PALYNOFACIES, PALEOENVIRONMENT AND SEDIMENTATION RATE ANALYSES OF KUDU-3 WELL, BIDA BASIN, NIGERIA

Chukwuma-Orji, J.N.[1], Obaje, N.G.[2], Waziri, S.H.[1], Olarewaju, K.[1] and Adegoke, O.I.[1]
[1]Federal University of Technology, Department of Geology, Minna, Nigeria.
[2]Ibrahim Badamasi Babangida University, Department of Geology and Mining, Lapai, Nigeria
Corresponding E-mail: **jacinta@futminna.edu.ng**

Abstract
This study describes the palynofacies analyses carried out on nineteen ditch cutting samples within the depth interval of 31 – 58 m (27 m thick) from Kudu-3 well, Bida Basin with the view to assess the palynofacies, palaeoenvironment of deposition and sedimentation rate. Lithologic description shows that the lithology of the studied interval consists of silty mudstone, sandy mudstone, siltstone and sandy siltstone lithologic units, indicating Enagi Siltstone. Acid methods for recovery of particulate organic matter from samples were followed. The analyses yielded low to moderate recovery of dinocysts, pollen and spores, small to large sizes of palynomaceral1 (irregularly shaped, orange-brown to dark-brown coloured and opaque plant debris), palynomaceral 2 (irregularly shaped, brown-orange coloured platy plant materials), and few occurrences of palynomaceral 3 (pale to brown coloured, cuticular, and translucent plant materials) and palynomaceral 4 (black to dark brown coloured, blade/needle like shaped plant materials).Paleoenvironment and bathymetric interpretation using palynological marine index (PMI), environmental diagnostic taxa and palynomacerals show that the studied interval was deposited in fresh water to brackish water environment. The presence of inner neritic dinoflagellate cysts such as *Palaeocystodinium* sp., *Achosmosphaeridium* sp., *Oligospheridium* sp., *Leiosphaeridia* sp., and *Oligospheridium complex* suggest marine influence within the bathymetric range of 0 – 20 m (upper-shoreface to lower-shoreface). The rate of sedimentation interpretation using number/percentage of well-preserved palynomorph forms recovered per depth suggests low rate of sedimentation (0.5 cm/1000 years) to relatively high rate of sedimentation (30 cm/1000 years) within the studied interval since hemipelagic accumulation rate is in the range of 5 – 300 mm/1000 years. Brackish water environment and high rate of sedimentation support significant deposition and accumulation of organic matter, quick burial and hydrocarbon generation

Keyword: *Palynofacies, paleoenvironment, paleobathmetry, sedimentation rate, Bida Basin.*

Introduction

Palynofacies deals with the analyses of particulate organic matter assemblage in sedimentary deposits. It is useful in exploration geology, rate of sedimentation, paleobathymetry and depositional environment deductions. Paleobathymetry on the other hand deals with the study of ancient water depth (paleodepth). Benthic foraminifera and dinoflagellates are usually used as paleo-depth indicator. They provide information about the condition of the sea floor (Stover et al., 1999) and inhabit a wide range of environment ranging from the shallow marine to the deep marine environments and also useful in unravelling prevailing environmental conditions at the time of sediments deposition. Sedimentation rate defines how fast the overburden load is applied to the compacting sedimentary formations deposited (Peter, 2019). The rate at which sediments is deposited differs depending on the location. A channel in a tidal flat can see the deposition of a few metres of sediment in one day, while on the deep ocean floor each year only a few millimetres of sediment accumulate (Reading, 1996). Onodoku et al. (2017) described the environment of deposition of kudu-1 well using the palynomorphs contents as terrestrial to nearshore dominated environment but paid no attention to the palynomaceral contents. This work considers the use of both palynomorphs and palynomacerals in the peleoenvironmental interpretation and sedimentation rate of the sedimentary succession penetrated by Kudu-3 well.The use of palynomorphs and palynomacerals in paleoenvironmental and sedimentation rate interpretation are important in basin evaluation and successful exploration of mineral resources especially hydrocarbon. Nigeria's economy is mostly dependent on export and domestic sales of hydrocarbon products from the Niger Delta Basin, hence reducing the hydrocarbon reserve in the basin. This has motivated the shift in hydrocarbon exploration to other frontier inland sedimentary basins of Nigeria in order to balance the resource distribution of the Nation's wealth. The Bida Basin is one of the inland basins of Nigeria that might have significant hydrocarbon accumulation potential as well as other mineral deposits of economic interest (Tsepav and Mallam, 2017).

