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Determination of reservoir properties for Nahr Umr Formation based on core plugs, lithofacies, and well logs in Noor oilfield, southern Iraq

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Abstract

In southern Iraq and neighboring countries, the Nahr Umr formation is one of the important Cretaceous reservoirs. The petrophysical characteristics of formation were determined using core plugs, lithofacies, and well logs from five wells in the Noor oilfield. Reservoir properties and facies analyses are used to divide the Nahr Umr formation into two members (limestone in the upper part and main sandstone in the lower). , The limestone member is characterized by low effective porosity and permeability, while the main sandstone member is considered a reservoir. According to petrographic observation with Gamma-ray log, four lithofacies were recognized in the main sandstone member of Nahr Umr formation. These lithofacies are well-sorted quartz arenite sandstone, poorly sorted Quartz arenite sandstone, Sandy shale, and Shale.

Calculation of the various reservoir properties (shale volume, effective porosity, permeability, and water saturation) using the (Interactive Petrophysics v3.5) program and linking them with the lithofacies by computer-processed interpretation (CPI) of the available wells. Divided the sandstone member into three units: A, B, and C, and each unit consists of many reservoir sandstone subunits separated by shale and streaks of limestone. Average reservoir properties of units A and B are good to very good related to high porosity, permeability, and economy hydrocarbon saturation (low water saturation). At the same time, these properties are decreased in unit C. The Sandston member of borehole No-5 was the best reservoir characterization, especially in the thickness of the reservoir units and the low shale content.

Keywords: Nahr Umr formation, Noor oil field, Lithofacies, Reservoir

تحديد الخصائص المكمنية لتكوين نهر عمر بالاستناد على قطع اللباب، السحنات الصخرية، و مجسات الابار في حقل النور النفطي، جنوب العراق

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الخلاصة

يعد تكوين نهر عمر أحد تكوينات العصر الطباشيري وأحد مكامن الانتاج الرئيسية في جنوب العراق والمناطق المجاورة. تم دراسة وتقدير خصائص التكوين البتروفيزيائية بالاستناد على قطع اللباب، السحنات الصخرية والجس البئري لخمسة آبار ضمن حقل النور النفطي. استخدمت التحليلات الصخرية وتفسيرات الخصائص البتروفيزيائية لتقسيم تكوين نهر عمر إلى عضوين (العضو الجيري في الجزء العلوي والعضو ذات الغالبية الرملية في الجزء السفلي). تميز عضو الحجر الجيري بخصائص مكمنيه (مسامية فعالة ونفاذية) منخفضة بينما يعتبر العضو الرملي هو المكمن في هذه الدراسة. من خلال الشرائح الرقيقة تم دراسة التحليل السحني ومقارنته مع التغيير في مجس الكاما وبذلك تم التعرف على أربعة سحنات صخرية في العضو الحجر الرملي في تكوين نهر عمر هي 1− سحنة الحجر الرملي الكوارتزي الارينايتي جيد الفرز. 2− سحنة الحجر الرملي الكوارتزي الارينايتي رديء الفرز. 3− سحنة الحجر الرملي السجيلي. 4− السحنة السجيلية.
حساب الخواص المكمنية المختلفة (حجم السجيل، المسامية الفعالة، النفاذية، والتشبع المائي) باستخدام برنامج (Interactive Petrophysics v3.5) وربطها مع التحليل السحني من خلال تحليل نتائج التفسير المعالَج بالحاسوب (CPI) للآبار المتوافرة تم تقسيم العضو الرملي إلى ثلاث وحدات وهي A، B، C. تتكون كل وحدة من عدد من الوحدات المكمنية الفرعية مفصولة بالسجيل وطبقات رقيقة من الحجر الجيري. معدل الخصائص المكمنية (المسامية الفعالة والنفاذية والتشبع ذات التصنيف الاقتصادي للهيدروكربونات) للوحدتين A وB يصنف جيد إلى جيد جدًا. بينما تنخفض هذه الخواص في الوحدة C. العضو الرملي في البئر رقم 5 يعتبر هو الأفضل عن بقيت الابار لامتيازه بزيادة السمك وبقلة المحتوى السجيلي.

Introduction

The Cretaceous deposits of the Mesopotamian basin, which contain carbonate and sandstone reservoirs and a significant amount of oil, are among the world's richest oil elements [1]. This study deals with one of the most important reservoirs in southern Iraq, the Nahr Umr formation. Five oil wells within the Noor oil field to estimate the reservoir properties based on well logs data, core plugs, and lithofacies. The results of computer processing interpretation (CPI) of well logs associations with lithofacies are used to identify the Nahr Umr reservoir unit. The volume of shale, porosity (total and effective), permeability, water saturation, and hydrocarbon saturation were all estimated factors. The effect of lithofacies qualities in each unit is also taken into consideration.

