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Petrophysical Investigation of the Hawas Formation within the Concession Area (J-field-NC-186) in the Northwestern Region of the Murzuq Sedimentary Basin, Libya

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ABSTRACT

This research includes a study of the petrophysical parameters of the Hawaz Formation in the Murzuq Basin, which was deposited in the pre-Cambrian to Quatrain ages, with a thickness of about 5000 to 6000 meters. The thickness varies in different areas of the basin. The depositional environment of the Murzuq Basin is characterized by diverse sedimentary formations, which include sandy formations that are a major part, where sand dunes and arid areas of clay and silt are found in some areas, reflecting the history of deposition in ancient aquatic environments and carbonate formations that include limestone, indicating ancient marine environments. In this study, the zone that carries good reservoir properties was obtained, where the volume of clay (Volume of Shall) was calculated using the gamma ray log (Gama Ray log) and the percentage was about 30%, and the primary porosity was calculated through s (Sonic log) and density logs (Density log) and the primary porosity was in the range of 12.6%, as well as the total porosity (Total Porosity) was calculated about 11% and also the water saturation (Water Saturation) was calculated and was about 20% using Archie's equation, while the oil saturation was about 80% and this gives excellent productivity for this formation.

الملخص

تقييم المعايير البتروفيزيائية لتكوين حواز الترسيبي في حوض مرزق الرسوبي: دراسة جيولوجية ومكمنية تتناول هذه الدراسة التقييم البتروفيزيائي لتكوين حواز الترسيبي في حوض مرزق الرسوبي، والذي يمتد عبر فترات جيولوجية مختلفة مما قبل الكمبري حتى العصر الرباعي، بسمك يتراوح بين 5000 إلى 6000 متر. يتميز الحوض بتفاوت سمكه بين مناطقه المختلفة، مع تنوع بيئاته الترسيبية التي تشمل تكوينات رملية واسعة، وكثبان صحراوية، إضافة إلى تكوينات كربونية كالحجر الجيري، مما يعكس تاريخًا جيولوجيًا متنوعًا بين البيئات البحرية والرسوبية القديمة. في هذه الدراسة، تم تقييم الخصائص المكمنية لتكوين حواز الترسيبي، حيث قُدر حجم الطين بحوالي 30% باستخدام بيانات أشعة جاما، وهو مؤشر على جودة المكمن، إذ أن زيادته تؤدي إلى تقليل المسامية الفعالة. كما تم حساب المسامية الأولية بنحو 12% باستخدام التسجيل الصوتي، بينما بلغت المسامية الكلية 14%. إضافةً إلى ذلك، تم تحديد تشبع النفط بحوالي 80% باستخدام معادلة أرشي، مما يدل على قدرة تخزينية عالية. تعكس هذه الخواص البتروفيزيائية الممتازة إمكانات تكوين حواز الترسيبي كمكمن نفطي عالي الجودة داخل حوض مرزق الرسوبي، مما يجعله هدفًا استثماريًا مهمًا في قطاع النفط والغاز.

KEYWORDS: Petrophysical parameters. Hawaz Formation in the Murzuq Basin. Gamma ray log. Sonic log. Density log. Volume of clay (shall). Porosity (primary, total). Water saturation (Sw). Oil saturation (So).

1. INTRODUCTION

The Marzuq Basin, located in Southwestern Libya, is one of the most important basins in the North African region. The structural fabric that was given to the continental lithosphere of North Africa during the Proterozoic event played an important role in the early life. An important role in controlling the structural and stratigraphic development of the basin (Craig, 2008). During the early Paleozoic tectonism, a series of northwest-southwest-trending arcs and sub-basins were created across North Africa, shallow marine deposits and transgressive open marine facies.

