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Petrophysical Studies of Reservoir A&B of Kolo Creek Field, Onshore, Niger Delta

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Abstract-Petrophysical properties and reservoir fluid volume is used as a tool for qualifying and quantifying hydrocarbon reserve. This model proves applicable in current reservoir simulation and evaluation practices which enhanced better reservoir performance. The technique and the work flow applied in this research have direct implication for understanding similar reservoir system in the Niger delta fields. Fault mapping, modelling and horizon mapping was carried out, then 3D reservoir grid was generated. Petrophysical parameters were estimated by the use of equation models from the Gamma Ray Log (GR), Resistivity Log (LLD), Density Log (RHOB), Neutron density. Reservoir A is within a depth range of 11764.82ft-11919.29ft and has a net thickness of 88.11. With a very good porosity of more than 20% and an excellent interconnection of the pore volume, It has quality reservoir character that will ensure an excellent flow path for hydrocarbon fluid which is good for an easy and economical recovery mechanism. Reservoir B with a NTG of 0.55, very good porosity and excellent permeability shows similar trend to reservoir A. Volumetric results shows both reservoir sands has good productivity.

Keywords- *Simulation, Productivity, Petrophysical, Structural, Reservoir*

I. INTRODUCTION

In reservoir studies emphasis is given to the characterization that can be used to evaluate how easy a quantity of hydrocarbon is recoverable and producible. For instance, if recovering reservoir fluid is considered, then the reservoir character such as porosity and permeability becomes the focal point.

Modern reservoir characterization has become extremely important to oil companies since its arrival (Amogu, 2011). On the petrophysical evaluation of reservoir sands, Ulasi et al (2012), Omoboriowo et al. (2012), Rotimi et al. (2013), Alao et al. (2013) and Mode et al. (2015) have independently investigated some wells in south eastern onshore part, in eastern onshore part and central part of the Niger Delta basin respectively, and noted that the petrophysical properties of the reservoir sands of the Niger Delta are high enough to permit hydrocarbon production. Keelan (1982) discussed the variety of measurement protocols, characterized certain rock properties such as porosity, permeability, grain density, and capillary pressure, and showed how these properties varied with the geological factors such as the environment of deposition. Log motifs were used to describe the paleo environment of deposition for hydrocarbon bearing sands in areas (Rider, 2002). He noted that the shape of gamma ray and spontaneous potential logs though non-unique are reliable for indicators of prevailing lithologies. Selley (1976), proposed a relatively simple method to distinguish clastic depositional environment using the gamma ray curve and the presence or absence of glauconite and carbonoceous material.

According to John W Kramers (2010), Reservoir characterization is the development of a detailed understanding of the reservoir, how it is put together and how it reacts to the production strategy. The ultimate goal of an Exploration and Production (E&P) company in the oil industry is to explore and produce hydrocarbon in an economic, safe and environment friendly manner. In other words, the purpose of being in the oil and gas business is to maximize the Net Present Value (NPV) of the asset. As the energy demand of the world continues to grow due to improved standard of life associated with technological advancement and breakthroughs, so also are the challenges associated with exploration and development of new fields, especially because most of the easy-to-find hydrocarbon reserves have already been discovered.

This study aim at evaluating petrophysical properties that will explain the fluid distribution and type, total volume of hydrocarbon in place as a tool that can be used for static simulation modeling. The area under consideration lies within the onshore depobelt of the Niger Delta Basin, where thick Late Cenozoic Clastic sequence of Agbada Formation were deposited in a deltaic fluvio-marine environment.

