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Evaluation of Petrophysical Characteristics of Mishrif and Yamama Reservoirs, in Garraf Oil Field, Southern Iraq, Based on Well-Logging Interpretation

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Abstract

The Mishrif and Yamama Formation are the main reservoirs in the Garraf oilfield, Nasiriyah city, of the Euphrates Subzone, Mesopotamian Basin, Southern Iraq. The Garraf oilfield structural pattern corresponds with the similar anticline forming the oilfields of Rafidain and Dujaila and is parallel to the main trend of Zagros, indicating simple coaxial deformation.

The petrophysical properties are evaluated using the Interactive Petrophysics V3.5 software. This comprises determining the lithology, mineralogy, and matrix for the investigated reservoirs, as estimating clay volume, total, effective, and secondary porosity, water saturation, permeability, and determining the net pay and gross thickness.

The findings of this investigation indicated that the Mishrif formation is divided into two main units separated by a marl layer, with the upper unit having poor reservoir qualities and the lower unit having favorable ones. As a result, there are nine reservoir units in the lower main unit (M1, M1.2, M2, L1, L1.2, L2, L2.2, L2.3, and L2.4). The best and largest reservoir unit capacity is Unit L1.2, with exceptional petrophysical characteristics. Lower units L2.2, L2.3, and L2.4 are nearly saturated in reservoir water, with a little oil in some wells.

YA, YB1, and YB2 are the three reservoir units that make up the Yamama formation. Unit YA is the best reservoir unit because of its petro physical properties.

Key word: The petrophysical qualities of Units YB1 and YB2 are poor, and they contain a significant amount of reservoir water.

تقييم الخصائص البتروفيزيائية لمكمني المشرف واليمامة في حقل الغراف النفطي ، جنوب العراق ، بالإعتماد على تفسير المجسات البئرية

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الخلاصة

يعتبر كل من تكويني المشرف واليمامة المكمنين الرئيسيين في حقل الغراف النفطي ، في مدينة الناصرية ، في منطقة Euphrates Subzone ضمن حوض مابين النهرين، جنوب العراق. يتوافق النمط التركيبي

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لحقل الغراف النفطي مع الخط المنحني المماثل الذي يشكل حقلي نفط الرافدين والدجيلة وهو موازٍ لاتجاه زاغروس الرئيسي ، مما يشير إلى تشوه محوري بسيط.

تم تقييم الخواص البتروفيزيائية باستخدام برنامج IP v3.5 . تضمن ذلك تحديد الصخارية ، التركيب المعدني، ونوع الماتركس للمكامن التي تم فحصها ، وكذلك تقدير حجم الطين ، والمسامية الكلية والفعالة والثانوية ، وتشبع المياه ، والنفاذية ، وتحديد انطقة العطاء والسمك الكلي للمكمن.

أشارت نتائج هذا البحث إلى أن تكوين المشرف ينقسم إلى وحدتين رئيسيتين تفصل بينهما طبقة المارل ، حيث تتميز الوحدة العلوية بخصائص مكمنية رديئة، اما الوحدة السفلية لها خصائص جيدة. نتيجة لذلك ، توجد تسع وحدات مكمنية ثانوية في الوحدة الرئيسية السفلية وهي (M1، M1.2، M2، L1، L1.2، L2، L2.2، L2.3 ، و L2.4). أفضل وأكبر سعة لوحدة الخزان هي الوحدة L1.2 ، والتي تتميز بخصائص بتروفيزيائية استثنائية. الوحدات السفلية L2.2 و L2.3 و L2.4 مشبعة تقريبًا بالمياه المكمنية، مع وجود كمية قليلة من النفط في بعض الآبار في حقل الغراف.

YA و YB1 و YB2 هي الوحدات المكمنية الثلاثة التي تشكل تكوين اليمامة. وحدة YA هي أفضل وحدة مكامنية لما لها من خصائص بتروفيزيائية. تعتبر الصفات البتروفيزيائية للوحدتين YB1 و YB2 فقيرة وتحتوي على كمية كبيرة من المياه المكمنية.

1. Introduction

The Garraf oil field is located in Dhi Qar Governorate, south of Iraq, around 265 km southeast of Baghdad DC, 85 km north of Nasiriya city (**Figure 1)**. According to the longitudinal tectonic classification of Iraq for [1], the Garraf oil field is situated in the Mesopotamian basin of the Stable Shelf. It is specifically located in the Euphrates Subzone. The Euphrates Subzone is characterized by short longitudinal anticlines extending from the northwest to the southeast. Dimensions of the Garraf oil field is 5 km width and 24 km length according to [2]. The Garraf oil field is a longitudinal anticline structure, the fold axis trends NW-SE [2], see (**Figure 1)**.

[3]Studied reservoir properties of Mishrif Formation in Garraf oil field using geophysical well logs. [4] Studied the modelling of petrophysical properties and reserve estimation of Mishrif Formation in Garraf oil field.

The major goal of this research is to identify the petrophysical characteristics as well as lithology of each reservoir unit in the Mishrif and Yamama formations in the Garraf oil field based on well log sets. In addition, the research will use well log sets to estimate net to gross values in order to prospect the hydrocarbon output of reservoir units in the Mishrif and Yamama formations in the Garraf oil field. Data of one vertical well was studied in this research: Well X-3. The Garraf oil field was discovered in 1984; 109 wells were drilled in the oilfield since it was discovered. The major field reservoirs involving the largest most significant oil accumulations are the Mishrif and Yamama formations. In contrast, the minor reservoirs of the oil field are Ratawi and Zubair formations.

