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Reservoir Properties and Reservoir Model of the Mu Formation in the X Oil Field of Northern Iraq

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Abstract

The Mu Formation is considered one of the most widespread Cretaceous periods in Iraq and its typical section is located in the province of Sulaimani in the Qamchuqa region. The study area is located in the X oil field, which is located to the southwest of the dome of Baba and southwest of the city of Kirkuk about 12 km and represents an asymmetrical subsurface fold whose axis extends in a Northwest-Southeast direction and the field is located in the unstable platform zone in the Foothill zone. The Formation consists of limestone and dolomitic limestone, organodetrital and argillaceous, the upper contact of the Formation is unconformable with the Dokan Formation, while the lower contact is graded with the Upper Sarmord Formation. The current study showed that most of the parts of the Formation contain a shale rate of less than 35%, and it was found through the logs (density, neutron and gamma rays) that the effective porosity rate is determined between (4-15) %, the rate of shale content is between (21-34) % and the permeability rate is between (0.66-13.8) mD in a well XA, while in the XB well, the shale content rate ranges between (21-38)%, the effective porosity rate is between (8-18) %, and the permeability rate is between (1.6-18.8) mD. The Formation was divided into six reservoir units depending on the variation of shale content, porosity rate and permeability. The reservoir unit (MUE, MUC) is considered the best reservoir unit in the XA well, while the MUF unit has bad reservoir qualities in the same well. In the XB well, MUC & MUE are considered to be the best reservoir units, while MUF & MUB have less reservoir specifications compared to the previous two units. The water and hydrocarbon saturations were calculated with the movable and residual fractions of the invaded and uninvaded zones, as well as the total volume of water and oil within the Formation. After calculating the reservoir properties, the three-dimensional reservoir model was drawn by Petrel software to clarification the distribution of hydrocarbon saturation of the formation units; the net pay thickness of the Formation was calculated.

Keywords: Mu Formation; Reservoir Model; permeability.

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الخواص المكمنية والموديل المكمني لتكوين Mu في حقل X النفطي شمالي العراق

الخلاصة:

يعتبر التكوين من أكثر تكاوين العصر الطباشيري الاسفل انتشارا في العراق ويقع مقطعه النموذجي في محافظة السليمانية في منطقة قمجوقة. تقع منطقة الدراسة في حقل خباز والذي يقع بدوره الى الجنوب الغربي من قبة بابا وجنوب غرب مدينة كركوك بحوالي 12كم ويمثل طية تحت سطحية غير متناظر يمتد محورها بأتجاه شمال غرب-جنوب شرق ويقع الحقل في منطقة الرصيف غير مستقر (unstable platform) في منطقة أقدام التلال .(Foothill zone) يتألف التكوين من الحجر الجيري والحجر الجيري الدولومايتي، الفتاتي العضوي و الارجيلايتي يعتبر الحد الاعلى للتكوين غير متوافق مع تكوين دوكان اما الحد السفلي فيكون متدرج مع تكوين سارمورد الاعلى (بيطوة). يختلف سمك التكوين بسبب التغييرات الجانبية وتأثير التعرية ويعد من التكاوين المنتجة في 19 حقلا، إلا ان التكوين يمتلك خواص مكمنية جيدة حيث يصل معدل المسامية الى (10-22)% والنفاذية تصل الى (10-15)% ملى دارسي. اظهرت الدراسة الحالية بأن معظم اجزاء التكوين قيد الدراسة تحتوي على محتوى للسجيل بمعدل اقل من 25% وتبين من خلال المجسات (الكثافة والنيترون) بان معدل المسامية الفعالة محددة مابين (4-15)% وبان معدل النفاذية مابين (0.66-13.8) ملي دارسي في بئر XA اما في بئر XB محتوى السجيل كان بمعدل اقل من 24% ومعدل المسامية الفعالة مابين (8-18) % ومعدل النفاذية مابين (1,6-18,8) ملي دارسي. تم تقسيم التكوين الى ستة وحدات مكمنية في بئر XA بالاعتماد على تباين حجم السجيل ومعدل المسامية والنفاذية وتعتبر الوحدة المكمنية (MUE, MUC) افضل وحدة مكمنية اما الوحدة MUF فتحتوي على صفات مكمنية رديئة في البئر نفسه. اما في بئر بلد XB تعتبر الوحدتين MUC & MUE من افضل الوحدات المكمنية اما الوحدتين MUF&MUB فهي تتصف بمواصفات مكمنية رديئة. تم حساب التشبع المائي والنفطي بجزئية القابل للحركة والمتبقي للنطاقين المكتسح وغير المكتسح وكذلك تم احتساب نوعية الخزان ونطاق الجريان ضمن التكوين بعد حساب الخواص المكنينة تم رسم موديل المكمني للتوزيع هذه خواص بأستخدام Petrel-14 software وكذلك تم حساب سمك العطاء الصافي.

1. Introduction:

The Formation of Mu is one of the most common Cretaceous periods in Iraq, the thickness of the Formation varies from one region to another and according to the lateral changes and the effect of erosion, the Formation has high reservoir properties, where the porosity rate reaches (10-22) % and permeability reaches (10-15) % mD [1]. It is one of the formations produced in 19 fields [2]. The Mu Formation in the Taq Taq oil field has a porosity rate between (5-16.6) % [3]. the Mu Formation in the X oil field was divided into two units, the upper unit was considered the best reservoir unit [4]. The study area is located to the southwest of the Baba Dome and southwest of the city of Kirkuk about 12 km and represents an asymmetrical subsurface fold whose axis extends in a Northwest-Southeast direction [5]. The field is located in the unstable platform zone in the Foothill zone according to the divisions of [2].