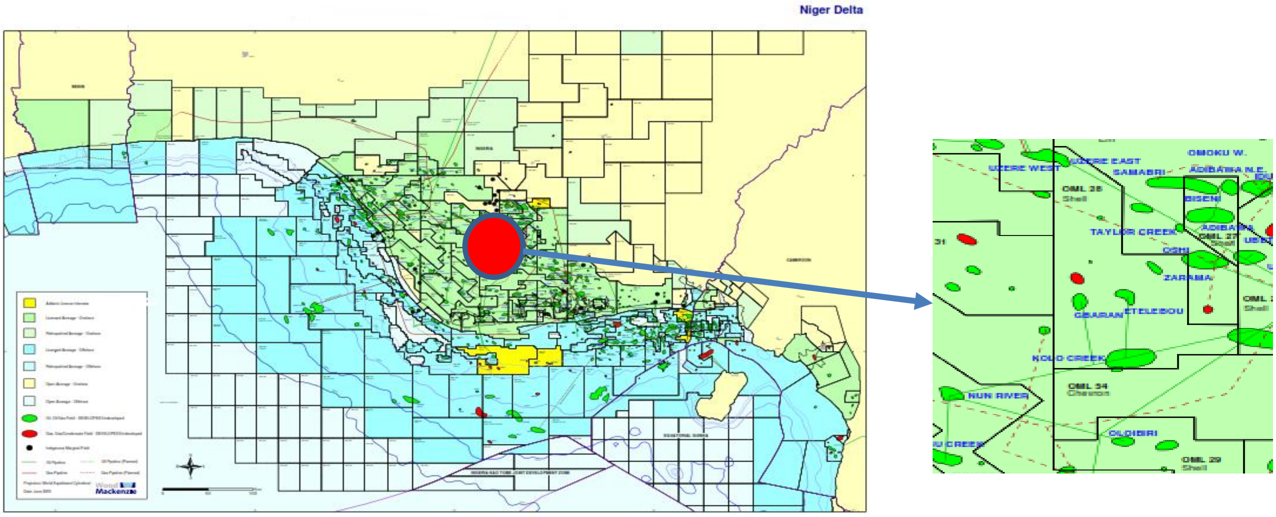

Figure 1. Showing map of the study area

II. GEOLOGICAL SETTING OF THE STUDY AREA

The Niger is situated in the Gulf of Guinea and extends throughout the Niger Delta Province. From Eocene to the present, the delta has prograded southwestward, forming depobelts that present the most active portion of the delta at each stage of the development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000km^2 (Kulke, 1995), a sediment volume of 500,000km^3 (Hospera, 1965), and a sediment thickness of over 10km in the basin depocenter (Kaplan etal, 1994).

The onshore portion of the Niger Delta is delineated by the geology of southern Nigeria and southwestern Cameroon. The northern boundary is the Benin Flank, an East-Northeast trending hinge line South of the West Africa basement massif. The North-Eastern boundary is defined by outcrops of the cretaceous on the Abakaliki High and further East-South-East by the Calabar Flank, a hinge line bordering the adjacent Precambrian.

The offshore boundary of the Niger Delta is defined by the Cameroon volcanic line to the East, the eastern boundary of the Dahomey Basin (the eastern-most West African transform-fault passive margin) to the west, and the 2km sediment thickness contour.

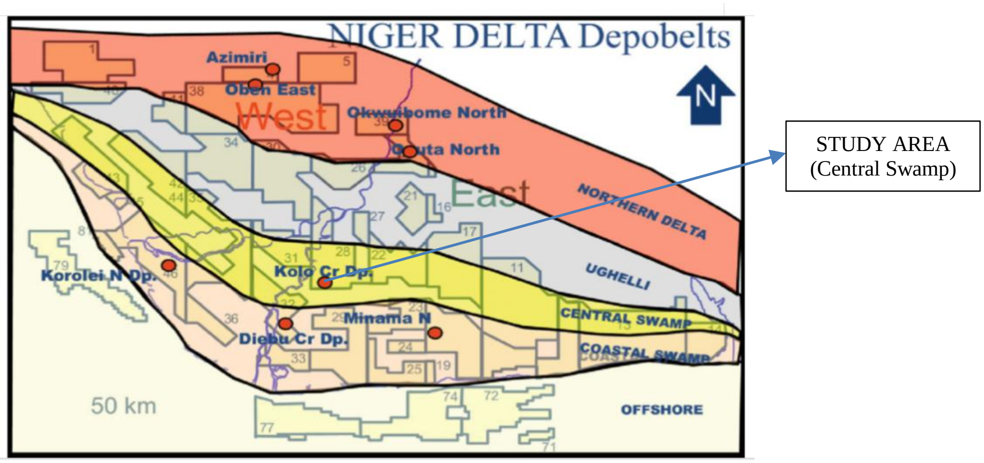

Figure 2. Niger delta depobelt, (Onikoyi et al, 2014) indicating the study area

III. METHOD

A. The reservoir modelling work flow

The reservoir modelling proceeds in three stages. The stages consist of fault mapping and modelling, horizon mapping (horizon are usually tied with well tops before being mapped) and building of a simple 3D reservoir grid.