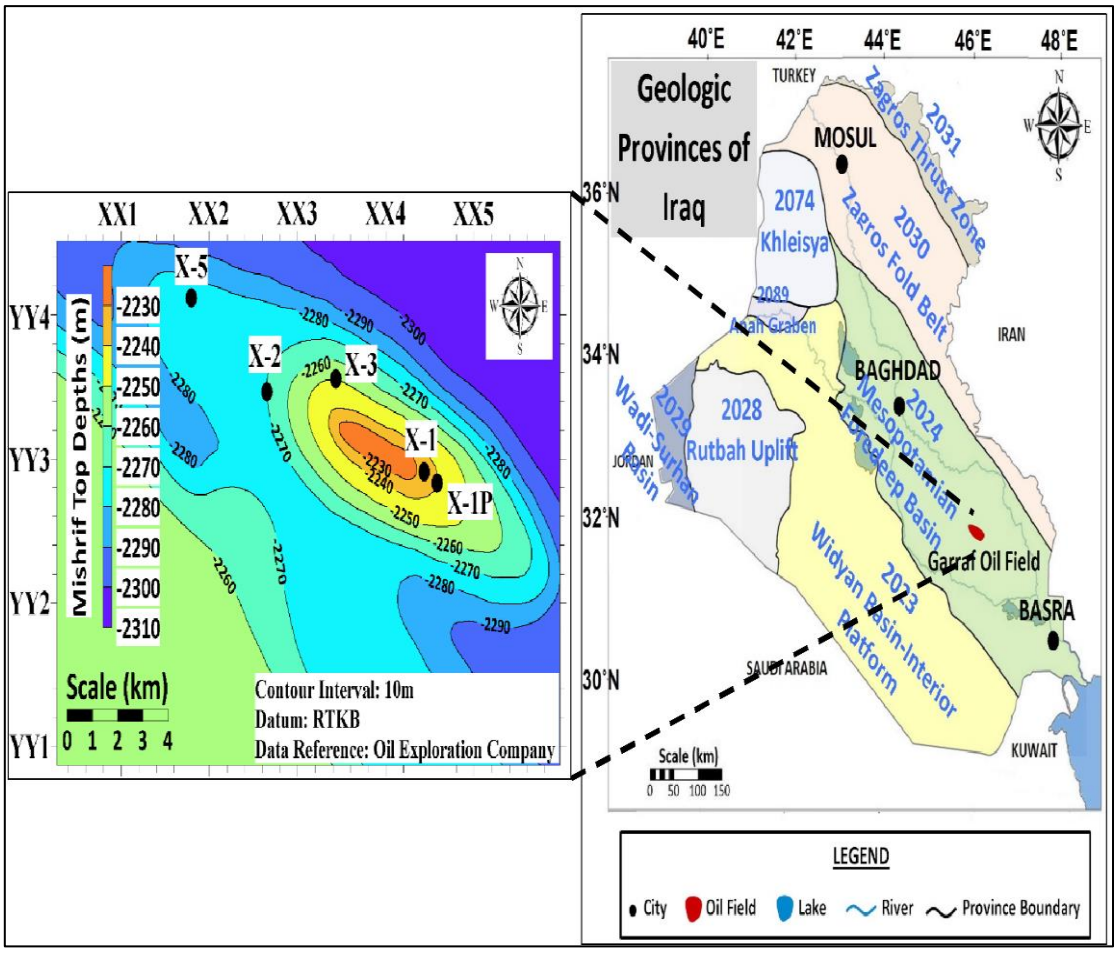

Figure 1-Geologic provinces of Iraq map, modified from [5], with a 2D structural contour map of Garraf structure at the top of Mishrif Formation.

