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SOME IMPORTANT POLLEN AND SPORES OF THE UPPER MIOCENE–PLIOCENE SEDIMENTS, NZAM-1 WELL, ANAMBRA BASIN, SOUTHEASTERN NIGERIA

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ABSTRACT

Palynological study of the uppermost section of Nzam-1 Well with interval 113-366 m in Anambra Basin, Nigeria was investigated to determine the geologic age based on the occurrences of pollens and spores, and to compare the result obtained with established ages from other biostratigraphic tool. The methodology of sample preparation involved the logging of the samples in order of depth, litho-description, and laboratory chemical processes. The chemical processes include initial acid decarbonisation of the samples, sample digestion with hydrofluoric acid, sieving of the samples with 10 µm mesh to remove clay particles; and then the oxidation of the organo-debris. The samples were later subjected to heavy liquid separation, using zinc bromide to separate the maceral from the organic debris. The maceral was rinsed with water and ethanol beforebeing mounted on the glass slide with DPX. The stratigraphic interval investigated revealed that it belonged to the Echitricolporites spinosus zone or Zone P800 and subzone P820-P880. It was characterized by the co-occurrences of marker forms such as Cyperaceaepollis sp., Nymphae lotus, Retistephanocolpites gracilis, Echiperiporites estalae, Arecipites sp., and Crototricolpites crotonoisculptus. The interval also contains stratigraphically important geologic age diagnostic pollen such as Podocarpus millanjianus, Multiareolites formosus, Zlivisporites neogenicus, and Zonocostites ramonae. The bio-assemblages were indicative of the Upper Miocene-Pliocene age of the Ogwashi-Asaba Formation. Older forms such as Crassoretitriletes vanraadshooveni, Striamonocolpites rectostriatus, Praedapollis sp., and Perfotricolpites digitatuswere derived fossils which suggested that Ogwashi Asaba Formation was reworked sediment.

Keywords: Decarbonisation, Marker form, Upper Miocene-Pliocene, Derived fossil, Reworked sediment

INTRODUCTION

The Anambra Basin is a Cretaceous sedimentary basin situated in the southeastern part of Nigeria. It has a thick sedimentary deposit of about 9000 m which inhabits commercial hydrocarbon. It was described to have a roughly triangular-shaped basin which covers an area of about 40,000 sq.km, extending northwards in the Benue River (Olubayo, 2010). The basin is bounded to the south by the Niger Delta hinge line. It extends north-westward into the Bida Basin, northward to the Jos Massif and northeastward to the

Benue Trough. The eastern and western limits of the basin are defined by the Abakaliki Anticlinorium and Okitipupa Massif respectively.

The structural evolution of the Anambra Basin has been described by Ojoh (1992) and Obi *et al*. (2001). The origin of the basin is generally believed to be linked to the Santonian tectonics of the Abakaliki-Benue Basin, during which an N–S compression between the African and Eurasia plates folded the Abakaliki Anticlinorium (Obi *et al*., 1995). The tectonic event in the Anambra Basin was prior to a sedimentary platform, which was thinly covered by sediments. The folding of the Anticlinorium laterally shifted the depositional axis into the Anambra Platform which then began to accumulate sediments, shed largely from the Abakaliki Anticlinorium (Benkhelil, 1989; Murat, 1972; Obi et al., 2001). This assertion was however, debunked in the work of Ola-Buraimo and Akaegbobi (2013) and Ola-Buraimo, (2020) because the shifted axis that resulted in the deposition of sediments in the Anambra Basin seem to lack empirical biostratigraphic scientific basis and reasoning.

In the Anambra basin, theoldest sedimentsdates to Albian to Lower Cenomanian and belongs to Asu River Group (Ola-Buraimo and Akaegbobi, 2013; Table 1). Three major tectonic phases gave rise to three successive depocentres (Short and Stauble, 1967; Murat, 1972; Obi *et al*., 2001; Oboh-Ikuenobe*et al*., 2005).

Table 1. Chart for the Early Cretaceous strata in theSoutheastern Nigeria (After Nwajide, 1990)

<table>
<tr><td>AGE</td><td colspan="2">ABAKALIKI-ANAMBRA BASIN</td><td>AFKPO BASIN</td></tr>
<tr><td>M.Y
30</td><td>Oligocene</td><td>Ogwashi-Asaba formation</td><td>Ogwashi-Asaba formation</td></tr>
<tr><td>54.9</td><td>Eocene</td><td>Ameki/Nanka formation/
Nsuebe sandstone(Ameki eroup)</td><td>Ameki formation</td></tr>
<tr><td>65</td><td>Paleocene</td><td>Imo formation
Nsukka formation</td><td>Imo formation
Nsukka formation</td></tr>
<tr><td>73</td><td>Maastrichtian</td><td>Ajali formation
Mamu formation</td><td>Ajali formation
Mamu formation</td></tr>
<tr><td>83</td><td>Campanian</td><td>Nkporo Oweli formation/Enugu shale</td><td>Nkporo shale/Afikpo sandstone</td></tr>
<tr><td>87.5</td><td>Santonian</td><td rowspan="2">Agbani sandstone/ Awgu shale</td><td>Non-deposition/erosion</td></tr>
<tr><td>88.5</td><td>Coniacian</td><td rowspan="2">Eze Aku Group (include Amasiri sandstone)</td></tr>
<tr><td>93</td><td>Turonian</td><td rowspan="2">Asu River Group</td></tr>
<tr><td>100</td><td>Cenomanian-Albian</td></tr>
<tr><td>119</td><td>Aptian
Barremian
Hauterivian</td><td colspan="2">Unnamed Group</td></tr>
<tr><td colspan="2">PRECAMBRIAN</td><td colspan="2">BASEMENT COMPLEX</td></tr>
</table>

