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Petrophysical Properties and Oil Initially in Place (OIIP) of the Byda Formation, NC74 Concession, Sirte Basin, Libya

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ABSTRACT

The Byda Formation is one of the main reservoirs in the Sirte Basin, Libya. This study evaluates its petrophysical properties in the Al-Samah Field (NC74) using well-log data from three wells (F1, F2, and G1). Reservoir characterization included calculating shale volume (Vsh), effective porosity (Φ), permeability (K), water saturation (Sw), and oil saturation (So), followed by lithology interpretation and oil initially in place (OIIP) estimation using the volumetric method. The results indicate that the reservoir is predominantly limestone with moderate to good reservoir quality. The average effective porosity was about 12%, the average permeability was **577.73** mD, and the average oil saturation was approximately 50%**.** Well F1 exhibited the best reservoir quality. The estimated OIIP was 7.5 MMSTB**.** These findings provide valuable information for reservoir characterization, reserve estimation, and future field development.

Keywords: Byda Formation; Sirte Basin; Well Logs; Petrophysical Evaluation; Oil Initially in Place

الخصائص البتروفيزيائية وتقدير النفط الأصلي (OIIP) لتكوين البيضاء ، منطقة الامتياز NC74، حوض سرت، ليبيا

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ملخـــــــص البحـــــــث

يُعد تكوين البيضاء أحد أهم المكامن في حوض سرت، ليبيا. تهدف هذه الدراسة إلى تقييم الخصائص البتروفيزيائية لتكوين البيضاء في حقل السماح ضمن منطقة الامتياز NC74، اعتمادًا على بيانات تسجيلات الآبار لثلاثة آبار (F1 وF2 وG1). وشمل توصيف المكمن حساب حجم الطفل الصفحي (Vsh)، والمسامية الفعالة (Φ)، والنفاذية (K)، وتشبع المياه (Sw)، وتشبع النفط (So)، بالإضافة إلى تحديد الليثولوجيا وتقدير كمية النفط الأصلي في المكان (OIIP) باستخدام الطريقة الحجمية. أظهرت النتائج أن المكمن يتكون بصورة رئيسية من الحجر الجيري، ويتمتع بخصائص مكمنية تتراوح بين المتوسطة والجيدة. وبلغ متوسط المسامية الفعالة نحو 12%، ومتوسط النفاذية 577.73 ملي دارسي (mD)، في حين بلغ متوسط تشبع النفط حوالي 50%. كما أظهر البئر F1 أفضل الخصائص المكمنية مقارنة بالآبار الأخرى. وقد

قُدرت كمية النفط الأصلي في المكان بحوالي 7.5 مليون برميل قياسي (MMSTB). وتوفر هذه النتائج معلومات مهمة لتوصيف المكمن، وتقدير الاحتياطيات النفطية، ودعم خطط تطوير الحقل مستقبلًا.

الكلمات الدالة: تكوين البيضاء، حوض سرت، الخصائص البتروفيزيائية، النفط الأصلي (OIIP)، تسجيلات الآبار،

1. Introduction

Libya's sedimentary basins constitute an integral part of the geological framework of North Africa and were formed through successive tectonic and sedimentary events extending from the Paleozoic Era to the Quaternary Period [1]. These processes resulted in diverse sedimentary successions and well-developed petroleum systems. Geological studies indicate that sedimentary rocks in Libya began to accumulate during the Cambrian Period and continued throughout the Paleozoic, Mesozoic, and Cenozoic eras [2]. Alternating continental and marine depositional environments, driven by fluctuations in sea level [3], provided favorable conditions for the development of hydrocarbon source rocks, reservoir rocks, and effective cap rocks [4,5].

The Sirte Basin is the largest and most productive sedimentary basin in Libya, containing a significant proportion of the country's proven hydrocarbon reserves and numerous economically important oil fields. The basin was formed as a result of extensional tectonic movements associated with the breakup of the African continent during the Late Cretaceous and continuing into the Paleogene [6]. Petrophysical evaluation plays a fundamental role in hydrocarbon exploration, reservoir development, and field management, as successful reservoir exploitation and reserve estimation depend on an accurate understanding of reservoir rock properties [7]. The most important petrophysical parameters include porosity, permeability, shale volume, and fluid saturation, which are key indicators of reservoir quality and production potential [8]

Well logs are among the most widely used tools for determining these reservoir properties because they provide continuous and reliable information on the physical characteristics of subsurface formations throughout the borehole [9]. Well-log data contribute significantly to reservoir characterization, identification of productive zones, reserve estimation, and decision-making related to drilling, field development, and production planning, thereby supporting the efficient exploitation of hydrocarbon resources while reducing technical and economic risks [10]

The Byda Formation is one of the major producing formations in the Sirte Basin and represents an important carbonate reservoir that has contributed substantially to oil production from several fields. The current production from the Byda fields is approximately 11,000 barrels of oil per day, transported through a 24-inch pipeline and subsequently through a 30-inch pipeline to the Ras Lanuf export terminal. Approximately 34% of the original recoverable reserves remain recoverable using conventional production methods [11].

This study aims to evaluate the petrophysical properties of the Byda Formation in the Al-Samah Field using well-log data to calculate porosity, permeability, shale volume, water saturation, and oil saturation, and to analyse the relationships among these parameters and identify the most productive reservoir intervals. Furthermore, the study estimates the Original Oil Initially in Place (OIIP) using the volumetric method to improve reservoir characterization and provide reliable information for reserve evaluation and future field development.