Early Paleozoic tectonism effectively controlled the Late Ordovician reservoir sand distribution of Silurian hot shall (which intercalates with early-forming fault blocks) There are four main sedimentary basins in Libya, and the Murzuq Basin is one of them. Three of these basins belong to the Paleozoic era, while the fourth basin belongs to the Mesozoic era.It is roughly triangular in shape, narrowing southward from Libya to Niger. It features the erosive remains of a much larger Paleozoic sedimentary basin that originally covered most of North Africa. Paleozoic, some Mesozoic, and Cenozoic sediment sequences lie above the Pre-Cambrian crystalline basement, and in the central part of the basin, the total sediment thickness exceeds 3500 m^2 (Echikh, K. 1998).The north-south edge of the Ghat/Tecomit arc separates the Murzuq Basin from the Illizi Basin, Algeria, to the west, and is sandwiched between three tectonic elements: the Chickadee Uplift in the north, the Tibesti/Harouge Uplift in the east, and the Precambrian Hogar Uplift in the west that extends into Algeria and Niger.The entire sediment series is well exposed along the basin margin, as well as on the southern side of the Qarqaf Arch (Davidson, et al.).The complete sedimentary succession is present only in a few areas associated with the Caledonia and Hercynia formations, and other unconformities that have less influence on all the formations, and in the heart of the arch (Qarqaf) formation, crystalline basal outcrops are present in relatively smaller areas (Figure 1) (Selley, 1997).The Hawaz Formation was first studied by (Massa, et al.1960) and was named after Mount Hawaz. It is described as "typically consisting of cross-bedded quartzitic sandstone, in part kaolinitic, with thin intercalations of shale (Pierobon, 1991).

During the Ordovician, the northern African part of the Earth's western Old Continent formed a passive margin and was covered by a broad, shallow-water marine platform. Most of the sedimentary units that make up the stratigraphic column of the basin are widespread and have good correlation in the subsurface and rocks

The Murzuq Basin has a relatively simple composition and stratigraphy, and contains sedimentary rocks ranging in age from the Cambrian to the Tertiary and Quaternary. The maximum thickness in the center of the Murzuq Basin (Ubari Basin) is about 3,500 metres. The structure of the Murzuq Basin is very simple, as there are semi-horizontal or slightly sloped faulted layers, and the faults are mostly parallel to the axis.

Tectonic movements affected the basin to a greater or lesser extent from the middle of the Paleozoic (Caledonian) to the post-Oligocene (Alpine) era.

She noted that during the Paleozoic, the sedimentary backfill of the Murzuq Basin was a typical part of Paleozoic basins in other parts of the world, and that marine intrusions came from the northwest. The depositional history of the Murzuq Basin is relatively uncomplicated with some clearly distinct facies patterns. The main sedimentary deposits identified in the Murzuq Basin in concession area NC-186 are located north of concession area NC-115 in southwestern Libya in the Sahara Desert near the village of Ubari, about 720 km from the Mediterranean Sea. There are also subsurface areas and on rocky outcrops. Also to the south in the Murzuq Basin The classical Hawaz Highlands structure was formed during the Hawaz erosional event. The Basal Tanizoft Hot Oil Shale Member is the main source rock in the area, while the main regional seal is the Silurian Oil Shale Formation. (Geological Society of London ,2015). This study is based on a previous sedimentary description of the Hawaz Formation (Jil Ortiz et al., 2019) using subsurface data from 35 wells located across the north-central sector of the Murzuq Basin (Gil-Ortiz, et al 2022). Evaluation of Petrophysical Parameters of the Hawaz Formation at the J Oil Field, Concession NC186 in the Murzuq Basin, Libya, through Well Log Analysis of Ten Exploratory Wells (Mohamed, 2016).

1.1 Location of study area

The concession area covers an area of 4,295 square kilometers and is located between latitudes 26,400 and 27,000 and longitudes 12,000 and 13,100 (Figure 1) within the Murzuq sedimentary basin.

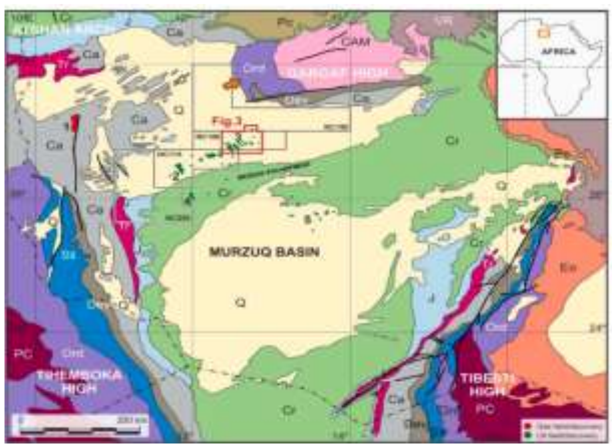

Figure 1. Index Map of Marzuq Basin Shows The Outline Bounding Structural Features and study area J-field-NC186. (Jil Ortiz et al., 2019)

1.2 The main objective of the study

- Evaluate the oil-bearing Hawaz Formation within J1-NC186 to determine the hydrocarbon saturations, Water Saturation, volume of Shall.

