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Lithological Characterization Using Parasequence Set for Depositional Environment of KD Field Shallow Offshore Niger Delta Basin

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The purpose of this study is to delineate the environment of deposition from gamma ray log using parasequence set, for the well 01,02 and 03 within KD field for hyrdrocarbon prospect.
Study Design: The result of the lithostratigraphic analysis carried out on three wells from the KB field are presented and discussed.
Place: The study was carried out in the shallow offshore Southern Niger Delta, Nigeria from wells 01, 02 and 03 of KD Field.
Methodology: Gamma ray logs were subjected to para sequence set before using and log motif Interpretation were referred to know the depositional environment of the KD field shallow offshore Niger Delta. The lithologic descriptions were complemented using logs analyses.
Results: Based on their lithologic properties, investigation of the three wells were based on reservoir A, B, and C in the study area. The depositional environment falls within the nearshore face to intermediate offshore part of the Delta. The Unit is estimated to be 176m thick and is

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characterized by sands and a sand-shale layer alternation. In this investigation, only the Agbada Formation were encountered, it is characterized by Aggrading, Prograding and Retrogradational parasequence set.

Keywords: Lithostratigraphy; Log Motif; parasequence; agbada formation; sandstones; shales; gamma ray log.

1. INTRODUCTION

One of the most prominent exploration regions in the Niger Delta has been the shallow offshore depobelts. Because of the shale sand intercalation that works as a seal and reservoir sand body, it has been revealed that the majority of the continental slope and basin floor have good reservoir quality. Lithostratigraphy is a physical method of reconstructing the deposition environment that cannot be replaced because it is the foundation of most depositional properties, alongside chemical and biological methods. The Niger Delta stratigraphy's basic building block is the depositional environment and its component facies. The Akata Formation (Pro delta Shales, Paleocene to Recent), Agbada Formation (Deltaic and paralic facies, Eocene to Recent), and the current Benin Formation (Fluvatile facie Oligocene-Recent) are the three formations that make up the Niger Delta Basin stratigraphy. The goal of this research is to use wireline log shapes derived from gamma ray log responses to estimate the depositional environment of the KD Field of wells 01, 02, and 03, based on reservoir scale and the reservoir encountered by this well are Res A,B and C.

1.1 Location of the Study Area Geology

The KD field is located in Nigeria's Niger Delta basin (Fig. 1a). Through the usage of enormous petroleum reserves, the Niger Delta has played a key role in enhancing the country's and neighboring countries' economies. Several authors have contributed to our understanding of the sedimentology, tectonics, stratigraphy, depositional environment, petrophysics, and hydrocarbon potential of the Niger Delta basin. The authors listed below have published about them [1,2,3,4,5,6,7,8]. In West Africa, the Niger Delta is located near the Gulf of Guinea [1]. The sub-aerial part of the Niger Delta covers around 75000 km2 and spans approximately 200 kilometers from peak to entry.

The entire sedimentary prism spans 140000 km^2, with a stratigraphic thickness of approximately 12 km at its thickest point [9]. The Akata, Agbada, and Benin Formations are three lithostratigraphic units that make up the broad sedimentary order stratigraphy [10]. From the Eocene to the present, the Benin Formation includes continental/ fluviatile deposits of up to 2500 m thick sands, gravels, and back swamps. Underneath the Benin Formation is the Agbada Formation. With minimal lignite, these are mostly interbedded sandstones and shale arranged into coarsening upward "offlap" cycles. The Akata Formation, which covers the Paleocene to the most recent period and contains up to 6500 m of marine clay with silty and sandy interbeds, underpins this unit [9]. They are viewed as a dynamic substratum that deforms in response to deltaic programming and sedimentary stress, similar to natural evaporites [5].

