Journal of the Nigerian Association of Mathematical Physics
Volume **18 (May, 2011), pp 157 – 164**
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Petroleum Potentials and Well Log Evaluation from Niger Delta Basin

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Abstract

It has being shown that the Niger Delta Basin has spectacularly maintained a thick sedimentary apron and certain petroleum geological features favourable for petroleum generation. This study reports the petroleum potential and well log evaluation of logs in three wells to characterize the reservoir sand bodies. The well log types used for quantitative analysis include resistivity, density and neutron logs. The gamma ray (GR) and calliper logs were mainly used for lithological identification and hole-washout detection respectively. Sandstone reservoir was determined from GR logs, while the well porosities were estimated with two complimentary techniques: Statistical and deterministic. The statistical estimation of porosity was done using a multi-mineral evaluation module in the PP evaluation application. The flow zone indicator method was used for permeability modelling. Archie equation was used go determine water saturation. The result revealed three wells contain four (4) different reservoir levels. The gamma ray and the resistivity logs show the porosities of the reservoir sand which averaged between 22-28%. Water saturation was generally low ranging between 0.14 - 0.19, while permeability values ranged from 0.005-0.035 (K MD). The general field report and well history in the study area shows that various pools have being produced overtime. The volume estimates of 2.54-43.90 MMBO for different reservoir intervals represent a deterministic STOIIP which could be produced with a water drive recovery mechanism since most reservoirs have effective aquifer system.

1.0 Introduction:

Petroleum exploration in Nigeria began as far back as 1908.The first commercial oil discovery was made at Oloibiri in 1956 (Ekweozor and Daukoru, 1994) and since that time, petroleum has played a progressively prominent role in the social and economical development of Nigeria.

Today, petroleum resources account for about 98% of the national economy. Nigeria is ranked 3rd in OPEC and in terms of oil production, (Wikipedia, 2010). The knowledge of reservoir dimension is an important factor in quantifying producible hydrocarbon (Schlumberger, 1989). Precise determination of reservoir is best obtained on well logs especially using the gamma ray and resistivity logs (Asquith, 2004). Because almost all oil and gas produced today come from accumulation in the pore spaces of lithology like sandstone, limestone or dolomites, the gamma ray log can be of much help in lithology identification i.e. to differentiate between the reservoir rock (sandstone) and the embedding shale. The resistivity logs on the other hand can be used for determining the nature of interstitial fluid i.e. differentiating between saline water and hydrocarbon in the pore spaces of the reservoir rocks. Since logs are recorded against depth, the hydrocarbon bearing interval can be determined.

In mapping hydrocarbon reservoir, studies of geologic structures that can hold hydrocarbon in place must be considered. Hydrocarbons are found in geologic traps i.e any combination of rock structure that will keep oil and gas from migrating either vertically or laterally (Wan Qin, 1995). These traps can either be structural, stratigraphic or a combination of both. According to Short and Stauble (1967), majority of the traps in the Niger Delta are structural, and to locate them, horizons are picked and faults mapped on seismic inline and cross lines to produce the time structure map.

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CONDITION FOR PETROLEUM OCCURRENCE

There are a number of basic conditions that have to be met for petroleum to occur in the subsurface. These include:

1. A sedimentary basin for the sediments to be deposited.
2. A source rock of mature age for the hydrocarbon to be generated.
3. A reservoir rock for the hydrocarbon to be hosted.
4. A migration path for the hydrocarbon to be moved from the source rock into the reservoir rock.
5. A cap rock or seal for the hydrocarbon to be trapped.

OIL OCCURRENCE IN THE NIGER DELTA BASIN

In Nigeria, there are several sedimentary basins namely; Niger Delta, Benue Trough, Chad-Bornu, Sokoto, Nupe, Dahomey basins e.t.c. However, the only basin in Nigeria that has being proven to be associated with economic hydrocarbon occurrences is the Niger Delta Basin (Frost, 1997). Three major depositional environments typical of most delta environment (marine, mixed and continental) are observable in the Niger Delta and are represented by Benin, Agbada and Akata formation. The Benin formation is over 90% sandstone with shale intercalations, it is continental in origin. The thickness of the formation generally exceeds 2000m. The Agbada formation is a sequence of sandstone and shale beneath the Benin formation; it is over 3000m thick. Major hydrocarbon accumulations are found within this formation. The Akata formation is the lowest unit with a uniform shale development. Thin sandstone lenses occur near the contact with the overlying Agbada formation. It is rich in microferna and is believed to be the major source rock, which generates the hydrocarbon that is found in the Niger Delta Basin.