Study Area

The Bida Basin is an inland sedimentary basin in Nigeria. It is a NW-SE trending intracratonic sedimentary basin extending from Kontagora to areas slightly beyond Lokoja. The studied well is located in Kudu town (Figure 1) which lies in northern Bida Basin with GPS coordinates of latitude 9° 21′ 12″ N and

longitude 5° 05′ 21″ E. There are four mappable stratigraphic units recognized in this area which are; Bida Sandstone, Sakpe Sandstone, Enagi Siltstone and Batati Formation (Adeleye and Dessauvagie, 1972; Obaje, 2009). The Bida Sandstone is divisible into two members, namely the Doko Member and the Jika Member. The Doko Member is the basal unit and consists mainly of very poorly sorted pebbly arkoses, sub-arkoses and quartzose sandstones. The Jima Member is dominated by cross-stratified quartzose sandstones, siltstones and clay stones. The Sakpe Ironstone comprises mainly of oolitic and pisolitic ironstones with sandy claystones locally at the base, which is followed by dominantly oolitic ironstone which exhibits rapid facies changes across the basin at the top. The Enagi Siltstone consists mainly of siltstones. Other subsidiary lithologies include mixture of sandstone-siltstone with clay stones. The Batati Formation consist of argillaceous, oolitic and goethitic ironstones with ferruginous claystone and siltstone intercalations and shaly beds occurring in minor proportions, some of which have yielded nearshore shallow marine to fresh water fauna (Adeleye, 1973; Obaje et al., 2011).

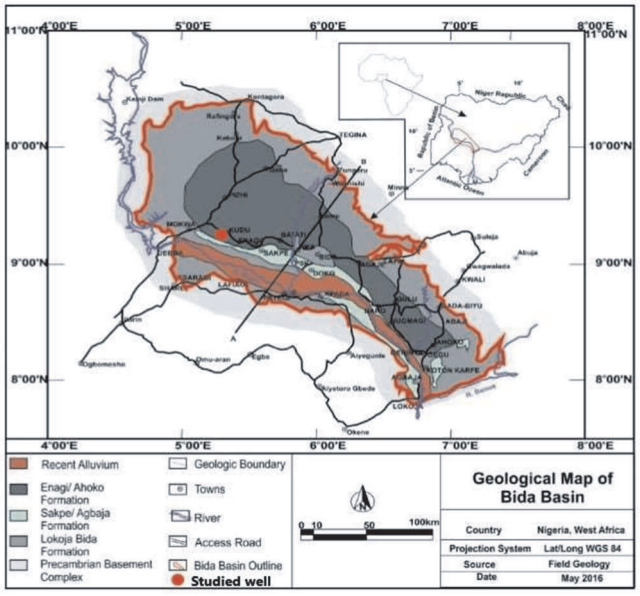

Fig. 1: Location of Kudu-3 well in the Bida Basin (Modified after Rahaman et al., 2018).