1.2 Niger Delta Petroleum System

Petroleum is discovered in the Niger Delta clastic wedge's Agbada Formation [11]. Within individual depobelts, the ratio of gas to grease tends to extend southward, according to the hydrocarbon distribution [5]. Based on the stratigraphy of a few petroleum-rich areas in the Niger Delta area, [12] developed a hydrocarbon habitat model. The ratios of gas to grease in reservoirs were recorded by [4,13,14,15,5,11,16]. estimate that bands generally correspond to the transition between continental and oceanic crust inside the axis of greatest sediment thickness.

1.3 Geology of the Study Area

The Niger delta basin has an estimated area of about 140,000 sq.km in the continental margin of the Gulf of Guinea on the coast of West Africa formed as a result of a failed rift junction during the separation of the South American plate and the African plates according to [17]. The latitude and longitude are 4° and 6° N and 3° and 6° E which lies in the southern part of Nigeria [18]. [4,14,19,12] proposed that the forming of the delta is controlled by pre and syn-sedimentary tectonics. Climatic changes, the proximity and type of sediment source area affects the growth of the delta, The Niger delta has evolved through stages of sedimentation from the Cenozoic period, down to the Middle Miocene over a progradation series dipping continental basement into the Gulf of Guinea [8]. The end effect of the regressive series was the offlapping sedimentation succession of about 1,200 meters thickness resulting in three units: the deep marine pro-delta Akata Formation (Paleocene to Recent), the shallow marine delta Agbada Formation (Eocene to Recent) and the Continental plain sand of the Benin Formation (Oligocene-Recent). The Niger delta is the most studied sedimentary basin in Nigeria in terms of its sediments' size and thickness and economic importance as its crude oil reserves remains a source of income for the country. A parasequence set is a group of genetically related strata with clear stacking pattern in relation to the sedimentation rate and accommodation space discussing progradation, retrogradation and aggradation in relation to shallow offshore Niger Delta Basin.

1.4 Akata Formation

This formation was formed during the Paleocene and a significant amount of shoreline transgression occurred.it is composed of thick shales, turbidities sands and small amount of clay. Because of the clay concentration, the shale became ductile and was squashed into shale diapirs throughout the basin. The thickness of the formation is believed to be 7000 meters.

1.5 Agbada Formation

Evolved during the Eocene, a major oil and natural gas bearing formation formed in a marine, fresh water or deep sea covered and rich in organic content. It is estimated to be 3700 metres thick.

1.6 Benin Formation

Oligocene in age and it is composed of continental flood plain sand and alluvial deposits. It is estimated to be 2000 meters thick and it is still being deposited today.

2. MATERIALS AND METHODS

The data set available for this research consists of a base map, well logs data from three wells which were used to delineate sand shale ratio from the aspect of reservoir. The data were gotten from Shell (SPDC). Schlumberger's petrel 2014 was used for processing the data set. Three wells were used for this study and was place vertically to ascertain the reservoir that were to be studied.