A typical seismic section of Niger Delta will reveal a number of synsedimentary structures resulting from the deltaic tectonic. The structures include growth faults, which are normal faults characterization by a concave fault plane resulting from the decrease of dip at depth. The growth index will be equal to unit thickness in down thrown block divided by unit thickness in the up thrown block and its value varied from 1 – 2.5. Rollover anticlines are associated to growth faults and result from dragging of the down dip block against the fault plane. Antithetic faults are synsedimentary structures but with a counter dip. Back to back structures are limited by the growth fault and antithetic fault. Clay ridges are located on the continental slope and their deepening increase rapidly inside the delta where only their crest is visible on the seismic section (Balarabe, 2003).

MATERIALS AND METHODS

The data used in this study includes digital suites of well logs and seismic sections obtained from the study area. The relevant wireline log signatures were employed to identify hydrocarbon bearing reservoirs, while reservoir petrophysical parameters like porosity, permeability, water saturation e.t.c were computed and documented (see table 1) using different relevant mathematical equations as shown below.

The gamma ray (GR) values were obtained from the expression for shale volume; V_{sh} given as;

$$V_{sh} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$$

i.e

$$GR = V_{sh}(GR_{max} - GR_{min}) + GR_{min}$$

Where V_{sh} represents the shale volume

GR is the gamma ray log reading

GR_{max} represent the gamma ray log reading in shale zone

GR_{min} represent the gamma ray log reading in clean sand zone.

The Laterolog Deep (LLD) and the Laterolog Shallow (LLS) were the two resistivity logs used, out of the usual three independent resistivity log measurements that are required to eliminate the effects of the invaded zone and determine the true formation resistivity. The LLD penetrates deep into the reservoir and is hardly influenced by borehole, mud cake and invaded zone. It usually reads the resistivity of the un-invaded reservoir rock (R_o or R) or virgin zone. Whereas, the LLS penetrates shallow into the reservoir and measures the invaded zone resistivity. It is significantly influenced by the borehole, mud cake and the invaded zone or the intermediate zone. It can be used to correct the LLD when necessary.

The Formation Resistivity Factor (FRF) also called the formation factor, F was computed using

$$F = {}^{a}/_{\phi^m}$$

where

a is a constant related to texture. Its value was assumed to be 0.62 for sandstone.

ϕ represents the total porosity of the formation.

m is equal to the cementation factor.

The water saturation level of was calculated from the Archie's equation as stated below.

$$R_t = \frac{R_w}{\phi^m {S_w}^n}$$

that is,

$$ {S_w}^n = \frac{R_w}{R_t \phi^m}$$

this implies that

$$S_w = \sqrt[n]{\frac{R_w}{R_t \phi^m}}$$

where;

R_t is the true formation resistivity or the total resistivity of the Hc formation
S_w represents the water saturation level
n is the saturation exponent, which describes the geometry of the current flow path through the water body in the presence of hydrocarbon (electrical insulators).
ϕ is the total porosity
m is the cementation exponent, while
R_w represent the water resistivity.

The permeability values were computed from Darcy's equation

$$q = \frac{KA}{\mu} \times \frac{dp}{dx}$$

i.e

$$K = \frac{q\mu}{A(\frac{dp}{dx})}$$

where;

q is the volume flux for horizontal flow in cm/s
K is the permeability constant in Darcys
A is the cross sectional area in cm^2
μ is the fluid viscosity in centipoises
$\frac{dp}{dx}$ is the hydraulic gradient (i.e. a change in pressure in the *x* direction of flow) in atm/cm.

The porosity values were computed using the equation

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

where;

ϕ is the porosity
ρ_{ma} is the matrix density
ρ_b is the bulk density
ρ_f is the fluid density

