Use of palynofossils in sequence stratigraphic interpretation of Oku-1 well sediments, Niger Delta, Nigeria

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Abstract

Palynofossils recovered from 1730 – 3730 m interval of the Oku -1 well in combination with lithological data provide information for the establishment of sequence stratigraphic framework. Marine incursion, paleo - salinity and sequence stratigraphic setting were determined using Palynological Marine Index (PMI = (Rm/Rt +1) 100 and Salinity Index (SI = In [(F+0.1) / (M+0.1)]/e. Quantitative results from twenty palynological samples combined with lithological data aided the sequence analysis. Terrestrial palynomorphs are common and abundant in the shale especially *Botryococcus braunii*, recorded fluctuating values of PMI (100.00) and indicate highstand system tracts. Palynofossils and lithological data indicate brackish water to fresh water paleo-depositional environment for the lower section and the overlying sandstone unit respectively. Constant values of PMI (100), lithological characteristics and significant amount of terrestrial alga *B. braunii* indicate lowstand system tracts.
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INTRODUCTION

Palynology is a good utility for the determination of palaeo-ecology, depositional environments, age, biostratigraphic studies (Romero Valero, 2014) and correlation of geological events in time and space (Jaramillo *et al*., 2010; Rodriguez- Forero*et al*., 2012; Romeo Valero, 2014). Palynological studies have been interpreted in a sequence stratigraphic context (Van Pelt and Habib, 1988; Gregory and Hart, 1992; Odedede *et al.*, 2012) among others. Generally, works involving palynological approach exists in the basin, but palyno - sequence stratigraphic approach has not been given adequate attention due to high resolution of palynofossils in finger printing cryptic features of the sediments relating to exploration of gas and oil, becomes an invaluable tool in modern geo-scientific investigations. In the Oku -1 well, the use of palynofossils in the context of sequence stratigraphic interpretation of the sediments will aid to define the depth intervals that have exploratory interest easily with reduced risk and operational costs (Rull, 2001). Oku-1 well is located in the Central swamp depobelt of the Niger Delta Basin (Fig. 1) and penetrated the Agbada Formation, major reservoir unit of the Basin. Re – evaluation of abandon wells and intensive exploration campaigns have been launched in recent times by the Nigerian Government. This study is undertaken as a part of contribution to nation building and support to policy of government, and to further increase oil production and boost revenue earnings as part of the economic recovery plan.

Geological setting

The Niger Delta basin (Fig. 2a – 2b) was formed as a result of a failed arm of a triple rift junction associated with the separation of the Africa and South America continents and subsequent opening of the South Atlantic Ocean (Evamy *et al.*, 1978). It was initiated by a eustatic episode that occurred during Late Cretaceous times. Regression occurs during the Maastrichtian and transgression (Paleocene). According to Obiosio (2011) "a prolong regression from the Eocene onwards with the deposition of fluvial – deltaic sediments which prograded into the South Atlantic formed the modern Delta." Stratigraphically, the Niger Delta Basin comprises three formations; Akata Formation (marine), Agbada Formation (transition to marine) and Benin Formation (continental environment of deposition). Generally, Niger Delta sediments were under – explored on the basis of sequence stratigraphic approach. The present study intends to document and assess the palynofossils extracted from Oku -1 well sediments for their sequence stratigraphic potentials.