The Formation consists of limestone and dolomitic limestone, organodetrital and argillaceous [5]. The upper contact of the Formation is unconformable with the Dokan Formation and the lower contact is graded with the upper Sarmord formation [2]. The current study aims to study the petrophysical and reservoir properties and the variation in these properties within

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the section of formation vertically and laterally and their importance as a reservoir oil rocks, where the study area included two subsurface sections in the X Oil field within the Kirkuk area represented by two wells (XA&B) using the Techlog software.

2. Materials and Methods

The current study based on well logs (Gamma Ray, Bulk Density, Neutron porosity, Spontaneous potential, Sonic, Resistivity) where the Neruralog software was used to convert these logs into digital data and use it in the Techlog software. For the purpose of calculating porosity, hydrocarbon saturation, Movable (MOS) and Residual (ROS) saturation as well as calculating secondary porosity and net pay thickness, the three-dimensional model was drawn to clarification the distribution of reservoir properties using the program (Petrel 2014). The reports on the wells available at the North Oil Company have also been reviewed.

3.Theory and Calculation

3.1 Shale Volume

The shale content is calculated through the (GR) log, which is the best way to determine the size of the shale due to its sensitive response to radioactive materials that are concentrated in the shale rocks and the availability of this log for all wells in this study, and according to the equation [6] the shale size content was calculated and corrected. the sections that contain the shale size less than 10% are clean sections and between (10-35) % are considered Shaly zone while the sections that more than 35%, they are considered from the Shale Zone Figure (1) it is found that a few sections have a high shale content and that the most of the sections are confined between 10-35%, which is considered a Shaly zone, Table (1).

3.2 Determine porosity

The total porosity calculated from the neutron and density logs is one of the best ways to calculate the primary and secondary porosity, and the total porosity value can be calculated by taking the average values of the density and neutron logs for each depth and according to the equation [8]. Figure (2) shows the total (PHIT) and effective (PHIE) that are used in reservoir calculations where the pores of the shale are not connected, so we note that most of the sections of the formation have porosity values reaches to 0%, except some sections that are more than 30% and this porosity is acceptable in limestone, while the secondary porosity, which represents the porosity (fractures, vug), is calculated from the difference between (the porosity

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calculated of the effective porosity values (PHIE_ND) and the effective porosity values calculated of the sonic logs values (PHIE_S) It is shown in Figure (2) that the secondary porosity corrected from the shale content in most of the formation sections is close to the total porosity.

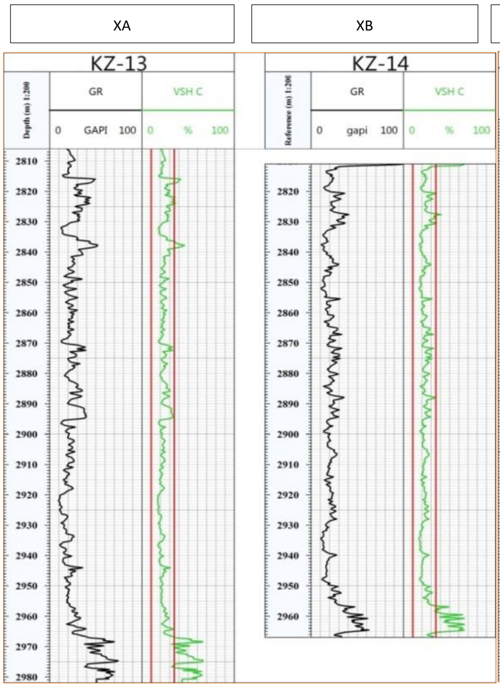

Fig. (1): Content shale in wells XA & XB of Mu formation

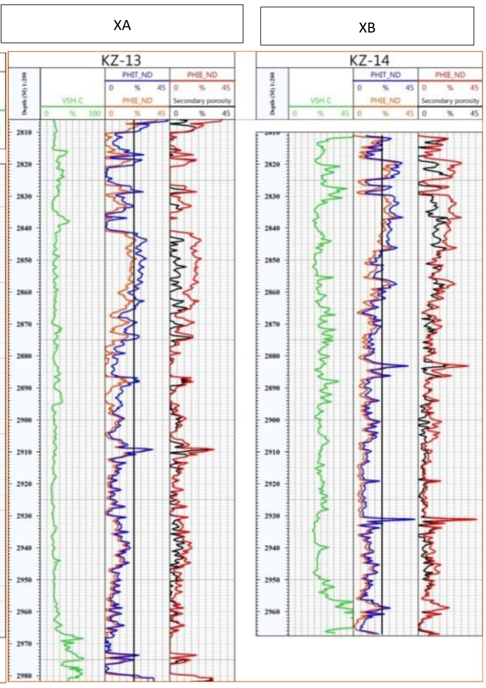

Fig. (2): Content shale (VSH), effect porosity (PHIE), total porosity (PHIT) and Secondary porosity in wells XA & XB of Mu formation

Table (1): Shale content zonation for Mu Formation

Formation	XA	Zonation	Thickness (m)	XB	Thickness (m)	Zonation
Mu Formation	2806-2816	Shaly zone	10	2811-2812	1	Shale zone
	2816-2818	Shale zone	2	2812-2827	15	Shaly zone
	2818-2837	Shaly zone	19	2827-2828	1	Shale zone
	2837-2839	Shale zone	2	2828-2956	128	Shaly zone
	2839-2967	Shaly zone	128	2957-2966	9	Shale zone
	2967-2982	Shale zone	15	2966-2967	1	Shaly zone

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3.3 Permeability

The permeability was calculated based by the values of the total porosity and corrected porosity logs using the Techlog software, which is based on the equation [7] to calculate the permeability. The permeability rate of the rock formation in the XA well reaches (3.9) mD either in the well XB It may reach (7.7) mD. Figure (4).