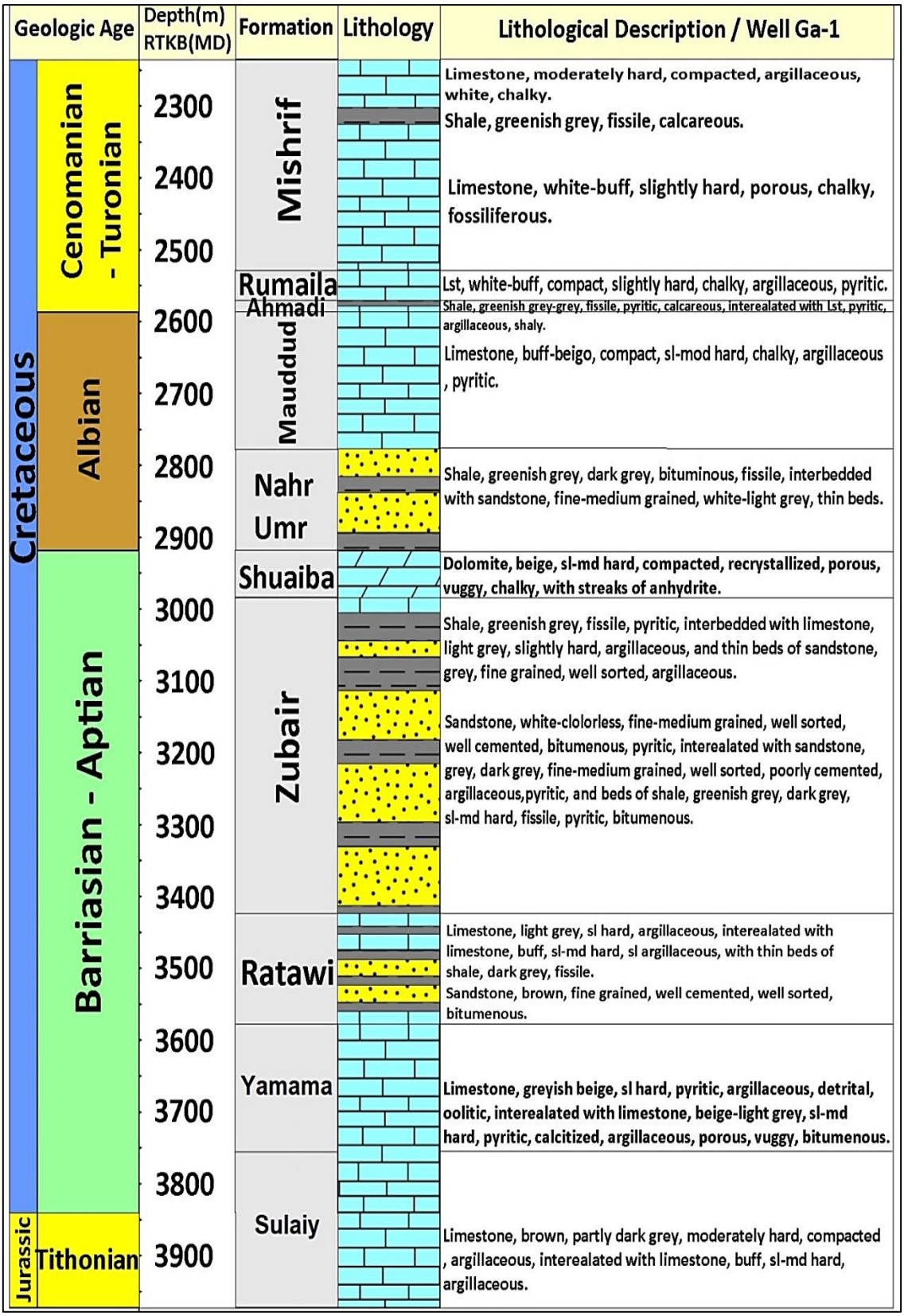

Figure 2- Stratigraphic column from U. Jurassic – Cretaceous of Garraf oil field in well X-3 according to the final well report of Oil Exploration Company.

2. Methodology

Data from available well logs represented by GR, SP, Density, Neutron, Sonic, and Resistivity logs of the studied well (X-3) were used to outline the study's stated goal. The necessary software (Didger v5 and IP v3.5 was used for digitizing the well logs, process and interpretinginterpreting the resulted data Each reading per 1m depth is selected for recording the input data measurements for IP software to determine petrophysical properties. A 2D structural contour map of the Garraf structure at the top of the Mishrif was plotted using Surfer software (**Figure 1)**.

3. Geological Setting and Stratigraphy

The Mishrif Formation was first identified as a heterogeneous formation consisting of organic and detrital limestones involving beds of rudist, algal, and coral reef limestones, capped by limonitic freshwater limestones [6]. In its type location, the Mishrif Formation is composed of dense, grey-white, algal limestones with shell fragments and gastropods on top, and consisting of detrital, brown, porous, partially very shelly as well as foraminiferal limestones with rudist debris on the bottom. The Mishrif Formation thickness in the Rumaila and Zubair oilfields is 270m. Along the Iraq-Iran border, the thickness in the Nahr Umr and Majnoon oilfields is 435m, while between Kut and Amara in the Abu Amud oilfield, the thickness is 380m. The Rumaila Formation is usually the underlying unit of the Mishrif Formation in southern regions of Iraq [1].

In 1952, Steinke and Bramkamp described the Yamama Formation in Saudi Arabia from outcrops [7]. [6] Described a 257 m interval in Ratawi-1 as the (Yamama-Sulaiy) Formation. The upper 203 m is now assigned to the Yamama Formation [8]. The formation is up to 400 m thick in the Euphrates area near Najaf and up to 360 m thick in SE Iraq. In the southern regions of Iraq, Yamama formation consists of pelloidal, oolitic, pelletal and pseudo-oolitic shoal limestones, plus it includes as well outer shelf argillaceous limestones. Oolitic reservoir units are present in several NW-SE trending depocentres [8] [9]. The Yamama Formation is Berriasian-Valanginian in age, according to [6]. The Yamama Formation was deposited in alternating deep inner shelf and oolitic shoal environments, according to [8], with subtle structural highs within a carbonate ramp controlling the process [1]. The formation was divided into three Lithofacies [10] [11]. At the bottom of the formation, the first represents granular limestone with good porosity and permeability. The middle part of the formation is composed of compacted limestone. The oolitic and grained limestone with good permeabilityis deposited in the upper part of the formation.

4. Results and Discussion

The major reservoirs of the Garraf oil field (Mishrif and Yamama) were studied through the Well X-3. The petrophysical properties were determined and computed based on the interpretation of the available well logs using Interactive Petrophysics V3.5 software after environmental corrections is performed, and computer processing interpretation (CPI) for both reservoirs were built using Interactive Petrophysics (IP) software as seen in (**Figure 7) and (Figure 8)**.

4.1. Petrophysical parameters and results

Petrophysical parameters must be obtained and evaluated to determine the reservoir characteristics of the Mishrif and Yamama formations. The petrophysical parameters are:

4.1.1. Lithology determination

The lithology and mineral composition of the Mishrif and Yamama formations were determined using four types of cross plots as mentioned in the following, see **Figures from (3) to (6)**:

a) Neutron-density lithology cross plot.

b) Neutron - Sonic lithology cross plot.

c) M-N Lithology cross plot.

d) Matrix identification (MID) cross plot.

4.1.2. Shale volume computation

Because clay is typically further radioactive than carbonate, the GR tool will be a suitable candidate for calculating the amount of clay in a a permeable reservoir. The shale volume is expressed as a decimal fraction or percentage is named V*shal*e. The measurement of the Gr index is the principal stage required for defining the shale volume by GR log [12] (**Figure 7) and (Figure 8)**.

4.1.3. Porosity calculation

Porosity was calculated from the density and sonic logs using its basic equations. It is necessary to distinguish between the types of porosity [13].

Total porosity (PHIT or Øt) is described as the ratio of all pores' volume to the bulk volume of a substance, whether all pores are related or not [14].

Effective porosity (Øeff) is another essential type of porosity. It represents the ratio of the volume of only interconnected pore in a material to the total volume of reservoir rock [14].

Secondary porosity is another minor type of porosity. This type is formed within a reservoir after deposition. Vuggy or secondary fracture porosity can be calculated by secondary porosity index (SPI) [14]. (Figures 7&8).

Secondary porosity arises from secondary geological processes represented by the diagenesis process that occurs after sediments deposition [15]. The secondary porosity involves vugular spaces found in carbonate rocks that were formed due to the leaching or fracture openings that were formed in fractured reservoirs [16]. The intervals of higher secondary porosity mean the effect of diagenesis processes on the porosity of the Mishrif Formation, such as dolomitization and dissolution [13].

