RESERVOIR CHARACTERIZATION USING SEISMIC AND WELL LOGS DATA
(A CASE STUDY OF NIGER DELTA)
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Abstract

During analysis, hydrocarbon saturation in relatively unconsolidated sandstone reservoirs is a pore fluid property that has been successfully mapped using seismic surveys. The presence of hydrocarbon typically lowers the seismic velocity and density of unconsolidated to moderately consolidated sandstone and this in turn create different acoustic impedance (product of density and seismic velocity). This study reveals the petroleum potential and attempt to make available Petrophysical results for the various reservoirs in three (3) selected wells as these results will help enhance the proper characterization of the reservoir sands. 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, V_{sh} was evaluated using linear and Steiber methods and Archie's equation was used in determining water saturation. The Petrophysical results reveal a good porosity (0.26 – 0.34), water saturation (0.09 – 0.32) and hydrocarbon saturation (0.77 – 0.83).

Key words: Reservoir sand, Well log, Water saturation, Linear and Steiber.

Introduction

Reservoir Characterization generally determine the gross volume within the trap that has the potential to hold hydrocarbons, the accuracy of reservoir estimation such as thickness and others Petrophysical parameters of each reservoir is a critical element in interpretation, estimation of reservoir properties such as Porosity, Water Saturation and others parameter from seismic and well logs data. During analysis, seismic data can quantitatively predict reservoir parameters; one of such basic step is to compare the seismic volume at the location of a well to the well's information often through the intermediary of a synthetic seismogram (a model seismic track derived from sonic and density logs). During analysis, efforts focus on estimating subsurface physical properties of rock units which are important in hydrocarbon exploration and exploitation. The knowledge of reservoir characterization is an important factor in quantifying producible hydrocarbon (Schlumberger, 1989). Precisely reservoir characterization can be obtained from well logs especially using gamma ray and resistivity logs (Asquith, 2004). In other to map hydrocarbon reservoir, studies of geologic structure that can hold hydrocarbon in place must be considered, since hydrocarbon in geologic traps i.e. combination of rock structure that will keep oil and gas from migrating either vertically or laterally. Due to the need to thoroughly evaluate prospects so as to determine optimal production strategies and also minimize risk that may be associated with hydrocarbon exploration has driven the development of an array of techniques which attempt to propagate log properties. One of such techniques in use is the deterministic and linear physical relationship between log properties and the corresponding seismic response of subsurface rock units (Muslim and Moses, 2011).

Well logs interpretation can be used in obtaining vital information and required properties, since a complete coring and core analysis of the entire pay zone is impractical.

A typical seismic section of Niger Delta will reveal 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 it value varies from 1 – 2.5. Rollover anticlines are associated to growth

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faults and result from dragging of the down dip block against the fault plane. Antithetic fault 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).

The aim of this paper is to use an integrated technique in computing various Petrophysical parameters, these techniques include using well log data and combining various mathematical equations (1 – 5) which ranges from the linear, non-linear (V_{sh} Stieber) and the Archie's equations. From the data use in computing the Petrophysical results such as the log data which consist of gamma ray, resistivity, density and neutron logs, the Stieber and Archie's equations were applied in carrying out Petrophysical evaluation such as the water saturation, porosity and the hydrocarbon saturation and the results obtained were summarized in (Table 1,2 and 3), this results will be compared with the recommendation results of random core samples from selected wells so as to establish and reduce interpretational errors.