$K= 62.5 *(PHIE^{6}/^{SWi\ 2})$ 1

Where;

PHIE= effect porosity

SW i= Irreducible water saturation is considering (0.2) if is missing.

3.4 Reservoir temperature calculation

The temperature of the formation (TF) is an important factor in the analysis of logs because the Resistivity of drilling mud (Rm), Resistivity mud filtrate (RMF) and Resistivity of formation water (RW) changes with temperature change, and the reservoir temperature has been calculated using Techlog, which depends on the following equation:

FTEMP =TLT + (BLT-TLT) *(Depth-TLI)/(BLI-TLI) 2

Where; TLT: top log temperature in °C

BLI: bottom log interval in M

BLT: bottom log temperature in °C

gradFT: gradient formation temperature in °C/M

4. Results and Discussion

4.1 Reservoir Units

The calculation of petrophysical properties by finding the values of shale content, porosity and permeability enables us to distinguish between units with different properties of the Reservoir regardless of the type of fluid in the Reservoir, where six reservoir units of formation in the wells XA and XB were distinguished depending on the variation in the values of the three properties above, Table (2) As an initial evaluation, it seems that the unit (MUC, MUE) in the two wells has high reservoir properties, and this is due to the shale content is low, the porosity is relatively high and the permeability is good, while the other units have lower reservoir

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properties due to low porosity and permeability, and through comparison between the two wells, it was found that the well (XB) is characterized by higher petrophysical properties than (XA).

4.2 Water Saturation

Water saturation (SW) as the percentage of the volume of water-filled voids to the total volume of rock voids [9]. Rocks containing hydrocarbons have higher Resistivity values than rocks filled with formation water and the increase of this water in the formations rocks gives lower values of Resistivity [10]. The water saturation was calculated according to the equation [11]. For the wells of the study area in the Invaded and uninvaded zones using logs (deep Resistivity, effective porosity and water Resistivity) water saturation is important in the interpretation of logs as the hydrocarbon saturation (SH) of the reservoir can be calculate by subtracting the water saturation value from the value one according to the following equation. Figure (5)

SH=1-SW.................................... 3

4.3 Calculate the total volume and movable of hydrocarbons

The total volume of water in the Invaded zone (BVxo) and uninvaded zone (BVw) with drilling mud filtrate was calculated by the equations:

BVw = Sw*PHIE_ND 4

BVxo = Sxo*PHIE_ND 5

Where: Sxo = water saturation in invaded zone

The total volume of hydrocarbons (BVO) of the Mu formation sequences, representing the Movable (MOS) and Residual (ROS) saturations, that which calculated from the following equations.

BVO = SH*PHIE_ND 6

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Table (2) average Reservoir properties of Mu formation Units in wells XA&XB

Units	The properties	XA	XB
MUA	Intervals(m)	2806-2816	**2811-2820**
	Thickness(m)	10	**9**
	Porosity	0.10	**0.13**
	Permeability	13.81	**11.5**
	V shale	0.23	**0.26**
	Hydrocarbon Saturation	0.36	**0.86**
	Water Saturation	0.64	**0.14**
MUB	Intervals(m)	2816-2841	**2820-2831**
	Thickness(m)	25	**11**
	Porosity	0.05	**0.16**
	Permeability	0.98	**18.88**
	V shale	0.25	**0.28**
	Hydrocarbon Saturation	0.24	**0.92**
	Water Saturation	0.76	**0.08**
MUC	Intervals(m)	2841-2870	**2831-2864**
	Thickness(m)	29	**33**
	Porosity	0.15	**0.18**
	Permeability	7.62	**16.84**
	V shale	0.23	**0.21**
	Hydrocarbon Saturation	0.63	**0.95**
	Water Saturation	0.37	**0.05**
MUD	Intervals(m)	2870-2897	**2864-2895**
	Thickness(m)	27	**31**
	Porosity	0.04	**0.10**
	Permeability	0.66	**4.74**
	V shale	0.25	**0.25**
	Hydrocarbon Saturation	0.12	**0.91**
	Water Saturation	0.88	**0.09**
MUE	Intervals(m)	2897-2946	**2895-2949**
	Thickness(m)	49	**54**
	Porosity	0.08	**0.08**
	Permeability	2.19	**3.06**
	V shale	0.21	**0.22**
	Hydrocarbon Saturation	0.63	**0.88**
	Water Saturation	0.37	**0.12**
MUF	Intervals(m)	2946-2982	**2949-2967**
	Thickness(m)	36	**18**
	Porosity	0.05	**0.08**
	Permeability	3.38	**1.61**
	V shale	0.34	**0.38**
	Hydrocarbon Saturation	0.12	**0.84**
	Water Saturation	0.88	**0.16**

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And calculate the Movable oil saturation according to the following equation:

MOS =Sxo-SW 7

Through the equation [10] the Residual oil saturation was calculated.

