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Formation evaluation for Mauddud Formation in Bai Hassan oilfield, Northern Iraq

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Abstract

Formation evaluation is a critical process in the petroleum industry that involves assessing the petrophysical properties and hydrocarbon potential of subsurface rock formations. This study focuses on evaluating the Mauddad Formation in the Bai Hassan oil field by analyzing data obtained from well logs and core samples. Four wells were specifically chosen for this study (BH-102, BH-16, BH-86, and BH-93). The main objectives of this study were to identify the lithology of the Mauddud Formation and estimate key petrophysical properties such as shale volume, porosity, water saturation, and permeability. The Mauddud Formation primarily consists of limestone and dolomite, with some anhydrites present. It is classified as a clean formation due to its low shale volume of approximately 17%. The results of the study show a low water saturation of around 30% and an effective porosity reaching up to 32% (with an average of 11%). The Mauddud Formation was further analyzed using the cluster analysis method, which identified four distinct hydraulic flow units (HFUs). The permeability of the Mauddud Formation was predicted using the flow zone indicator method, revealing a range from moderate to sound quality, averaging approximately 22 md.

Keywords: Formation evaluation; Normalization; Mauddud Formation; Flow Zone Indicator; Porosity; Water Saturation.

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1- Introduction

Formation evaluation is the essential application of technological innovations, scientific principles, and engineering concepts. In addition, it is an important method of interpreting quantitatively and qualitatively a combination of measurements taken inside a wellbore to detect hydrocarbon resources in geological formations adjacent to the well [1]. This process is considered a fundamental aspect of both petroleum engineering and geology disciplines. Experts in the field are responsible for gathering, organizing, and evaluating the necessary information that is essential for the specialists involved in exploration, drilling, production, reservoir management, and characterization of petroleum reservoirs [2]. Well logs interpretation provides an initial idea for evaluating and characterizing the reservoir, especially the rock and fluid properties for underground layers, and provides further understanding for the reservoir to identify the relationship between pore media and what it contains fluids [3]. Log data is important in reservoir engineering and is employed in the calculations, particularly when determining the reserve. Depending on the type of problem and the amount and quality of log data available to analysts, will determine the quality of the interpretation process for any structure of interest. The interpretation process of fundamental logs also includes the determination of resistivity for the field, salinity of the formation water, resistivity of mud filtrate, true total porosity, water saturation, and effective porosity. Additionally, predict the size of hydrocarbons in the formation, determine if the accumulation of hydrocarbons is commercial, and calculate the total reserves. For that, researchers can interpret available logs that will help us calculate the original oil in place. The transfer of fluid through a carbonate reservoir is a completely different process than through sandstone layers. This distinction results from the fact that void systems in carbonate rocks tend to be more intricate than those in sand rocks [4]. The major objective of this study is to identify the lithology of the formation, determine shale volume, and evaluate the petrophysical properties such as porosity, permeability, and water saturation of the Mauddud Formation in the Bai Hassan oil field using available well-logging and core data.

2- Area of study

Bai Hassan Oil Field was discovered in 1929. It is located in the northwest of the city of Kirkuk in the northern part of Iraq, parallel to the Avana dome in the Kirkuk oilfield. The field structurally falls within the range of low fold zones parallel to the Zagros Mountain range [5, 6] while according to the structural map of Iraq prepared by Buday, it is within the Batma-Chamchamal range which is the northeastern part of the Foothill zone range located within the Unstable Shelf area [7]. The Bai

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Hassan oil field is approximately 13km northeast of the Kirkuk field. Compared to the wells in the Kirkuk field, the wells in the Bai Hassan oil field are deeper.

The structure of the Bai Hassan oil field is approximately 34 km long and 3.8 km wide and trends from northwest to southeast. The structure consists of two domes, the Daoud Dome to the north-west, and the Kithke Dome to the south-east. The Kithke Dome is larger and more prolific and it has a significant surface expression in contrast with the Daoud Dome. Consequently, it was discovered and produced after several years of Kithke Dome production. The Shahl Saddle separates the two domes from each other physically. Actually, four wells selected in this study to cover the cretaceous reservoir are (BH-102, BH-16, BH-86, BH-93).

3- Methodology

The Mauddud Formation within the Bai Hassan oil field underwent evaluation using data obtained from well logs and core samples, with the assistance of Techlog software (2021). This study focused on four specific wells: BH-102, BH-16, BH-86, and BH-93. Initially, the data underwent rigorous, data Quality Control and Preparation procedures. The software was used to perform environment corrections on the well logs, which were then accordingly analyzed and displayed. Subsequently, crucial petrophysical properties such as Shale Volume, Porosity, Water Saturation, and Permeability were calculated. The final results were then interpreted to provide a comprehensive understanding of the Mauddud Formation.

4- Result and discussion

4.1. Well logs correction

a. Environmental corrections

Environmental corrections refer to the modifications made during and after wireline logging operations to improve the accuracy of logging measurements under specific hole conditions. These corrections are necessary to ensure that well logs provide high-quality data for the formation evaluation process [2]. The North Oil Company has made all necessary corrections to the selected well logs for this study. So, only one environmental correction has been made on the neutron porosity (CNL) matrix, which was converted from limestone to dolomite using formation salinity to compare neutron porosities with the lithology as shown in Fig. 1.

b. Normalization

Performing a quantitative formation evaluation using well log data requires taking into account the variations in the log response between different wells. This is because all well logs cannot share the same log response, such as maximum and minimum gamma-ray values. Therefore, to correct for these variations in gamma-ray response, a normalization method is employed. The normalization technique is crucial in well logging to ensure that accurate and reliable formation evaluation can be achieved using consistent and standardized log data. By considering these factors, the normalization method can achieve accurate and reliable results [8]. This is helpful when working with older datasets where it is unknown what corrections have been done in contrast applying blindly normalization to your data can result in geological variation and features being removed from the data [9].

Normalization Equation:

$$GR_{Norm} = GR_{Ref(min)} + \left(GR_{Ref(max)} - GR_{Ref(min)}\right) * \left(\frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}\right) \quad (1)$$

Where: $GR(min)$: Minimum value obtained from the reference region. $GR(max)$: Maximum value obtained from the reference region. $GRmin$: Minimum value from well being normalized. $GRmax$: Maximum value from well being normalized. $GRlog$: Input value from well being normalized.