B. Petrophysical evaluations

Petrophysical evaluation was based mostly on logs. These well logs were adequately digitized by reading the values form each of the respective tracks. Petrophysical parameters were estimated by the use of equation models (see table 3) from the following types of well logs that were obtained from Nigeria Petroleum Development Company (NPDC):

- Gamma Ray Log (GR).
- Resistivity Log (LLD)
- Density Log (RHOB)
- Neutron density

IV. RESULTS AND INTERPRETATION

From available well logs from two wells (KOCR-025 and KOCR-029), Sand A and Sand B show coarsening upward sequence which suggest a high energy deposition system. The transgressive sand at the top and prograding sand at the bottom of reservoir B inferred deltaic to clastic marine depositional environment. The delta border progradation coarsening upward sequence of reservoir A indicate deltaic and fluvial positional environment.

A. Petrophysical Evaluation

The sands (reservoir A and B) were evaluated using available well logs, to determine petrophysical properties. Petrophysical interpretation was based on the use of equation models to calculate parameters such as, porosity, permeability, Net-to-Gross ratio, hydrocarbon saturation. Equation models used for petrophysical evaluations for this research are presented in table1.

B. Volumetrics

Reservoir A and B hydrocarbon volume was estimated in kolo creek field, from seismic and well log data. Reservoir area estimated from the reservoir surface that was initially calculated from the mapped horizon (structural analysis of the seismic data). See fig 6. Table 3 shows equation model used for the volumetric estimation. Time structural map in fig 8 exhibits to a great extent the display in fig 6.

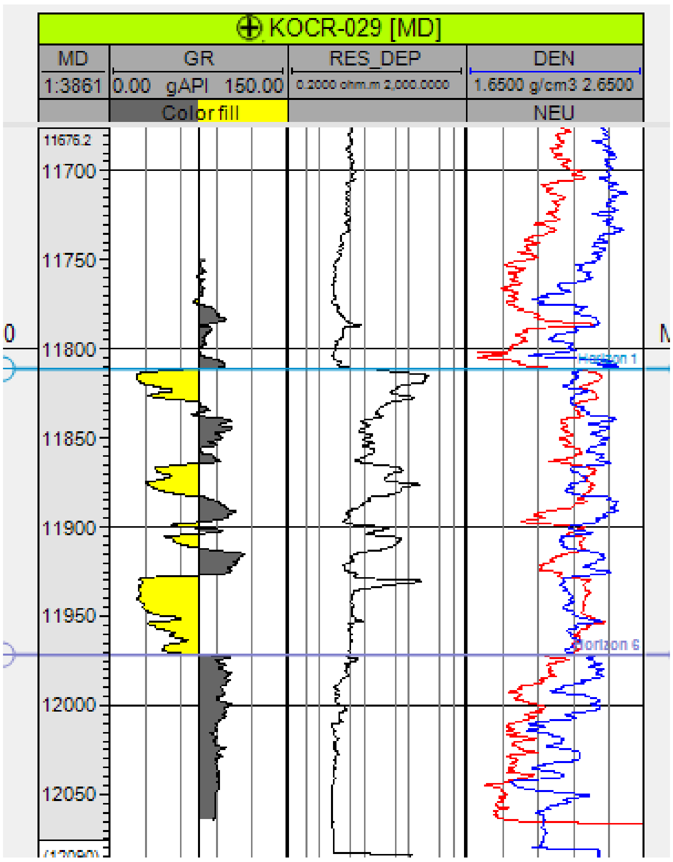

Figure 3. The use of neutron-density log tool to indicate a single phase (oil) reservoir A

