Journal of Scientific and Human Dimensions
مجلة الأبعاد العلمية والإنسانية
ISSN: 3106-1702
Volume 2, Issue 4, 2026, Pages: 431-439
Journal homepage: https://jshd.com.ly/index.php/jshd/en

Petrophysical Evaluation and Preliminary Flow Quality Ranking of the Faroud Member Using Well Logs: Al-Zanad Field, Sirt Basin, Libya

Abraheem Mohamed Jabouda[1]*, Sedeg Ahmed Jbouda[2], Adel Mohammed Alhaj [3]
[1,3] Department of Geological Engineering, Faculty of Engineering, Nalut University, Jado, Libya
[2]Department of Geology, Faculty of science, University of Zawia, Zawia, Libya

التقييم البتروفيزيائي وترتيب جودة الجريان الأولي لعضو فرود باستخدام سجلات الآبار: حقل الزناد، حوض سرت، ليبيا

ابراهيم محمد جبودة [1]*، صديق أحمد جبودة [2]، عادل محمد الحاج [3]
[3،1] قسم الهندسة الجيولوجية، كلية الهندسة، جامعة نالوت، جادو، ليبيا
[2] قسم الجيولوجيا، كلية العلوم، جامعة الزاوية، الزاوية، ليبيا

*Corresponding author: s.jbouda@zu.edu.ly

Received: August 29, 2026	Accepted: October 25, 2026	Published: November 12, 2026

Copyright: © 2026 by the authors. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Abstract

This study evaluates the petrophysical properties and provides a preliminary ranking of flow quality for the Faroud Member, Al-Zanad Field, Sirt Basin, Libya, using interpreted results from wells VVV4, VVV5, and VVV12. The confirmed log suite comprises gamma ray (GR), bulk density (RHOB), neutron porosity (NPHI), and resistivity. Reported parameters include shale volume, total and effective porosity, secondary porosity, water saturation, estimated permeability, net petrophysical thickness, hydrocarbon pore-volume thickness (HPV), and reservoir quality and flow-zone indicators (RQI and FZI). Effective porosity ranges from 16.70% to 23.10%, whereas estimated permeability ranges from 47.82 to 2666.55 mD. Well VVV12 has the lowest water saturation (49.40%) and the highest estimated permeability (2666.55 mD), and it yields the highest calculated RQI and FZI. Well VVV5 has the greatest net petrophysical thickness (40 ft) and HPV (3.148 ft). Although VVV4 has the highest reported total and effective porosity and secondary porosity, it is a dry well and has the lowest estimated permeability and the highest water saturation among the three wells. This contrast demonstrates that porosity alone does not establish effective flow quality or prove hydrocarbon occurrence. The preliminary flow-quality ranking based on estimated permeability, RQI, and FZI is VVV12, followed by VVV5 and VVV4. The ranking remains indicative because permeability is model-derived, core calibration is unavailable, and the RQI/FZI values were calculated from well-average data.

Keywords: Al-Zanad Field; Sirt Basin; Faroud Member; well logs; effective porosity; permeability; RQI; FZI; flow quality.

الملخص

تهدف هذه الدراسة إلى تقييم الخصائص البتروفيزيائية وتقديم ترتيب أولي لجودة الجريان في عضو فرود بحقل الزناد، الواقع ضمن حوض سرت بليبيا، وذلك بالاستناد إلى النتائج التفسيرية لبيانات الآبار VVV4 و VVV5و VVV12. وتتمثل مجموعة سجلات الآبار المؤكدة والمتاحة في سجل أشعة غاما(GR) ، وسجل الكثافة الحجمية(RHOB) ، وسجل