1.1 Location of the Study Area

The study area is located within NC74 Concession in the southwestern part of the Sirte Basin, one of the most important hydrocarbon-producing sedimentary basins in Libya. The area extends between latitudes 27°48′ N and 28°05′ N, and longitudes 18°30′ E and 19°20′ E [12], near the Al Haruj Al Aswad region in its northeastern part, as shown in Figure 1. The study area includes several producing wells whose well-log data were used to evaluate the petrophysical properties of the Byda Formation and estimate the Oil Initially in Place (OIIP).

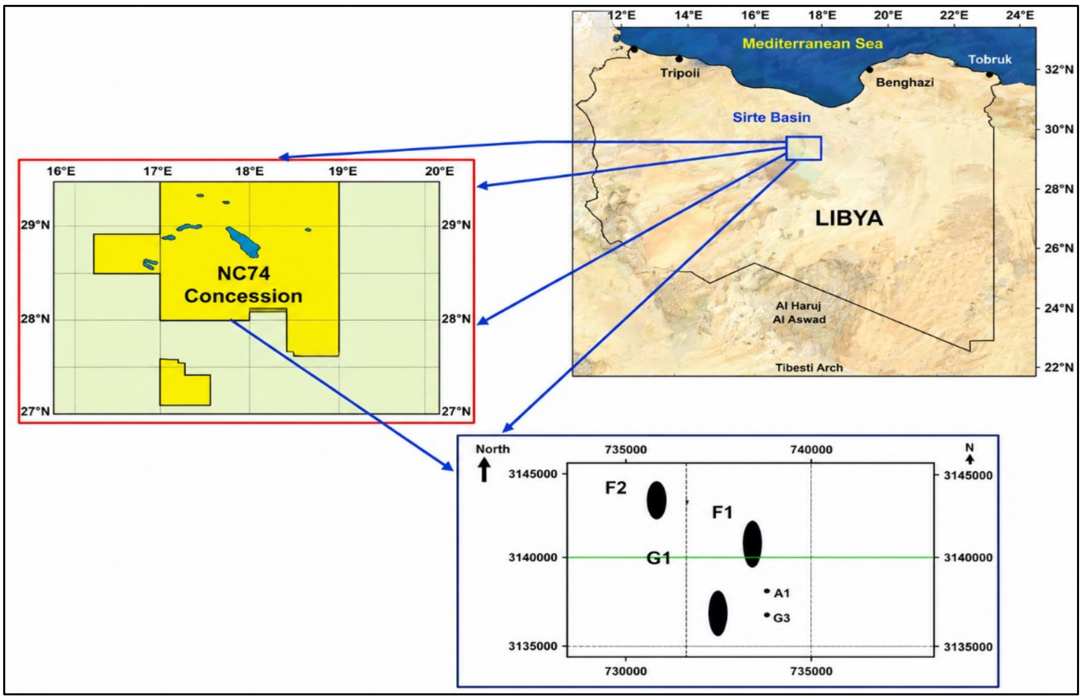

Figure 1. Location map of the study area (NC74 Concession, Sirte Basin, Libya) [12].

1.3 Geology of the Sirte Basin

The Sirte Basin is located in north-central Libya, south of the Gulf of Sirte, and is the largest and most productive hydrocarbon-bearing sedimentary basin in the country, covering an area of approximately 600,000 km². It is bounded by the Mediterranean Sea to the north, the Al Hamada Al Hamra Uplift and Gargaf Arch to the west, the Cyrenaica Platform and Sarir Trough to the east, and the Al Haruj Al Aswad region and the Tibesti Arch to the south. The basin is characterized by a complex structural framework formed as a result of extensional tectonic activity during the Cretaceous Period, which produced a series of horsts and grabens that controlled sedimentation and facies distribution [13].

Since the Paleozoic Era, the Sirte Basin has undergone alternating continental and marine depositional environments, resulting in thick successions of clastic, carbonate, and evaporitic rocks. The interaction between tectonic activity and sedimentation led to the development of a complete petroleum system consisting of source rocks, reservoir rocks, cap rocks, and structural and stratigraphic traps, making the basin one of the richest hydrocarbon provinces in North Africa [13]. The study area is located within the NC74 Concession in the Al-Samah Field, a producing oil field in the central part of the Sirte Basin.

2 .Methodology

2.1 Data Collection

This study was based on well-log data obtained from three producing wells in the Al-Samah Field, located within the NC74 Concession in the Sirte Basin. The analyzed wells include Well F1, covering a depth interval of 8800–8965 ft (Table 1), Well F2, covering 9130–9258 ft (Table 2), and Well G1, covering 9250–9368 ft (Table 3).

