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Palynological Investigation of TTtex-1 Well, coastal marsh depobelt of Eastern Niger Delta Basin, Nigeria

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ABSTRACT: *Palynofacies analyses of the strata penetrated by TTtex-1 Well were carried out with the aim of investigating the stratigraphic sequence penetrated by the Well to establish palynostratigraphic zones, the relative age and the paleoenvironment of deposition. Sixty-two ditch cutting samples within the interval of 2179 – 3523 m were analyzed. The use of acid in the sample preparation for palynofacies analyses were used. The result of the analyses produced relatively low to abundant occurrences of pollen and spores shows abundance of small, medium, and large sizes of palynomacerals I and II, few occurrences of palynomacerals III and IV. The lithology consists of intercalations of shale and sandstone units with few intercalations of argillaceous sandstone units, this designates the studied interval to be Agbada Formation. The interval studied were dated to be middle Miocene to late Miocene based on the recovered age indicative marker species such as Multiareolites formosus, Zonocostatites ramonae, Crassoretitriletes vanraadshoveni Verrutricolporites rotundiporus, and Racemonocolpites hians. A taxon range zone: Ainipollinite verus zone and Two interval range palynostratigraphic zones: Multiareolites formosus – Zonocostatites ramonae, Verrutricolporites rotundiporus - Crassoretitriletes vanraadshoveni were proposed. The stratigraphic interval studied was deposited in the Coastal-marsh (marginal marine) environments based on paleoenvironmental interpretation of the palynofacies associations and the lithology.*

KEYWORDS : *Palynofacies, paleoenvironment, palynostratigraphic zone, TTtex-1 Well*

INTRODUCTION

Palynofacies could be described as the entire acid resistant palynological matter (organic matter) present in a sedimentary deposit. Combaz (1964) introduced the term to mean the total microscopic constituent of the organic components in sedimentary rock samples. Successive authors have assigned different names to the organic components such as Organic matter (Gehmann 1962; Lorente 1990; Batten and Stead 2005), palynodebris (Boulter and Riddick 1986;

Van der Zwan 1990; Boulter 1994) and Kerogen or palynomacerals (Tyson 1995; Araujo et al. 1998; Oyede 1992; Thomas et al. 2015). Palynofacies as defined by Tyson (1995) is more intriguing; as a body of sediment containing a distinctive assemblage of palynological organic matter thought to reflect a specific set of environmental conditions or to be associated with a characteristic range of hydrocarbon-generating potential. Batten and Stead (2005) defined palynological facies generally to mean organic matter that is recovered from unconsolidated sediment by the standard palynological processing technique of processing a rock sample with HCl and /or HF. have an There is an associated palynofacies with every sedimentary deposit containing organic matter these could be prasinophycean algal bodies, dinoflagellate cysts, acritarch, foraminiferal linings, miospores (small spores and pollen grains), structured fragments such wood tissues and cuticles (fragments of plants or Phytoclasts) and unstructured materials having a unformulated appearance. These organic matters are abundance in both continental and marine deposits. They are resistant to, high temperature, pressure, acid, microbial decay and dissolution in water. Applications of palynofacies analysis includes several stratigraphic proxies such as chronostratigraphy, biostratigraphy lithostratigraphy and sequence stratigraphy. Its stratigraphic application is useful for the detail correlation of reservoir units within oilfields and used in successions where there is paucity or total absence of conventional boistratigraphic markers (Batten and Stead, 2005). Palynofacies analyses is useful in the interpretation of the processes controlling deposition; it also provides basis for reconstruction of paleogeography, paleoecology, paleoenvironment and paleoclimate.

An outstanding contribution to knowledge in palynology of the Niger Delta was made by Germeraad et al. (1968). The study was based on the assemblages of palynomorph from the Tertiary sediments of three tropical regions in Asia, Africa (Nigeria) and parts of South America. They established nine pantropical zones using quantitative top and base occurrences of diagnostic species such as *Verrucatosporites usmensis, Echitricolporite spinosus, Monoporites annulatus, Crassoretitriletes vanradshoveni, Magnastrites howardi,* and *Proxapertites operculatus*.

Twenty-nine informal palynological zones of the Niger delta were established using alphanumeric coding method (Evamy et al. 1978); these seems to form the proxy for zonal scheme of Shell Petroleum Development Company. The study and palynological interpretation of the palaeoenvironments of Miocene strata of the well Igbomotoru-1, Niger delta was carried out by Oboh et al. (1992). The study used the lithological analysis and the abundance or paucity occurrence of *Zonocostites ramonae* in the samples to interpret the environment of deposition, a transitional environment with marine influence was adduced. Summarily, this research is aimed at carrying out the palynofacies analyses of the ditch cuttings retrieved from TTtex-1 Well so as to establish the palynostratigraphic zonation, biochronology and paleoenvironment of deposition of the sequence penetrated by the well.

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Location of the studied well relative to the Geology of the Niger Delta Basin

Niger delta lies between latitudes 4° and 6° N and longitudes 3° and 9° E in the Southern part of Nigeria (Fig. 1). The coordinates that describe the locations of TTtex-1 Well are 4.82°N and 6.86°E in the Coastal Swamp Depobelt of the Eastern Niger Delta Basin (Fig. 1). Short and Stauble (1967) recognized three major formations in the subsurface of the Niger delta. Studying from the youngest formation these formations are the Akata, Agbada and Benin formations. The Akata Formation generally consists of open marine and prodelta dark grey shale with lenses of siltstone and sandstone (Weber 1971). The coarsening upward sequences are composed of shales, siltstones, and sandstones which include delta front and lower delta plain deposits. This corresponds to the Agbada Formation which consists of cyclic coarsening-upward regressive sequences. (Weber 1971). The Benin Formation comprises a succession of massive poorly indurated sandstones, thin shales, coals, and gravels of continental to upper delta plain origin. The three formations were deposited in continental, transitional and marine environments (Ola and Adewale 2014). Doust and Omatsola (1990) proposed the Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp, and Offshore depobelts as the depositional belts in the Niger Delta (Fig. 1). The age of these depobelts is distinguished by their age and most importantly by their location.

