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Effect of the Deep Marin Balambo Formation on the Qamchuqa Reservoirs in Jambur Field

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Abstract

A shallow-marine carbonate known as Qamchuqa Formation was originally discovered in northern Iraq's Qamchuqa Gorge at an outcrop section. For the present study the available conventional well logs include gamma ray, porosity logs (density, and neutron) with the resistivity logs used to achieve the depositional environment of the studied area in selected wells Ja-21, Ja-32, Ja-41, Ja-46, and Ja-18. The Aptian-Albian age include lower and upper Qamchuqa formations, respectively are considered a major reservoir in Jambur Oil field; therefore, the present study focused only on lower and upper Qamchuqa formations. Deep marine environment Balambo Formation separated the Aptian-Albian reservoir into three parts each part is different in petrophysical properties and lithology composition. Zone -1 is shoal facies including lower and upper Qamchuqa formations composed of dolomite, dolomitic limestone and limestone, this part is far from interfingers with Balambo Formation. Zone -2 is mixed facies between shoal facies and basinal facies composed of limestone, marly limestone,shaly limestone and with a few streaks of dolomitic limestone. This part includes well Ja-32, Ja-41, and Ja-46. Zone -3 basinal facies include Balambo Formation composed of limestone, shaly and marly limestone involving well Ja-18 only. These differences above caused interfingering and lateral change in both reservoir units (lower and upper Qamchuqa formations) with Balambo Formation, and both are not depicting reservoir in Zone -2 and especially in Zone -3. The current study explains well Ja-18 located on the permanent basin and well Ja-32, Ja-41, and Ja-46 located between permanent basin and neritic zone (mixed zone or slope margin); therefore, the south east of Jambur Oil field abandoned to drill in it to Cretaceous age.

Keywords: Qamchuqa Formation, Balambo Formation, Jambur Oil field, Interfingers, Reservoirs.

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تاثير البيئة البحرية العميقة لتكوين بلامبو على الصفات المكمنية لتكوين قمجوقة في حقل جمبور

الخلاصة:

ان تكوين قمجوقة عبارة عن كاربونات بحرية ضحلة اكتشف لأول مرة في منطقة شمال العراق في وادي قمجوقة، وفي هذه الدراسة استخدمت مجسات الابار (كاما، ومجسات المسامية (الكثافة والنيوترون) مع مجسات المقاومة المستخدمة لتحقيق البيئة الترسيبية لمنطقة الدراسة في الآبار المختارة في حقل جمبور- 18 و 32 و 41 و 46 و 21)، والذي يشمل عمري الالبيان-ابتيان لتكوينين قمجوقة العليا والسفلى على التوالي ويعتبر المكمن الرئيسي في حقل جمبور النفطي لذلك ركزت الدراسة الحالية على تكوينات قمجوقة العليا والسفلى، ان البيئة البحرية العميقة لتكوين بلامبو فصل مكمن الالبيان –ابتيان الى ثلاثة أجزاء كل جزء يختلف في الخصائص البتروفيزيائية والمكونات الصخرية، المنطقة الأولى عبارة عن سحنات ضحلة مكونة من الدولومايت والحجر الجيري الدولومايتي وهذا الجزء بعيد كل البعد عن تداخل تكوين بلامبو، المنطقة الثانية مكونة من سحنات مختلطة مابين السحنات الضحلة والعميقة ومكونة من الحجر الجيري المارلي مع بعض الطبقات الرقيقة من الحجر الجيري الدولومايتي وهذا الجزء يشمل الابار جمبور-32 و41 و46، اما المنطقة الثالثة مكونة من سحنات بيئة عميقة لتكوين بلامبو متمثلة بالحجر الجيري المارلي والسجيل و يشمل البئر جمبور- 18، اما بالنسبة للتغيرات الجانبية للتوزيع السحني على طول الحقل فقد اثرت على المواصفات المكمنية خاصة في منطقة البئر جمبور- 18 الواقع في منطقة الحوض الدائم، اما الابار جمبور- 32 و41 و 46 تقع في المنطقة الانتقالية من الحوض الدائم الى البيئة النيرتية (بيئة المنحدر) وبهذا يكون الجزء الجنوب الشرقي لحقل جمبور لايحفر فيها ابار طباشرية وذلك لسوء المواصفات المكمنية في هذا الجزء.

1. Introduction:

Jambur Oil field is one of the multiple reservoirs productive fields from both Tertiary and Cretaceous ages in North Oil Company since the last century. The Cretaceous reservoirs in Jambur Oil field consist mainly of carbonate rocks include lower and upper Qamchuqa formations (Aptian-Albian) age, and they are one of the important oil reservoirs in northern Iraq particularly in Jambur Oil field. Lower and upper Qamchuqa formations are good reservoirs separated by upper Sarmord Formation which is a non-reservoir formation between them. The present study attempts to explain lateral lithological changes affected on reservoir properties, both formations are present in all drilled wells in Aptian-Albian age except in well Ja-18 because it entirely laterally changed in to Balambo Formation (Hauterivian-Albian) age. The Balambo Formation affected petrophysical properties of lower and upper Qamchuqa formations of the southeast of the field. That is why the SE of the field does not have any luck to drill a well in it, but in the Tertiary reservoir a well can be drilled in it because Balambo Formation has not affected the Tertiary reservoir.