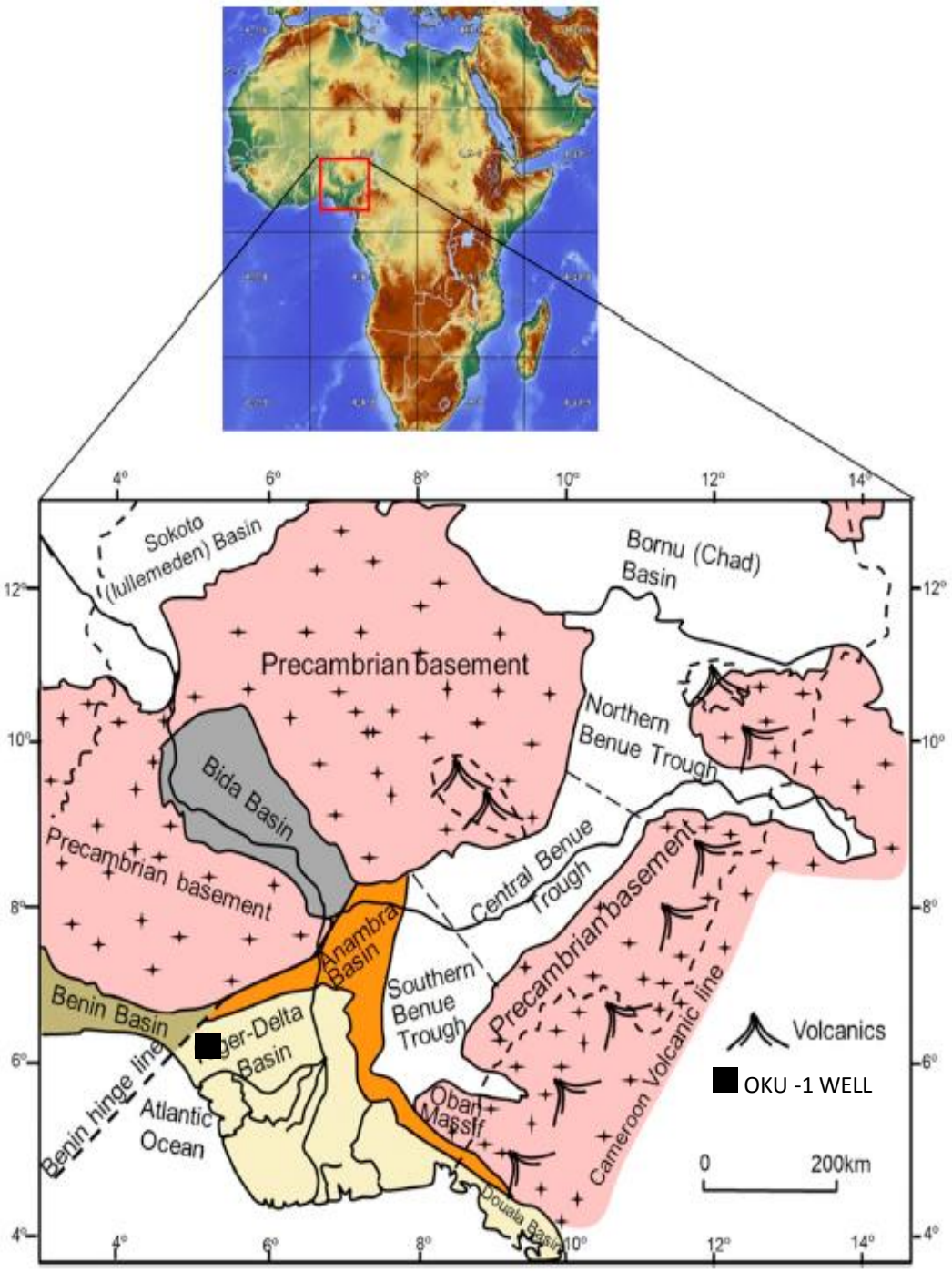

Fig. 1 : Geological Map of Nigeria showing the location of Oku – 1 well, Niger Delta
(Modified after Benkelil, 1989 and Edegbai *et al.*, 2019)