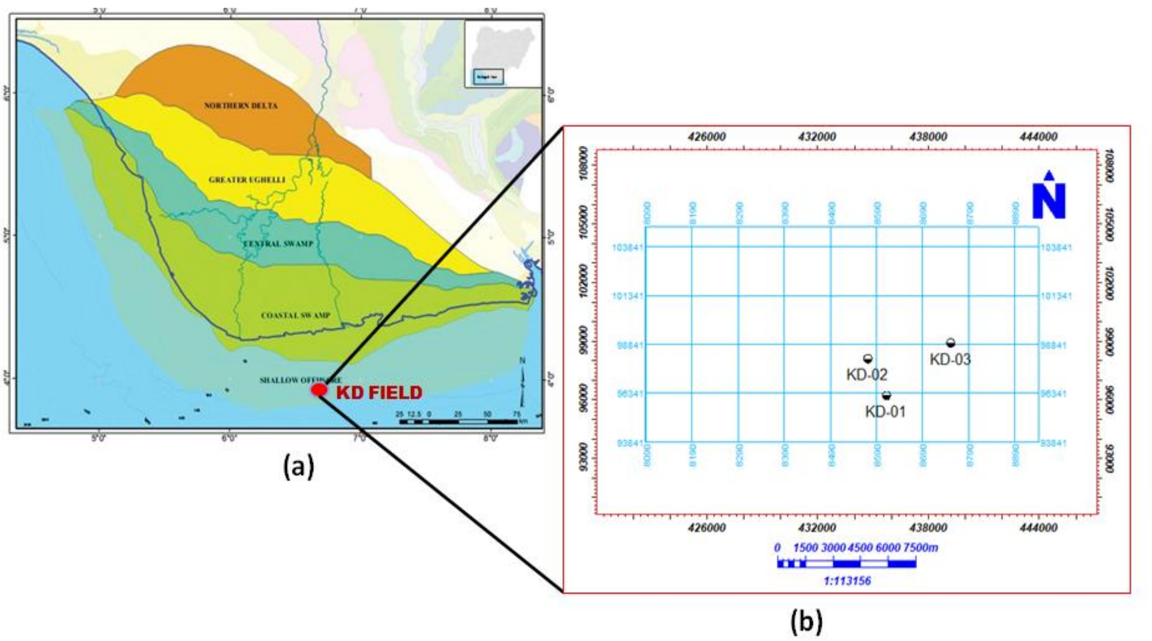
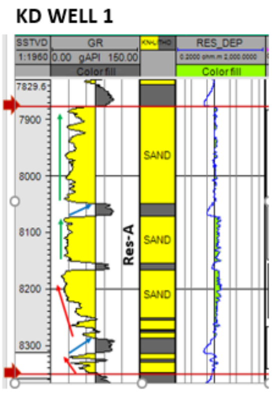


Fig. 1. Location of the study area (a) Niger Delta Map showing the different depobelts and study location (Red Ellipse) modified after [10], (b) Base map of KD Field showing the positions of wells and seismic lines

3. RESULT AND DISCUSSION

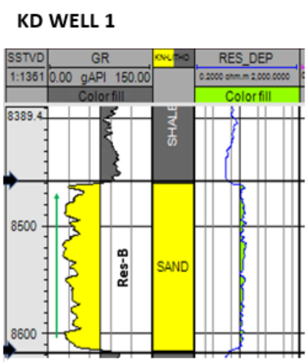
3.1 Gamma Ray Log

Using gamma ray log values, which are a function of radioactive elements, the lithology was determined. In siliciclastic depositional conditions, each lithology produces gamma radiation elements of potassium 40, uranium, and thorium, and the lithology can be established based on the rate of emission. Shale lithology is linked to a high gamma ray response, whereas sandstone lithology is linked to a low gamma ray response. The gamma ray log can also be used to estimate depositional energy by determining the distribution of grain sizes. As a result, a high gamma ray value corresponds to a high mud-to-sand ratio, and a low gamma ray value corresponds to a low mud-to-sand ratio. Each gamma ray log motif has its own set of features that can be used to estimate deposition environment, shale concentration, and grain size distribution. Gamma ray response to stacking pattern/grain size variation model used in the above figures were adopted by [20]. Fig 2,3 and 4 of KD well 1, shows that Reservoir A, consist of both Aggrading, Prograding and Retrograding stacking pattern which gives a suggestive depositional environment of distributary channel fill.