4.1.4. Water saturation calculation

According to traditional logging data, there are different types of important water saturation models for non-clean or shale-bearing sandstone reservoirs. For non-clean or shale-bearing as well as heterogeneous formations, the formula of Archie does not work well. In measuring water saturation, Simandoux considered another conductivity source emerging from clay [17]. The Indonesian equation was developed by Poupon and Leveaux (1971) to account for the high amount of shale and freshwater formations contained in Indonesia reservoirs. The equation was developed by using computer-made cross-plots to determine the relationship between the value of water saturation and the value of the true resistivity of the formation [18].

Mishirif and Yamama formations in the Gharaf oil field are non-clean carbonate formations with variable quantities of shale within the different units of the studied formations. Therefore, Archie's model does not work fine in the interpretation of water saturation. Simandoux and Indonesian models were used in this study the to calculate water saturation to the studied formations. See (**Figure 7) and (Figure 8)**.

4.1.5. Hydrocarbon saturation calculation

The hydrocarbon saturation is the quantity of pore volume in a rock occupied by oil, typically detected by the difference amongst unity and water saturation. However, the residual hydrocarbon saturation is the differences between unity and water saturation in the flushed interval [19]. Both water saturation (S_w) , as well as water saturation of the flushed zone (Sxo),, can be used to calculate the amount of moveable hydrocarbon [20]. Table 1.

4.1.6. Permeability computation

There are many methods of estimating permeability from wireline tools, but the Timur and Morris equations are used to calculate the permeability of Mishrif and Yamama formations in studied well because it's the more reliable for Iraq's carbonate reservoirs. The constants for calculation permeability in Interactive Petrophysics (IP V 3.5) are: Timur : a = 8581 b = 4.4,

and c = 2 and Morris Biggs Oil: a = 62500 b = 6, and c = 2. These equations apply only to zones of irreducible water saturation, such as the hydrocarbon zones above the transition zone. See (**Figure-7) and (Figure-8)**.

4.1.7. Net pay and gross thickness measurements

To evaluate studied reservoirs, net pay and gross thickness must be calculated, where net pay represents the thickness of the porous and permeable zone of an evaluated formation that contains commercial amounts of hydrocarbon. The net to the gross ratio (N/G %) can be defined as the ration between the thickness of net pay and the thickness of the total pay zone. This is an essential factor in hydrocarbon volumetric calculation of reservoir [21]. The zone of a reservoir in that effectively contributesto petroleum production represents the net pay of that reservoir. This value is calculated using appropriate cut-off values applied to petrophysical parameters. Shale volume, water saturation, and porosity cut-off values represent important petrophysical parameters to calculate net pay of the studied reservoirs, where using these petrophysical parameters is important to identify between reservoir zone from the non-reservoir zone of studied formations. It can distinguish between wet or dry zone and oil-filled zone depending on the cut-off value of water saturation (Sw). See (**Figure 3) and (Figure 6)**.

In the net pay thickness measurement, 50% and 8% as the default values of water saturation and porosity respectively for Mishrif Formation, and 50% and 6% as the default values of water saturation and porosity respectively for Yamama Formation in Garraf oil field have been applied.

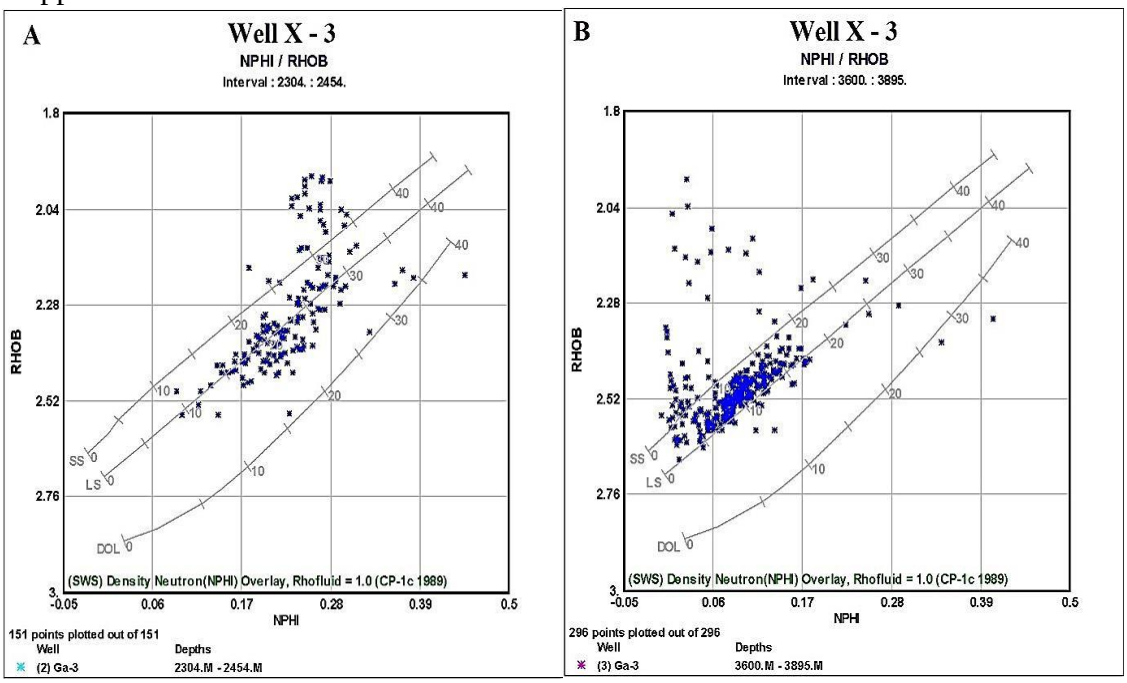

Figure 3-Neutron – Density cross plots of (A) Mishrif Formation and (B) Yamama Formation of Well X-3 in Gharaf oil field.