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Earlier workers advocated three different phases for the sedimentation in the basin. The first phase (Albian–Santonian) featured the deposition of the Asu River Group, EzeAku and Awgu Formations within the Abakaliki-Benue Trough which was flanked to the east by the Anambra Platform and to the southwest by the Ikpe Platform (Short and Stauble, 1967; Benkhelil, 1989*;* Murat, 1972; Obi et al., 2001; Oboh-Ikuenobe*et al*., 2005).

However, based on palynological evidence Ola-Buraimo and Akaegbobi (2013b) believed that the oldest sediment which constitutes the Asu River Group is Albian-Early Cenomanian in age situated within the Anambra Basin. The second phase (Campanian-Eocene) was characterized by compressive movements along the NE-SW axis which resulted in the folding and uplift of the Trough into an anticlinorium. This forced the Anambra Platform to subside and form the Anambra Basin and the Afikpo Syncline. However, another school of thought believes that the older sediments which comprise Asu River Group, Eze Aku Formation and Awgu Shale are all part of the Anambra Basin (Ola-Buraimo, 2020). The deposition of the Nkporo Group, Mamu Formation, Ajali Sandstone, Nsukka Formation, Imo Formation and the Ameki Group then followed the older sediments sedimentation (Tab 1.).

The lithostratigraphic succession in the Anambra Basin was first studied by Reyment (1965) then, later documented by Nwajide (1990; Tab. 1). However, it was succinctly described in the work of Ola-Buraimo (2020). The Asu River Group was succeeded by Eze-Aku Shale dated Upper Cenomanian to Turonian (Ola-Buraimo 2013). This is overlain by Awgu Shale dated Coniacian age (Ola-Buraimo, 2013).

The younger Cretaceous sediments compriseCampania Nkporo Shale, Owelli Sandstone and Enugu Shale (Reyment, 1965; Obi, 2000; Ola-Buraimo and Akaegbobi, 2013b; Ola-Buraimo 2020). Nkporo Group is overlain by the Mamu Formation, deposited in the Early Maastrichtian age (Kogbe, 1989; Obi, 2000, Ogala*et al*., 2009*;* Ola-Buraimo and Yelwa, 2018). The Mamu Formation comprisesasuccession of siltstone, shale coal seam and sandstone (Kogbe, 1989; Ogala*et al*., 2009). The Ajali Sandstone (Maastrichtian) overlies the Mamu Formation (Reyment, 1965; Nwajide 1990), which consists mainly of unconsolidated coarse-fine grained poorly cemented sandstone and siltstone (Kogbe, 1989).

The Ajali Sandstone is overlain by the Late Maastrichtian Nsukka Formation (Bankole and Ola-Buraimo, 2016). A conformable facies was reported to exist between the Nsukka and Imo Formations. The marine transgression of the Middle Eocene led to the deposition of the Ameki Formation which was followed by an unconformity before the younger Ogwashi/Asaba Formation (Ola-Buraimo and Ehinola, 2021). However, the youngest Ogwashi-Asaba Formation was assigned Neogene age based on the application ofkeydinoflagellate forms (OlaBuraimo and Akaegbobi, 2012). This present study is to further investigate the Ogwashi/Asaba Formation from another palynological perspective based on the study of pollen and spores from another exploratory oil well location (Nzam-1 Well). This study will ascertain the veracity of the earlier Neogene age ascribed to it by earlier researchers through the use of dinoflagellate tool. The location of the Nzam-1 Well is presented in Figure 1.