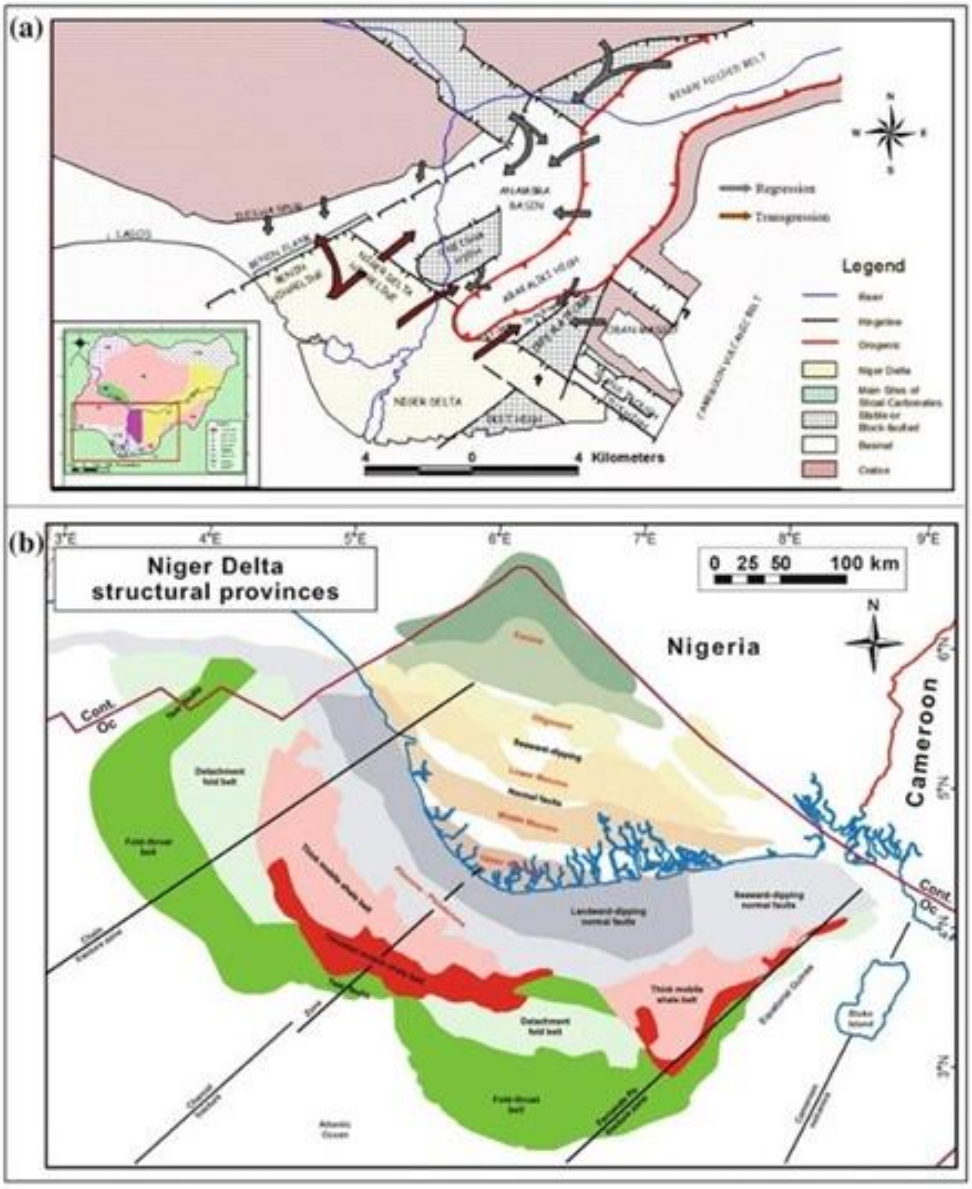

Fig 2: Tectonic Setting and structural elements of the Niger Delta Basin. (a) Tectonic Map showing the Niger Delta (after Kogbe, 1989). (b) Regional structural provinces map of the Niger Delta showing the Fracture Zones (after Kogbe, 1989).

MATERIALS AND METHODS

Ditch cutting samples that penetrated OKU Well-1 from the depth of 1730 - 3730 m belonging to the Agbada Formation were described lithologically and texturally with the aid of visual Chart of Tucker (2003). Litholog was created for the entire section and samples were further analysed palynologically using techniques of Traverse (2007). Palynomorphs with biostratigraphic value and of geological interest were photographed (Appendix 1). Qualitative and quantitative analysis of samples was also undertaken to provide data for further interpretations. Determination of marine incursion (transgressions / regressions), paleo -salinity and sequence stratigraphic setting were achieved using Palynological Marine Index (PMI = (Rm/Rt +1) 100 devised by Helenes *et al.*, (1998) and Salinity Index (SI = In [(F+0.1) / (M+0.1)]/e put forward by Rull (2002). F, Rt correspond to freshwater while Rm and M represent marine palynofossils respectively.

