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# PETROPHYSICAL ANALYSIS OF MARS FIELD OFFSHORE DAHOMEY BASIN NIGERIA

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**ABSTRACT**

Petrophysical evaluation of the Mars Field in the Dahomey Basin, Nigeria was done to identify and analyze petrophysical properties of the reservoirs in the field. This was achieved by the use of 3 wells from the field. This research determines the lithology, shale volume (Vsh), porosity (Φ), permeability (K), fluid saturation. Two hydrocarbon-bearing reservoirs age from three wells were identified which was then subdivided into different levels in this research. The average permeability value of the reservoirs is 20.0140md while porosity value ranges between 18%-39%. Fluid types within the reservoir were identified to be Gas, Oil, Condensate and water based on the Neutron-Density log motif. The petrophysical analysis of the field reveals that reservoir porosity ranges from 11-26%, hydrocarbon saturation ranges from 0.07-0.91, water saturation ranges from 0.93-0.09, volume of shale ranges from 0.09-0.22 and net-to-gross ranges from 0.46-0.878. From this research it was identified that the prolific reservoir within the Dahomey basin is within the Turonian and Cenomanian reservoir with good quality reservoir and producible hydrocarbon saturation.

**KEYWORDS:**
Dahomey/Benin Basin;
Petrophysics;
Volume of shale;
Porosity;
Water saturation;
Potential reservoir;
Turonian;
Cenomanian.

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## 1. Introduction

THIS document reviewed the hydrocarbon accumulation within the offshore Dahomey basin using composite logs. This study involves the use of readily available logs to determine rock properties, fluid content, and draw inferences about the reservoir quality within the Mars Field Dahomey Basin Nigeria. There are two main reservoir intervals: a Turonian, dominantly gas/condensate reservoir with an oil leg; and a deeper, Cenomanian oil reservoir.

MARS Field is located approximately 24 kilometers offshore western Nigeria, on the West African Transform Margin (fig. 1).

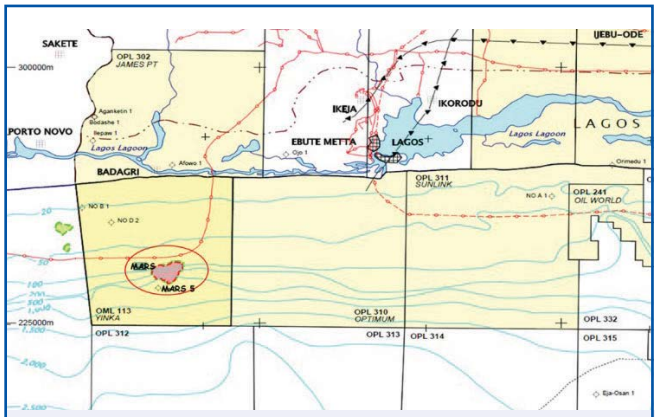


**Fig. 1. Map showing location of MARS field**

## 2. Geological settings

The MARS field is located within the Benin (Dahomey) basin which is a combination of inland, coastal and offshore basin, the onshore parts of which underlie the coastal plains of southwest Nigeria, Benin, Togo and Ghana. A faulted basement high, the Okitipupa Ridge separates Benin basin from the Niger delta basin. This transform margin is characterized by pull-apart basins which are bounded by faults. This is seen in Tano and Keta basins in Cote D'Ivoire, and Ghana and Benin basin. The major lithology of the basin is Sand, Shale and Carbonates. The sedimentary deposit can be divided into five cretaceous sequence the Nkporo Shale, Awgu Formation, Abeokuta Group, Albian Sands and Older Folded Sediment (fig. 2 and 3).

## Materials and methods

The available petrophysical dataset used for MARS petrophysical review consisted basically of Well head data, log curves (LAS files), deviation surveys and well picks for MARS wells. No core data was made available for this review.

The petrophysical properties of each reservoir unit identified in this study were calculated using empirical petrophysics formular. The potential hydrocarbon reservoir was identified using gamma ray, and the fluid type were identified using resistivity logs together with neutron-density log.

