

## Petrophysical Properties Evaluation for Reservoir Characterisation of SEYI Oil Field (Niger-Delta)

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**ABSTRACT:** This paper presents results of a study conducted to determine and evaluate the petrophysical properties of "SEYI" oil field, Niger delta with a view to understand their effects on the reservoirs hydrocarbon prospect and oil productivity of the field. The evaluated properties include porosity, permeability, fluid saturation, net / gross thickness and mobility which are all inferred from geophysical wire-line logs. A suite of wire-line logs comprising of gamma ray, resistivity, spontaneous potential and density logs for four wells from 'SEYI' oil field were analysed for reservoir characterisation of the field. The analyses carried out involves delineation of lithologies, identification of reservoirs and fluid types, wells correlation and determination of petrophysical parameters of identified reservoirs. Seven reservoirs namely: A, B, C, D, E, F and G were delineated with their tops and bases at depth from 2396m to 3429m. Their analysis indicate the presence of hydrocarbon in all the reservoirs. Computed petrophysical parameters across the reservoirs gave porosity as ranging from 0.22 to 0.31; permeability 881.58md to 14425.01md and average hydrocarbon saturation of 41.44%, 20.29%, 30.82%, 37.92%, 51.20%, 91.97% and 85.11% for reservoir A, B, C, D, E, F and G respectively. These results together with the determined movable hydrocarbon index (MHI) values (0.05 to 0.75) of the reservoir units suggest high hydrocarbon potential and a reservoir system whose performance is considered satisfactory for hydrocarbon production.

**KEYWORDS:** Wells correlation, wire-line logs, hydrocarbon prospect, porosity, Niger Delta.

### 1 INTRODUCTION

The 'SEYI' oil field is located within the coastal swampy area of Niger delta, Nigeria (Figure 1). The petrophysics of any oil field include reservoir fluid properties and reservoir rock properties which could affect oil recovery and amount of oil production. These properties encompass porosity, permeability, fluid saturation, mobility among others. The successful evaluations of these properties are necessary for determining the hydrocarbon potential of a reservoir system performance and also help to predict the behaviour of complex reservoir situations.

To the reservoir engineering these parameters are important i.e. rock porosity and fluid saturations are the principal factor involved in determining the amount of oil and gas originally in place while permeability is a measure of the ease with which fluid flows through the pore spaces of rock [1]. Table 1 according to [2] provides an effective explanation of porosity and permeability description of reservoirs. The movable hydrocarbon index, MHI value specifies the movability condition of hydrocarbon in a reservoir during invasion.

In this study, the gamma ray (GR), spontaneous potential (SP), resistivity (LLD), and density (PHID) logs were analysed and interpreted in order to define lithologic units of prospective zones, differentiating between hydrocarbon bearing and non-hydrocarbon bearing zone(s), definition of reservoir geometry through well to well correlation and determination of the petrophysical parameters value of zones of interest (reservoirs) in the field such as porosity, permeability, movable hydrocarbon index, water saturation and hydrocarbon saturation.

