New Oligocene to Early Miocene Palynomorph Zonation of GZ-1 Well, Onshore Western Niger Delta, Nigeria

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ABSTRACT: Palynological studies was carried out on GZ-1 well from the onshore western Niger Delta in order to recognized a new detected developments in the varieties of key pollen and spore taxa that have shorter and more distinguished interval zones to advance stratigraphical delineation. Palynological analysis was carried out using the conventional maceration technique for recovering acid insoluble organic-walled microfossils from sediments. The result yielded rich and diversified palynomorphs. The main assemblage were dominated by angiosperm pollen grain (dominant global flora from Late Cretaceous onwards) followed by pteridophytes/bryophyte spore. Dinoflagellate cysts, on the contrast, were less diverse while the Gymnosperm pollen were scarce. The identified palynomorph were used to establish seven main zones - AF1 Psilatricolporites crassus zone, AF2 Verrucatosporites usmensis zone, AF3 Triplochiton scleroxylon zone, AF4 Crassoretritiletes vanraadshooveni zone, AF5 Acrostichum aureum zone, AF6 Gemmatiporites ovwashiensis zone and AF7 Retitricolporites irregularis zone in this study. Established on quantitative events, the zones were also divided into seven subzones with some having finer subdivisions into (a) and (b) ranging in age from Early Oligocene to Early Miocene. Previous unfiled event trends of important indicator taxa of spores and pollen accredited to Pelliceria, Caesalapinoideae, Stenochlaena palustris, Polypodiaceae, Lygodium microphyllum, Polyopodiaceae, Adiantaceae and Amanoa (Euphorbiaceae) have assisted improvement of formerly used palynological zonation schemes in the Niger Delta. It is anticipated that this quantitative zonation scheme erected, will help with imminent palynostratigraphical studies in the onshore Niger delta area.

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large to capture understated palynological events. The zonation of Morley (2000), offers additional improvements, with quantitative events, but then is less consistent in the western part of the Niger Delta. Adeonipekun et al., (2015), worked on Late Miocene to Early Pleistocene three exploration wells from the western delta region of the Niger Delta to find an acceptable solution that will aid the recognition of shorter interval zones, understated subtle events and advance the palynostratigraphical resolution of the region. They discovered new palynological features that assisted them to defined five main palynological assemblage zones from their study. New events and features were recognized and the varieties and occurrence developments of the palynomorphs used have been verified in over 100 exploration wells from across the offshore Niger Delta. With these, missing sections were identified and enhanced stratigraphical modelling through the use of sequence stratigraphical procedures. This study is on new palynomorphs zonation in the Early Oligocene to Early Miocene sediments of GZ-1 well, onshore western Niger Delta. Fig. 1 shows the location of GZ-1 well.