Table 1. Input Data and Petrophysical Parameters Used for Well F1 [12]

Remarks	Data		Unit	Remarks	Data	Unit
Rmf at surface	1.01		ohm.m	GRmax	88.56	API
Ts	78		ºF	GRmin	1.5	API
B.H .T	232		ºF	ρbma	2.86	g/c3
GG	0.016			ρbf	1.1	g/c3
Rmfavrage	0.332		ohm.m	Δtma	44	us/ft
Ri	13.5		ohm.m	Δtf	189	us/ft
Rm	0.072		ohm.m	Rw	0.012	ohm.m
Ri/Rm	187.5		ohm.m	Φaverage	0.102	/
Rb	0.61938		/	Faverage	8379.81	/
RW/Rb	0.01937		/	Φclay	0.24	/
ρw-ρh	0.6		g/c3	Rshale	10.7531	ohm.m
Δtshale	85		/	C	250	/
Δtsh-Δtma/Δtf-Δtma	0.28276			ρh	0.4	g/c^3
100/Δtsh	1.17647			ρw	1	g/c^3

The dataset included Gamma Ray (GR), Resistivity, Density, Neutron, and Sonic logs, together with essential formation-fluid parameters, such as formation water resistivity (Rw), mud filtrate resistivity (Rmf), bottom-hole temperature (BHT), and other formation constants required for petrophysical calculations. These well-log data provided the basis for reservoir characterization, lithology identification, and the estimation of petrophysical properties and the Oil Initially in Place (OIIP).

Table 2. Input Data and Petrophysical Parameters Used for Well F2 [12]

Remarks	Data	Unit	Remarks	Data	Unit
Rmf at surface	1.01	ohm.m	GRmax	74	gAPI
Ts	78	ºF	GRmin	8	gAPI
B.H .T	232	ºF	ρbma	2.85	g/c3
GG	0.016		ρbf	1.1	g/c3
Rmfavrage	0.325	ohm.m	Δtma	46	us/ft
Φnav	7.72	%	Δtf	189	us/ft
Φsav	9.468	%	Rw	0.021	ohm.m
Φdav	9.769	%	Swav	60.04	%
Rb	0.1075	ohm.m	Soav	39.962	%
RW/Rb	0.1925	ohm.m	Φclay	0.1	/
ρw-ρh	0.6	g/c3	Rshale	10.753	ohm.m
ρh	0.4	g/c3	C	250	/
/			ρw	1	g/c3

The available data vary among the three wells depending on the type of logs performed and the quality of the acquired data for each well. Therefore, not all tables include the same parameters. All available data for each well were used in the petrophysical calculations (Tables 2 and 3).

Table 3. Input Data and Petrophysical Parameters Used for Well G1 [12]

Remarks	Data	Unit	Remarks	Data	Unit
Rmf at surface	1.01	ohm.m	GRmax	50	gAPI
Ts	78	ºF	GRmin	14	gAPI
B.H .T	232	ºF	ρbma	2.85	g/c3
GG	0.016	/	ρbf	1.1	g/c3
Δtshale	85	us/ft	Δtma	45	us/ft
Δtsh-Δtma/Δtf-Δtma	0.27778	us/ft	Δtf	189	us/ft
100/Δtsh	1.17647	us/ft	Rw	0.022	ohm.m
C	250	/	/	/	/
ρh	0.4	g/c3	/	/	/
ρw	1.1	g/c3	/	/	/

2.2 Data Processing

After collecting the well-log data, the datasets were organized and reviewed to ensure completeness and quality. Unrealistic readings and data affected by drilling conditions or logging errors were excluded to ensure the reliability of the data used in the analysis. The data were then arranged according to the depth intervals of the Byda Formation for each well, with formation boundaries defined and subdivided into appropriate units for petrophysical analysis.

Subsequently, the well-log data, including Gamma Ray (GR), Resistivity, Density, Neutron, and Sonic logs, as well as formation fluid data, were prepared for petrophysical property calculations. All data processing and preliminary calculations were performed using Microsoft Excel, while Surfer software was used to generate contour maps, and Petrel software was applied to build a 3D reservoir model and distribute petrophysical properties within the Byda Formation. [14-15].

2.3 Petrophysical Evaluation

The main petrophysical properties of the Byda Formation were calculated using well-log data, including:

- Volume of Shale (Vsh)
- Effective Porosity (Φ)
- Water Saturation (Sw)
- Oil Saturation (So)
- Permeability (K) [16].

These properties were computed using standard petrophysical equations commonly applied in carbonate reservoir evaluation, integrating density, neutron, sonic, and resistivity log responses to achieve reliable reservoir characterization [17].

2.4 Lithology Identification

The lithology of the reservoir was determined by analyzing the relationship between Neutron Log and Sonic Log, in addition to comparing the results with standard Schlumberger crossplots, in order to distinguish carbonate from clastic lithologies and identify the dominant rock type within the Byda Formation.

2.5 Petrophysical Mapping

After calculating the petrophysical properties for each well, average values were extracted and used to generate contour maps showing the spatial distribution of porosity, permeability, water saturation, and oil saturation within the study area. These maps were created using Surfer software, while the data were also exported to Petrel software to construct a three-dimensional reservoir model illustrating the spatial distribution of petrophysical properties within the reservoir.

2.6 Oil Initially in Place (OIIP) Estimation

The original oil in place (OIIP) was estimated using the volumetric method. Initially, the **Gross Rock Volume (GRV)** was calculated based on reservoir dimensions using Equation (1).

$$\boldsymbol{GRV} = 1/2(X \times Y) \qquad (1)$$

Where:

- **GRV** = Gross Rock Volume (ft^3)
- **X** = Reservoir area (ft^2)
- **Y** = Reservoir thickness (ft) . [18].

