Sedimentology and Depositional Environment of Reservoir Sands of Kanga Oil Field Onshore Niger Delta

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***Abstract*: In this study, reservoir sands from seven wells Kanga Oil field in the Onshore Niger Delta were analyzed sedimentologically to determine the level of spatial distribution of significant heterogeneity in the subsurface and infer the depositional environments. From the sedimentological analyses, three reservoir intervals J100, K100 and L100 of interest were identified based on the gross thickness of the reservoir sand, cleanliness of the reservoir sand and presence of hydrocarbon, and correlated across the field using suites of wire line logs. The environment of deposition was interpreted using gamma-ray log motif and lithologic description from Sidewall samples. The environments of deposition have been interpreted as Channel sands, Upper Shoreface, Lower Shoreface and Marine Shale, a reflection that the sediments was deposited in medium to low energy environment which favors the deposition of fine to medium grains sediments**

***Key words*: sedimentology, depositional environment, reservoir, lithologic and hydrocarbon**

I. INTRODUCTION

Petroleum resides in the tiny pore spaces and open fractures of reservoir sands (Schlumberger, 1989). To find them, a detailed sedimentological and petrophysical analysis is needed to guide production and well placements, well paths for optimal hydrocarbon recovery. The key process controlling variation in stratal patterns and facies distribution is accommodation and sedimentation supply. Accommodation is created by a combination of tectonics and sea level fluctuations while the filling of the basin is a product of sediment supply, influenced by the combined effects of basin geometry, physiography, provenance, and climate.). Studying the spatial variability of saturating reservoir fluids (hydrocarbon) is a significant aspect of oil and gas production.

The paper is seeks to establish relationships between reservoir properties with various depositional environments within the Onshore Niger Delta through a detailed sedimentological study.

Geology of The Niger Delta Basin

The Niger Delta as a prograding sedimentary complex which evolved from the separation of the African and South American continental plates. The origin of the Niger Delta is believed to have began after the development of the **RRR** (ridge-ridge-ridge) system. The failed arm of this triple structure is the Anambra-Benue rift valley within which the oceanic crust was inactive. The rivers depositional centers moved seawards thus making the coastal plain deposits to become progressively younger in that direction (Burke, 1971; Wright, 1976).

The Tertiary Niger Delta is divided into three formations, namely Akata, Agbada and Benin Formations (Evamy *et.al*, 1978; Etu-Efeotor, 1997; Agbada Formation is believed to be the main reservoir of hydrocarbon in the Niger Delta.

Location of Study Area

The study Area is located within the Central Swamp Depobelt, Onshore Niger Delta ., The field lies between Longitudes 5˚00ˈ00̎ N and 8˚00ˈ00̎ N and Longitudes 4˚00ˈ00̎ E and 6˚00ˈ00̎ E. See Figure 1

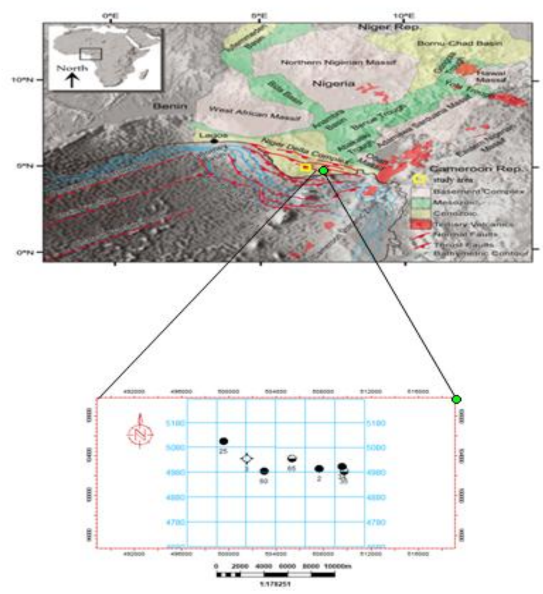


Figure 1 Location of the study area, onshore Niger Delta region (modified after, Corredor *et al.*, 2005

II. MATERIALS AND METHODS

Materials

The materials for this study includes 3-D Seismic data, Well log data and Side Wall Samples across seven wells.