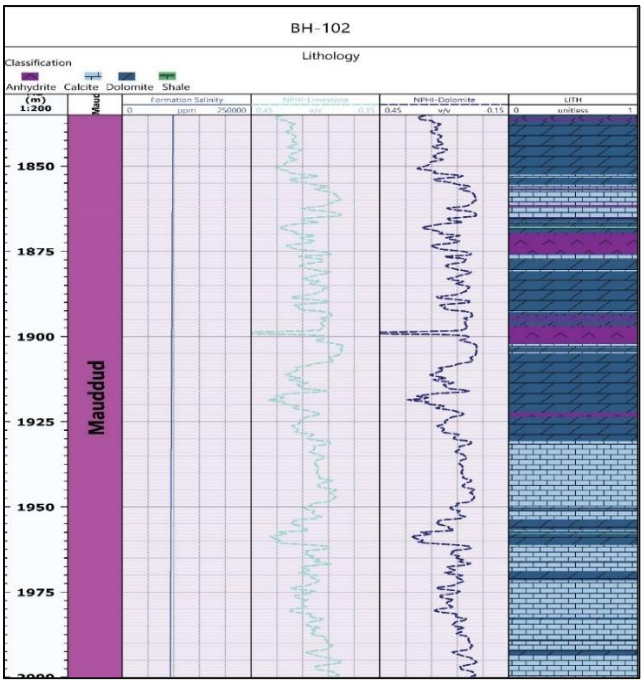
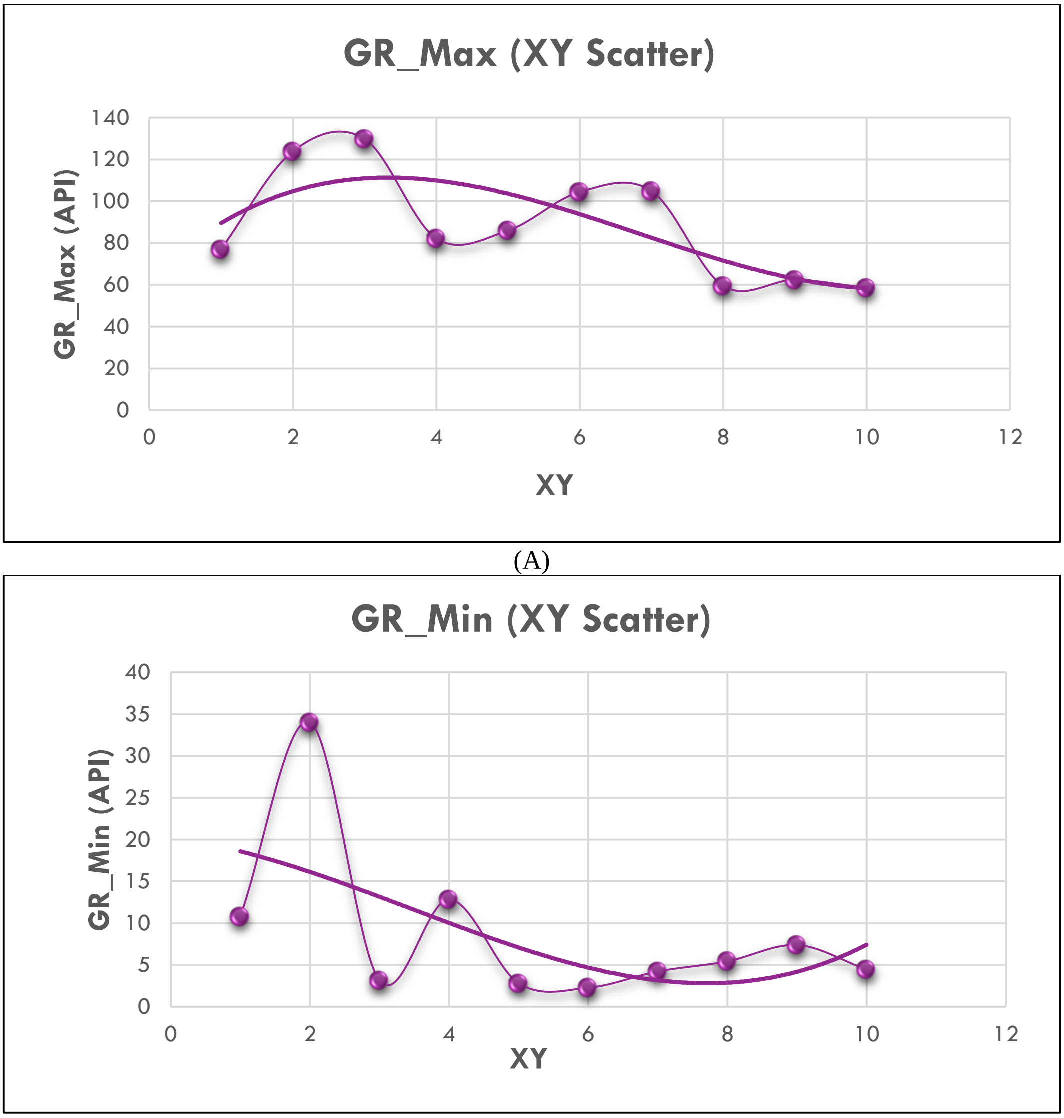


Fig. 1. Neutron porosity (CNL) correction for Well BH-102

Gamma-ray reference region was generated using Trend Surface 3rd order Eq. 2 to identify the max and min reference Gamma-ray values based on the wells' location (X and Y) as shown in Fig. 2. Fig. 3 clarifies the histogram to identify the Max and Min Gamma-ray values for well BH-102. Fig. 4 clarifies the difference between gamma rays and gamma rays normalized for the studied wells.