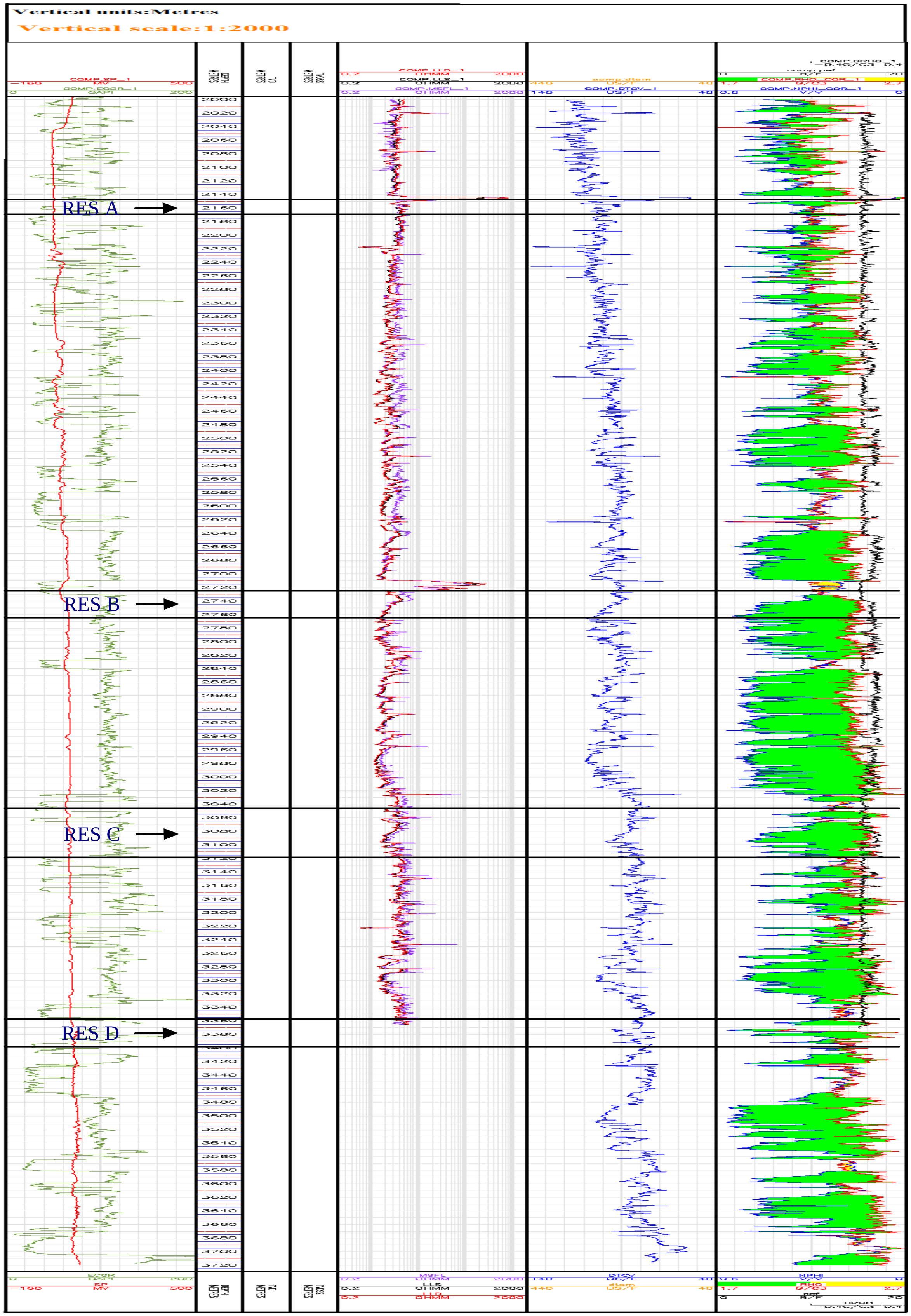

Fig. 1: Composite Log for Well 1

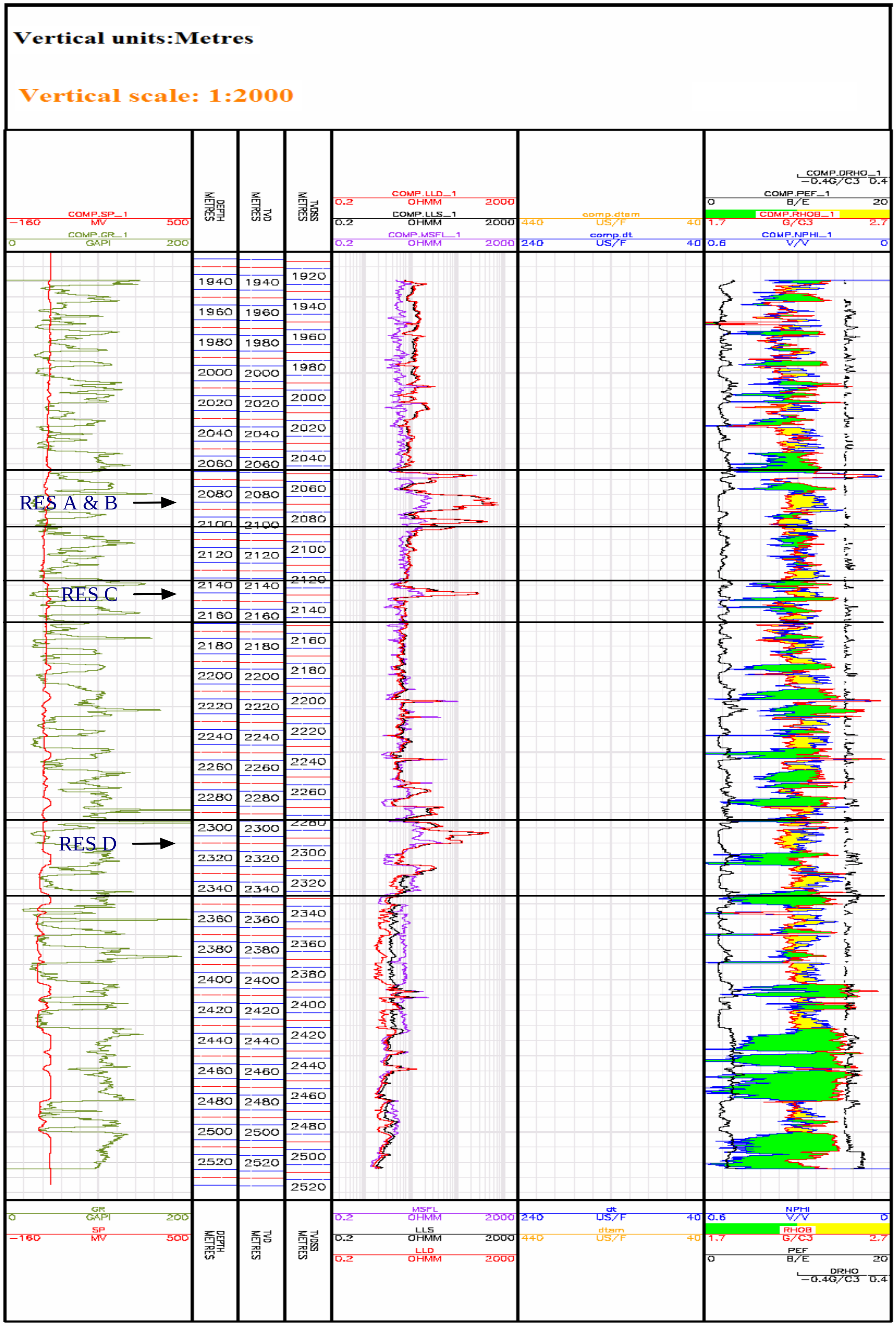

Fig. 2: Composite Log for Well 6

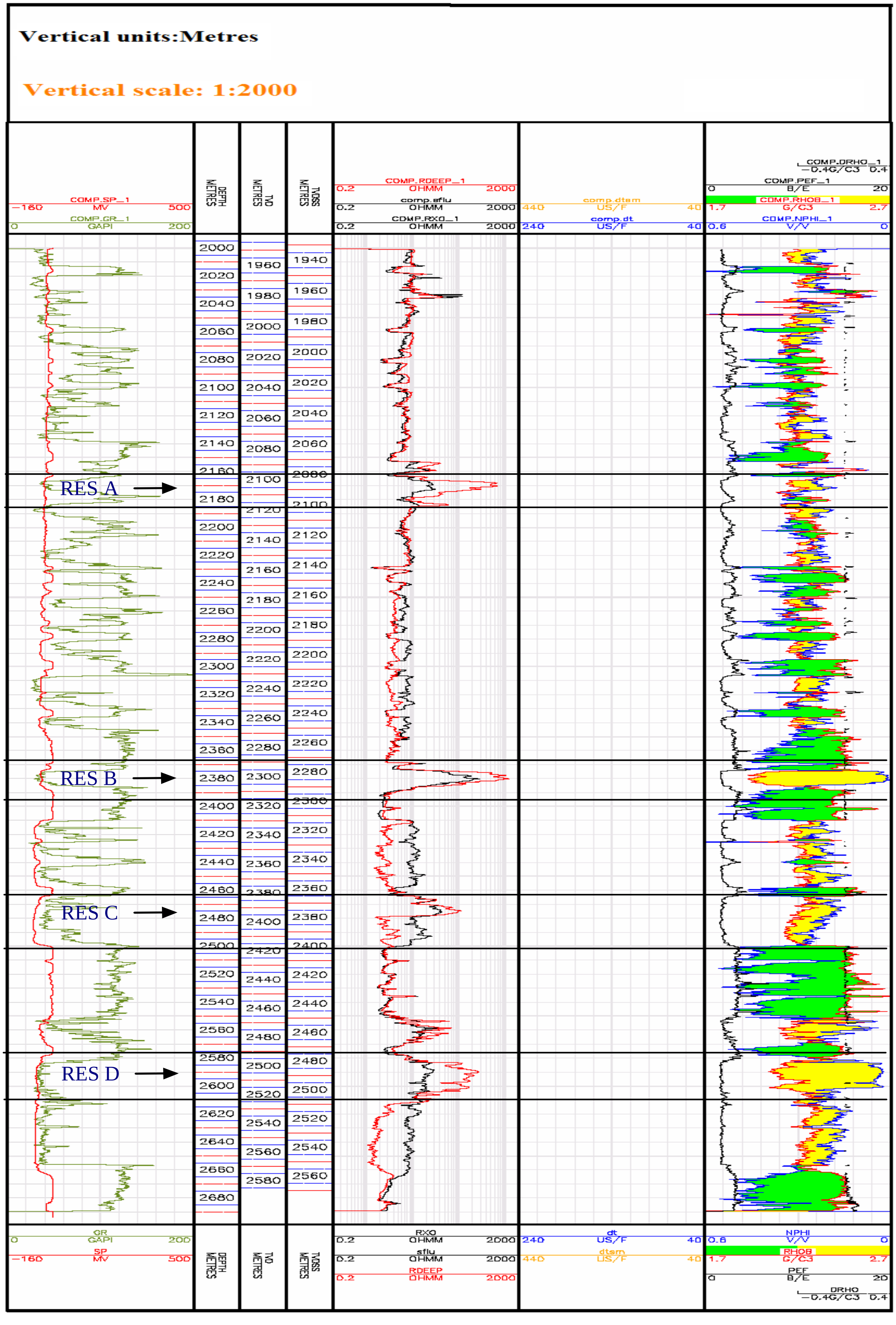

Fig. 3: Composite Log for Well 8

RESULTS AND DISCUSSION

Results of the three well logs obtained in this study are presented in Figures 1, 2 and 3 above. While summary of results of the petrophysical parameters obtained in this study are presented in table 1. The well results presented in Figures 1, 2 and 3 revealed four (4) different reservoirs levels which are marked as A, B, C and D respectively for easy identification and occurred at different depths. From the presented petrophysical results in Table 1, the gamma ray (GR) and the resistivity logs show the porosities of the reservoir sand which averaged between 22-28%. Water saturation was low ranging between 0.14-0.19, while the permeability values ranged between 0.005-0.035 (K MD). The general field report and