Subsequently, the Gross Rock Volume (GRV) value was used to estimate the original oil in place (OIIP) using the volumetric equation (2):

$$\boldsymbol{OIIP} = \frac{GRV \times (G/N) \times \phi \times So}{Bo} \qquad (2)$$

Where:

- **GRV** = Gross Rock Volume.
- **N/G** = Net-to-Gross Ratio.
- **Φ** = Effective Porosity.
- **So** = Oil Saturation.
- **Bo** = Oil Formation Volume Factor. [18].

The average petrophysical parameters derived from the wells F1, F2, and G1 were used to calculate effective porosity and oil saturation, while the reservoir geometric data were used to compute the Gross Rock Volume (GRV), and subsequently to estimate the original oil in place (OIIP).

3. Results and Discussion

3.1 Well Log Interpretation

3.1.1 Petrophysical Interpretation and Reservoir Zonation of Well F1

Figure (2) illustrates the well-log interpretation of Well F1 within the Byda Formation. Based on the responses of Gamma Ray, Resistivity, porosity, water saturation**,** and shale volume, the reservoir was divided into four zones, including two hydrocarbon-bearing intervals separated by two shale-rich intervals. The first oil-bearing zone **(**8800–8860 ft**)** is characterized by low Gamma Ray values, high resistivity, low water saturation, and low shale volume, indicating clean reservoir rocks with good reservoir quality and high hydrocarbon saturation. The good agreement between neutron and density porosity logs further confirms the presence of effective porosity favorable for hydrocarbon accumulation.

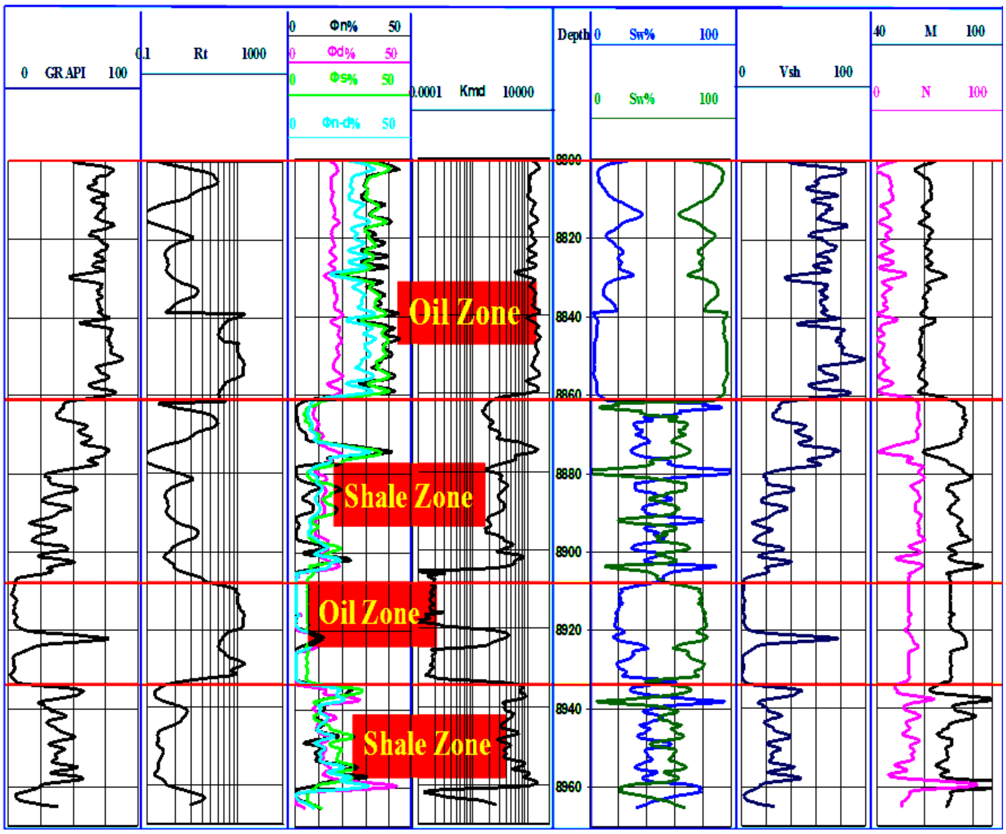

Figure 2. Well log interpretation and reservoir zonation of Well F1

The interval between 8870 and 8900 ft is characterized by high Gamma Ray values, high shale volume, and low resistivity, indicating shale-rich rocks with poor reservoir quality. In contrast, the interval between 8900 and 8930 ft exhibits high resistivity, low shale volume, and low water saturation, representing a second productive hydrocarbon-bearing zone. The lower interval **(**8930–8960 ft**)** shows increased Gamma Ray values, high water saturation, and low resistivity, reflecting poorer reservoir quality due to increased shale content. These vertical variations indicate reservoir heterogeneity, which is typical of carbonate reservoirs.

3.1.2 Petrophysical Interpretation and Reservoir Zonation of Well F2

Figure (3) illustrates the well-log interpretation of Well F2 within the Byda Formation. The reservoir was divided into two zones: an upper hydrocarbon-bearing interval (9125–9150 ft) and a lower water-bearing interval. The oil-bearing zone is characterized by low Gamma Ray values, high resistivity, low water saturation, and low shale volume, indicating relatively clean reservoir rocks with effective porosity and favorable conditions for hydrocarbon accumulation.

