush burning, farming or contains construction materials.

(b) PALYNOLOGICAL PREPARATION: A total of 26 samples were prepared for palynological studies. About 5 gram of each sample was placed in a labeled cup in which 100ml of 70% hydrofluoric acid (HF) was added with the aim of separating the palynomorphs from the other rock debris by digesting the silica in sample. The samples were then washed and the slides prepared. A portion of the kerogen was mixed with 0.1% PVA solution, pipette onto a cover slip and allowed to dry. The remainder of the kerogen was sieved at 20µ. A portion of the sieved material was mixed with PVA solution pipette onto a cover slip and allowed to dry. The cover slips were mounted upon a microscope slide using petropoxy 154. The slides were properly labeled and observed under research microscope through which snapshot was taken. See plate 1 for the pictures of palynomorphs.

RESULTS AND INTERPRETATIONS

The results have been separated into Lithology, Percentage distribution of the palynomorphs, Pollen assemblage zones, Paleoecology and Paleoenvironment.

(A) LITHOLOGY:

The lithological and textural characteristics were derived by the use of hand lens and physical examination. It was characterized by sandstone and siltstone with the sand grains exhibiting fine to coarse grained size. They were well to moderately sorted, minor rootlets. The sand grains sub-angular to sub-rounded and light to dark grey in colour. The siltstone contains a significant fraction of clay.

(B) PERCENTAGE DISTRIBUTION OF PALYNOMORPHS:

The distribution of palynomorphs varied considerably from one geographic location to another. The sampling points of the samples were arranged using their coordinates (latitudes) in a descending order, starting with the locations that have the highest latitude from north to south. It is important to note that the sampling was not done stratigraphically. Pollen and spores preservation was good in most of the samples and the microflora was rich and well-diversified. The total number of palynomorphs counted per gram of the analysed samples ranged from 1 to 81, with the lowest abundance at sample 11 and 36 and the highest abundance at samples 1 and 27. The summary of the percentage distribution of the various groups of palynomorphs as shown in Tables 1- 4 are explained below:

Numerical Count = Total number of each palynomorph group per sample.

Total Count = Sum total of all the numerical count per sample.

Percentage Count = $\frac{\text{Numerical Count}}{\text{TotalCount}} \times 100$

SAMPLE 1: Sample 1 shows an abundance of pollen and spores which consists of 50% Pollen, 25% Spores, 5 % Dinoflagellate, 5% Acritarch, 5% Fungal spore and a low percentage of Diatom at 5%. The dominance of pollen and spores indicates a more terrestrial depositional environment. The presence of a few marine environment indicators in a pollen/spores dominated assemblage probably indicates infiltration of marine water into the terrestrial environment (Oloto, 2009).

Group	Numerical Count	Total Count	Percentage Count (%)
Pollen	11	22	50
Spore	5	22	25
Dinoflagellate	1	22	5
Acritarch	1	22	5
Fungal spore	1	22	5
Foram linning	1	22	5
Diatom	2	22	5

Table 1 : Percentage Distribution for Groups of Palynomorphs in Sample 1.

SAMPLE 2: Sample 2 is rich in palynomorphs as they are composed of 60% Pollen, 22% Spore, 10% fungal sporeand 8% acritarch.

Group	Numerical Count	Total Count	Percentage Count (%)
Pollen	10	16	60
Spore	4	16	22
Fungal Spore	2	16	10
Acritarch	1	16	8

Table 2: Percentage Distribution for Groups of Palynomorphs in Sample 2.

SAMPLES 4: Fungal spore is highly present in this sample 4. 14% Pollen, 29%, fungal spore, 29%

Dinoflagellate, 14% foram linning and 14% acritarch. The abundance of the fungal spore/ Dinoflagellate implies deposition in a marine environment.