ROS= 1-Sxo 8

It is seen from Figure (3) the distribution of saturation ratio (Water, Movable and Residual) within the porosity of the formation that the movable saturation extends along the section of the formation and is the highest percentage in the unit (MUE) and then the unit (MUC). Residual oil saturation is concentrated in unit (MUC) and then (MUD, MUE) the presence of Residual oil in sections with high porosity indicates the presence of separate porosity (isolated).

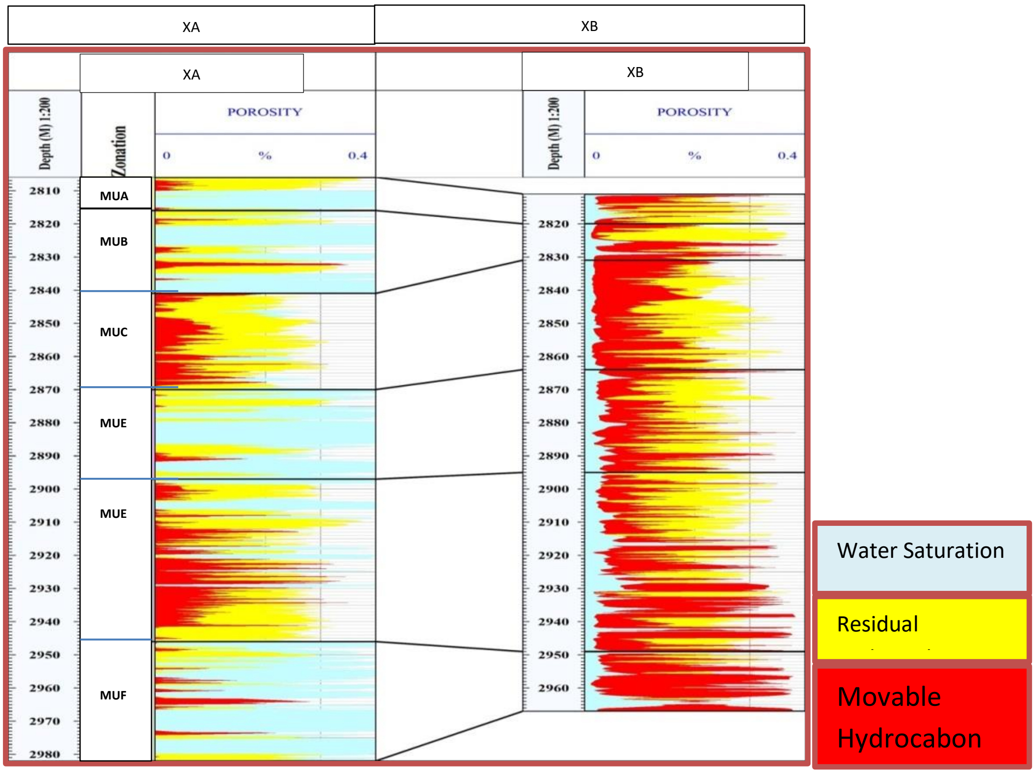

Fig. (3): Water Saturation, Movable Hydrocarbon and Residual Hydrocarbon in wells (XA&XB) of Mu Formation

4.4 Movable Hydrocarbon Index (MHI)

The hydrocarbon movement index is used as a fast method to estimate hydrocarbon movement when the water saturation in the invaded zone (SXO) is greater than the water saturation in the uninvaded zone and hydrocarbons are probably to drive from the invaded zone. According to

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[12] If the SW/SXO ratio (MHI) is one or greater there is no movement of hydrocarbons regardless of whether the zone contains hydrocarbons or not, and if the MHI ratio is less than (0.7) for sandstone and less than (0.6) for limestone, this is an indicator of the presence of hydrocarbon movement. A reservoir with an MHI of less than 0.6 indicates the presence of hydrocarbons with sufficient permeability of movement during the invasion process by drilling fluid. [13]. A curve (MHI) was drawn for the Formation Figure (4) and the dividing line (0.6) as a limit of separation between the movable and non-movable hydrocarbons It is noted in the well XA that most parts of the Formation contain movable hydrocarbons, especially in (MUE). (MUC) where the corrected porosity and permeability increase, but in another area there are narrow horizons for the movement of hydrocarbons in which the corrected porosity and the permeability of the Formation are relatively low, while in XB we note the majority of the Formation contains values (MHI) less than (0.6) The two units (MUE and MUC) are considered one of the best reservoir units in terms of hydrocarbon movement, in which the porosity and permeability of the Formation increases, as for the rest of the units it is noted a narrow horizons for hydrocarbon movement, in which the ratio of porosity and permeability of formation decreases.

4.5 Net Thickness Determination to Net/Cross College

Total thickness (Gross**):** It is the entire thickness of the reservoir unit storing hydrocarbons, and not necessarily all the total thickness is a productive reservoir, therefore the total thickness (cross) is distinguished from the net thickness (Net). Net thickness (Net): It is the sum thicknesses of the oil storage zones within the reservoir unit.

In this study through the program (Techlog) the total thickness and Net/Gross were calculated for the Mu formation in both wells. Tables (3) and (4).