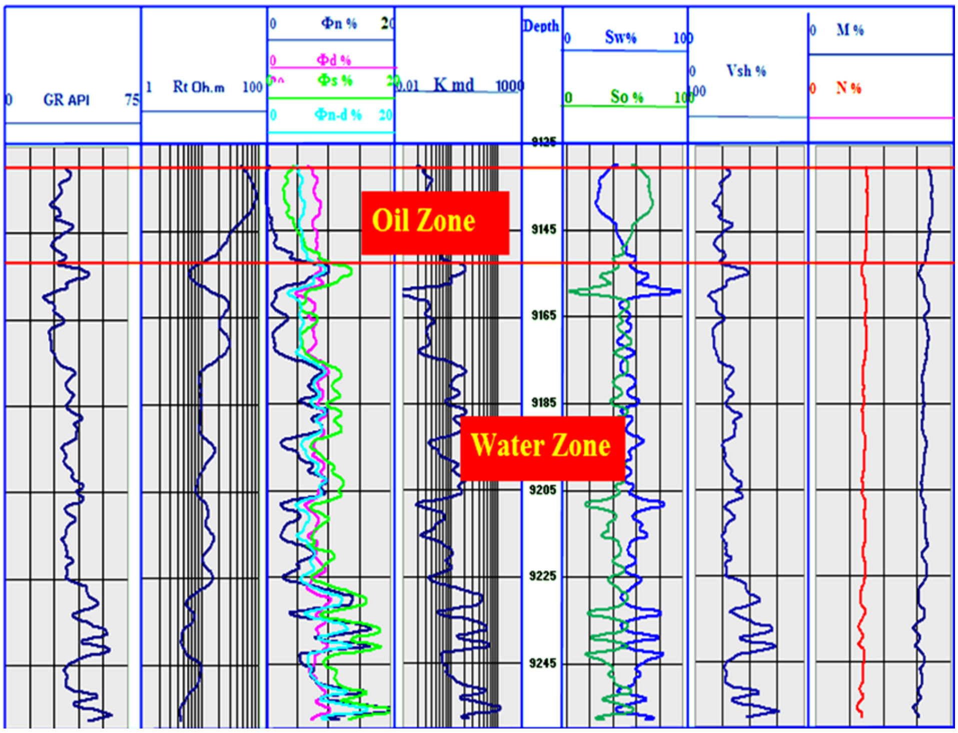

Figure 3. Well log interpretation and reservoir zonation of Well F2

The interval between 9150 and 9245 ft is characterized by decreasing resistivity and increasing water saturation, indicating a transition to a water-bearing zone near the oil–water contact (OWC)**.** Despite the presence of porosity, the high water saturation limits hydrocarbon productivity. The consistently low Gamma Ray and shale volume values indicate that the reduced reservoir quality is mainly controlled by fluid saturation rather than lithological changes.

3.1.3 Petrophysical Interpretation and Reservoir Zonation of Well G1

Figure (4) illustrates the petrophysical interpretation of Well G1 within the Byda Formation. The reservoir was divided into two zones: an upper hydrocarbon-bearing interval (9245–9285 ft) and a lower water-bearing interval (9285–9345 ft). The upper zone is characterized by low

Gamma Ray values, high resistivity, low water saturation, and high oil saturation, indicating good reservoir quality and favorable conditions for hydrocarbon accumulation. In contrast, the lower zone exhibits decreasing resistivity and increasing water saturation, indicating a water-bearing interval with reduced hydrocarbon potential. The consistently low Gamma Ray values suggest that the decline in reservoir quality is primarily controlled by fluid saturation rather than lithological variation.