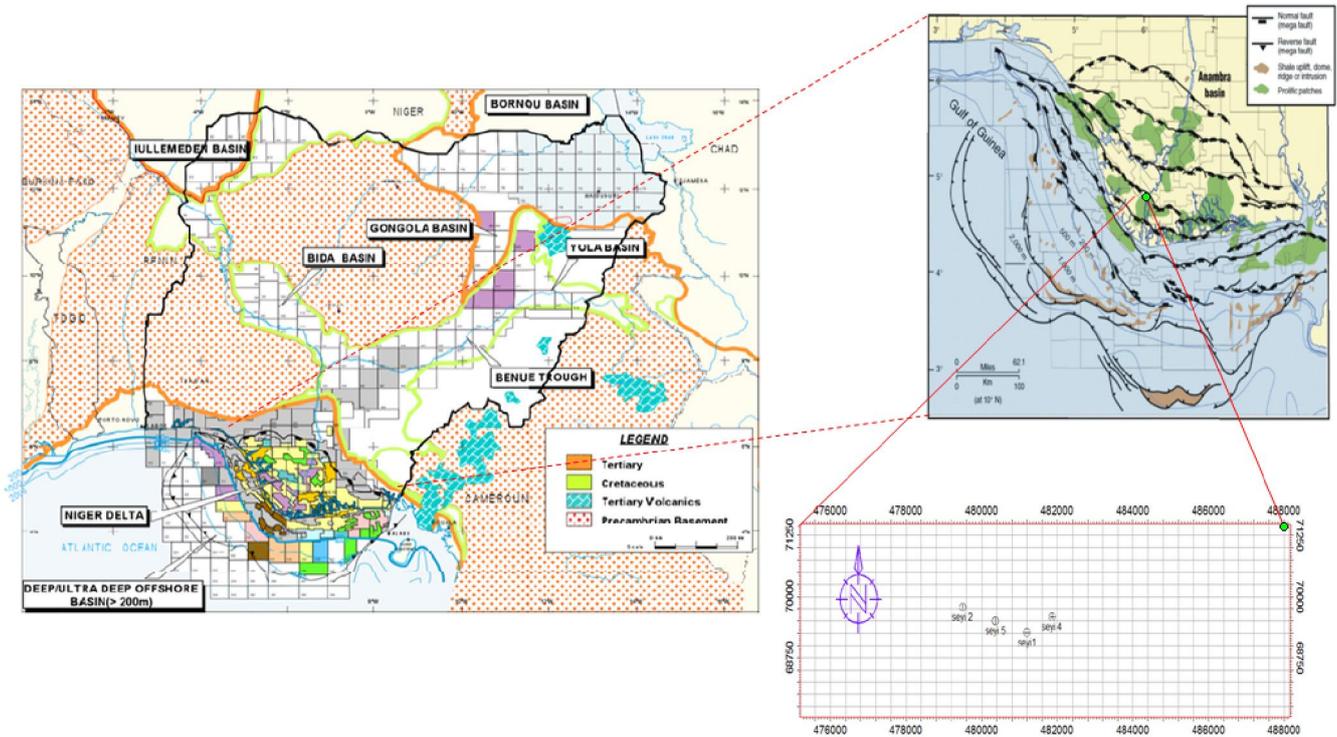


Fig. 1. Map of Nigeria Showing the Location of the Niger Delta and the Base map of study area showing the well locations

Table 1. Porosity and Permeability values for Reservoirs Qualitative Description (Adapted from Rider, 1986)

Qualitative Evaluation of Porosity	
Percentage Porosity (%)	Qualitative Description
0 - 5	Negligible
5 - 10	Poor
15 - 20	Good
20 - 30	Very Good
> 30	Excellent
Qualitative Evaluation of Permeability	
Average K_ Value (md)	Qualitative Description
< 10.5	Poor to fair
15 - 50	Moderate
50 - 250	Good
250 - 1000	Very Good
> 1000	Excellent

## 2 GEOLOGY OF THE STUDY AREA

The Niger Delta which extend between longitude 3<sup>0</sup> and 9<sup>0</sup>E and latitudes 4<sup>0</sup>30' and 5<sup>0</sup>20' N, covers an area of about 7500 km<sup>2</sup>. It is a large acute delta situated in the Gulf of Guinea (Fig.1). From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development [3]. These depobelts form one of the largest regressive deltas in the world. Its stratigraphy has been described in detail by [4] and [5] of which they recognized three lithostratigraphic units i.e. the Benin, Agbada and Akata Formations (Fig.2).