Methods

The sedimentological analysis was accomplished using lithologic descriptions from the SWS and GR log motif. Lithology was identified using gamma ray (GR) log, neutron-density (NPHI-RHOB) logs, and SWS. Histogram plot of GR log values for all the wells are plotted, and the sand and shale baselines are determined. The sand baseline (GR_{sand}) is taken as the lowest average GR reading from where sand is 100% while shale baseline (GR_{sh}) is taken at 100% shale where GR reading is highest. The GR log reading was utilized for GR_{sh} determination. (Cannon, 2018). In wells that have no SWS, grain size information was inferred from the well logs using well log motifs. The results from sedimentological analysis were used to interpret the environment of deposition and assess reservoir quality.

III. RESULTS AND DISCUSSIONS

Sedimentology and Environment of Deposition

The results of the three reservoirs (J100, K100 and L100) identified across the field are presented in Figures 2, 3, 4 and 5. These reservoirs were selected based on Gross thickness of the reservoir sand, cleanliness of the reservoir sand, presence of hydrocarbon and availability of relevant logs. J100 reservoir has significant shales at the top in Well 2 and 3 (Figures 6 and 7). K100 reservoir is shaly at the lower sections of Well 2and 3 (Figures 6 and 7). L100 reservoir was not identified in Well 6 due to the shallowness of the well. The thick shales underlying and overlying these reservoir rocks are both believed to be source rocks and caprocks in the field. Which is predominant in the Niger Delta (Doust and Omatsola, 1990)

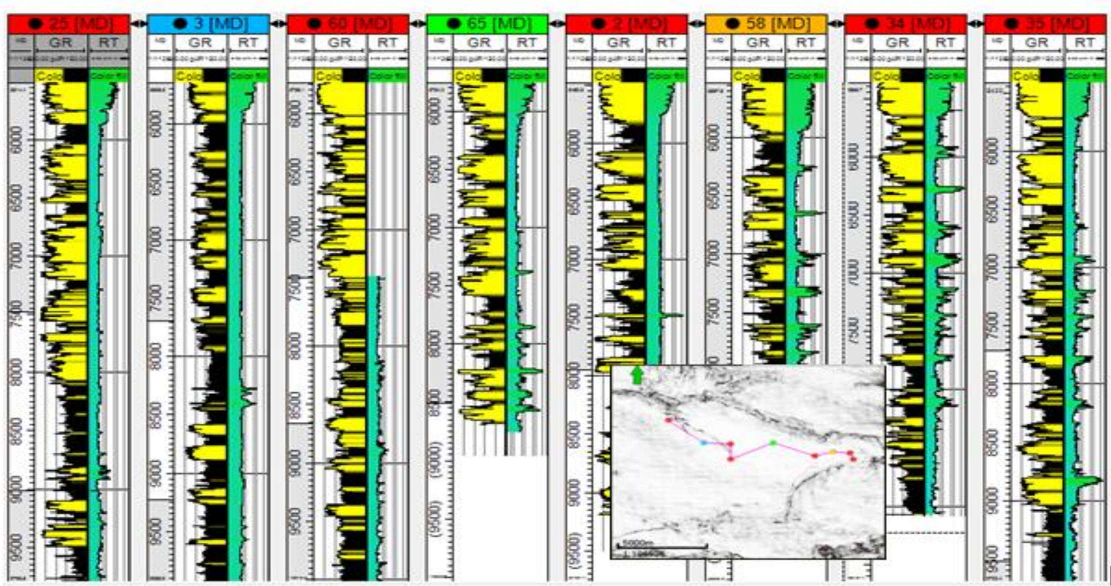


Figure 2: Sand and shale lithologies identified after establishing baselines and defining net sand cutoff. Inset map at bottom right shows line of cross-section