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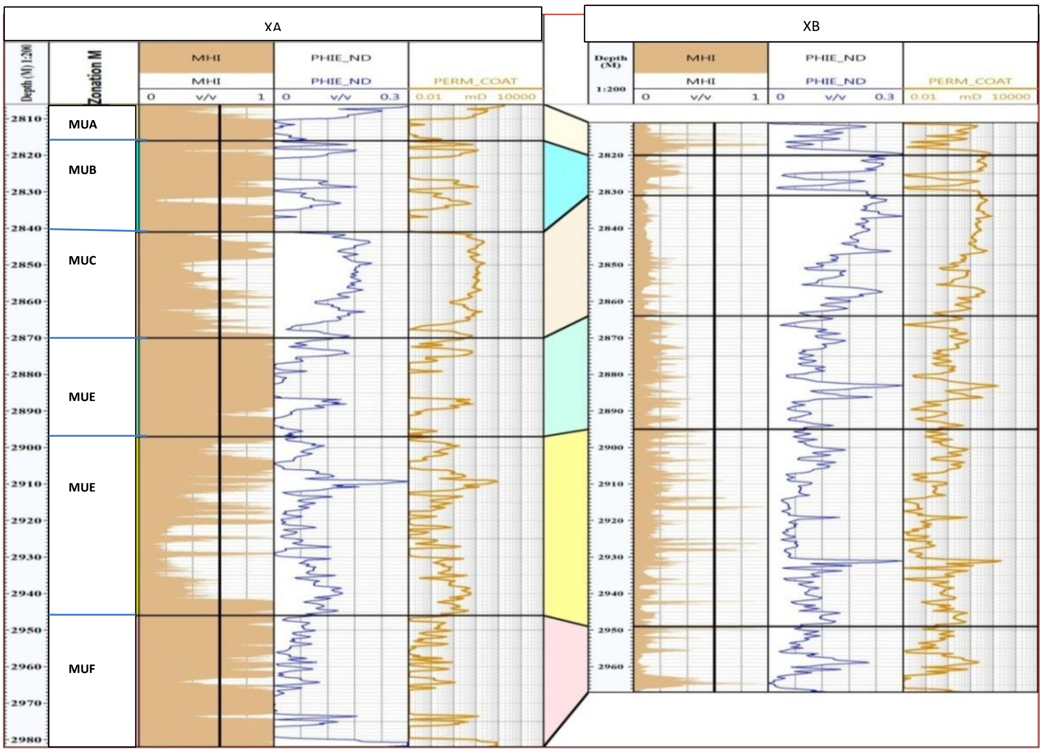

Fig. (4): Movable Hydrocarbon Index, Effect porosity and Permeability in wells XA&XB of Mu Formation.

Table (3) Gross, Net pay, Net to Gross and average of (porosity, content shale, water saturation) within Net pay to Mu Formation in well XA

Zones	Flag Name	Top	Bottom	Gross	Net pay	Net to Gross	Av_Shale Volume	Av_Porosity	Av_Water Saturation
MUA	PAY	2806	2816	10	4.265	0.427	0.24	0.205	0.157
MUB	PAY	2816	2841	25	9.608	0.384	0.257	0.108	0.338
MUC	PAY	2841	2870	29	28.799	0.993	0.228	0.152	0.317
MUD	PAY	2870	2897	27	8.077	0.299	0.246	0.092	0.576
MUE	PAY	2897	2946	49	41.301	0.843	0.208	0.087	0.233
MUF	PAY	2946	2982	36	8.534	0.237	0.259	0.082	0.59

Table (4) Gross, Net pay, Net to Gross and average of (porosity, content shale, water saturation) within Net pay to Mu Formation in well XB

Zones	Flag Name	Top	Bottom	Gross	Net pay	Net to Gross	Av_Shale Volume	Av_Porosity	Av_Water Saturation
MUA	PAY	2811	2820	9	8.324	0.925	0.23	0.14	0.071
MUB	PAY	2820	2831	11	11	1	0.285	0.17	0.052
MUC	PAY	2831	2864	33	33	1	0.211	0.182	0.044
MUD	PAY	2864	2895	31	31	1	0.248	0.106	0.074
MUE	PAY	2895	2949	54	53.543	0.992	0.215	0.084	0.09
MUF	PAY	2949	2967	18	14.038	0.78	0.32	0.084	0.089

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4.6 Interpretation of reservoir logs

It is noted from the figures (6) that the curves of (corrected shale content (vsh c), total porosity (PHIT) and corrected (PHIE), water saturation (SW_AR) with movable oil saturation (MOS). The area between (SW_AR) and (MOS) represents by Residual Oil Saturation (ROS), Water saturation in the invaded zone (SXO), Water volume in the area invaded with mud filtrate (BVWXO), the total volume of water (BVW) and finally the total volume of oil (BVO), where we note that the percentage of shale volume in the reservoir is less than 35%, except in some sections, and it is clear from the figure wherever it increase the percentage of shale decreases effective porosity and therefore the percentage of movable oil saturation decreases, and it is also clear from the figure as the water saturation increases In the invaded zone, the movable oil saturation decreases, and it appears from the two figures that the water saturation is high at the well XA compared to the well XB, Figure (5).