Methodology
Study Area
The Niger Delta Basin is situated at the southern end of Nigeria boarding the Atlantic Ocean and extends from about Longitude 30^0 $00'E$ to $9^0 00'E$ and Latitude $4^0 3' N$ to $5^0 20' N$ (Lambert, 1981).
Geology
It is the youngest sedimentary basin within the Benue trough system. The Niger development began after the Eocene tectonic phase, having the Niger and Benue Rivers as is main supplier of sediments. Three lithostratigraphic units are distinguishable in the Tertiary Niger Delta. The Akata formation which is predominantly marine prodelta shale is overlain by the paralic sand/shale sequence of the Agbada Formation. The upper most section is the continental upper deltalic plain sands – the Benin formation. Virtually all the hydrocarbon accumulations in the Niger Delta occur in the sands and sandstones of Agbada formation where they are trapped by rollover

anticlines related to growth fault development (Ekweozor and Dankoru, 1994).
Reservoir Rocks
We can define reservoir rock as one that has porosity and permeability that allows it to contain a significant amount of extractable hydrocarbon. Petroleum reservoir in the Niger Delta is produced from sandstone and unconsolidated sands predominantly in the Agbada formation. The characteristic of the reservoirs in the Agbada formation are controlled by depositional environment and the depth of burial (known) reservoir rocks are Eocene to Pliocene (Evamy *et al.*, 1978). Hydrocarbon are found in reservoir rock, that is, any combination of rock structure that will keep oil and gas from migrating either vertical or laterally (Wan Qin, 1995), majority of the traps in Niger Delta are structural and to locate, horizons are picked and faults mapped on seismic inclines and crosslines to produce the time structure map. For there to be petroleum accumulation a set of geological circumstance is needed for the accumulation of Oil and Gas to recapitulate, these are;
(1) A migrations route for the hydrocarbon to move from the source to the traps.
(2) The existence of a suitable trap structure.
(3) Burial of the source rock to maturity.
(4) The trinity of source, reservoir and seal rocks.
Sampling/Data Collection
The data used in this study consist of digital seismic data, a suit of well logs; the well logs suite consists of Gamma ray, Resistivity, Neutron and Density logs which will be used in evaluating Petrophysical properties such as Hydrocarbon saturation (H_{c_sat}), Porosity (Φ), Water Saturation (S_w) and Water Resistivity (R_w). The Gamma ray and Resistivity logs are use in determining the reservoir zones and the presence of hydrocarbon. The details method applied are as follows;
V_{sh} from natural Gamma ray using Linear and Steiber Methods

(1) V_{sh} linear (V_{sh} _ gr _l) $= \dfrac{GR - GR_{CL}}{GR_{SH} - GR_{CL}}$ 1

(2) The above equation expresses V_{sh} linear with increase of gamma ray reading

Where;
GR = Gamma ray log reading in zone of interest (API units)
GR_{CL} = Gamma ray log reading in 100% clean zone
GR_{SH} = Gamma ray log reading in 100% shale

(3) V_{sh} Steiber (V_{sh} _gr_s) = $\dfrac{0.5 \times V_{sh\_gr\_l}}{1.5 - V_{sh\_gr\_l}}$ 2

From the above methods, the non-linear gamma ray (V_{sh} Steiber) will predict less V_{sh} than the linear method. The non-linear method is usually used in unconsolidated rocks since they are known to be more chemically immature and may contain radioactive minerals such as Feldspars which can contribute to gamma but unrelated to shale volume.

(4) The formation Resistivity Factor (FRF); also called the formation factor (F) was computed using

$$F = \frac{a}{\Phi^m}$$ 3

Where;
A = constant related to texture, its value is assumed to be 0.62 for sandstone
Φ = represent the total porosity of the formation
m = cementation factor

Perhaps the use of values of m = 2, a = 1 and n = 1.

(5) The water Saturation level is calculated using the Archie's equation as stated below

$$R_t = \frac{R_w}{\Phi^m S_w^n}$$ 4

That is,

$$S_w^n = \frac{R_W}{R_t \Phi^m}$$ 4.1

This implies that;

$$S_w = \sqrt[n]{\frac{R_w}{R_t \Phi^m}}$$ 4.2

Where;
R_t = the true formation resistivity or total resistivity of the hydrocarbon formation (H_c)
S_w = the water saturation level
n = the saturation exponent, which describes the geometry of the current flow path through the water body in the presence of hydrocarbon
Φ = the total porosity
m = the cementation exponent
R_w = the water resistivity