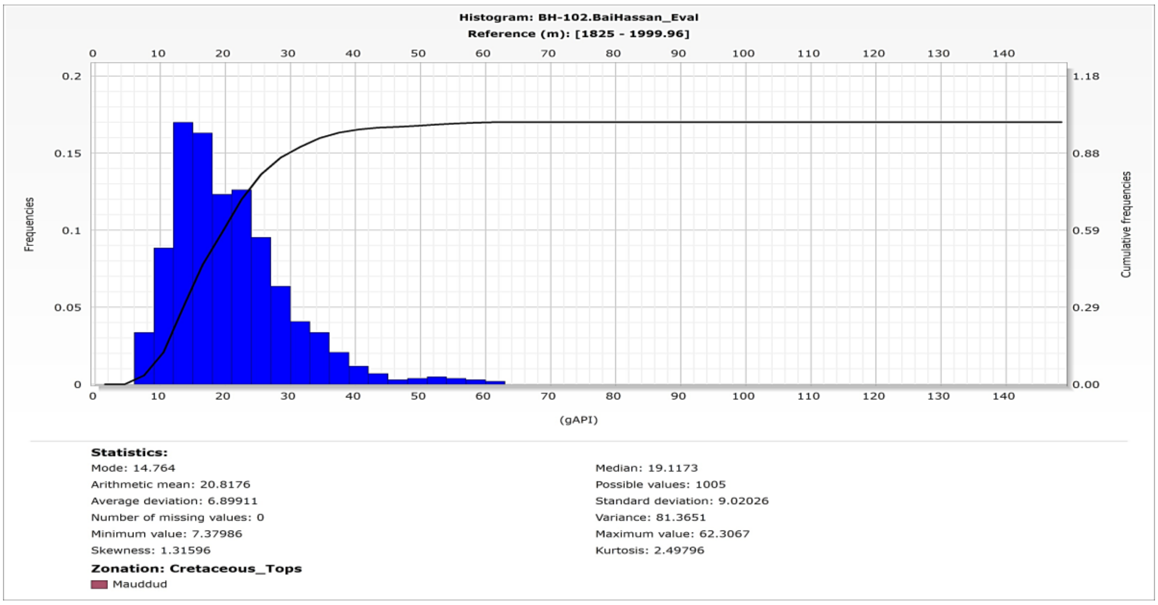
$$\mathrm{GR}_{Ref(min/max)} = \mathrm{a} + \mathrm{bX} + \mathrm{cY} + \mathrm{dXY} + \mathrm{eXY^2} + \mathrm{fX^2Y} + \mathrm{gX^2} + \mathrm{hY^2} + \mathrm{iX^3} + \mathrm{jY^3} \quad (2)$$



(A)

(B)

Fig. 2. Multi-Well) scatter-plot with regression for both (A) gamma ray maximum and (B) gamma ray minimum



Statistics:
Mode: 14.764
Arithmetic mean: 20.8176
Average deviation: 6.89911
Number of missing values: 0
Minimum value: 7.37986
Skewness: 1.31596

Median: 19.1173
Possible values: 1005
Standard deviation: 9.02026
Variance: 81.3651
Maximum value: 62.3067
Kurtosis: 2.49796

Zonation: Cretaceous_Tops
▨ Mauddud

Fig. 3. Gamma-ray histogram

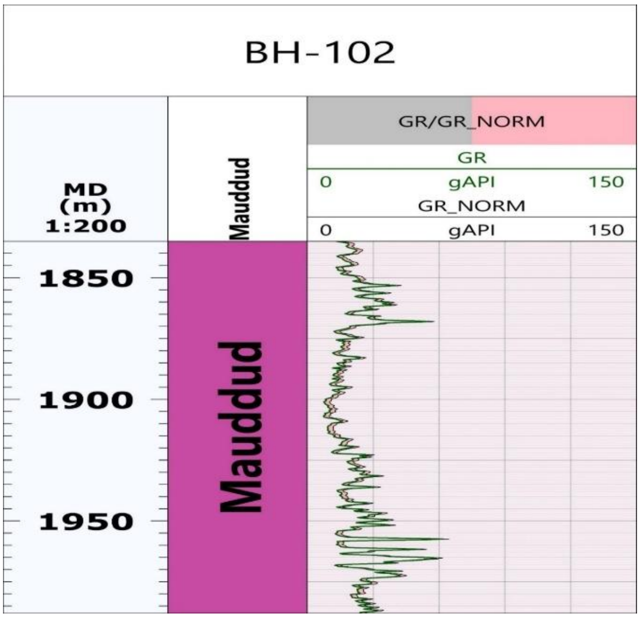


Fig. 4. Gamma-ray vs. gamma-ray normalization

4.2. Lithology identification

Identifying the lithology is crucial in the formation evaluation process. The term lithology is used to describe the physical properties of rocks, as it is challenging to determine porosity when the matrix contains unknown minerals or other unknown properties[10]. There are numerous graphical methods that are considered useful tools for understanding rock classification in each formation [11]. These methods are also used to compare various log readings to define porosity. Among them are different types of two- and three-dimensional cross-plots. Cross plots are a common method that exhibits the effect of combinations of logs reacting to porosity and lithology, giving a visual vision of the type of lithology mixtures [11, 12]. Two cross-plots were used in this study to identify the lithology of the Mauddud Formation as follows:

a. Neutron-density cross plot

Neutron density Cross-plot is commonly used to identify lithology such as limestone, sandstone, and dolomite. Fig. 5 clarifies the neutron-density cross plot of the Mauddud Formation according to the Por-13 chart (freshwater (1g/cm3)) by Schlumberger, which shows the presence of limestone, dolomite, and a limited quantity of anhydrite outside the dolomite line.

b. M-N lithology plot

The approach combines petrophysical logs, specifically DT, NPHI, and RHOB, to identify the formation's Lithologies. The lithology can be identified using two dependent variables, M and N, described by the following equations [13]:

$$M = \frac{\Delta t_f - \Delta t}{\rho_b - \rho_f} \times 0.01 \quad Or \quad M = \frac{\Delta t_f - \Delta t}{\rho_b - \rho_f} \times 0.003 \text{ (metric unit)} \qquad (3)$$

$$N = \frac{\emptyset_{Nf} - \emptyset_N}{\rho_b - \rho_f} \qquad (4)$$

Where: Δtf: Travel time of fluid within the formation (us/ft). Δt: Travel time within the formation (us/ft). ρb: The density of the formations from the log reading (g/cm^3). ρf: The density of the fluid (g/cm^3). $\emptyset Nf$: The fluid neutron porosity. ØN: The formation of neutron porosity.

