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# Hydrocarbon Movability Studies of Sapele Deep Field, Delta State, South-South Nigeria.

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## Abstract

*Sapele Deep field is an onshore space of OML 41, situated in the north-western part of Delta State, South-south oil province, and it is among the prolific fields in the region of study. Well logs from six wells were integrated to study the hydrocarbon movability potential of the field. The hydrocarbon movability potential of the field was delineated by looking at the various hydrocarbon movability factors such as the flush in the zone, movable oil infiltration, residual oil deposited and hydrocarbon movability indicator. The study area on the average has flushed zone water saturation (**Sxo**) of 0.84, hydrocarbon saturation of 0.55, transferable hydrocarbon saturation is 0.39, residual hydrocarbon retention is 0.19 and movable hydrocarbon indicator is 0.51.*

***Keywords*:** Hydrocarbon movability index, Flushed zone, Residual oil retention and Movable oil retention.

## INTRODUCTION

The integration of teams of petrophysicists, geologists, petroleum engineers and geophysicists engaging in work together has altered our view of the distinctiveness inherent in oil and gas basin. Whereas it used to be commonly perceived that oil and gas reservoirs were relatively simple geologic features, the reality is that they are quite complex and they can be subdivided into architectural elements or compartments on the basis of several structural and stratigraphic features (Slatt, 2006).

The importance of hydrocarbon movability study of a reservoir cannot be over emphasized due to the fact that only a tiny proportion of oil in the end is available in most reservoirs. This therefore, calls for improved recovery, posing challenge of a better understanding of how reservoir behaves. This prompts the measurement of movable oil saturation responsible for the highest volume of oil that can be taken or sourced eventually from a reservoir.

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Taking cognizance of the quality of a reservoir is a major point in the profiling process of a reservoir. Reservoir quality is therefore defined by its capacity to store hydrocarbons, storage capacity is a function of porosity, whereas ability to deliver depends on how permeable it (reservoir) is. Thus, both porosity and permeability are the main reservoir quality controlling factors (El Sharawy and Nabawy, 2019).

Airen and Mujakperuo (2023) evaluated the petrophysical properties of the Sapele Shallow Field, Niger Delta Area, Southern Nigeria using log data. They identified one oil-bearing field. Their petrophysical parameters presented average porosity range from 0.30 – 0.36, permeability values were from 2707.9 – 3721.9 mD and average hydrocarbon saturations were 0.51, 0.42, 0.47, 0.46, 0.47 and 0.49 for the respective wells.

Mujakperuo and Airen (2023) did a structural and stratigraphical reservoir evaluation of Sapele Deep Field, Niger Delta, Southern Nigeria. They used 3D and seismic cube and well log data to assess the reservoir's structural and stratigraphical framework. Their results showed that there are zones at deeper and intermediate intervals with well-developed trapping mechanisms and booming amplitudes that have not been drilled.

Emudianughe and Utah (2022) assessed the hydrocarbon of the Sapele field for moveable hydrocarbon indices with the objective of establishing its fluid types and hydrocarbon saturations. Their results revealed typical lean beddings in the formation across the 8 wells, with the same array of net thickness.

Airen and Mujakperuo (2023) appraised the petrophysical properties of the Sapele Deep Field, Niger Delta, Southern Nigeria. Their study had access to 3 wells and 13 reservoirs. Their results gave reservoir lithology to be 6.67 m (22.01 feet) of net sand thickness, permeability 1454.05 mD, shale volume 0.16 mD, net – to – gross 0.47 and water saturation 0.48.

This paper is aimed at ascertaining the hydrocarbon movability in the Sapele Deep region of Delta State, South-south Nigeria; an occurrence that was corroborated by previous researches in the study area.

***Location of the Study Area***

Sapele Deep field is an onshore space of OML 41, situated in the South-south, Delta State, Nigeria (Figure 1 and 2). It lies within Latitude $5^0$ 53′ 54.43″ N and
Longitude $5^0$ 33′ 42.22″ E.