2. Geological Background

An investigated Jambur Oil field is located about 40km southeast of Kirkuk Governorate, northeastern Iraq (Figure 1). Qamchuqa Formation is a shallow water carbonate with widespread distribution as an outcrop in northern and northeastern Iraq in the High Folded Zone and in the subsurface of the Foothill Zone towards southern Iraq, extending to the Arabian Gulf [1]. The

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Jambur structure includes asymmetrical anticline with axis extending in southeast-northwest direction. It is considered to be one of the giant structures within Kirkuk oil fields, which situated to the southeast of Khabaz and Bai-Hassan oil fields. The Qamchuqa Formation is considered one of the major reservoirs all over Zagros foreland basin. This formation in the present study represented by Upper and Lower Qamchuqa formations that interfingered with Balambo Formation deposited during the Early Aptian–Late Albian. Upper Qamchuqa represents the equivalent to the Mauddod Formation and Lower Qamchuqa represents the equivalent to Shuaiba Formation [2].

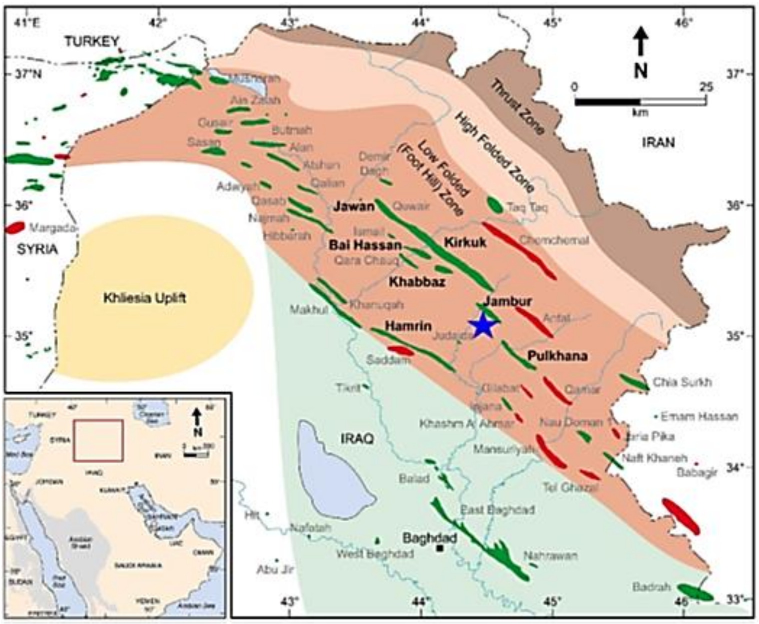

Fig. (1): Map of northern Iraq showing the location of Jambur Oil field [3].

3. <u>Data and Methodology</u>

The fullest well data include gamma ray, porosity (density and neutron), and resistivity logs which are the main data used to estimate upper and lower Qamchuqa formations in five selected wells (Ja-21, Ja-32, Ja-41, Ja-46, and Ja-18), whereas for the well Ja-50 the mentioned well log data is absent, while Ja-18 only gamma ray log is present. The used software is Techlog for interpretation and correlation, while Strata and Surfer Golden software for correlation, digitizing and drawing maps, respectively. On the other side, the Microsoft excel was used for drawing geological column.

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4. Results and Discussion:

In this study, lithological description, shale volume, porosity, and water saturation were calculated for each well based on the available wireline well log data. then correlated between studied wells.

4.1 Cretaceous geological column and lithological description in Jambur Oil field

Description for each formation within the current study is based on the studies of North Oil Company (Figure 2). Balambo Formation interfingers with Lower Cretaceous; therefore, described and connected with generalized description of Jambur Oil field because appeared in southeast of it only.