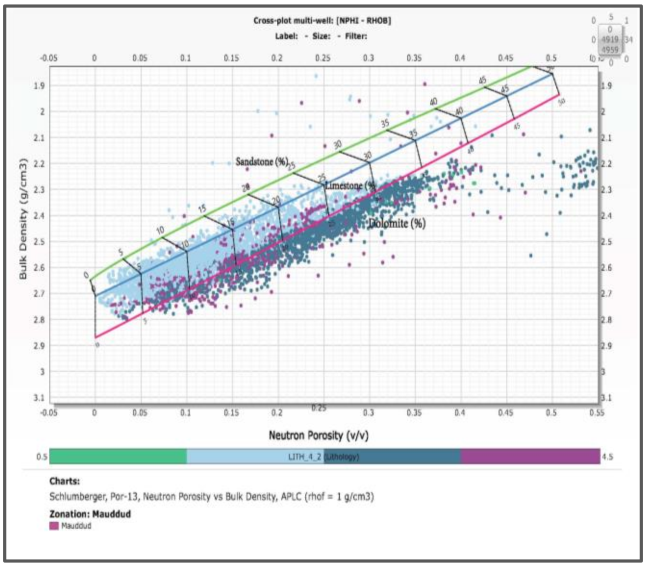


Fig. 5. Multi-Well (Neutron–Density) cross-plot showing distribution of the lithology

In addition to lithology indication, the M-N plot is used for finding the secondary porosity, which raises the M value as density falls while keeping the value of N constant because Δt is insensitive to secondary porosity. The lithology distribution shown in the M-N cross plot has been verified to be consistent with the distribution illustrated on the neutron-density cross plot within the Mauddud Formation, as shown in Fig. 6.

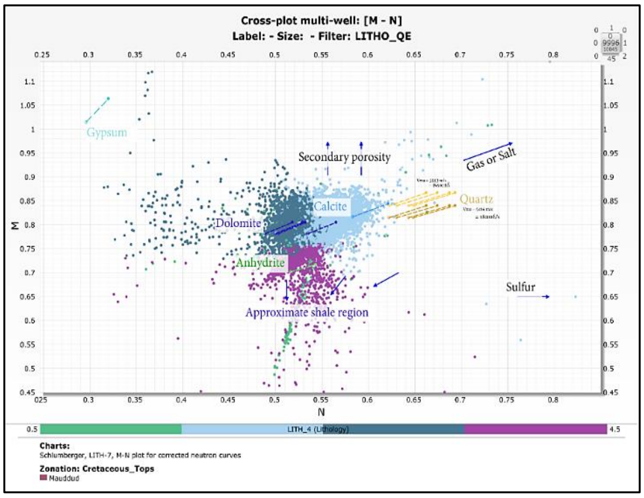


Fig. 6. Multi-Well (M – N) cross-plot

4.3. Estimation of shale volume

One of the most public problems in formation evaluation is the impact of shale on reservoir rocks [14].

Estimating shale volume is an essential stage in the formation evaluation process because it affects the calculations of the reservoir's porosity, and permeability and lowers reservoir quality [14, 15]. Calculating shale volume is necessary to identify reservoir barriers and determine the net thickness.

a. Estimation of shale volume from gamma ray log (GR_{Norm})

The gamma-ray technique is one of the most popular and accurate single-indicator techniques for calculating shale volume [16]. Gamma-ray log measures radioactivity in the elements like potassium, thorium, and uranium. It provides the most accurate estimation of shale volume, detecting radioactivity in shale formations. High gamma ray readings indicate high concentrations of radioactive minerals, while low gamma ray readings indicate low concentrations in formations like carbonate and sandstone [17]. The first step of estimation of shale volume from gamma-ray normalization is to calculate the gamma-ray index using the equation below:

$$IGR = \frac{GR_{Norm} - GR_{matrix}}{GR_{shale} - GR_{matrix}} \tag{5}$$

Where: IGR: Fraction of GR index. GR_{Norm}: Normalized GR log reading in the zone of interest. GR_{Matrix}: GR reading in the clean zone (API). GR_{Shale}: GR reading in the shale zone (API).

In the second step, the volume of shale was estimated using the older rock equation for Larionov as shown below [13]:

$$Vsh = 0.33 * (2^{(2*IGR)} - 1) \tag{6}$$

Where: Vsh: Represent the volume of the shell.

Mauddud Formation appears to be a clean formation with a low shale volume as shown in Fig. 7, approximately (17%) due to the depositional environment of the Mauddud Formation.

4.4. Porosity estimation

One of the essential properties of rocks is porosity, which measures the ability of rocks to store hydrocarbons. It is equal to the pore volume divided by the bulk volume and symbolized by Φ [18]. The porosity ranges from 1% to 35% in carbonate reservoirs [19] Porosity is measured either from core samples in the laboratory or from porosity well logs interpretations [13]. The porosity of the rock may be easily calculated using one of three types of logs: the neutron log, the formation density log, the sonic log, or a combination of them which is considered a reliable method for determining porosity. The readings of this equipment are dependent on the characterization of formation close to the wellbore. Also, effective porosity was calculated by excluding the volume of shale from the total porosity.

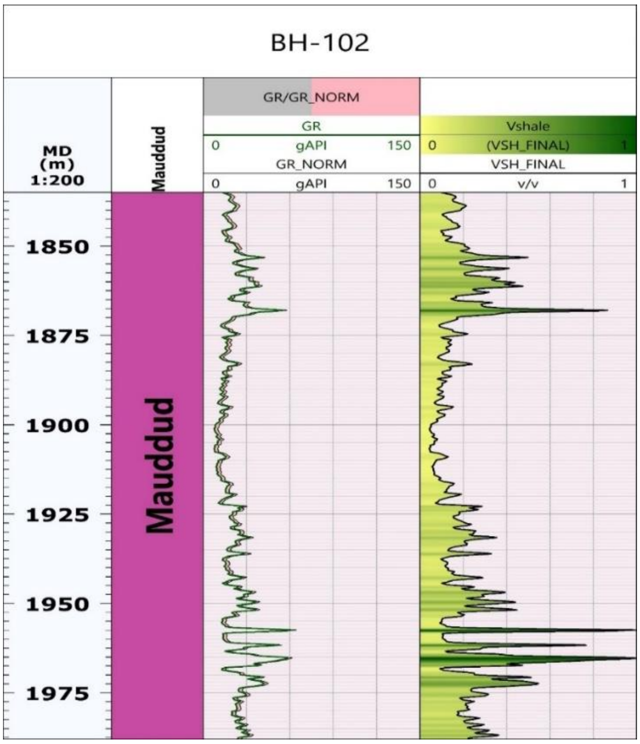


Fig. 7. Shale volume using gamma-ray normalization for Well BH-102

Determining the ultimate total and effective porosity depended on porosity logs available in each well. Selecting a model that represents formation porosity is considered one of the essential factors that identify formation characterization. The matching between the porosity from different models and the core porosity was the foundation for selecting the method that represents the formation porosity and then generalized for the other studied wells that didn't have any core data. The core data for wells was compared with the calculated porosity and the method that gives the best matching in each well was selected as shown in Fig. 8. The results clarified that the Mauddud Formation has porosity values reaching 32% (averaging 11%).