المسامية النيوترونية(NPHI) ، وسجلات المقاومية الكهربائية .(Resistivity) وتشمل المعلمات البتروفيزيائية المعروضة حجم السجيل، والمسامية الكلية والفعالة، والمسامية الثانوية، والتشبع المائي، والنفاذية التقديرية، والسماكة الصافية البتروفيزيائية، وسماكة حجم المسام الحاوية على الهيدروكربونات(HPV) ، إضافة إلى مؤشري جودة المكمن ومناطق الجريان (RQI وFZI). أظهرت النتائج أن المسامية الفعالة تتراوح بين 16.70% و23.10%، في حين تتراوح قيم النفاذية التقديرية بين 47.82 و2666.55 ملي دارسي. وسجل البئر VVV12 أقل قيمة للتشبع المائي، بلغت 49.40%، وأعلى قيمة للنفاذية التقديرية، بلغت 2666.55 ملي دارسي، كما حقق أعلى قيمتي لمؤشري جودة المكمن ومناطق الجريان RQI) و .(FZIفي المقابل، سجل البئر VVV5 أكبر سماكة صافية بتروفيزيائية، بلغت 40 قدماً، وأعلى قيمة لسماكة حجم المسام الحاوية على الهيدروكربونات(HPV) ، بلغت 3.148 قدماً. وعلى الرغم من تسجيل البئر VVV4أعلى قيم للمسامية الكلية والفعالة والمسامية الثانوية، فإنه بئر جاف، كما سجل أدنى قيمة للنفاذية التقديرية وأعلى قيمة للتشبع المائي بين الآبار الثلاثة. ويبرز هذا التباين أن ارتفاع المسامية وحده لا يُعد دليلاً كافياً على جودة الجريان الفعالة، كما لا يثبت بالضرورة وجود تجمعات هيدروكربونية. وبناءً على قيم النفاذية التقديرية ومؤشري جودة المكمن ومناطق الجريان، تم تحديد الترتيب الأولي لجودة الجريان على النحو الآتي: البئر VVV12 في المرتبة الأولى، يليه البئر VVV5، ثم البئر .VVV4 ومع ذلك، تظل هذه النتائج مؤشراً أولياً وتحتاج إلى مزيد من التحقق، نظراً إلى أن قيم النفاذية مستمدة من نماذج حسابية، وعدم توافر بيانات معايرة من اللباب الصخري، فضلاً عن اعتماد حساب مؤشري RQI و FZIعلى متوسطات القيم البتروفيزيائية لكل بئر.

الكلمات المفتاحية :حقل الزناد؛ حوض سرت؛ عضو فرود؛ سجلات الآبار؛ المسامية الفعالة؛ النفاذية؛ مؤشر جودة المكمن (RQI)؛ مؤشر مناطق الجريان(FZI) ؛ جودة الجريان.

1. Introduction

Petrophysical evaluation is fundamental to understanding reservoir storage capacity and fluid-flow behaviour. Reservoir quality is not controlled by porosity alone; it also depends on pore size, geometry, connectivity, rock fabric, and diagenetic processes such as dolomitization, dissolution, cementation, and fracturing. These controls are particularly important in carbonate reservoirs, where permeability may vary substantially among intervals with comparable porosity.

The Sirt Basin is one of Libya's major petroleum provinces. Its geological evolution involved tectonic subsidence, block faulting, and the development of structural highs and lows. This structural framework provides an important regional context for reservoir distribution and hydrocarbon accumulation. Nevertheless, the influence of structure on reservoir flow quality cannot be demonstrated from well-average petrophysical values alone; detailed structural, seismic, and depth-dependent reservoir data are required.

This study focuses on the Faroud Member in Al-Zanad Field and compares the reported petrophysical properties of wells VVV4, VVV5, and VVV12. The objectives are to describe the inter-well variation in reservoir properties, assess the implications for flow quality, and establish a preliminary ranking using estimated permeability and the reservoir quality index (RQI) and flow zone indicator (FZI), while explicitly accounting for the dry status of VVV4 and the limitations of the available dataset.

2. Study Area and Geological Setting

Al-Zanad Field is located in the southwestern part of Concession 11 West, within the Sirt Basin, between approximately 28°55′ and 29°05′ N and 17°25′ and 17°30′ E, according to the supplied study-area document. The field lies within a tectonically complex basin characterized by structural highs, depocentres, and fault systems developed during successive phases of extension and subsidence.