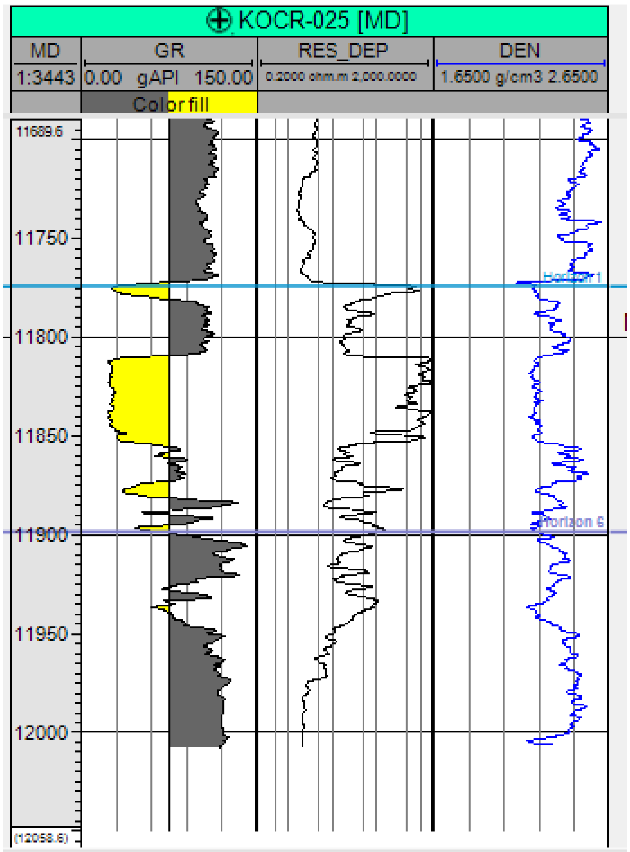

Figure 4. Use of resistivity and density tool to illustrate a high saturation hydrocarbon reservoir "B"