Materials and Methods

A total number of nineteen ditch cutting samples within the depth interval of 31 – 58 m (27 m thick) from the Kudu-3 well were subjected to palynofacies analysis. The sample preparation and analysis were carried out in the Crystal Age Laboratory Nigeria Limited, Ikorodu, Lagos State, Nigeria. The lithologic description of the ditch cutting samples was based on the physical inspection of the samples with the aid of magnifying hand lens and a chart for the textural analysis of clastic sediments. The laboratory techniques of digesting sediments in hydrochloric and hydrofluoric acids for silicates and carbonates removal were followed to process the samples for the recovery of palynomorphs and palymomacerals. Fifteen grams of each sample was taken, poured into well labelled plastic cups and arranged in a fume cupboard. Each sample was digested for 35 minutes in 40% hydrochloric acid for removal of carbonate and 24 hours in 40% hydrofluoric acid for the removal of silicate. Sieving was done using a Brason Sonifer to filter away any remaining inorganic matter (silicates, clay, and mud) and heavy minerals to concentrate organic matters present in the sample. Controlled oxidation was given to the sieved residue using concentrated nitric acid (HNO_3). The residue was stained with Safranin O, before being mounted on glass slides and analyzed with the aid of an Olympus Binocular light transmitted microscope. For palynomacerals recovery, the same procedure for palynomorphs recovery was followed, except that the oxidation process with HNO_3 was omitted in order not to bleach the palynomacerals.

Palynomorph Marine Index (PMI), a semi quantitative interpretation technique useful in the determination of depositional environment, was employed for paleoenvironmental interpretation. PMI is the ratio of abundance of marine derived palynomorphs to terrestrially derived palynomorphs, expressed in percentages. It is calculated using the formula PMI= (Rm/Rt + 1)100 (Helenes et al., 1998). Where Rm = Number of marine derived palynomorph (Dinoflagellates + Acritarch + Foraminifera lining + Prasinophytes) taxa per sample. Rt = Number of terrestrially derived palynomorphs (Pollen + Spores + Fungal remains) taxa per sample. High, low and nil values of PMI indicate marine, brackish and fresh water environments respectively.

Results, Interpretations and Discussions

The lithologic description of the studied samples consists of siltstone, silty mudstone, sandy mudstone and mudstone. The grain size ranges from particle size smaller than 0.002 to 0.006 mm. Visual comparison of the ditch cutting samples with munsell colour chart indicates light-gray to greenish-gray colour. The lithologic description shows that the studied interval is from Enagi Siltstone (Obaje, 2009).

The results of the palynofacies analyses carried out on nineteen ditch cutting samples of Kudu-3 well yielded low to moderate dinocysts, pollen and spores, small to large sizes of palynomaceral1 (irregularly shaped, orange-brown to dark-brown coloured and opaque plant debris), palynomaceral 2 (irregularly shaped, brown-orange coloured platy plant materials), and few occurrences of palynomaceral 3 (pale to brown coloured, cuticular, and translucent plant materials) and palynomaceral 4 (black to dark brown coloured, blade/needle like shaped plant materials). The palynomorphs comprising of 18 pollen species, 11 spore species, 5 dinoflagellate cysts and 2 algae species with a total of 341 palynomorph specimens. The dinoflagellates cysts are marine indicators. The result of the analysis is presented in the palynofacies distribution chart of Kudu-3 well (Figure 2). The photomicrographs of recovered palynomorphs and palynomacerals are presented in figure 3.