The Study Area

Noor oil field is located in the southeast of Iraq within the Missan Governorate, situated near the border between Iraq and Iran, approximately 350 km southeast of Baghdad and 17 km northeast of the city of Amara (Figure 1). The structure of the field has about 30 km long and 15 km wide. The Noor oil field was discovered in 1973 based on a seismic survey, which the Iraqi oil exploration company carried out was. The first well, Noor-1, was drilled in 1978 by the Iraqi well drilling company. Then, 18 oil wells were drilled, covering the Noor oilfield structure. Six of the wells included in this study (No-1, No-3, No-5, No-7, No-10, and No-13) penetrated the Nahr Umr formation, which is considered one of the main oil-producing reservoirs in the field.

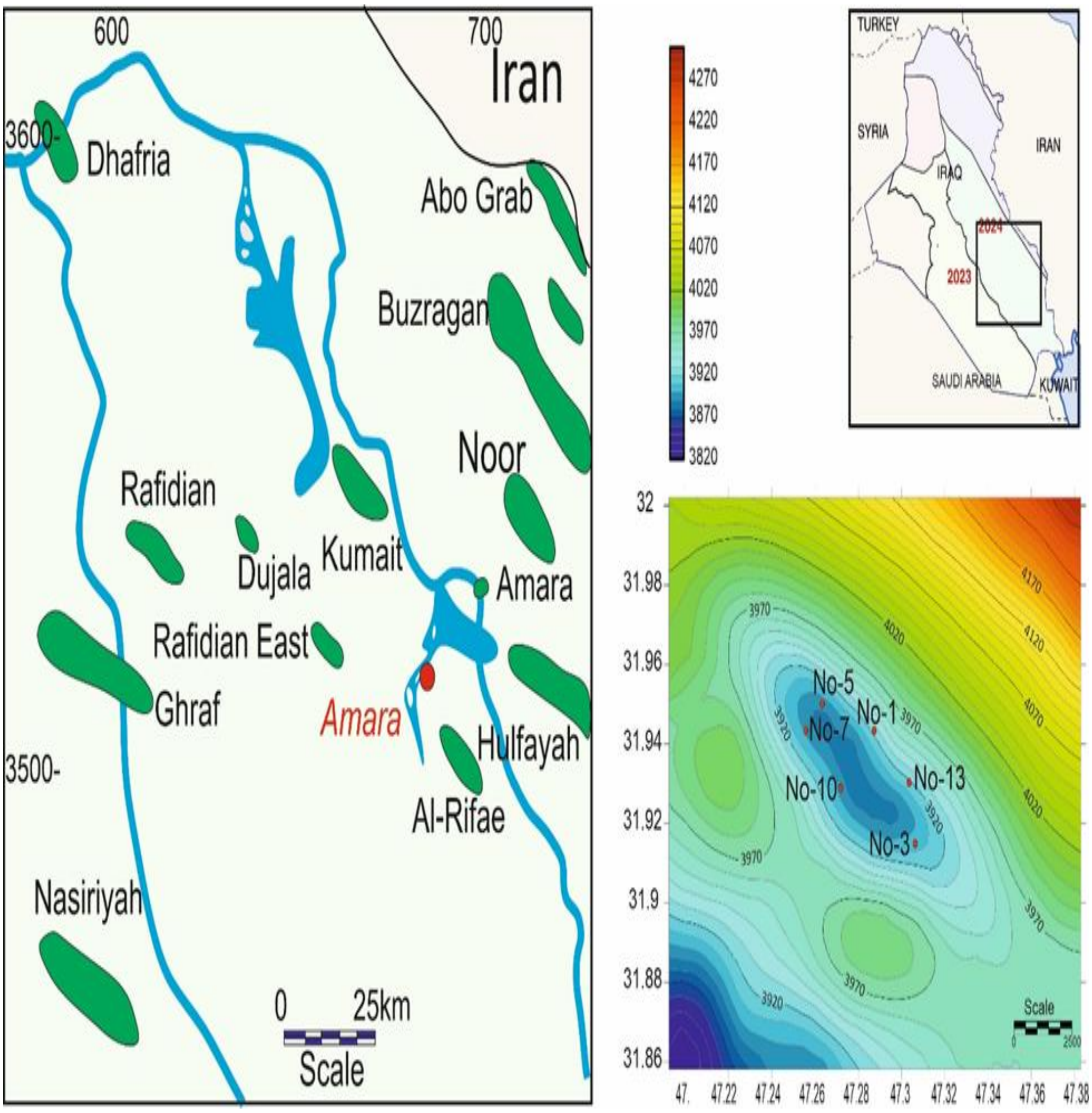

Figure 1-Left; Location map of Noor oilfield, southeast of Iraq. Right; Structural map at the top of Nahr Umr formation in Noor Oilfield, elevation below sea level (Data source from O.E.C. report).

Geological Setting and Stratigraphy

As indicated by Jassim and Goff (2006), the structure of the Noor oil field is tectonically located within the stable shelf Mesopotamian zone and precisely in the Tigris sub-zone. Two relatively low amplitude NW-SE trend groups of buried anticlines associated with longitudinal faults (confirmed by seismic surveys) and an EW transverse trend characterize it. The Ramadi-Musaiyib and Tikrit-Amara Fault Zones, which are part of the Najd Fault System and the Kut-Dezful Fault System, respectively, are where these anticlines are located [2]. The structure of the Noor oil field is an anticline with an axis trending NW-SE. The dip of the northern and southern limbs of the anticline is 1.3o and 1o, respectively [3] (Figure 2).