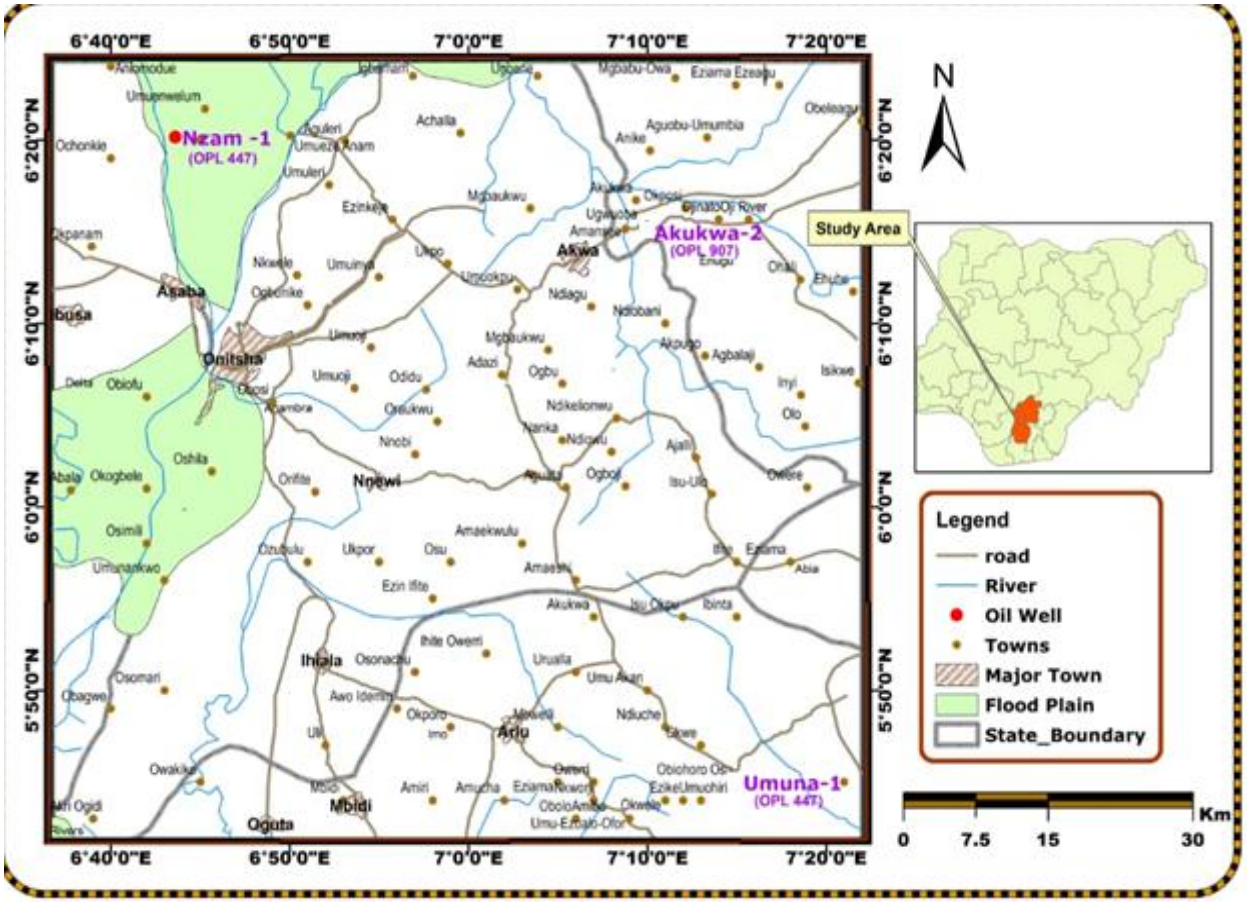

Figure 1. Map of Nigeria showing map of southern Nigeria (inset), with the location of Nzam- 1 well.

METHODOLOGY

Nine ditch-cutting samples from Nzam-1 Well were initially profiled and described lithologically based on colour, composition, texture, fossil content, and post-depositional diagenetic effect. The shalesamples were processed, following standard laboratory procedures. The shale samples were gently crushed with mortar and pestle for easier chemical decarbonisation with dilute hydrochloric acid (HCl) to eliminate the presence of calcite. This was followed by sample digestion with hydrofluoric acid (HF) forthe breakdown of silica and disaggregation of the claystone particles by soaking them overnight. The soaked samples were stirred intermittently over a period of 24 hours towards achieving complete digestion (Ola-Buraimo, 2020).

The samples were subsequently sieved in the next stage of the preparation using a 10µm sieve mesh. The washed-away clay particles enabledthe concentration of organomacerals. The recovered organic debris was later bleached by treatment with concentrated nitric acid (HNO^3) to enhance the sculptural elements of the palynomorphs (Ola-Buraimo and Muhammed, 2024). This process helped to improve the identification of the pollen, spores, dinoflagellates and other important forms when viewed under the microscope. This stage was succeeded by the separation of the macerals from the organic debris usinga zinc bromide solution. The maceral floated at the top, decanted, and rinsed with distilled water and ethanol before it was finally mounted on glass slides. Theprepared palynological glass slide was ready for analysis using an OPTICA B-150 model microscope after it was allowed to core for about two days.

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RESULT AND INTERPRETATION

Interval: 113-366 m

Formation: Ogwashi/Asaba

Zone: *Echitricolporites spinosus* (Germeraad *et al*., 1968)

Zone: P800; Subzone: P820-880

Age: Upper Miocene-Pliocene

The zone is located in interval 113-390 m, dated Late Miocene to Pliocene age. Thelower part of the interval was characterised by the appearance of new forms such as *Cyperacaepollis* sp. (Plate 1, no. 1) and *Nymphae lotus* (Plate 1, no.2; Tabs. 2 and 3). At depth 335 mwas the appearance of marker forms like *Podocarpus millanjianus* (Plate 1, no. 3) and *Zonocostites ramonae*. Other microflora that are noted to characterise Late Miocene and Pliocene deposits were*Arecipites* sp.(Plate 1, no. 4), *Crototricolpites crotonoisculptus, Retistephanocolpites gracilis* (Plate 1, no. 5), *Multiareolites formosus* (Plate 4.29, no. 6), *Echiperiporites estalae* (Plate 1, no.7), *Canthium* type (Plate 1, no. 8) and *Retitricolporites irregularis* (Plate 1, no. 9).