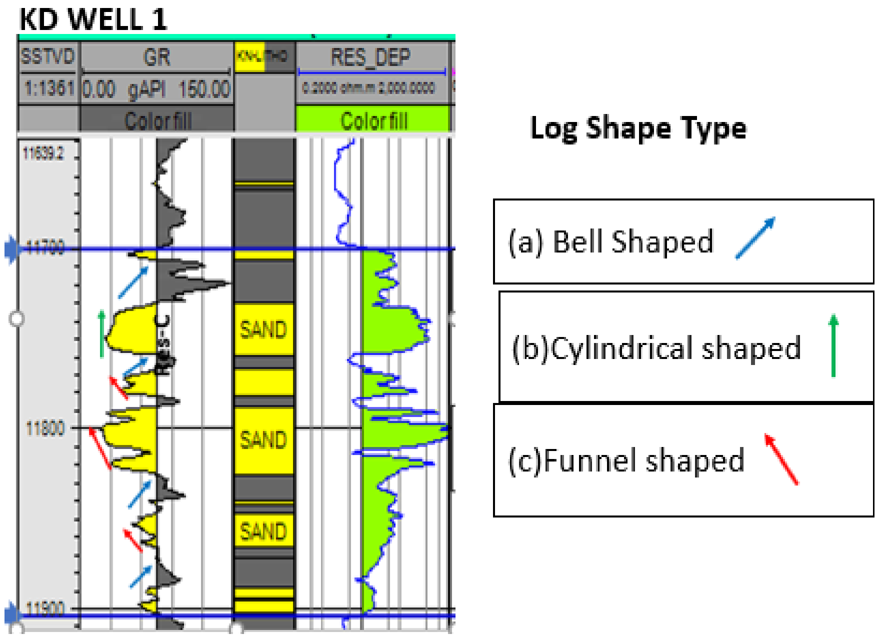
Log Shape Type	Parasequence (Stacking pattern)/ Facies Type	Suggestive Depositional Environment
	Sandstone	**Marine environment**
(a) Serrated shaped	(a) Aggrading stacking pattern (Saw teeth)	Fluvial flood plain, storm dominated shelf and distal deep marine slope
(b)Cylindrical shaped	(b) Aggrading stacking pattern	Braided fluvial, distributary channel fill
(c)Funnel shaped	(c) Prograding stacking pattern	Crevasse splay, river mouth bar, delta front, shore face, sub marine fan lobe.
	Shale	**Marine environment**
(d) Bell Shaped	(d) Retrograding stacking pattern	Fluvial point bar, tidal point bar, deep tidal channel fill, tidal flat.

Fig. 2. Parasequence and environment of deposition using Log Motif of KD 01 well (Reservoir A) After [20]



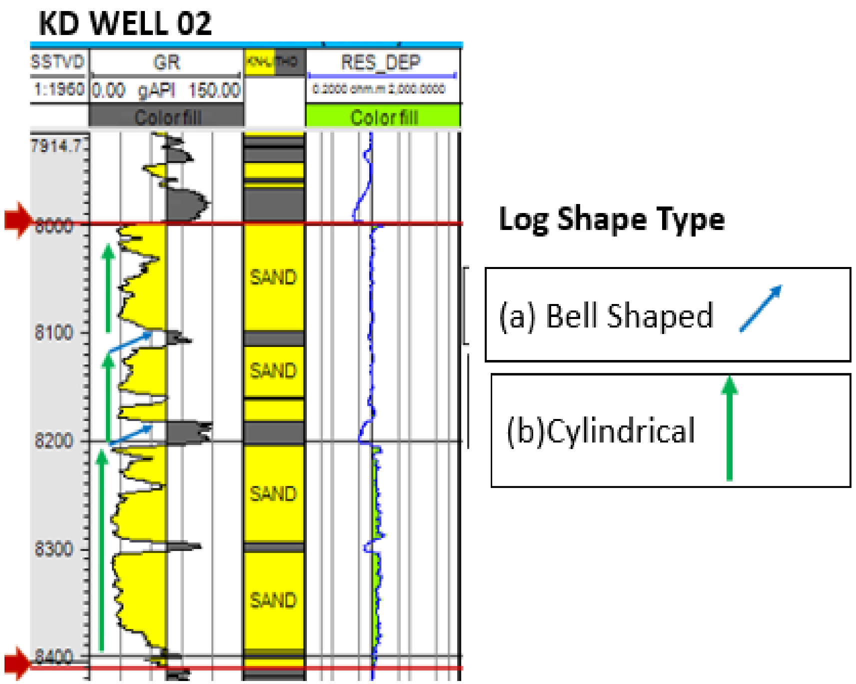
Log Shape Type	Parasequence (Stacking pattern)/ Facies Type	Suggestive Depositional Environment
	Sandstone	**Marine environment**
(a) Serrated shaped	(a) Aggrading stacking pattern (Saw teeth)	Fluvial flood plain, storm dominated shelf and distal deep marine slope