Nahr Umr formation belongs to the late Tithonian-Early Turonian AP8 Megasequence, which was deposited in a huge contemporary intra-shelf basin with a new process of southern NeoTethys ocean floor spread [2]. In the Foothill Zone and Tigris subzone of the Mesopotamian Zone, the megasequence is the thickest, reaching 1200 m near Baghdad [2]. In 1984, Glynn Jones identified the Nahr Umr formation in southern Iraq from the Nahr Umr structure. Formation consists of black shale interbedded with medium to –fine-grained sandstone, with pyrite and amber [4]. Nahr Umr formation gradationally underlies Mauddud

formation within the Mesopotamian Basin and unconformably overlies Shuaiba formation. In the studied area, the thickness of Nahr Umr formation ranges from 198 m. to 215 m [2].
In Kuwait, the Nahr Umr formation is equivalent to the Burgan formation [5]; [6]. In addition, it passes through the shales and limestones of the Kazdhumi formation in southwest Iran [7], formation is comparable to Safaniya and Khafji formations in northern Saudi Arabia [8]. In the foothill zone, the Nahr Umr formation correlates with the Jawan and upper Sarmord [9], and upper Qamchuqa and lower Balambo in the high folded Balambo-Tanjero zone [2] (Figure 3B). Its porosity varies from 16% to 23%, and its permeability varies from 20 to 3000 mD [10].

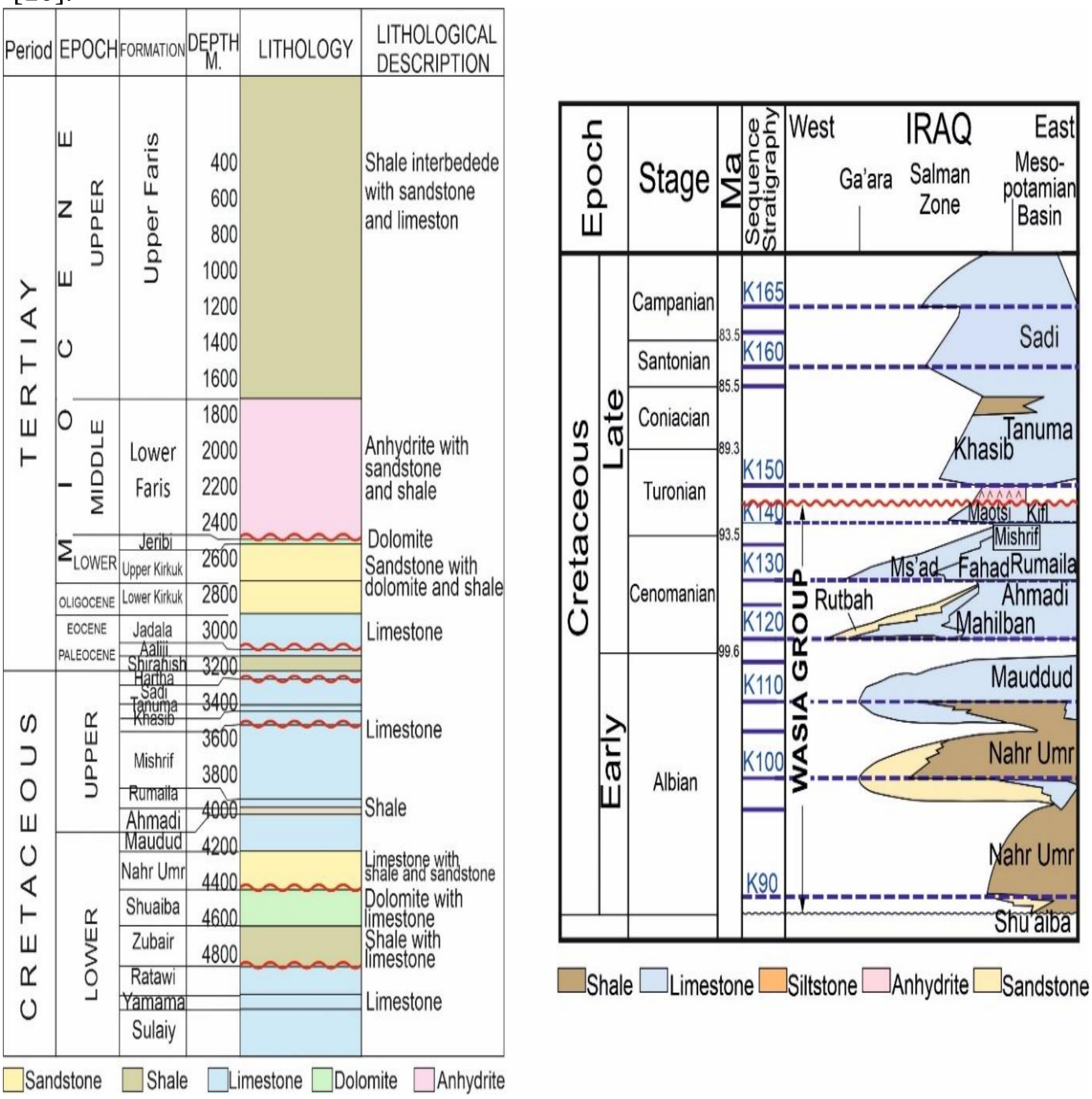

Figure 2-Left; Stratigraphic column and description at well No-1 (MOC report). Right; stratigraphic correlation of Nahr Umr formation modified from [5]; [2].