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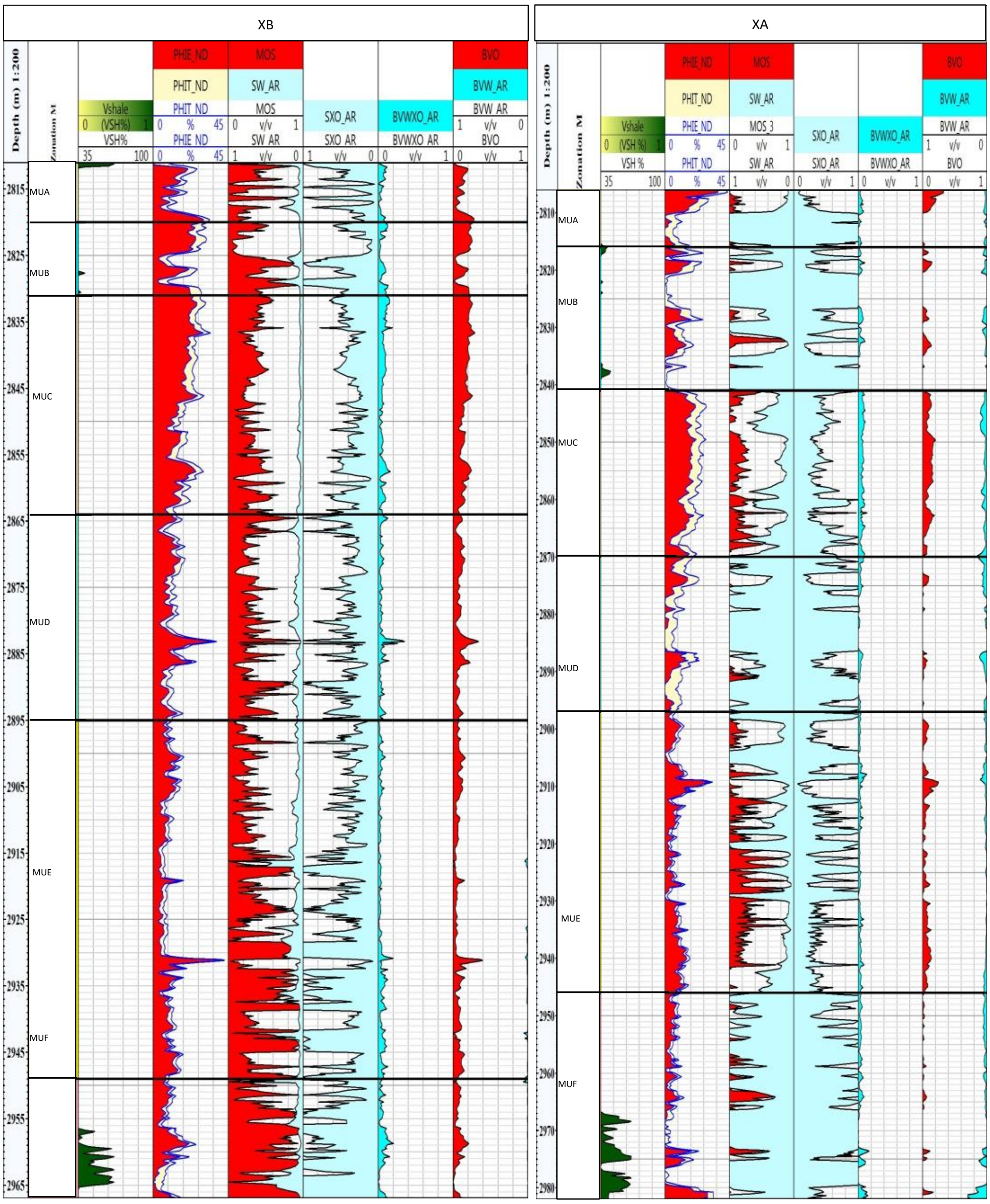

Fig. (5): Shale content, total porosity, correct porosity, movable oil saturation, water saturation, water saturation in invaded zone , bulk water volume in invaded, bulk oil volume, and bulk water volume of Mu formation in well XA&XB

4.7 Modeling of the Formation

The reservoir study requires the identification and knowledge of the petrophysical properties and their relationship to rock facies because of their importance in determining the reservoir location, movement and production of hydrocarbon fluids [14]. The reservoir model is predicted on the

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basis of the diagnosis of petrophysical units of rocks such as porosity, permeability and hydrocarbon saturation. The Formation of the Mu in the current study based on its petrophysical properties was divided into six reservoir units. The most important steps for the work of the reservoir model, the program (Petrel 2014) was used to prepare a three-dimensional reservoir model. A -used different mathematical methods in the process of distribution of reservoir properties and the purpose of which was to obtain one appropriate value for each petrophysical property in one cell for each unit reservoir, note that the dimensions of the cell are (200 * 200). B- Petrophysical distribution The petrophysical properties of the zone in the wells were distributed using sequential Gaussian simulation algorithm to find the values of these properties between the distances in the wells taking into consideration the upper contact of the reservoir units. Using the program (Petrel 2014) a three-dimensional reservoir model was drawn to distribute the hydrocarbon saturation within the reservoir units of X field as in Figures (6, 7).