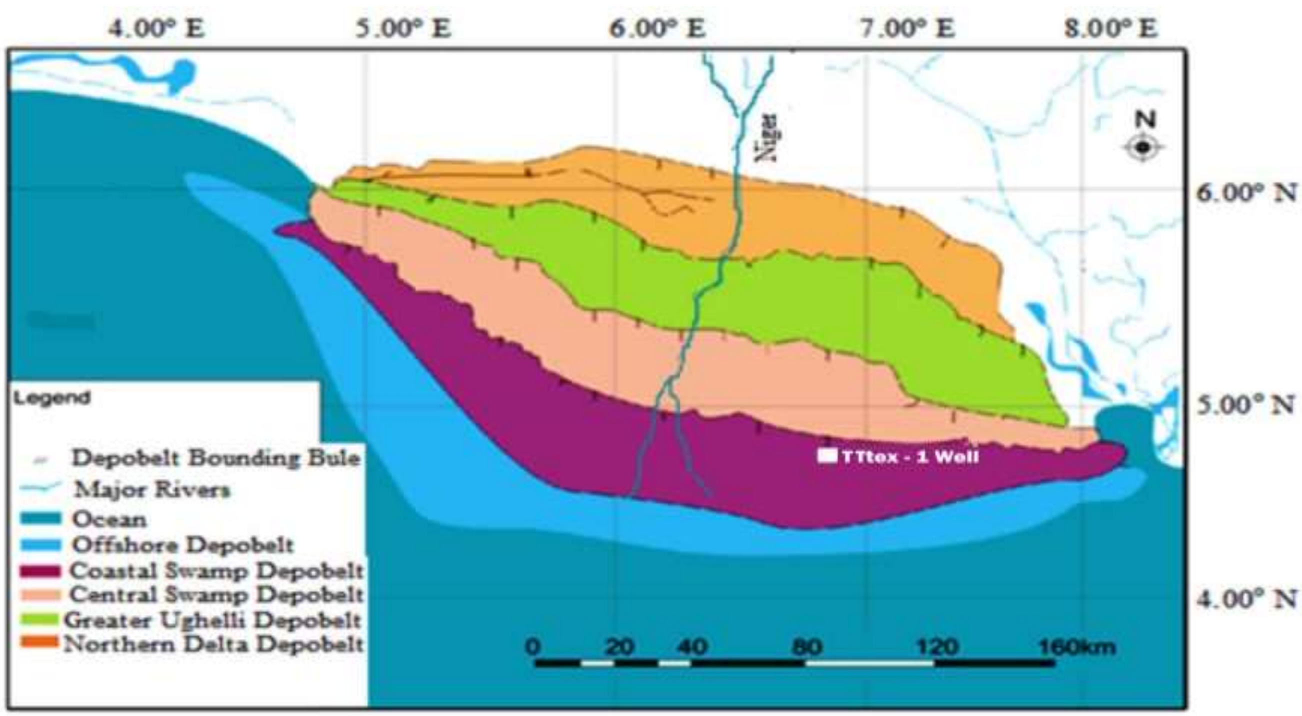

Figure 1: Location of the studied well on the Niger Delta Basin Depobelt map (This map is modified after Okosun and Chukwuma-Orji 2016)

METHODOLOGY

Lithologic description

Lithologic description of the stratigraphic intervals studied was done by observation and of the textural characteristics of clastic sediments. Fissile and platy samples indicate shale while samples with fine to coarse grained sizes indicates various sandstone sizes. The use of Gamma-ray log was used to compliment the description since its statutory that high and low values of Gamma log signify shale and sandstone lithologies (Adegoke 2002; Olayiwola and Bamford 2016).

Organic matter recovery

Acid method of sample preparation for organic matter recovery was adopted. Eighty-four ditch cutting samples from TTtex-1 Well within the interval of 2152 – 3523 m were analyzed. Twenty-five grams of each sample were subjected to treatment with 10% HCl under a fume cupboard; this allows for the complete removal of carbonates materials present in the various samples. This was followed by complete neutralization with distilled water. Then 40% concentration of Hydrogen fluoride (HF) was added to the samples which were left for 24 hours to ensure a complete digestion of the silicates present in the samples. Thereafter, the HF was carefully decanted, then followed by complete neutralisation with distilled water to remove fluoro-silicate compounds usually formed from the reaction with HF. Sieving and separation were performed using Brason Sonifier 250 to filter away the remaining inorganic matter (silicates, clay, and mud) and heavy minerals to recover organic matters. Brason Sonifier is an electric device used with the aid of 5-micron sieve and it operates in a sonic vibration to filter out inorganic matter and heavy minerals. The sieved residue was given controlled oxidation using concentrated nitric acid (HNO_3). For palynomacerals recovery, the same procedure for sample preparation for palynomorphs recovery was followed, except that the oxidation process with HNO_3 was omitted in order not to bleach the palyno debris. The recovered organic matters were uniformly spread on arranged cover slips of 22/32 mm and were then allowed to dry for mounting. The mounting medium used for permanent mounting of cover slip onto glass slide was Loctite (Impruv) and was dried with natural sunlight for 5 minutes.