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*Shale Volume Estimation*

Generally, shale volumes were calculated from Clavier equation using gamma ray log after determining GR minimum and GR maximum values for each zone.

$$Vsh_{index} = \frac{Gr - Gr_{\min}}{Gr_{\max} - Gr_{\min}} \quad (1)$$

$$Vsh_{clavier} = 1.7 - \sqrt{3.38 - (Vsh_{index} + 0.7)^2} \quad (2)$$

Where $Gr$ is the gamma ray curve reading in the zone of interest, $Gr_{\min}$ is the $Gr$ log in 100% matrix, $Gr_{\max}$ is $Gr$ reading in 100% shale, $Vsh_{index}$ is linear equation and $Vsh_{clavier}$ is Clavier method equation.

*Porosity Estimation*

Porosity of the rock is the estimation of the pore spaces within the reservoir, while effective porosity is the estimation of the connected pore spaces in the rock. The porosity of the potential reservoir was estimated using the density log.

$$\varnothing_t = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fl}} \quad (3)$$

$$\varnothing_e = \frac{(\rho_{ma} - \rho_b - V_{sh} \times (\rho_{ma} - \rho_{cl}))}{(\rho_{ma} - \rho_{fl} \times S_{xo} - \rho_{hy} \times (1 - S_{xo}))} \quad (4)$$

Where $\varnothing_t$ – total porosity, $\varnothing_e$ – the effective porosity, $\rho_{ma}$ – the matrix density, $\rho_b$ – the bulk density, $\rho_{cl}$ – the wet clay density, $\rho_{fl}$ – the fluid density, $\rho_{hy}$ – the hydrocarbon density, $V_{sh}$ – the volume of shale and $S_{xo}$ – the flushed zone water saturation.

*Water Saturation Estimation*

Use Water saturation is the estimation of the water within the pore spaces in the reservoir. The water saturation was estimated using Archies equation and the resistivity of water was estimated using Pickett plot.

$$S_w = \frac{(a - R_w)^{1/n}}{(R_t - \varnothing_t^m)^{1/n}} \quad (5)$$

Where $S_w$ is the water saturation, a is the tortuosity factor, $R_w$ is the formation water resistivity, n is the saturation exponent, $m$ is the cementation exponent, $\varnothing_t$ is the total porosity.

## 4. Result and discussion

The wells within the Mars Field were correlated to identify the potential reservoirs. seven reservoirs were identified, five reservoirs within the Turonian zone which are the Turonian 1, Turonian 2, Turonian 3, Turonian 4, Turonian 5 (fig. 4), and two reservoirs with-

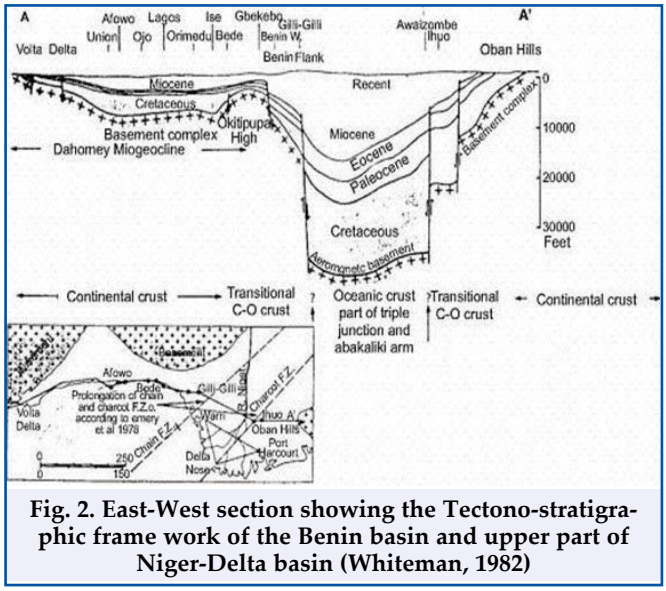


**Fig. 2. East-West section showing the Tectono-stratigraphic frame work of the Benin basin and upper part of Niger-Delta basin (Whiteman, 1982)**