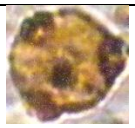
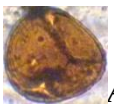
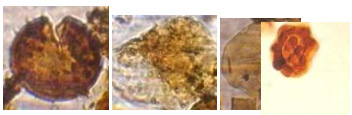
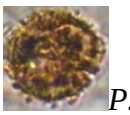
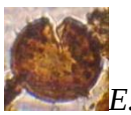
At depth 232 msome of these forms continue to appear while other diagnostic forms that depict Pliocene age such as *Podocarpus millajianus* appeared in association with *Echiperiporites estalae, Elaeis guineensis* (Plate 1, no. 11), *Striamonocolpites rectosriatus* and *Arecipites* sp. The interval is particularly characterised by Neogene dinoflagellate cysts such as *Multispinula quanta* (Plate 1, no. 12), *Impagidinium* sp. (Plate 2, no. 5), *Operculodinium centrocarpum* (Plate 2, no. 1), *Operculodinium* sp., *Selenopemphix nephroides* (Plate 2, no. 2), *Tuberculodinium vancampoae* (Plate 2, no. 3) and *Polysphaeridium zoharyi*. This assemblage of organic wall organism is similar to dinoflagellates that characterized the Neogene sediment of the Ogwahi /Asaba Formation in Umuna-1 Well as described by Ola-Buraimo and Akaegbobi (2012).

The upper part of the interval where the analysis of the well samples ends is marked by the co-occurrence of *Crassoretitriletes vanraadshooveni* (Plate 1, no. 10), *Laevigatosporites* sp. (Plate 1, no. 14), *Arecipites* sp., *Monoporites annulatus* and *Retibrevitricolporites obodoensis* (Plate 1, no. 13). Other stratigraphically important pollen, spores, and dinoflagellate cysts recovered in the interval that are diagnostic of the zone are presented in Plates 1-4. The assemblage of fossils recovered in this interval is comparable to Zone P800 (subzone P820-P880) dated Upper Miocene to Pliocene (Evamy *et al*., 1978; Ola-Buraimo and Akaegbbi, 2012; Ola-Buraimo, 2020). Therefore, theinterval 133-366 m of the *Echitricolporites spinosus*zone is assignedUpper Miocene to Pliocene age; straigraphically equivalent to Ogwashi-Asaba Formation (Fig. 2). However, the result obtained in this well for the Ogwashi-Asaba Formation is in contrary to geologic age (Oligocene) given by Nwajide (1990) and Late Eocene to Early Miocene opined byUmeji (2002) and but partly similar to the Pleistocene age suggested by Umeji (2012). One of the marker pollen identified in the sample (*Podocarpus millanjianus*) was reported in the work of Umeji (2012) andshe noted the co-occurrence of Oligocene and Pliocene forms, similar to the investigated samples in the Nzam-1 Well.

The interval is characterized by quantitative regular occurrence of *Achrosticum* sp., moderate regular occurrence of *Arecipites* sp. The co-occurrence of *Striamonocolpites rectastritus, Elaeis gueneensis*, and *Podocarpus millanjianus* marked the Miocene/Pliocene boundary. The M/P boundary is further marked by high diversity of miospores. *Retibrevitricolporites protrudens* shows high quantitative base occurrence here, However, *Monocolpites* sp., *Achrosticum* sp., and *Nymphaelotus* show high to moderate quantitative occurrence at the lower and upper parts of the stratigraphic section. The interval is further characterized by fair to rare continuous occurrence of *Psilatricolporites crassus*, while *Anthocerus*

sp. occurs only at the upper part of the interval suggested to belong to Pliocene age (Figs. 2 and 3).

The Oligocene forms present in the assemblage are reworked grains and they are referred to as derived fossils. The derived fossils are not significantly useful for biostratigraphical age dating. Thus, only younger fossilspresent were used for age dating of the sediment whereby Upper Miocene to Pliocene age was given to Ogwashi-Asaba Formation. This same phenomenon of derived fossis presence in Ogwashi/Asaba Formation was observed in the work of Ola-Buraimo and Akaegbibi (2012). There is an unconformable stratigraphic relationship between the Ogwasi/Asaba Formation and the underlying, older Ameki Formation. Therefore, the youngest dated sediment in the Anambra Basin from this study is Upper Miocene-Pliocene in age (Figs. 2 and 3). This assertion is similar to Neogene age given to the formation by Ola-Buraimo and Akaegbobi (2012) based on diagnostic dinoflagellates age dating. A summary of the established zone, bases of their erection, ages and corresponding formations that depict the geologic age, palynological zone, paleoenvironment of deposition of respective formationwas presented in Figure3.