**Geological setting:** The geology of the Niger delta has been described and defined by Short and Stauble (1967). Reijers (2011), submitted that the formation of the Niger Delta began in the Eocene, with the first deltaic sediments deposited to the south and east of the former Cretaceous coastline in the ‘northern delta depo-belt’. Several transgressive and regressive events have successively taken place (Short and Stauble 1967; Evamy et al., 1978) and according to Reijers (2011), these processes have given rise to the delta complex being deposited farther and farther offshore to the south. The lithofacies of the Cenozoic Niger Delta is mainly assembled into continental, transitional and marine leading to three Formations, viz., in ascending order: the Akata, Agbada and the Benin Formations. Fig. 2. The Akata Formation (marine sediments) is from Paleocene to Recent. Short and Stauble (1967); Reijers et al., (1997); Doust and Omatsola (1990). The Imo shale is the outcrop equivalent categorized by continuous, uniform shale and turbidites sand deposition in marine environment. The shales of this Formation are largely under compacted. Akpoyovbikye (1978). On top of the marine sequence is the Eocene to Recent Agbada Formation. Avbovbo (1978). The Agbada Formation consists of repeated coarsening-upward regressive sequences composed of shales, siltstones, and sandstones deposited in delta front and lower delta plain settings. Weber (1971). It’s establishes the actual deltaic portion of the sequence. Lambert-Aikhionbare and Ibe (1984), opined that the Agbada Formation is composed of the petroleum bearing reservoir rocks while the Akata Formation bears the source rocks. Ekweozor and Okoye (1980). Topping the sequence is generally the continental Benin Formation, which consist of a succession of Eocene to Holocene massive poorly indurated sandstones, thin shales, coals, and gravels of continental to upper delta plain origin. Okosun et al., (2016). The Benin Formation is superimposed by diverse types of Quaternary deposits, Boboye and Fawora (2007), deposited on littoral and deltaic plain environments. Weber and Daukoru (1975). Fig. 2 shows the schematic representation of diachronous nature of major lithofacies units and stratigraphic relationships of clay-filled channels on the Delta Flanks.
MATERIALS AND METHODS
Twenty grams from each of the ditch cutting samples provided by NPDC were used for the palynological study, following the technique of Wood et al., (1996). The sediment were digested for 30 minutes in 40 % hydrochloric acid to remove carbonates, then 72 hours in 48 % hydrofluoric acid for the removal of silicates. This was followed by complete neutralization with distilled water. Removal of the fluoride gel (formed during the HF treatment) was done using hot concentrated HCl acid and wet sieving the residue using a 10-μm polypropylene Estal Mono sieve. The residues were oxidized for 30 minutes in 70 % HNO₃ to render the fossils translucent for transmitted light microscopy; rinsed in 2 % K OH solution to neutralize the acid, swirled and stained with Safranin-O to increase the contrast for identification and photography. Heavy-liquid separation with ZnBr₂ (2.2 s.g) and separating of the remains with a 20 μm sieve. The residues were spotted with pipette on cover slip, left to dry and were then mounted on glass slides using Canada basalm as adhesive mounting medium. Palynomorph residue were then studied with a transmitted light binocular microscope; rinsed in 2 % K OH solution to neutralize the acid, swirled and stained with Safranin-O to increase the contrast for identification and photography. Heavy-liquid separation with ZnBr₂ (2.2 s.g) and separating of the remains with a 20 μm sieve. The residues were spotted with pipette on cover slip, left to dry and were then mounted on glass slides using Canada basalm as adhesive mounting medium. Palynomorph residue were then studied with a transmitted light binocular microscope to identify the different palynomorphs (pollen, spores and dinoflagellate cysts). Where possible, about 200 - 300 grains including (fern spores and pollen) were counted from each slide for quantitative palynological analysis. Photomicrographs of well-preserved palynomorphs were taken with the aid of Sony digital camera (14.1 mega pixels). Identification of Palynomorphs (pollen, spores and dinoflagellate cysts) was undertaken by matching with palynological work of relevant publications and web-based albums. The statistical data (palynological count) obtained was computerized using the StrataBug 2.0 software (palynological count) obtained was computerized using the StrataBug 2.0 software. Qualitative and quantitative events of both the single taxa and the whole assemblage composition establishes the sub-zones. Thus, they are subject to biological evolution/extinction in addition to palaeoclimatic and ecological factors.

RESULTS AND DISCUSSION
Palynostratigraphy in GZ-1 well: The palynological analysis yielded rich and diversified palynomorphs of seventy one genera and one hundred and one (101) species. Seventy-four (74) pollen species, fourteen (14) spore species and thirteen (13) dinoflagellate cysts species - six (6) Peridinoid cysts with seven (7) Gonyaulacoid cysts were recovered. The main assemblage were dominated by angiosperm pollen grain (dominant global flora from Late Cretaceous onwards) followed by pteridophytes/bryophyte spore. Dinoflagellate cysts, on the contrast, were less diverse while the Gymnosperm pollen were scarce. In the palynomorph proportion, miospore make up about 86.7 %. The Angiosperm pollen (70 %), Gymnosperm pollen (2.9 %), monolete spore (4.9 %), trilete spore (8.9 %) whereas marine origin (dinoflagellates cysts) make up 12.8 %. The Gonyaulacoid (6.9 %) are more dominant than Peridinoid (5.9 %) in the recovered dinoflagellate cysts. Table 1.