Methods and Materials
1- Sample collection stage: 21 core samples were taken from the Missan Oil Company store. With 9 samples from well No-3 and 12 samples from well No-13. The sampling process depended on the alteration of lithology.
2- Experimental part: twenty-one core samples were selected for making forty thin sections. A polarized microscope was used to examine the slides for facies determination.
3- Log's collection: The logs generally are resistivity(LLD and MSFL), Density, Neutron, Sonic, Gamma-ray, Spontaneous Potential, and Caliper for five wells (No-1, No-3, No-5, No-

7, and No-13) and prepared for analysis and interpretation to evaluate petrophysical parameters that include the volume of shale, porosity, permeability, and fluids saturation for each reservoir unit by using the IP 3.5 software.

4- Petrophysical Parameters

The parameters of petrophysical properties include:

4- 1 Volume of shale (Vsh): To estimate the volume of shale, the Schlumberger equation (1974) [11] was used to derive Vsh from gamma-ray logs:

$$IGR = (GRlog - GRmin) / (GRmax - GRmin) \quad (1)$$

Where: IGR = index of gamma-ray; GRlog = –gamma-ray reading of formation; GRmax = maximum –gamma-ray (shale); GRmin = minimum –gamma-ray (clean sand or carbonate); The Nahr Umr formation consider older rocks, therefore, using a formula of Dresser Atlas (1979) [12] to determine theshale volume

$$Vsh = 0.33 * [2^{(2*IGR)} - 1] \quad (2)$$

4- 2 Porosity: Total porosity is measured using a Neutron– Density combination. The direct porosity is measured using the neutron log after being corrected using Tiab & Donaldson's equation [13]:

$$\Phi Nc = \Phi N - (Vsh * \Phi Nsh) \quad (3)$$

Where: ΦNc = corrected porosity for no clean rocks is derived from Neutron log; ΦNsh = Neutron porosity of shale; density-derived porosity from the bulk density of clean liquid-filled formations when the density of the saturating fluids (ρf) and the matrix density (ρma) are identified, using Wyllie et al., (1958) equation [14]

$$\Phi D = (\rho ma - \rho b) / (\rho ma - \rho f) \quad (4)$$

Where ρma = density of matrix (2.68 gm /cm^3 for sandstone [15]; ρf = density of fluid (1.1 gm/ cm^3 for saline water [15]).

Remove shale effect from porosity calculation in intervals, which have shale volume, is more than 10%; we used Dresser Atlas, (1979) [12] equation:

$$\Phi Dc = \Phi D - (Vsh * \Phi Dsh) \quad (5)$$

Where: ΦDc = porosity by density log corrected from shale effect; ΦDsh = density porosity for shale.

Total porosity (Φt) is calculated as follows:

$$\Phi t = (\Phi N + \Phi D) / 2 \quad (6)$$

The effective porosity (Φe) is calculated, using equation of Schlumberger (1998) [15]

$$\Phi e = \Phi t * (1\text{-}Vsh) \quad (7)$$

Primary porosity determine by sonic log based on Wyllie time average equation below [14]:

$$\Phi S = (\Delta tlog - \Delta tma) / (\Delta tf - \Delta tma) \quad (8)$$

The following equation is used to correct sonic porosity from the shale effect within the formation.

$$\Phi Scorr = \Phi S - (Vsh * \Phi Ssh) \quad (9)$$

Where: ΦS= porosity derived from sonic log; Δtlog = interval tansit time in the formation; Δtma = rock matrix transit time interval; ΦSc = corrected sonic porosity; Δtf = interval transit time in the fluid in the porous formation; ΦSsh = apparent porosity of the shale.

The secondary porosity index (SPI) is computed by the equation [16]:

$$SPI = (\Phi t - \Phi Sc) \quad (10)$$

4-3 Permeability is calculated by using the Timur formula from wireline logs [17]

$$K = 0.136 \frac{\Phi^{4.4}}{Swi^2} \quad (11)$$

Where: K = permeability in mD; Swi =irreducible water saturation.

4 -4 Fluids saturation

Water saturation (Sw) in the uninvaded zone is calculated according to Simandoux's equation [18]. This equation has been used in this study because the shale content of the Nahr Umr Formation is more than 15 %.

$$Sw = \left[\frac{0.4 * Rw}{\Phi^2}\right] * [\sqrt{\{\left(\frac{Vsh}{Rsh}\right)^2 + \sqrt{\left(\frac{5 * \Phi^2}{Rt * Rw}\right)}\}} - (\frac{Vsh}{Rsh})] \quad (12)$$

Where: Rw = Resistivity of water formation; Rt=true Resistivity; Rsh = true resistivity of nearby shale.