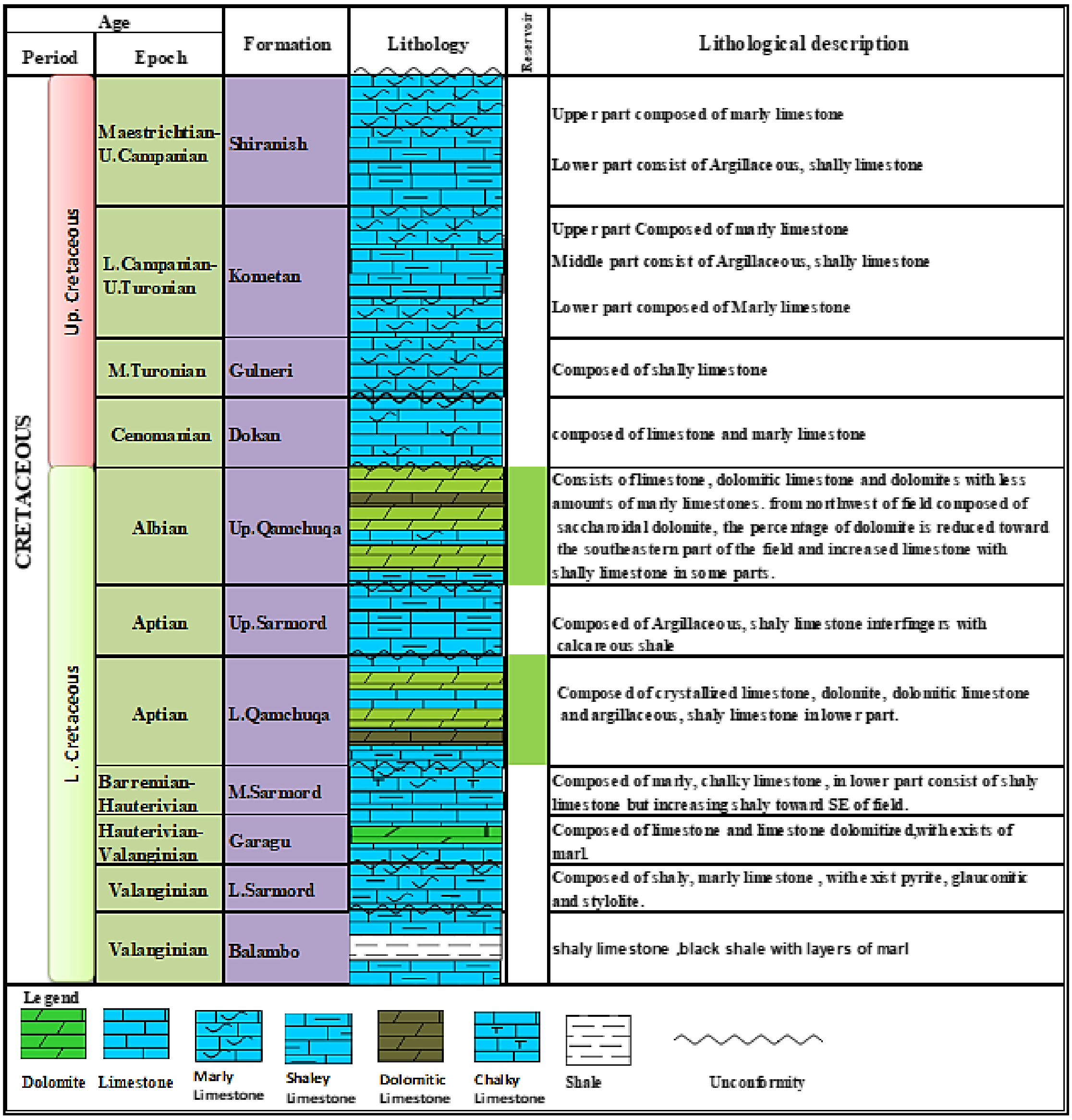

Fig. (2): Geological column and subsurface lithological description.

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4.2 Stratigraphic correlation

This study explains subsurface stratigraphic correlation from Valanginian- Maastrichtian age in Jambur Oil field. This correlation applied to show and indicate interfinger and total lateral change between formations. The upper Cretaceous Period includes Shiranish, Kometan, Gulneri, and Dokan formations. The Shiranish, upper and middle Kometan formations are not interfingering with Balambo Formation (Figure 3), while the lower Kometan and Gulneri formations are interfingering with Balambo Formation in well Ja-18. The Dokan Formation interfingers with Balambo Formation in well Ja-18 and Ja-32. All formations mentioned above in Late Cretaceous Period in Jambur Oil field are not reservoir. The Early Cretaceous Period involves Qamchuqa Formation, upper Sarmord Formation, lower Qamchuqa Formation, Middle Sarmord Formation, Garagu Formation, and lower Sarmord Formation. In well Ja-32, Ja-41, and Ja-46, all formations mentioned above in Early Cretaceous are interfingering with Balambo Formation, but in well Ja-18, all formations from upper Qamchuqa to middle Sarmord wholly are replaced by Balambo Formation [4], Except the Garagu and lower Sarmord formations were not drilled in well Ja-18. In well Miran-1 (ME-1), the Balambo Formation interfingers with Qamchuqa Formation [5]. This scenario also repeats in well Ja-32, Ja-41, and Ja-46. For knowledge, the distance between Jambur Oil field and Miran Oil field is approximately 100 km.