Group	Numerical Count	Total Count	Percentage Count (%)
Pollen	1	6	14
Fungal Spore	3	6	28
Dinoflagellate	2	6	30
Acritarch	1	6	14
Foram linning	1	6	14

Table 3 : Percentage Distribution for Groups of Palynomorphs in Samples 4

SAMPLE 5: The sample contains 46% pollen, 46% spore and 8% fungal spore. The sample contains an abundance of pollen and spore. The fungal spores indicate a swampy depositional environment.

Group	Numerical Count	Total Count	Percentage Count (%)
Pollen	6	13	46
Spore	6	13	46
Fungal spore	1	13	8

Table 4: Percentage Distribution for Groups of Palynomorphs in Sample 5.

SAMPLE 6: The palynomorph assemblage of sample 6 shows that Pollen has 22%, Spore 50%, fungal spore 14%, Dinoflagellate 7%, Acritarch 7% and Foram. The abundance of the pollen and spores indicates that sample 34 is more of continental environment.

Group	Numerical Count	Total Count	Percentage Count (%)
Pollen	3	14	22
Spore	7	14	50
Fungal spore	2	14	14
Dinoflagellate	1	14	7
Acritarch	1	14	7

Table 5: Percentage Distribution for Groups of Palynomorphs in Sample 6.

(C) POLLEN ASSEMBLAGE ZONES:

The evolution of organisms through time provides the framework for a system of zonation by which discrete units of time represented by accumulation of sediments can be recognized. A segment of a stratigraphic record that is characterized by particular species of index fossils may be formally recognized as a zone. Some zones are defined by the presence of single specie while others are distinguished by the presence of two or more species. A zone is generally named for a species that characterizes it. It receives its name from one or more of these fossils. The basis for recognizing assemblage zones include; variations in the fossil taxa, abundance of specimens or both. The assemblage zone may indicate ecologic facies, age or both. The recognized assemblage zones are discussed under previously recognized major zones (Germeraad, Hopping and Muller)

Zone I: ***Elaeis guineensis***

Subzone: Miocene – Pliocene

Locations 1, 4, 6

Definition: Species first appearing at the base of the zone – *Zonocostitesramonae, Monoporites annulatus,Echnimonocolpites, Retitricolporites sp, Multiareolites formosus, Magnaperiporites spinosus. Psilatricolporites operculatus, Psilatriporites sp and indeterminate pollen.*Species first appearing at the top of the zone – *Nympheapollis clarus, Retisphenanocolpites gracillis and Echiperiporites sp.* Species last occurring within the zone –*Indeterminate pollen*. Species last occurrence at the top of the zone – *Echiperiporites sp*.

Remark: Base of the zone is marked by abundance of *Zonocostites ramonae.* Increase in abundance of grass pollen(*Monoporites annulatus*) within the zone. Rich in Pteridophyte spores towards base of the zone and

presence of *Elaeisguineensis* pollen.

Zone II: *Psilamonocolporites sp*

Subzone: Miocene – Pliocene

Locations 2, 4

Definition: Species first appearing at the base of the zone – *Gramminaecuticle, Aletepollenites sp, Psilastephanocolporites sp, Psilamonocolpites sp, Striatricolpites catatumbus.* Species last occurring at the base of the zone – *Striatricolpites catatumbus.*

Remark: Rich palynomorph assemblages. Base of the zone is marked by decrease inabundance of *Zonocostites ramonae* and increased representation of *Psilamonocolpites. Reduced presence of Elaeis guineesis.*

Zone III: ***Polydopollenites sp***

Subzone: Miocene – Pliocene

Locations 7 – 9

Definition: Species first appearing at the base of the zone – *Cyperaceapollis sp, Polydopollenites, Brevicolporites guinetti.* Species last occurring within the zone – *Synocolporites, indeterminate pollen and Psilatriporites.* Species last occurring at the top of the zone – *Gramminaecuticle, Aletepollenites sp, Psilastephanocolporites sp, Psilamonocolpites sp, Striatricolpites catatumbus*

Remark: This zone is characterized by the presence of *Cyperaceapollis sp* and a slight decrease in *Multiareolites formosus.* It is relatively low in pteridophyte spores