- Identify the different types of porosity and identify the rock content and the depositional environments of the Hawaz Formation using the information available from one well (J1).

2. METHODOLOGY

In this study, several specific analytical steps were used in the well logging data in the study area for the interpretation process:

(1) Filter the raw log response data to remove and correct anomalous data points.

(2) Correction of neutron, sonic, density and resistivity logs for environmental conditions.

(3) Plotting of well logging data after correction as a function of depth. Data processing and interpretation mainly rely on rapid display of log responses, then displaying the data using interactive rock physics software, and plotting petrophysical parameters in the form of cross-sectional plots.

3. METHODS USED IN THIS STUDY

Various readings of electrical, radiological and acoustic logs are taken at fixed depth levels every 0.5 feet. These readings were used as follows:

3.1 Graphical method

This method includes representing the readings of the neutron, density and acoustic logs versus with the true resistivity readings on the other hand, in order to calculate the water saturation values (Sw) (Water Saturation) and the density values of the rock content (ρ mat) as well as the acoustic time of the content (Δt mat). The water resistivity in the layer was also determined, which is symbolized by the symbol (Rw) (Water Resistivity). This method is called the Hingle plot.

3.2 Analysis by equations

This method includes determining the primary porosity from the sonic log, the total porosity from the density log, the neutron log, the effective and secondary porosity, the shale content, as well as the water and oil saturation.

3.3 Qualitative interpretations of well logs

These interpretations, which evaluate the reservoir of well J4 and the graphical relationships based on log readings, then determine the following.

3.3.1 Water saturation and Oil saturation

from the Hingle cross Plot, which is a relationship between True Resistivity (Rt) and Sonic Log, as well as a relationship between (Rt) and (Density Log) for a single well as shown in (Figure 2), in which the relationship between True Resistivity (Rt) and Sonic Log (Δtlog) was used to determine the value of Δtmat = 55.5 µsec/ft, this value was obtained from the intersection of the water saturation line (Sw 100%) with the horizontal line (Δt), the intersection point is (Δt mat), where the porosity (ø) is zero and Using equation (1), the value of (Δtlog = 71.75) can be obtained after taking an estimated value for porosity (øs = 12.60%). After performing the calibration between the porosity line, which starts from zero at (Δtmat = 55.5 μsec/ft), and the (Δt) line, (Ro = 10Ωm) was determined from the curve. From this, the formation factor (F = 63) was determined from equation (3), and thus (Rw = 0.158) could be calculated from equation (5). We also note that the production zone is below the (Sw 20%) line, which indicates that the formation is good in terms of oil productivity.