Lithostratigraphic description of sediments in Oku well -1

Oku -1 penetrated through the depth of 1730 to 3730 m and the sedimentary succession (Fig.3) encountered at various depth are outline below:

1730 – 1910 m - It is made up of sandstone, grey in color, coarse-grained and well sorted. Palynoflora

recorded includes *B. braunii*, and *Tricolporites* species

1910 – 2220 m - This unit is made up of sandstone, grey in colour, very coarse –grained and moderately sorted. Palynofossils recorded includes B. braunii, *Retimonocolpites* sp., and *Pachydermites diederixi.*

2220 – 2290 m -Sandstone, dark grey in colour, coarse-grained, and well sorted. Dominated by B. *braunii, fungal spore,* and *Leiotriletes* sp.

2290 – 2430 m - Sandstone, dark grey, contains granules and characterized by *B. braunii*.

2430 – 2530 m – Shaly sandstone comprises *B. braunii, P. diederixi,* and *Monosulcites* sp.

2530 – 2560 m – sandstone made up of mixtures of granules with some pebbles. *B. braunii* and *Proxapertites sp* .

2560 - 2990 m – Shale, laminated and contains *B. braunii, Monosulcites* species, *Tricolpites* species, *Pteris* species, and *Triporites* species

2990 – 3030 m – Shaly sand, laminated contains *B. raunii, Monocolpitesmarginatus, Indeterminate, Psilatricolporitescrassus, Leiotriletes* species, *P. diederixi, Pteris* sp and *Microforaminiferal wall lining.*

3030 – 3460 m – Shale comprises *B. braunii, Monoporites annulatus, Psilatricolporites crassus, Tricolpites* species, *Croton type, Tetradites* species *,Psilatricolpites* species, *Retimonocolpites* species, *P. diederixi, and Retitricolpites sp.*

3460 – 3730 m – Shale, laminated contains *B. braunii, Leiotriletes* species *P. diederixi, Retitricolpites sp.*

Sequence stratigraphic framework of sediments in Oku -1 well

Paleosalinity in OKU -1 sediments was reconstructed using the approach proposed by Rull, (2002) based on the ratio between the relative frequencies of marine and fresh water palynomorphs encountered (Fig.4 ; see Appendix 1). Salinity index ranges from 0.32 – 1.89 (Fig. 4) and indicates major marine to minor marine influence (Rull, 2002). Also, strong marine inundations were predominant at the bottom section (shale) than the upper section of the well.