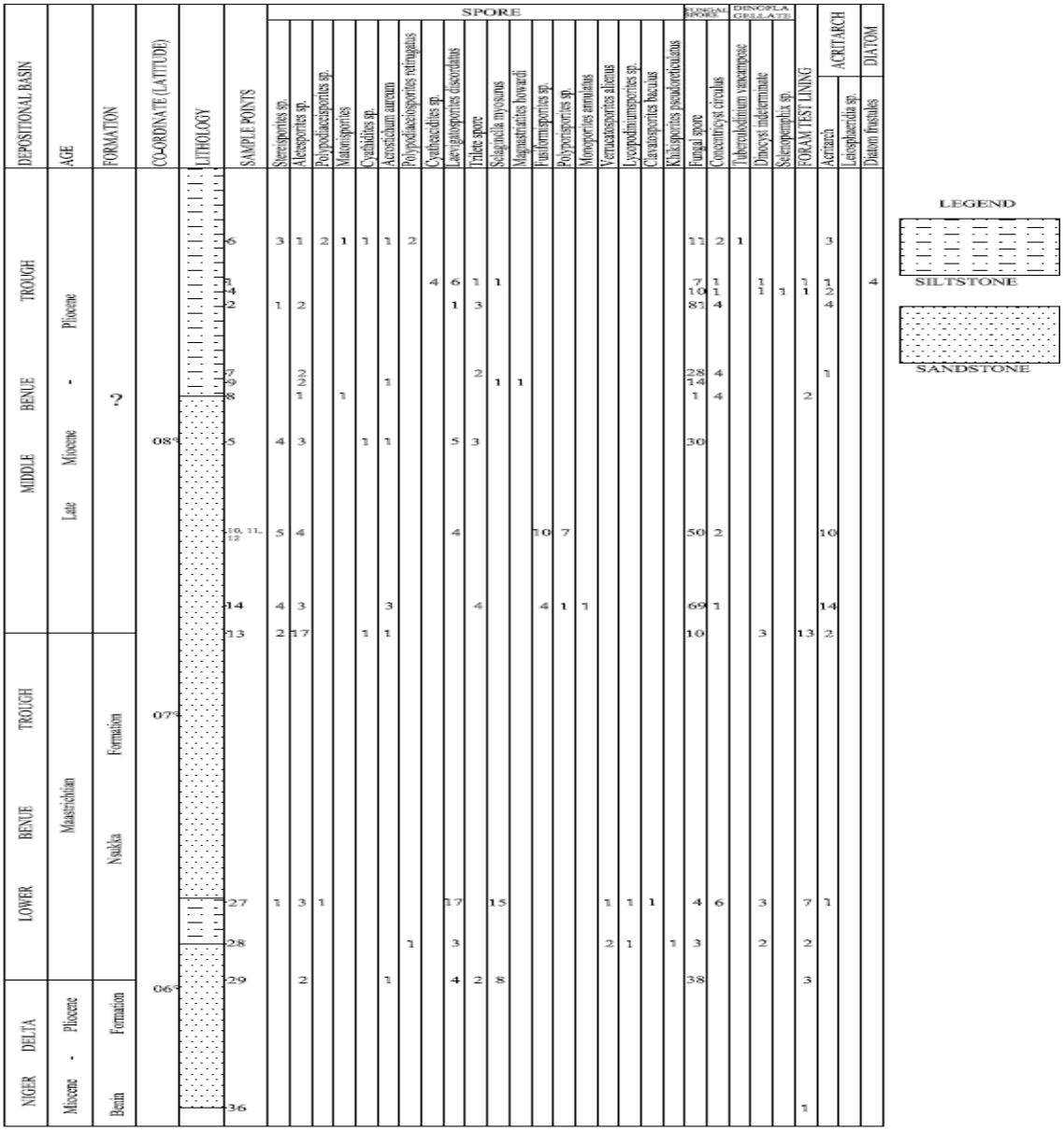

Figure 2: Palaeogeographic Spread of the Palynomorphs

(D) INTERPRETATION:

Sample 1: yielded abundant paylnomorphs, it was sampled along Makurdi road, Maraba in Nassarawa state. It is believed to be part of the Middle Benue trough. The pollen assemblages gotten here include *Monoporites annulatus, Zonocostites ramonae, Retistepanocolpites gracillis, Elaeis guineensis, Echimonocolpites sp, Retitricolpites sp, Multitiareolites formosus, Magnaperiporites spinosus,Psilatriporites sp and Psilatricolpites opercatus.* The spores recovered here included; *Cyatheacidites sp, Laevigatosporites discordatus, Aletesporites sp, Trilete spore and Selaginella myosurus,* few acritarch, dinoflagellate and foram test lining were also present

in sample 1.

The sample gotten from Akunza village, Maraba in Nassarawa state yielded pollen such as *Gramminae cuticle, Zonocostites ramonae, Aletepollenites sp, psilastephanocolpites sp, Elaeis quineensis, psilamonocolpites, Striatricolpites catatumbus, Nympheapollis clarus.* The spores found here include *Stereisporites, Aletesporites* and *Trilete spore*. *Concentricyst circulus* was found here also along with very few fungal spores. Very few species of pollen was seen here, *Zonocostites ramonae* was the only specie of pollen in sample 4, *Selenopemphix* and dinocyst indeterminate were the dinoflagellates present. Abundance of spores was seen in this sample. The sample was located in Duduguru junction in Nassarawa state.

Echitricolporites spinosus, Nympheapollis clarus, Peregrinipollis nigericus, Psilatriporites sp and Elaeis quineensis are the pollen assemblages represented in the sample gotten from Duduguru village of Nassarawa state. The spore's assemblages include; *Laevigatosporites discordatus, Aletesporites sp, Trilete spore, Acrostichum aureum* and very *few fungal spores.* This sample was gotten from Acaraju road in Nassarawa state. It is believed to be part of the Lafia formation. The pollen assemblage found here includes; *Nympheapollis clarus, Retistephanocolpites gracillis and echiperiporites sp. Stereisporites sp, Aletesporites sp, Polypodiaceiosporites retirugatus, Matonisporites sp, Acrostichum aureum and Cyathidites sp.* Very few fungal spores were found here. *Tuberculodinium vancompoae*is the only specie of dinoflagellates found in sample 6.

Sample 7 obtained from Akanga town in Nassarawa state yielded *Syncolporites sp, Indeterminate pollen, Echitricolporites spinosus, Psilatricolpites sp* and *Nympheapollis clarus*. *Trilete spore* and *Aletesporites* were seen in this sample

New species of pollens were found in Kadarko, They include *Cyperceapollis sp, Polydopollenites sp, Brevicolporites quinetti* and *Multieareolites formosus. Selaginella myosurus, Magnastriatites howardi, Aletesporites* and *Matonisporites sp*were the spores recovered here. Ishere village in Benue state yielded just spore palynomorphs; *Acrostichum aureum* and *Aletesporites.*

Samples from Makurdi – Yandev road, Ikayongo, Ikayongo stop 2 in Benue State, yielded abundant spores assemblage, they include;*Acrostichum aureum, Retitriporites sp, Laevigatosporites discordatus, Aletesporites sp, Stereisporites sp, Cyathidites sp.*

The pollen, *Retistephanocolpites gracillis* was found in sample 13, spores assemblage found here include *Aletesporites sp, Stereisporites sp, Cyathidites sp*and *Acrostichum aureum* with few *Dinocyst indeterminate* and foram test lining .

Abundance of palynomorphs was found in sample 14 gotten from Howe village in Benue state. The pollen assemblage recovered include; *Proteacidites sp, Retistephanocolpites gracillis, Zonocostites ramonae, Retitricolporites sp, Echiporites spinosus, Gramminae cuticle, Nympheapollis clarus, Psilatriporites sp,*

Monoporites annulatus and Fenestrites spinosus. The spore's assemblage includes *Stereisporites sp, Polyporisporites sp, Laevigatosporites discordatus. Concentricyst circulus* and Acritarch was also present here.