Depth(m)	Lithology	Formation	Marker fossils	Age
113 151 232	_--_--_-- _--_-_---- _-_--_-- _-__---- __----__- __-----_-- -__---- __---_--- ____---- ____--- ____--- ____----_- --__--- __--__--- ____---_-- -___---_- ---_---__- ---_-- ____----- __-__-- __----__- ---_---- __--__-- __-_--__- --__--_- _--_--_-- _----_-- __--_--- _---_---_- ----____-- __--_---- _-__-__--	Ogwashi-Asaba	 *Laevigatosporites sp*  *R. obodoensis*   *E. Spinosus*  *Anthocerus sp.*   *P. Irregularis*  *E.estalae*	Late Miocene To Pliocene

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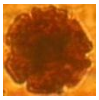
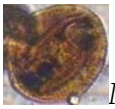
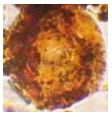
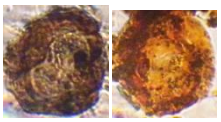
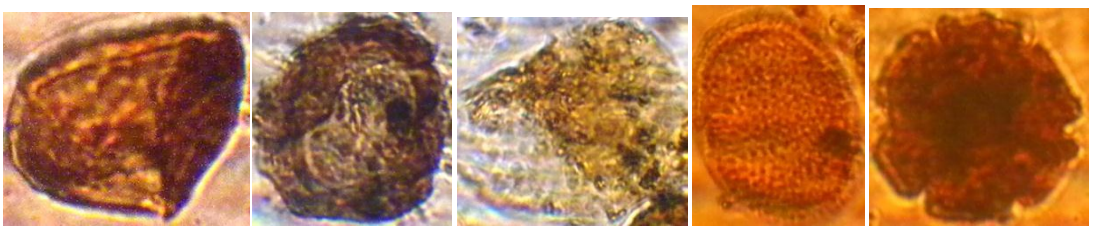
256 335 366	-__---- ____---__- ----__- ____----- ____--- ____---_-- __--____-- -_____---- -____---- _---____-- -__--____- --__---_-- __--__-- __------ ____-__--- _---____-- _------ _____--_-- __-____--- -__---- __--_--- __---__-- -_---__--- -____--__- -__---__- --__---_- ____--- ____--__-- ---____--- __---- _____----- _____---- _----__--- ----_____- -_____---- _____--- __--__--- -__------- ____-__--- -_____-- ____---- __--_-__- --_-_----- -__---__- s		 *Arecipites sp.*  R. *gracilis*  *M. estalae*  *Podocarpus millanjianus*   *Cyperaceaepollissp.*  *Nymphae lotus*	

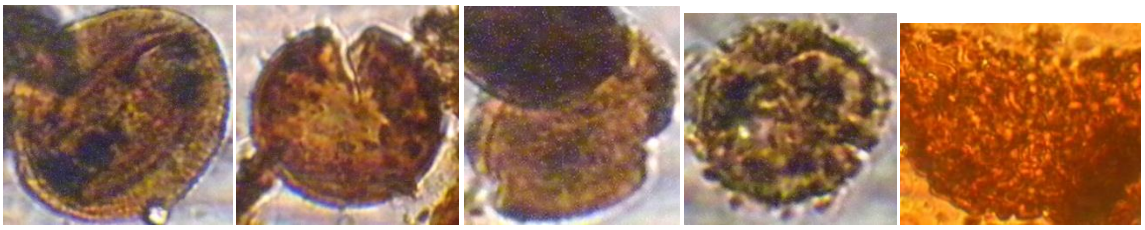
Figure 2. Marker fossils appearances with depth in interval 113-366 m

Magnification ×800

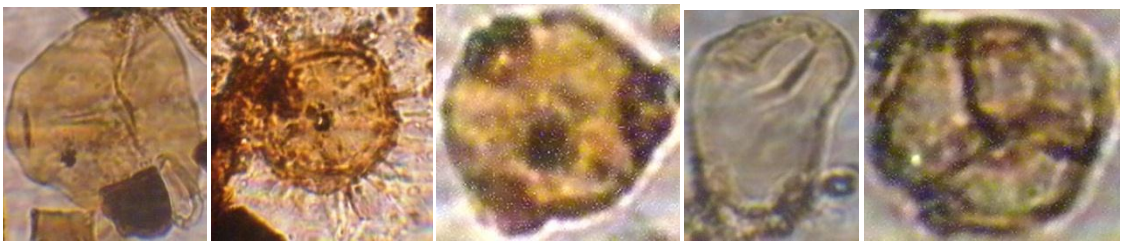


1

2 **3** **4** **5**



6 **7** **8** **9** **10**



11 **12** **13** **14** **15**

Plate 1. Palynomorph assemblage of interval 113-366 m

1 *Cyperaceaepollis* sp.
2 *Nymphae lotus*
3 *Podocarpus millanjianus*
4 *Arecipites*sp.
5 *Retistephanocolpites gracilis*
6 *Multiareolites formosus*
7 *Echiperiporites estalae*
8 *Canthium*type
9 *Retitricolporites irregularis*
10 *Crassoretitriletes vanraadshooveni*
11 *Elaeisguineensis*
12 *Multispinula quanta*
13 *Retibrevitricolporites obodoensis*
14 *Laevigatosporites* sp.
15 *Anthocerus* sp.