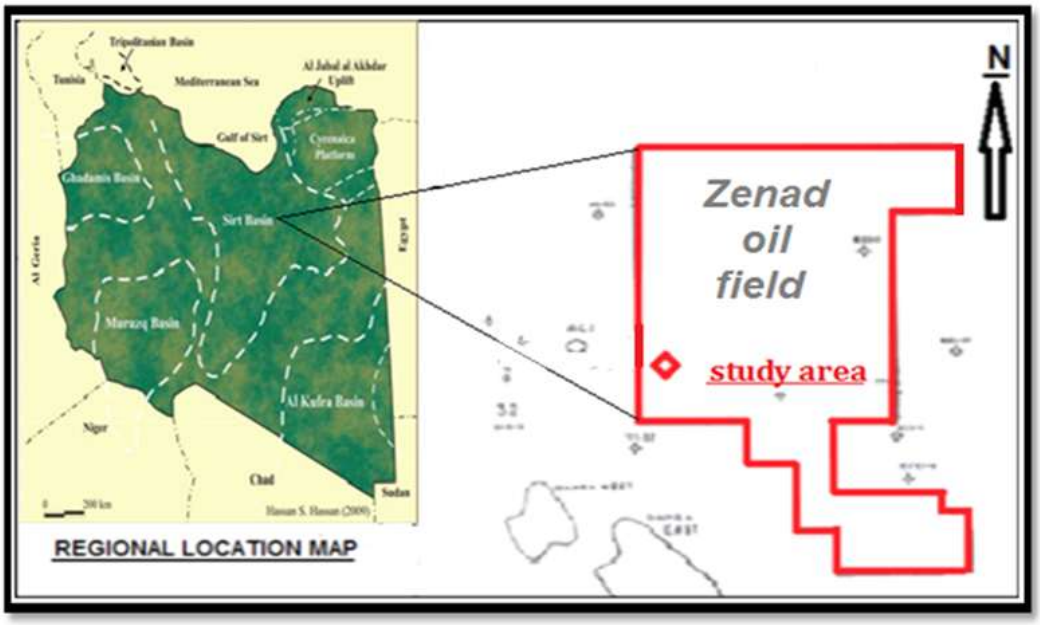


Figure 1: Regional location of Al-Zanad Field and the study area within the Sirt Basin.

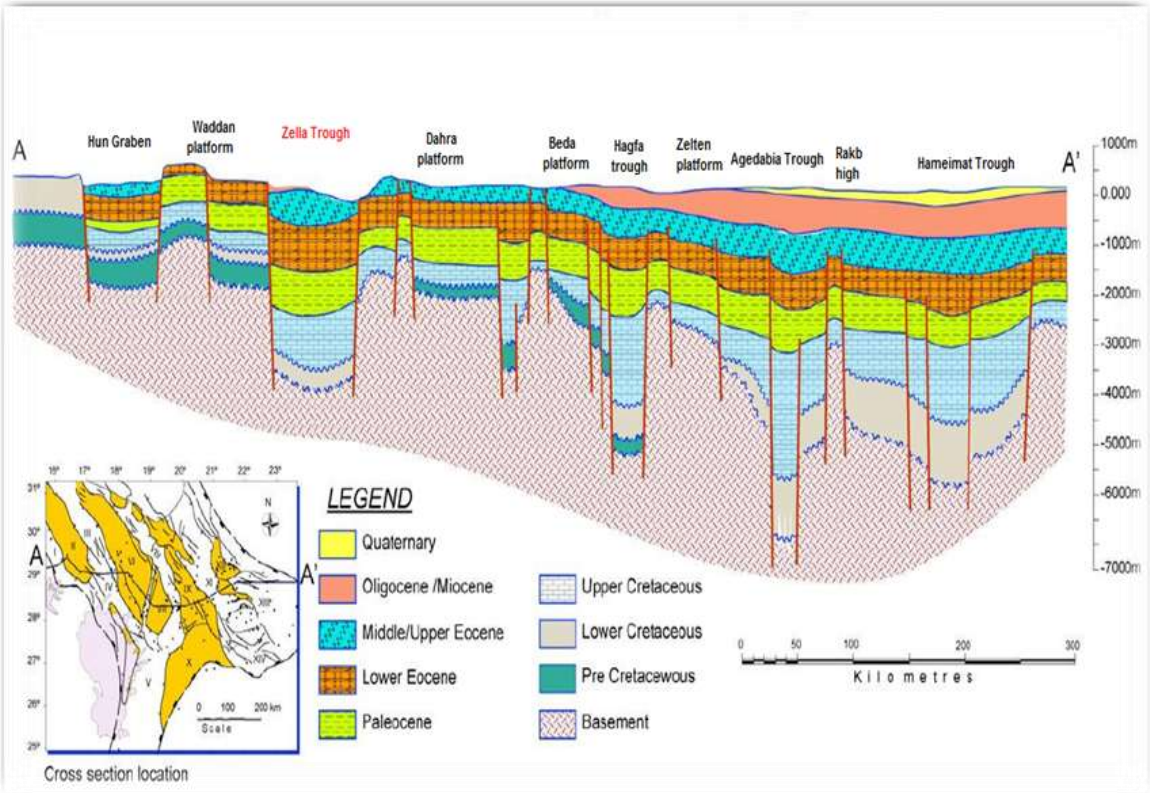


Figure 2: Regional structural cross-section illustrating the main structural elements of the Sirt Basin.