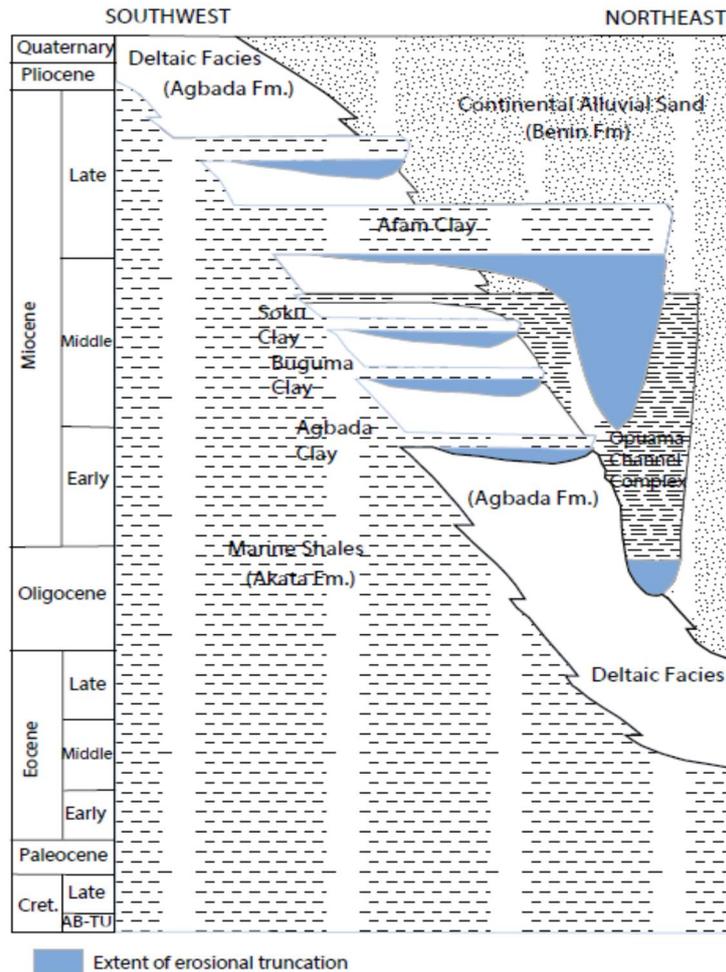


Fig. 2. Stratigraphic Column showing the three Formations of the Niger Delta (Modified after Doust and Omatsola, 1990)

The Benin Formation is a continental Eocene to Recent deposit of alluvial i.e. up to 2000 m thick, the uppermost and youngest rock stratigraphic unit, while the Agbada Formation is a paralic sequence that is characterized by the alternation of sand bodies and shale layers. It is also associated with syndepositional growth faulting and as well contains the bulk of the known oil accumulation in the Niger Delta. The Akata formation is the lowest unit at the base of the delta. It is of marine origin and is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt. The Akata formation is undercompacted in much of the delta [6].

The growth faults in the Niger Delta according to [7] are considered to be the major migration conduit and leading factor controlling the hydrocarbon distribution pattern in the Niger Delta. Most known traps in Niger Delta fields are structural although stratigraphic traps are not uncommon.

### 3 MATERIAL AND METHODS

#### 3.1 DATA ANALYSIS

The analysis of petrophysical logs in this study was aimed at a qualitative and quantitative determination of the properties of delineated reservoirs. The gamma ray (GR) and spontaneous potential (SP) logs were examined for lithologic information. In the reservoir formations vis a vis at shale beds, gamma ray (GR) log which measures natural radioactivity in formations reflects the shale contents while the SP log displays excursion from the shale base line, hence both logs were used for the identification of sand / shale lithology in the study area. The resistivity log in combination with the GR log were used to differentiate between hydrocarbon and non-hydrocarbon bearing zones. In hydrocarbon bearing formation, the resistivity log signatures show high resistivity values than when in water bearing formation. The discrimination of the various

fluid types i.e. oil / gas within reservoirs could not be achieved because of the non availability of neutron log among materials used in carrying out the study.

Using the gamma ray log, lithologic correlation of equivalent strata across the four wells was performed by matching for similarity the intervals of logs from different wells. At the same time, the potential hydrocarbon reservoirs in the various wells were correlated using the gamma ray and resistivity logs to determine their lateral extent, possible existence of faults, dips and or unconformities. Their outcome is presented as correlation panels shown in Figure 3

Quantitatively, the petrophysical parameters are estimated using empirical formulae as follows;

**3.1.1 SHALE VOLUME ESTIMATION:**

Shale volume ( $V_{sh}$ ) was calculated using the [8] formula in equation (1) which uses values from the gamma ray (GR) in equation (2)

$$V_{sh} = 0.083^{(2(3.7 \times I_{GR}) - 1.0)} \tag{1}$$

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \tag{2}$$

In equation (2),  $I_{GR}$  is the gamma ray index,  $GR_{log}$  is the picked log value while GR minimum and GR maximum indicate values picked in the sand and shale base lines respectively.

**3.1.2 DETERMINATION OF POROSITY**

Porosity,  $\phi_D$  is defined as the percentage of voids to the total volume of rock. According to [8], this parameter is determined by substituting the bulk density readings obtained from the formation density log within each reservoir into equation (3)

$$\phi_D = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} - V_{sh} \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \tag{3}$$

And where  $\rho_{ma}$ ,  $\rho_b$  and  $\rho_f$  are matrix density, formation bulk density and fluid density respectively.