Both palynology and palynomaceral slides were examined under the Olympus Binocular light transmitted microscope. The palynomaceral slides were subjected to quantitative analysis of different types of palynomacerals (type 1, 2, 3, and 4) as well as structureless organic matter (SOM). Identification of palynomorph and palynomacerals were done through the use of palynological albums and the published works of previous researchers (Germeeraad et al. 1968; Oyede 1992; Ige 2009; Bankole 2010; Ige et al. 2011; Ajaegwu et al. 2012; Durugbo and Aroyewun 2012; Ola and Adewale 2014; Thomas et al. 2015).

RESULTS / FINDINGS

Lithological analysis

The lithology of the studied interval consists of alternating shale/mudstone and sandstone unites with few intercalations of argillaceous sandstone (sandy shale and siltstone) units (Fig. 2). This suggests that the studied interval belongs to Agbada Formation. The shale/mudstones are mostly grey to brownish grey in colour, moderately hard to hard, platy to flaggy in appearance. The sandstones are predominantly milky white, coarse to fine grained, angular to subangular to rounded, and poorly to well sorted in texture.

Palynological analysis

The result of palynofacies analysis is presented in palynomorph and palynomacerals distribution chart of TTtex-1 Well (Fig. 2). The chart presents the different palynomorph taxa and types of palynomacerals encountered at the different studied depth intervals. Palynological analysis yielded significant number of pollen and spores with low to moderate diversity. Pollen and spores were dominant. The results of this study are similar to that obtained in the palynofacies studies of Ida -4, Ida-5 and Ida-6 wells Niger Delta Basin (Chukwuma-Orji et al. 2017a and b). Photomicrographs of some of the recovered forms are illustrated in Fig.3.

The spores recorded include the species of *Crassoretitriletes vanraadshoveni, Magnastriatites howardi, Acrostichum aureum, Aletisporites* sp., *Cyperaceaepollis* sp., *Lycopodium* sp., *Selaginella myosorus, Laevigatosporites* sp, *Verrucatosprites* sp., and *Pteris* sp.,

The pollen species recovered are: *Elaies guineensis, Praedapollis flexibilis, Multiareolites formosus, Striatricolpites catatumbus, Retibrevitricolporites protudens, Alnipollinites verus, Podocarpus milanjianus, Pachydermites diederixi, Zonocostites ramonae, Monoporites annulatus, Racemonocolpites hians, Psilatricoloporites crasssus, Retitricolporites irregularis, Peregrinipollis nigericus, Gemamonocolpites* sp., *Verrutricolporites rotundiporus, Numulipollis neogericus, Canthium* sp, *Coryius* sp., sapotaceae, *Psilatricolporites* sp., *Podocarpidites* sp. *Chenophodipollis* sp., and *Retitricolporites* sp.
The algal cysts present are *Botryococcus braunii and* no dinoflagellate cyst was recovered.

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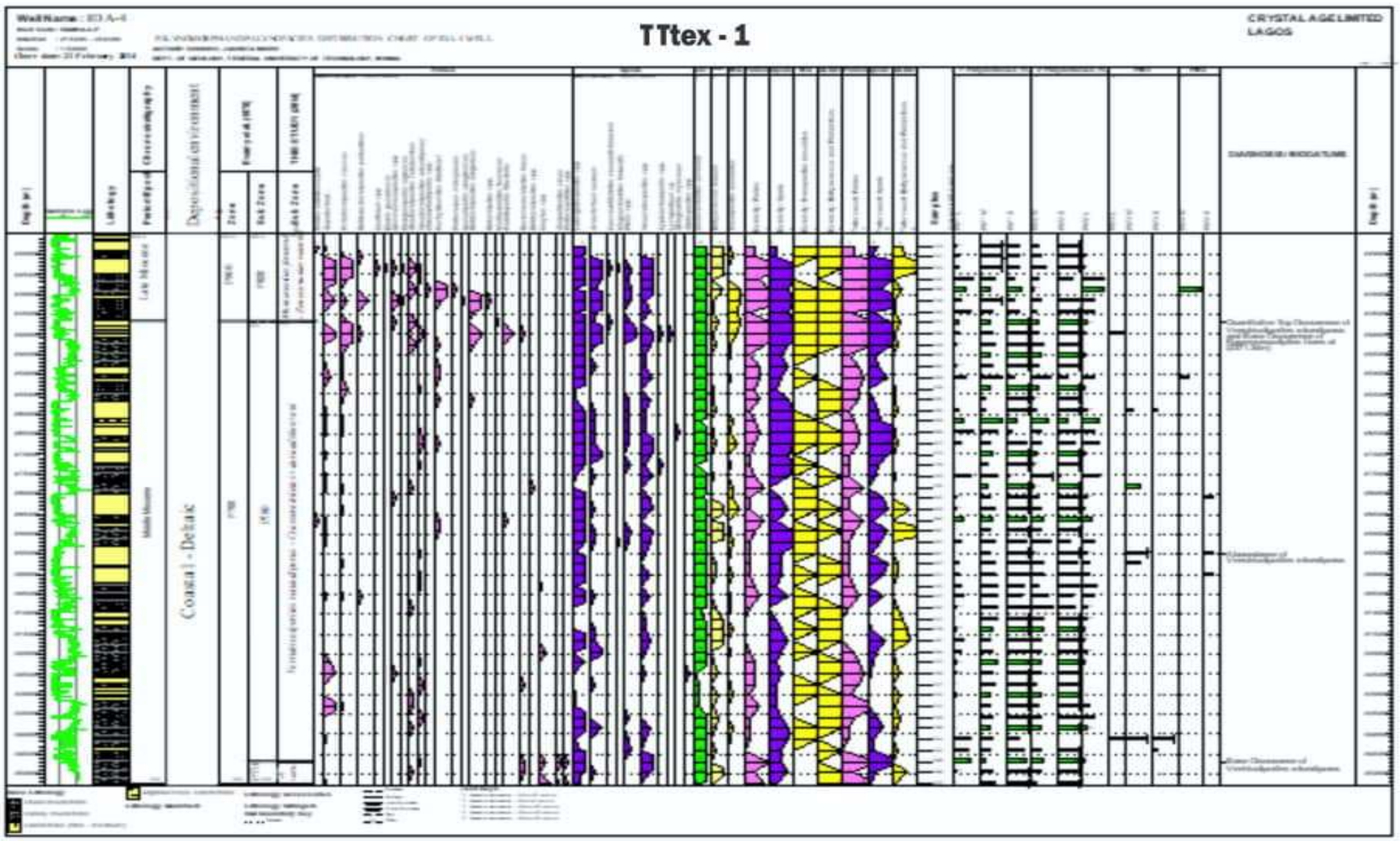