Fig. 3. Parasequence and delineation of environment of deposition using log motif for KD 01 well (Reservoir B)



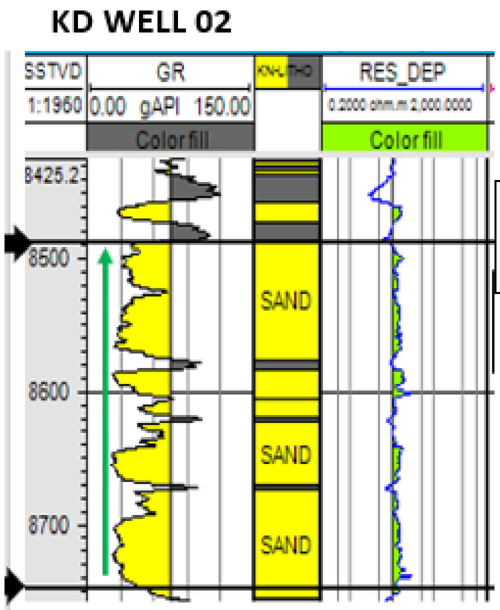
Parasequence (Stacking pattern)/ Facies Type	**Suggestive Depositional Environment**
Shale	**Marine environment**
(a) Retrograding stacking pattern	Fluvial point bar, tidal point bar, deep tidal channel fill.
Sandstone	**Marine environment**
(b) Aggrading stacking pattern	Braided fluvial, distributary channel fill, submarine canyon fill
(c) Prograding stacking pattern	Crevasse splay, river mouth bar, delta front, shore face, sub marine fan lobe.

Fig. 4. Parasequence and Delineation of Environment of deposition using Log Motif for KD 01 well (Reservoir-C)



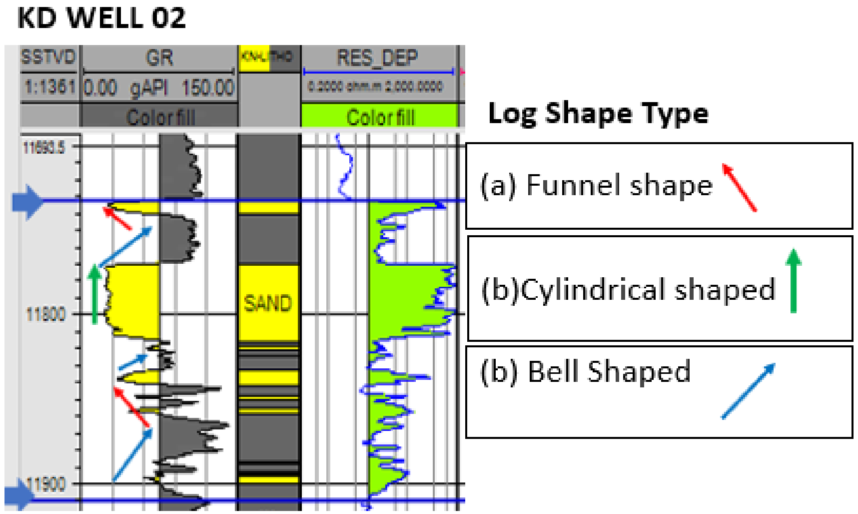
Parasequence (Stacking pattern)/ Facies Type	Suggestive Depositional Environment
Sandstone	**Shallow Marine environment**
(a) Retrograding stacking pattern	Fluvial point bar, tidal point bar, deep tidal channel fill, tidal flat.
(b) Aggrading stacking pattern (Blocky)	Braided fluvial, distributary channel fill, submarine canyon fill

Fig. 5. Parasequence and Delineation of Environment of deposition using Log Motif for KD 02 well (Reservoir-A)