4.8 Model Discussion

We notice that the thickness in Reservoir Unit (MUA) at XB was (10) meters and in XA it was (11) meters. This unit has an effective porosity of up to (13)% and a hydrocarbon saturation rate in this unit (86) % in XB and in XA had effective porosity rate (10)% and hydrocarbon saturation rate (36)%, While Reservoir Unit (MUB) The thickness of this unit at XB (11) meters and its thickness at XA was (25) meters and this unit is characterized by an effective porosity of up to (14) % and a hydrocarbon saturation rate of (92)% at the well XB either at XA up to (5)% and hydrocarbon saturation rate up to (24%), however Reservoir Unit (MUC): The thickness of this unit reach to (23) meters in XB and at XA with a thickness of (29) meters and is characterized by a porosity rate of up to (18) % at the well XB and a hydrocarbon saturation rate of up to (95%) either in the well XA The effective porosity rate reaches (15) % and the hydrocarbon saturation rate reaches (63)% and this unit is considered one of the best reservoir units, whilst Reservoir Unit (MUD) The thickness of this unit reaches at the well XB to (31) meters, while at the well XA thickness (27) meters This unit is characterized by an effective porosity rate of up to (10) % and the hydrocarbon saturation rate was (91)% either in the well XA The effective porosity rate reached (4)% and the hydrocarbon saturation rate was (12%), however Reservoir Unit (MUE) The thickness of this unit reach to (54) meters at the well XB, while in the well XA it was (49) meters thickness and this unit is characterized by an effective porosity rate of (8) % in the two wells and a hydrocarbon saturation rate of up to (88)% at the well XB In the well XA was %(63), finally Reservoir Unit (MUF) The thickness of this unit

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reach to (18) meters at the well XB, while in the well XA was (36) meters thickness and this unit is characterized by an effective porosity rate (8) % and a hydrocarbon saturation rate was (84)% either at XA The effective porosity rate reached (5)% and the hydrocarbon saturation rate was (12)%.

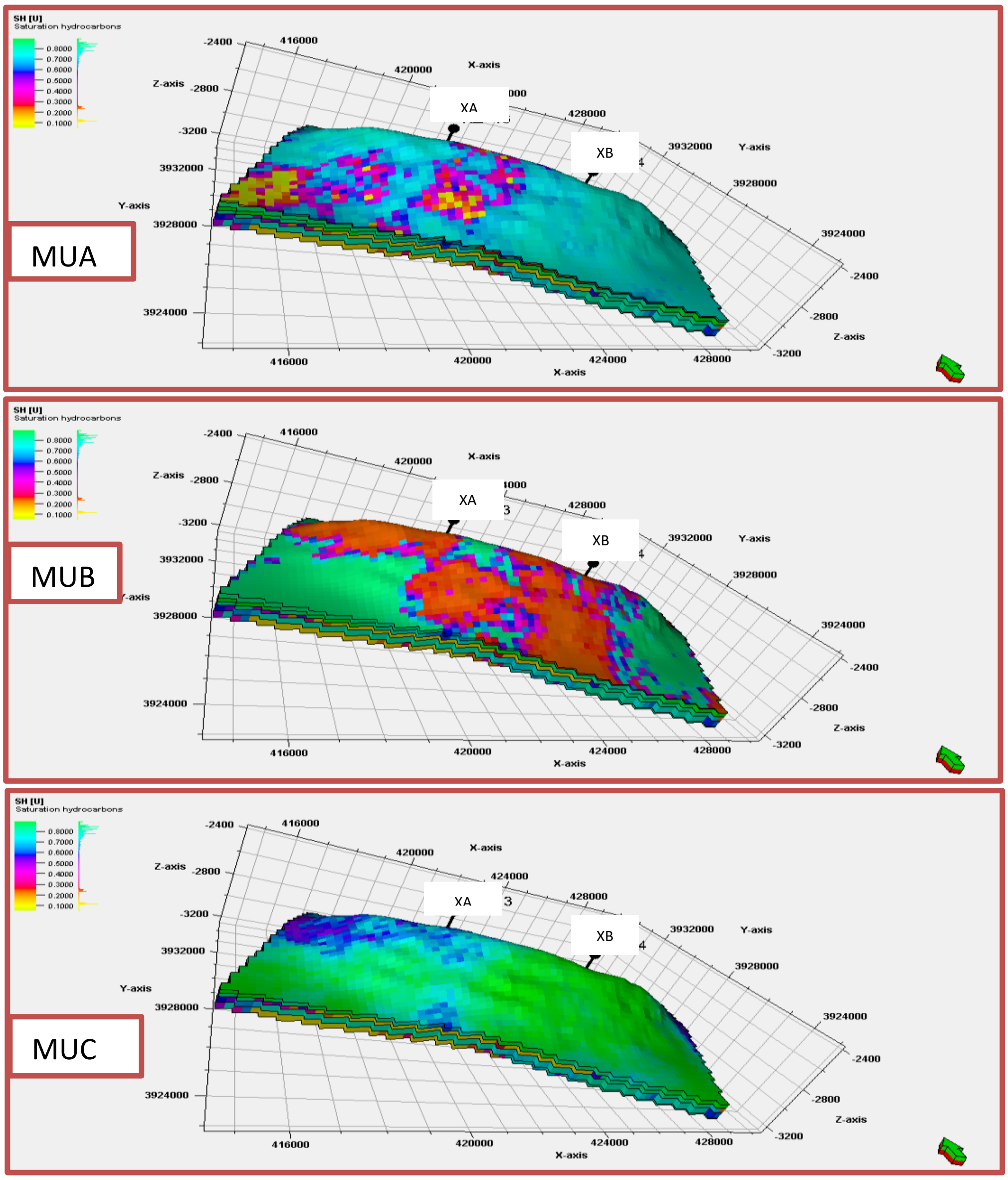

Fig. (6): Distribution of Hydrocarbon Saturation within Mu formation units in X field.