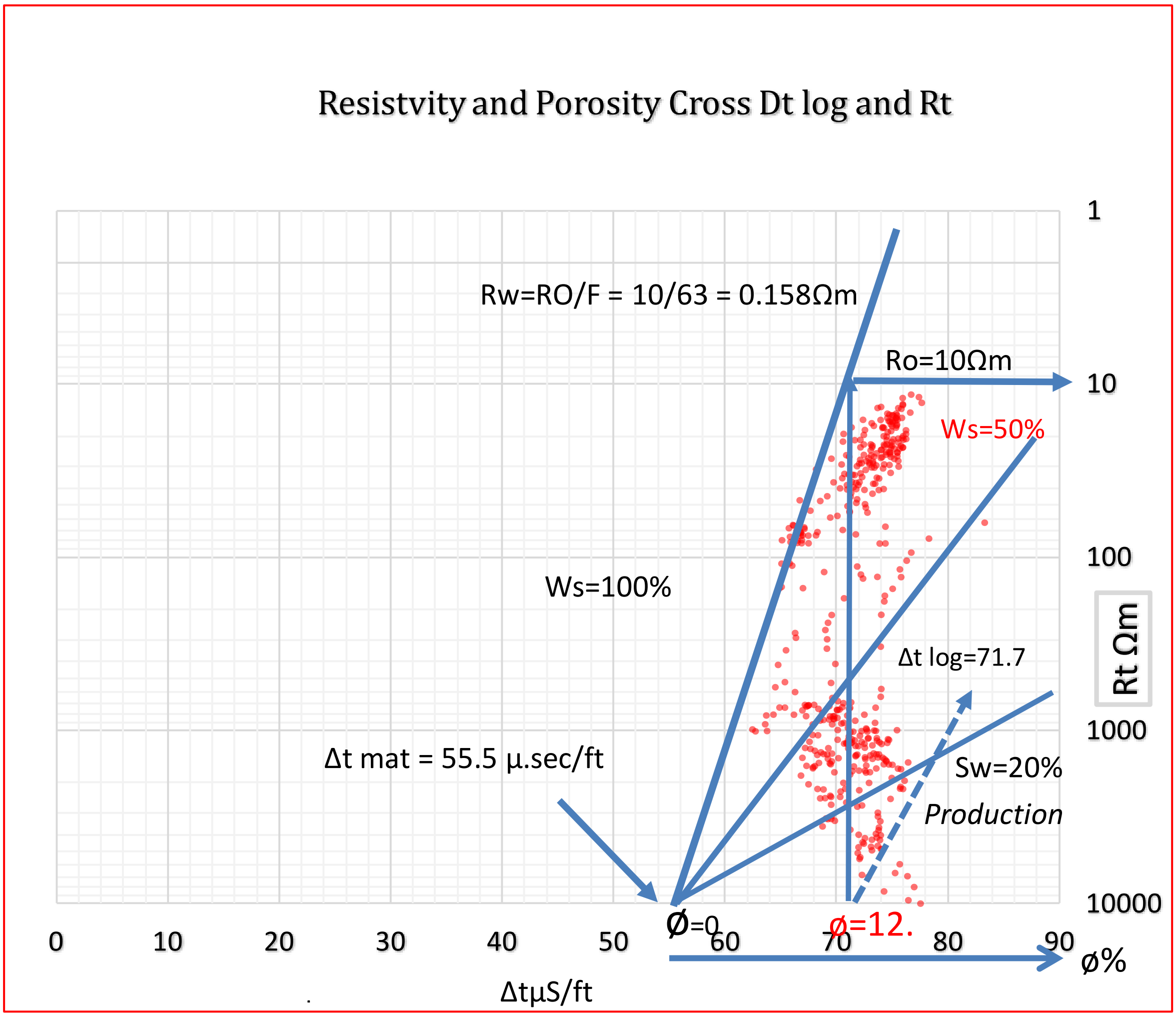

Figure 2 shows the relationship between true resistivity and sonic log in the well (Hingle Plot)

3.4 Rock Content Type

The lithological content was identified from the relationship used to confirm the initial results between the neutron log and the density log (Figure 3), and the second between the sonic log and the neutron log (Figure 4).