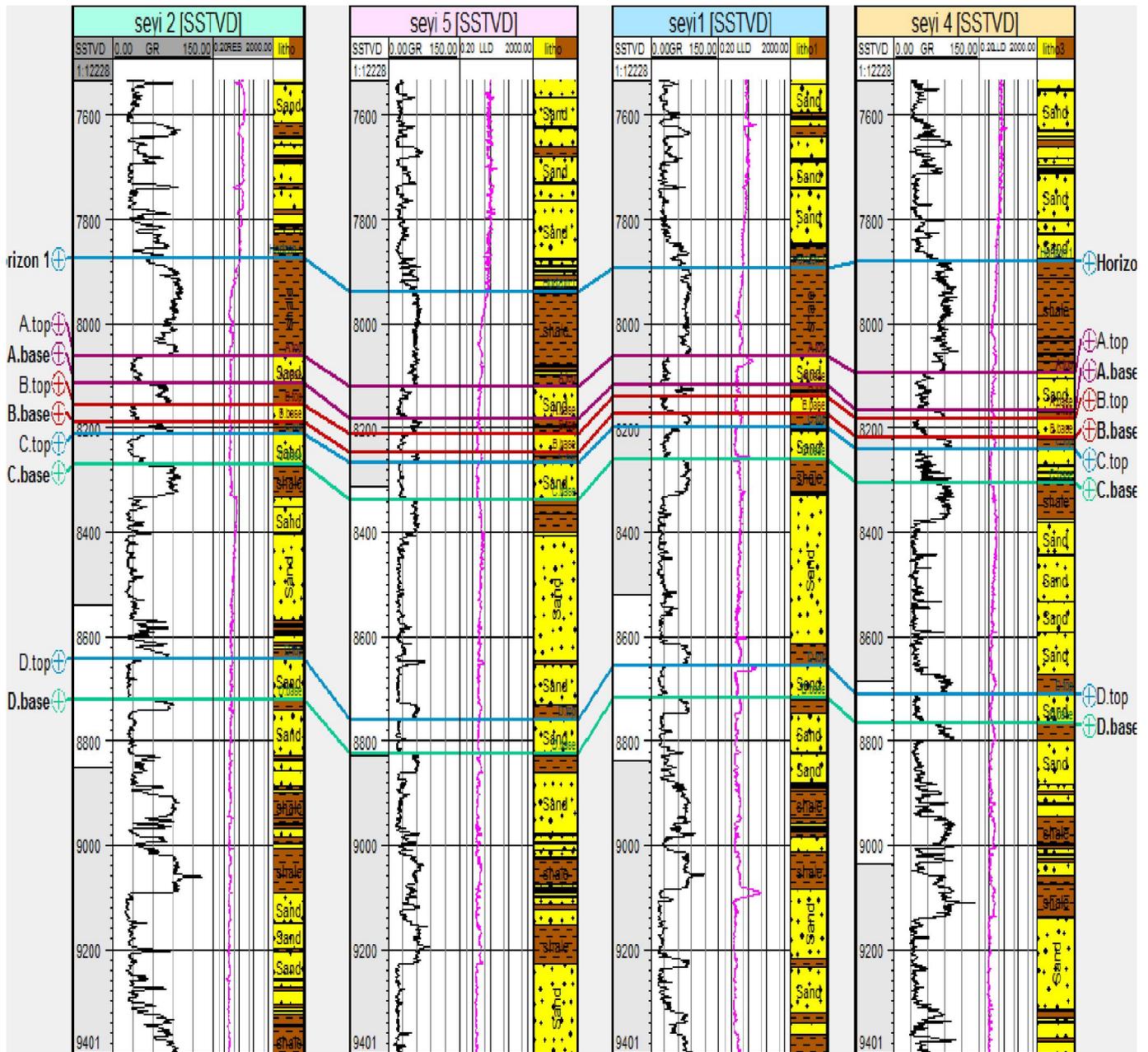


Fig. 3. Lithologic Correlation Panel showing Delineated Reservoirs at Depths Interval (2396m - 2896m) across SEYI field

3.1.3 CALCULATION OF WATER SATURATION

To calculate water saturation,  $S_w$  of uninvaded zone, the method used requires a water resistivity  $R_w$  value at formation temperature calculated from the porosity and resistivity logs within clean water zone, using the  $R_o$  method given by the following equation:

$$R_w = \frac{\phi^m R_o}{a} \tag{4}$$

$R_w$  is the water resistivity at formation temperature,  $\phi$  and  $R_o$  are the total porosity and deep resistivity values in the water zone respectively. Tortuosity factor is represented as “a” and m is the cementation exponent, usually 2 for sands [9]. In the water zone, saturation should be equal to 1, as water resistivity  $R_w$  at formation temperature is equal to  $R_{wo}$

Water saturation,  $S_w$  can then be calculated using Archie’s method, given by:

$$S_w = \left( \frac{R_w}{R_{wa}} \right)^{1/n} \quad (5)$$

where  $n$  is the saturation exponent and  $R_{wa}$  is water resistivity in the zone of interest, calculated in the same manner as  $R_w$  at formation temperature [10].