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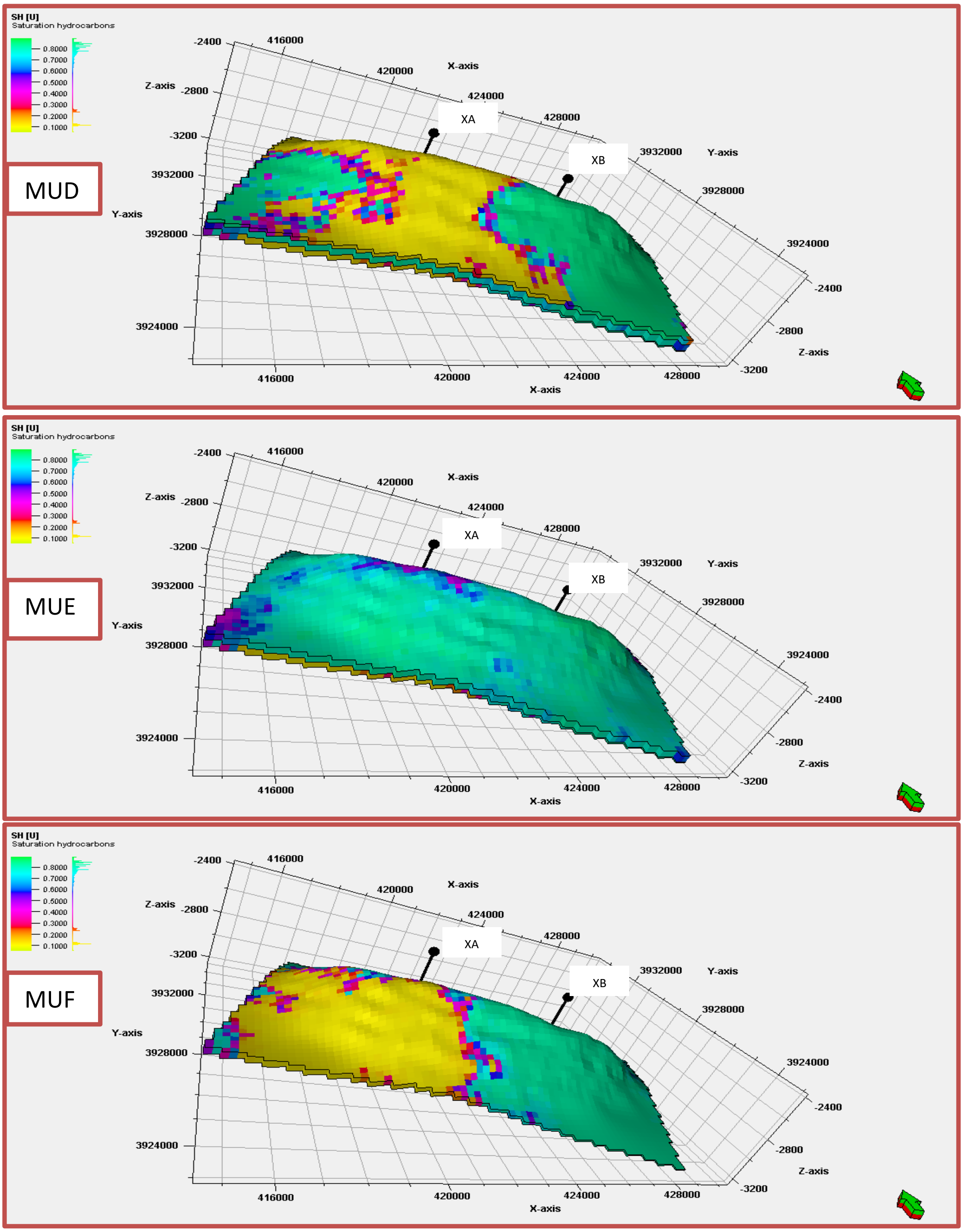

Fig. (7): Distribution of Hydrocarbon Saturation within Mu formation units in X field.

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5. Conclusions

- Based on the petrophysical properties analysis and logs, the Formation generally contains shale by less than (35) %, except for some narrow zones in the upper and lower part.
- The rate of porosity corrected for the Formation depending on the porosity logs (density and neutron) ranges between (4-18) %.
- The rate of formation permeability depending on the corrected porosity values and the total porosity ranges between. (3.9-7.7) mD.
- The Formation was divided into six reservoir units based on petrophysical properties and it was found that the two units (MUC and MUE) are the best reservoir units.
- We observe the movable oil saturation along the reservoir in XB, except for some narrow zone where the Residual oil saturation is concentrated, while in XA, the movable oil saturation is concentrated in the two units (MUC and MUE) and in the rest of the units it is relatively few.
- The movable hydrocarbon index shows that the majority of the formation sections are within a movable zone in the well XB except for some narrow zone, while in the well XA the movable hydrocarbon index is concentrated in two units (MUC, MUE) and the rest of the units there is a narrow zone of hydrocarbon movement.
- Through the three-dimensional model of hydrocarbon saturation distribution, we observe an increase in hydrocarbon saturation with the well XB.

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