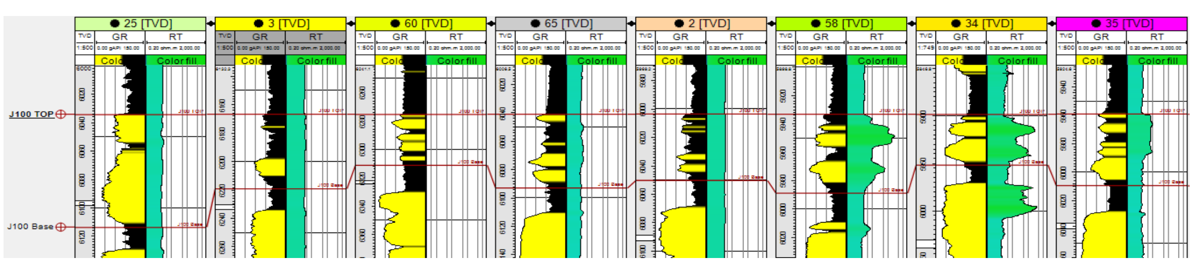


Figure 3: Reservoir J100 top and base mapped and correlated across all the wells

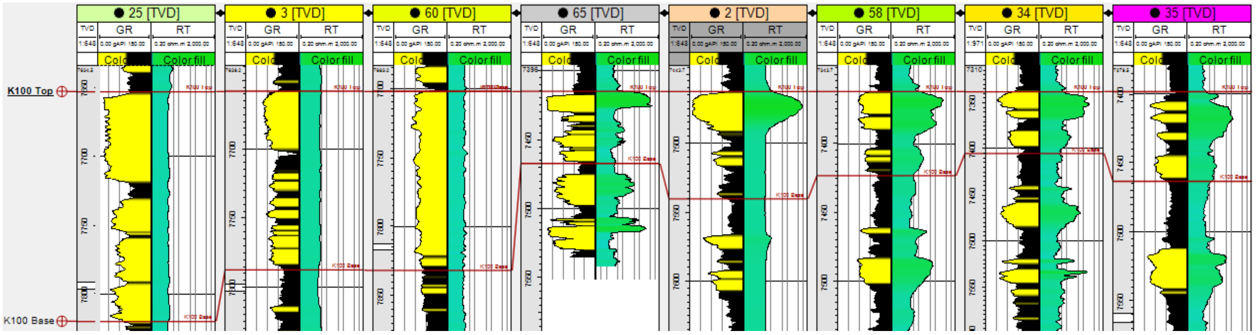


Figure 4: Reservoir K100 top and base mapped and correlated across all the wells

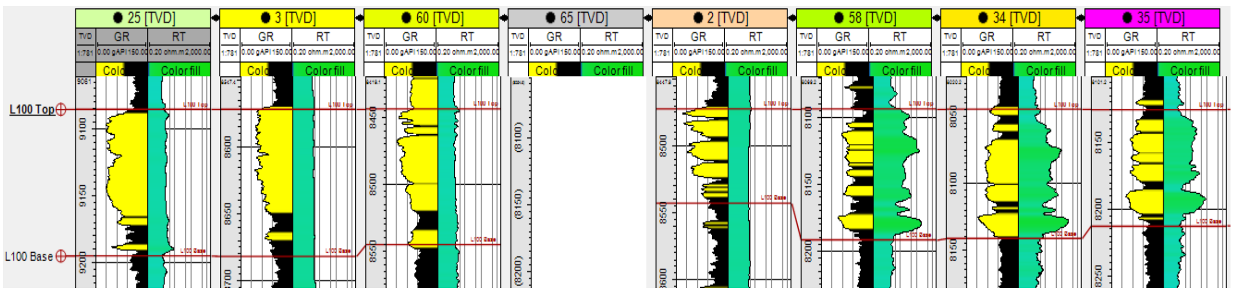


Figure 5: Reservoir L100 top and base mapped and correlated across all the wells

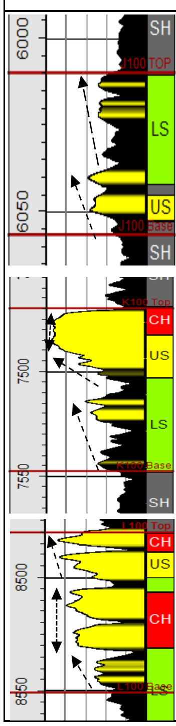
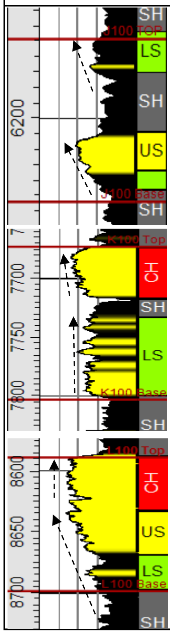
GR Log	Depth (ft)	Lithology	Reservoir	GR Log Motif	Depositional Facies	Lithologic Description	Associated Minerals
	6000	Shale			Shale	Dark grey, slightly calcareous at some spots, silty and frangible, no visible sedimentary structure	Contains little pyrite and little plant remains.
			J100	Funnel top (Prograding)	Lower Shoreface		
	6050	Sand		Funnel base (Prograding)	Upper Shoreface	Brown; medium to very fine; silty;slightly clayey; moderately sorting; no visible sedimentary structure; loosely consolidated	Contains rare pyrite
					Shale		
	7475	Sand	K100	Blocky Top (Aggrading)	Channel	Brown; medium to very fine; silty; slightly clayey; moderately sorting; no visible sedimentary structure; loosely consolidated	Contains rare pyrite
	7510	Clayey Sand		Funnel base (Prograding)	Upper Shoreface	Grey; very fine to silt; well sorted; no visible sedimentary structure; loosely consolidated	Contains few carbonaceous matter; few pyrite and rare shell fragments.
	7530	Shale			Lower Shoreface	Brownish grey; calcareous at some spots; silty; frangible; no visible sedimentary structure	Contains little plant remains.
					Shale		
	8490	Sand	L100	Funnel Top (Prograding)	Upper shoreface and channel at top	Grey; fine to very fine; with rare medium; slightly clayey; no visible sedimentary structure; loosely consolidated	Contains rare pyrite.
				Blocky	Channel		
	8550	Sand		Funnel base (Prograding)	Lower Shoreface	Brown; very fine to silt with rare fine grains; well sorted; with irregular argillaceous sreaks; loosely consolidated	Contains few pyrite; few carbonaceous matter and few calcareous sandstone.