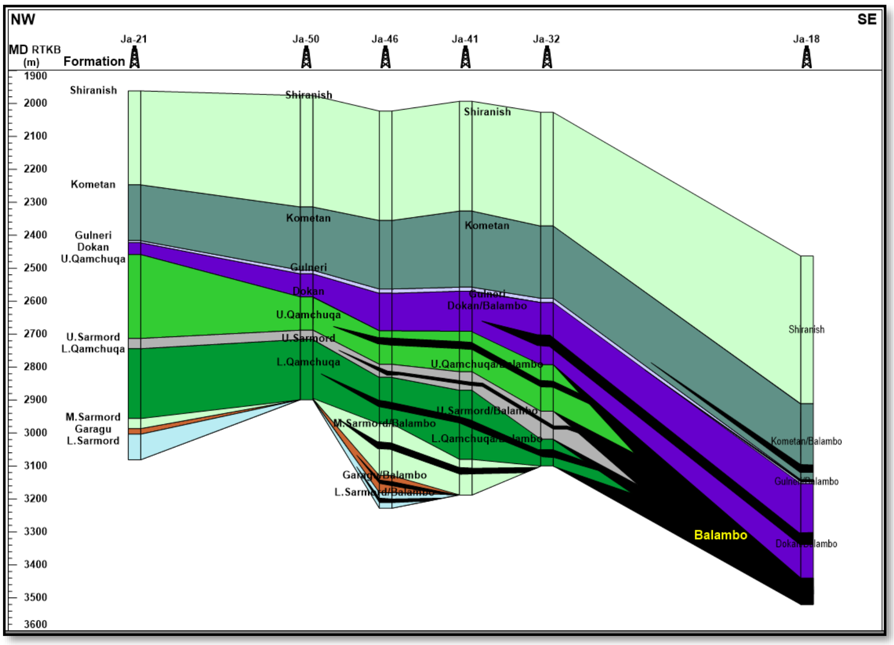

Fig. (3): Stratigraphic correlation of the studied wells.

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4.3 Shale volume

The presence of shale in the formation has severe effects on petrophysical properties and reduces effective total porosity and permeability of the reservoir [6; 7]. Moreover, existence of shale causes uncertainties in formation evaluation and proper estimation of oil and gas reserves [8]. Shale volume can be calculated from various logs. A common method for determined the ratio of shale existence in reservoir rocks used gamma ray log considered to be a good shale indicator [9]. Techlog 15.3 was used for determining the Cretaceous older rock represented upper and lower Qamchuqa Formation by using the equation below.

$Vsh= 0.33\times(2^2\times Igr-1)$ for older rocks.

Shale volumes for lower and upper Qamchuqa formations have been calculated in the studied wells (Ja-18, Ja-32, Ja-41, Ja-46, and Ja-21). Noticeably, the value of shale volume is different in both formations, lower and upper Qamchuqa formations (Figure 4). These differential values of shale volume depend on the intensity interfingers of both reservoirs (shoal facies with basinal facies) which are Qamchuqa and Balambo formations in well Ja-46, Ja-41, and Ja-32.

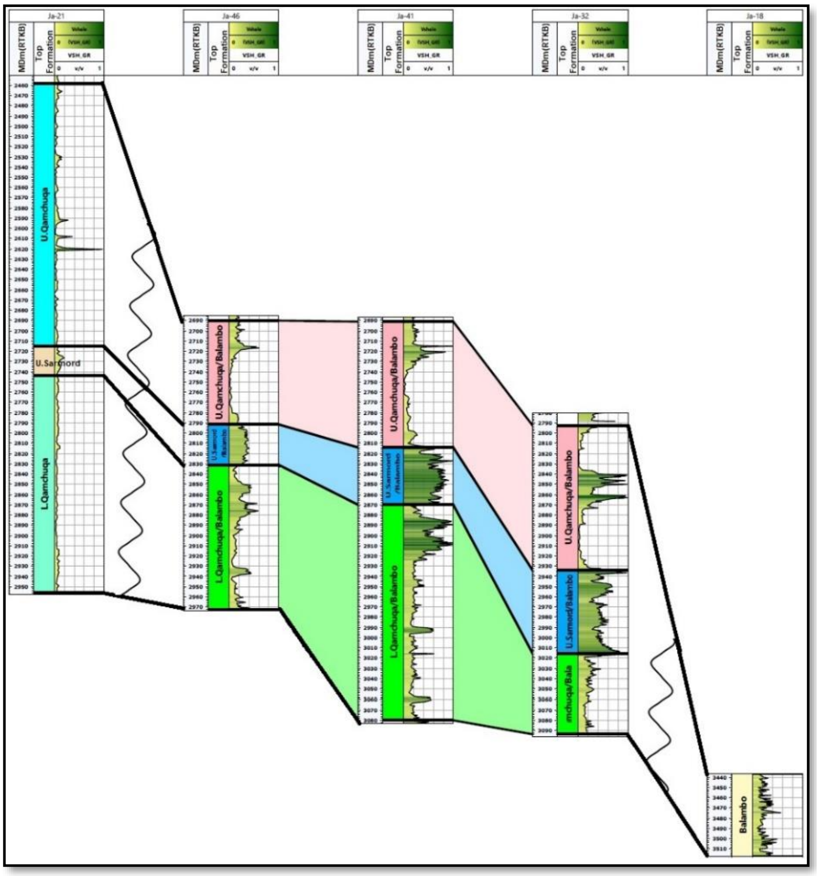

Fig. (4): Curve plots of the calculated shale volume of the studied wells.