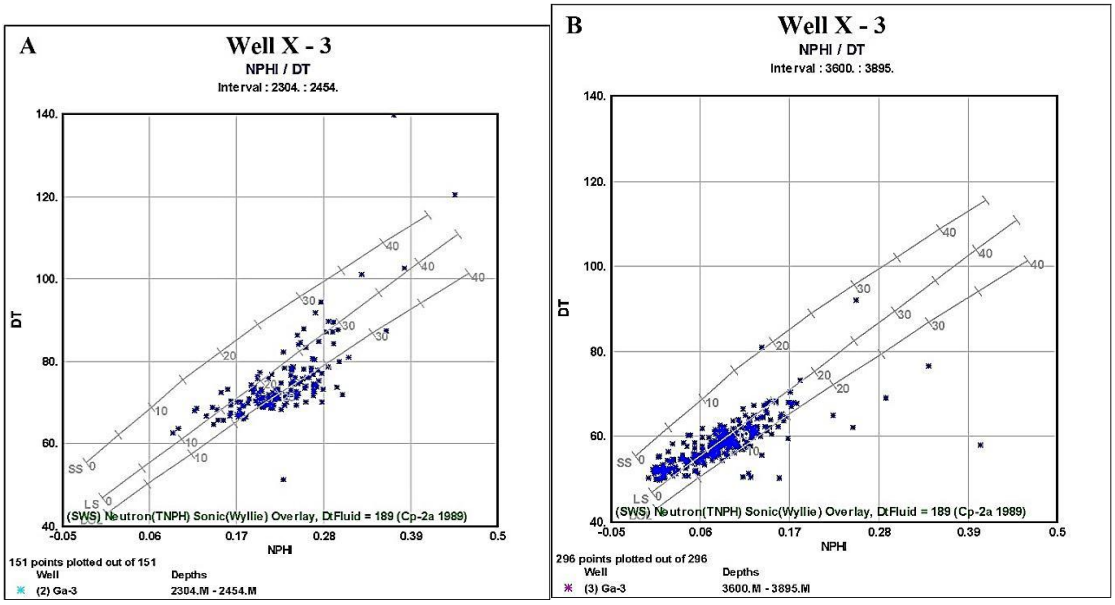

Figure 4-Neutron–Sonic cross plots of (A) Mishrif Formation and (B) Yamama Formation of Well X-3 in Gharaf oil field.

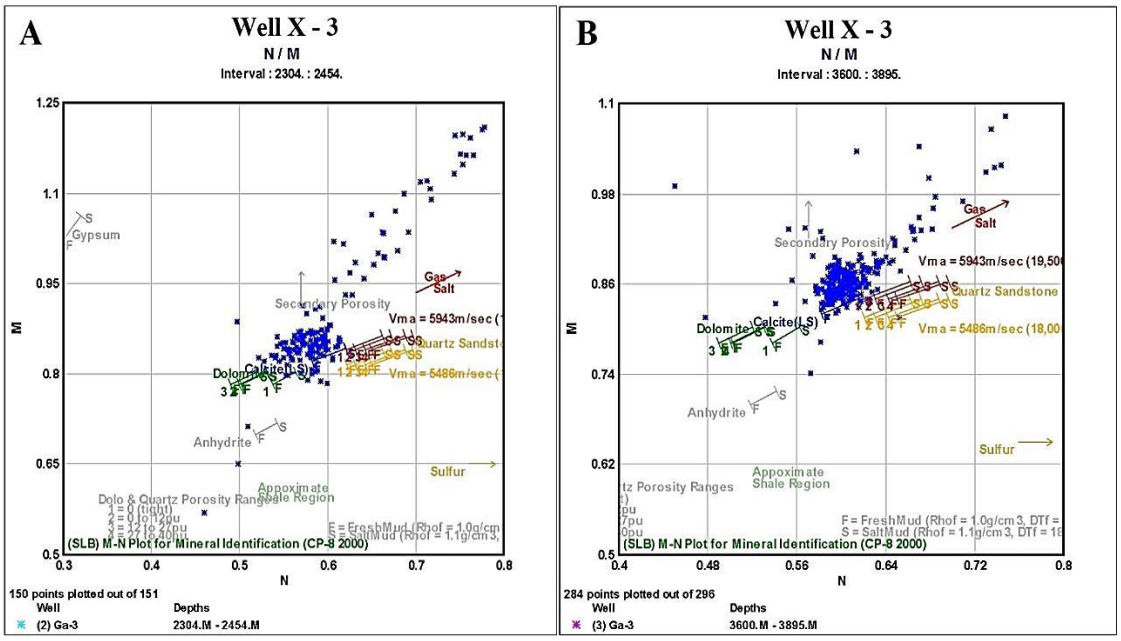

Figure 5-M - N cross plots of (A) Mishrif Formation and (B) Yamama Formation of Well X-3 in Gharaf oil field.

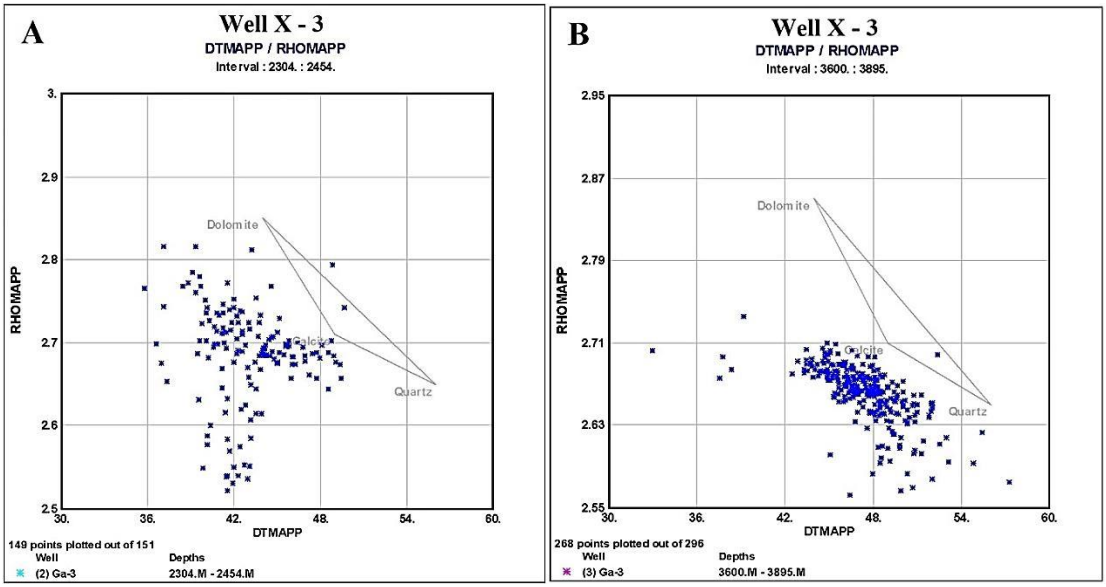

Figure 6-MID cross plots of (A) Mishrif Formation and (B) Yamama Formation of Well X-3 in Gharaf oil field.