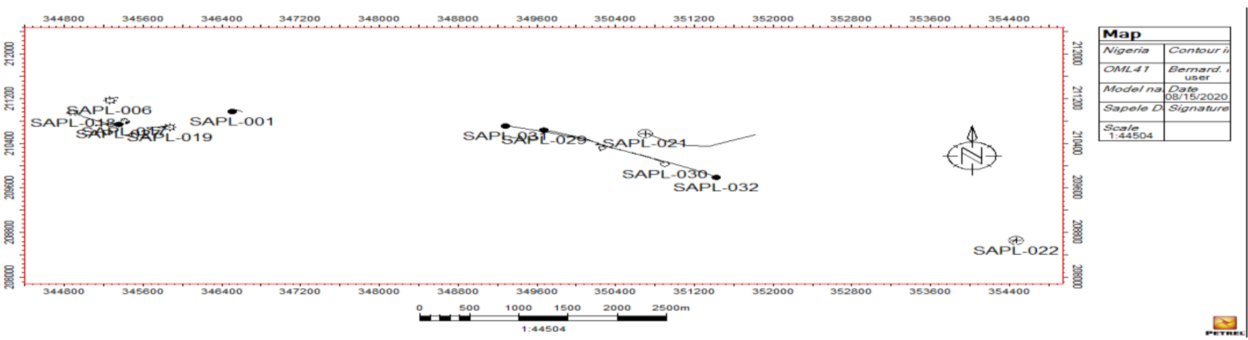


**Figure 1: Base map of oil wells in the study area (Using Petrel®2016)**

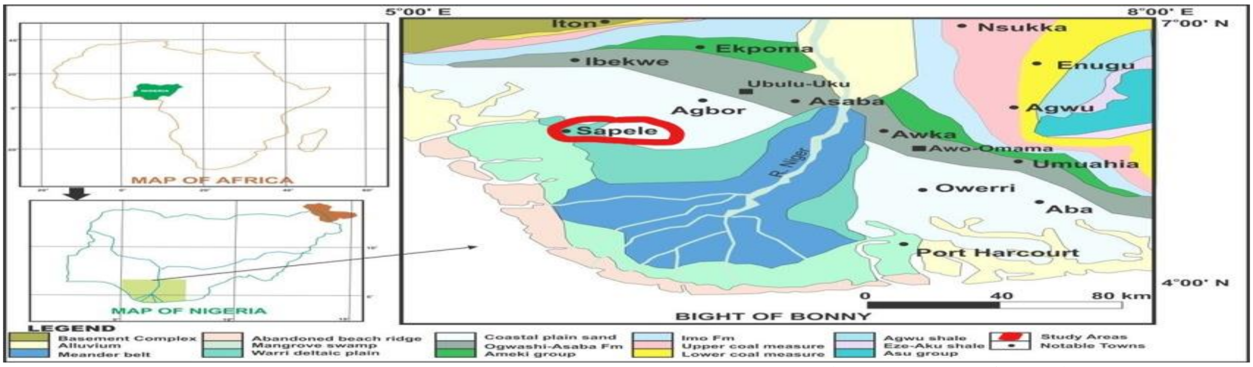

**Figure 2: Geological Map of the Niger Delta Basin showing the Study Area (Oyebanjo *et al.*, 2018).**

## METHODOLOGY

Composite well log data (Gamma Ray, Resistivity, Density and Neutron Logs) used were procured from Seplat Energy PLC for the petrophysical evaluation of the reservoirs and some of the petrophysical parameters were subsequently calculated with the use of the following formulae:

***Shale Volume ($V_{sh}$)***

Shale Volume was evaluated by first finding the Gamma Ray log, $I_{GR}$.

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

Where: $I_{GR}$ = Gamma Ray Index, $GR_{log}$ = Gamma Ray from log,
$GR_{max}$= Maximum Gamma Ray for shale, $GR_{min}$= Minimum Gamma Ray for clean sand

$$Vsh = 0.083 \times (2^{3.7 \times I_{GR}} - 1)$$

Where $V_{sh}$ = Volume of Shale

***Effective Porosity***

For effective porosity to be determined, porosity must first be calculated from the density log by using the following equation:

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

Where:
$\Phi_D$= Porosity, $\rho_{ma}$ = matrix density, $\rho_b$ = bulk density, $\rho_f$ = fluid density
Effective porosity was then calculated using porosity values from the following equation:

$$\Phi eff = (1 - Vsh) \times \Phi_D$$

Where $\Phi eff$ = Effective Porosity

***Permeability***

Permeability is concerned with how rocks are able to allow the passage of fluids. To determine permeability, we first find out irreducible water saturation using the following formula:

$$S_{wirr} = \sqrt{\frac{F}{200}}$$

Where:
$S_{wirr}$ = Irreducible water saturation
F = Formation factor

$K = 307 + 26552\,\Phi^2 - 3450\,(\Phi Swirr)^2$

Where $K$= permeability

***Formation factor***

Formation factor was obtained from the following formula:

$$F = \Phi_D \frac{0.62}{2.15}$$

Where:
F = Formation factor

The ability of hydrocarbon to move from a reservoir to earth surface (well head) can be delineated by looking at the various hydrocarbon movability factors such as the flushed zone (Krygowski, 2003), movable oil saturation (Asquith and Gibson, 1982; Archie, 1942), residual oil saturation (Asquith and Gibson, 1982) and hydrocarbon movability index (Ilavalaga, 2018; Hamada, 2006; Schlumberger, 1989).

**RESULTS AND DISCUSSION**
Analysis *of Well 27*
Well 27 combines both 1 and two-phase two reservoirs with 6 one phase gas reservoirs, 2 two-phase (Gas/oil) reservoirs and 3 one-phase oil reservoirs (Figure 3a and 3b). This well cut across 11 reservoirs from the 13 present reservoirs in the study area.