Sample 27 was gotten from Abakiliki – Afikpo road. The sample showed the introduction of new pollen species; *Fenestrites spinosus, Cycadocolpites sp,Podocarpidites sp*and few new species assemblages namely; *Lycopodiumsporites sp, Verrucatosporites alienus* and *Clavatosporites baculus.Leiosphaerida sp* was the dinoflagellates represented in this location. Sample 28 gotten from from Amuzu (Amuzu Ezza South L.G.A) in Afikpo. The pollen assemblage found here include; *Echiperiporites sp,Psilaperiporites minimus and robutis* and *Triatripollenites sp*. The spores assemblage include *Verrucatosporites alienus,Polypodiaceiosporites retirugatus, lycopoclium sporites sp* and the introduction of *Khikisporites pseudoreticulatus.* Presence of acritarch and dinocyst are noted.

In Abommege village (12.61km to afikpo) sample 29 has gotten and if yielded a higher percentage of pollen to that of spores with *Fenestrites spinosus, Retistephanocolporites sp Echitriporites spinosus, Zonocostits ramonae*, *Psilastephanocolpite sp, Monoporites annulatus, Retitricolpites*, representing the pollen assemblage. *Selaginella myosurus,Acrostichum aureum, Laevigatosporites* discordatus represents the spores assemblage in this sample. Very few acritarch and fungal spore was found here.

Uguwaku village in Umuahia where sample 36 was gotten has abundant acritarch sp contained in the sample. Pollen and spores are poorly represented here.

(E) PALYNOMORPH TREND:

There is abundance of pollen and spores throughout the transverse from North to South latitude as seen in Figure 2. A steady increase of pollen and spores is seen from Acaraju rd, Nassarawa state to Maraba in Makurdi, a decrease in terrestrial palynomorphs is noticed from Maraba to Duduguru junction, while there is an even distribution of fungal spore, dinoflagellates, foram test lining and Acritarch. The pollen and spores gradually increase from Akunza village to where we have a pollen peak at Ishere town, Benue state with the absence of spores, fungal spore also has its peak here at Ishere town.

Foram test lining spreads abundantly from Ishere town down to Duduguru village while a decrease that is noted in pollen assemblage with an increase in spores assemblage with a steady existence of foram test lining till Howe in Benue state.

A decrease is further noted in the pollen and spores assemblage with an evenly distributed dinoflagallate, foram test lining, dinoflagellate and acritarch at Igbor, Benue state.

From Igbor in Benue state to Abommege close to Afikpo, a steady increase is seen in recent pollen and spores assemblages with abundance of foram test lining and acritarch.

From the figure 2 it can be seen that foram test lining terminates temporarily from Abakiliki – Afikpo road to Amuzu village and reappears from Amuzu to Abommege. There is abundance of acritarch from Abommege to Uguwaku in Abia state, this location is devoid of spores and pollens.

(F) PALEOENVIRONMENT/PALEOECOLOGY:

The dominance of pollen and spore can be seen throughout the locations. Pollen and spores represent terrestrial environments. Aquatic forms (fresh water and marine) are of importance in some locations. The presence of fungal spore with little of acritarch from location s 4 - 14 indicatesfresh water /swamp forest. The presence of fresh water algae *Concentricyst circulus*, indicates sedimentation in coastal and shallow marine environments close to mangrove vegetation. *Concentricyst circulus* are more typical of freshwater environments but can also occur in slightly brackish water due to its tolerance to salinity (Rull, 1997b). The Maastrichtian palynomorphs that characterize the Nsuka Formation includes *Retistephanocolpites gracillis, zonocostites ramonae, echiperiporites sp, psilastephanocolporites sp,*this is consistent with the presence of alluvial plain deposits flooded by fresh water. Fungal spores, dinoflagellates, acritarchs, diatoms and foram test lining are also represented and the fresh water algae *Concentricyst circulus* which are consistent with the presence of alluvial environments characterized by fresh water swamp.