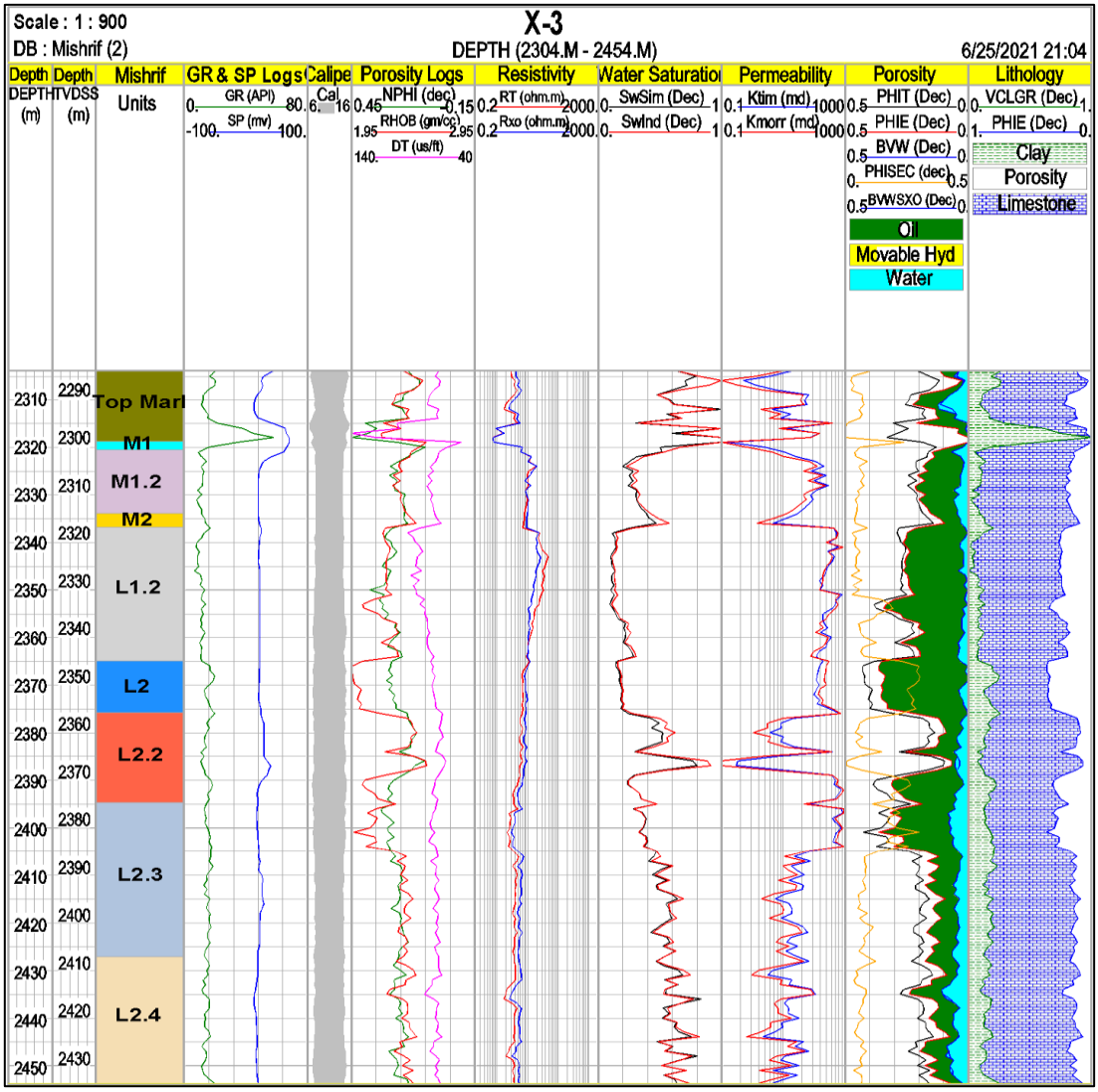

Figure 7- Computer Processes Interpretation (CPI) of the reservoir part of Mishrif Formation in Well X-3 of Garraf oil field.