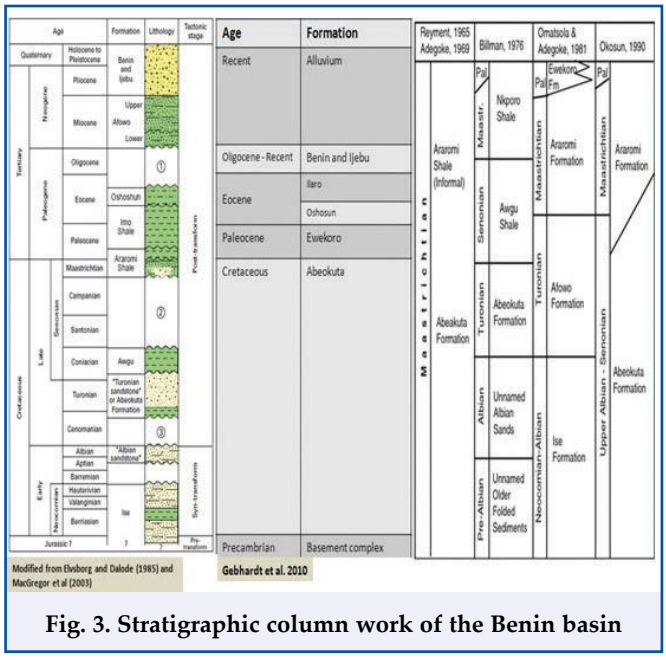


**Fig. 3. Stratigraphic column work of the Benin basin**

**Table 1**

**Available log curves and depth of availability**

| Well | Start md (m) | Stop md (m) | Start md (ft) | Stop md (ft) | Start md (ft) | Stop md (ft) | Start md (ft) | Stop md (ft) |
|---|---|---|---|---|---|---|---|---|
| | GR | | RT | | RHOB | | NPNI | |
| Mars 5 ST1 | 7900 | 10642 | 7900 | 10642 | 7900 | 10606 | 7900 | 10606 |
| Mars 5 ST2 | 4322.75 | 12446.5 | 4322.75 | 12446.5 | 9740 | 12379 | 9740 | 12379 |

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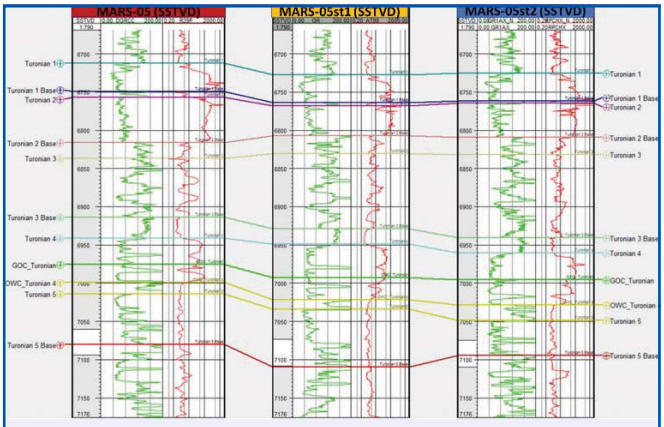