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Magnification ×800

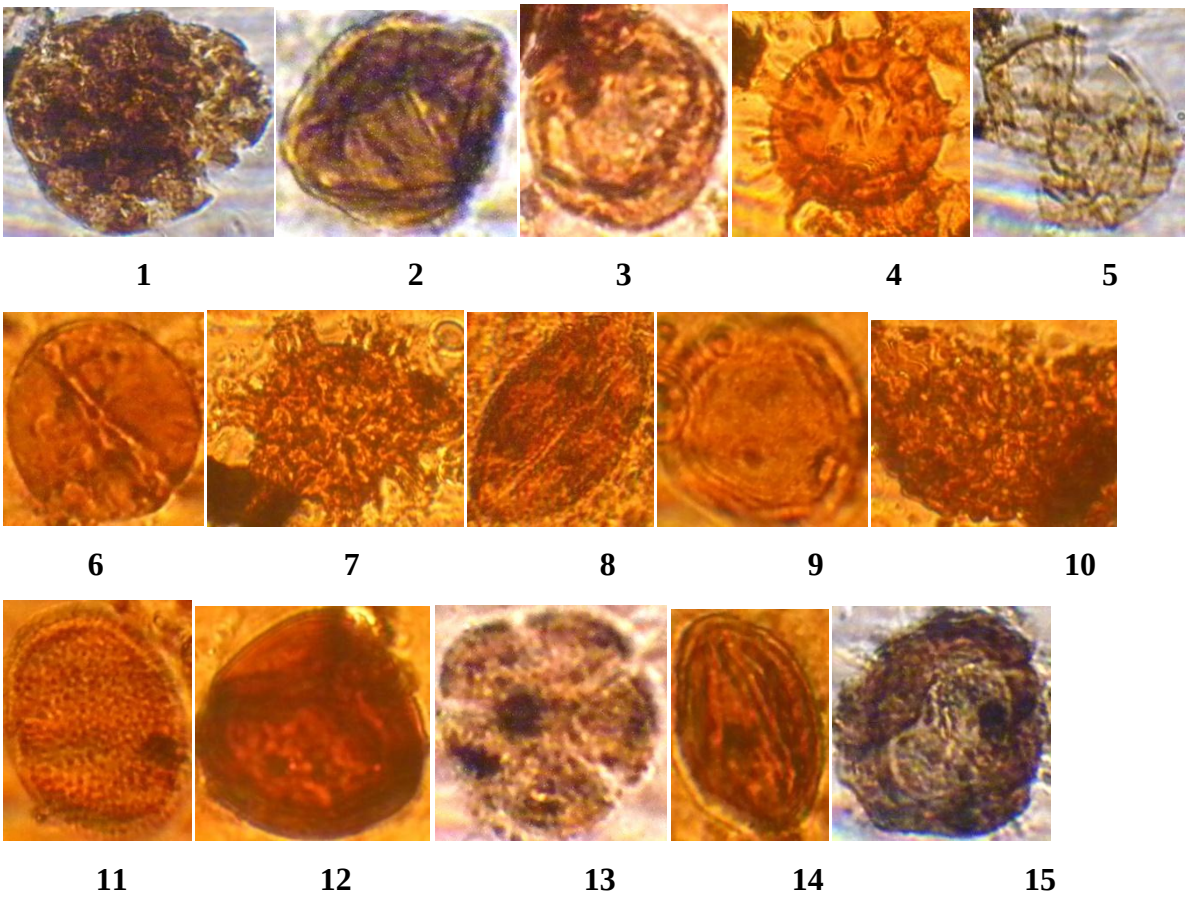

Plate 2. Palynomorph assemblage of interval 113-390 m

1 *Operculodinium centrocarpum*
2 *Selenopemphix nephroides*
3 *Tuberculodinium vancampoae*
4 *Spiniferites mirabilis*
5 *Impagidinium*sp.
6 *Monocolpites marginatus*
7 *Histrichokolpoma rigaudae*
8 *Retimonocolpites* sp.
9 *Uapaca*sp.
10 *Crassoretitriletes vanraadshooveni*
11 *Arecipites* sp.
12 *Anthocerus* sp.
13 *Retistephanocolpites* sp.
14 *Tricolporites* sp.
15 *Nymphae lotus*