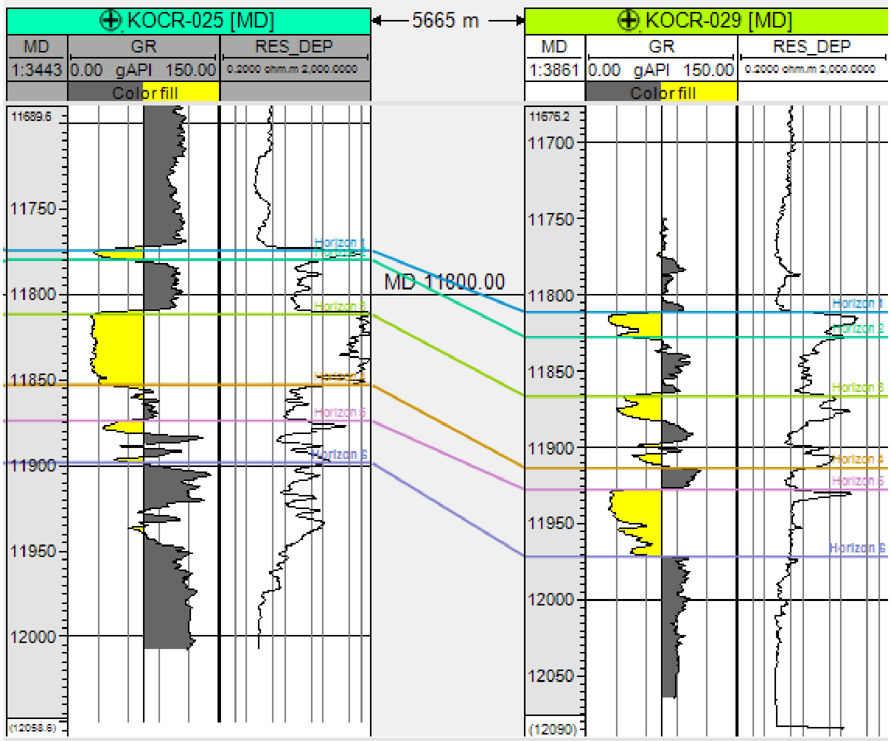

Figure 5. Correlated sand A and B in the Kolo creek field

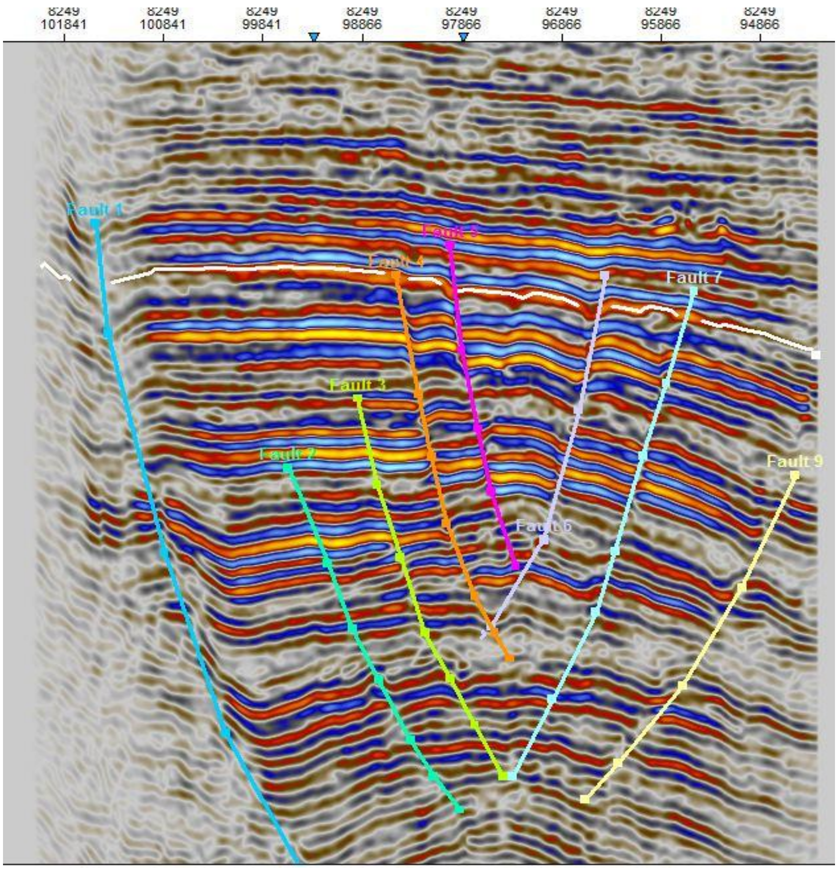

Figure 6. Structural analysis of the reservoir in Kolocreek field

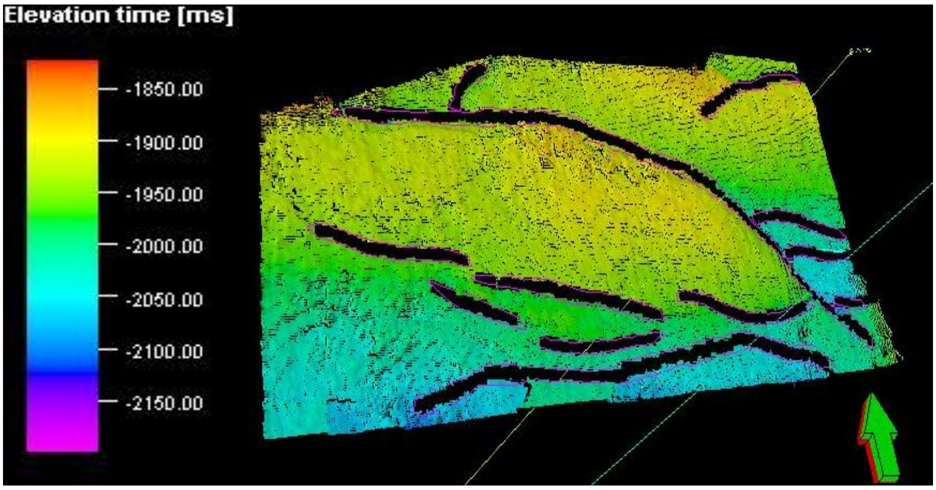

Figure 7. Fault and horizon grid model

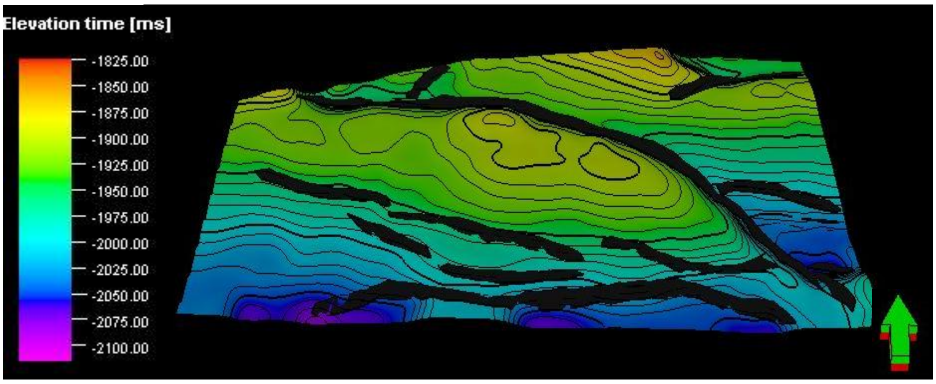

Figure 8. Time structural map

TABLE I. EQUATION MODELS USED FOR PETROPHYSICAL AND VOLUMETRIC EVALUATION (BOB HARRISON, LONDON RUSSIAN STYLE. 1995)

No.	Equation	Source
1	$IGR = \frac{GRlog-GRmin}{GRmax-GRmin}$	
2	$Vsh = 0.083(2^{3.71IGR}-1.0)$	Larionov equation, (1969)
3	$\Phi_D = \frac{\rho ma-\rho b}{\rho ma-\rho f}$	
4	$\Phi_{eff} = (1-Vsh)* \Phi_D$	(Bob Harrison, London Russian Style. 1995)
5	$S_w = \frac{0.082}{\Phi D^2}$	(Udegbunam, et al 1988)
6	$F = \frac{0.62}{\emptyset_D{}^{2.15}}$	
7	$Swirr = \sqrt{\frac{F}{2000}}$	
8	$K=307+26552\Phi^2-3450(\Phi_{Swirr})^2$	
9	$STOIIP = \frac{7758Ah\Phi(1-s_{wirr})}{B_{oi}}$	
10	$G = \frac{43560Ah\Phi(1-s_{wirr})}{B_{gi}}$	

TABLE II. PETROPHYSICAL RESULT SUMMARY

Sand	Well	Top(ft)	Base(ft)	H(ft)	Netsand(ft)	NTG	φ(ave)	K(ave)	S_w(ave)
A	KOCR-029	11764.82	11919.29	154.47	88.11	0.57	0.20982	1546.733	0.401
B	KOCR-025	11773.75	11896.52	122.77	67.25	0.55	0.216	1617	0.3982

TABLE III. VOLUMETRIC RESULT SUMMARY

Sand	Well	STOIIP	GIIP
A	KOCR-029	1025000000	
B	KOCR-025	779649198	4377612668

From table 2, we see that Sand A is within a depth range of 11764.82ft-11919.29ft and has a net thickness of 88.11. With a very good porosity of more than 20% and an excellent interconnection of the pore volume, Sand A has shown to exhibit quality reservoir character that will ensure an excellent flow path for hydrocarbon fluid which will ensure an easy and economical recovery mechanism. Sand B with a NTG of 0.55, very good porosity and excellent permeability shows similar trend to Sand A. Volumetric results shows both reservoir sands has good productivity.

V. CONCLUSION:

The 3D Grid horizon and reservoir model (Fig 7) presented in this study illustrated a structural analysis work flow which is applicable to structural deep play for detailed fault and seal analysis. Petrophysical and volumetric evaluation made, played by the equation models in table1, re-emphasized the use of petrophysical parameters to accurately qualify and quantify a hydrocarbon reserve which is applicable to well control studies.

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