Iraqi Journal of Science, 2023, Vol. 64, No. 2, pp: 718-729
DOI: 10.24996/ijs.2023.64.2.20

ISSN: 0067-2904

Petrophysical Properties of Mauddud Formation in Selected Wells in Al-Ahdab Oil Field, Middle Iraq

Ali S. Hameed*, Rasha F. Faisal
Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

Received: 14/3/2022 Accepted: 4/8/2022 Published: 28/2/2023

Abstract

This paper aims to calculate the petrophysical properties in the Al-Ahdab field in the middle of Iraq within the Mauddud Formation. This study was based on the information available from well logs. The interactive petrophysical software IP (V4.5) was used to calculate the porosity, hydrocarbon saturation and shale volume, divide the formation into reservoir units and buffer units, and evaluate these units in each well. The Mauddud was divided into five units, two of them were considered good reservoirs having good petrophysical properties (high porosity, Low water saturation, and low shale volume). The other three are not reservoirs because of poor petrophysical properties.

Keywords: Ahdab petroleum Field, Mauddud Formation, Petrophysical Properties, CPI.

تقييم الخصائص البتروفيزيائية لتكوين المود في حقل احدب النفطي

علي سعد حميد*, رشا فوزي فيصل
قسم علم الارض, كليه العلوم, جامعه بغداد, بغداد, العراق

الخلاصه

الهدف من هذا البحث هو حساب الخصائص البتروفيزيائية في حقل الأحدب ضمن تكوين مودود. استندت هذه الدراسة إلى المعلومات المتاحة من مجسات البئر. تم استخدام برنامج IP في هذه الدراسة لحساب المسامية والتشبع الهيدروكربوني وحجم السجيل. واستنادا على نتائج التحليل البتروفيزيائي تم تقسيم التكوين الى وحدات مكمنية وأخرى عازلة. استنتج من هذه الدراسه أن تكوين مودود تنقسم إلى خمس وحدات، اثنتان منها فقط تعتبر خزانًا جيدًا لما لها من خصائص بتروفيزيائية جيدة (مسامية عالية، تشبع مائي قليل، حجم سجيل قليل). اما الوحدات الثلاثة الأخرى فلا تعد خزانات بسبب عدم جودة الخصائص البتروفيزيائية..

Introduction

The Mauddud Formation is composed of Orbitolina-bearing limestone and dolomites deposited in the Albian–Cenomanian Sequence age [1]. The Cretaceous carbonate sequence has important hydrocarbon resources in several sections of the Arabian Plate. Some of these reservoirs are found in the Mauddud Formation in southern Iraq and in numerous oil fields [2]. The Mauddud Formation is formed of organic limestone separated by shale layers that are

*Email: alisaadah96@gmail.com

"green or bluish." [3]. Henson originally described the Mauddud Formation in an unpublished report from the Dukhan-1 well in Qatar in 1940 [4]. The study aims to explain information from the two well logs that penetrate the Mauddud Formation in the Ahdab oil field (ADM 4-7 and ADM 3-4) and distinguish between units with favorable reservoir characteristics and those that do not. Well log interpretation, also known as a petrophysical assessment, entails a set of computations used to assess and regulate reservoir parameters like shale volume, porosity, and water saturation. Various logs can be utilized to quantify reservoir compartmentalization and determine porosity and water saturation.

The site of Ahdab in Wasit city is 180 km southeast of Baghdad and 18 km west of Kut City, to the south of the Al Ahdab oil field in the middle of Iraq (Figure 1). Longitude: 45° 30 - 45° 46 E and Latitude: 32° 23 - 32° 35 N are the geographical coordinates for the study area, which is approximately 649.8 km^2. The Ahdab oil area lies in the middle of the Mesopotamia plain [5].