Magnification ×800

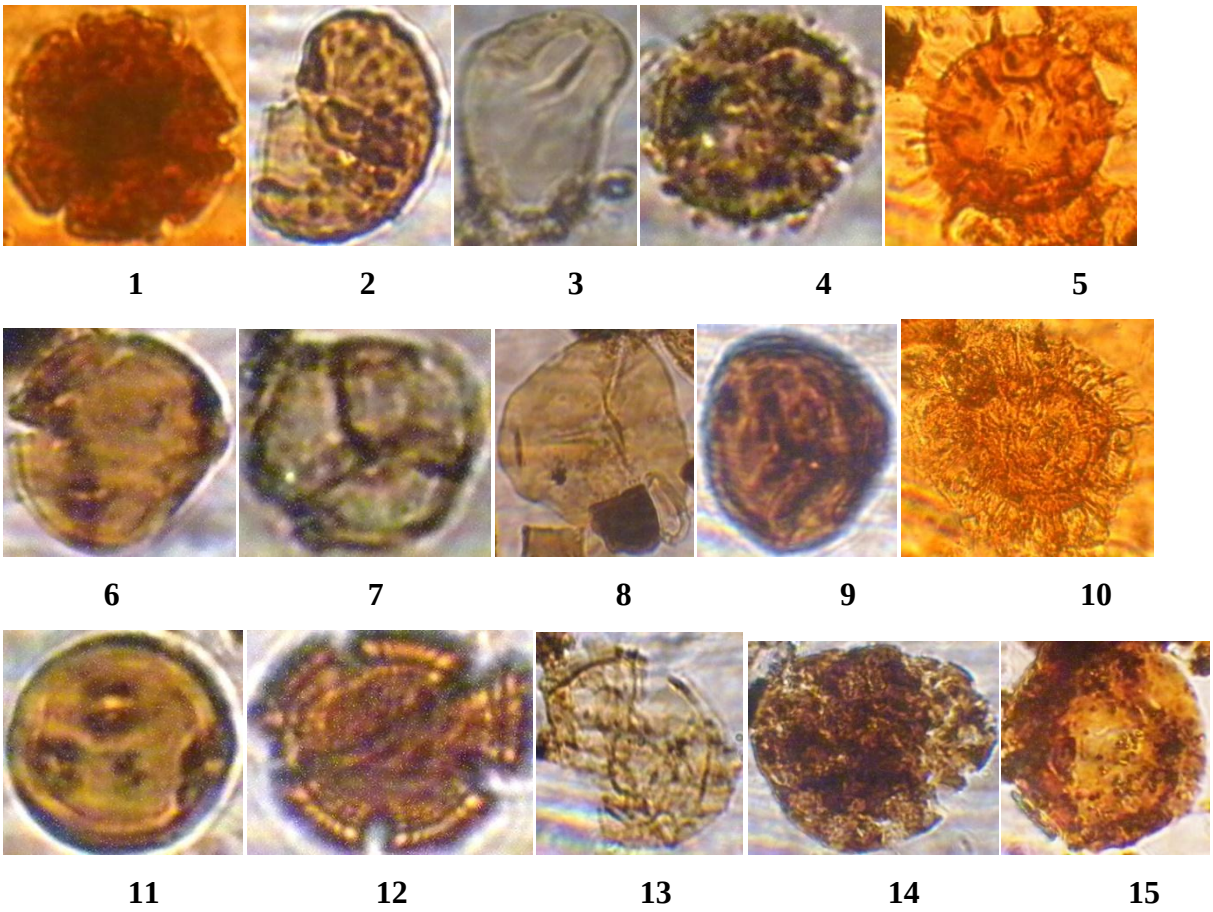

Plate 3. Palynomorph assemblage of interval 113-366 m

1 *Retistephanocolpites gracilis*
2 *Verrucatosporites usmensis*
3 *Laevigatosporites* sp.
4 *Retitricolporites irregularis*
5 *Spiniferites mirabilis*
6 *Psilatricolporites crassus*
7 *Anthocerus* sp.
8 *Elaeis guineensis*
9 *Zlivisporites neogenicus*
10 *Nematosphaeropsis labyrinthea*
11 *Uapaca*sp.
12 *Stephanocolpites*sp.
13 *Impagidinium* sp.
14 *Operculodinium centrocarpum*
15 *Nymphae lotus*

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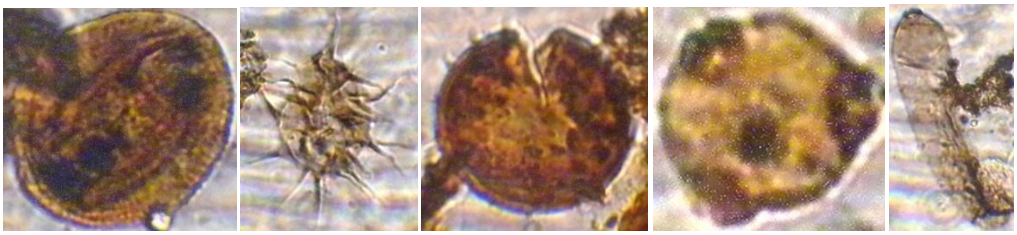

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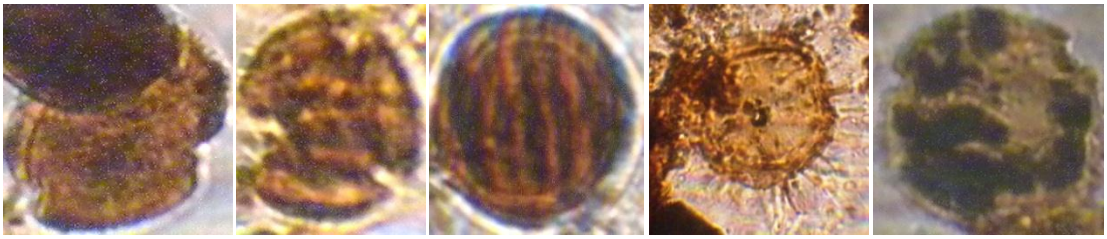
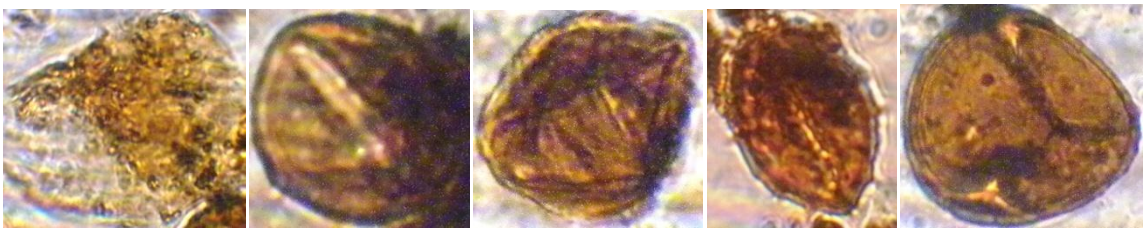


67 89 10



11 12 13 14 15

Plate 4. Palynomorph assemblage of interval 113-390 m

1 *Multiareolites formosus*

2 *Echitricolporites spinosus*

3 *Echiperiporites estalae*

4 *Retibrevitricolporites obodoensis*

5 NPP

6 *Canthium* type

7 *Tricolpites* sp.