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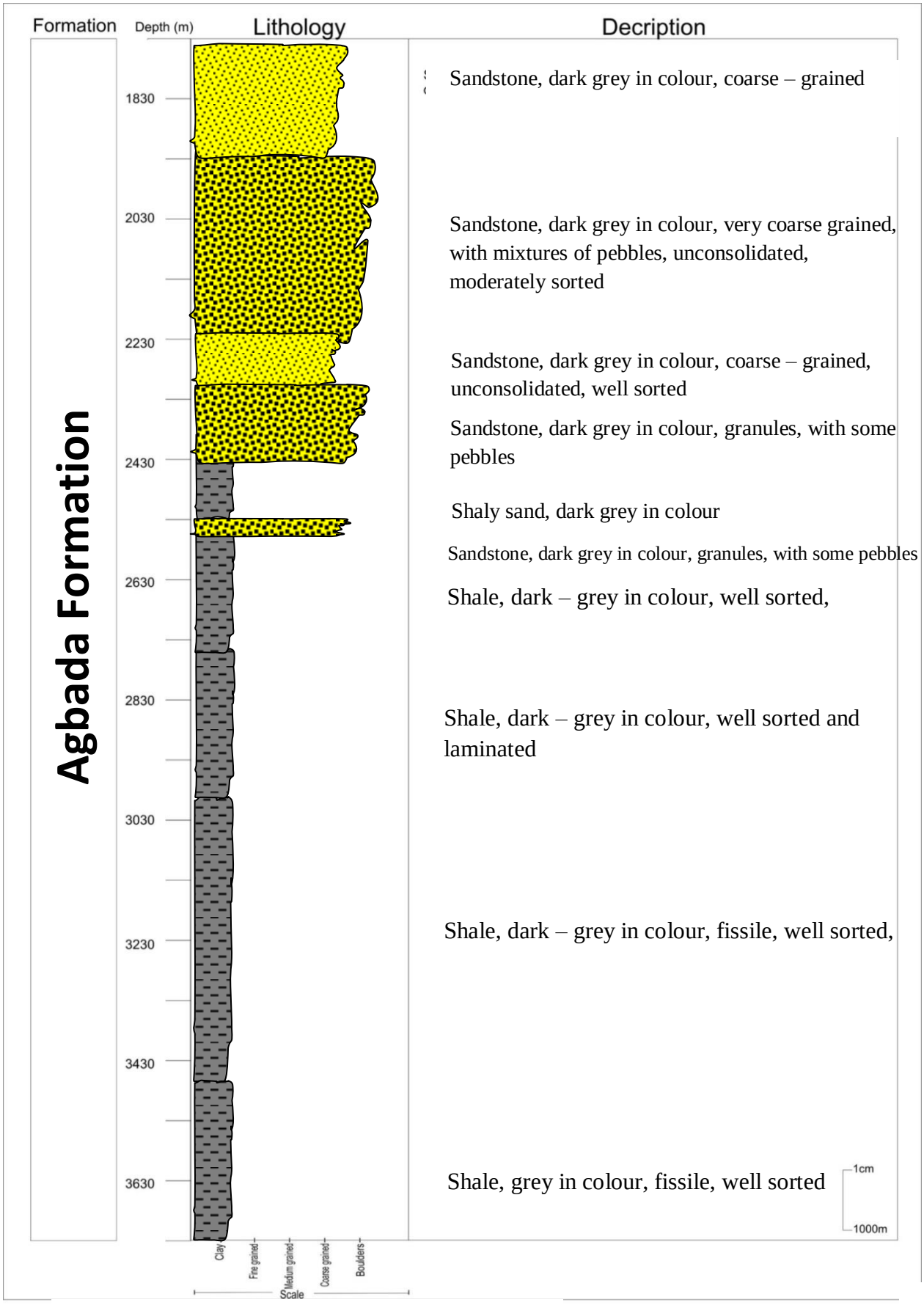

Fig. 3: Lithological description of Oku-1 well, Niger Delta.