Water saturation in the invaded zone (Sxo) is calculated from the equation [19]:

$$Sxo = \{(a * Rmf) / (Rxo * m)\}\ 1/n \quad (13)$$

Rmf = mud filtrate resistivity; Rxo = measured resistivity of the invaded zone; a = tortuosity factor; m = cementation factor; n = saturation exponent. Archie's coefficients (a, m, and n) shaly sand clastic rocks equals 1.65, 1.33,2 respectively [20].

Hydrocarbon saturation (Sh) was calculated by Asquish's equation [21]:

$$Sh = 1 – Sw \quad (14)$$

Moveable hydrocarbon saturation (MOS) was calculated based on Spain's equation [22]:

$$MOS = Sxo – Sw \quad (15)$$

Residual hydrocarbon saturation (ROS) was calculated by using Schlumberger's equation [23]:

$$ROS = 1 – Sxo \quad (16)$$

Results and Discussions

Facies analysis:

1-Well sorted quartz arenite sandstone lithofacies (Lf.NA-1): The sub-angular to sub-rounded grain type mode of fine-grained well-sorting sandstone distinguishes lithofacies. As quartz arenite sandstone, the sandstone in these lithofacies comprises more than 90% quartz. The lithofacies have very low gamma-ray values in the middle unit (Figures 3 and 4).

2- Poorly sorted Quartz arenite sandstone lithofacies (Lf.NA-2): The sandstone grain range includes a wide range of sand sizes, from sub-round to coarser grains, and a mixture of rounded and non-rounded grains. More than 90% of the quartz in sandstone is found in lithofacies, a type of quartz known as quartz arenite. Poorly sorted, extremely low gamma-ray readings that decrease upward with rising gamma-ray log bell shape differentiate this (Figures 3 and 4).

3- Sandy shale lithofacies (Lf.NA-3): this lithofacies appeared as shale lenses with high shale values and funnel shape mode. The main components of this facies, distinguished by high gamma-ray values with funnel shape mode, are mud-dominated rocks with quartz grains distinguished by angular grain shape. The primary component of these facies is a sand-dominated rock with quartz grains distinguished by angular form. (Figure 3C).

4-Shale lithofacies (Lf.NA-4): In all components of succession, these facies appeared shale rocks, with high bell-mode shaped gamma-ray values, primarily characterize it (Figure 3D).