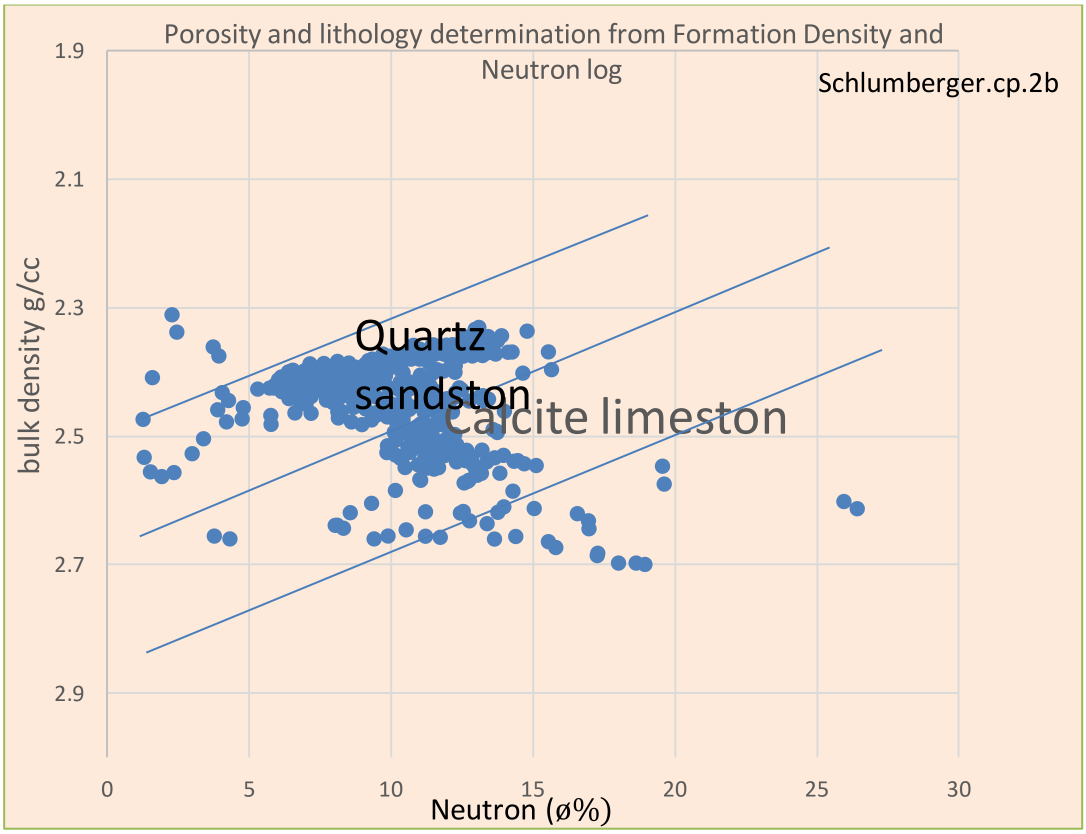

Figure 3 shows the relationship between the neutron log and the density log in the well

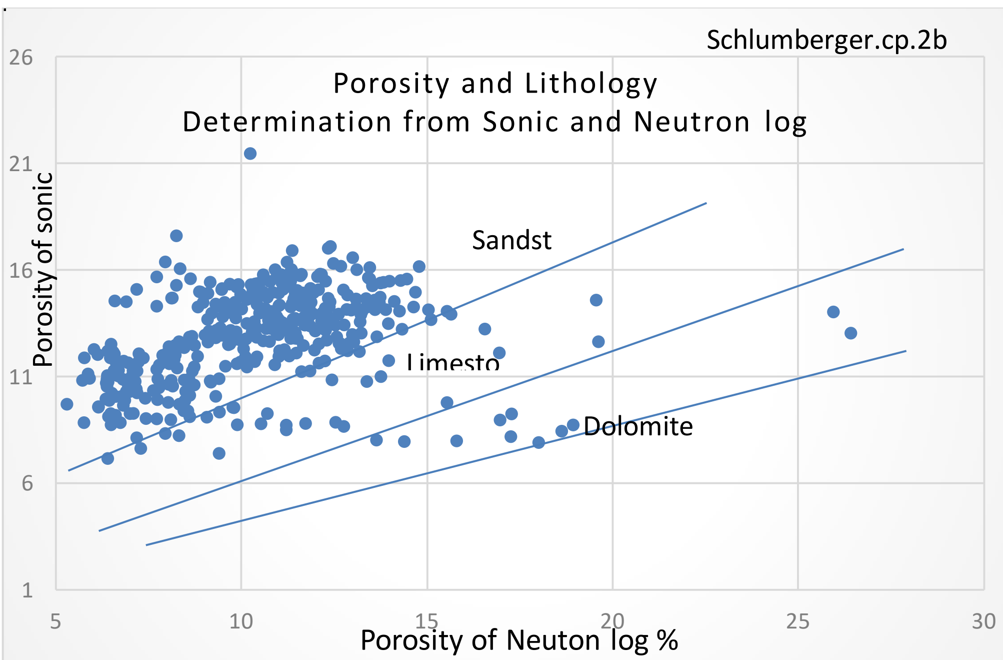

Figure 4 shows the relationship between the sonic log and the neutron log in the well