Figure 2: Palynomorphs and palynomacerals distribution chart of TTtex-1 Well

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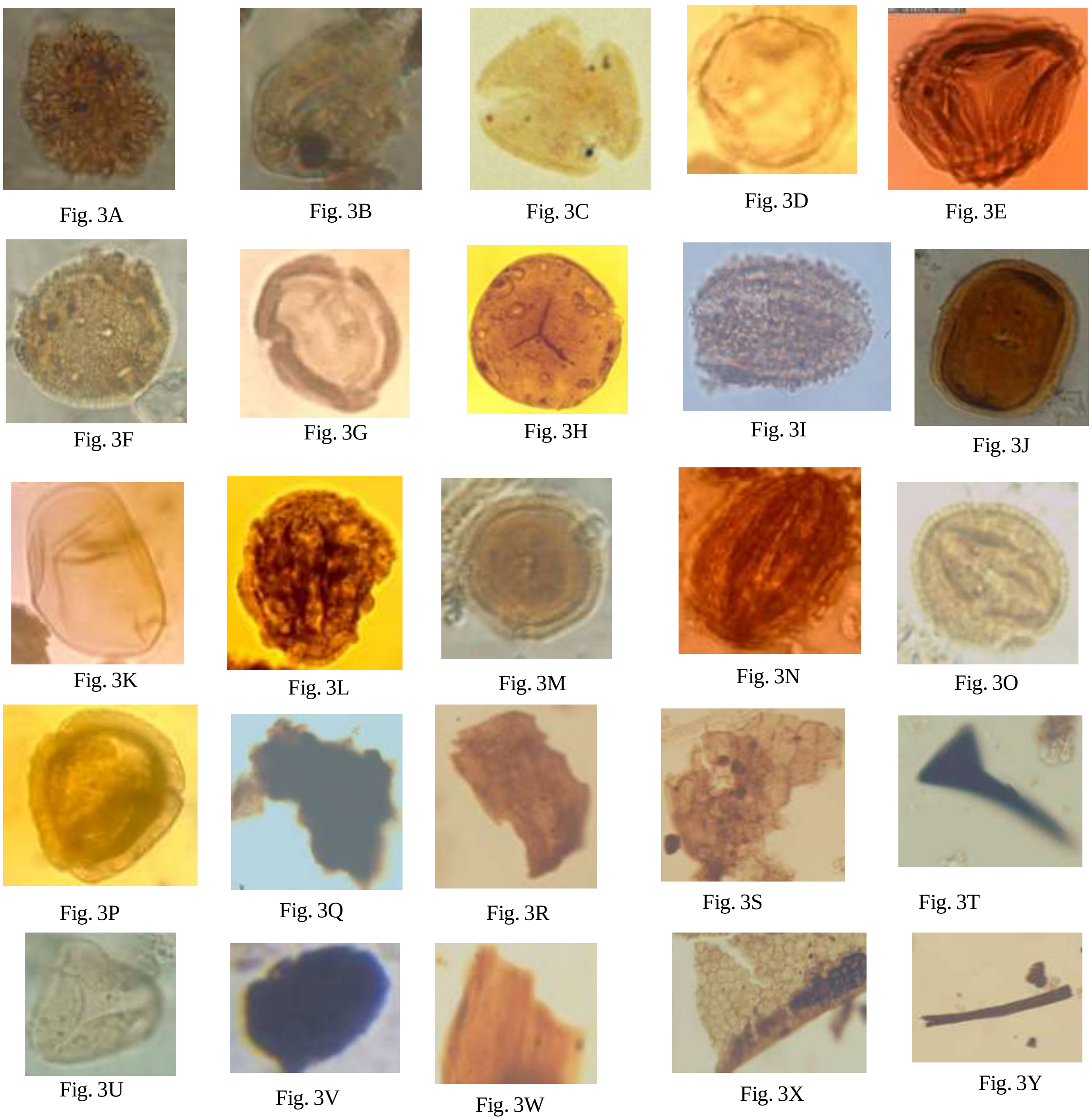