The Sirt Basin is of considerable petroleum significance due to the integration of the essential elements of a petroleum system, including source rocks, reservoir rocks, seals, and traps. Regional studies indicate that reservoirs within the basin comprise carbonate and clastic rocks, as well as fractured basement rocks. Geological structures and fault systems also play a significant role in hydrocarbon entrapment, migration, and the spatial distribution of hydrocarbon accumulations.

The evolution of the Sirt Basin was associated with a phase of subsidence and block faulting during the Late Cretaceous, which resulted in the development of several structural highs and lows. Regional geological studies

also indicate a general northeast trend in some of the major structural features, together with the presence of faults associated with the basement rocks

AGE			FORMATION	MEMBER	DEPTH	LITHOLOGY	DESCRIPTION
CENOZOIC	TERTARY	LOWER EOCENE	GIR	HON EVAPORITES	1935		ANHYDRITE + DOLOMITE ANHYDRITE SHALE + DOLOMITE
				FACHA DOLOMITE	512		DOLOMITE + SOME ANHYDRITE
		UPPER PALEO-CENE	ZELTEN	KHEIR	350		SHALE + CLAY + LIMESTONE
				ZELTEN	620		SHALE + ARGILLACEOUS + LIMESTONE
		LOWER PALEO-CENE	DAHRA	DAHRA	481		LIMESTONE + ARGILLACEOUS + DOLOMITE + SHALE
				MABRUK	217		ANHYDRITE + SHALE+DOLOMITE
				FARRUD	300		DOLOMITIC + LIMESTONE

Figure 3: Stratigraphic column of the geological succession in the study area, reproduced from the supplied study material.

3.Stratigraphic Framework and Lithological Characteristics

The stratigraphic succession described for the Zella Basin comprises several formations and members with different lithological characteristics. These units include carbonate rocks, dolomite, shale, anhydrite, and other sedimentary components. Their distribution and lithological variations provide the geological context for evaluating the reservoir characteristics of the Faroud Member.

1. Dahra Formation

The Dahra Formation consists of claystone interbedded with thick limestone layers. The claystone ranges in colour from dark grey to dark green, whereas the limestone beds are described as lithified and may exhibit compact, fissile, or waxy textures. The average thickness reported for this formation is approximately 462 ft.

A. Faroud Member

The Faroud Member represents the principal producing interval in most of the oil fields within the Zella Depression. It consists predominantly of light-coloured dolomite and is characterized by extensive distribution and favourable reservoir properties, particularly porosity and permeability.

Given its importance as a producing interval, the Faroud Member constitutes the main target of the present study. Its petrophysical evaluation is based on the interpreted well-log data from wells VVV4, VVV5, and VVV12, with particular emphasis on effective porosity, water saturation, estimated permeability, and preliminary flow-quality indicators.

B. Mabrouk Member

The Mabrouk Member consists mainly of limestone and anhydrite. These lithologies are described as forming the sealing interval overlying the Faroud Member. Their presence is therefore relevant to the stratigraphic relationship between the reservoir and the overlying sealing succession.

2. Zaltan Formation

The Zaltan Formation was deposited from the Late Early Tertiary to the Eocene. It consists of successive limestone units separated by thin shale interbeds. The succession is also described as containing a soft clay-rich component, generally exhibiting grey to cream colours.

The deposition of this formation is considered contemporaneous with that of the Khair Formation. Its reported average thickness is approximately 606 ft.

A. Khair member

The Khair member extends from the Early Tertiary to the Early Eocene. It comprises three principal lithological components, with shale being the dominant constituent, together with chalky material and gypsum. The formation is predominantly calcareous and contains various fossils and the mineral pyrite. Its reported thickness is approximately 332 ft.

3. Al-Jir Formation

The Al-Jir Formation is associated with the Cretaceous succession and is described as having undergone several episodes of structural subsidence and collapse, accompanied by dolomite deposition, limestone lithification, and shale accumulation.

The formation is subdivided into two members: the Facha Member and the Houn Member.

A. Facha Member

The Facha Member consists predominantly of dolomite, with successive dolomitic beds displaying crystalline textures. These characteristics are attributed in the original geological description to the pressure affecting the sedimentary layers during this stage. The interval is also characterized by the deposition of substantial quantities of materials described as having relatively high permeability. Its reported thickness is approximately 188 ft.

B. Houn Member

The Houn Member was deposited during the Cretaceous and consists of successive layers of dolomite, anhydrite, and brown-coloured sedimentary rocks with dense crystalline textures. Fossils are relatively scarce, whereas shale is abundant. The succession is also described as exhibiting significant faulting and fracturing, together with the occurrence of halite. Its reported average thickness is approximately 2,058 ft.