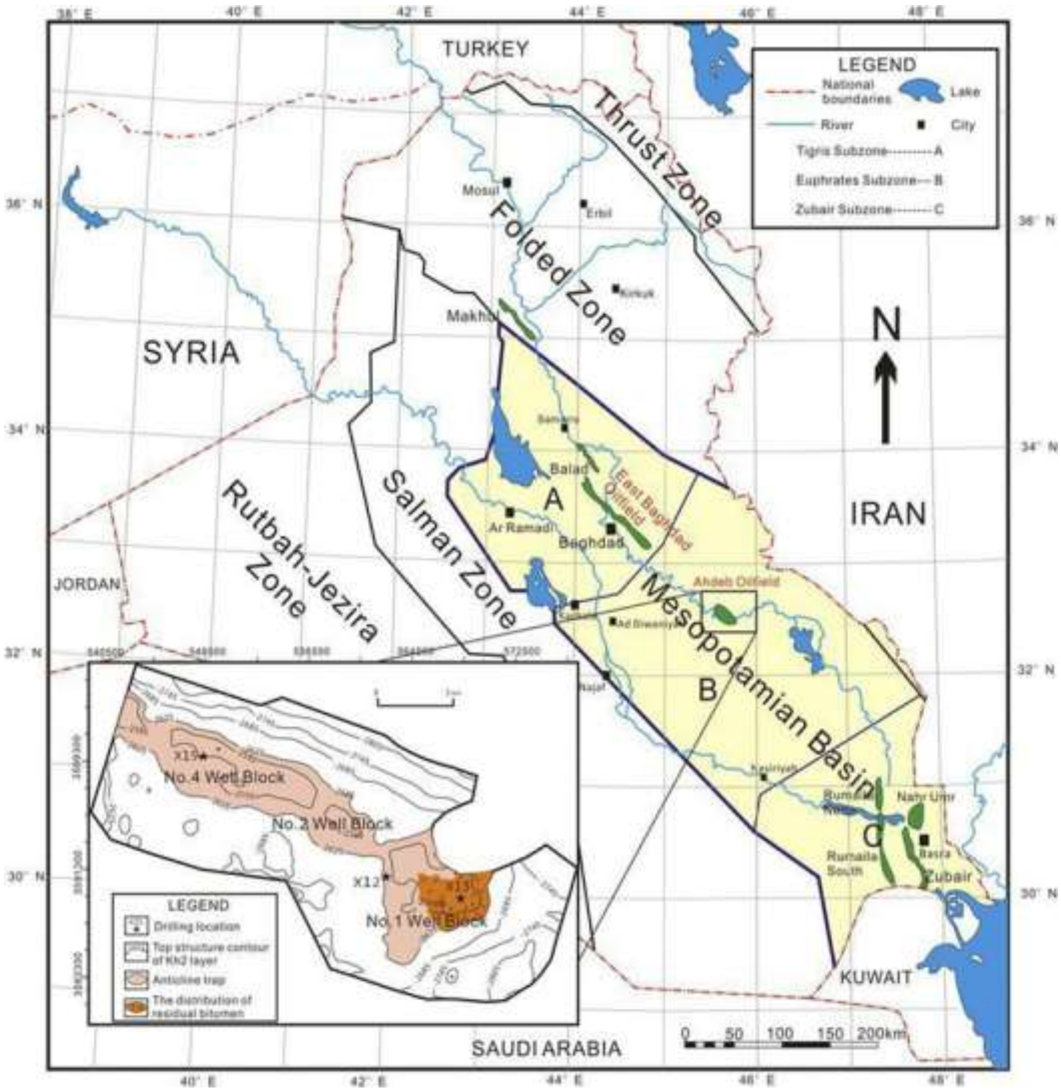

Figure 1: The study area is depicted on a map [5].

Methodology

This study used interactive petrophysical software IP 2018 (V4-5) to interpret the petrophysical properties (Vsh, porosity, water and hydrocarbon saturation). The Mauddud Formation was divided into many units according to those petrophysical properties. Also, the IP program determined lithology and mineralogy in three ways: N-D cross-plot for lithology determination, M-N Cross-plot for mineral determination and Matrix Identification (MID) Cross Plot. This table shows the numbers of wells used and their thicknesses.

Table 1: Specifications of the wells used in the Maudud Formation

well	top	Bottom	thickness
ADM 3-4	3092 m	3182 m	90 m
ADM 4-7	3086 m	3170 m	83 m

Structure and Geologic Setting

The Ahdab structure is situated within the Mesopotamia Plain on the stable platform[5], forming a long anticlinal extended WNW-ESE. AD-1, AD-2, and AD-4 are the three types of domes that make up the structure. The dome AD-1 is slightly higher than the others. The anticline's two sides are not steep; the south side's dip angle is 0.7-0.9, the north side's dip angle is 2, and the north limb is stepper than the south limb [6]. The Mauddud Formation (Lower Cenomanian) is situated between Ahmadi and Nahr Umar Formations. It overlies Nahr Umar Formation from below caused by a geological gap that arose during the inundation of a clastic-dominated shelf, leading to the deposition of shallow-water carbonates. The formation's top contact with the Ahmadi Formation indicates that clastics once again dominated the shelf [2] .

The lower contact of the Mauddud succession and its equivalent to the northward (Upper Qamchuqa) is a conformable and gradational surface with the Nahr Umr, lower Balambo or Lower Sarmord formations in the north of Iraq. The upper contact has a depositional break and is either non-sequential or unconformable; it is an unconformity in the north, Central Iraq, and northeast [7]. The Upper part of Qamchuqa is directly overlaid by Turonian formations, for example, in the Makhul and the Mileh Tharthar areas [8]. An unconformity surface also marks the upper contact of this formation in the Rutba Subzone [9] and Kuwait [10]. In Kuwait, the Mauddud Formation was deposited during a highstand in a shallow inner shelf environment of the Late Albian age developing from the transgressive Low Stand of the Burgan Formation [10], [7].

Assessment of Lithological units and Mineralogical composition:

The term lithology refers to the fundamental mineralogy of rocks [11]. More exact suggestions for lithology, porosity, and other data can be established by applying Common lithologic cross plots among well log combinations. [12].

1-N-D Cross Plot for lithology determination:

It is considered one of the most essential and earliest quantitative interpretive techniques for assessing lithology and matrix of formation in addition to porosity in gas-bearing Formations (N-D abbreviation Neutron- Density). The main plot benefits from the matric density variations between the three common rock types (sandstone, limestone and dolomite) [13]. Figure 2 shows an **N-D** cross plot for two wells, where it was found that most of the points of the formation of Mauddud are located within the limestone, and there are a few of them located toward the dolomite**.**

2- M-N Cross-Plot for mineral 6++ determination:

This method uses the porosity logs data because the worth of M-N depends on the formation porosity and the mineral mixtures (M and N). A porosity ratio graph determined from a sonic log to that from a density log (M) against the porosity ratio from a neutron log to that from a density log (N) is defined by these equations [14].

$$M = \frac{\Delta tf - \Delta t\ log}{\rho b - \rho f} \times 0.01 \qquad \ldots\ldots\ldots\ldots(1)$$

$$N = \frac{\text{ØNF} - \text{ØN}}{\rho b - \rho f} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:
Δtf, = time of interval transit.
Δt log = time of interval transit.
Pb = density of formation bulk.
Pf = fluid density .
ΦNf, = neutron porosity for fluid =1.
ΦN = neutron porosity.
Figure 3 shows the M-N cross plot for four wells, almost of point Mauddud formation in calcite and some dolomite with a secondary porosity.