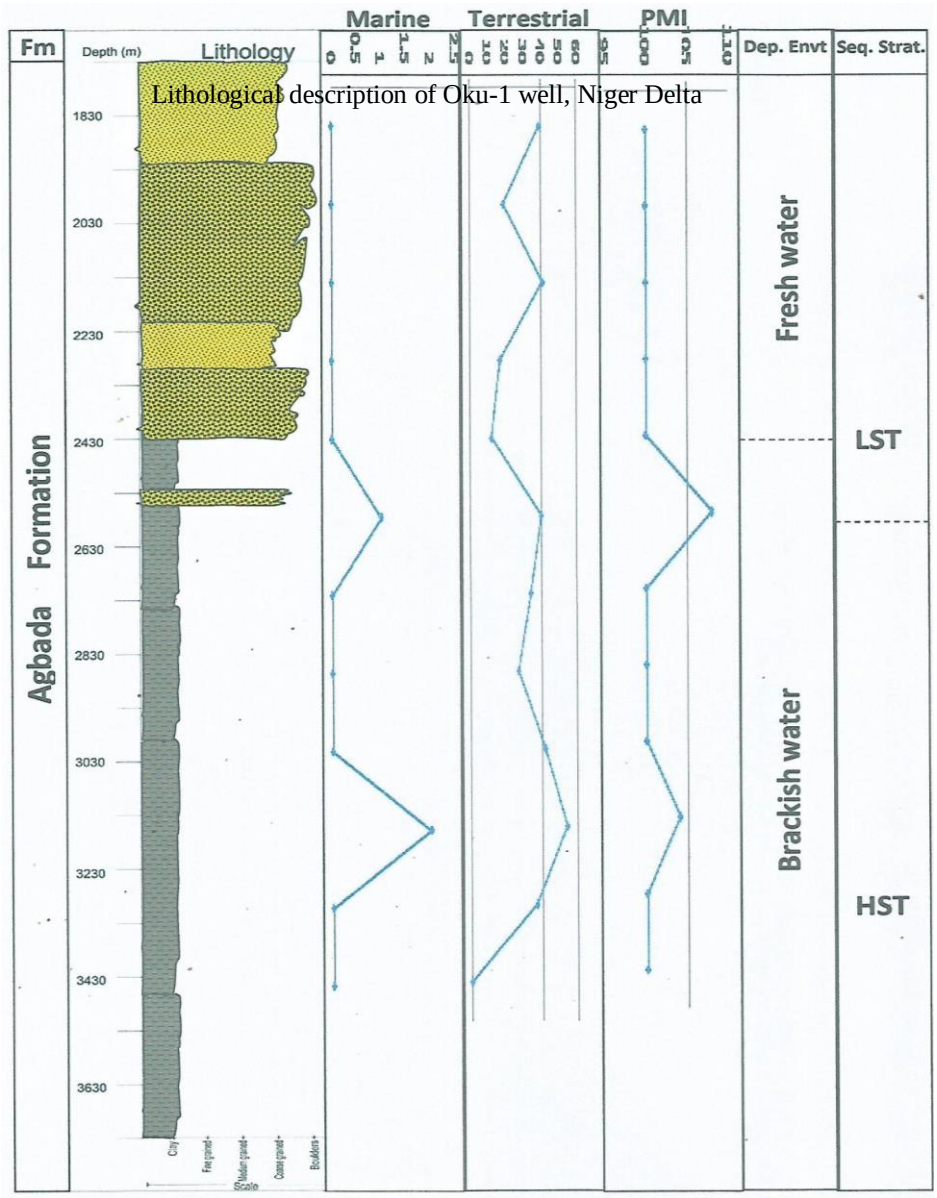

Fig. 4: Palynological marine index, paleodepositional and sequence stratigraphic framework of Oku – I well, Niger Delta

DISCUSSION

Oku -1 well is composed mainly of sandstones, shaly sandstones and shales. Palynological marine index values and lithological characteristics of the sediments aided the depostional and sequence stratigraphic deductions. The lower part of the section (3630 – 3030 m) represents brackish water and contains shale. The lowermost strata from 2430 m to 3630 m contain rich terrestrial palynofossils and laminated shale, probably represents Highstand system tracts. The presence of laminated shales represent a low energy transgressive episodes supported by the peak of PMI values (Fig.4). The shale constitutes the main source rock in the area. The upper part (2430 - 1830 m) of the sequence is characterised by medium grained sandstones, abundant *B. braunii* and other terrestrial palynofossils. This sequence is interpreted as freshwaters due to dominance of *B. braunii*, lack of dinoflagellete cysts and low PMI values (Fig.4). Barrenesses of dinoflagellate cysts in the studied section suggest strong fresh water influx (Helenes *et al*., 1998) and low salinity. Consideration of the predominant palynofossils and lithological features of the sandstones indicate a lowstand system tract