3.4.1 Quantitative interpretations of geophysical logs

Determination of petrophysical parameters for the reservoir formation of Well J1 determination of porosity (Primary): primary porosity is determined using Sonic logs (Øs) using Equation (1). Determination of total porosity: using equation (2), Determination of Shall content using equation (4) for Gamma Ray, and Determination of Water and Oil Saturations using Equations (6) and (7) (Archie).

$$Ø_s = \frac{\Delta tlog - \Delta tmat}{\Delta tf - \Delta tmat} \qquad (1)$$

$$ø\ total = \sqrt{(ød^2 + øn^2\ /2)} \qquad (2)$$

$$F = \frac{0.62}{\phi^{2.5}} \qquad (3)$$

$$V\ shall = 0.33 \times 2^{\wedge} (2*IGR - 1) * 100 \qquad (4)$$

$$Rw = \frac{R0}{F} \qquad (5)$$

$$SW = \frac{\sqrt{F.Rw}}{Rt} \quad \text{Water saturation} \qquad (6)$$

$$So = 1 - Sw \quad \text{Oil saturation} \qquad (7)$$

3.4.2 Quick Interpretation of Well Logs

- From the (figure 5) which shows the petrophysical curves of the well logs that were conducted in the well J1, the gamma ray log shows a clear decrease in shale content from a depth of (4120-4280). The proportion of the layer or shale increases slightly until the end of the depth, and the readings were around (30 API).
- Regarding resistivity (Rd, Rs), we observe a high resistivity value, which measures the true resistivity of the formation (Rt). This is the zone that the drilling mud filtrate has not yet reached. It can be read from the deep resistivity log (Deep Resistivity) (Rd). The resistivity starts to increase at the depth level where the gamma ray value decreases. This increase can be interpreted as the reservoir in this part containing hydrocarbon materials (oil). Oil is an electrically insulating material, so the Rd log value increases, and the resistivity value decreases in the part that contains formation water. At this depth, this can be interpreted as the oil-water contact."
- The density log shows that density varies with depth, which indicates changes in lithology. This can be interpreted in terms of the rock type. Most of the readings were in the range of 2.55 g/cm³ to 2.6 g/cm³, which suggests that the oil reservoir consists of sandstone."

- Equations (6-7), these calculations are plotted as water and oil saturation/shale volume versus depth. We observe a high oil saturation and low water saturation at the same depths previously identified in the gamma and resistivity log interpretations. The results were (Sw = 20%, So = 80%, Shale Volume = 30%).

Therefore, the previous results can be interpreted as the oil reservoir (Ahwaz Formation) possessing excellent geological characteristics that make it one of the important formations for oil storage in the study area (within the Murzuq Basin).