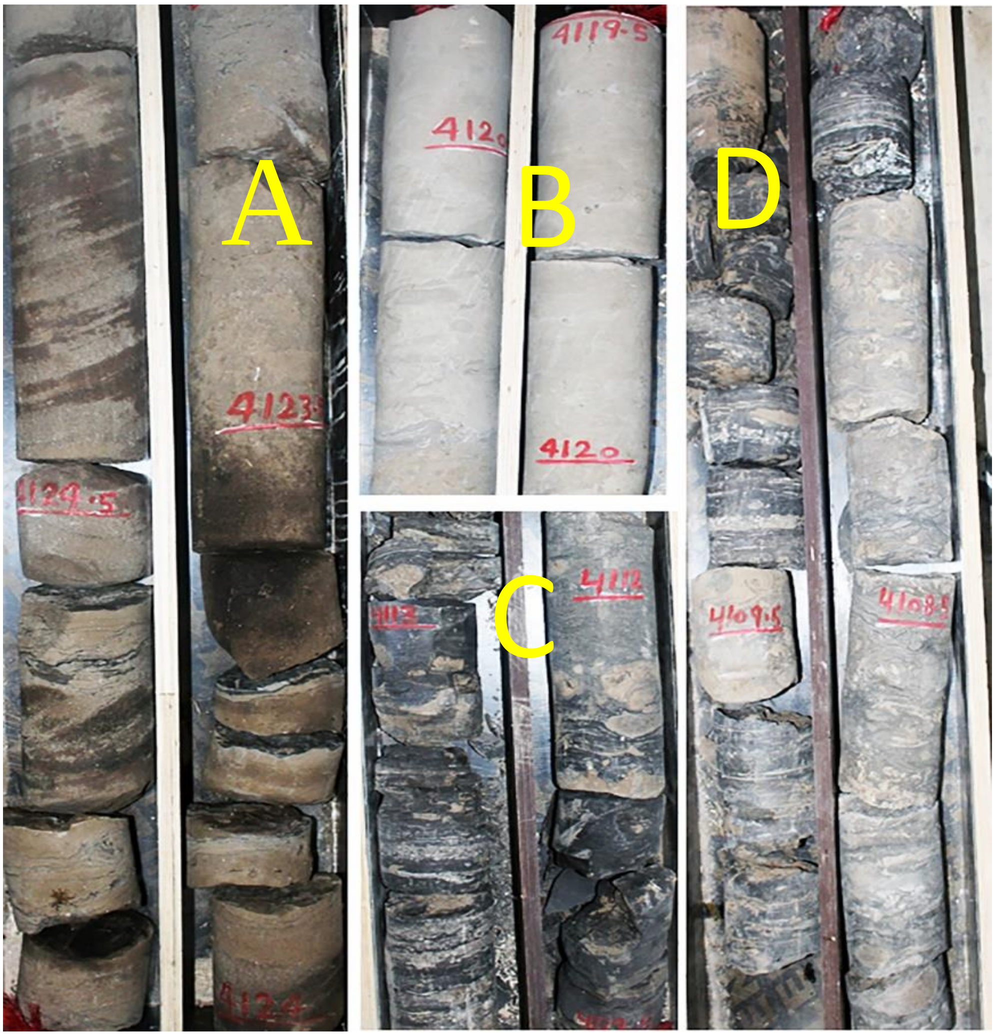

Figure 3-Core samples of Nahr Umr formation showing different lithofacies in Noor 13, A-represent Lf.NA-1, B- Lf.NA-2, C- Lf.NA-3 and D- Lf.NA-4.The core samples box measures 1 meter in length.

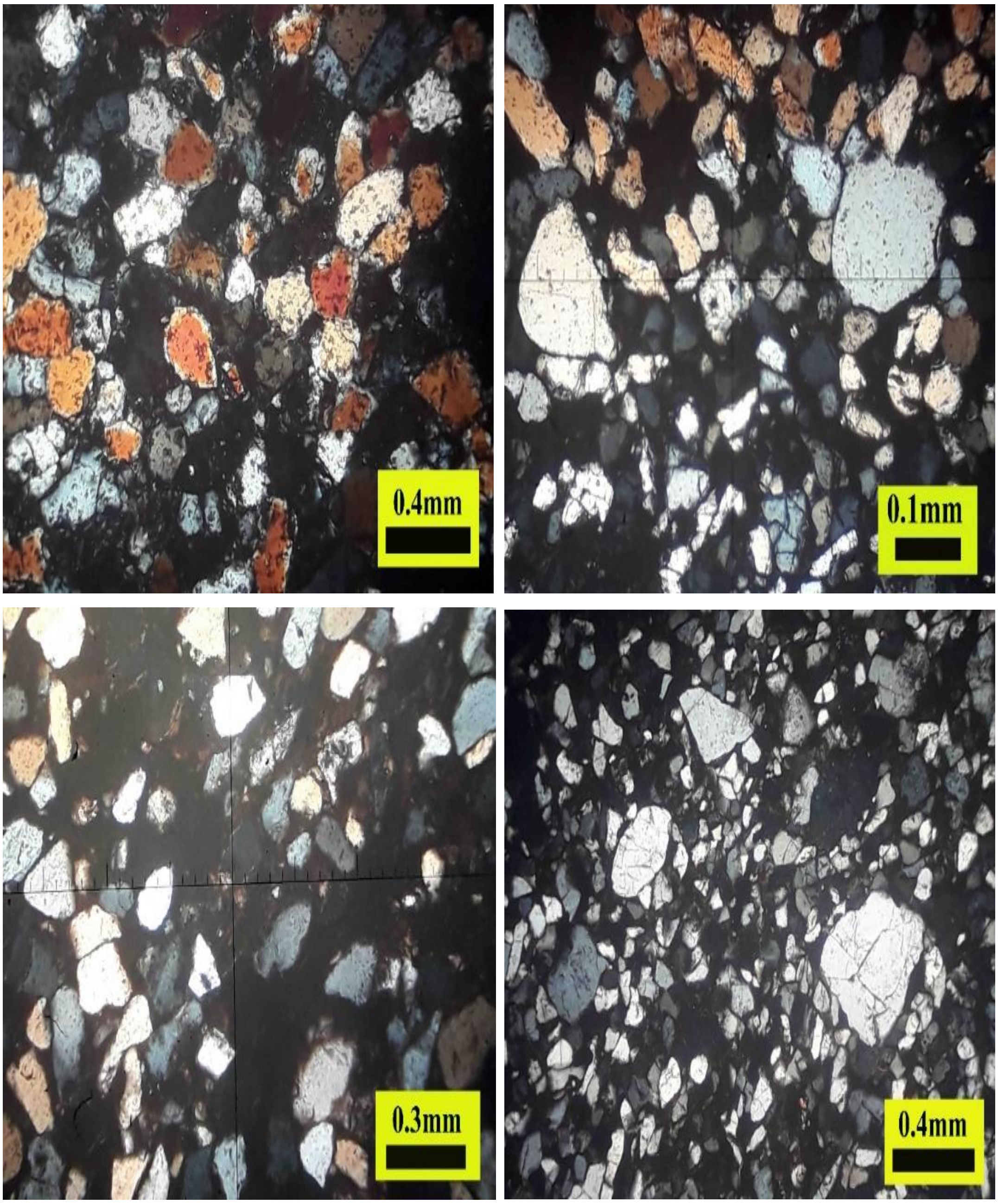

Figure 4-The facies analyses of the Nahr Umr Formation in Noor oilfield.