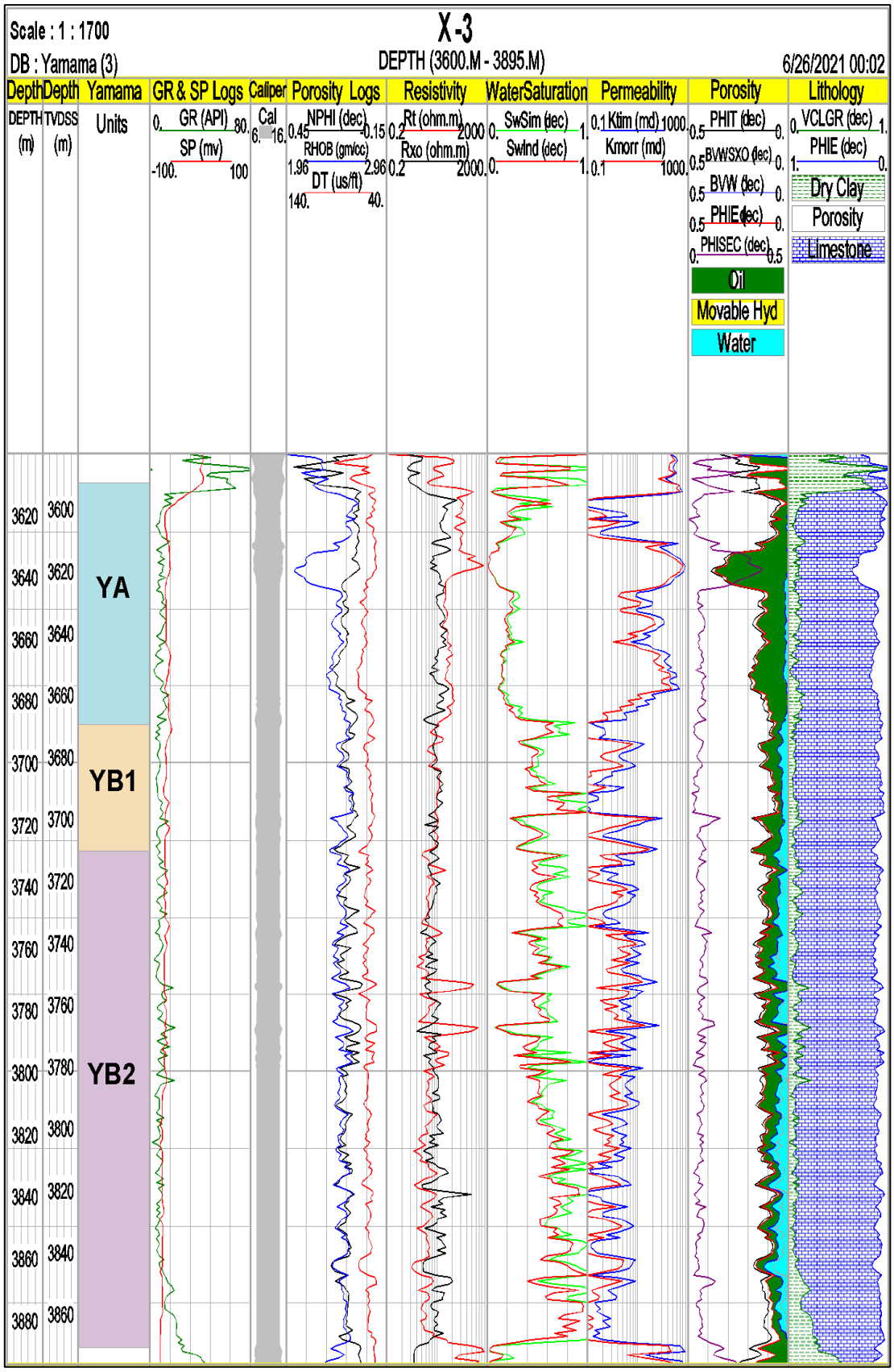

Figure 8- Computer Processes Interpretation (CPI) of Yamama Formation in Well X-3 of Garraf oil field.

Table 1- Net pay and average of the main petrophysical properties of Mishrif and Yamama reservoirs in Well X-3 of Garraf oil field

Mishrif Reservoir / Well X-3 RTKB = 17.54 m											
Units	Top		Bottom		Gross Thick.	Net Thick.	N/G	Av. PHIE%	Av. Sw%	Av. Vcl%	Av. Sh%
	MD	TVDSS	MD	TVDSS							
M1	2318.73	2301.19	2320.45	2302.91	1.72	0.00	0.00	---	---	---	---
M1.2	2320.45	2302.91	2333.82	2316.28	13.37	12.32	0.92	17.90	28.70	08.80	71.30
M2	2333.82	2316.28	2336.71	2319.17	2.89	2.89	1.00	12.30	40.40	13.30	59.60
L1.2	2336.71	2319.17	2364.93	2347.39	28.22	28.22	1.00	24.50	15.50	08.40	84.50
L2	2364.93	2347.39	2375.78	2358.24	10.85	10.85	1.00	34.20	18.00	18.80	82
L2.2	2375.78	2358.24	2394.65	2377.11	18.87	11.87	0.63	21.50	31.60	18.00	68.40
L2.3	2394.65	2377.11	2427.15	2409.61	32.50	17.85	0.55	22.80	39.80	17.00	60.20
L2.4	2427.15	2409.61	2454	2436.46	26.85	02.00	0.07	17.30	47.40	15.10	52.60
Yamama Reservoir / Well X-3 RTKB = 17.54 m											
Units	Top		Bottom		Gross Thick.	Net Thick.	N/G	Av. PHIE%	Av. Sw%	Av. Vcl%	Av. Sh%
	MD	TVDSS	MD	TVDSS							
YA	3609.04	3591.5	3687.54	3670	78.54	67.00	0.85	15.40	15.60	09.40	84.40
YB1	3687.54	3670	3728.54	3711	41.00	16.04	0.39	11.60	39.80	07.40	60.20
YB2	3728.54	3711	3889.54	3872	161.00	17.96	0.11	12.00	38.30	09.30	61.70