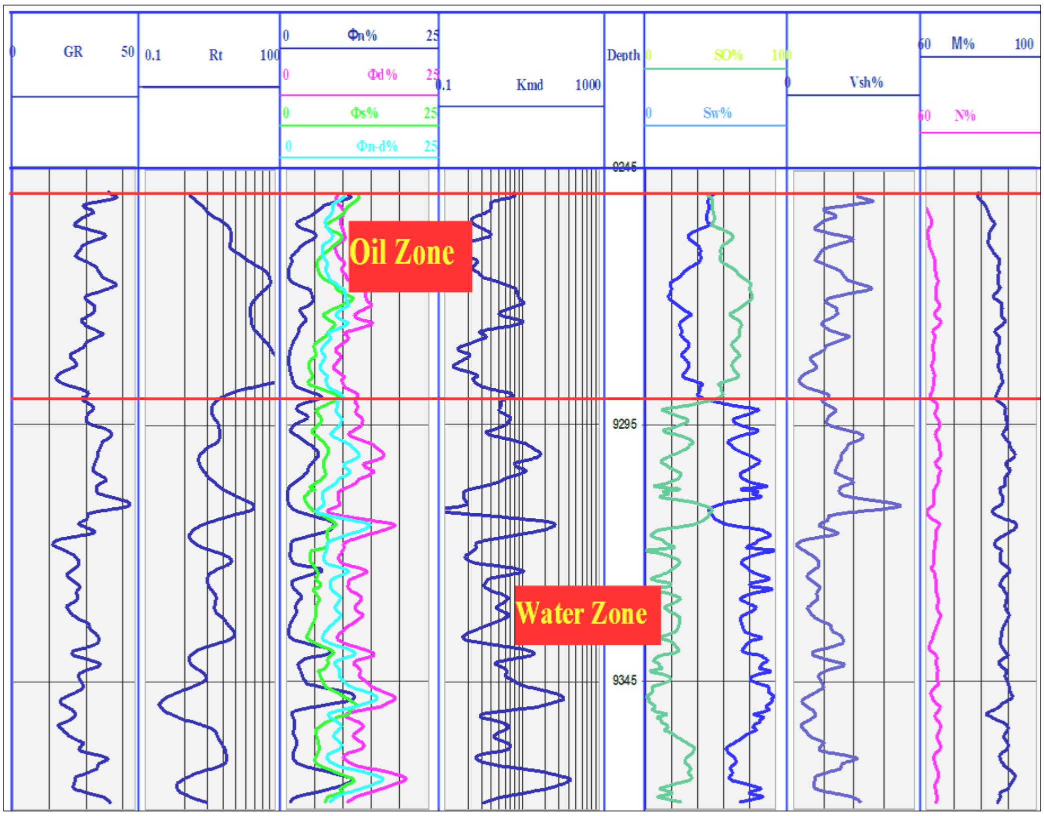

Figure 4. Well log interpretation and reservoir zonation of Well G1.

Compared with wells F1 and F2, Well G1 exhibits moderate reservoir quality with a thinner hydrocarbon-bearing interval. The higher water saturation relative to F1 reflects lateral heterogeneity in fluid distribution within the Byda Formation, likely controlled by depositional and structural variations. Overall, the upper interval of Well G1 represents the most productive part of the reservoir, while the lower interval contributes less to recoverable hydrocarbons.

3.2 Lithology Interpretation

Lithology identification of the Byda Formation was carried out using the relationship between interval transit time (Δt) and neutron porosity (Φn) based on the Schlumberger crossplot method. Figure (5) shows the lithological interpretation for Well G1, where most data points fall within the limestone domain, indicating that the reservoir is predominantly composed of limestone.

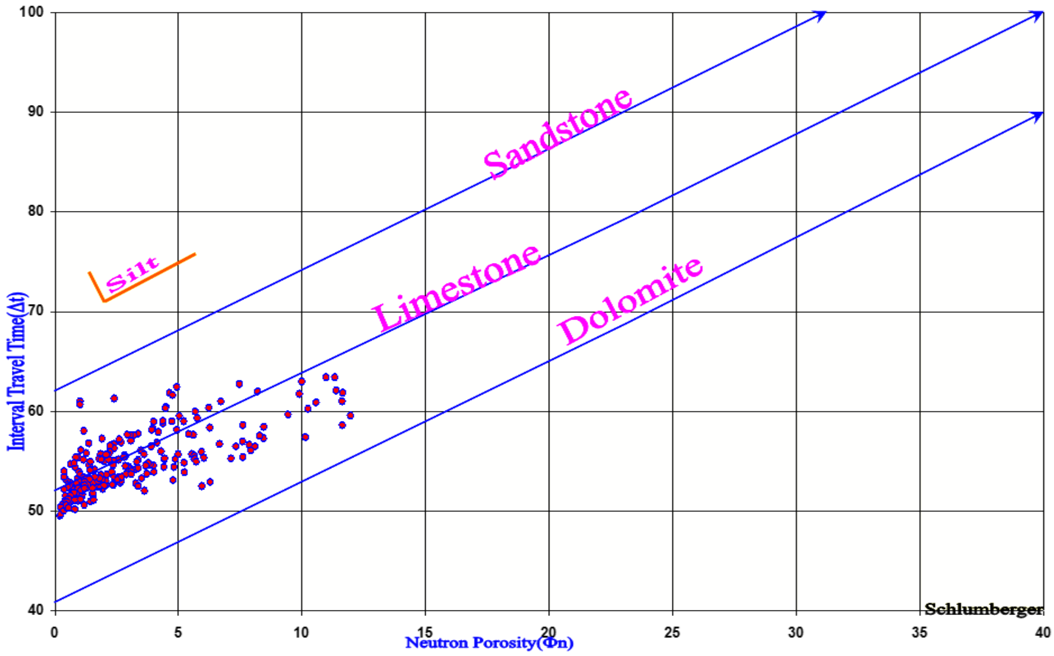

Figure 5. Lithology identification of Well G1 in the Byda Formation using the Schlumberger Δt–Neutron Porosity (Φn) crossplot.

The results confirm that no significant evidence of dolomite or sandstone dominance is observed. The porosity values fall within the moderate range, indicating fair to good reservoir quality. This interpretation is consistent with Gamma Ray logs, which indicate low shale content in productive zones, and resistivity logs, which show higher values in hydrocarbon-bearing intervals. Results from Wells F1 and F2 show a similar lithological trend, confirming that limestone is the dominant rock type across the studied wells. Therefore, differences in reservoir performance are mainly attributed to variations in petrophysical properties rather than lithological changes. Overall, the Byda Formation is characterized by a carbonate limestone reservoir system, consistent with petrophysical analysis and hydrocarbon saturation trends, supporting the reliability of reservoir characterization and OIIP estimation.