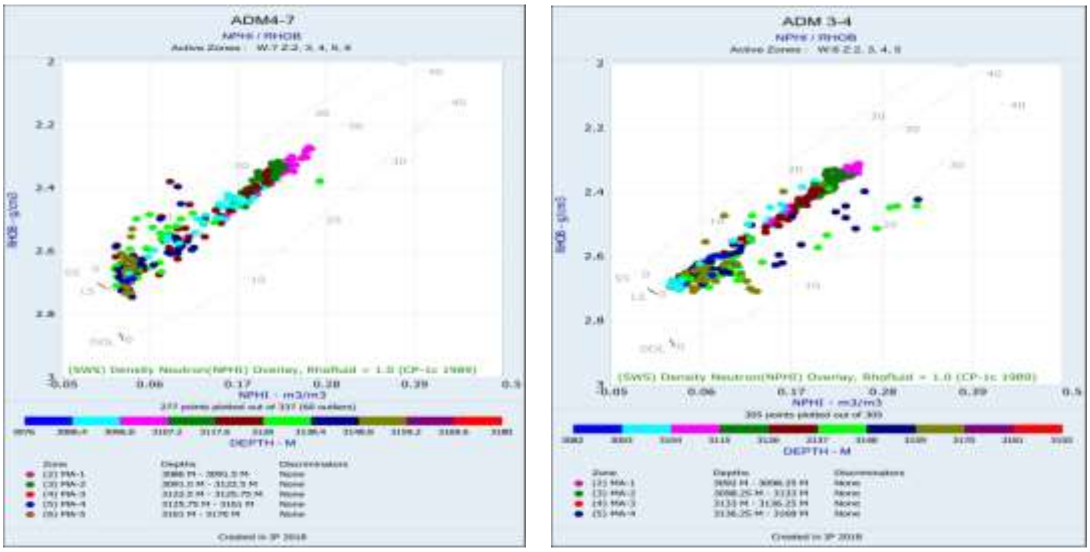

Figure 2: N-D Cross plot of Mauddud Formation in Two wells.

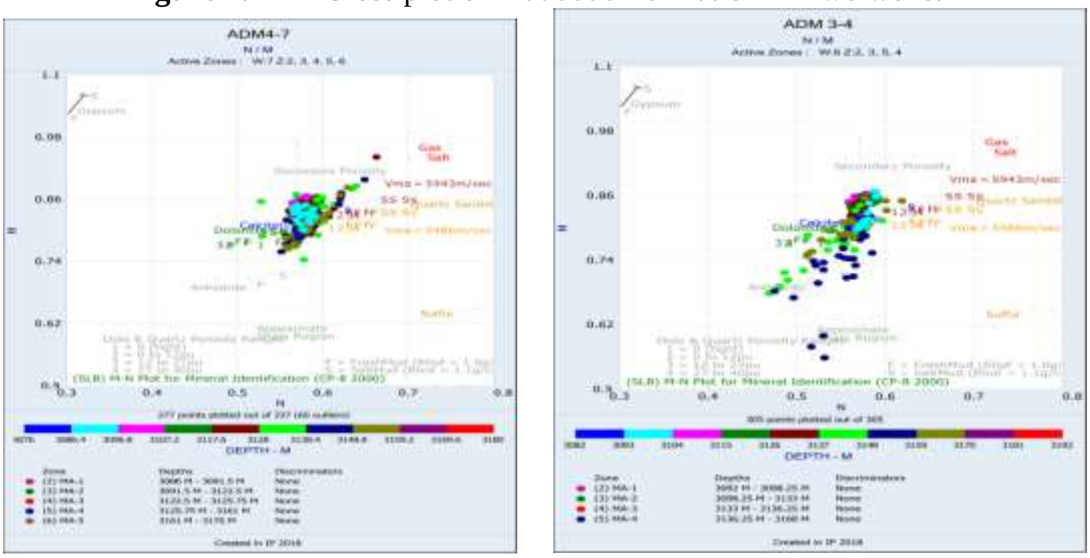

Figure 3: M-N cross plots of Mauddud Formation in Two wells.

3- Matrix Identification (MID) Cross Plot

To depict a link between apparent-matrix density (RhoMatrix) (g/cc) and apparent-matrix transit time (DTmatrix) (s/ft) in a reservoir requires the availability of porosity logs data. The (RhoMatrix) and (DTmatrix) can be generated by calculating the apparent total porosity (ta) as determined by the calculated neutron density value, as shown in the formulae below. [15].

$$Rhomaa = \frac{\rho b - \emptyset ta * \rho f}{1 - \emptyset ta} \qquad \text{………..} (3)$$

$$\Delta tmaa = \frac{\Delta t\ \log - \emptyset ta * \Delta tf}{1 - \emptyset ta} \qquad \text{………..} (4)$$

Where:

Rhomaa,= apparent density of the matrix (gm/cc).

Δtmaa,= apparent transit time in the rock matrix (μsec/ft).

ta,= total porosity apparent.

Δtf,= time of interval transit

Δt log,= time of interval transit (log reading).

Pb = density of formation bulk.

Pf = density of the fluid (in the freshwater 1 (g/cm3) and in the salt mud 1.1 (g/cm3).

Figure 4 shows the **MID** cross plot for four wells almost points of the Mauddud Formation in calcite and some tward Dolomite.