(Odedede *et al.*, 2012). This unit may be a potential reservoir target in the entire sedimentary section studied. Depth interval of 1910 – 2220 m is characterized by brackish/marine palynomorphs such as *B. braunii*, *Retimonocolpites* species, and *P.diederixi* and a salinity index of 0.77. This indicates a minor marine influence (Rull, 2002) and 2290 - 2430m, consists of sandstone, devoid of marine palynofossils, and mainly of fresh water algae (*B. braunii)* pointing to terrestrial environment of paleo – deposition (Odedede *et al.*, 2012). Also, 2560 -3630 m is characterized by laminated shale, brackish /marine palynofossils; *Monosulcite*sp, *Tricolpites*sp, *Pteris* sp. *Triporites* sp., and foraminiferal lining. A salinity index of 0.32 was recorded and indicate signature of a major marine influence in the area of study (Rull, 2001).

CONCLUSION

Oku -1 well is dominantly fresh//brackish waters paleo - depositional environments and comprises mainly terrestrial palynofossils; *B. braunii*. Paleosalinity ranges from 0.32 – 1.89 indicating episodes of major to minor marine inundations. The shaly unit (2560 – 2990 m) recorded highest salinity indices, micro - foramineferal lining, and provide evidence of marine incursions while the upper (1730 – 1910 m) section made up of sandstones, low palynological marine (< 110), indicate a lowstand system tracts..