(6) The porosity values was computed using the below equation

$$\Phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$ 5

Porosity can also be evaluated from modified Archie's equation in the presence of shale (Schlumberger, 1989).

$$\frac{1}{R_t} = \frac{\Phi^m S_w^2}{aR_w(1 - V_{sh})} + \frac{V_{sh} S_w}{R_{sh}}$$ 5.1

Where;
Φ = porosity
ρ_{ma} = the matrix density
ρ_b = the bulk density
ρ_f = the fluid density
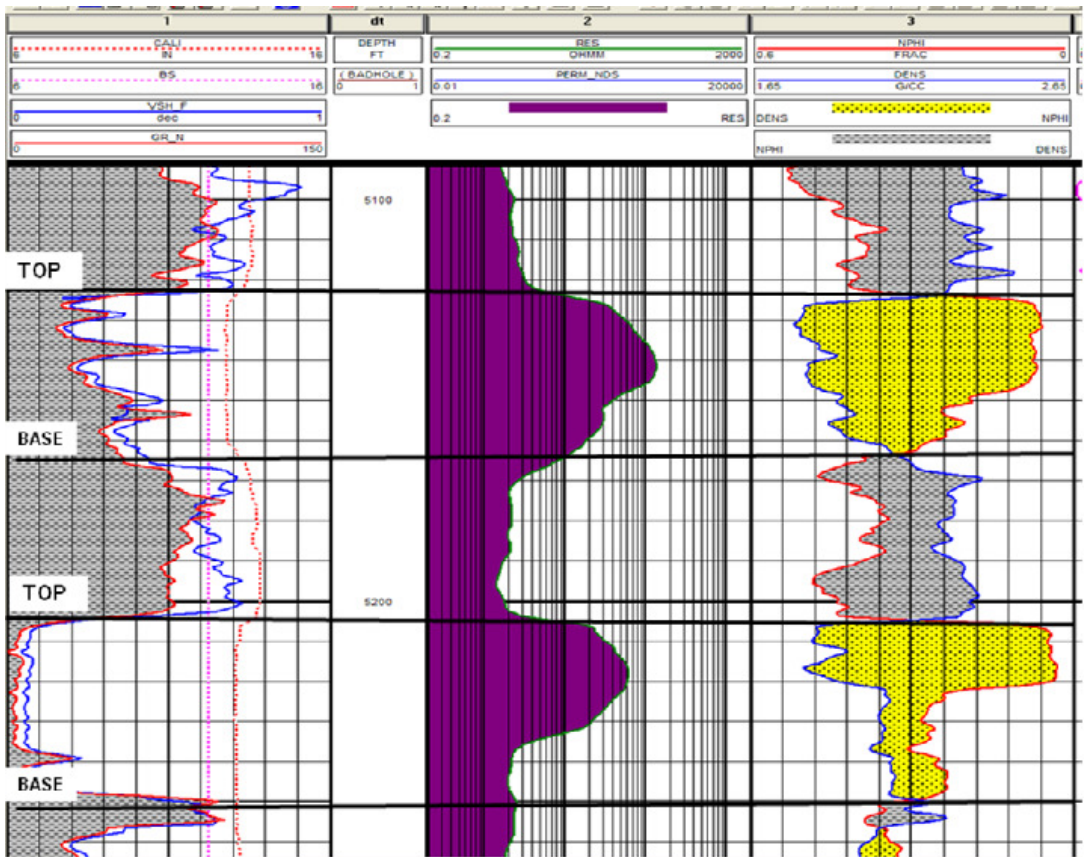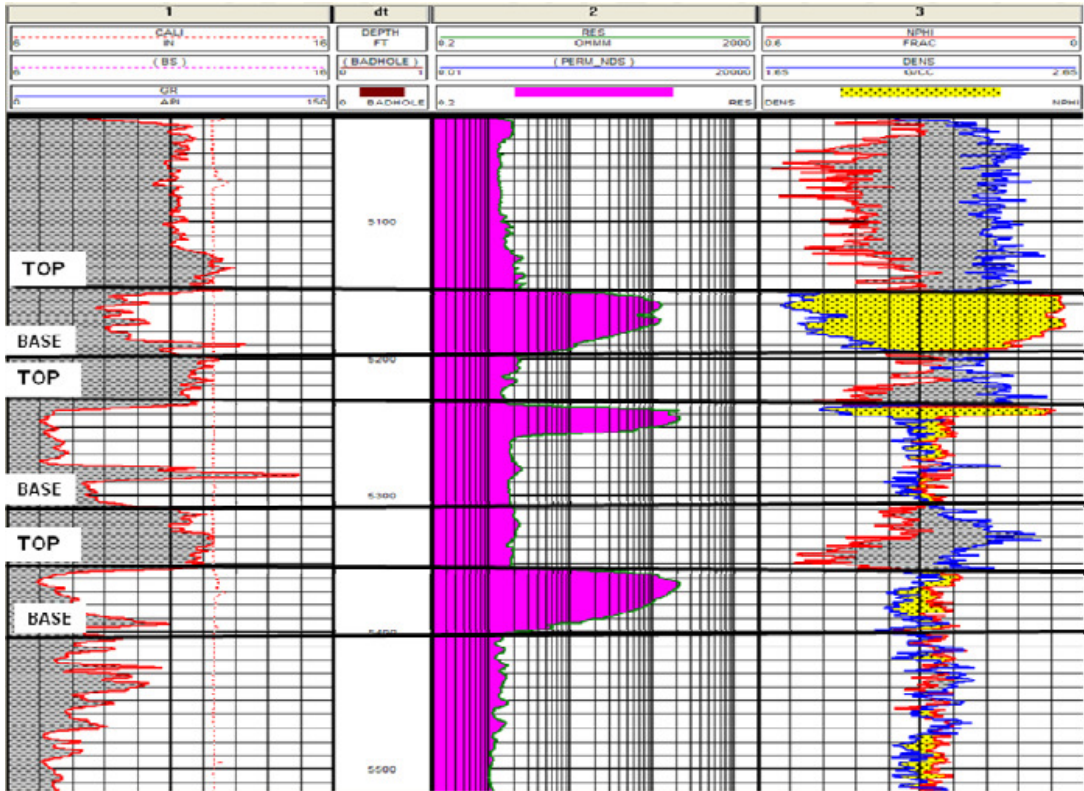R_t = formation resistivity