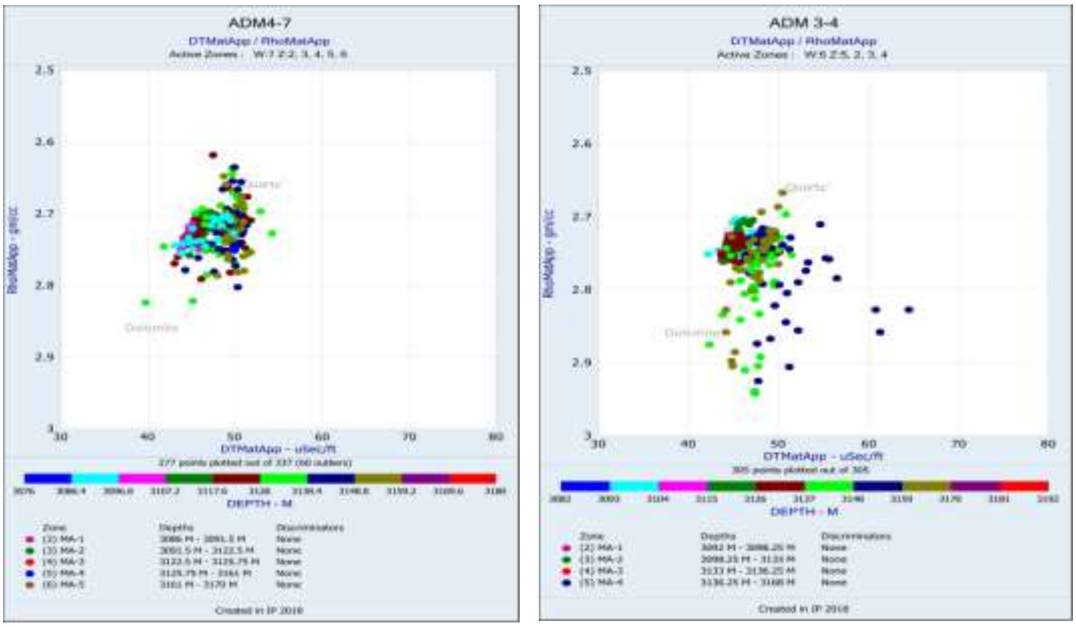

Figure 4: MID cross plot for Mauddud Formation from Two wells.

Petrophysical parameters:

1- *Volume of shale from GR log*

The shale volume thereof has a strong effect on the porosity interpretation and water saturation of a formation, which can influence hydrocarbon saturation [16]. The shale volume within the Mauddud Formation was calculated using the Gamma-ray log, with the maximum reading as a shale site and the lowest reading as a clean point. The amount of shale in a reservoir is relative to its ability [17] . The gamma ray index (IGR) was calculated to compute shale amount using the following equation [18]:

IGR = (GRlog- GRmin) / (GRmax – GRmin)

Where GRlog = gamma ray reading of formation; GRmin = minimum gamma ray reading (clean sand or carbonate); GRmax = maximum gamma ray reading (shale). Based on the age of the formation, the following equation was used to estimate the shale volume of old rocks [19]

$$Vsh = 0.33 * (2^{2* \mathrm{IGR}} - 1) \quad \ldots\ldots\ldots\ldots\ldots (8)$$

Where: Vsh = volume shale. ,IGR = index of gamma-ray

Figure 6 depicts the volume of shale in the Mauddud Formation in the ADM 3-4 and ADM 4-7 wells.

2- Assessment of Porosity

Porosity defines the percentage of pore volume to the bulk volume of reservoir rock, and it is symbolized by (ϕ). Pores of rocks also represent a natural reservoir of gas, oil, and water [20].

Total Porosity (Φt)

This type of porosity is the volume proportion of all pores in rock to the total volume of the material, and these pores are not necessarily connected or not [20]. The following equation can be used to calculate porosity using neutron and density logs [18].

$$\Phi t = \frac{\Phi N + \Phi D}{2} \quad \ldots\ldots\ldots\ldots \mathbf{(5)}$$

Where: Φt = total porosity (Neutron-Density log).,ΦN = neutron porosity., ΦD = density porosity.

Effective Porosity (Φe)

<u>That is the ratio of pore volume that is connected to the reservoir rock's entire volume [21].</u>

$$\Phi e = \Phi t \times (1 - VSh) \quad \ldots\ldots\ldots \mathbf{(6)}$$

\

Where: Φe = Effective porosity., Φt =Total porosity (Neutron-Density log)., Vsh = volume of shale.

Initial porosity

Initial porosity refers to the pores connected with the sediment's initial depositional structure, i.e. the pore region between the depositional grains and inside the depositional matrix [22] .

Secondary porosity index (SPI):

Secondary porosity refers to pores that form after sediments have been formed due to geological processes [23]. Porosity can be calculated using the equation below [15]

SPI = (Φt – Φs) ………… (7)

Where: SPI = Secondary porosity index. ,Φt = Total porosity (Neutron-Density log).,

Φ*s* = Porosity from the sonic log.

In ADM 3-4 and ADM 4-7 wells, Figure 5 illustrates the association between the PHIT and SPI. We found that the PHIT esteem is larger often than the SPI value, with a rise in particular locations attributed to stages of digenesis in this formation, such as dolomitization and dissolution. Additionally, the most accurate readings of effective porosity were found in units MA-2 and MA-4, ranging from 8% to 22%.