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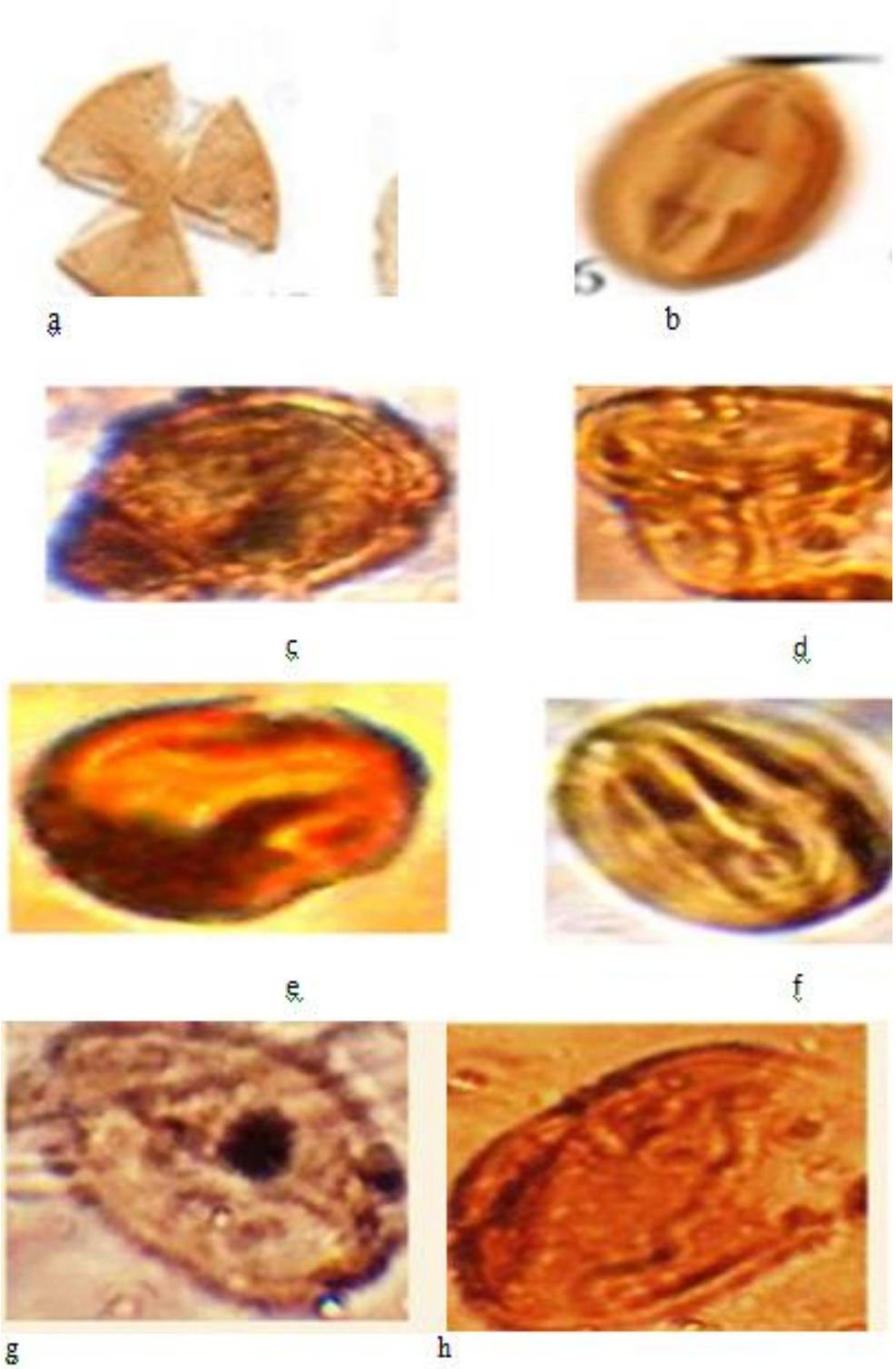
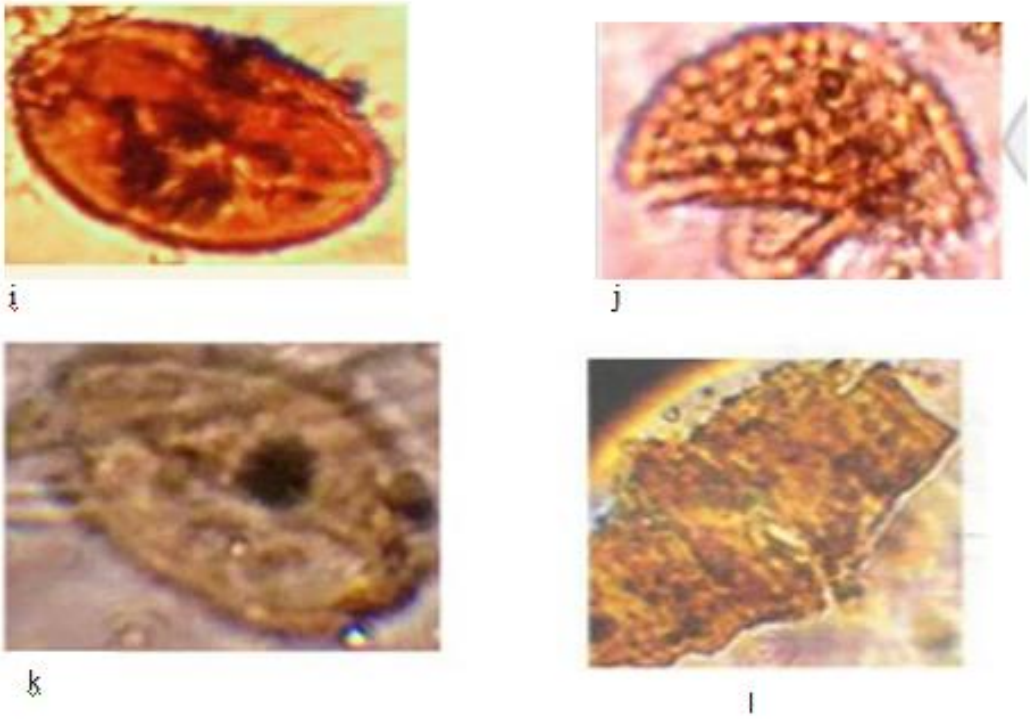
Appendix: Some key palynofossils encountered in Oku -1 well





a. :*Retitricolporites* sp, **b**:*Psilatricolpites* sp, **c**: *P. diederixi*, **d**: *Leiotriletes* sp, **e**: *Triporites* sp, **f**: *Tricolporites* sp.,**g**: *Monosulcites* sp,**h**: *Tetradites* sp., **i**: *Monoporites annulatus*,**j**: *Pteris*sp, k: *Retimonocolpites* sp.l: *B.braunii*