**Fig. 4. Mars 5ST1 and ST2 correlation with offset well (Mars 5) in Turonian zone**

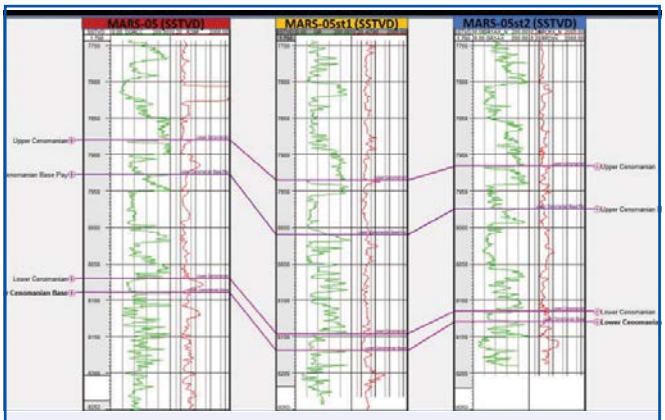


**Fig. 5. Mars 5ST1 and ST2 correlation with offset well (Mars 5) in Cenomanian zone**

**Table 2**

**Calculated average net properties of Mars 5ST1**

| Zones | Top (TVDSS) | Bottom (TVDSS) | Refe-rence unit | Gross | Net | Net to Gross | AV_Shale Volume | AV_Effective Porosity | AV_Effective Water Saturation | Fluid Type |
|---|---|---|---|---|---|---|---|---|---|---|
| Turonlan 1 | 6727.3 | 6763.71 | ft | 36.43 | 26.79 | 0.74 | 0.1 | 0.16 | 0.13 | GAS ZONE |
| Turonlan 2 | 6766.5 | 6806.61 | ft | 40.09 | 37.13 | 0.93 | 0.1 | 0.18 | 0.12 | GAS ZONE |
| Turonlan 3 | 6813.7 | 6928.48 | ft | 114.79 | 17.08 | 0.15 | 0.11 | 0.2 | 0.39 | GAS ZONE |
| Turonlan 4 | 6951 | 7078.97 | ft | 128 | 50.65 | 0.4 | 0.11 | 0.18 | 0.27 | OIL & GAS |
| Upper Cenomanian | 7933.4 | 8010.22 | ft | 76.83 | 0 | 0 | | | | WET |
| Lower Cenomanian | 8145.6 | 8169.45 | ft | 23.83 | 0 | 0 | | | | WET |

**Table 3**

**Calculated average net properties for Mars 5ST2**

| Zones | Top (ft Tvdss) | Bottom (ft Tvdss) | Gross (ft) | Net (ft) | Net to Gross | AV. Shale Volume | AV. Effective Porosity | AV. Effective Water Saturation | Fluid Type |
|---|---|---|---|---|---|---|---|---|---|
| Turonlan 1 | 6725.43 | 6761.91 | 36.48 | 26.05 | 0.71 | 0.11 | 0.25 | 0.09 | GAS |
| Turonlan 2 | 6764.72 | 6809.46 | 44.74 | 41.18 | 0.92 | 0.22 | 0.25 | 0.09 | GAS |
| Turonlan 3 | 6831.85 | 6940.71 | 108.86 | 50.16 | 0.46 | 0.13 | 0.21 | 0.35 | COND.? |
| Turonlan 4 | 6960.45 | 7028.6 | 68.15 | 58.09 | 0.85 | 0.09 | 0.23 | 0.15 | GAS & OIL |
| Upper Cenomanian | 7916.18 | 7974.68 | 58.09 | 0 | | | | | WET |
| Lower Cenomanian | 8115.25 | 8129.06 | 13.81 | 0 | | | | | WET |

**Table 4**

**Calculated average net properties for Turonian 4**

| Wells | Zones | Flag Name | Top (ft Tvdss) | Bottom (ft Tvdss) | Gross | Net | Net to Gross | AV. Shale Volume | AV. Effective Porosity | AV. Effective Water Saturation | Fluid Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MARS-5 ST1 | Turonlan 4 | GAS PAY | 6950.974 | 6993.174 | 42.2 | 37.008 | 0.877 | 0.119 | 0.176 | 0.246 | GAS ZONE |
| MARS-5 ST1 | Turonlan 4 | OIL PAY | 6993.173 | 7022.299 | 29.125 | 23.496 | 0.807 | 0.132 | 0.173 | 0.486 | OIL ZONE |
| | | | | | | | | | | | |
| MARS-5 ST2 | Turonlan 4 | GAS PAY | 6960.445 | 6996.598 | 36.153 | 31.731 | 0.878 | 0.076 | 0.26 | 0.11 | GAS ZONE |
| MARS-5 ST2 | Turonlan 4 | OIL PAY | 6996.598 | 7028.595 | 31.997 | 27.164 | 0.849 | 0.102 | 0.199 | 0.227 | OIL ZONE |

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in the Cenomanian zone which are upper Cenomanian and Lower Cenomanian reservoir (fig. 5).