Figure 6: Results of GR motif and sedimentological analysis utilized for environment of deposition analysis for Well 2



GR Log	Depth (ft)	Lithology	Reservoir	GR Log Motif	Depositional Facies	Lithologic Description	Associated Minerals
	6170	Shale			Shale	Dark grey; silty; frangible; no visible sedimentary structure	Contains abundant plan tremains and fairly abundant pyrite.
	6180	Sandy Shale	J100	Funnel top (Prograding)	Lower Shoreface	Dark grey; very silty; slightly calcareous; frangible.	Few calcite and lignite; rare limonite; mica flakes and plant remains
	6190	Shale			Shale	Dark grey; silty; frangible; no visible sedimentary structure	Contains abundant plan tremains and fairly abundant pyrite.
	6210	Sand		Funnel base (Prograding)	Shoreface	Grey, medium to coarse grained; silty; very well sorted; calcareous; loosely consolidated.	Rare pyrite; carbonaceous material and calcite.
	6230	Shale					
	7700	Sand		Blocky Top (Aggrading)	Channel	Grey; coarse to medium; silty; no visible sedimentary structure; loosely consolidated.	Contains rare pyrite
	7730	Shale			Shale		
	7760	Shaly Sand	K100	Serrated	Lower Shoreface	Grey; very fine to silt; well sorted; no visible sedimentary structure; loosely consolidated	Contains little plant remains.
	7820	Shale					
	8600	Sand	L100	Blocky Top (Prograding)	Upper shoreface and channel at top	Grey; very coarse to very fine; silty; poorly sorting; no visible sedimentry structure; loosely consolidated	Contains fairly abundant small plant remains and a few pyrite.
				Funnel base	Lower Shoreface		
	8710	Shale			Shale	Dark grey; very calcareous at some spots; silty; frangible; no visible sedimentary structure	Contains abundant plantremains and fairly abundant pyrite.

Figure 7: Results of GR motif and sedimentological analysis utilized for environment of deposition analysis for Well 3