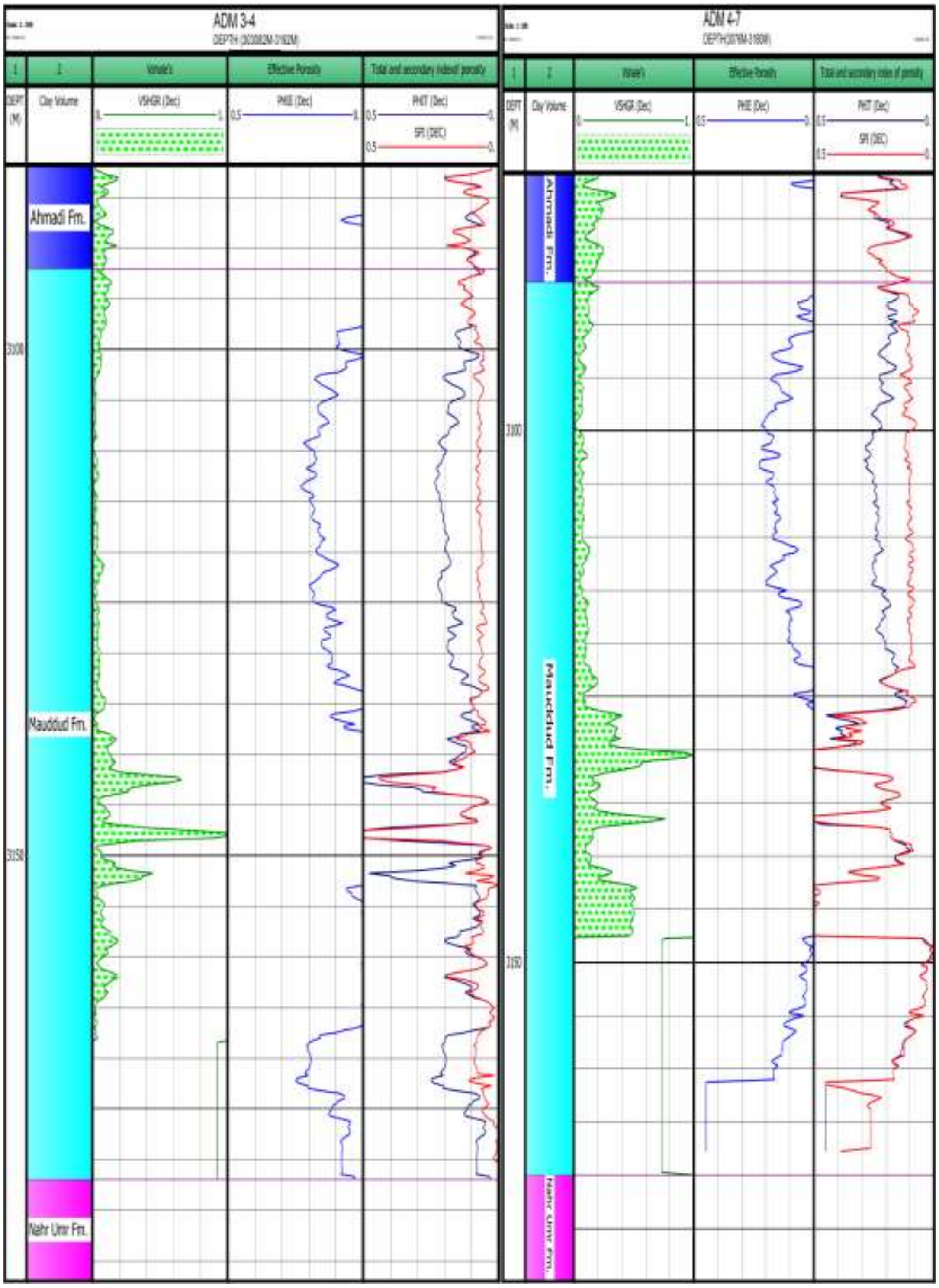

Figure 5: GR log, In two wells, ADM 3-4 and ADM 4-7, effective porosity (PHIE) and the relationship between total porosity (PHIT) and secondary porosity (SPI) were measured.

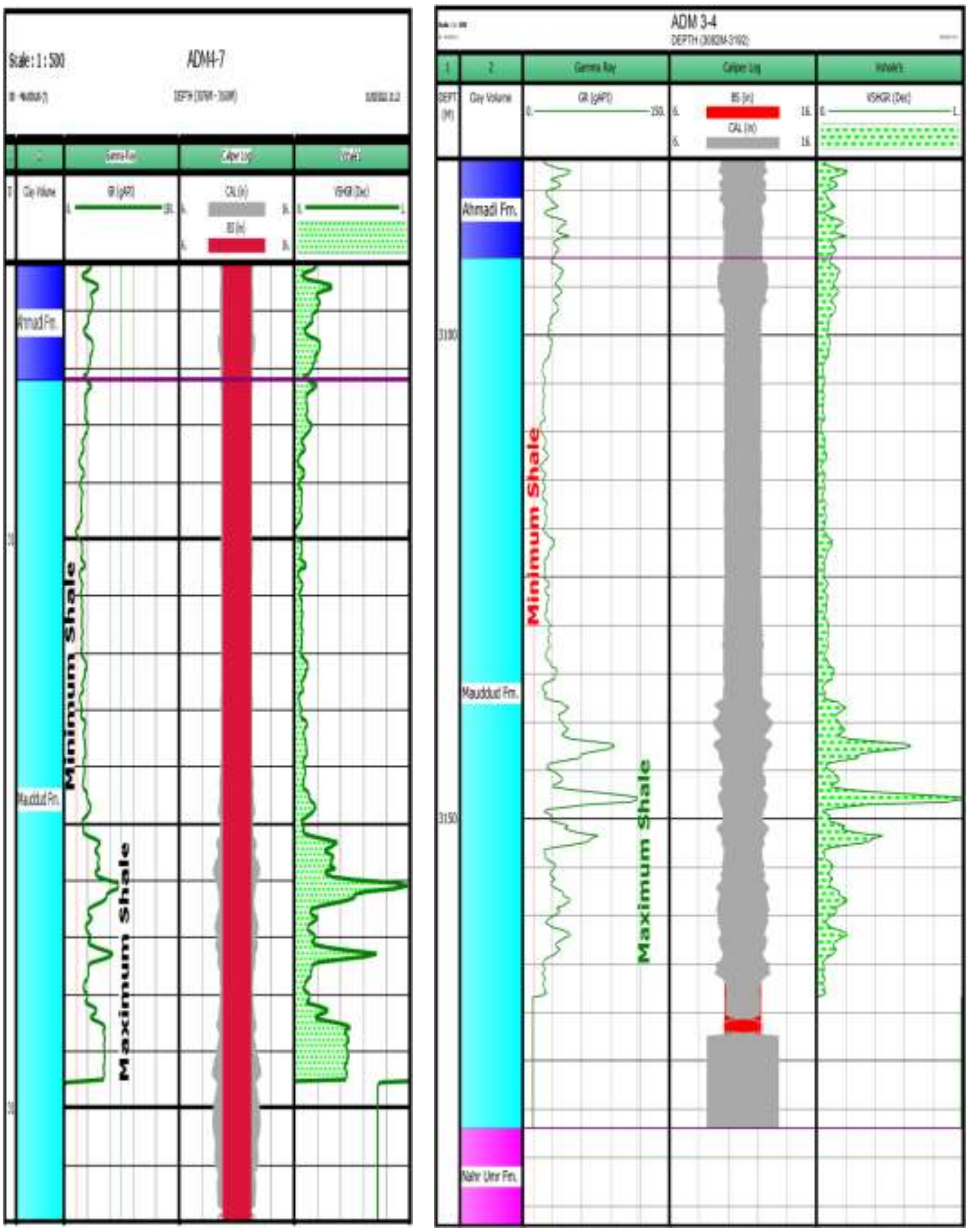

Figure 6: Shale Volume (VCLGR) calculation by GR log in two wells ADM 4-7 and ADM 3-4.