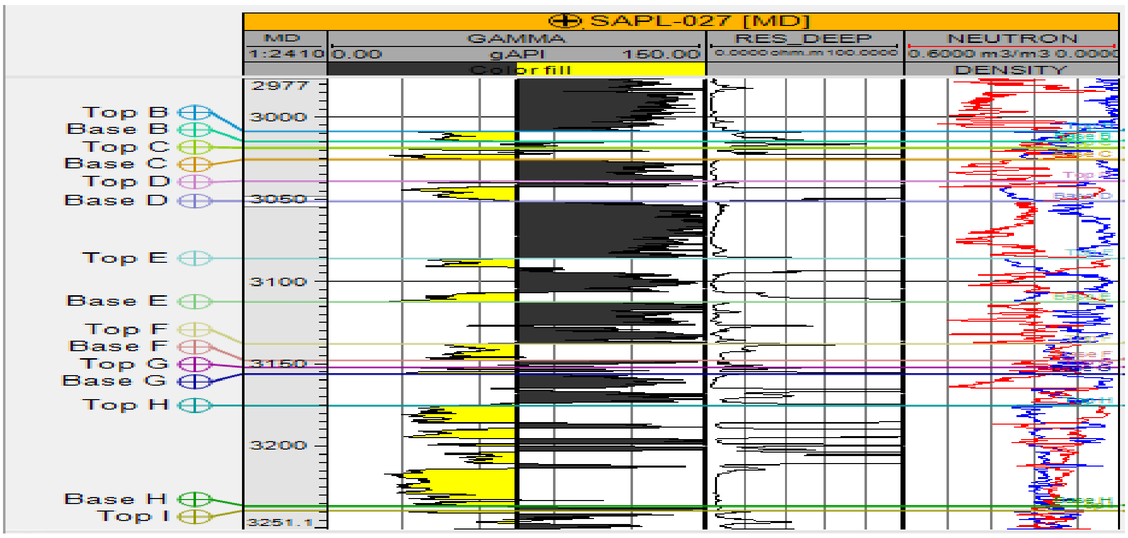


**Figure 3a: Well log signature of well 27 (Using Petrel®2016).**

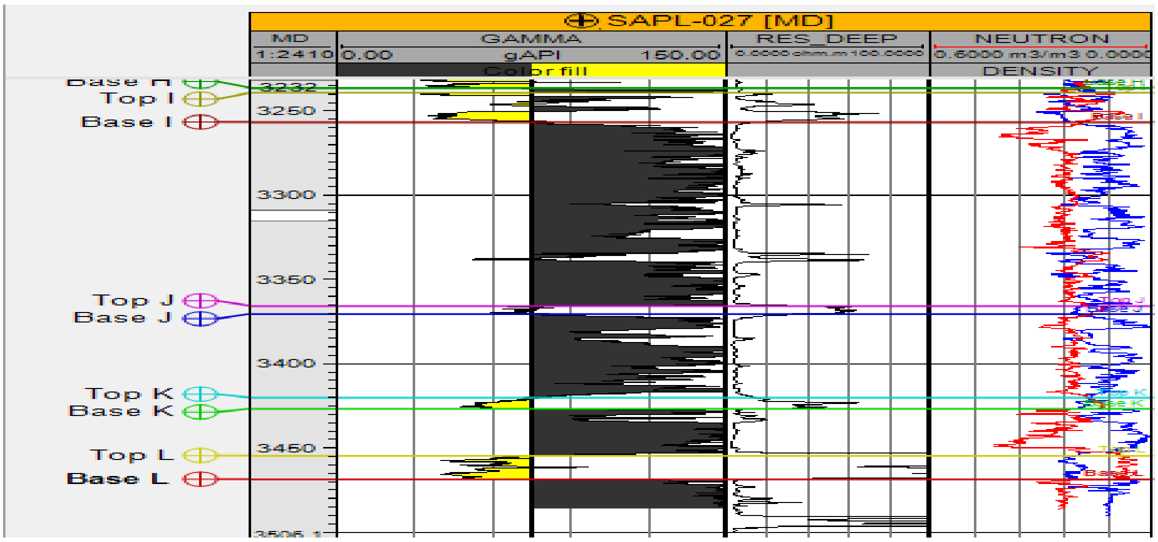

**Figure 3b: Well log signature of well 27 from 3232 m to 3506.10 m (Using Petrel®2016).**

From Table 1, the delineated reservoir has a gross thickness of 67.77 m, net productive thickness of 62.13 m, a mean porosity value of 0.23 (23%), mean permeability value of 1769.15 mD and water saturation of 0.42 (42%).

**Table 1: Petrophysical Summary of Well 27 Reservoirs**

| Reservoirs | Thickness (M) | Vsh | Net Sand (M) | Φ | EffΦ | K(mD) | F | NTG | Swirr | Sw | Sh |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B | 6.27 | 0.25 | 5.11 | 0.2 | 0.16 | 1393.83 | 27.77 | 0.81 | 0.12 | 0.59 | 0.41 |
| C | 6.86 | 0.46 | 5.5 | 0.27 | 0.2 | 2232.58 | 23.12 | 0.80 | 0.11 | 0.47 | 0.53 |
| D | 12.24 | 0.09 | 3.97 | 0.31 | 0.28 | 2782.08 | 8.73 | 0.32 | 0.07 | 0.13 | 0.87 |
| E | 26.58 | 0.06 | 5.11 | 0.26 | 0.24 | 2056.56 | 12.66 | 0.19 | 0.08 | 0.39 | 0.61 |
| F | 9.71 | 0.45 | 6.34 | 0.18 | 0.12 | 1146.23 | 37.38 | 0.65 | 0.14 | 0.78 | 0.22 |
| G | 4.03 | 0.05 | 4.01 | 0.26 | 0.24 | 2037.52 | 12.82 | 0.99 | 0.08 | 0.14 | 0.86 |
| H | 71.8 | 0.25 | 8.51 | 0.23 | 0.18 | 1703.77 | 18.2 | 0.47 | 0.09 | 0.47 | 0.53 |
| I | 17.61 | 0.35 | 5.97 | 0.23 | 0.17 | 1768.04 | 16.32 | 0.34 | 0.09 | 0.55 | 0.45 |
| J | 4.93 | 0.26 | 2.13 | 0.21 | 0.16 | 1511.37 | 17.88 | 0.43 | 0.09 | 0.36 | 0.64 |
| K | 6.57 | 0.14 | 4.29 | 0.19 | 0.16 | 1244.96 | 24.41 | 0.65 | 0.11 | 0.47 | 0.53 |
| L | 14.19 | 0.15 | 11.19 | 0.22 | 0.19 | 1583.68 | 17.25 | 0.75 | 0.09 | 0.22 | 0.78 |
| **Mean** | | | | | | | | | | | |
| | **16.44** | **0.23** | **5.65** | **0.23** | **0.19** | **1769.15** | **19.69** | **0.58** | **0.10** | **0.42** | **0.58** |

Φ = Porosity, EffΦ = Effective Porosity, F = Formation Factor, NTG = Net to Gross Ratio, Swirr = Irreducible Water Saturation, Sw = Water Saturation, Sh = Hydrocarbon Saturation.