3.1. Geological Implications for Faroud Member Reservoir Evaluation

The stratigraphic and lithological descriptions of the Zella Basin indicate considerable variation in rock composition, particularly between carbonate, dolomitic, shale, and anhydrite-bearing intervals. Such lithological variations are important when evaluating the petrophysical characteristics of the Faroud Member because mineral composition, depositional texture, and subsequent geological modification may influence the development and connectivity of pore spaces.

The Faroud Member is particularly significant because it is described as a predominantly dolomitic reservoir interval with favourable porosity and permeability. Accordingly, the present study focuses on evaluating its petrophysical properties using gamma-ray (GR), bulk-density (RHOB), neutron-porosity (NPHI), and resistivity logs.

The interpreted results reveal variations in reservoir properties among the three investigated wells. Although well VVV4 exhibits the highest reported total and effective porosity, it is a dry well and has the lowest estimated permeability. In contrast, wells VVV5 and VVV12 show substantially higher estimated permeability, with VVV12 recording the highest values of permeability and the derived reservoir quality and flow-zone indicators (RQI and FZI).

These differences demonstrate that reservoir quality cannot be assessed on the basis of porosity alone. Instead, effective porosity, water saturation, permeability, and the distribution of reservoir intervals must be considered together when evaluating the potential flow characteristics of the Faroud Member.

The geological framework presented here therefore provides the stratigraphic and lithological context for interpreting the petrophysical results and establishing a preliminary ranking of flow quality among the investigated wells. However, the available information does not establish a direct causal relationship between specific structural features and the observed permeability variations

4. Materials and Methods

4.1. Well Dataset and Available Logs

The study uses interpreted results from three wells: VVV4, VVV5, and VVV12. The confirmed available log suite comprises gamma ray (GR), bulk density (RHOB), neutron porosity (NPHI), and resistivity. The original well-distribution map is reproduced without changing the well locations or map content.

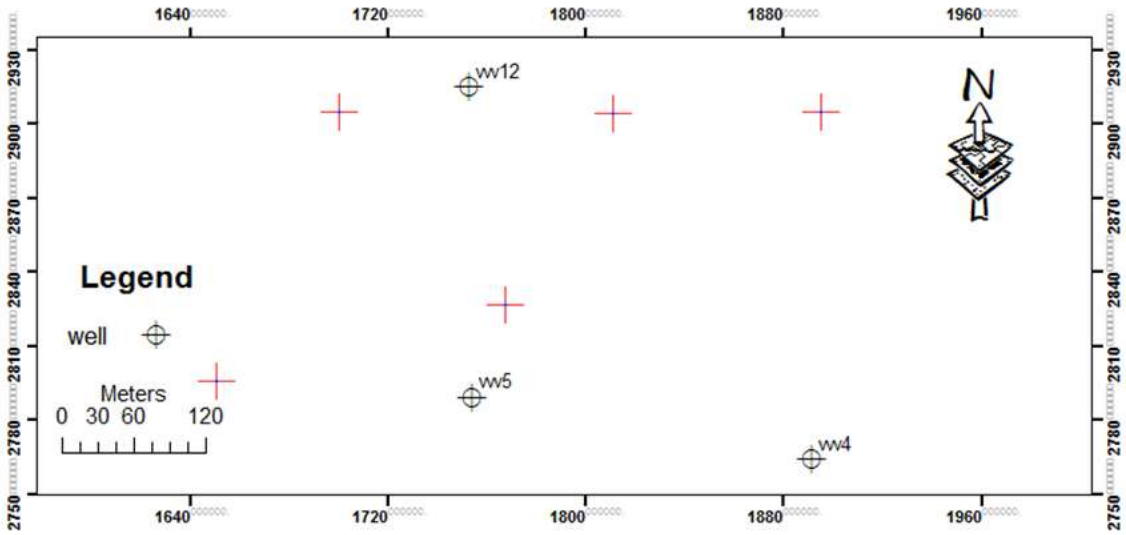


Figure 4: Spatial distribution of the studied wells (VVV4, VVV5, and VVV12) in Al-Zanad Field. Source: supplied study map.

Some previously reported secondary-porosity values were derived using a relationship involving sonic porosity. Since a sonic log is not included in the currently confirmed log suite, these values are retained as previously reported results and are not recalculated in this version.