Figure 3: Palynomorphs and Palynomacerals recovered from the studied wells (x400). **Fig. 3A** *Botryococcus braunii* ; **Fig. 3B** *Gemmamonoporites* sp. Van Der Hammen and Garcia De Mutis 1965; **Fig. 3C** *Retitricolporites* sp.; **Fig. 3D** *Monoporites annulatus* Van Der Hammen 1954; **Fig. 3E**, *Magnastriatites howardii* Germeraad et al., 1968; **Fig. 3F** *Retibrevitricolporites protrudens* Legoux 1978; **Fig. 3G** *Zonocostites ramonae* Germeraad et al. 1968**; Fig. 3H** *Acrostichum*

aureum Oloto 1994; **Fig. 3I** *Racemonocolpites hians* Bankole et al. 2014; **Fig. 3J** *Multiareolites formosus* Van Der Hammen 1954; **Fig. 3K** *Laevigatosporites* sp. Oloto 1994; **Fig. 3L** *Peregrinipollis nigericus* Legoux 1978; **Fig. 3M** *Numulipollis neogenicus* Durugbo et al. 2010; **Fig. 3N** *Striaticolpites catatumbus* Germeraad et al. 1968; **Fig. 3O** *Verrutricolporites rotundiporus* Vander Hammen and Wijstra 1964; Fig. 3P, *Psilatricolporites crassus* Vander Hammen and Wijstra 1964; Fig. **3Q** Palynomaceral I; Fig. **3R** Palynomaceral II; **Fig. 3S** Palynomaceral III; **Fig. 3T** Palynomaceral IV; **Fig. 3U** *Elaies guineensis*; **Fig. 3V** Palynomaceral I; **Fig. 3W** Palynomaceral II; **Fig. 3X** Palynomaceral III; **Fig. 3Y** Palynomaceral IV.

Palynomacerals

The palynomacerals analysis yielded abundant records of palynomercerals I and II, few occurrences of palynomacerals III and IV and no record of structureless organic matter was recorded **(Fig. 2** and **Fig. 3).**

Palynomaceral 1 (PM1)

In this study, the observed palynomaceral 1 (PM1) appeared orange-brown to dark-brown in colour, opaque, irregular in shape, structureless and varies in preservation (Fig. 3). Oyede (1992) described PM1 as particulate organic matter (Alginite) that is orange-brown to dark-brown in colour, dense in appearance, irregular in shape, structureless and varies in preservation. It is heterogeneous and of higher plant in origin and some are products of exudation processes such as the gelification of plant debris in the sediments. PM1 includes small, medium and large sizes of flora debris, humic gel-like substances and resinous cortex irregularly shaped materials (Oyede 1992; Thomas et al. 2015).

Palynomaceral 2 (PM2)

The Palynomaceral 2 (PM 2) observed in this study is irregular in shape, brown-orange in colour, and platy in structure (Fig. 3). According to Oyede (1992) palynomaceral 2 (Exinites) is usually brown–orange colour, structured but irregular in shape. It encompasses platy like structured plant materials (leaves, stems or small rootlet debris), algae debris and a few amounts of humic gels and resinous substances. It is more buoyant than palynomaceral 1 because of its thinner lath-shaped character.

Palynomaceral 3 (PM 3)

The PM 3 observed in this study, generally is translucent and contained stomata, pale to brown in colour and is irregular in shape (Fig. 3). Oyede (1992) stated that PM 3 (Vitrinite) is pale, relatively thin and irregularly shaped and occasionally contains stomata. Also, it includes structured plant material, mainly of cuticular origin and degraded aqueous plant material. It is more buoyant than palynomaceral 2 (Thomas et al. 2015).

Palynomaceral 4 (PM 4)
The observed PM 4 in this study varies from black to dark brown in colour, with blade or needle like shapes (Fig. 3). Oyede (1992) described PM 4 (Inertnite) as being black to charcoal black in colour. Also, it is equidimensional, blade or needle shaped material. It is uniformly opaque and structureless, but may occasionally show cellular structure. The components of this palynomaceral are of different origins and they include compressed humic gels, charcoal and geothermally fusinized material. Blade-shaped palynomaceral 4 is extremely buoyant and resistant to degradation. Thus, they are often transported over long distances (Oyede 1992; Thomas et al. 2015). Concentration of PM-4 characterizes high energy environment.

DISCUSSION

Palynostratigraphic zonations and Age determination
The palynostratigraphic zones proposed in this study were based on the international stratigraphic guide - an abridged version of Murphy and Salvador (1999). The works of Germeraad et al. (1968); Evamy et al. (1978); Oboh et al. (1992); Ige (2009); Bankole, (2010); Aturamu and Ojo (2015) and Olayiwola, and Bamford (2016) were consulted. Age diagnostic marker species were used to determine the age of the studied interval in the well. Three biozones were proposed in the studied wells: *Multiareolites formosus – Zonocostites ramonae*, *Verrutricolporites rotundiporus* - *Crassoretitriletes vanraadshoveni* and *Alnipollinite verus* zones.

***Multiareolites formosus – Zonocostites ramonae* Zone**
Stratigraphic interval: 2179 – 2371 m
Definition: This is an Interval zone. The top of the zone is defined by the first downhole occurrence (FDO) of *Zonocostatites ramonae* at 2179 m while the base is marked by the last downhole occurrence (LDO) of *Multiareolites formosus* and *Crassoretitriletes vanraadshoveni* at 2371 m.