4.5. Determination of formation water resistivity

The total contained water in an otherwise hydrocarbon-bearing reservoir rock is best called "formation water". The measurement of formation water resistivity is essential for accurate assessment of water saturation. The method used in this study to estimate the formation of water resistivity depends on the relationship between water resistivity and salinity. This relationship depends on salinity, and conductivity which are considered the inverse of resistivity. The formation temperature was used to convert Rw values from standard condition (68 degrees F) to borehole condition. Table 1 shows the conductivities of NaCl solutions at various concentrations at 20°C (68°F).

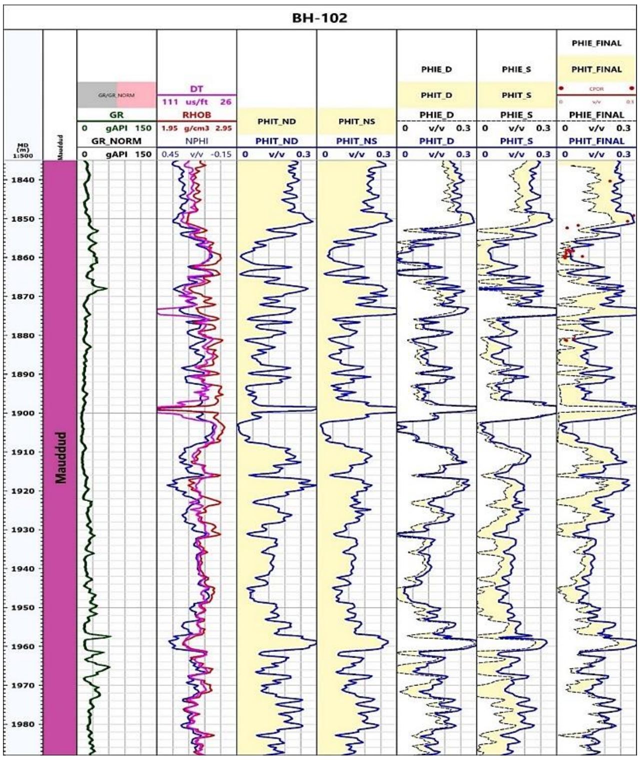


Fig. 8. Total and effective porosity for Well BH-102

Table 1. The conductivities of NaCl solutions at various concentrations at 20°C (68°F)

% Conc. NaCl	**ppm NaCl**	**mS/cm at 20°C**	**Ohm.m at 20°C**
0.5	5000	8.2	1.2195
1	10000	16	0.6250
2	20000	30.2	0.3311
5	50000	70.1	0.1427
10	100000	126	0.0794
15	150000	171	0.0585
20	200000	204	0.0490
25	250000	222	0.0450

The conductivity values can be converted into resistivity (ohm.m) by taking the reciprocal and multiplying by 10 to maintain consistency of units as shown in the equation below:

$$R_W@68F = \frac{10}{C_w} \quad (7)$$

Where: C_W: conductivity of water.

The ARPS equation can be used to convert the Rw@68Deg F value to formation temperatures, using the geothermal gradient [22].

$$R_w@T_f = R_w@68°\mathrm{F} \times \frac{68+6.77}{T_f+6.77} \quad (8)$$

The formation temperature at this technique is calculated by the equation below:

$$T_f\,@°F = \mathrm{GG} \times mTVDSS + \mathrm{Ts} \quad (9)$$

The average formation water resistivity at the Mauddud Formation was 0.040 ohm at formation temperature.

4.6. Fluid saturation estimations

Fluid saturation is among the most important petrophysical parameters that are used in reserve estimates of oil and gas reservoirs. Fluid saturations are estimated from resistivity measurements by using Archie's equation depending on the small shale volume content of the studied reservoir and its reliability in the region of study [20]. The application of this equation requires the determination of Archie's parameters a, m, and n, which are among the most important parameters affecting the value of hydrocarbon saturation.

a. Archie parameters estimation

Determining the water saturation in heterogeneous carbonate reservoirs can be hard because Archie's equation is only appropriate for clean, homogenous formation and has a strong dependence on the physical characteristics of the rock [21]. In this study, the Pickett plot has been used for the estimation of Archie parameters (n, a, and m).

b. Pickett plot method

This plot can be used to find Archie's parameters (a and m) for the water zone and (n) for the hydrocarbon zone, as well as to estimate accurate values for water resistivity (Rw). In the Pickett plot the deep resistivity plotted against porosity on a log-log scale, m value obtained from the slope of a straight line on the lowest resistivity value represented 100% water saturation zone intercept the 100% porosity. The values of Archie parameters from the Pickett plot method were (a=1, n=2.3, m=1.70, and Rw=0.040) as shown in Fig. 9. The results clarified that low water saturation (Averaging 30%) in the Mauddud Formation as shown in Fig. 10.

4.7. Rock type

Data from Mauddud well logs have been subjected to cluster analysis in order to characterize the electrofacies within the reservoir. Objects from this technique were grouped based on comparable characteristics and distinguished from other objects that were distinct using a model of the Hierarchical wards' algorithm.

Two log elements have been selected in this method: Gamma-ray (GR), sonic, and effective porosity which is a reflection of porosity logs (RHOB and DT logs). Four electrofacies were distinguished within the Mauddud Formation which corresponds to four different rock types (RT) as shown in Fig. 11.