4.2. Shale-Volume Estimation

The gamma-ray index (IGR) was calculated using:

$$IGR = (GRlog - GRclean) / (GRshale - GRclean)$$

The shale-volume transformation reported in the original calculation method is:

$$Vsh = 0.083 [2^{(3.7\ IGR)} - 1] \times 100$$

The final Vsh values are retained as reported because depth-sampled input values are not available here for an independent numerical reconstruction of the transformation and well averages.

4.3. Porosity Estimation

Density porosity was estimated using:

$$\varphi D = (\rho ma - \rho b) / (\rho ma - \rho f)$$

The original method reports matrix and fluid densities of 2.71 and 1.10 g/cm³, respectively. A single matrix density may not fully represent lithological variation in a mixed carbonate succession and should therefore be considered a methodological limitation. Corrected neutron-porosity readings were combined with density porosity using the arithmetic mean:

$$\varphi ND = (\varphi D + \varphi N) / 2$$

Effective porosity was estimated as $\varphi eff = \varphi ND(1 - Vsh)$. The calculation was performed at individual depth samples and then averaged by well. Consequently, the reported mean effective porosity should not be replaced by a calculation using only the well-average total porosity and well-average shale volume.

4.4. Water and Hydrocarbon Saturation

Water saturation was estimated using the Archie equation:

$$Sw = [aRw / (\varphi^m Rt)]^{(1/n)}$$

The reported parameters are a = 1, m = 0.9, and n = 2; formation-water resistivity was derived from a Pickett plot in the original interpretation. The porosity term used in the Archie equation (total or effective porosity) and the numerical Rw value should be stated consistently in the final submission if the journal requests full reproducibility.

Hydrocarbon saturation was calculated as the complement of water saturation: Shc = 1 − Sw. Where this complement is described as oil saturation (So), it assumes an oil-dominated hydrocarbon phase. This calculation alone is not independent evidence of oil occurrence or producibility, particularly in dry well VVV4.

4.5. Net Petrophysical Thickness and Hydrocarbon Pore-Volume Thickness

Cutoffs were applied at each depth sample, rather than to well averages: porosity ≥ 10%, water saturation < 50%, and shale volume < 25%. The thicknesses of intervals satisfying all cutoffs were summed to obtain net petrophysical thickness. For dry well VVV4, this value is not interpreted as confirmed productive oil pay.

Hydrocarbon pore-volume thickness was calculated at each depth sample and summed:

$$\mathbf{HPV_i = \Delta h_i \times \varphi_{eff,i} \times (1 - S_{w,i}); \quad HPV_{total} = \Sigma\, HPV_i}$$

Effective porosity and water saturation are expressed as decimal fractions, and Δh is in feet. HPV therefore represents an equivalent hydrocarbon-filled pore thickness per unit area (ft), not an absolute hydrocarbon volume or reserve estimate.

4.6. Reservoir Quality Index and Flow Zone Indicator

The reservoir quality index was calculated using:

$$\mathbf{RQI = 0.0314 \sqrt{(K / \varphi_{eff})}}$$

Normalized porosity was calculated as φz = φeff/(1 − φeff), followed by FZI = RQI/φz. Permeability is expressed in mD and effective porosity as a fraction. Since the available calculations use well-average values and the permeability estimates are not calibrated to core measurements, RQI and FZI are treated as indicative comparison indices rather than a definitive hydraulic flow-unit (HFU) classification.

5. Results and Discussion

Table 1 Summary of Petrophysical Properties

Well	Vsh (%)	PHIT (%)	PHIE (%)	PHIsec (%)
VVV4	10.98	25.94	23.10	14.25
VVV5	5.27	20.10	19.40	4.46
VVV12	7.33	18.10	16.70	5.55

Note: PHIsec values are retained from the previously reported calculations and are not independently recalculated here.

VVV4 has the highest reported total and effective porosity and the highest reported secondary porosity. VVV5 has the lowest shale volume. These properties do not, individually, establish the best flow quality. The values must be considered alongside permeability, saturation, and the known dry status of VVV4. Secondary-porosity values are included as reported, because the sonic log required to reproduce their derivation is not part of the confirmed dataset.

Table 2 Water and Hydrocarbon Saturation

Well	Sw (%)	Calculated Shc/So (%)
VVV4	60.04	39.96
VVV5	61.62	38.38
VVV12	49.40	50.60

VVV12 has the lowest reported water saturation and the highest calculated hydrocarbon saturation. The average water saturations of VVV4 and VVV5 exceed 50%; however, some individual depth intervals may still satisfy the applied cutoff because the cutoff was applied sample by sample. VVV4 is confirmed to be a dry well. Its calculated value of 39.96% is simply the complement of water saturation and must not be interpreted as proof of actual oil presence.