8 *Psilastephanocolpites* sp.

9 *Multispinula quanta*

10 *Uapaca*type

11 *Podocarpus millanjianus*

12 *Monocolpites marginatus*

13 *Selenopemphix nephroides*

14 *Mauritiidites crassibaculatus*

15 *Anthocerus* sp.

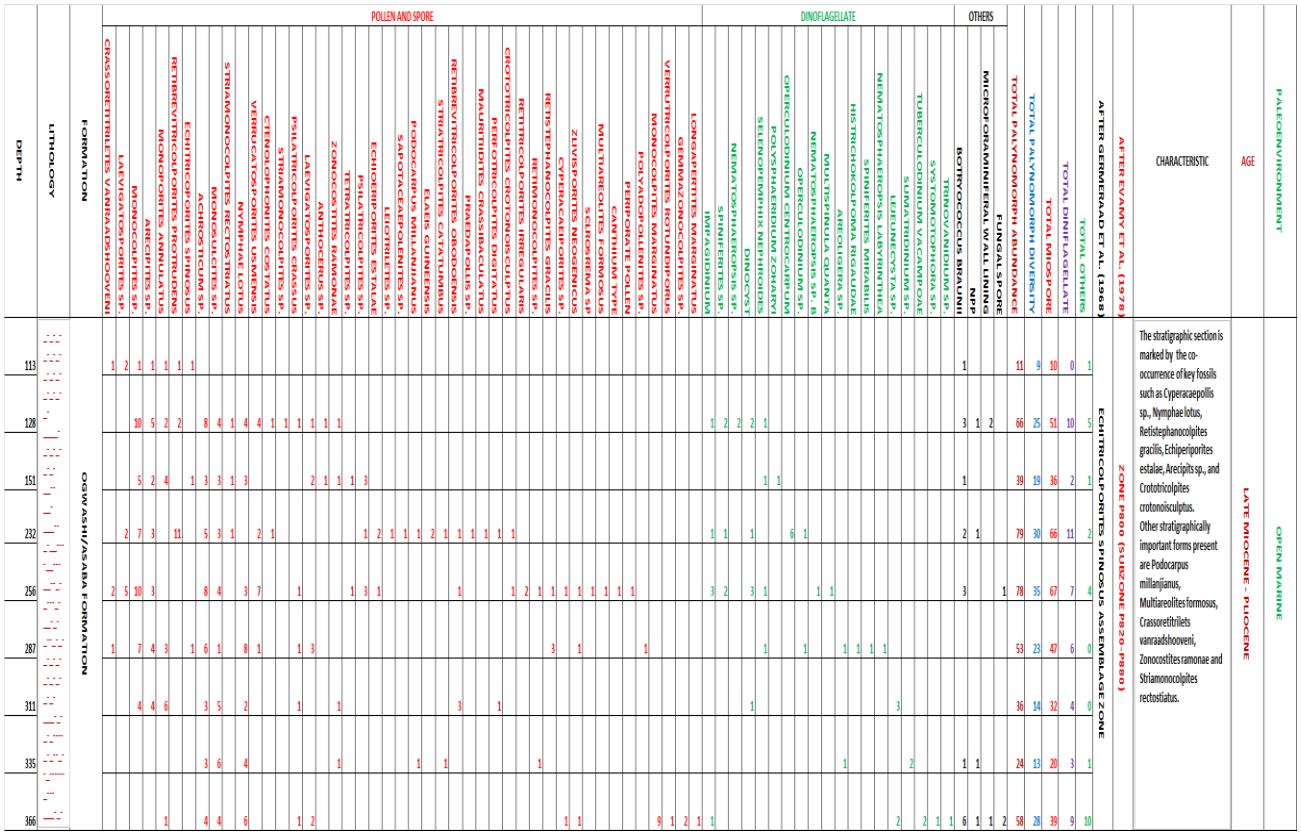


Figure 3. Checklist of palynomorph distribution in interval 113-366 m, Nzam-1 Well

CONCLUSION

The stratigraphic interval investigated belongs to the *Echitricolporites spinosus* zone or Zone P800 and subzone P820-P880. The interval is defined by the occurrences of as *Cyperaceaepollis* sp., *Nymphae lotus*, *Retistephanocolpites gracilis*, *Echiperiporites estalae*, *Arecipites* sp., and *Crototricolpites crotonoisculptus*. The investigated interval also containsdiagnostic pollen such as *Podocarpus millanjianus*, *Multiareolites formosus*, *Zlivisporites neogenicus*, and *Zonocostites ramonae*. The assemblages are indicative of the Upper Miocene-Pliocene age of theOgwashi-Asaba Formation. However, older forms such as *Crassoretitriletes vanra adshooveni*, *Striamonocolpites rectostriatus*, *Praedapollis* sp., and *Perfotricolpites digitatus* which are derived fossils suggest that Ogwashi Asaba Formation is reworked sediment.

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