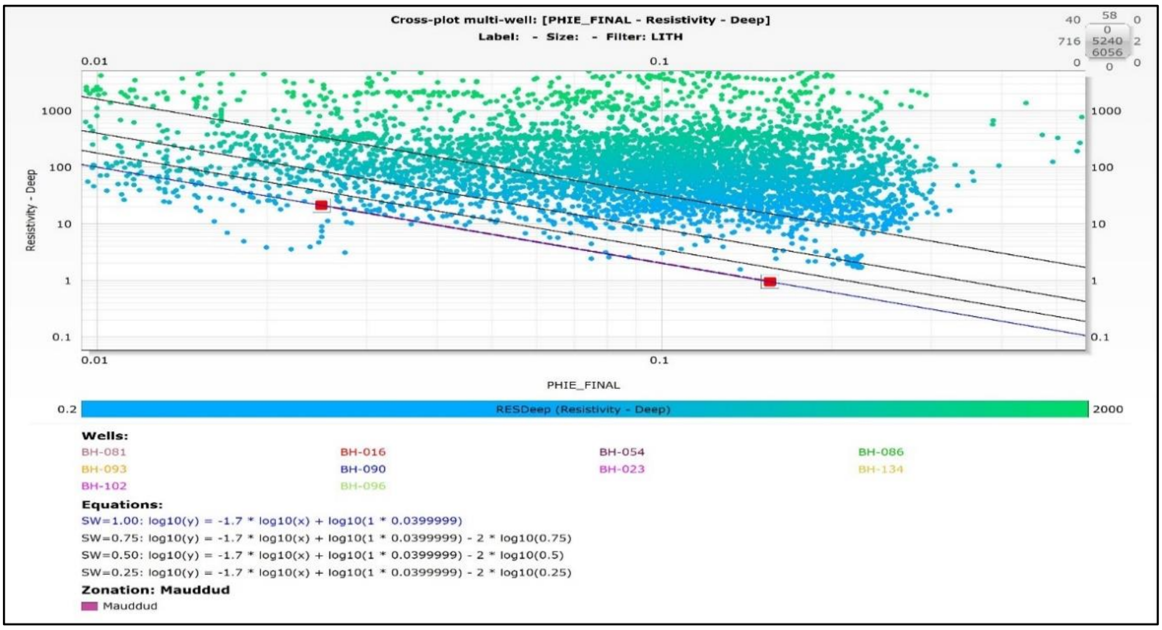


Fig. 9. Multi-Well (resistivity-deep – effective porosity) pickett plot (Carbonates)

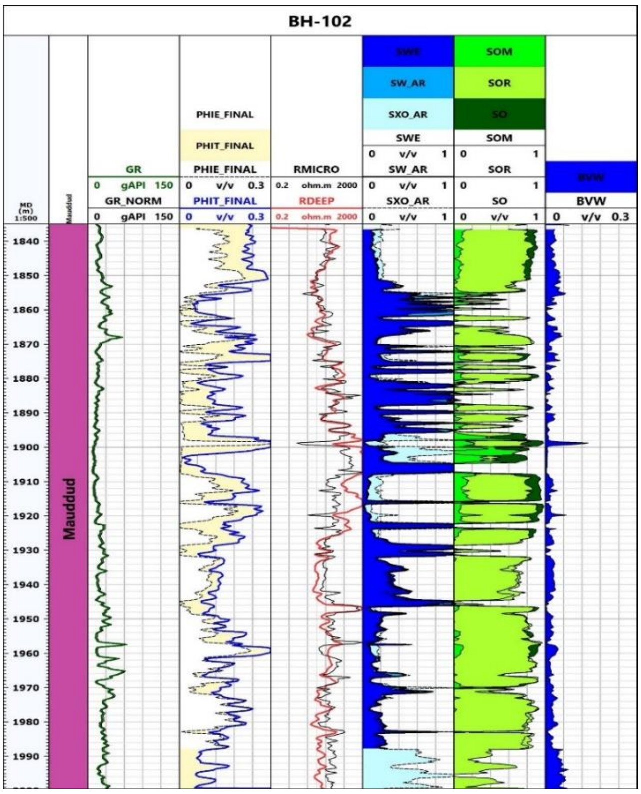


Fig. 10. Total and effective water saturation for Well BH-102

4.8. Permeability estimation

Permeability is considered an important flow parameter that describes the ability of a subsurface formation to transmit fluid, even though it is the most spatially varied, uncertain, and hard to predict of all the formation properties. Different ways are available for permeability estimation with a reliable degree of accuracy. In this study, the FZI method was used for permeability prediction for the Mauddud Formation as follows:

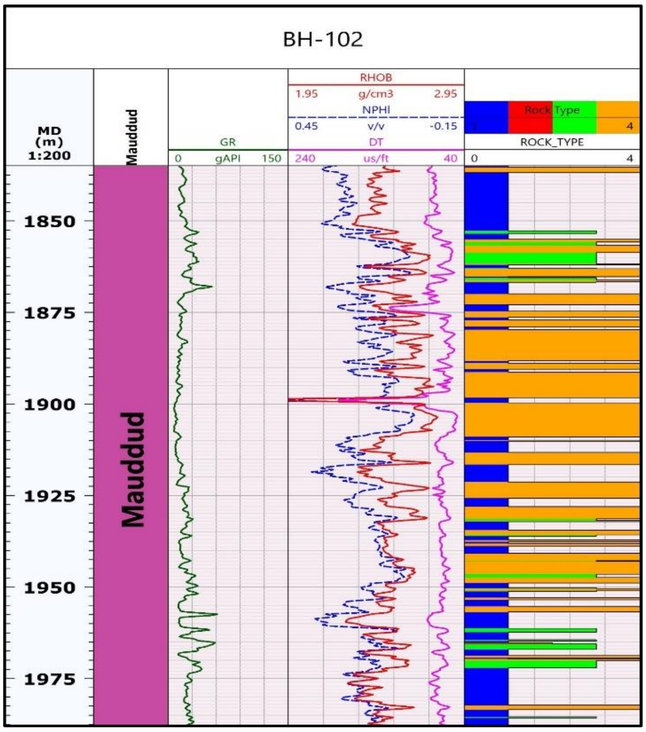


Fig. 11. Electrofacies classification from cluster analysis for well BH-10

a. Flow zone indicator method

One of the important methods for the classification and identification of hydraulic units, as well as for describing reservoir permeability**,** depends on the geological properties of the material and different pore geometries in rock mass[22, 23]. A flow zone indicator (FZI) may be used to detect diagenesis effects, low-quality rocks, and high-productive zones [24, 25]. FZI is calculated using core data from the cored wells, and it is often applied to uncored wells by correlating it with log characteristics. The final approach is given influent equations:

$$RQI = 0.0314\sqrt{\frac{K}{\emptyset_e}} \tag{10}$$

$$\emptyset_Z = \frac{\emptyset_e}{1-\emptyset_e} \tag{11}$$

$$FZI = \frac{RQI}{\emptyset_Z} \tag{12}$$

Reservoir Qua1ity Index (RQI), an estimate of the reservoir rock's average hydraulic radius, is the most critical parameter in this classification methodology[26]. Based on the values of FZI, which represent different HFUs, four groups were recognized previously in the permeability–porosity plot Fig. 12. The correlation equation for the permeability was created for each hydraulic flow unit with good correlation coefficient values except for HFU0 see Table 2.