### 3.1.4 DETERMINATION OF HYDROCARBON SATURATION

Hydrocarbon Saturation,  $S_h$  is the percentage of pore volume in a formation occupied by hydrocarbon. It can be determined by subtracting the value obtained for water saturation from 100% i.e.

$$S_h = (100 - S_w) \% \quad (6)$$

### 3.1.5 CALCULATION OF PERMEABILITY

Permeability,  $K$  is the property of a rock to transmit fluids. For each identified reservoir permeability,  $K$  is calculated using equation (7)

$$K = \sqrt{\frac{250 \times \phi^2}{S_{wir}}} \quad (7)$$

where  $S_{wir}$  is the irreducible water saturation [11]

### 3.1.6 ESTIMATION OF MOVABLE HYDROCARBON INDEX (MHI)

The movable hydrocarbon index (MHI) was derived using:

$$MHI = S_w / S_{xo} \quad (8)$$

Where  $MHI > 1$  implies that hydrocarbon was not moved during invasion and  $MHI < 0.7$  implies that hydrocarbon was moved during invasion. The parameters  $S_w$  and  $S_{xo}$  are water saturation of the uninvaded zone and the flushed zone respectively.

The productivity of each delineated reservoir rock at the zone of interest are estimated by evaluating results of their calculated petrophysical parameters using equation (1) – (8) .

## 4 RESULTS AND DISCUSSION

### 4.1 QUALITATIVE INTERPRETATION

For the log interpretation in Figure 3, its litho-stratigraphic correlation furnishes knowledge of the general stratigraphy of the study field. Seven sand bodies marked reservoir A, B, C, D, E, F and G were correlated across the field. This analysis show that each of the sand units extends through the field, varies in thickness and some units occurring at greater depth than their adjacent unit i.e. possibly an evidence of faulting. The shale layers were observed to increase with depth along with a corresponding decrease in sand layers. This pattern in the Niger delta indicates a transition from Benin to Agbada Formation. From the analysis, particularly the resistivity logs, all the seven delineated reservoirs were identified as hydrocarbon bearing reservoir across the four wells i.e. SEYI-2, SEYI-5, SEYI-1 and SEYI-4.

### 4.2 QUANTITATIVE INTERPRETATION

The methodology as earlier reported was chosen for the quantitative interpretation of the delineated reservoirs in each well. Table 2 represents the results of some computed petrophysical parameters for well SEYI-4 in reservoir A - G. In the case of reservoir C in Figure 3, this reservoir was penetrated at depths (2503 - 2521) m in well SEYI-2, (2520 - 2542) m in SEYI-5, (2498 - 2518) m in SEYI - 1 and (2512 - 2530) m in well SEYI-4. The reservoir has an average gross thickness of 19.51m and an average net/gross ratio of 96.11%. The average effective porosity, permeability, water saturation and hydrocarbon saturation of the reservoir are 0.26, 3589 md, 69.18% and 30.82% respectively. The movable hydrocarbon index (MHI) ranges from 0.41 to 0.92 with bulk volume of movable oil ranging between 1.99% and 6.26%. Shown in Figure 4 are charts depicting the relationship in percentage of some of the calculated petrophysical parameters for reservoirs E and G across the wells.