m = cementation factor
S_w = Water saturation
a = formation factor coefficient
R_w = formation fluid resistivity
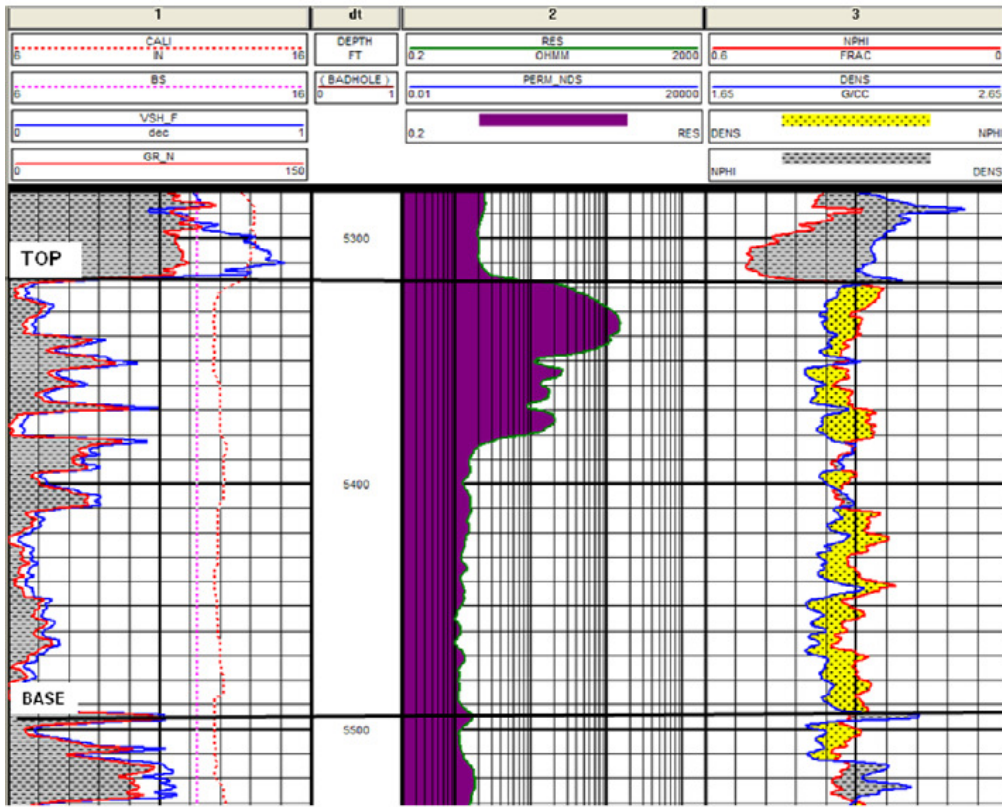V_{sh} = volume of shale
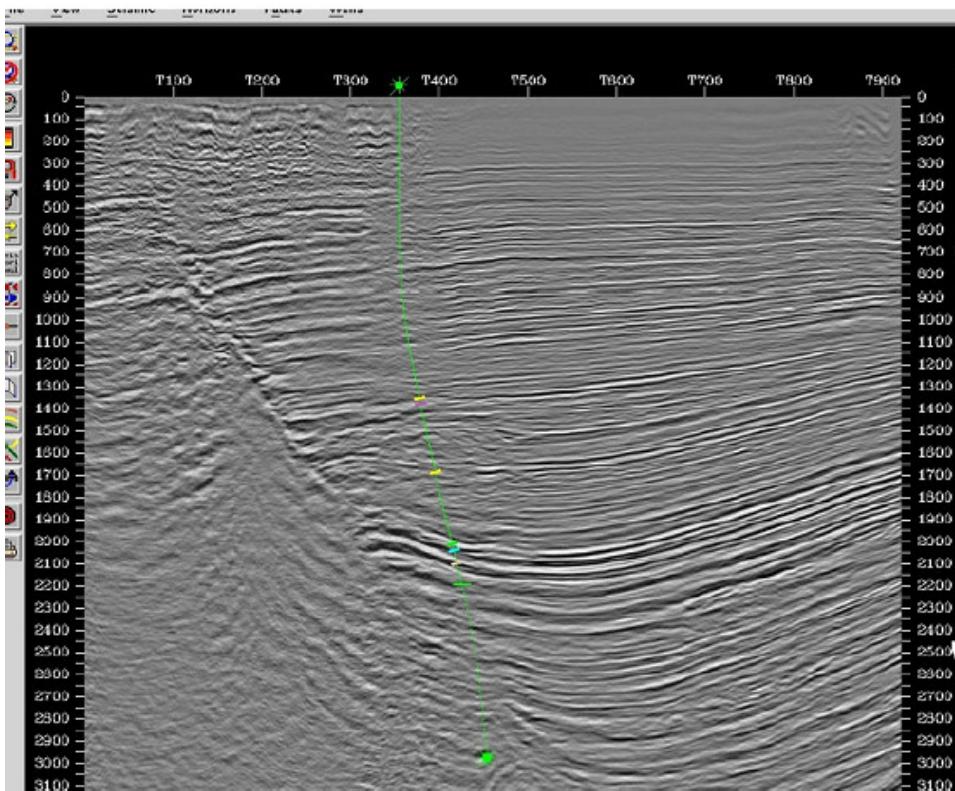R_{sh} = resistivity of the shale