The results of the permeability evaluation clarified that the Mauddud Formation has moderate to good quality about 22%.

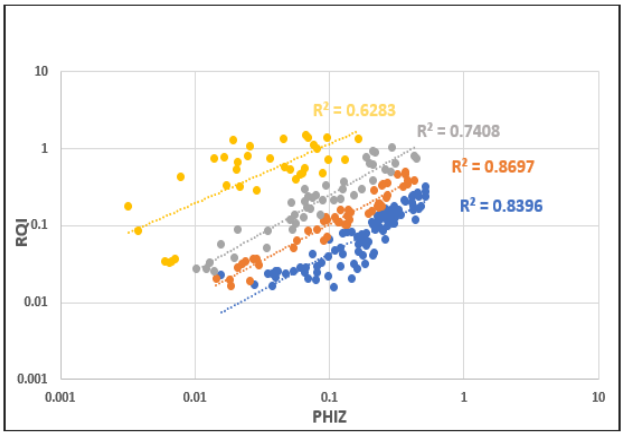


Fig. 12. Multi-Well RQI – PHIZ cross-plot

Table 2. Characterizing reservoir rock using the HFU method

HFU	K- Ø Relationships	R^2	Description
RT1	**K=62716 PHI** $^{2.6025}$	0.72	Best rock properties
RT2	**K=11633PHI**$^{3.1442}$	0.64	Good rock properties
RT3	**K=1678.7PHI**$^{3.0621}$	0.81	Moderate rock properties
RT4	**K=450.3PHI**$^{3.2957}$	0.82	bad rock properties

5- Conclusions

This study has led to the following conclusions:

1. The Neutron Porosity (CNL) Matrix was converted from Limestone to Dolomite using formation salinity in order to compare neutron porosities based on the lithologies of the wells.
2. The Gamma-ray log was normalized to correct the gamma-ray log response based on the reference gamma-ray of the region.
3. By utilizing Neutron-Density and M-N cross plots, the lithology of the Mauddud Formation was determined. The studies conducted to ascertain the lithology and mineralogy of the formation confirmed that it is primarily composed of limestone, with calcite as the main mineral, and also contains secondary minerals such as dolomite and anhydrite.
4. The Mauddud Formation is considered a complex formation due to its heterogeneity and a clean formation due to its low shale volume, which is approximately 17%.
5. The porosity values of the Mauddud Formation reach up to 32%, with an average of 11%.
6. The Mauddud Formation has low water saturation (with mostly oil present) around 30%.
7. The permeability of the Mauddud Formation was determined to be of moderate to good quality, approximately 22md.

Nomenclature

Rw: Water Resistivity
Sw: Water Saturation
FZI: Flow Zone Indicator
CDF: Cumulative Distribution Factor

References

[1] L. A. Khamees, A. A. A. A. Alrazzaq, and J. I. Humadi, "Different methods for determination of shale volume for Yamama formation in an oil field in southern Iraq," *Materials Today Proceedings*, vol. 57, pp. 586–594, 2022. https://doi.org/10.1016/j.matpr.2022.01.455

[2] F. S. Kadhim and H. Al-Sudani, "Petrophysical Properties of Khasib Formation in East Baghdad Oil Field Southern Area," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 21, no. 4, pp. 41–48, 2020. https://doi.org/10.31699/IJCPE.2020.4.5

[3] K. Katterbauer, A. A. Al-Yousif, and A. Marsala, "Intelligent Reconciliation of Well Logs–A Pathway Towards 4IR Assisted Log Interpretation," *in Abu Dhabi International Petroleum Exhibition & Conference*, *OnePetro*, 2020. https://doi.org/10.2118/202621-MS

[4] S. S. Zughar, A. A. Ramadhan, and A. K. Jaber, "Petrophysical Properties of an Iraqi Carbonate Reservoir Using Well Log Evaluation," *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 21, no. 1, pp. 53–59, 2020. https://doi.org/10.31699/IJCPE.2020.1.8

[5] R. C. Van Bellen, "The Stratigraphy of the Main Limestone" of the Kirkuk, Bai Hassan, and Qarah Chauq Dagh Structures in North Iraq," *Journal Institute of Petroleum*, Vol. 42, No. 393, 1956, pp. 233-263.

[6] H. V. Dunnington, "Generation, migration, accumulation, and dissipation of oil in northern Iraq: Middle East," *GeoArabia*. Volume 20, Number 4, October 2005. https://doi.org/10.2113/geoarabia100239

[7] T. Buday, “The Regional geology of Iraq: Tectonism Magmatism, and Metamorphism. II Kassab and MJ Abbas and Jassim,” *SZ (Eds), GEOSURV, Baghdad, Iraq*, 1987.

[8] R. Akkurt, M. Miller, B. Hodenfield, I. Pirie, D. Farnan, and M. Koley, “Machine learning for well log normalization,” *SPE Annual Technical Conference and Exhibition, OnePetro*, September 23 2019. https://doi.org/10.2118/196178-MS

[9] D. E. Shier, “Well log normalization: Methods and guidelines,” *Petrophysics-The SPWLA Journal Formation Evaluation and Reservior Description*, vol. 45, no. 03, 2004.

[10] A. H. Tali and G. M. Farman, “Use conventional and statistical methods for porosity estimating in carbonate reservoir in southern iraq, case study,” *Iraqi Geological Journal*, pp. 30–38, 2021. https://doi.org/10.46717/igj.54.2D.3Ms-2021-10-22

[11] H. Y. Ali, G. M. Farman, and M. H. Hafiz, “Study of Petrophysical Properties of the Yamama Formation in Siba Oilfield,” *Iraqi Geological Journal*, pp. 39–47, 2021. https://doi.org/10.46717/igj.54.2C.4Ms-2021-09-23

[12] G. B. Asquith, D. Krygowski, and C. R. Gibson, “Basic well log analysis, ” *American Association of Petroleum Geologists Tulsa*, vol. 16,2004.