Table 3 Permeability, Net Thickness, and HPV

Well	Estimated K (mD)	Net petrophysical thickness (ft)	HPV (ft)
VVV4	47.82	36	1.764
VVV5	2138.58	40	3.148
VVV12	2666.55	26	2.671

Permeability shows the largest inter-well contrast. VVV12 has the highest estimated permeability, followed by VVV5 and VVV4. The estimated permeability of VVV12 is approximately 55.8 times that of VVV4. Such a contrast cannot be explained by porosity alone and may reflect differences in pore connectivity, fractures, rock fabric, or diagenetic modification. VVV5 has the greatest net petrophysical thickness and HPV, whereas VVV12 has the highest estimated permeability. This distinction indicates that storage-related measures and flow-related measures do not necessarily identify the same well as the best-ranked.

The reported net thicknesses represent intervals satisfying the stated petrophysical cutoffs. They should not all be described as productive thicknesses, especially for dry well VVV4. Permeability values are model-derived estimates rather than direct core measurements, because no core-permeability calibration data were supplied.

Table 4 RQI, FZI, and Preliminary Flow-Quality Ranking

Well	RQI (μm)	Φz	FZI (μm)	Preliminary rank
VVV4	0.452	0.300	1.504	3
VVV5	3.297	0.241	13.697	2
VVV12	3.968	0.200	19.791	1

The RQI and FZI values produce the same preliminary order as estimated permeability: VVV12, VVV5, and VVV4. This ranking is indicative and should not be treated as an absolute classification or proof of production status. Establishing robust flow-unit boundaries requires depth-resolved calculations, permeability calibration against core data, and assessment of reservoir heterogeneity.

5.1. Interpretation of Dry Well VVV4

VVV4 is particularly important to the interpretation. Despite its relatively high reported total and effective porosity and secondary porosity, it is a dry well and has the lowest estimated permeability and relatively high water saturation. This demonstrates that pore volume alone does not guarantee hydrocarbon accumulation or effective production. Reservoir performance also depends on pore connectivity and the presence of an effective petroleum system, including charge, trap, and seal. The available data do not establish the specific cause of VVV4 being dry; further interpretation would require integration with structural and seismic information, well tests, and evidence relating to charge and seal integrity.

6. Conclusions

1. The petrophysical evaluation of the three investigated wells (VVV4, VVV5, and VVV12) revealed considerable variations in the reservoir properties of the Faroud Member at Al-Zanad Field. These variations reflect a degree of inter-well reservoir heterogeneity, as evidenced by differences in effective porosity, estimated permeability, water saturation, and net petrophysical thickness. The results indicate that reservoir quality is not uniformly distributed across the study area.
2. Effective porosity (PHIE) values ranged from 16.70% to 23.10%, indicating variations in the storage capacity of the Faroud Member among the investigated wells. Nevertheless, higher porosity does not necessarily indicate better fluid-flow capacity. Reservoir flow performance is also controlled by pore connectivity, pore-throat dimensions, pore-size distribution, rock fabric, and post-depositional modifications. Therefore, porosity should be evaluated in conjunction with permeability and other relevant petrophysical parameters.
3. Estimated permeability values exhibited a wide range, from 47.82 to 2666.55 mD, indicating substantial differences in the fluid-transmission characteristics of the investigated wells. This variation highlights the limitations of using porosity as a standalone indicator of reservoir quality. Instead, integrating effective porosity with estimated permeability and flow-quality indices provides a more comprehensive assessment of the reservoir's potential fluid-flow characteristics.
4. Based on estimated permeability, the Reservoir Quality Index (RQI), and the Flow Zone Indicator (FZI), well VVV12 exhibited the strongest preliminary flow-quality indicators, followed by VVV5 and VVV4. This ranking suggests that VVV12 has relatively more favorable flow-related properties than the other investigated wells. However, this classification remains preliminary and should not be considered a definitive hydraulic flow unit classification.
5. Well VVV5 recorded the greatest net petrophysical thickness, reaching 40 ft, as well as the highest Hydrocarbon Pore Volume per Unit Area (HPV), at 3.148 ft. These results indicate that VVV5 has the largest calculated contribution of hydrocarbon-saturated pore thickness among the investigated wells, based on the adopted calculation procedure and available interpreted data. In contrast, well VVV12 recorded the highest estimated permeability (2666.55 mD) and the lowest water saturation (49.40%), further supporting its relatively favorable reservoir quality in terms of estimated flow capacity and calculated hydrocarbon saturation.
6. Well VVV4 represents an important case for understanding the complex relationship between porosity, flow quality, and hydrocarbon productivity. Despite recording the highest total and effective porosity values among the investigated wells, VVV4 is a dry well. It also exhibited the lowest estimated permeability (47.82 mD) and the highest water saturation (60.04%). This observation demonstrates that high porosity and calculated hydrocarbon saturation, when considered independently, do not provide conclusive evidence of hydrocarbon accumulation or producibility. Consequently, petrophysical

indicators must be interpreted in conjunction with the actual well status, geological and structural information, and direct evidence of hydrocarbon occurrence.