Log Shape Type	Parasequence (Stacking pattern)/ Facies Type	Suggestive Depositional Environment
(a)Cylindrical	**Sandstone**	**Marine environment**
	(b) Aggrading stacking pattern	Braided fluvial, distributary channel fill, submarine canyon fill

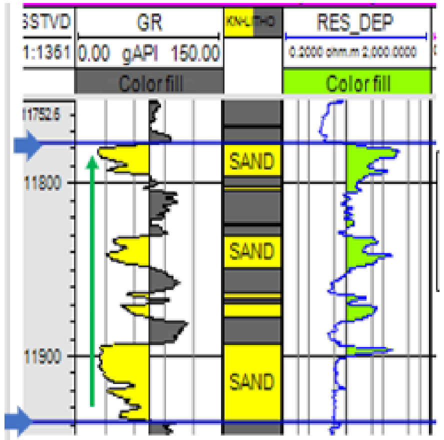
Fig. 6. Parasequence and Delineation of Environment of deposition using Log Motif for KD 02 well (Reservoir-B)



Parasequence (Stacking pattern)/ Facies Type	**Suggestive Depositional Environment**
Sandstone	**Marine environment**
(a) Prograding stacking pattern	Crevasse splay, river mouth bar, delta front, shore face, sub marine fan lobe.
(b) Aggrading stacking pattern	Braided fluvial, distributary channel fill
Shale	**Marine environment**
(c) Retrograding stacking pattern	Fluvial point bar, tidal point bar, deep tidal channel fill, tidal flat.

Fig. 7. Parasequence and Delineation of Environment of deposition using Log Motif for KD 02 well (Reservoir-C)

KD WELL 03



Log Shape Type

(a) Serrated shaped

Parasequence (Stacking pattern)/ Facies Type	Suggestive Depositional Environment
Sandstone	**Marine environment**
(a) Aggrading stacking pattern (Saw teeth)	Fluvial flood plain, storm dominated shelf and distal deep marine slope

Fig. 8. Parasequence and Delineation of Environment of deposition using Log Motif for KD 03 well (Reservoir-C)

3.1.1 Serrated Cylindrical Log Motifs

Funnel, and Bell-shaped gamma ray log motifs were all encountered in the study. Serrated cylindrical log type, is linked to equal deposition and an aggradational stacking pattern with abrupt bottom and higher bounds.

3.1.2 Funnel-shaped

This is connected with an increase in sand content and an upward reduction in gamma ray response. The stacking pattern is a prograding kind, and the trend indicates an increase in energy level.

3.1.3 Bell Shape Log Type

This is linked to a high gamma ray sensitivity, and the lithology is primarily fining in this case. The trend indicates that the energy level is decreasing, and the stacking pattern is retrogradational [Fig. 5,6,7].

Fig. 8, for well 03, the well penetrated only one reservoir, which is reservoir C. It is majorly serrated type in shape, which is typical of marine environment because of the depth which occur at 11,800 m.

The Gamma ray log pattern was used to construct reservoir depositional facies, and two primary lithologies (Shale and Sand) were discovered. Sand units are prospective reservoir rocks that can store oil and gas, while shale units are potential source rocks or seals, according to the two major lithologies identified. In this study, three reservoirs were identified as Res A, Res-B, and Res C, with two reservoir facies (A and B) developing in the field's center and south-eastern areas. In the northwestern portion of the depositional axis, the reservoir facies were either not penetrated or eroded, which could be the possible reason why well 03 of KD field could only penetrate Res C.