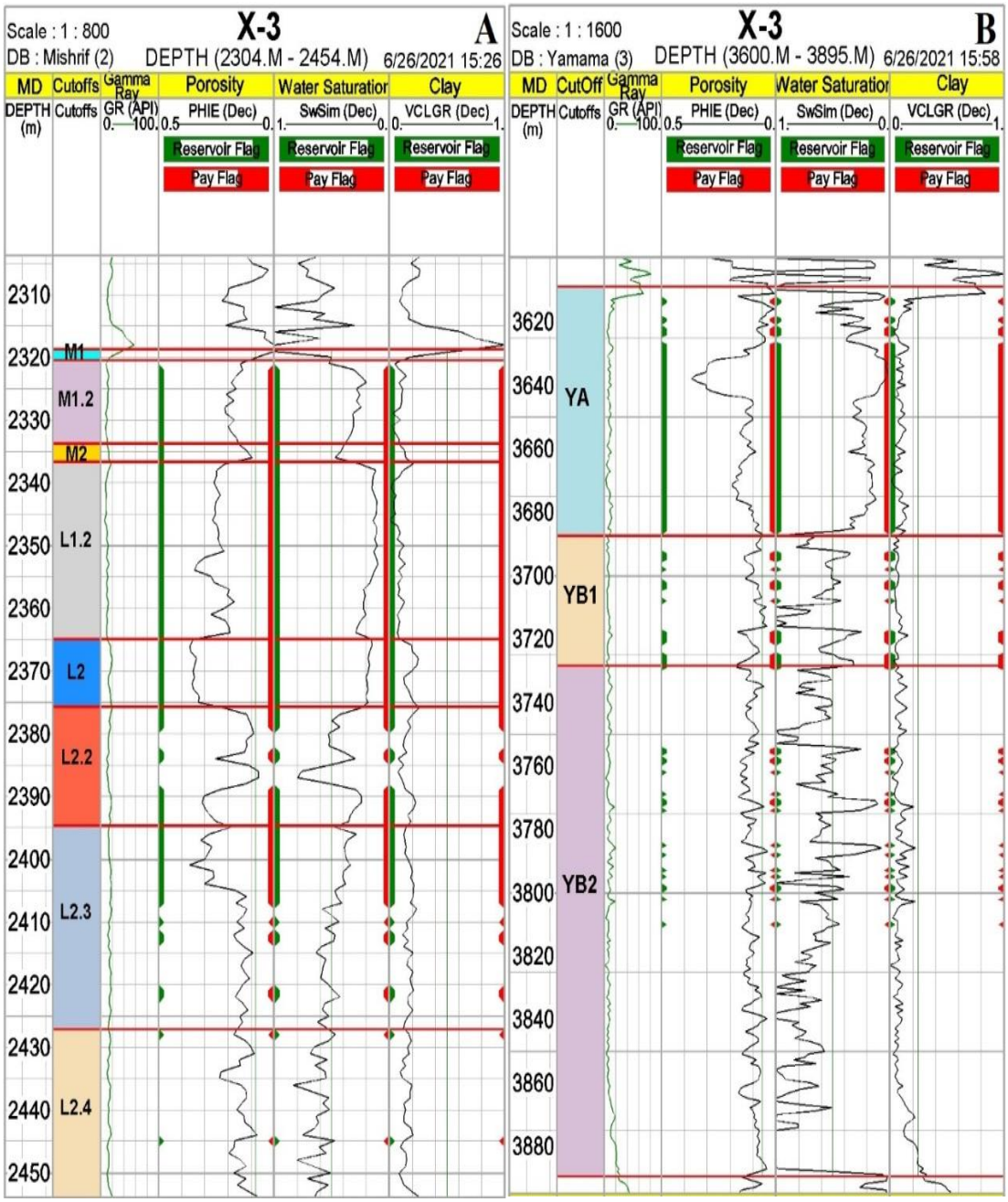

Figure 9-Net-pay and reservoir parameters of (A) Mishrif reservoir and (B) Yamama reservoir in Well X-3 of Garraf oil field.

5. Discussion

According to the results of the reservoir analysis and CPI for the lower unit in Well X-3, the Mishrif Formation consists of eight reservoir units represented by: M1, M1.2, M2, L1.2, L2, L2.2, L2.3, L2.4, each unit has different petrophysical properties from others in the same well and also from well to another. Units M1 and M2 have poor reservoir properties. Unit M1.2 has good reservoir properties. Units L1.2 and L2 have excellent petrophysical properties, and they are considered the best reservoir units for oilUnits. Unit L1.2 is the largest reservoir unit for the Mishrif Formation, where it contains a large proportion of oil in the Well X-3. In the Mishrif Formation, the lower units L2.2, L2.3, and L2.4 are almost fully saturated in reservoir water with a minor proportion of oil in Well X-3 in the Garraf oil field.

The Yamama Formation consists of three reservoir units from upper to lower, respectively YA, YB1, and YB2. Each unit has different petrophysical properties from others in the same

well and isfrom well to another. In the Yamama Formation, unit YA has good petrophysical properties, and it is considered the best reservoir unit for oil of Yamama Formation. It contains a large proportion of oil in the studied well X-3. In the Yamama Formation, units YB1 and YB2 have low petrophysical properties. They contain a large percentage of reservoir water in the studied well X-3.

6. Conclusions:

- Determination of the lithology of Mishrif and Yamama formations using four types of cross plots. This proved that the lithology of both Mishrif and Yamama formations consisted mainly of limestone.
- Through the MID and M-N cross plots, it was proved that the Mishrif and Yamamah formations consist of primary mineral composition, calcite, and secondary mineral dolomite.
- The Mishrif Formation consists of two main units separated by a marl layer, the upper unit has low reservoir properties, and the lower unit has good reservoir properties. According to the results of the reservoir analysis and CPI for the lower unit in Well X-3, it consists of eight reservoir units represented by: M1, M1.2, M2, L1.2, L2, L2.2, L2.3, L2.4, each unit has different petrophysical properties from others in the same well and also from well to another.
- In the Mishrif Formation, Units M1 and M2 have poor reservoir properties. Unit M1.2 has good reservoir properties. Units L1.2 and L2 have excellent petrophysical properties, and they are considered the best reservoir units for oil. Unit L1.2 is the largest reservoir unit for the Mishrif Formation, where it has reliable reserves of oil in the Well X-3.
- In the Mishrif Formation, the lower units L2.2, L2.3, and L2.4 are almost fully saturated with reservoir water with few reserves of oil in Well X-3 in the Garraf oil field.
- The Yamama Formation consists of three reservoir units from upper to lower, YA, YB1, and YB2. Each unit has different petrophysical properties from others in the same well and isfrom well to another.
- In the Yamama Formation, unit YA has good petrophysical properties, and it is considered as the best reservoir unit for oil of the Yamama Formation. It has an economical quantity of oil in the studied well X-3.
- In the Yamama Formation, units YB1 and YB2 have low petrophysical properties; they contain a large percentage of reservoir water in the studied well X-3.

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