3-Hydrocarbon and Water Saturation

Water saturation is what the rock pores contain a formation water, while hydrocarbon saturation is one minus the water saturation and symbolizes them, respectively,(Sw, and Shr) [11]. Archie used the following equations to determine the uninvaded zone's (Sw) and invaded zone's (Sxo) water saturation [24].

$$Sw = \{(a * Rw) / (Rt * \_m)\}1/n \qquad \text{.................. (9)}$$

$$Sxo = \{(a * Rmf) / (Rxo * \_m)\}1/n \qquad \text{............. (10)}$$

here Rw = resistivity of water formation ; a = tortuosity factor (1) ; m = cementation factor (2); n = saturation exponent(2) .
The saturation of hydrocarbons was then determined using this formula:

$$Sh = 1 - Sw \qquad \text{……………………….(11)}$$

The residual hydrocarbon saturation was determined using the [23].

$$ROS = 1\text{-}Sxo \qquad \text{……………………….(12)}$$

The movable hydrocarbon saturation was then determined using the equation:

$$MOS = Sxo\text{-}Sw \qquad \text{………………………..(13)}$$

Where Shr represents saturation of residual hydrocarbons, Shm represents saturation of moveable hydrocarbons, Sxo represents water saturation in the invaded zone, and Sw represents water saturation in the uninvaded zone.

Analysis of Bulk Volume

Bulk volume water for the uninvaded zone (BVW) and the invaded zone (BVXO) is an output of formation water saturation (Sw) and its porosity and can be calculated from the following equation [11].

$$BVw = Sw * \emptyset \qquad \text{………………(14)}$$

$$BVxo = Sxo * \emptyset \qquad \text{…………………(15)}$$

The bulk volume of hydrocarbons, on the other hand, can be computed using the following equation:

$$Bvo = Sh * \Phi \qquad \text{……………………..(16)}$$

where Bvo = bulk volume of hydrocarbon; Sh = hydrocarbon saturation; Φ = porosity.

Examined Formation Reservoir

According to petrophysical properties, this formation in the Ahdab Petroleum Field was classified into five reservoir regions. There are two of them are key reservoirs with a large amount of oil, whereas the rest are not (Figures 7, 8, 9, , and 10) from top to bottom. The following description depicts the reservoir properties of Mauddud units:

Unit One (MA-1)

MA-1 unit is an uppermost reservoir unit with 2 to 11.25 m thick. It was considered a bad reservoir unit (barrier) because it has bad petrophysical properties, the average water saturation value ranges from 0.46 to 0.86. The effective porosity ranges from 0.027-0.057, with an increase in shale volume where ranging from 0.072 to 0.17.

Unit Tow (MA-2)

The MA-2 unit is an important reservoir unit, has 5.75 to 36.75m thick with a good petrophysical properties. The average water saturation value ranging from 0.39 to 0.47 while effective porosity ranges from 0.11 to 0.17 with a decrease in shale volume, where ranging from 0.036 to 0.095. Therefore, this unit is interpreted as an oil-bearing zone.

Unit Three (MA-3)

The MA-3 unit, 1-2.5m thick considered a bad reservoir unit (barrier). This unit has bad petrophysical properties. The average of water saturation value ranging from 0.45 to 1, while effective porosity ranges from 0.005 to 0.05 with an increase in shale volume (0.07-0.3).

Unit Four (MA-4)

The MA-4 unit, considered a second important reservoir unit after unit MA2, has 17.5 to 32m thick.. It is of good petrophysical properties characterizing by the average water saturation value ranging from 0.48 to 0.43, while effective porosity ranges from 0.016 to 0.14 with a decrease in shale volume (0.07-0.21). Therefore, this unit is interpreted as an oil-bearing zone.

Unit Five (MA-5)

This unit is the lowest reservoir unit, and has a 3.3-17m thick. Which is considered a bad reservoir unit (barrier), the average water saturation value ranges from 0.03 to 0.21 while effective porosity ranges from 0.21 to 0.45, with an increase in shale volume where ranging from 0 to 0.08.