Due to unavailability of core data, average net properties have been calculated in the wells used for the evaluation by assuming the following petrophysical cut-off; volume of shale (VSH) <= 50%, Porosity (PHIE) => 10% and Water Saturation (SW) <= 60%. Table 2 -4 shows Mars 5ST1 and 5ST2 reservoir property averages by wells. Figure 6-12 shows evaluation plot of Mars 5ST1 and Mars 5ST2.

The Mars 5 ST1 average reservoir properties shows that the fluid in Turonian reservoir is oil and Gas and the Cenomanian reservoir is wet. The water saturation of the Turonian reservoir ranges from 13% to 39%, and porosity is about 16% to 20%.

The Mars 5 ST2 average reservoir properties shows that the fluid in Turonian reservoir is oil, Gas and condensate while the Cenomanian reservoir is wet. The water saturation of the Turonian reservoir ranges from 9% to 35%, and porosity is about 21% to 23%.

The Mars 5 ST1 and ST2 has oil and gas in Turonian 4, the sum average reservoir property of Turonian 4 is shown in table 4 below.

*Turonian 1 Reservoir*

It is Gas bearing in both MARS 05ST1 and MARS 05ST2 wells. Based on open-hole log interpretation, MARS 05ST1 logged a GUT at -6727.22ft tvdss and GDT at -6764.15ft tvdss, MARS 05ST2 logged a GUT at -6725.43ft tvdss and GDT at -6761.91ft tvdss. Figure 6-7 below shows the Log strip of Turonian 1 in MARS 05ST1 and 5ST2.

*Turonian 2 Reservoir*

It is Gas bearing in both MARS 05ST1 and MARS 05ST2 wells. Based on open-hole log interpretation, MARS 05ST1 logged a GUT at -6767.99ft tvdss and GDT at -6807.22ft tvdss, MARS 05ST2 logged a GUT at -6764.72ft tvdss and GDT at -6809.45ft tvdss. Figure 8-9 below shows the Log strip of Turonian 2 in MARS 05ST1 and 5ST2.

*Turonian 3 Reservoir*

It is Gas bearing in both MARS 05ST1 and MARS 05ST2 wells. Based on open-hole log interpretation, MARS 05ST1 logged a HUT at -6830.29ft tvdss and HDT at -6928.76ft tvdss, MARS 05ST2 logged a GUT at -6831.85ft tvdss and GDT at -6940.68ft tvdss. Figure 10-11 below shows the Log