<table>
<thead>
<tr>
<th>Types of palynomorph species and their count Approx. Percentage value</th>
<th>Monolete spore</th>
<th>Trilete spore</th>
<th>Angiosperm pollen</th>
<th>Gymnosperm pollen</th>
<th>Gonyaulacoid dinocysts</th>
<th>Peridinoid dinocysts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx. Percentage value</td>
<td>5</td>
<td>9</td>
<td>71</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>101</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>9</td>
<td>70</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>100</td>
</tr>
</tbody>
</table>

The proportion of angiosperm pollen recovered are the highest in the studied well as shown in table 1. Fig. 3 shows the area plot of the percentage value of the different palynomorphs. The following species characterized the monolete spores: *Verrucatosporites spp.*, *Verrucatosporites usemensis* and *Varirago spores* spp. while the trilete spore were characterized by - *Acrostichum aureum*, *Cyaithites australis*, *Leiotriletes spp.*, *Magnastriatites howardi*, *Polypodiaceoisporites spp.*, *Elaiis guineensis* and *Foveotriletes margaritae* among others. The gymnosperm pollen are exemplified herein by two genera - *Ephedrites* and *Podocarpidites*. They were sparsely represented in the well. The following species: *Lingulodinium spp.*, *Selenopemphix spp.*, *Pheidinum africanus*, *Lejeuneecysta spp.*, *Amiewalan, FO; Balogun, FO*
Cordosphaeridium inodes, Operculodinium spp. among others represent the dinoflagellate cysts. The commonest species are the Lejeunecysta spp. Also, foraminiferal test linings, freshwater algae and fungal spores were recognized.

Descriptions and characteristics of new zones and sub-zones in the study well: The corresponding zones compares with the zones of Germeraad et al., (1968); Evamy et al., (1978) and Legoux (1978). Table 2 shows the abbreviations and definitions used in the zonation discussion.

Palynological zones demarcated in the studied well: Seven main zones have been documented, AF1 (Psilatricolporites crassus zone), AF2 (Verrucatosporites usmensis zone), AF3 (Triplochiton scleroxyylon zone), AF4 (Crassoretiritelles vanraadshooveni zone), AF5 (Acrostichum aureum zone), AF6 (Gemmatriporites ogwashiensis zone) and AF7 (Retitricolporites irregularis zone). Also seven subzones were demarcated - AO1, AO2, AO3, AO4, AO5, AO6 and AO7.

Table 2: Abbreviations used in the palynological zonation scheme for this study.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDO</td>
<td>First Downhole Occurrence (stratigraphic top or extinction event)</td>
</tr>
<tr>
<td>LDO</td>
<td>Last Downhole Occurrence (stratigraphic base or evolutionary appearance)</td>
</tr>
<tr>
<td>LAD</td>
<td>Last Appearance Datum</td>
</tr>
<tr>
<td>FAD</td>
<td>First Appearance Datum</td>
</tr>
<tr>
<td>OB</td>
<td>Quantitative base (a decrease in numerical abundance down-section)</td>
</tr>
<tr>
<td>QT</td>
<td>Quantitative top (an increase in numerical abundance down-section)</td>
</tr>
<tr>
<td>DD</td>
<td>Downhole decrease</td>
</tr>
<tr>
<td>PO</td>
<td>Peak occurrence</td>
</tr>
<tr>
<td>RO</td>
<td>Regular occurrence</td>
</tr>
<tr>
<td>DI</td>
<td>Downhole increase</td>
</tr>
<tr>
<td>TRO</td>
<td>Top Regular Occurrence</td>
</tr>
<tr>
<td>Spp.</td>
<td>Specie</td>
</tr>
<tr>
<td>Cf.</td>
<td>Compared with</td>
</tr>
</tbody>
</table>

Two of the subzones (AO2 and AO3) were further subdivided into (a and b). Within the Early Oligocene two sub-zones (AO1 and AO2) were established. One subzone each (AO3 and AO4) was demarcated within Early - Late Oligocene and Late Oligocene - Early Miocene.

Three subzones (AO5, AO6 and AO7) were defined within the Early Miocene. The assemblages of the new zones and sub-zones have more comprehensive explanations of their distributions and relative abundances of the component taxa present within them.