well history in the study area shows that various pools have being produced overtime. A volume estimate of 2.54 - 43.90 MMBO (Million barrels of oil) for different reservoir intervals represent a deterministic STOIIP (Stock tank oil initially in place) which could be produced with a water drive recovery mechanism since most reservoirs have effective aquifer system.

TABLE 1: SUMMARY OF RESULTS OF ESTIMATED PETROPHYSICAL DATA

	Reservoir (RES) Level	**GR**	**LLD**	**LLS**	**RHOB**	**NPHL**	**FRF**	**Porosity Φ (PHIT) (%)**	**Φ Avg (%)**	**Water Sat. (Sw) Archie**	**Perm (K MD)**
WELL 1	A	11.00	36.30	34.00	29.96	12.98	3.12	27	24	0.17	0.009
	B	26.90	62.90	60.70	69.92	28.49	2.47	27		0.15	0.018
	C	12.90	35.20	34.80	41.78	18.53	2.47	24		0.16	0.018
	D	12.65	35.80	35.40	44.55	15.68	2.14	19		0.15	0.028
WELL 6	A	83.00	62.30	60.10	36.92	20.61	3.72	26	25	0.19	0.005
	B	104.50	74.54	72.78	35.84	21.03	3.13	26		0.17	0.008
	C	185.80	71.87	70.02	37.26	23.75	2.00	21		0.14	0.035
	D	393.80	131.55	130.00	80.15	47.58	2.47	25		0.16	0.018
WELL 8	A	77.50	34.80	32.50	26.34	12.51	3.72	22	23	0.19	0.005
	B	84.30	32.20	26.90	20.28	10.64	3.72	25		0.18	0.006
	C	304.30	75.70	82.56	72.17	33.38	2.14	20		0.15	0.025
	D	209.30	68.60	81.50	53.27	28.44	2.47	24		0.17	0.014

CONCLUSION

This work reveals that the computed porosities and water saturation are good enough for commercial hydrocarbon production. With the integration of good quality seismic and well log data to evaluate the subsurface petroleum potential, it is clear that hydrocarbon occurs in sandstone zone in the Niger Delta Basin, which has proved to be effective in appraising the limit of the reservoirs and also determine the remaining hydrocarbon volumes even with limited data. This work thus shows the cost effectiveness of integrating available information of seismic and log in the absence of high cost of cores and engineering data.

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