(A) Well sorted quartz arenite sandstone lithofacies (Lf.NA-1) in Noor- 13, Depth: 4102.5m. Textures (Grain Size: 0.125-0.25mm-Fine Sandstone, Roundness: Sub Rounded, Sphericity: High Sphericity).
(B) Poorly sorted quartz arenite sandstone lithofacies (Lf.NA-2) in Noor- 13, Depth: 4119.7m. Textures (Grain Size: 0.0625-0.25mm-Very fine and fine Sandstone. Roundness: Sub Rounded, Sphericity: High Sphericity).
(C) Well sorted quartz arenite sandstone lithofacies (Lf.NA-1) in Noor-3, Depth: 4092.4 Textures (Grain Size: 0.0625-0.125mm-Very Fine Sandstone. Roundness: Sub Rounded, Sphericity: High Sphericity).
(D) Poorly sorted Quartz arenite sandstone lithofacies (Lf.NA-2) in Noor-3, Depth: 4106.2m. Textures (Grain Size: 0.0625-0.25mm Very Fine and fine Sandstone, Roundness: Sub Rounded, Sphericity: High Sphericity).

Evaluation of Nahr Umr Reservoir Units

Nahr Umr formation of the Noor oilfield primarily consists of limestone in the upper part and main sandstone in the lower part. Since the lower limestone member has poor reservoir properties (low effective porosity and permeability), it is classified as a non-reservoir. In this study, the main sandstone member represents the main reservoir, divided into three units based on the reservoir characterization through computer process interpretation (CPI) of the studied wells (Figure 5, Tables 1, and 2).

Unit (A)

Several reservoir subunits have been identified and separated by a barrier of shale and streaks of limestone in Unit (A), which consists of interbedded sandstone with shale (Shale lithofacies). The petrophysical characterization of this unit is considered excellent. The average effective porosity and permeability range from good to very good, as represented by (Lf.NA-1, Lf.NA-2, and Lf.NA-3) lithofacies. The volume of shale increases in the middle of the basin (No-1 and No-13) and decreases in the direction of the north and south of the basin. The thickness of reservoir sub units ranges from (7 to 13m).

Unit (B)

This unit represents the middle unit of the main sandstone member. It consists mainly of sandstone with shale and streaks of limestone. Unit (B) has a good porosity effective in all wells except well No-5 has very good porosity. The average permeability is from good in wells (No-1, No-3, and No-13) to very good in well (No-5 and No-7). The shale volume average in this reservoir unit ranges from 6% in the north basin (No-5) to 15% in the south of the basin (No-3). The total thickness of this reservoir unit varies between (25-12.5m). The results are shown in (Table 2 and Figure 5).

Unit (C)

This reservoir unit is predominantly composed of shale, with a total thickness of 6 to 14 meters. The average effective porosity of unit (C) decreases, especially in wells (No-7 and No-13), which are considered to be of a fair type while improving in other wells, which are considered to be of the good type. The permeability average for this reservoir unit is good in all wells . The amount of shale varies considerably from 22% to 41%, as shown in Table 2. Lithofacies (Lf.NA-4) is dominated in this unit.