Table 4 reveals the new palynostratigraphical biozonation of the Early Oligocene - Early Miocene erected for GZ-1 well, based on pollen, spore, dinoflagellate cysts distributions and quantitative events.

ZONE AF1: (Psilatricolporites crassus zone) - Early Oligocene
Top of zone: QB Striatricolpites catatumbus
Base of zone: Not seen in the studied intervals.

ZONE AF2: (Verrucatosporites usmensis zone) - Early Oligocene

Top of zone: QT Retitricolporites irregularis

Base of zone: QB Striaticolpites catatubus

Characteristics: Several barren depth were identified within the zone. QB Verrucatosporites usmensis, LDO Bombacacidites annae and Magnastratiates howardi.

Consistent Retitricolporites protrudens, DD Podocarpus milanjianus. Rare Graminidites annulatus. RO freshwater swamp species and marine palynomorph - Polysphaeridium zoharyi and Lejeuneecysta spp., low in abundance of mangrove swamp. Cordosphaeridium inodes specie is restricted to this zone of the well. Presence of reworked pollen and spore (Mauritiidites crassieinus, Verrucatosporites usmensis and Psialticolporites operculatus).

**Table 3:** Some of the recovered pollen and spore with their author references, botanical affinities and ecologies for the studied well.

<table>
<thead>
<tr>
<th>Taxon, author</th>
<th>Botanical Affinity</th>
<th>Natural Habitat/Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrostichum austreum, Kar (1992)</td>
<td>Polyopiaceae, Adiantaceae</td>
<td>Mangrove swamp</td>
</tr>
<tr>
<td>Cicatricossporites dorogensis, Potonie and Gellitch (1933)</td>
<td>Dicksoniacae</td>
<td>Mesophilous forest/Montane Forest</td>
</tr>
<tr>
<td>Crassorettriletes vanraausnhoveni, Gerneraad et al., (1968)</td>
<td>Lygodium microphyllum</td>
<td>Humid marsh and coastal swamps</td>
</tr>
<tr>
<td>Ectites guineensis</td>
<td>Palmae</td>
<td>Rain forest</td>
</tr>
<tr>
<td>Lervigatatorporites haardti, Thomson and Pflug (1953)</td>
<td>Polypodiaceae</td>
<td>Mangrove swamp</td>
</tr>
<tr>
<td>Magnastratiates howardi, Gerneraad et al., (1968)</td>
<td>Parkeriacae,Ceratoptersis, Adiantaceae,</td>
<td>A tropical freshwater-fern</td>
</tr>
<tr>
<td>Verrucatosporites usmensis, Van Der Hammen (1956b)</td>
<td>Stenochlaenca palastris, Polypodiaceae</td>
<td>Mesophilous forest/Lowland Rainforest</td>
</tr>
<tr>
<td>Podocarpus milanjianus, William et al., (2013)</td>
<td>Podocarpaceae</td>
<td>Afromontane</td>
</tr>
<tr>
<td>Arecipites exilimuratus, Legoux (1978)</td>
<td>Areaceae</td>
<td>Rain forest</td>
</tr>
<tr>
<td>Belkikollis etagens, Legoux (1978)</td>
<td>Acantnaceae</td>
<td>Montane Forest</td>
</tr>
<tr>
<td>Echiperiporites estaelae, Gerneraad et al., (1968)</td>
<td>Malvaceae, Thespesia populnea</td>
<td>Coastal swamp</td>
</tr>
<tr>
<td>Graminidites annulatus, Gerneraad et al., (1968)</td>
<td>Poaceae (Gramineae)</td>
<td>Savanna</td>
</tr>
<tr>
<td>Pachydermites dierixi, Saland- Cheboeddaeff (1990)</td>
<td>Clusiaceae, Hypriacaeae</td>
<td>Coastal swamp/Fresh Water Swamp</td>
</tr>
<tr>
<td>Peregrinippolis nigericus, Clarke (1966)</td>
<td>Caesalpinoideae</td>
<td>Riverine/Leguminous plants</td>
</tr>
<tr>
<td>Praedopolpis flexilis, Legoux (1978)</td>
<td>Fabaceae/Leguminosae?</td>
<td>Rain forest</td>
</tr>
<tr>
<td>Praedopolpis filtricans, Boltenhagen and Saland- Cheboeddaeff (1973)</td>
<td>Fabaceae/Leguminosae?</td>
<td>Rain forest</td>
</tr>
<tr>
<td>Poliatcolporites crassus, Van Der Hammen and Wymstra (1964)</td>
<td>Pelliceria, Caesalpinoideae</td>
<td>Mangrove swap</td>
</tr>
<tr>
<td>Psialticolporites operculatus, Van Der Hammen and Wymstra (1964)</td>
<td>Euphorbiaceae, Alchornea cordifolia</td>
<td>Riverine/Freshwater swamp</td>
</tr>
<tr>
<td>Racemonocolpites hians, Legoux (1978)</td>
<td>Palmae</td>
<td>Freshwater Swamp</td>
</tr>
<tr>
<td>Retitricolporites obodoensis, Legoux (1978)</td>
<td>Euphorbiaceae/Rubiaceae</td>
<td>Freshwater swamp/Lowland Rain forest</td>
</tr>
<tr>
<td>Retitricolporites protrudens, Legoux (1978)</td>
<td>Euphorbiaceae/Rubiaceae</td>
<td>Sub-tropical broad leaved ever green tree</td>
</tr>
<tr>
<td>Retitricolporites typicus, Sah (1967)</td>
<td>Oleaceae</td>
<td></td>
</tr>
<tr>
<td>Retitricolporites irregularis, Van der Hammen and Wymstra (1964)</td>
<td>Amanoa (Euphorbiaceae)</td>
<td>Freshwater swamp/Riverine</td>
</tr>
<tr>
<td>Spirosyncolpites brunii, Legoux (1978)</td>
<td>Loganiaceae, Fagraea sasakii</td>
<td>Rain forest</td>
</tr>
<tr>
<td>Verrucatosporites ramiflora, Van Der Hammen and Wymstra (1964)</td>
<td>Crenea, Lythraceae</td>
<td>Mangrove/Coastal swamp</td>
</tr>
<tr>
<td>Zonocostites ramona, Gerneraad et al., (1968)</td>
<td>Rhizophoraceae, Bruguiera, Ceroips and Caralia</td>
<td>Mangrove swamp</td>
</tr>
</tbody>
</table>