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4.4 Porosity Calculation and Shale Impact Removing

Porosity is the ratio of the bulk volume occupied by space volume, and is represented as a fraction or as a percentage [10]. To determine porosity by three major porosity tools (sonic, density, and neutron logs). Primary porosity is an amount of pore space present in the sediment formed during depositional of sediments, while secondary porosity is formed during diagenesis at any time after deposition, which results from dissolution, recrystallization, and fracturing [11]. Whereas the total porosity included primary and secondary porosity while effective porosity is the interconnected pore volume available to free fluids (hydrocarbon or water) within it [12].

4.4.1 Density Porosity

Density tools are the most important logs to give accurate porosity [13]. The porosity can be calculated from the density tools by (Eq. 1)

$\phi D = D_{matrix} - D_{log} / D_{matrix} - D_{fluid}$ .... (Eq.1)

ϕD = Density porosity

D_{matrix} = for limestone 2.71, dolomite 2.87, sandstone 2.66, and anhydrite 2.98

D_{log} = from log reading.

D_{fluid} = 1 for fresh water and 1.01 for saline water.

4.4.2 Neutron Porosity

Neutron tool is measuring liquids (HI) present in space of rock, porosity from neutron log can be calculated directly from log reading. The porosity is affected by the presence of shale volume in the formation. The presence of shale in the formation will record high values of the porosity in formation; therefore, correction of shale impact is required, and the correction to the neutron and density log is needed [9]. The below equations 2 and 3 are used for correcting the porosity logs (Density and Neutron):

$\phi Dc = \phi D - V_{sh} \times \phi D_{sh}$ ………. (Eq. 2)

ϕDc = corrected Density porosity from shale

ϕD = Density porosity

ϕD_{sh} = Density porosity of adjacent shale

V_{sh} = Volume of shale

$\phi Nc = \phi N - V_{sh} \times \phi N_{sh}$ ………. (Eq. 3)

ϕNc = Corrected Neutron porosity from shale

ϕN = Neutron porosity

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ϕN_{sh} = Neutron porosity of adjacent shale

V_{sh} = Volume of shale

4.4.3 Combination of Neutron and Density log

The neutron - density corrected porosity (effective porosity) values are used to determine the total porosity by using (Eq. 4).

PHIE_ND= (ϕDc + ϕNc) / 2 ………. (Eq.4)

PHIE_ND = Neutron-Density porosity corrected (effective porosity)

ϕNc = Neutron porosity corrected

ϕDc = Density porosity corrected

It is noticed on (Figure 5), Lower Qamchuqa/Balambo formations in well Ja-32 only present total porosity without effective porosity, but Upper Qamchuqa/Balambo formations in same well showed existing effective porosity. In well Ja-41and Ja-46 showed presence of effective porosity in Lower Qamchuqa/Balambo and Upper Qamchuqa/Balambo formations. Both formations, Lower and Upper Qamchuqa/Balambo, in well Ja-41and Ja-46 and Lower Qamchuqa/Balambo in well Ja-32 showed bad petrophysics properties by interfingering with Balambo and U. Sarmord Formation. In Ja-21, both formations had a good effective porosity because this well is faraway interfingering with Balambo Formation.

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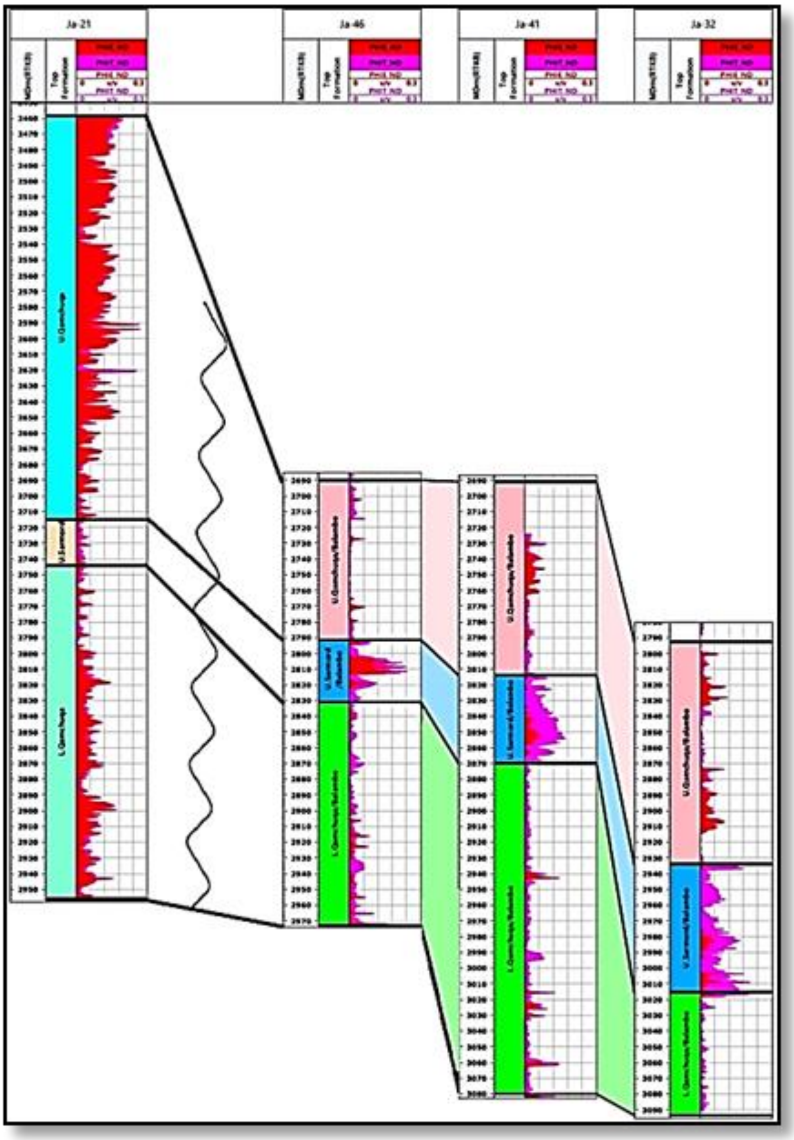