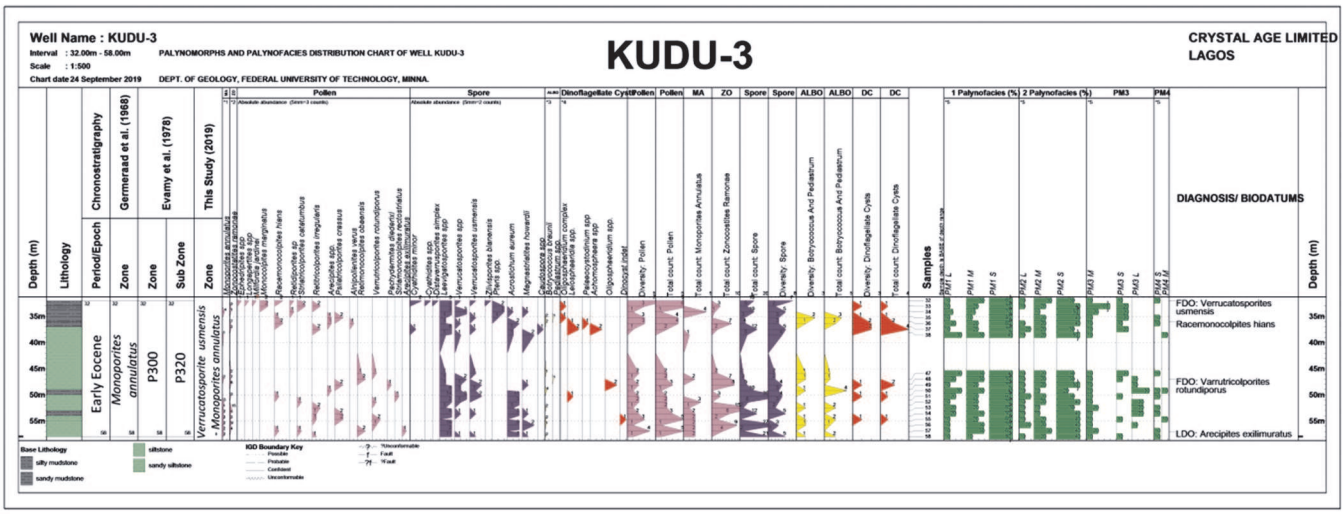

Fig. 2: Palynofacies distribution of Kudu-3 well

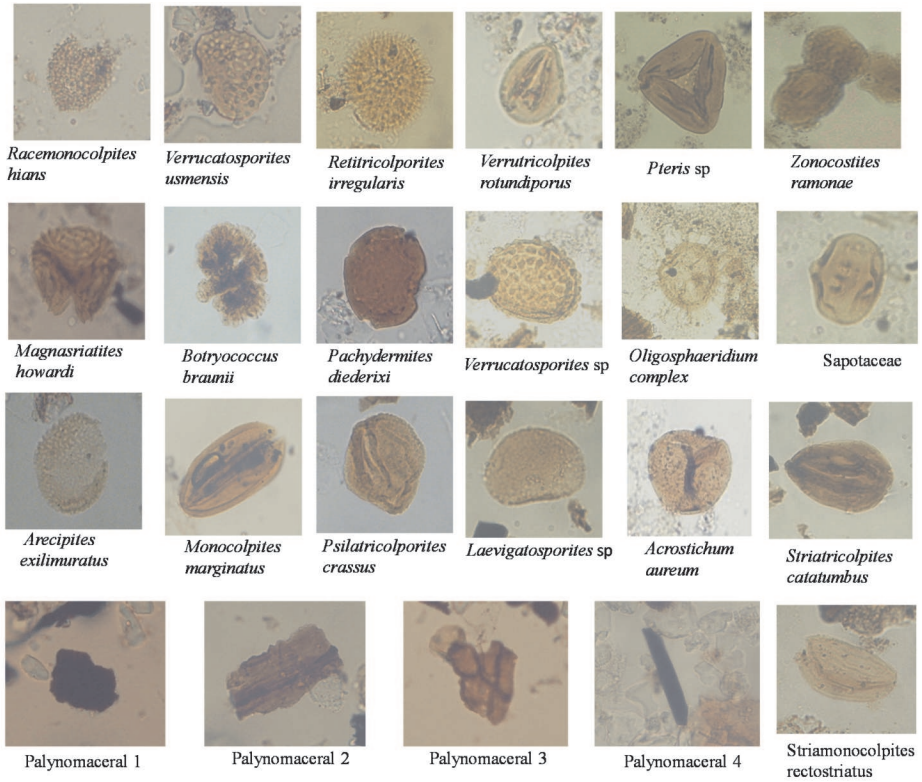

Fig. 3: Microphotograph of recovered palynomorphs and palynomacerals (x400)

Paleobathymetry / Paleoenvironment of Deposition

The paleobathymetry / paleodepositional environment of the studied well was made based on the biofacies information interpreted from the qualitative and quantitative evaluation of the palynomorph assemblages and integration of the lithologic description of the section. The parameters considered in the interpretation of the paleoenvironment are: the palynological marine index, presence/absence of environmental diagnostic marker species and palynomacerals.