The depositional events in the studied reservoirs was determined from the interplay of lithology, grain size, sorting sedimentary structurues and associated heavy minerals using litholic description of the side wall samples. The sedimentology was tired to GR log interpretation to identify the depositional events (Figure 6-7). The shale lithology in reservoir J100 of Well 2 is dark gray, silty, minor pyrite, plants remains and calcareous with no sedimentary structures. (See Figure 6). The presence of pyrite in the shales suggest open water conditions where oxygen prevails while the minor plant remains indicates that the shales may be continental in origin. Similar shale composition have been observed in Well 3 but with higher amounts of pyrite and plant remains (Figure 7). The upper part of reservoir J100 may have similar composition with Well 2. The top of reservoir J100 is has sandy shale,dark gray, very silty and slightly calcareous. In addition to calcite, limonite, lignite, mica flakes and plant remains. The GR log motif revealed a progradational pattern for this interval, suggesting a lower shoreface environment due to the high shale content and heterolithic nature of the sediment. This suggests that the the top of th reservoir J100 has poor quality due tas a result of the high shale content. The lower section of reservoir J100 in Well 2 as from the sedimentological analysis shows that the sands are brownish with medium to fine grains. The sands are silty, moderately sorted with no visible sedimentary structure. Pyrite scattered within the sands is rare. Reservoir J100 in Well 3, has medium to coarse grains with minor silts. The sands are very well sorted, calcareous. In addition, has rare calcite minerals, pyrite and carbonaceous materials. Gamma Ray log motif revealed a progradational pattern for the sands, indicating a thickening upward sequence. The environment of deposition inferred for this sand body is upper shoreface. The presence of thick, moderately to well sorted sands are indicative of a good quality reservoir. Hence, the top of the reservoir J100 has poor quality while the lower part of reservoir J100 has very good quality for hydrocarbon production. Reservoir K100 in Well 2, shows that the top is predominantly sands as revealed from GR log and sedimentological analysis. The sands are brownish, medium to fine grained, clayey, moderately sorted and pyritic, indicative of an anoxic environment. The GR log, of the top of the sand has a blocky motif, indicative of channel environment of deposition. In Well 3, reservoir K100 is grayish, medium to coarse grained, silty, loosely consolidated with no visible sedimentary structure. The Gamma Ray log also revealed that the top of this sand has a block motif, indicative of channel deposits. The sands are coarse grained and moderately sorted, and are classed as having good reservoir quality. The central part of reservoir K100 sand in Well 2 is grayish, very fine to silty, well sorted and shaly with no sedimentary structure. This section of the reservoir has few pyrites and rare shell fragments, indicative of land derived sediments. The sands are interpreted as uppershore based on the GR log motif. The lower part of reservoir K100 in Well 2 is shaly at a 7530ft, calcareous and silty with no visible sedimentary structure. The shales contain little plant remains which is indicative of continental derived materials. The GR log revealed that this portion of the reservoir has a progradational stacking pattern with shales predominating at the baase and decreasing upwards. In well 3, the bse of the K100 reservoir is a fine to silty, well sorted shaly sand which are loosely consolidated with little plant remains. The GR log motif revealed that this portion of the sands are heterolithic, and is interpreted as a lower shoreface. The upper portion of the K100 reservoir has better quality than the lower section of the reservoir because the reservoir shows a generally thickening upward sequence which is capped by a blocky sand sequence at the top of the reservoir. The top of the L100 reservoir in Well 2 at a depth of 840 ft is gray in colour, fine to medium grains, loosely consolidated with no sedimentary structures present. On the gamma ray log, the sands are funnel shaped revealing a progradational parasequence stacking pattern but with minor clay intercalations. The sands are interpreted as upper shoreface, with a channel at the top. There were no clay intercalations recognized on the GR motif for the upper section of the L100 reservoir in well 3. Sedimentological analysis showed that the upper part of L100 reservoir is composed of sands that are fine to very coarse, silty, poorly sorted, loosely consolidated with no visible sedimentary structure. GR log motif revealed upper shoreface sands with channels at the top. Although these sands are very coarse, they are poorlly sorted and this may significantly affect the quality of the reservoir.

The lower section of the L100 reservoir in Well 2 at a depth of 8550 ft is brownish, very fine to silty, slightly clayey, loosely consolidated with no visible sedimentary structure. The sands contains few pyrite, few carbonaceous matter and few calcareous sandstones. GR motif revealed a progadational pattern for the sands, and lower shoreface environment was inferred based on the high concentration of interbedded shales. The reservoir also revealed a funnel shaped GR motif for the lower section of the L100 reservoir sand, indicating lower shoreface depositional environment.

IV. CONCLUSION

Three reservoirs have been mapped across seven wells within the Kanga Oil Field Onshore Niger Delta. The sedimentological analyses revealed that the grain size ranges from coarse, medium to very fine, and four lithofacies have been interpreted as as upper shoreface, lower shoreface channel sand, and shale is a reflection that the sediments has been deposited in medium to low energy environment which favors the deposition of fine to medium grains sediments.

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