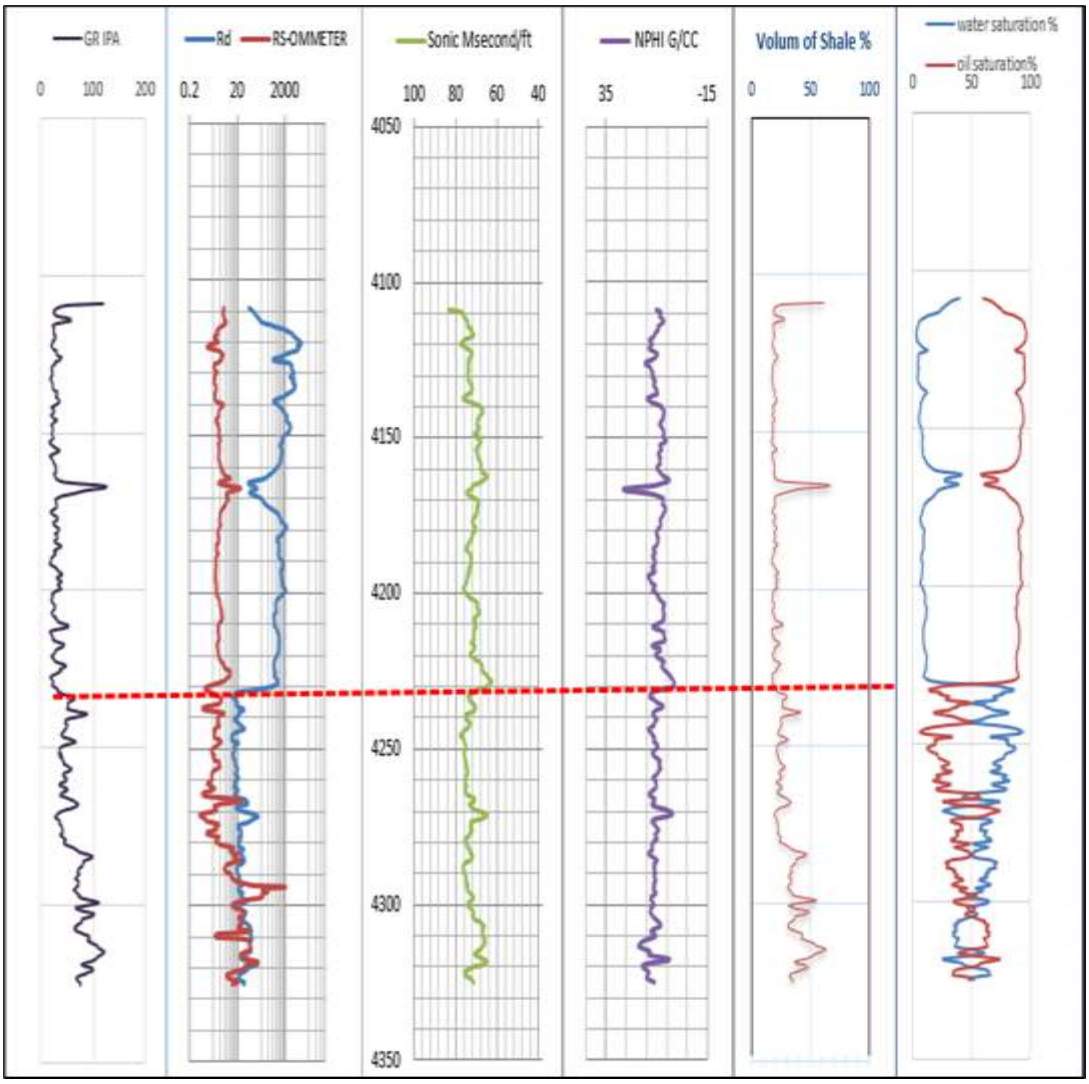

Figure 5 illustrates the petrophysical properties of the reservoir for well (J4)

4. CONCLUSIONS

To evaluate and study the Ahwaz Formation, well logs for resistivity, density, neutron, sonic, and gamma ray were used to determine the petrophysical parameters of the Ahwaz Formation.

In this study, the primary porosity and its average value of approximately 12.6%, and the total porosity and its average value of approximately 14% were determined for the Ahwaz Formation. The shale volume does not exceed 30%. Water and oil saturations were also determined, in addition the rock type of the Ahwaz Formation was identified by applying relationships between the density log and the neutron log, and between the sonic log and the neutron log, which proved that the Ahwaz Formation is mainly composed of sandstone with some dolomite and anhydrite.Regarding the oil-water contact, it was identified through the neutron and density logs, which are used to determine the gas-oil contact, and was found at a depth of 4230 ft. The Ahwaz Formation is considered highly productive, with an oil saturation exceeding 80%.

5. RECOMMENDATIONS

We recommend the following observations:

1. The Rw value was calculated from graphical relationships only. Therefore, we recommend calculating it using different methods, such as conducting laboratory analyses of the reservoir water.
2. This evaluation relied on log analyses of the Ahwaz Formation. Therefore, we recommend more detailed studies, such as taking samples from the well and conducting laboratory studies on them to calculate porosity, permeability, and water and oil saturation.
3. The study was limited to evaluating the Ahwaz Formation in well J1-NC184. Therefore, we recommend studying a larger number of wells in this concession to determine the horizontal distribution of this formation.

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