From the PMI plot (Figure 4), the sample intervals of 32-33, 34-37, 48-49, 50-51 and 54-55 m have low PMI values (6.67 – 23.53%) and have been inferred to have been deposited in brackish environment. The presence of inner neritic dinoflagellate cysts such as *Palaeocystodinium* sp., *Achosmosphaeridium* sp., *Oligospheridium* sp., *Leiosphaeridia* sp., and *Oligospheridium complex* suggest marine influence within the bathymetric range of 0 – 20 m (upper-shoreface to lower-shoreface). Also the following intervals sample intervals 31-32, 33-34, 37-42, 46-47, 47-48, 55-56, 56-57 and 57-58 m all have zero PMI values and thus were deposited in fresh water environment. The presence of fresh water algae *Botryococcusbraunii* and *Pediastrum*sp. supports this deduction. The interval consists of moderate number of pollen and spores particularly *Monoporites annulatus, Retitricolporites irregularris, Racemonacol poritehians, Verrutricol poritesrotundiporus, Verrucatos poriteusmensis, Laevigatosporites* sp., *Acrostichumaureum, and verrrucatosporites* sp. The recorded Palynomacerals 1 and 2 consist of large, medium and small sizes. The abundant records of poorly sorted palynomacerals 1, 2, 3 and 4 (Figure 2) are indication of terrestrial/coastal deltaic environment of deposition with influx of fresh water from moderate quantities of *Botryococcusbraunii*. *Pediastrum*sp.and *Laevigatosporites*sp. recorded within the interval (Oyede, 1992)

Rate of Sedimentation

The depth interval of 37 – 47 m is marked with rare to non-recovery of palynomorphs forms. The palynomorphs count at this interval ranges from 0 – 7 with percentage recovery range of 0 – 2.0%. This interval is inferred to be of low rate of sedimentation, which resulted in the destruction of palynomorph forms by oxidation due to exposure to atmospheric condition. The studied intervals of 31 – 37 m and 47 – 58 m are

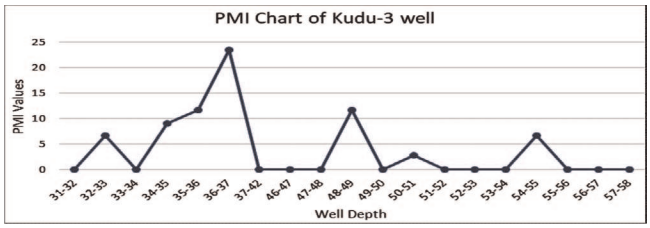

Fig. 4: Palynomorphs Marine Index (PMI) plot for Kudu-3 well.

marked by relatively high recovery of palynomorph forms. The range of palynomorph count and percentage of palynomorphs recovered are 11 – 20 (3.2 – 5.7%) and 11 – 39 (3.2 - 11.2%) respectively. The percentage of recovered palynomorphs and number of palynomorphs count at these depth intervals indicate relatively higher rate of sedimentation. The palynomorphs that were well preserved at this depth interval includes *Monosporitesannulatus, Zonocostitesramonae, Verrucatosporiteusmensis, Acrostichumaureum*and *Laevigatosporites*sp. (Figure 3).