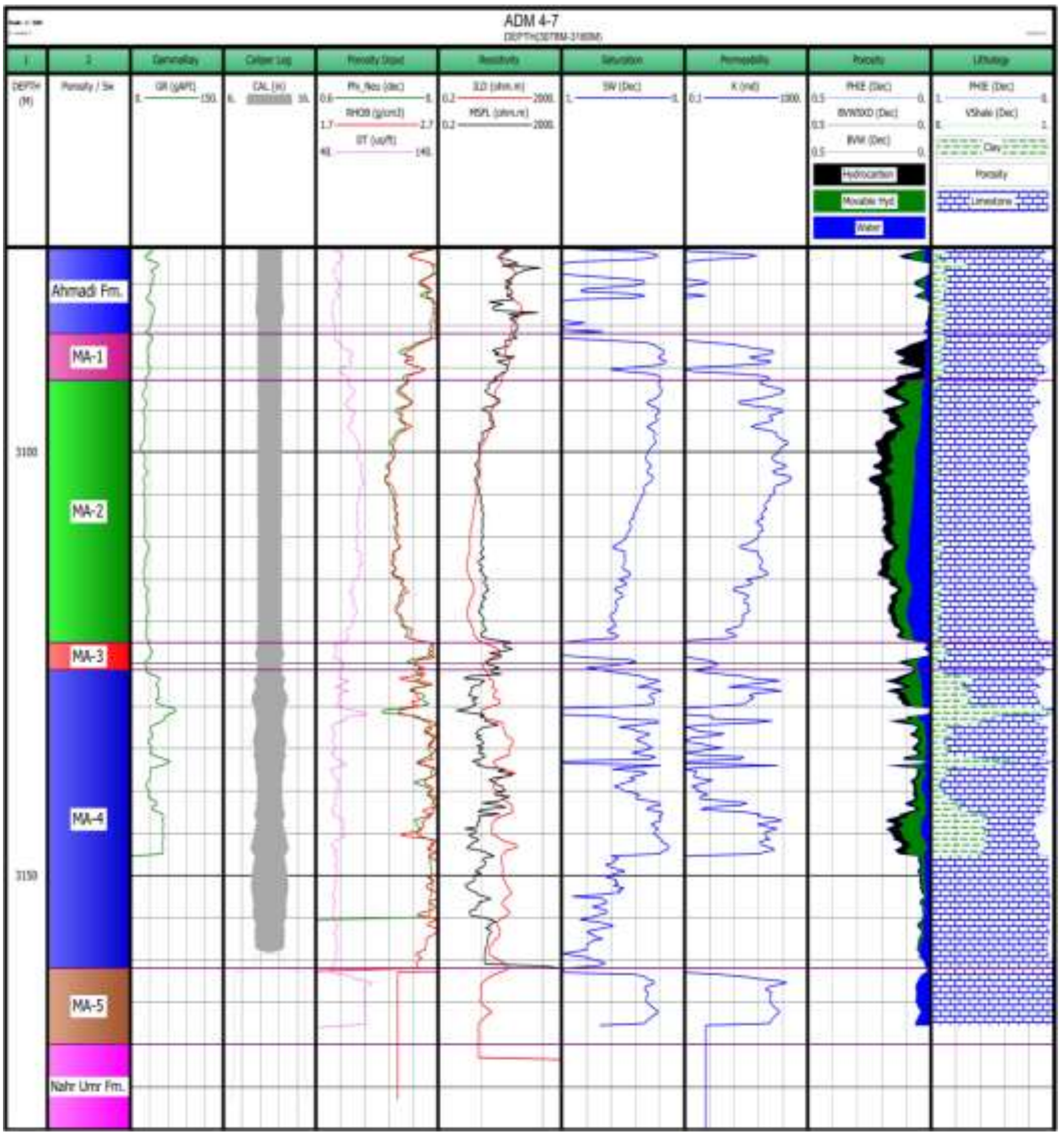

Figure 7: Shown CPI of Mauddud Formation in well(ADM 4-7).

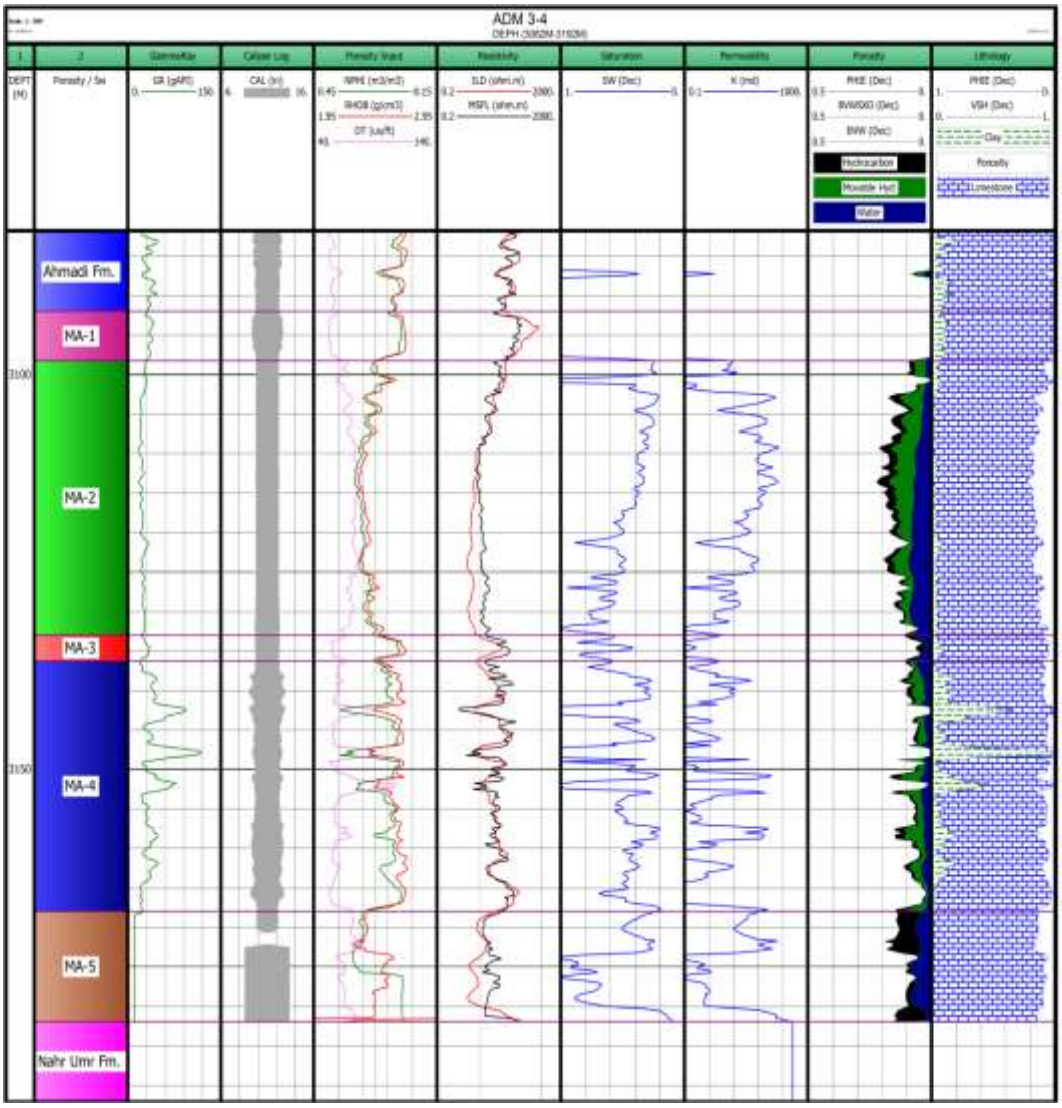

Figure 8: Shown CPI of Mauddud Formation in well (ADM 3-4)