3.2 Interpretation of Depositional Environment

The environment of deposition was determined by integrating the findings obtained from gamma ray log motifs (Stacking pattern and parasequence sets) before comparing with that of [21] being classified as upper shoreface to intermediate offshore (Fig 9)

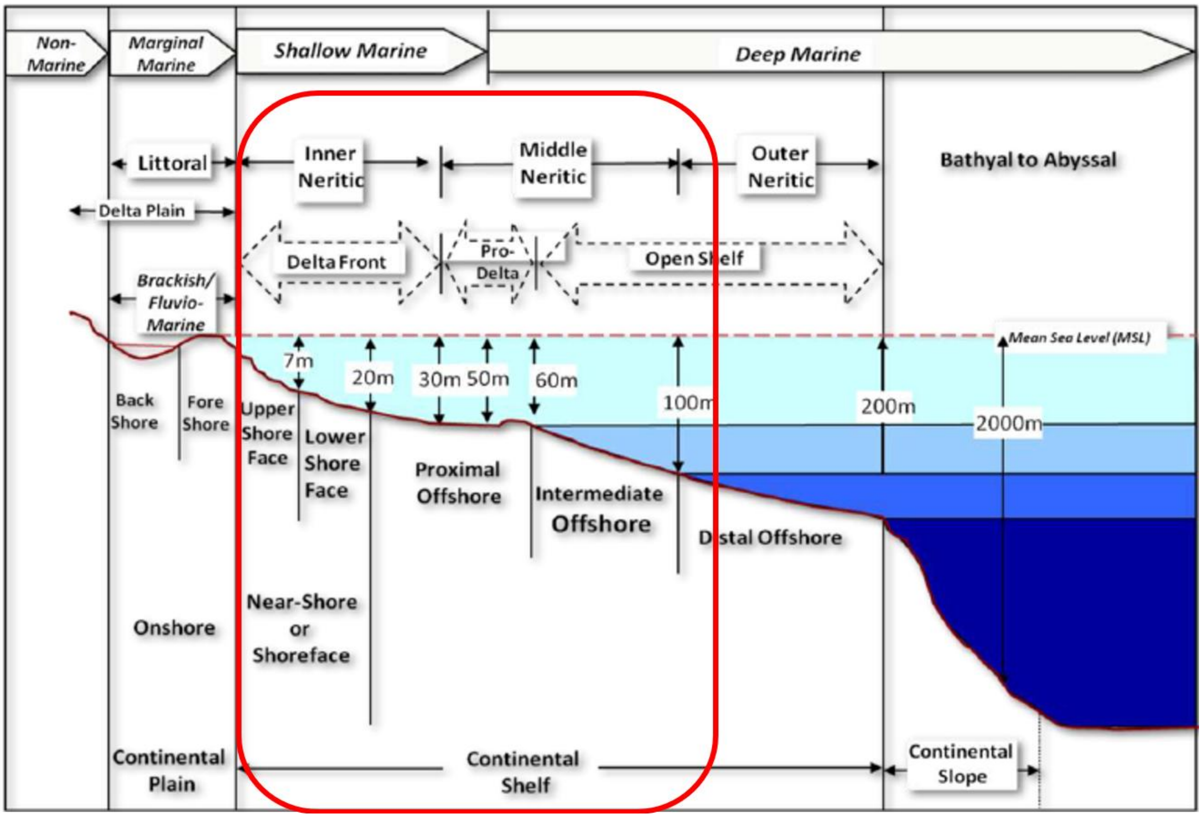


Fig. 9. Depositional environments and bathymetric ranges used for paleoenvironmental interpretation [21], showing the environment of deposition for KD FIELD within the red line

4. CONCLUSION

The lithostratigraphy and deposition environment of the KD Field have been assigned to the Transitional to Shallow Marine Environment, this was done based on reservoir scale. The two-lithology encountered in the field were Sand and shale, which is typical of the Agbada formation in the Niger Delta Basin. The Shale tends to act as a cap rock while the sand act as the host of the hydrocarbon in place. Lithogical study on reservoirs rocks cannot be overhaul base on its usefulness in exploration and production stage of any oil field. The dominating sand content inferred from the gamma ray log places the research location within the paralic Agbada Formation. In this investigation, three reservoirs were employed, which are Res A, B and C. The depositional environment was defined and inferred using the gamma ray curves, stacking pattern, and parasequence set. The usefulness of gamma ray log in lithofacies and depositional environments was further demonstrated in this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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