CONCLUSION

The result of this work indicate that a total number of 17 samples which were collected across a geographic spread from north to south which yielded a range of palynomorphs assemblage data. The distribution of palynomorphs varied considerably from one geographic location to another. Pollen and spores preservation was good in most of the samples and the microflora was rich and well diversified.

The pollen and spores were gradually increasing from the north to south across the latitudinal geographic spread with a negligible number of marine representatives, indicating sedimentation in terrestrial environment, and some latitudes showed incursion of marine water. The locations of the samples fall within the Benue trough of Nigeria with the last location being part of the Benin formation of the Niger Delta. Five biozones were recognised base on the appearance of new palynomorphs and was named by the most abundant form in the zone; *Elaeis quineensis, ,Psilamonocolporites sp, Polydopopollenites sp, Echitricolporites spinosus, Proteacidites sp and Cycadocolpites sp.* The paleoenvironment ranged from alluvial to transition (tidal zones) and the paleoecology infers fresh water to mangrove swamp vegetation. It is important to note that the entire section figure 2 was not sampled stratigraphically but laterally using coordinates from North to South.

REFERENCES

1. Adams, D.P., and Mehringer, P.J., JR. 1975. Modern pollen surface samples: An analysis of subsamples;

Journal of Research of the United States Geological Survey, 3:733-736.

2. Avbovbo, A. A., 1978. Tertiary Lithostratigraphy of Niger Delta. Am. Assoc. Petrol. Geol. Bull., 62: 295-306.

3. Ekweozor, C.M., and Okoye, N.V., 1980. Petroleum Source – bed Evaluation of Tertiary Niger Delta. Bull. Amer. Assoc. Petrol Geol 64 p 1251-1258.

4. Germeraad, J.H., Hopping, C.A., and Muller, J., 1968. Palynology of Tertiary sediments from tropical areas. Rev. Palaeobotan. Palynol., 6, 189-348.

5. Hoque, M., 1984.Pyroclastics from the Lower Benue Trough of Nigeria and their tectonic implications. J. Afr. Earth Sci., 2, 351-358..

6. Mildenhall,D.C., 1988. Deer velvet and palynology: An example of the use of forensic palynology in New Zealand;Tuatara,30:1-11..

7. Omoboriowo, A.O and Oloto I.N. 2014. Palynological Data Acquisition of Middle and Lower Benue Trough. International Journal Of Science Invention Today 3(5), 404-422.

8. Omoboriowo, A.O and Soronnadi-Ononiwu, G..C. 2012. Palynological and Paleoenviromental Studies of the Mamu Formation, Anambra Basin. International Journal of Pure and Applied Sciences and Technology. 10(2), 1-11.

9. Oloto, I.N., 1990. Palynological assemblage from the Danian of south west Nigeria.Acta Palaeobotanica 30 (112); 23 30.

10. Sowunmi, M.A., 1981b. Aspects of Late Quaternary vegetational changes in West Africa. J. Biogeography., 82: 457-474.

11. Tuttle, M.L.W., Charpentier, R.R., and Brownfield, M.E., 1999. The Niger Delta petroleum system: Niger Delta Province, Nigeria, Cameroon and Equatorial Guinea, Africa. USGS Open-File Report 99-50-H

12. Uma, K.O., and Onuoha, K.M., 1990. Groundwater resources of the Lower Benue Trough, Southern Nigeria. In: The Benue Trough structure and evolution. Ofoegbu, C.O. (ed.). 77-91.

13. Weber, K.J., and Daukoru, E., 1975. Petroleum geology of the Niger delta: Tokyo, 9th World Petroleum Congress Proceedings, v. 2, p 209-221.

14. Zaborski, P.M., 1983. Campano – Maastrichtian ammonites, Correlation and Paleogeography in Nigeria. Journal Africa Earth Sciences 1, 59-63.