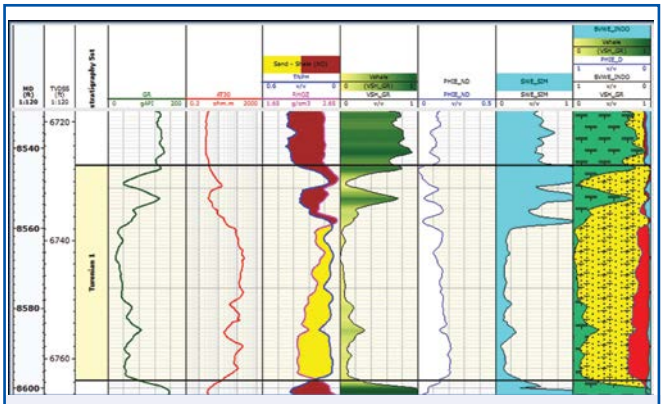

**Fig. 6. Turonian 1 Evaluation plot Mars 5ST1**

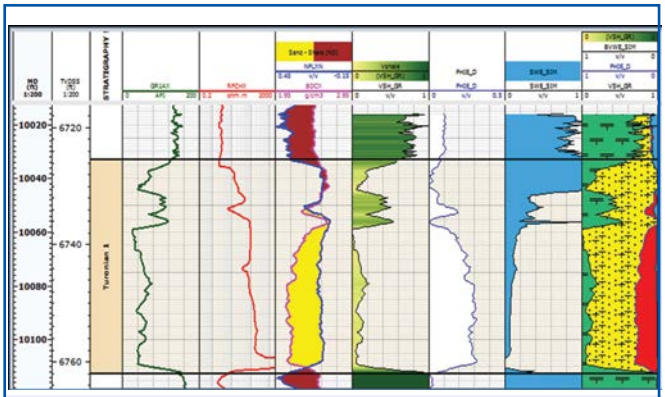

**Fig. 7. Turonian 1 Evaluation plot Mars 5ST2**

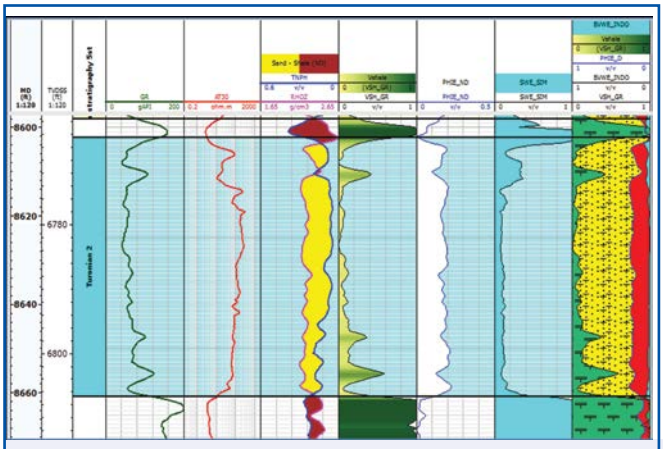

**Fig. 8. Turonian 2 Evaluation plot Mars 5ST1**

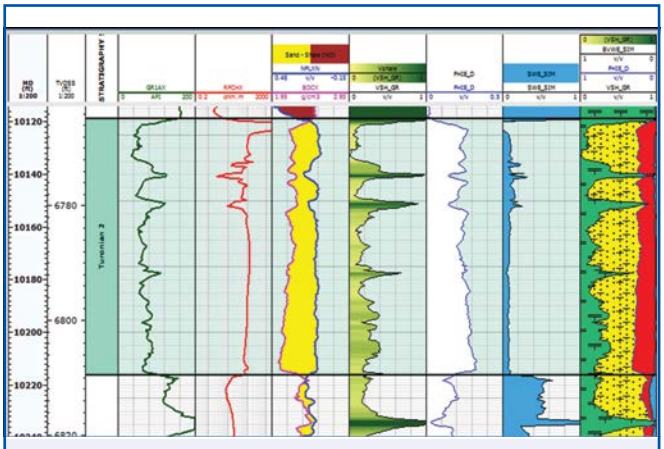

**Fig. 9. Turonian 2 Evaluation plot Mars 5ST2**

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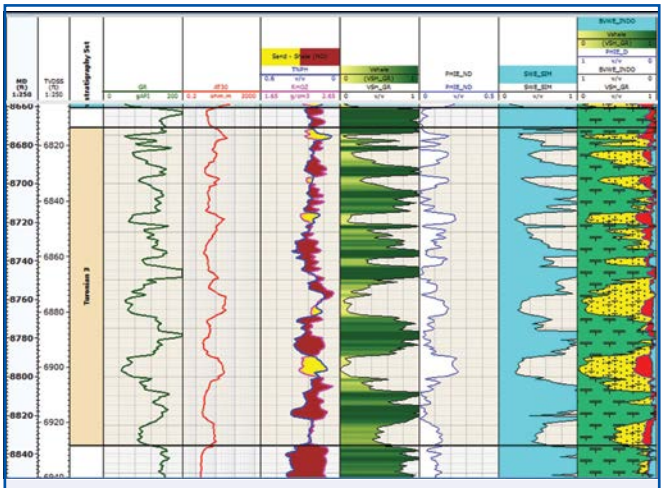