7. The RQI and FZI results indicate variations in pore-system characteristics and flow capacity among the investigated wells. Well VVV12 recorded the highest values of both indices, followed by VVV5 and VVV4. These parameters provide a preliminary basis for comparing relative flow quality. However, calculating RQI and FZI from well-average petrophysical properties limits the ability to identify hydraulic flow units accurately. A more reliable classification requires depth-resolved calculations and an assessment of the distribution and relationships of these parameters throughout the reservoir interval.
8. The estimated permeability values and the derived reservoir-quality and flow-zone indicators presented in this study should be regarded as indicative rather than definitive. This limitation arises primarily from the absence of laboratory permeability measurements from core samples and the unavailability of detailed depth-resolved data for independent verification of the calculations. Accordingly, the proposed flow-quality ranking (VVV12 > VVV5 > VVV4) should be interpreted as a preliminary relative assessment rather than a definitive prediction of well productivity.
9. Overall, this study emphasizes the importance of adopting an integrated approach to the evaluation of carbonate reservoirs by combining effective porosity, water saturation, estimated permeability, reservoir-quality and flow-zone indicators, and net petrophysical thickness. Reliance on a single petrophysical parameter may lead to incomplete or misleading interpretations of reservoir performance. Furthermore, integrating well-log interpretations with geological and structural information, together with available well-test and production data, is recommended to improve the understanding of reservoir-quality distribution and the factors controlling fluid-flow efficiency within the Faroud Member at Al-Zanad Field.

7. Study Limitations and Recommendations

This study is based on interpreted results for three wells; raw log files and depth-sampled calculation tables were not available for independent recalculation. The confirmed log suite does not include a sonic log, although some previously reported secondary-porosity values were derived using sonic porosity. Core-permeability measurements were also unavailable for calibration of the estimated permeability. Accordingly, a definitive hydraulic flow-unit classification and a conclusive explanation for the dry status of VVV4 cannot be established from the available information.

Future work should verify shale volume, porosity, saturation, and cutoff application at depth-sample level; consistently document the porosity input to the Archie equation and the formation-water resistivity value; and calibrate permeability estimates against core measurements where available. Integration of structural maps, seismic interpretation, and well-test information is also recommended to better evaluate the relationship between geological structure and reservoir flow quality.

References

[1] Amaefule, J. O., Altunbay, M., Tiab, D., Kersey, D. G., & Keelan, D. K. (1993). *Enhanced reservoir description: Using core and log data to identify hydraulic (flow) units and predict permeability in uncored intervals/wells.*

[2] Asquith, G., & Krygowski, D. (2004). *Basic well log analysis (2nd ed.)*. American Association of Petroleum Geologists.

[3] Ellis, D. V., & Singer, J. M. (2007). *Well logging for earth scientists (2nd ed.).* Springer.

[4] Hallett, D. (2002). *Petroleum geology of Libya. Elsevier*.

[5] Haines, T. J., Michie, E. A. H., Neilson, J. E., & Healy, D. (2016). *Permeability evolution across carbonate hosted normal fault zones. Marine and Petroleum Geology,*

[6] Amir, H. S., Fathy, M., Reda, M., & Mostafa, T. (2025). *Integrated core-log petrophysical evaluation of the Sarir Formation reservoir units, southeastern Sirte Basin, Libya*. Journal of Umm Al-Qura University for Applied Sciences.

[7] Swei, G. H., & Tucker, M. E. (2012). *Impact of diagenesis on reservoir quality in ramp carbonates: Gialo Formation (Middle Eocene), Sirt Basin, Libya*. Journal of Petroleum Geology,

[8] Kushlaf, A. A., & El Mezweghy, A. E. (2020). *Hydrocarbon potentiality of Facha reservoir in Aswad Oil Field, Sirt Basin, Libya*. Journal of Applied Science,

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of **JSHD** and/or the editor(s). **JSHD** and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.