Equivalent zone: P560

Sub-zone AO2a: (Early Oligocene)

Top of sub-zone: QB Verrustephanocolpites complanatus

Base of sub-zone: QB Striaticolpites catatubus

Characteristics: Consistent Zonocostites ramona, Pachydermites dierixi, Praedopolpis flexilis, Racemonocolpites hians, Retitricolporites irregularis, Striaticolpites catatubus, Peregrinippolis nigericus, Verrucatosporites usmensis toward the base of the subzone. PO Proteacidites cooksonii. LDO Bombacacidites annae and Magnastratiates howardi.

Equivalent zone: P560 (upper part).
<table>
<thead>
<tr>
<th>Paleocene</th>
<th>Early Oligocene</th>
<th>Middle Oligocene</th>
<th>Late Oligocene</th>
<th>Early Miocene</th>
<th>ZONAL MARKERS AND PALEONTOLOGICAL EVENTS</th>
<th>SUBZONAL MARKERS AND PALEONTOLOGICAL EVENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleocene</td>
<td>Early Oligocene</td>
<td>Middle Oligocene</td>
<td>Late Oligocene</td>
<td>Early Miocene</td>
<td>ZONAL MARKERS AND PALEONTOLOGICAL EVENTS</td>
<td>SUBZONAL MARKERS AND PALEONTOLOGICAL EVENTS</td>
</tr>
<tr>
<td>P560</td>
<td>A2</td>
<td>Triplochiton scleroxylon</td>
<td>TRO</td>
<td>Pollisporites irregularis. Rare/consistent/mangrove pollen</td>
<td></td>
<td>AO4</td>
</tr>
<tr>
<td>P580</td>
<td>A2</td>
<td>Triplochiton scleroxylon</td>
<td>TRO</td>
<td>Polypodiaceoisporites irregularis. Rare/consistent/mangrove pollen</td>
<td></td>
<td>AO3</td>
</tr>
</tbody>
</table>
Sub-zone AO2b: (Early Oligocene)
Top of sub-zone: QT Retitricolpites irregularis
Base of sub-zone: QB Verrustephanocolpites complanatus
Characteristics: Rare/consistent/common of most palynomorph comparable to the underlying subzone. LDO aff. Selaginella myosurus, Event of Podocarpus milanjianus. FDO Leiotriletes spp. and Magnanmonoporites gemmatus. RO marine palynomorph - Polysphaeridium zoharyi and Lejeunecysta spp.
Equivalent zone: P560 (lower part).