Characteristics: The assemblages of palynomorphs taxa that characterize this zone include *Zonocostites ramonae, Crassoretitriletes vanraadshoveni*, *Numulipollis neogericus, Multiareolites formosus* and *Retibrevitricolporites protrudens.* Other taxa occurring within the zone are sapotacea, *Psilatricoloporites crasssus, Peregrinipollis nigericus, Laevigatosporites* sp., *Verrucatosprites* sp., *Aletisporites* sp., *Pteris* sp., *Acrostichum aureum* and *Magnastriatites howardi*.
Age: The zone is dated late Miocene because of the presence of *Crassoretitriletes vanraadshoveni, Multiareolites formosus* and *Peregrinipollis nigericus.*

Remark: The zone is equivalent to P800 zone and P820 subzone of Evamy et al. (1978). The zone is marked by very rich recovery of *Zonocostites ramonae, Monoporites annulatus, Botryococcus braunii* and *Laevigatosporites* sp. There is single occurrence of *Podocarpus* *milanjianus* within the zone. The base occurrence of this species marks late Miocene – early Pliocene boundary (Morley 1997). Its occurrence within the zone could have resulted from caving in and mixing of rock cuttings during drilling. Also occurring within the zone is pollen indeterminate which could probably be reworked specimens because it is not well preserved.

Verrutricolporites rotundiporus - Crassoretitriletes vanraadshoveni
Zone Stratigraphic interval : 2371 - 3469 m

Definition: This is an Interval zone, the top of the zone is defined by the last downhole occurrence (LDO) of *Crassoretitriletes vanraadshoveni*, *Multiareolites formosus* and base regular occurrence of *Gemamonocolpites* sp at 2371 m while the base is marked by the last downhole occurrence of *Verrutricolporites rotundiporus* at 3469 m.

Characteristics: The zone is characterized by the presence and lowermost documented occurrence of *Racemonocolpites hians, Retibrevitricolporites protudens, Pachydermites diederixi, Psilatricoloporites crasssus, Gemamonocolpites* sp, *Multiareolites formosus, Verrutricolporites rotundiporus* and sapotaceae within the zone. The occurrence of *Zonocostites ramonae* and *Monoporites annulatus* are rich within this zone.
Age: The zone is dated middle Miocene because taxa such as *Verrutricolporites rotundiporus, Retibrevitricolporites protudens,* and *Racemonocolpites hians* are diagnostic of middle Miocene.
Remark: The is equivalent to P700 zone and P780 subzone of Evamy *et al*, (1978)

i. *Alnipollinite verus* Zone
Stratigraphic interval: 3469 - 3523 m
Definition: This is a Taxon-range zone. The top and base of the zone is defined by the first and last downhole occurrence of *Alnipollinite verus* at the depth of 3469 and 3523 m respectively. The first and last downhole occurrence of *Podocarpidites* sp also marks the top and base of the zone.

Characteristics: The zone is characterized by the lowermost documented occurrence of *Striatricolporites catatumbus, Laevigatosporites* sp, sapotaceae, *Zonocostates ramonae*, *Acrostichum aureum*, *Monoporites annulatus* and *Racemonocolpites hians*. *Retibrevitricolporites protrudens*- a species with an age range of Oligocene to Pliocene has its LOD within the zone.
Age: The zone is dated middle Miocene. The stratigraphic position of the zone and the presence of the above-mentioned taxa that defined and characterized the zone aided its age assignment.
Remark: The zone is equivalent to P700 zone and P770 subzone of Evamy et al. (1978).

Correlation of the established palynostratigraphic zones with the Niger delta Cenozoic chart

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The established zones of this study and their P zones equivalent of Evamy et al. (1978) are correlated with the Niger delta Cenozoic chart (Fig. 4). The correlation reveals that the studied well is located in the coastal swamp depobelt. It also confirms the assigned age of the studied interval to be middle to late Miocene.