**Fig. 10. Turonian 3 Evaluation plot Mars 5ST1**

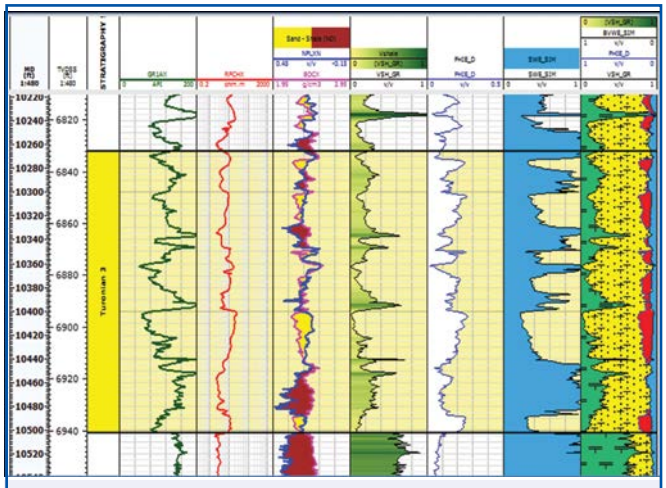

**Fig. 11. Turonian 3 Evaluation plot Mars 5ST2**

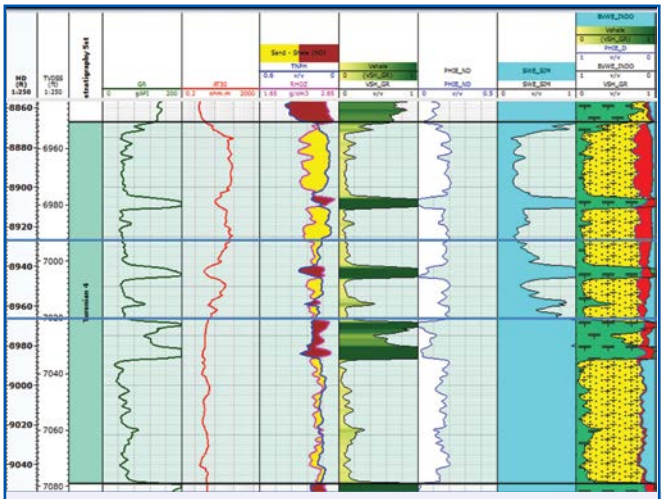

**Fig. 12. Turonian 4 Evaluation plot Mars 5ST1**

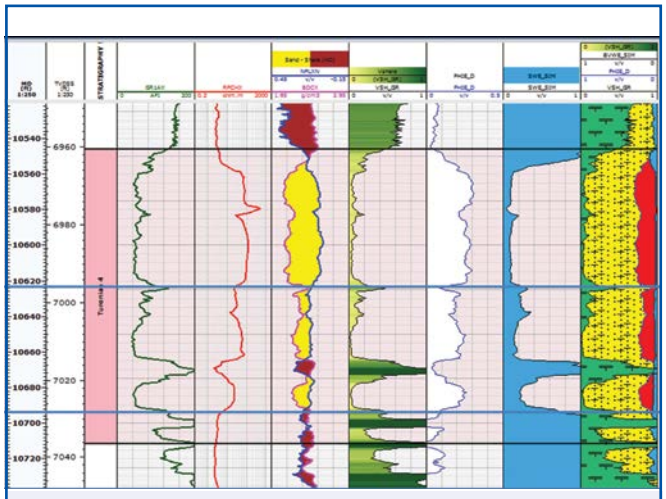

**Fig. 13. Turonian 4 Evaluation plot Mars 5ST2**

strip of Turonian 3 in MARS 05ST1 and 5ST2.

*Turonian 4 Reservoir*

It is Gas and Oil bearing in both MARS 05ST1 and MARS 05ST2 wells. Based on open-hole log interpretation, MARS 05ST1 logged a GUT at -6948.76ft tvdss, GOC at -6992.69ft tvdss, OWC at -7023.74ft tvdss and WDT at -7031.15ft tvdss, while MARS 05ST2 logged a GUT at -6960.45ft tvdss, GOC at -6995.73ft tvdss, OWC at -7028.64ft tvdss and WDT at -7036.16ft tvdss. Figure 12-13 below shows the Log strip of Turonian 4 in MARS 05ST1 and 5ST2.