Conclusions

Palynological analysis carried out on nineteen (19) ditch cutting samples of Kudu – 3 well in Bida Basin, yielded moderate number of pollen, spores and dinoflagellete cyst such as *Monoporites annulatus, Retitricolporites irregularris, Racemonocol poritehians, Verrutricol poritesrotundiporus, Verrucatos poriteusmensis, Laevigatosporites* sp*, Acrostichumaureum, and verrrucatosporites* sp., *Palaeocystodinium* sp, *Achosmosphaeridium* sp., *Oligospheridium* sp., *Leiosphaeridia* sp., and *Oligospheridium complex*. Lithology of the studied interval consists of silty mudstone, sandy mudstone, siltstone and sandy siltstone units, indicating Enagi Siltstone. Paleoenvironment and bathymetric interpretation show that the studied interval was deposited in fresh water to coastal deltaic/brackish water environment. The presence of marine dinocysts is indication of marine influence within the bathymetric range of 0 – 20 m (upper-shoreface to lower-shoreface).Coastal deltaic / brackish water environment supports significant organic matter accumulation. The rate of sedimentation interpretation suggests low rate of sedimentation (0.5 cm/1000 years) to relatively higher rate of sedimentation (30 cm/1000 years) within the studied interval since hemipelagic accumulation rate is in the range of 5 – 300 mm/1000 years. The intervals with relatively higher rate of sedimentation suggest quick burial of deposited organic matter, necessary for organic matter preservation and hydrocarbon generation.This work suggests possible potential of hydrocarbon accumulationin the Bida Basin.

References

Adeleye, D.R. (1973): Origin of Ironstone, an example from the Middle Niger Basin, Nigeria. Journal of Sedimentary Petrology, vol. 43, pp. 709-727.

Adeleye, D. R. and Desssauvagie, T. F. J. (1972):*Stratigraphy of Niger Embayment nearBida, Nigeria*. University press, Ibadan.

Helenes J., De-Guerra C. and Vásquez J.(1998): Palynology and Chronostratigraphy of the Upper Cretaceous in the subsurface of the Barinas area, western Venezuela. American Association of PetroleumGeogogists' Bulletin,vol. 82, pp.1308-1328.

Obaje, N. G. (2009):*Geology and Mineral Resources of Nigeria*. Springer-Verlag Berlin Heidelberg.

Obaje, N.G., Moumouni, A., Goki, N.G. and Chanda, M.S. (2011):Stratigraphy, Paleogeography and Hydrocarbon Resource Potentials of the Bida Basin in NorthCentral Nigeria. Journal of Mining and Geology, vol. 47, pp. 97-114.

Onoduku, U.S., Okosun, E.A., Obaje, N. G., Goro, A.I., Salihu, H.D. and Chukwuma-Orji,J.N. (2017):Palynological Evidence of a Campanian-Maastrichtian Age of theCentral Bida Basin, Nigeria: Implication for Paleoenvironment, Paleoclimate and Hydrocarbon Prospectivity. Minna Journal of Geosciences, vol.1, pp. 165-178.

Oyede, A. C. (1992):Palynofacies in deltaic stratigraphy. Nigerian Association of Petroleum Explorationist Bulletin,vol. **7**, pp. 10-16.

Peters, K. E. (1996):"Guidelines for Evaluating Petroleum Source Rock Using Programmed Pyrolysis". American Association of Petroleum Geologists Bulletin,vol. 70, pp. 318-329.

Rahaman, M.A.O., Fadiya, S.L., Adekola, S.A., Coker, S.J., Bale, R.B., Olawoki, I.J. Omada, O.A., Obaje, N.G., Akinsanpe, O.T., Ojo, G.A. and Akande, W. G. (2018): A revised stratigraphy of the Bida Basin, Nigeria. Journal of African Earth Sciences,vol.151, pp. 67-81.

Reading, H. G. (1996): *Sedimentary Environments: Processes, Facies and Stratigraphy*3rd ed., Blackwell Science.

Stover L. E., Brinkhuis, H., Damassa S. P., de Verteuil L., Helby R. J., Monteil E., Partridge A. D., Powell, A. J., Riding, J. B., Smelror M. and Williams, G. L. (1999):"Mesozoic-Tertiary dinoflagellates, acritarchs and prasinophytes," *in Palynology: principles and applications, American Association of Stratigraphic Palynologists Foundation,* J. Jansonius and D. C. McGregor Eds., vol. 2**,** pp. 641-750.

Tsepav, M.T. and Mallam, A. (2017): Evaluation of Depth to Magnetic Basement over someparts of the Nupe Basin, Nigeria by Source Parameter Imaging Method using Aeromagnetic Data. International Journal of science and Research Technology, vol.8, pp.120-1