ZONE AF3: (Triplochiton scleroxylon zone) Early - Late Oligocene
Top of zone: TRO Polypodiaceoisporites retrigatus
Base of zone: QT Retitricolpites irregularis
Equivalent zone: P580.

Sub-zone AO3a: (Early - Late Oligocene)
Top of sub-zone: RO Retimonocolpites irregularis
Base of sub-zone: QT Retitricolpites irregularis
Characteristics: Consistent/common Acrostichum aureum, Verrucatosporites spp. PO Triporotetradites aff. Letouzeyi, Verrucatosporites usmensis. Rare most of the palynomorph. LDO Gemmatriletes clavatus, Anthocleista cf. vogeli, Psilatricolporites annuliporis.
Equivalent zone: P580 (lower part).

Sub-zone AO3b: (Early - Late Oligocene).
Top of sub-zone: TRO Polypodiaceoisporites retrigatus
Base of sub-zone: RO Retimonocolpites irregularis
Characteristics: Rare/consistent of most palynomorph comparable to the underlying subzone. Rare Zonocostites ramonae. TRO Pachydermites diederixi, Racemonocolpites hians, Retitricolpites irregularis, Acrostichum aureum, Verrucatosporites spp. and Praedopolis africanus.
Equivalent zone: P580 (upper part).

ZONE AF4: (Crassoretiritriletes vanraadschooveni zone) Late Oligocene - Early Miocene
Top of zone: TRO Verrucatosporites usmensis
Base of zone: TRO Polypodiaceoisporites retrigatus
Characteristics: General rare/consistent/common/abundant recovery of palynomorph in the zone. Rare Bombacacidites annae, Marginipollis concinnus, Graminidites annulatus. FDO Cicatricoisporites dorogenisi, aff. Retitricolpites bendeensis. Acme event of Acrostichum aureum. Abundant occurrences of mangrove swamp pollen - Zonocostites ramonae, Acrostichum aureum, relative abundance of savanna pollen Peregrinipollis nigericus, fresh water swamp pollen - Striatopollis catatumbus and Retitricolpites irregularis. TRO Verrucatosporites usmensis and Retimonocolpites irregularis. RO Lejeunecysta spp. Event of Crassoretiritriletes vanraadschooveni restricted to this zone of the well. The presence of reworked sediments (Ephedrites spp., Verrucatosporites usmensis, Psilatricolporites operculatus). Equivalent zone: P620.

ZONE AF5: (Acrostichum aureum zone) - Early Miocene
Top of zone: FDO Proxapertites cursus
Base of zone: TRO Verrucatosporites usmensis

ZONE AF6: (Gemmatriletes ogwashiensis zone) - Early Miocene
Top of zone: QT Striaticolpites catatumbus, QT Gemmatriletes ogwashiensis
Base of zone: FDO Proxapertites cursus

ZONE AF7: (Retitricolpites irregularis zone) - Early Miocene
Top of zone: Not seen in studied sections.
Base of zone: QT Striatricolpites catatumbus, QT Gemmatriporites ogwaswiensis
Characteristics: Rare/consistent common/abundant of palynomorph recovery in the zone, QB Gemmatriporites ogwaswiensis, Psilitricolpites operculatus. QT Magnastratiattes howardi and Acrostichum aureum. RO Graminidites annulatus and Zonocystites ramonae. PO Polyplodiaceoisporites retirugatus. The presence of reworked sediments (Psilitricolpites operculatus). The zone is completely devoid of marine-derived fossils.
Equivalent zone: ?P670

Dating of the zonation scheme: The ages assigned to the zones and sub-zones are shown in table 4, that demonstrates relationships to the previous schemes of Germeraad et al., (1968), Evamy et al., (1978) and Legoux (1978).