3.3 Petrophysical Properties

Petrophysical evaluation of the Byda Formation was carried out by calculating porosity, permeability, shale volume, water saturation, and oil saturation for Wells F1, F2, and G1. The results indicate considerable reservoir heterogeneity. Figure (6) shows a positive correlation between porosity and permeability in Well F1, indicating improved pore connectivity and fluid flow. A production cutoff of approximately 1 mD corresponds to a porosity of about 10%, below which reservoir productivity decreases significantly. Among the studied wells, Well F1 exhibits the best reservoir quality, whereas Well F2 shows poorer reservoir properties due to higher water saturation. Well G1 displays moderate reservoir characteristics, with a productive upper interval and a water-bearing lower interval. These results demonstrate that porosity, permeability, and water saturation are the primary factors controlling reservoir quality and provide a reliable basis for estimating the Oil Initially in Place (OIIP).

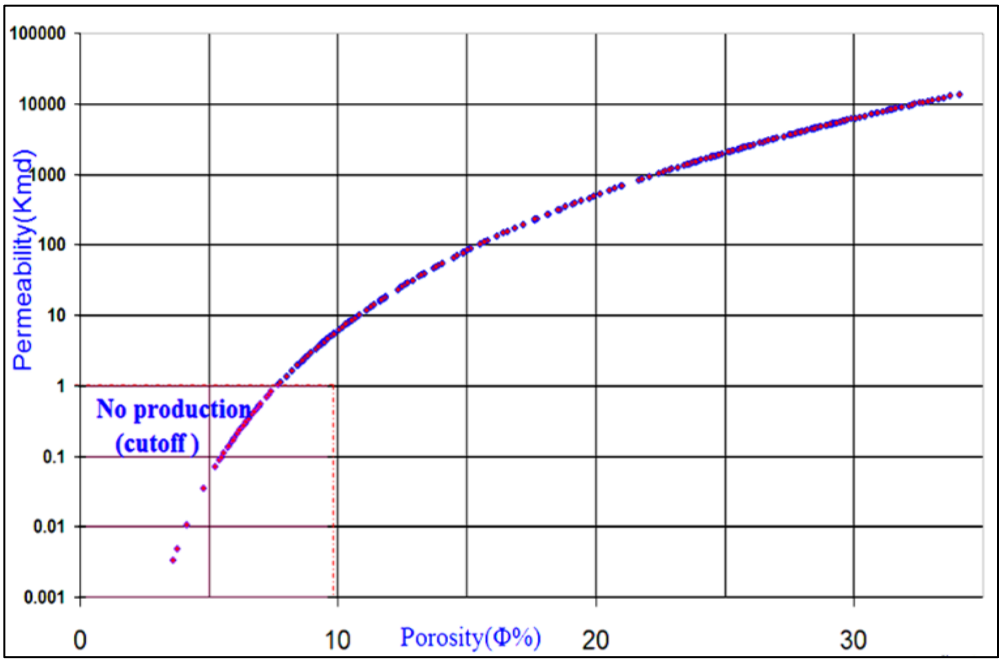

Figure 6. Relationship between permeability and porosity of Well F1, NC74 concession

3.4 Average Petrophysical Parameters

Table (4) presents the average petrophysical properties of Wells F1, F2, and G1, along with the overall field average. The results show clear variations in reservoir properties, reflecting the heterogeneous nature of the Byda Formation within the Al-Samah Field.

Table 4. Average Petrophysical Properties of the Studied Wells and Field Average

wells	Average							
	Vsh_{av}%	$Φn_{av}$%	$Φd_{av}$%	$Φs_{av}$%	$Φn\_d_{av}$%	K_{av}md	Sw_{av}%	So_{av}%
Well F1	40.23	17.24	12.15	19.62	15.68	1719.24	31.75	68.25
Well F2	32.84	6.04	8.33	9.70	8.338	4.30	54.47	45.53
Well G1	29.43	3.173	12.22	6.82	12.22	9.65	63.79	36.21
Average field	34.16	8.81	10.9	12.04	12.07	577.73	50.033	49.997

Well F1 exhibited the best reservoir quality, with the highest combined porosity (15.68%), permeability (1719.24 mD), and oil saturation (68.25%), together with the lowest water saturation (31.75%). In contrast, Well F2 showed poorer reservoir quality, with low permeability (4.30 mD) and higher water saturation (54.47%). Well G1 displayed moderate reservoir properties but recorded the highest water saturation (**63.79%**) and the lowest oil saturation (36.21%), indicating predominantly water-filled pore spaces. Overall, the Byda Formation exhibits moderate to good reservoir quality, with average values of 12.07% combined porosity, 577.73 mD permeability, 50.03% water saturation, and approximately **50%** oil saturation. The observed heterogeneity among the wells, mainly controlled by permeability and water saturation, significantly influences the estimation of Oil Initially in Place (OIIP) and reservoir development planning.

3.5 Oil Initially in Place (OIIP) Estimation

The Oil Initially in Place (OIIP) was estimated using the average petrophysical properties derived from the three wells and applying the volumetric method. A reservoir area of 1,722,000 ft^2 and an average net pay thickness of 40 ft were used to calculate the Gross Rock Volume (GRV), which was estimated at 344,400,000 ft^3.

Using the average effective porosity, oil saturation, and formation volume factor, the OIIP was estimated to be approximately 7.5 MMSTB. This result indicates that the Byda Formation contains economically significant hydrocarbon resources, with the largest contribution originating from reservoir intervals characterized by high porosity, high permeability, and low water saturation, particularly in Well F1, The variation in petrophysical properties among the three wells had a direct influence on the estimated hydrocarbon volume. The excellent reservoir characteristics of Well F1 significantly increased the overall OIIP, whereas the higher water saturation and lower permeability observed in Wells F2 and G1 reduced their relative contribution to the total oil volume. These findings demonstrate that integrating petrophysical evaluation with the volumetric method provides a reliable estimate of OIIP and offers valuable support for reservoir development planning and future production strategies.