Table 2. Some Computed Petrophysical Parameters for well SEYI-4 Field

PARAMETERS	RESERVOIRS						
	A	B	C	D	E	F	G
Net /Gross (%)	100	100	84.45	100	68.53	77.99	27.41
$V_{sh}$	0.176	0.121	0.161	0.159	0.376	0.224	0.242
$\phi_D$	0.38	0.32	0.32	0.31	0.28	0.2	0.17
$\phi_e$	0.31	0.28	0.27	0.26	0.3	0.21	0.24
$R_o$	0.63	0.63	0.63	0.63	0.63	0.63	0.63
$R_t$	2.07	1.34	1.29	1.42	58.26	115.29	1097.91
$R_w$	0.08	0.07	0.06	0.06	0.08	0.04	0.05
$F$	7.69	9.57	10.35	11.23	8.25	17.77	13.33
Swirr (%)	6.2	6.92	7.19	7.49	6.42	9.43	8.16
Sw (%)	55.17	68.57	69.88	66.61	10.4	7.39	2.4
Sh (%)	44.83	31.43	30.12	33.39	89.6	92.61	97.6
Sxo (%)	88.78	92.73	93.08	92.19	63.59	59.4	47.41
$K$ (md)	14425.01	6292.98	4678.78	3439.94	11042.22	603.4	1791.6
BVW (%)	17.1	19.2	18.87	17.32	3.12	1.55	0.57
$I$	3.29	2.13	2.05	2.25	92.48	183	1742.71
MHI	0.62	0.74	0.75	0.72	0.16	0.12	0.05

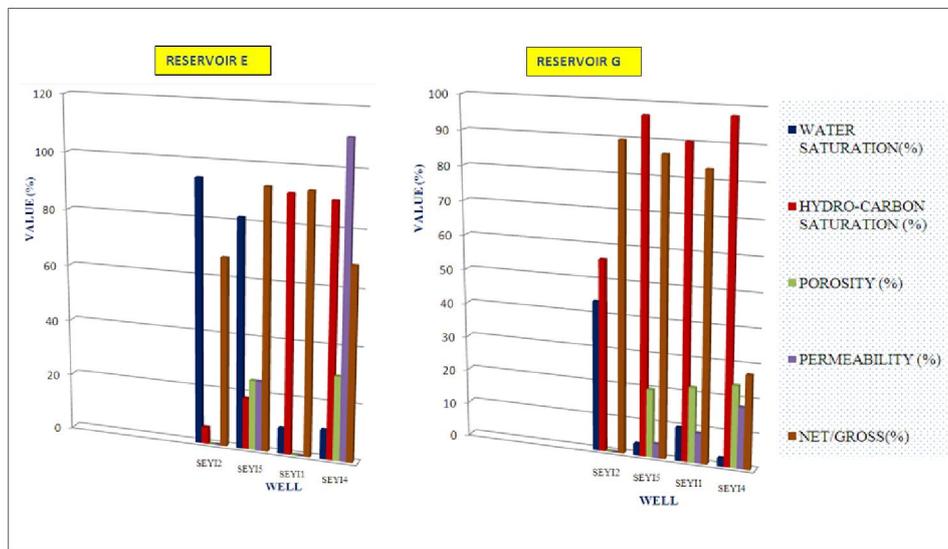


Fig. 4. Chart showing relationship between percentage effective porosity, permeability, water saturation, hydrocarbon saturation and net/gross of RESERVOIR E and G

In Table 3 are summary of results of the important petrophysics parameters utilize as variables that determine reservoir quality. These parameters are subjected to statistical analysis by considering their values across all the delineated reservoirs in the four wells of the study area (Fig. 5). The reservoirs porosity was estimated from density log (RHOB) using porosity formula with shale correction by [8] and these values ranges from 0.22 to 0.31 indicating an outstanding reservoir quality and reflecting probably well sorted coarse grained sandstone reservoirs with minimal cementation. The reservoir units' permeability range was from 881.58md to 14425.01md with reservoir unit A having the highest value. In the appraisal of a well's productivity, the permeability of reservoir unit is an important parameter vis a vis productivity is related to the mathematical product of permeability, k, and thickness, h of that unit. The hydrocarbon bearing reservoir units in the study field have hydrocarbon saturation,  $S_h$  ranging from 20.29% to 91.97% indicating that the proportion of void spaces occupied by water is low consequently high hydrocarbon saturation and high hydrocarbon production. The movability of hydrocarbon

in each reservoir was determined (see Table 2) and considered satisfactory for the production of hydrocarbon. According to [12], if OMI is less than 0.7 for sandstone, then movable hydrocarbon is indicated.