Early Oligocene: The upper part of the Early Oligocene age (P560) was delineated in GZ-1 well at 9447 ft. based on the increase of Retibreviricolpites obodoensis/protrudens. Oboh et al., (1997), used the presence of the specie Retibreviricolpites obodoensis to define the Oligocene age. The specie Loranthacites natalie reproduced in Oligocene sediment likewise agrees with the work of Salard-Cheboda (1990), who age dated the Oligocene to Eocene strata in Cameroun, Gabon and Congo using Loranthacites natalie specie. P540 was not delineated in the well due to the absence of Arecipites exilimuratus. The lower part of the Early Oligocene (P520) was demarcated at 10,172 ft. established based on the occurrence of Racemonocolpites hians. The marine dinoflagellate cysts encountered in the studied well generally come to an agreement with the sporomorph date mentioned above. Durubgo (2013), recorded Lejeunecesta and Selenopemphix spp. as developed during the Palaeocene and had their peak all through the Oligocene in the Niger Delta, Nigeria. Similarly, Bruno et al., (2011), identified abundant and fairly well-preserved dinoflagellate cysts which enabled the recognition of Oligocene age using largely Lejeunecesta species signified by cf. Lejeunecesta communis, Lejeunecesta lata, Lejeunecesta spp. cf. Lejeunecesta granosa, cf. Lejeunecesta globosa, Lejeunecesta beninensis and additional dinoflagellate cysts such as Pheiodinium magnificum, Pheiodinium africanum, Tuberculodinium vancampoe, Selenopemphix nephroides and Cordosphaeridium inodes. The Oligocene age was delineated by Biffi and Grignani (1983), based on Pheiodinium magnificum, Pheiodinium africanum with various species of Lejeunecesta and Selenopemphix recovered from the Niger Delta sediments. Pheiodinium africanum was used in association with species of Lejeunecesta represented by Lejeunecesta spp. cf. L granosa, Selenopemphix nephroides and Cordosphaeridium inodes to support the sporomorphs marker species to establish the Oligocene age in the studied well.

Late Oligocene: The quantity base of Peregrinipollis nigericus define the base of the latest Oligocene age in the well. This is similar to the palynological zonal scheme (P580) of Evamy et al., (1978) of the Niger Delta Basin, Magnastratiattes howardi zone of Germeraad et al., (1968) and latest Oligocene (Chattian) spores and pollens B2-1 zone of Legoux (1978). The late Oligocene age was demarcated at 6725 ft. based on the quantity base of Peregrinipollis nigericus. Essien et al., (2016), Adeigbe and Ochigbo (2017), used similar palynomorph to age date Middle Miocene to Early Oligocene sediment. The late Oligocene interval is also categorized by significant reduction in percentage of occurrences of Zonocystites ramonae as recorded in the well.

Oligocene/Miocene Boundary: The First Downhole Occurrence (FDO) of Cicatricosisporites dorogensis is generally used as an Oligocene/Miocene boundary marker specie in Nigeria. Germeraad et al., (1968), Legoux (1978), had assigned the age range of the Agbada Formation between Oligocene and Early Miocene using the same marker specie. Essien et al., (2016) and Artzner and Dorhofer (1978), delineated the Oligocene/Miocene boundary (O/M) boundary by the FDO of Cicatricosisporites dorogensis and the Last Downhole occurrence (LDO) of Verrutricolpites laevigatus. The FDO occurrence of Cicatricosisporites dorogensis identified at 3688 ft. was used to define Oligocene/Miocene boundary in the well.