3.6 Hydrocarbon Accumulation

Figure 7 illustrates the hydrocarbon distribution within the Byda Formation based on the structural map and reservoir structural model. The green areas represent oil-bearing zones, whereas the blue areas represent water-bearing zones.

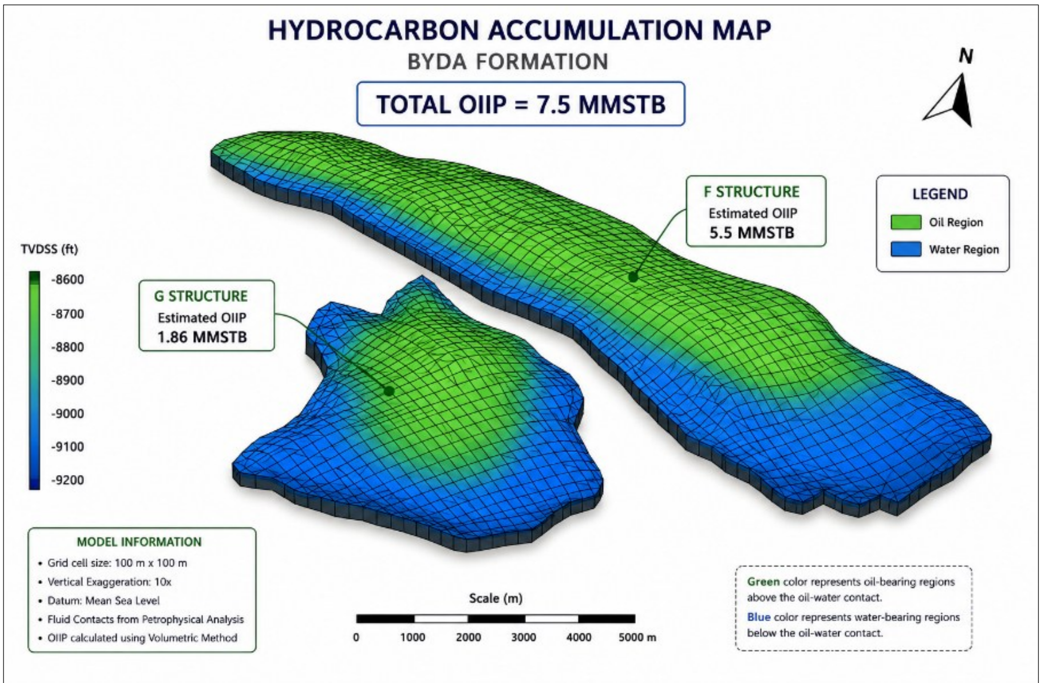

Figure 7. Hydrocarbon accumulation model showing the distribution of oil and water and the estimated original oil in place (OIIP) within the F and G structures of the Byda Formation.

The volumetric assessment indicates that the total Original Oil Initially in Place (OIIP) of the Byda Formation is approximately 7.5 MMSTB. The results further show that the F Structure contains the largest share of the hydrocarbons, with an estimated 5.5 MMSTB, whereas the G Structure contains approximately 1.86 MMSTB. This distribution reflects the structural and petrophysical differences between the two structures, where more favorable structural conditions and superior reservoir quality promoted greater hydrocarbon accumulation within the F Structure.

These findings are consistent with the well-log interpretation and petrophysical evaluation, which demonstrated that intervals characterized by higher porosity, greater permeability, and lower water saturation represent the most favorable locations for hydrocarbon accumulation. Consequently, the results confirm the reliability of the fluid distribution model developed in this study.

4. Conclusion

This study evaluated the petrophysical properties of the Byda Formation in the Al-Samah Field (NC74) using well-log data and volumetric analysis. The results indicate that the reservoir is predominantly composed of limestone and exhibits moderate to good reservoir quality. The average effective porosity was approximately 12%, while the average permeability reached 577.73 mD, indicating favorable reservoir characteristics for hydrocarbon accumulation and fluid flow. The average oil saturation was approximately 50%, reflecting the presence of both oil and formation water within the reservoir. Among the studied wells, Well F1 showed the best reservoir quality, with higher porosity, permeability, and oil saturation than Wells F2 and G1. Using the volumetric method, the original oil in place (OIIP) was estimated at approximately 7.5 MMSTB, with most of the reserves concentrated in the F Structure. These findings demonstrate that integrating well-log interpretation with petrophysical evaluation provides a reliable approach for reservoir characterization and reserve estimation, supporting future reservoir development and field management.

Previous Related Publication

This manuscript is an extended and substantially revised version of the authors' previously published work entitled "Oil Initial in Place (OIIP) Determination Using the Volumetric Method of the Wells F1, F2, NC74 in Sirt Basin", published in *Surman Journal for Science and Technology* (2026). The present study includes significant improvements, including the incorporation of an additional well (G1), expanded petrophysical evaluation, lithology interpretation, reservoir zonation, improved methodology, enhanced discussion, updated references, and a comprehensive re-analysis of the Byda Formation within the NC74 concession. The manuscript has been substantially rewritten and presents new analyses and results beyond those reported in the earlier publication.

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