*Table 3. Summary of the Average Petrophysical Parameters for all Reservoirs in SEYI field*

RESERVOIR	WELL NAME	$\phi$ (%)	K (%)	$S_w$ (%)	$S_H$ (%)	NET/GROSS (%)
A	SEYI-2	-	-	75.48	24.52	100
	SEYI-5	22	8.82	76.91	23.09	100
	SEYI-1	-	-	26.7	73.3	100
	SEYI-4	31	144.25	55.17	44.83	100
	<b>Average</b>	26.5	76.53	58.57	41.44	100
B	SEYI-2	-	-	85.77	14.23	100
	SEYI-5	25	24.99	89.92	10.08	100
	SEYI-1	-	-	74.57	25.43	100
	SEYI-4	28	62.93	68.57	31.43	100
	<b>Average</b>	26.5	43.96	79.71	20.29	100
C	SEYI-2	-	-	84.48	15.52	100
	SEYI-5	25	24.99	89.92	10.08	100
	SEYI-1	-	-	32.44	67.56	100
	SEYI-4	27	46.79	69.88	30.12	84.45
	<b>Average</b>	26	35.89	69.18	30.82	96.11
D	SEYI-2	-	-	74.07	25.93	100
	SEYI-5	24	17.91	85.69	14.31	100
	SEYI-1	-	-	21.97	78.03	100
	SEYI-4	26	34.4	66.61	33.39	100
	<b>Average</b>	25	26.16	62.09	37.92	100
E	SEYI-2	-	-	94.06	5.94	67.37
	SEYI-5	25	24.99	81.65	18.35	92.67
	SEYI-1	-	-	9.1	90.9	92.3
	SEYI-4	30	110.42	10.4	89.6	68.53
	<b>Average</b>	27.5	67.71	48.8	51.2	80.22
F	SEYI-2	-	-	-	-	-
	SEYI-5	-	-	-	-	-
	SEYI-1	28	62.93	8.67	91.33	56.76
	SEYI-4	21	6.03	7.39	92.61	78
	<b>Average</b>	24.5	34.48	8.03	91.97	67.38
G	SEYI-2	-	-	43.91	56.09	89.65
	SEYI-5	20	4.05	3.44	96.56	86.49
	SEYI-1	22	8.82	9.81	90.19	83.25
	SEYI-4	24	17.92	2.4	97.6	27.41
	<b>Average</b>	22	10.26	14.89	85.11	71.7

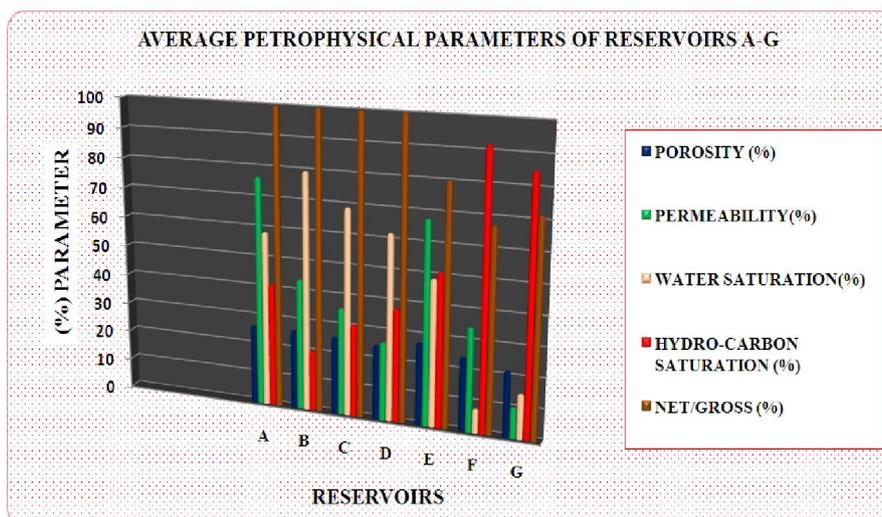


Fig. 5. Relationship between percentage average effective porosity, permeability, water saturation, hydrocarbon saturation and net/gross of RESERVOIR A - G

## 5 CONCLUSION

The petrophysical properties evaluation of 'SEYI' field for its reservoirs characterisation was made possible by careful analysis and interpretation of its well logs. The results shows the feild's delineated reservoir units having porosity ranging from 0.22 to 0.31 indicating a suitable reservoir quality, permeability values from 881.58md to 14425.01md attributed to the well sorted nature of the sands and hydrocarbon saturation range from 20.29% to 91.97% implying high hydrocarbon production. These results in addition with the reservoir units oil movability index (MHI) values suggest high hydrocarbon potential and a reservoir system whose performance is considered satisfactory for hydrocarbon production.

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