Early Miocene: Early Miocene age (P620) was delineated in the present study based on the First Downhole Occurrence of Praedapollis africanus at 4962 ft. This agrees with the work of Legoux (1978), who used the marker specie to establish the early phase of Miocene and is also comparable to the submission of Evamy et al., (1978) (P620) for the Niger Delta, Nigeria. Aquitanian to Bourdigalian (P630) age was delineated at 4039 ft. based on the increase of Praedapollis flexibillis. Bourdigalian (P650) age was delineated at 3186 ft. based on the quantity base of Magnastratiattes howardi marker specie. Adeigbe and Ochigbo (2017), had delineated age range from Middle Miocene to Early Oligocene using Magnastratiattes howardi, Praedapollis flexibillis, Praedapollis africanus, Cicatricosisporites dorogensis, Peregrinipollis nigericus, Retirevitricolporites obodoensis/protrudens, Arecipites exilimuratus and Racemonocolpites hians species. Oloto (2014),

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likewise used the occurrence of *Verrucarolporites rotundiporis* and *Praedapollis africanus* occurrence to support the existence of P620-P770 subzone (Early-Middle Miocene). According to Germeraad et al., (1968), *Rhizophora (Zonocostites ramoneae)* is absent from pre-Miocene sediments and start occurring abruptly in high percentages in the lowermost Miocene. From the record of this pollen in the well, it agrees with the report of Germeraad et al., (1968).

Seven main zones have been documented, AF1, AF2, AF3, AF4, AF5, AF6 and AF7 in this study. Boundaries of the AF zones corresponds with the P500 and P600 zone and sub-zones P520, *P*540, P560, P580, P620, P630, P650 and *P*670 of Evamy et al., (1978) with more inclusive descriptions of the distributions and relative quantities of the constituent taxa obtained. The supreme important indicator taxa (zonal markers) are *Psilatricolporites crassus, Verrucatosporites ussensis, Triplechiton scleroxylon, Crassoretiriletes vanraadshooveni, Acrostichum aureum, Gemmatriporites ogwashiensis* and *Retitricolporites irregularis*. Zones AF1, AF2 and AF3 (P520 - *P*540, P560 and P580) were characterized by spormorph marker species (*Racemonocolpites hians, Retibrevircolporites obodoensis* and *Peregrinipollis nigericus*) in association with marine species of *Phelodinium africanum Lejeuneycysta* spp. cf. *L. granosa, Selenopemphix nephroides* and *Cordosphaeridium inodes* in establishing the Oligocene age. Zones AF4, AF5 and AF6 (P620, P630 and P650) were defined by FDO of *Praedapollis africanus, increase of Praedapollis flexibilis* and base quantity of *Magnastratites howardi.*

Some finer scale subdivisions were, conversely, recognized in the present study. All the zones have subzones (AO1, AO2, AO3, AO4, AO5 AO6 and AO7). Subzone AO2 and AO3 were further subdivided into a and b each. These sub-zones are based on qualitative and quantitative occurrences of individual taxa and general assemblage component, subject to biological development/extermination in addition to palaeoclimatic and ecological factors.

The new palynological zonation scheme of this study uses a combination of stratigraphical tops and bases as GZ-1 well quantitative changes. The several zones and subzones were demarcated with the assistance of the recovered pollen and spores botanical and ecological affinities. Mangrove in association with fresh water swamp and rainforest vegetation pollen and spore ascribed to Polypodiaceae, Parkeriaceae, Lygodiaceae, Euphorbiaceae, Clusiaceae, Pelliceria, Caesalpinioideae, Palmae and Rhizophoraceae families are the main palynomorphs recovered in all zones resulting from assemblages of plants that are currently prevalent in the Niger Delta. The *Podocarpus milanjianus* pollen, charred cuticle and possibly some Poaceae pollen could have been transported by air to the locations where they were deposited from areas within the inland savannah regions.

**Conclusion:** Palynological studies have recognized a new detected developments in the varieties of key pollen and spore taxa. Seven main zones have been documented, AF1, AF2, AF3, AF4, AF5, AF6 and AF7 which were further subdivided into seven subzones with some having finer subdivisions with age ranged from Early Oligocene to Early Miocene. Previous undocumented occurrence trends of important indicator taxa of spores and pollen have assisted improvement of formerly used palynological zonation schemes in the Niger Delta. It is anticipated that this quantitative zonation scheme erected, will help with imminent palynostratigraphical studies in the area.

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