Fig. (5): Total porosity(PHIT_ND) and Effective porosity(PHIE_ND) from shale content for studied well.

4.5 Water saturation (Sw) and Hydrocarbon Estimation

The calculation hydrocarbon and water saturation are one of the basic objectives of well logging to the evaluation of the reservoir rock [14]. Water saturation is a fraction of pore volume that filled the reservoir with water formation [15]. To determine the water and hydrocarbon saturations below Arche equations Eq. 5 and Eq. 6 are used by applying Techlog 15.3 software.

$S_w = [(R_w \times A)/ (PHIE\_ND^m \times R_t)]^{½}$ ………. (Eq. 5)

S_w = Water saturation

R_w = Resistivity water

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a=constant

m=cementation factor

R_t=Deep resistivity

$Sh = 1-S_w$ ………. (Eq. 6)

Sh=Hydrocarbon saturation

In well Ja-41 and Ja-46, both reservoirs showed a bad hydrocarbon accumulation (Figure 6), but in well Ja-32 only in Upper Qamchuqa a few hydrocarbons accumulation appeared. In well Ja-21, Lower Qamchuqa and Upper Qamchuqa formations are a good reservoir productive oil because it is far away from interfingers with the Balambo Formation. The existence of fluids in the Qamchuqa reservoir (Lower and Upper) depends on the presence of fractures and pores in all parts of the field because the southwestern flank of the field is affected by a group of reverse faults (three faults) (Figure 7) and its effect is clearly visible in well Ja-32 affected by the F3 fault and well Ja-41 affected by the F4 fault. Either the F5 fault was determined based on or by the results of seismic surveys [4].

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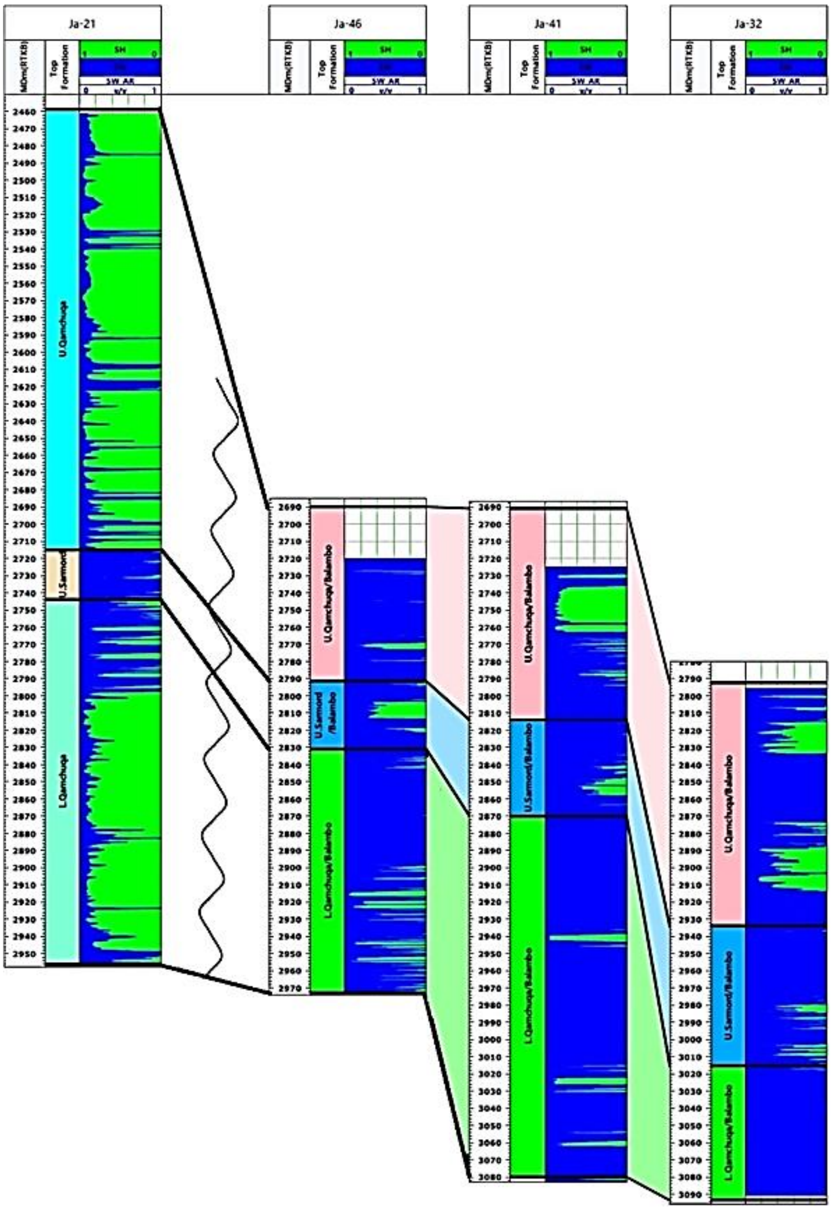