From Table 2, well 27 reservoirs have hydrocarbon movability index of 0.20 to 0.65 except reservoir "F", whose hydrocarbon movability index is 0.82. This means that hydrocarbon will move out of reservoirs to well surface during production apart from reservoir "J". Well 27 reservoirs on the average, has a flushed zone saturation of 0.82 (82%), hydrocarbon saturation of 0.58 (58%), movable hydrocarbon saturation of 0.41 (41%), residual hydrocarbon saturation of 0.18 (18%), and hydrocarbon movability index of 0.49. This outcome corresponds with Hamada (2006). Thus, well 27 is a prolific well with great hydrocarbon retrieval.

**Table 2: Summary of Hydrocarbon Movability of Well 27**

| Reservoirs | Sxo | Sh | MHS | RHS | HMI |
|---|---|---|---|---|---|
| B | 0.90 | 0.41 | 0.31 | 0.10 | 0.65 |
| C | 0.86 | 0.53 | 0.39 | 0.14 | 0.55 |
| D | 0.66 | 0.87 | 0.53 | 0.34 | 0.20 |
| E | 0.83 | 0.61 | 0.44 | 0.17 | 0.47 |
| F | 0.95 | 0.22 | 0.17 | 0.05 | 0.82 |
| G | 0.67 | 0.86 | 0.53 | 0.33 | 0.21 |
| H | 0.86 | 0.53 | 0.39 | 0.14 | 0.55 |
| I | 0.89 | 0.45 | 0.34 | 0.11 | 0.62 |
| J | 0.81 | 0.64 | 0.45 | 0.19 | 0.44 |
| K | 0.86 | 0.53 | 0.39 | 0.14 | 0.55 |
| L | 0.74 | 0.78 | 0.52 | 0.26 | 0.30 |
| **Mean** | | | | | |
| | **0.82** | **0.58** | **0.41** | **0.18** | **0.49** |

**Table 3: Cumulative Average Hydrocarbon Movability of Sapele Deep**

| Wells | Sxo | Sh | MHS | RSH | MHI |
|---|---|---|---|---|---|
| Well 01 | 0.79 | 0.62 | 0.41 | 0.21 | 0.42 |
| Well 06 | 0.85 | 0.53 | 0.38 | 0.15 | 0.54 |
| Well 17 | 0.86 | 0.53 | 0.38 | 0.15 | 0.54 |
| Well 18 | 0.86 | 0.51 | 0.37 | 0.29 | 0.56 |
| Well 19 | 0.85 | 0.55 | 0.4 | 0.15 | 0.52 |
| Well 27 | 0.82 | 0.58 | 0.41 | 0.18 | 0.49 |
| **Mean** | | | | | |
| | **0.84** | **0.55** | **0.39** | **0.19** | **0.51** |

## CONCLUSION

Thirteen (13) hydrocarbon sand bodies were delineated and correlated across the study area. Petrophysical analysis reveals that the study area has very good to excellent petrophysical properties with an average gross thickness of 268.60m (886.38 ft), net sand thickness of 6.67 m (22.01 ft), porosity value of 0.21 (21%), permeability of 1493.14 mD, shale volume of 0.16, net-to-gross value of 0.51 and water saturation (Sw) of 0.43 (43%).

The petrophysical properties infers that the delineated sand bodies possess good hydrocarbon storage and transmission ability, which are the two main qualities to look out for in a reservoir and from log evaluations, Sapele deep reservoirs were delineated in the Agbada formation.

The cumulative hydrocarbon movability as summarized in Table 3, confirms that the field averages flushed zone water saturation (**Sxo**) of 0.84, hydrocarbon saturation of 0.55, movable hydrocarbon saturation of 0.39, residual hydrocarbon saturation of 0.19, movable hydrocarbon index of 0.51 and a high recovery factor of 81% (0.81) which is as a result of gas presence and significant water drive.

Conversely, with the field residual hydrocarbon of 0.19 (19%), it therefore implies that 0.39 (39%) out of 0.51 (51%) field hydrocarbon saturation will move to the surface (wellhead) during production. Hence, it can be inferred that a high hydrocarbon movability rate is present, which makes the field a very good prospect.

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