## Conclusion

A Petrophysical analysis of MARS field reservoirs in MARS 5ST1 and 5ST2 wells was carried out as part of an on-going drilling program with the aim to identify and quantify hydrocarbon pay zone within the MARS 5ST1 and 5ST2 wells in the Field.

The Petrophysical evaluation techniques adopted in this project include hydrocarbon correction of porosity logs, VSH calculation from GR, calculation of SW using Modified Simandoux shaly sand model, thereby accounting for the effect of the presence of clay in the shaly sands.

Fluid contacts for the reservoirs were identified across the wells using resistivity logs.

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# Петрофизический анализ месторождения Марс в бассейне Дагомеи, Нигерия

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## Реферат

Петрофизическая оценка месторождения Марс в бассейне Дагомеи, Нигерия, была проведена для выявления и анализа петрофизических свойств коллекторов месторождения. Это было достигнуто за счет использования 3-х скважин с месторождения. Эти исследования определяют литологию, объем сланца ($V_{ш}$), пористость ($Ф$), проницаемость ($K$), флюидонасыщенность. Были выявлены два возрастных резервуара углеводородов из трех скважин, которые затем были разделены на разные уровни в этом исследовании. Среднее значение проницаемости коллекторов составляет 20.0140 мД, а значение пористости колеблется в пределах 18-39%. Типы флюидов в резервуаре были идентифицированы как газ, нефть, конденсат и вода на основе логарифма плотности нейтронов. Петрофизический анализ месторождения показывает, что пористость коллектора колеблется в пределах 11-26%, насыщенность углеводородами колеблется в пределах 0.07-0.91, водонасыщенность колеблется в пределах 0.93-0.09, объем сланца колеблется в пределах 0.09-0.22, а отношение нетто-к-валу колеблется в пределах 0.46-0.878. В результате этого исследования было установлено, что продуктивный коллектор в бассейне Дагомеи находится в пределах туронского и сеноманского коллектора с коллектором хорошего качества и продуктивной насыщенностью углеводородами.

***Ключевые слова*:** бассейн Дагомея/Бенин; петрофизика; объем сланцев; пористость; водонасыщенность; потенциальный резервуар; турон; сеноман.

# Nigeriyanın Dahomey hövzəsinin Mars sahəsinin petrofiziki təhlili

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## Xülasə

Nigeriyanın Dahomey hövzəsindəki Mars sahəsinin petrofiziki qiymətləndirilməsi yatağın petrofiziki xüsusiyyətlərini müəyyən edilməsi və təhlili məqsədilə aparılmışdır. Buna yataqda qazılmış 3 quyu məlumatının istifadəsi ilə nail olunmuşdur. Bu tədqiqat litologiyanı, şist (gil) həcmini ($V_{sh}$), məsaməliliyi ($Ф$), keçiriciliyi ($K$), maye doyumluluğunu müəyyən edir. Üç quyuda da iki karbohidrogenlə doymuş lay müəyyən edilmiş və sonra bu tədqiqat müxtəlif hissələrə bölünmüşdür. Layların orta keçiriciliyi 20.0140 mD, məsaməlilik isə 18-39% arasında dəyişir. Laylar daxilində maye növlərinin Neytron Sıxlığı əsasında Qaz, Neft, Kondensat və su olduğu müəyyən edilmişdir. Yatağın petrofiziki təhlili göstərir ki, lay məsaməliliyi 11-26%, karbohidrogenlə doyma 0.07-0.91, su ilə doyma 0.93-0.09, şist həcmi 0.09-0.22, məsaməlik 0.46-0.878 aralığında dəyişir. Bu tədqiqatdan müəyyən edilmişdir ki, Dahomey hövzəsi daxilində məhsuldar yataqlar yaxşı keyfiyyətli lay və çıxarılabilən karbohidrogenlə doymuş Turon və Senoman kollektorları daxilindədir.

***Açar sözlər:*** Dahomey/Benin hövzəsi; petrofizika; şist həcmi; məsaməlilik; su ilə doyma; potensial lay; Turon; Senoman.