Figure 1 Composite Log for Well 1

Figure 2 Composite Log for Well 2

Figure 3 Composite Log for Well 3

Figure 4 Siesmic Section Showing a Drilled Well

Table 1 Computed Petrophysical Parameters from Well 1

Well 1	Top (m)	Bottom (m)	Thickness (m)	GR	Density	Rt_den	Fluid_den	Phi	R_w	S_w	H_{c_sat}
	5150	5198									
A	5150	5160	10	63	1.80	200	0.2	0.347	0.324	0.104	0.896
B	5160	5168	8	58	1.85	200	0.2	0.323	0.324	0.110	0.890
C	5168	5170	2	60	1.87	200	0.2	0.318	0.324	0.113	0.889
D	5170	5194	24	62	1.81	30	0.2	0.345	0.324	0.272	0.728
E	5194	5198	4	86	1.90	8	0.2	0.306	0.324	0.324	0.416
			<u>48</u>								

Average Phi = sum of (Phi * Thickness) = $\frac{16.171}{48}$ = **0.337**
                                    Thickness

Average S_w = $\frac{3.677}{16.171}$ = **0.227**

Average H_c _ sat = $\frac{12.495}{16.171}$ = **0.773**

Table 2 Computed Petrophysical Parameters from Well 2

Well 2	Top (m)	Bottom (m)	Thickness (m)	GR	Density	Rt_den	Fluid_den	Phi	R_w	S_w	H_{c_sat}
	5233	5260									
A	5233	5238	5	33	1.85	300	0.2	0.327	0.324	0.090	0.910
B	5238	5245	7		1.90	297	0.2	0.306	0.324	0.096	0.904
C	5245	5260	15		2.07	50	0.7	0.290	0.324		

Average Phi = $\frac{8.126}{27}$ = **0.301**

Average S_w = $\frac{1.142}{8.126}$ = **0.175**

Average H_c _ sat = $\frac{6.707}{8.126}$ = **0.825**

Table 3 Computed Petrophysical Parameters from Well 3

Well 3	Top (m)	Bottom (m)	Thickness (m)	GR	Density	Rt_den	Fluid_den	Phi	R_w	S_w	H_{c_sat}
	5355	5400									
A	5253	5362	9	30	2.1	50	0.65	0.26	0.32	0.28	0.743
B	5362	5400	38	35	2.05	60	0.65	0.30	0.32	0.22	0.783
Water	5475	5510	35	30	2.05	2	1	0.36	0.36	-	-

Average Phi = 0.295
Average S_w = 0.224
Average H_c _ sat = 0.776

Results and Discussion

Evaluation and identifying reservoir zone is based on the ability of the interpreter to make use of available data in interpreting various parameters, attribute maps extracted on top of key horizons were used for better visualization and interpreting the morphological and reflectivity characteristics of the reservoir. The results of the interpreted well logs revealed that the hydrocarbon interval in the areas occur between the depth range of 5150 – 5198m for Well 1, 5233 – 5260m for Well 2 and 5353 – 5400m for Well 3.

The gamma ray and the resistivity logs shows that the reservoir are good quality reservoir sands with porosities averaging between 0.26 – 0.34, water saturation averaging between 0.09 – 0.32 and the hydrocarbon saturation averaging between 0.77 – 0.83 with thickness of the reservoirs sands ranging from 27 – 48m.well to seismic tie also reveal that the sands are hydrocarbon bearing reservoirs and has hydrocarbon indicators on seismic section. From the well logs used, (figure 1 – 3) and the results obtained (Table 1 – 3) reflects the reservoir zones and the Petrophysical parameters obtained from the well logs, from the well logs data it was noted that the reservoirs are separated by shales as these shales servers as seal to the reservoir.

Conclusion

For good Petrophysical analysis and reservoir evaluation of the subsurface reservoir, core samples should be taken randomly from well as this will help to establish Petrophysical parameters like permeability and other fluid densities in the various zone which will also be of better advantage in porosities evaluation. Quantitative porosity and water saturation values obtain from Petrophysical well log analysis are good enough for hydrocarbon production.

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