Conclusions

The cross plot of lithology and mineralogy shows that the rocky nature of this formation is primarily limestone, with a little quantity of dolomite and no sandstone at the top formation. Calcite is the mineral that makes it up. IP software was used to determine the (CPI) of two wells in the Ahdab oil field. According to the computerized interpretation, the Mauddud Formation is made up of five reservoir units (MA-1, MA-2, MA-3, MA-4 and MA-5). The units MA-2 and MA-4 are the actual reservoir units. On the other hand, the other units are barriers or non-reservoir assets due to their log response, which is characterized by low GR log and water saturation with high porosity values calculated from the sonic, density, and neutron logs.

References

[1] H. Q. Hameed and A. H. Saleh, “Petrophysical Evaluation of Mauddud Formation in Selected Wells from Ratawi Oil Field, Southern Iraq,” *Iraqi Journal of Science*, pp. 2956–2969, 2021.

[2] F. N. Sadooni and A. S. Alsharhan, “Stratigraphy, microfacies, and petroleum potential of the Mauddud Formation (Albian–Cenomanian) in the Arabian Gulf basin,” *AAPG bulletin*, vol. 87, no. 10, pp. 1653–1680, 2003.

[3] R. M. S. Owen and S. N. Nasr, “The stratigraphy of the Kuwait/Basrah area in: Weeks GL (editor) Habital of oil a symposium,” *Am. Assoc. Petr. Geol. Tulsa*, 1958.

[4] W. Sugden and A. J. Standring, “Qatar Peninsula: Lexique Strat,” *International Centre National Rechearche Scientifique*, 1975.
[5] T. K. Al-Ameri, A. J. Al-Khafaji, and J. Zumberge, “Petroleum system analysis of the Mishrif reservoir in the Ratawi, Zubair, North and South Rumaila oil fields, southern Iraq,” *GeoArabia*, vol. 14, no. 4, pp. 91–108, 2009.
[6] B. A. Al-Baldawi and M. E. Nasser, “Evaluation of Petrophysical Characteristics of Carbonate Mishrif Reservoir in Ahdeb oil Field, Central Iraq,” *Iraqi Journal of Science*, pp. 321–329, 2019.
[7] S. Z. Jassim and J. C. Goff, *Geology of Iraq*. DOLIN, sro, distributed by Geological Society of London, 2006.
[8] J. T. C. Hay and M. O. Algawi, “Final report on well Melih Tharthar No. 1,” *Manuscript report No. FWR*, vol. 35, 1958.
[9] S. A. Jassim, “Finite abelian surface coverings,” *Glasgow Mathematical Journal*, vol. 25, no. 2, pp. 207–218, 1984.
[10] A. F. Douban and P. Medhadi, “Sequence chronostratigraphy and petroleum systems of the Cretaceous Megasequences, Kuwait,” in *AAPG inernational conference and exhibition*, 1999, pp. 152–155.
[11] G. B. Asquith, D. Krygowski, and C. R. Gibson, *Basic well log analysis*, vol. 16. American Association of Petroleum Geologists Tulsa, 2004.
[12] R. C. Selley, *Elements of petroleum geology*. Gulf Professional Publishing, 1998.
[13] D. V Ellis and J. M. Singer, *Well logging for earth scientists*, vol. 692. Springer, 2007.
[14] G. L. Chierici, “Reservoir Rocks,” in *Principles of Petroleum Reservoir Engineering*, Springer, 1994, pp. 47–116.
[15] S. N. Erickson and R. D. Jarrard, “Velocity-porosity relationships for water-saturated siliciclastic sediments,” *Journal of Geophysical Research: Solid Earth*, vol. 103, no. B12, pp. 30385–30406, 1998.
[16] M. C. Bassiouni, “The United Nations Commission of Experts Established Pursuant to Security Council Resolution 780 (1992),” *American Journal of International Law*, vol. 88, no. 4, pp. 784–805, 1994.
[17] W. J. Mamaseni, S. F. Naqshabandi, and F. K. Al-Jaboury, “Petrophysical properties of the Early Cretaceous formations in the Shaikhan oilfield/northern Iraq,” *Earth Sciences Research Journal*, vol. 22, no. 1, pp. 45–52, 2018.
[18] A. A. R. Zohdy, G. P. Eaton, and D. R. Mabey, “Application of surface geophysics to ground-water investigations,” 1974.
[19] W. W. Larionov, “Borehole radiometry: 127 p,” *Moscow (Nedra)(in Russian)*, 1969.
[20] D. L. D. Rasmussen, D. L. L. Rasmussen, G. J. J. Rasmussen, and M. W. Longman, “Selected Bibliography–Paradox Basin and Four Corners Region,” 2009.
[21] M. H. Alkhaykanee and S. I. Al-Dulaimi, “Petrophysical interpretation of Euphrates Formation in Ajil Oil Field, Salah Al-Deen Governorate, Central Iraq,” *Iraqi Journal of Science*, pp. 568–582, 2019.
[22] P. H. Nelson, “Permeability-porosity relationships in sedimentary rocks,” *The log analyst*, vol. 35, no. 03, 1994.
[23] D. Tiab and E. C. Donaldson, *Petrophysics: theory and practice of measuring reservoir rock and fluid transport properties*. Gulf professional publishing, 2015.
[24] G. E. Archie, “The electrical resistivity log as an aid in determining some reservoir characteristics,” *Transactions of the AIME*, vol. 146, no. 01, pp. 54–62, 1942.