[13] R. A. Hashim and G. M. Farman, “Evaluating Petrophysical Properties of Sa’di Reservoir in Halfaya Oil Field,” *Iraqi Geological Journal*, pp. 118–126, 2023. https://doi.org/10.46717/igj.56.2D.9ms-2023-10-15

[14] Z. A. Mahdi and G. M. Farman, “A Review on Models for Evaluating Rock Petrophysical Properties,” *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 24, no. 1, pp. 125–136, 2023. https://doi.org/10.31699/IJCPE.2023.1.14

[15] M. H. Kamel and W. M. Mabrouk, “Estimation of shale volume using a combination of the three porosity logs,” *Journal of Petroleum Science and Engineering*, vol. 40, no. 3–4, pp. 145–157, 2003. https://doi.org/10.1016/S0920-4105(03)00120-7

[16] Z. A. Mahdi and G. M. Farman, “Estimation of Petrophysical Properties for the Zubair Reservoir In Abu-Amood Oil Field,” *Iraqi Geological Journal*, pp. 32–39, 2023. https://doi.org/10.46717/igj.56.1B.3ms-2023-2-11

[17] R. A. Hashim and G. M. Farman, “How to Estimate the Major Petrophysical Properties: A Review,” *Iraqi Journal of Oil & Gas Research*, vol. 3, no. 1, pp. 43–58, 2023. https://doi.org/10.55699/ijogr.2023.0301.1037

[18] F. Rashid, P. W. J. Glover, P. Lorinczi, R. Collier, and J. Lawrence, “Porosity and permeability of tight carbonate reservoir rocks in the north of Iraq,” *Journal of Petroleum Science and Engineering*, vol. 133, pp. 147–161, 2015. https://doi.org/10.1016/j.petrol.2015.05.009

[19] A. A. Suhail, M. H. Hafiz, and F. S. Kadhim, “Petrophysical Properties of Nahr Umar Formation in Nasiriya Oil Field,” *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 21, no. 3, pp. 9–18, 2020. https://doi.org/10.31699/IJCPE.2020.3.2

[20] Schlumberger, “Log Interpretation Principles / Application,Schlumberger Educational Services.” 1997.

[21] A. M. Al-Heeti and O. F. Al-Fatlawi, “Review of Historical Studies for Water Saturation Determination Techniques,” *Iraqi Geological Journal*, pp. 42–62, 2022. https://doi.org/10.46717/igj.55.2A.4Ms-2022-07-20

[22] A. M. Mohamad and G. M. Hamada, “Determination techniques of Archie’s parameters: a, m and n in heterogeneous reservoirs,” *Journal of Geophysics and Engineering*, vol. 14, no. 6, pp. 1358–1367, 2017. https://doi.org/10.1088/1742-2140/aa805c

[23] S. A. Jassam and C. H. Canbaz, “Petrophysical Analysis Based on Well Logging Data for Tight Carbonate Reservoir : The SADI Formation Case in Halfaya Oil,” *Iraqi Journal of Chemical and Petroleum Engineering*. vol. 24, no. 3, pp. 55–68, 2023. https://doi.org/10.31699/IJCPE.2023.3.6

[24] S. A. Lazim, S. M. Hamd-Allah, and A. Jawad, “Permeability Estimation for Carbonate Reservoir (Case Study/South Iraqi Field),” *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 19, no. 3, pp. 41–45, 2018. https://doi.org/10.31699/IJCPE.2018.3.5

[25] M. Khalid, S. E.-D. Desouky, M. Rashed, T. Shazly, and K. Sediek, “Application of hydraulic flow units’ approach for improving reservoir characterization and predicting permeability,” *Journal of Petroleum Exploration and Production Technology*, vol. 10, pp. 467–479, 2020. https://doi.org/10.1007/s13202-019-00758-7

[26] A. H. Tali, S. K. Abdulridha, L. A. Khamees, J. I. Humadi, G. M. Farman, and S. J. Naser, “Permeability estimation of Yamama formation in a Southern Iraqi oil field, case study,” *AIP Conference Proceedings, 2ND MUTHANNA INTERNATIONAL CONFERENCE ON ENGINEERING SCIENCE AND TECHNOLOGY*, 2023. https://doi.org/10.1063/5.0163281

التقييم الطباقي لتكوين مودود في حقل باي حسن، شمال العراق

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الخلاصة

يعد تقييم التكوينات عملية حاسمة في صناعة النفط لتقييم الخصائص البتروفيزيائية للتكوينات الصخرية تحت السطح وإمكانات الهيدروكربون. هدفت هذه الدراسة إلى تقييم تكوين المودود في حقل باي حسن النفطي باستخدام البيانات المتوفرة من سجلات الآبار والبيانات الأساسية. تم اختيار أربعة آبار في هذه الدراسة (BH-16، BH-86، BH-93، BH-102). تضمنت هذه الدراسة تحديد الصخور الخاصة بتكوين المودود وتقدير الخواص البتروفيزيائية مثل حجم الصخر الزيتي والمسامية والتشبع المائي والنفاذية. أظهرت النتائج أن الصخور الأولية هي الحجر الجيري وتحتوي على معادن ثانوية مثل الدولوميت والأنهيدريت. يعتبر تكوين مودود نظيفًا لأنه يحتوي على حجم صغير من الصخر الزيتي يبلغ حوالي ١٧%، مع انخفاض تشبع الماء والمسامية بحوالي ٣٠% و١١% على التوالي. وباستخدام طريقة التحليل العنقودي ومؤشر منطقة التدفق (FZI)، تم تحديد عدد أنواع الصخور وحساب نفاذية تكوين المودود. يحتوي تكوين المودود على اربعة أنواع من الصخور ذات قيم نفاذية تتراوح من الجودة المعتدلة إلى الجودة السليمة، حوالي ٢٢ مللي دارسي.

الكلمات الدالة: التقييم الطبقي، التطبيع، تكوين مودود، مؤشر منطقة التدفق، المسامية، درجة التشبع.