Fig. (6): Water and Hydrocarbon saturations for studied wells.

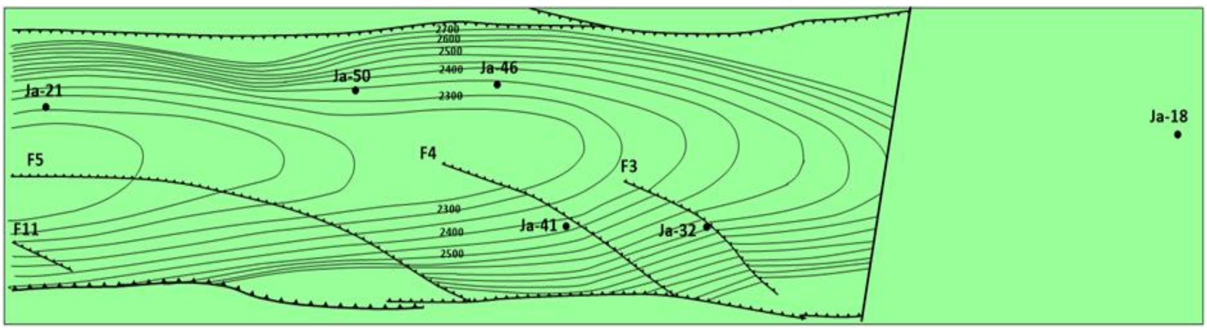

Fig. (7): Structure counter map on top of Qamchuqa reservoirs with indicated reverse fault.

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Cretaceous Period in northern Iraq are characterized by depositional features and some tectonic events; therefore, it is divided by Chatton and Hart [16; 17] into the following features:

1. Permanent basin: is a basin most negative area, sedimentation has been continued from Tithonian-Maastrichtian. Extends from Sulaymaniah City to Jambur Oil field passing through Pulkhana to the Naftkhana oil fields (Figure 6), and mainly represented by Balambo Formation.
2. Shelf (neritic zone): located among permanent basin from east and positive area of Gaara from west of Iraq (Figure 8). The area is characterized by neritc (shoal) deposition during all the early to middle Cretaceous Period where Garagu, Lower Qamchuqa (Shuaiba) and Upper Qamchuqa (Mauddud) formations were deposited.

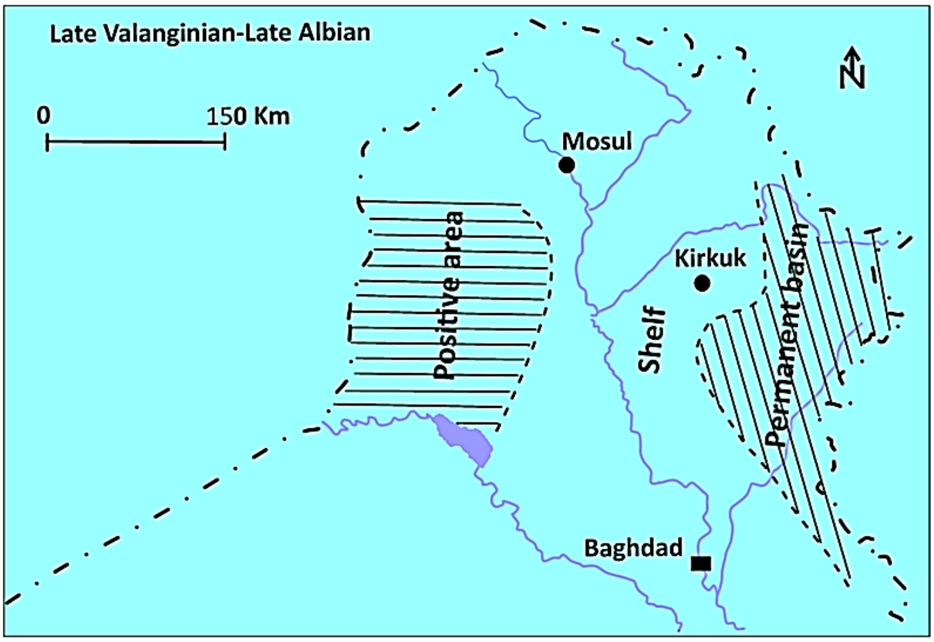

Fig. (8): Sedimentary basin for Early Cretaceous [17].