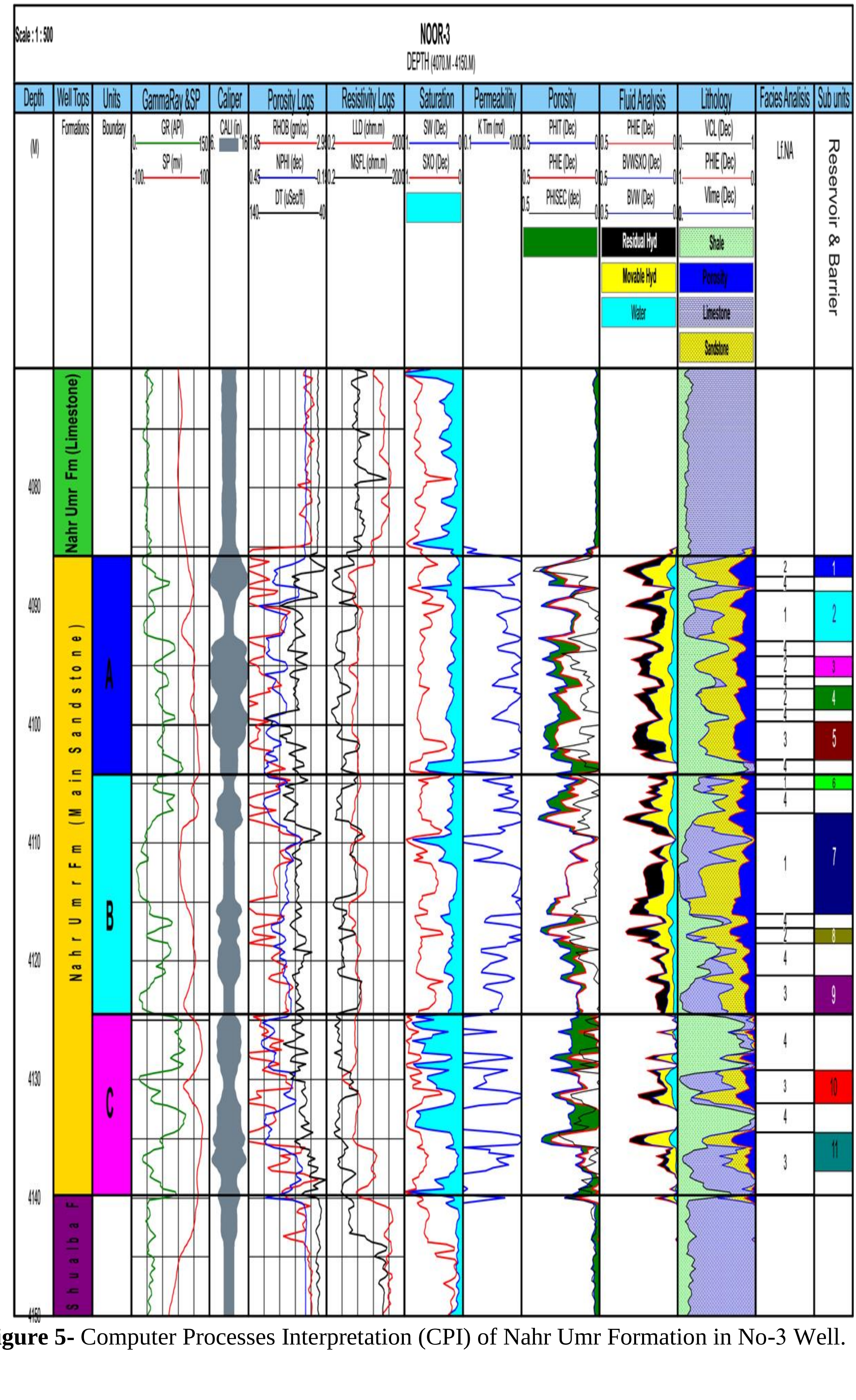

Figure 5- Computer Processes Interpretation (CPI) of Nahr Umr Formation in No-3 Well.

Table 1- Reservoir units' properties of Nahr Umr Formation in well No-3.

Noor -1				Unit thickness (m)	Average shale content VCL%	Average effective porosity PhiE%	Average permeability K(md) By Timur	Average water saturation Sw %	Average total hydrocarbon saturation Sh %	Fluid Type
Nahr Umr F	Member	Units	Sub Units							
Reservoir	Limestone			161.25	14	5	29	-	-	-
Reservoir	Main Sandstone	A	1	1.75	13	23	340	14	86	Hydrocarbon
			2	4.25	16	19	179	18	82	Hydrocarbon
			3	1.75	32	24	430	19	81	Hydrocarbon
			4	2	31	21	312	19	81	Hydrocarbon
			5	3.25	38	24	469	17	83	Hydrocarbon
		B	6	1.5	30	15	142	18	82	Hydrocarbon
			7	8.5	9	19	314	24	76	Hydrocarbon
			8	1.5	27	24	325	17	83	Hydrocarbon
			9	3.75	16	12	50	21	79	Hydrocarbon
		C	10	10	2.75	19	16	54	33	Hydrocarbon
			11	11	3.25	24	14	150	15	Hydrocarbon

Table 2- the average petrophysical properties for units A, B, and C (sub units' reservoir) in studied wells.

Petrophysical properties / Well No.	**Units**	**VCL %**	**PHIE %**	**K(mD)**	**Sw %**	**Sh %**	**The total thickness of reservoir subunits (m)**
No-1	**Unit A**	**48**	**18**	**148**	**29**	**69**	**10.5**
No-3		**26**	**22**	**320**	**18**	**82**	**13**
No-5		**19**	**21**	**216**	**27**	**73**	**7**
No-7		**32**	**18**	**262**	**25**	**75**	**10**
No-13		**50**	**23**	**319**	**19**	**81**	**10**
No-1	**Unit B**	**13**	**18**	**106**	**48**	**52**	**14.5**
No-3		**15**	**18**	**216**	**22**	**78**	**15.25**
No-5		**6**	**21**	**325**	**17**	**83**	**25.75**
No-7		**10**	**17**	**309**	**14**	**86**	**12.25**
No-13		**9**	**18**	**156**	**30**	**70**	**13.5**
No-1	**Unit C**	**41**	**17**	**117**	**24**	**76**	**6**
No-3		**22**	**15**	**106**	**23**	**77**	**6**
No-5		**33**	**18**	**214**	**24**	**76**	**7.25**
No-7		**39**	**12**	**161**	**26**	**74**	**14**
No-13		**27**	**14**	**95**	**28**	**72**	**6.75**

Conclusion

In this study, the Nahr Umr formation was divided into two members (limestone in the upper part and main sandstone in the lower). The petrophysical analysis of studied oil wells of

the Noor oilfield shows that the limestone member represents non-reservoirs. In contrast, the main sandstone member is considered the best reservoir for hydrocarbon accumulations.
The main sandstone member was divided into three reservoir units (A, B, and C). Each unit comprises several reservoir sandstone subunits separated by shale and limestone streaks. Units A and B have good to very good reservoir properties due to high porosity, permeability, and economic hydrocarbon saturation (low water saturation). On the other hand, Unit C has a decline in these properties. The best reservoir characterization can be showed in the No-5 well, especially in A and B units, due to higher thickness and low shale content.

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