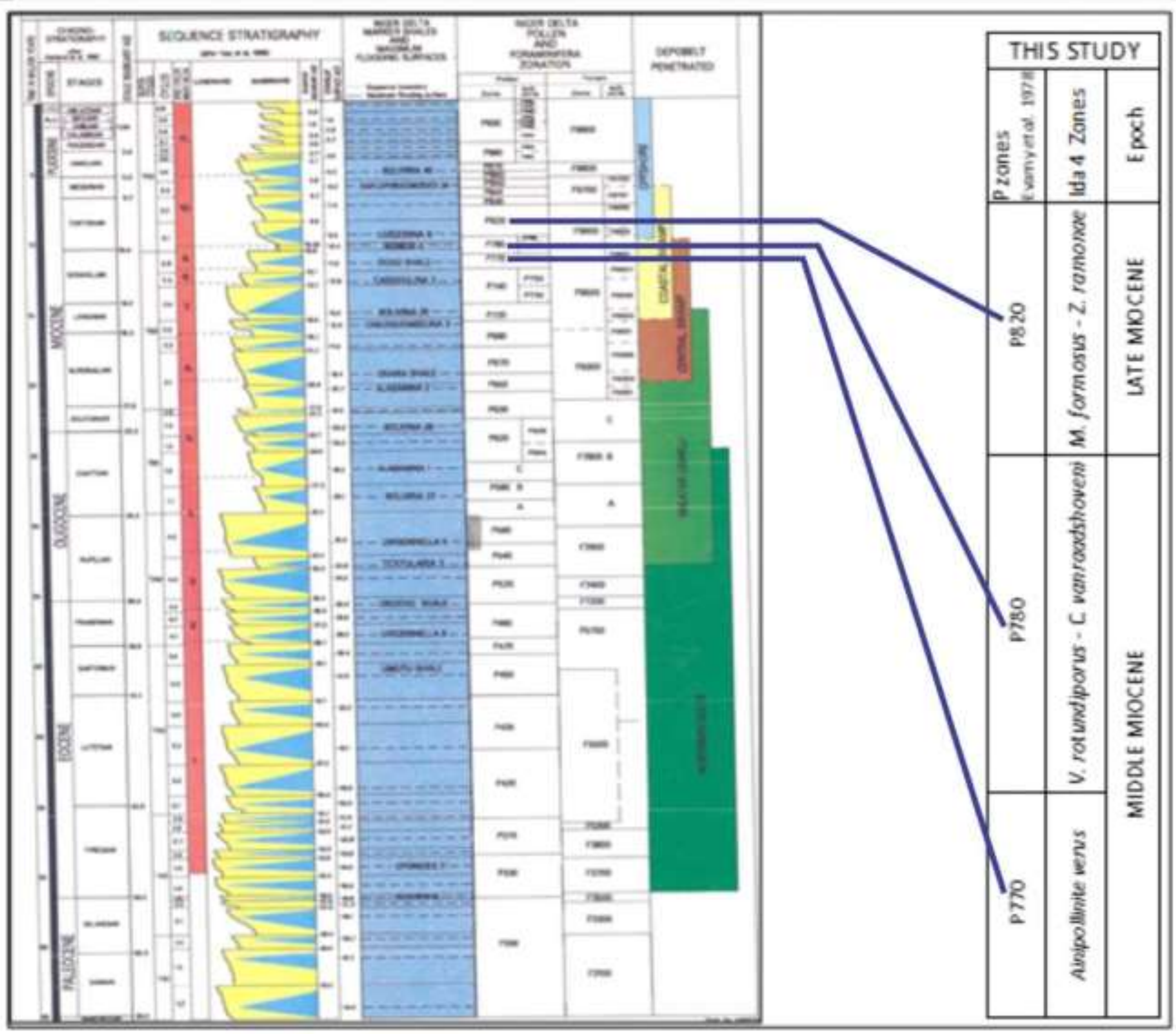

Figure 4: Palynostratigraphical zones erected in TTtex-1 Well in correlation with the Standard Niger Delta Cenozoic Chart showing the P zone (Evamy et al., erected in this research

Paleoenvironment of deposition

This involves the periodic changes in the depositional environment over geologic time. Evaluation of paleoenvironment of deposition is essential because different depositional environment give rise to reservoirs with different qualities and characteristics such as porosity, permeability, heterogeneity and architecture. Inference of the paleo depositional environments of the studied wells was made based on the following criteria:

i. The nature of organic matter (palynomercerals) recovered in the studied interval. The terrestrial/coastal and marine depositional environments have been distinguished to have distinctive and characteristic palynofacies (Oyede 1992; Thomas et al. 2015). The terrestrial/coastal environments are characterized by poorly sorted palynomacerals I and II, absence of dinocysts and common to abundant occurrence of fungal spores while marine environment is characterized by a good sorting of organic matter predominantly small to medium, common to abundant palynomacerals I and II, some needle-shaped to lath-shaped palynomaceral IV and presence of dinocysts and or foraminifera linings (Oyede 1992).
ii. Association of environmentally restricted diagnostic species such as *Zonocostites ramonae, Monoporites annulatus, Pachydermites diederixi, Psilatricoloporites crasssus, Laevigatosporites* sp and *Botryococcus braunii.*

Based on the above-mentioned criteria, lower delta plain to delta front and prodelta (subaerial delta to subaqueous delta plains) environment within coastal – deltaic environment of deposition has been inferred for the sediments encountered in the analysed intervals of TTtex-1 Well (Tab. 1 and Fig. 5).

The intervals; 2179 – 2800 m, in TTtex-1 Well was delineated to have been deposited in the lower delta plain environment. The lower delta plain is equivalent to fore shore and fluvio-marine environment (Fig. 5). The reasons for this deduction are:

i. The intervals are characterized by high representation of mangrove, freshwater swamp and rainforest swamp taxa, freshwater algae, savannah and montane taxa such as *Zonocostites ramonae, Monoporites annulatus, Striatricolpites catatumbus, Retibrevitricolporites protudens, Pachydermites diederixi, Psilatricoloporites crasssus, Verrutricolporites rotundiporus, Botryococcus braunii, Acrostichum aureum, Pachydermites diederixi* and *Laevigatosporites* sp.

ii. The abundant records of palynomacerals I and II indicate coastal deltaic environment of deposition with influx of fresh water from the moderate quantities of *Botryococcus braunii,* and *Laevigatosporites* sp. recorded within the interval.

iii. Aggradational, progradational and retrogradational log motifs characterize the sands (intercalated by shales) in the interval suggest their deposition as channel/bar complexes in a delta plain – delta front setting. Lithologically, the sands are off white, very fine to medium-grained, occasionally coarse to very coarse-grained/granule -sized, poorly to well sorted and sub-

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angular to sub-rounded. The shales are reddish brown to grey, silty, platy and moderately soft to moderately hard. These criteria indicate deposition in lower deltaic plain environments.