The Aptian-Albian age include Lower and Upper Qamchuqa formations are considered a major reservoir in Jambur Oil field; therefore, the present study focuses only on Lower and Upper Qamchuqa formations. Deep marine environment is Balambo Formation which separated the Aptian-Albian reservoir into three parts (Figure 9). Each part is different in petrophysical properties and lithology composition.

Zone -1: is shoal facies including Lower and Upper Qamchuqa formations composed of dolomite, and dolomitic limestone, this part faraway interfingers with Balambo formation.

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Zone -2: Is mixed facies between shoal facies and basinal facies composed of marly limestone with a few streaks of dolomitic limestone this part included well Ja-32, Ja-41 and Ja-46.

Zone -3: Is basinal facies including Balambo Formation composed of shaly limestone, shale and marly limestone involved well Ja-18 only.

These differences above caused interfingers and lateral change in both reservoirs (Lower and Upper Qamchuqa formations) with Balambo Formation, and both are not depicting reservoirs in Zone -2 especially in Zone -3. The current study explains Zone-3 (well Ja-18) is located on the permanent basin and well Ja-32, Ja-41, and Ja-46 are located between permanent basin and neritic zone (mixed zone or slope margin); therefore, the south east of Jambur Oil field involving Zone-3 abandoned to drill in it to cretaceous age. Accumulation of hydrocarbon in Zone-2 depends on intensity of both reservoirs interfingering with Balambo Formation. Zone-1 has good petrophysical properties and hydrocarbon accumulation for two reservoirs.

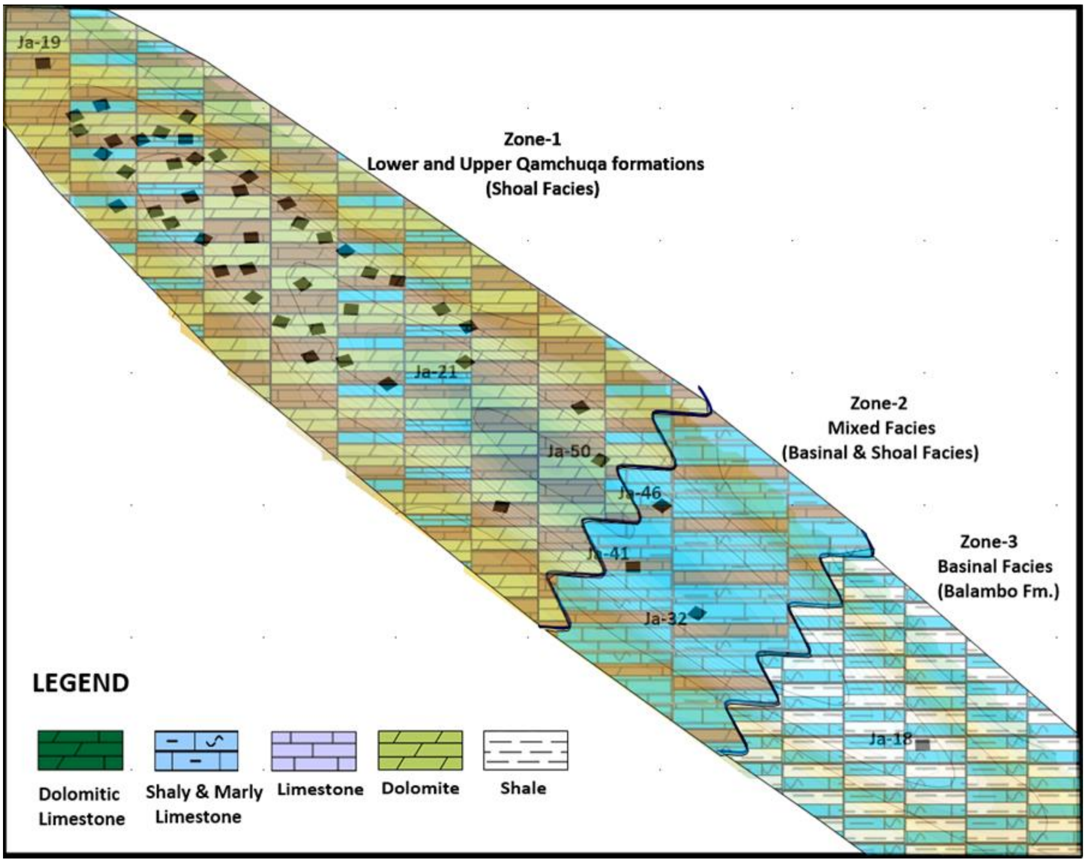

Fig. (9): Depositional environment of the Qamchuqa reservoir of the Jambur Oil field. The black dots refer to the wells.

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5. Conclusions

1. By Balambo Formation, Jambur oil field is separated into three sections: shoal facies,mixed facies and basinal facies.
2. The lithology, petrophysical properties and hydrocarbon accumulation of each section are not similar.

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