Similarly, the interval: 2800 – 2885 m was delineated to have been deposited in delta front (inner neritic) environment of deposition. The criteria for this deduction are:

i. The intervals are characterized by increased representation of montane taxa such as *Monoporite annulatus*, reduced occurrences of mangrove, freshwater swamp and rainforest swamp taxa compared to the above intervals.

ii. The palynomacerals 1 and 2 that occur are more of large and medium sizes than the small size.

iii. The sands and shale intercalations in this interval are characterized by blocky/aggradational log motifs (slightly serrate cylinder on funnel – shaped log character); suggesting their deposition as channels/channel fills in a delta front setting.

Table 1: Proposed environment of deposition in TTtex-1

TTtex-1 Well intervals (m)	Inferred Depositional environment
2179 – 2800	Subaerial delta (lower delta plain/fore shore)
2800 – 2885	Subaqueous delta (delta front/lower shore face) plain
2885 – 3523	Subaqueous delta (delta front to prodelta) plain

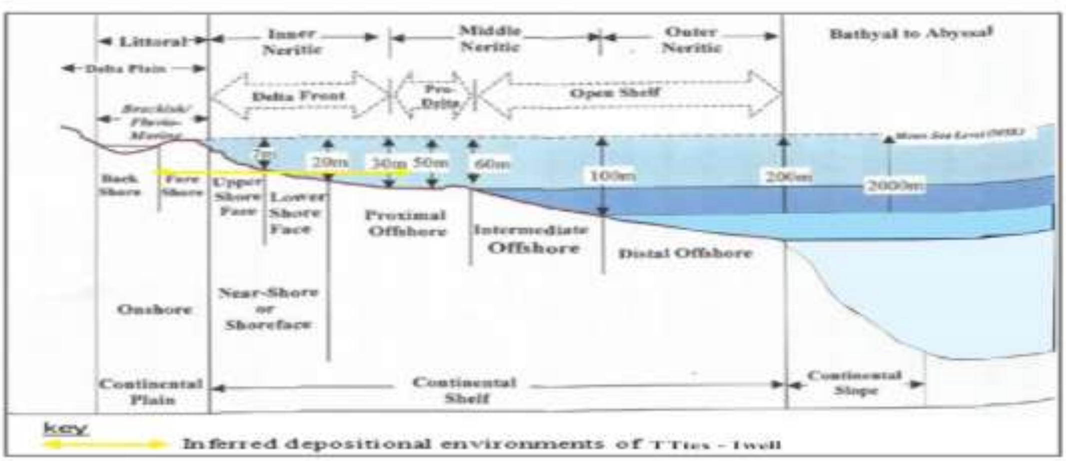

Figure 5: Depositional environments and bathymetric ranges used in paleoenvironmental interpretation (modified after Ijomah et al. 2016) TTtex-1Well.

The lowermost segment: 2885 – 3523 m of TTtex-1 Well is also inferred to have been deposited in delta front to prodelta environment of deposition. The reasons for this inference are:

i. The intervals are characterized by moderate representation of mangrove, freshwater swamp and rainforest swamp taxa *Zonocostites ramonae, Monoporites annulatus, Striatricolpites catatumbus, Retibrevitricolporites protudens, Pachydermites diederixi, Psilatricoloporites crasssus, Verrutricolporites rotundiporus, Botryococcus braunii, Acrostichum aureum, Laevigatosporites* sp. and *Pachydermites diederixi*, rare to non representation of savannah and montane taxa suggesting subaqueous delta environment.

ii. They are characterized by moderate to good sorting of palynomacerals 1 and 2, predominantly common to abundant small to medium sizes.

iii. The lithology is mostly shaly intercalated with sandstone units. The sandstone units exhibited multiserrate funnel, cylinder/subtle bell-shaped Gamma Ray log profiles interpreted as subaqeous mouth bars and distributary channel deposits indicates prograding shoreline.

Implication to Research and Practice

The proposed Palynostratigraphical zones of this study could contribute to the harmonization of Niger delta floral biozonation scheme. Coastal-deltaic (lower delta plain to prodelta) environments of deposition have been inferred for the studied interval based on the lithology and the palynofacies association.

CONCLUSION

Palynofacies were carried out on the strata penetrated by TTtex-1 Well using the ditch cuttings and gamma ray log provided by Chevron Nigeria Limited. Sixty-two ditch cutting samples within the interval of 2152 – 3523 m, in TTtex-1 Well were analysed. The analysis yielded low to abundant recovery of pollen and spores, small to large sizes of palynomacerals I and II, few occurrences of palynomacerals III and IV. The lithology showed alternation of shale and sandstone units with few intercalations of argillaceous sandstone units, indicating Agbada Formation. The alternation of shale and sandstone units forms good targets in petroleum exploration because they act as seal and reservoir rock units. The studied intervals were dated middle Miocene to late Miocene based on the recovered age diagnostic marker species such as *Multiareolites formosus, Verrutricolporites rotundiporus, Crassoretitriletes vanraadshoveni* and *Racemonocolpites hians.* Three palynostratigraphic zones were established in the three wells using the international stratigraphic guide for establishment of biozones. *Multiareolites formosus Zonocostites ramonae*, *Verrutricolporites rotundiporus - Crassoretitriletes vanraadshoveni* and *Ainipollinite verus* zones were established. The three zones proposed are equivalent to P770, P780 and P820 of Evamy et al. (1978). These were correlated to the Niger delta Chronostratigraphic chart. The correlation shows that the age of the studied interval of the well is middle to late Miocene and falls in the coastal swamp depobelt of the Niger delta.

Future Research

Integration of few other microfossils from TTtex-1 well could be studied to compliment research that has be done on the well. With this, more details will be revealed from the well.

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