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Characterization of Mishrif Formation Reservoir in Amara Oil Field, Southeast Iraq, Using Geophysical Well-logging

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Abstract

Reservoir characterization requires reliable knowledge of certain fundamental properties of the reservoir. These properties can be defined or at least inferred by log measurements, including porosity, resistivity, volume of shale, lithology, water saturation, and permeability of oil or gas. The current research is an estimate of the reservoir characteristics of Mishrif Formation in Amara Oil Field, particularly well AM-1, in south eastern Iraq. Mishrif Formation (Cenomanin-Early Touronin) is considered as the prime reservoir in Amara Oil Field. The Formation is divided into three reservoir units (MA, MB, MC). The unit MB is divided into two secondary units (MB1, MB2) while the unit MC is also divided into two secondary units (MC1, MC2). Using Geoframe software, the available well log images (sonic, density, neutron, gamma ray, spontaneous potential, and resistivity logs) were digitized and updated. Petrophysical properties, such as porosity, saturation of water, saturation of hydrocarbon, etc. were calculated and explained. The total porosity was measured using the density and neutron log, and then corrected to measure the effective porosity by the volume content of clay. Neutron -density cross-plot showed that Mishrif Formation lithology consists predominantly of limestone. The reservoir water resistivity (Rw) values of the Formation were calculated using Pickett-Plot method.

Keywords: Mishrif Formation, Amara oil field, Petrophysical Properties.

خصائص مكمن تكوين المشرف في حقل العمارة النفطي ,جنوب شرقي العراق بأستخدام المجسات الجيوفيزيائية

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الخلاصة

تمثل الدراسة الحالية تقييم الخصائص البتروفيزيائية لتكوين المشرف(السينوماني– التورانيين المبكر) لبئر Am-1لتكوين المشرف في حقل العمارة النفطي . لقد اعتمد التقييم البترفيزيائي على بيانات المجسات الجيوفيزيائية للآبار لتوضيح الخصائص المكمنية لتكوين المشرف في حقل العمارة. ان المجسات البئرية المتوفرة مثل(الصوتية والكثافة والنيوترون وأشعة كاما والجهد الذاتي ومجسات المقاومة النوعية) تم تحويلها الى قيم رقمية وتم اجراء التصحيحات وحساب المعاملات البتروفيزيائية مثل المسامية والتشبع المائي والتشبع الهيدروكاربوني الخ باستخدام برنامج Geoframe software. يعد تكوين المشرف المكمن الرئيسي في حقل

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العمارة ، حيث تم تقسيمه الى ثلاثة وحدات من الاعلى هي (MC,MB,MA) كما تم تقسيم الوحدة (MB) الى وحدتين ثانويتين هما (MB2,MB1) والوحدة (MC) الى وحدتين ثانويتين هما (MC2,MC1) تم قياس المسامية الكلية باستخدام الكثافة وسجل النيوترونات ، ثم يتم تصحيحها لقياس المسامية الفعالة بمحتوى حجم السجيل. تظهر المرتسمات المتقاطعة لمجسات الـ(نيوترون – الكثافة) ان الصخارية السائدة للتكوين هي الحجر الجيري. تم حساب قيم مقاوميه الماء المكمني (Rw) للتكوين بطريقة Pickett–Plot.

Introduction

Mishrif Formation is one of southern Iraq's most important reservoirs. Initial studies of Mishrif Formation in Amara oil field declared that the reservoir comprises 3 essential units, namely upper, middle, and lower, with different reservoir zones.

Petrophysical properties refer to the study of rock properties and their interactions with fluids (gases, liquid hydrocarbons, and aqueous solutions). Well logging is the technique of conducting petrophysical measurements in the subsurface earth formations through the drilled borehole in order to determine both the physical and chemical properties of rocks and the fluid they contain [1]. Due to the enormous amount of well logging data that can be provided, this technology plays a pivotal role in hydrocarbon exploration and production industry. Such techniques can be used in all phases of hydrocarbon exploration and production processes. Rapid and sophisticated development in well logging technology has revolutionized the hydrocarbon industry [2].

This study is conducted to evaluate the reservoir of Mishrif Formation in Amara oil field based on well logs data. We aimed to apply the acquired well log datasets collected from the Amara oil field (Am-1 well) to evaluate the lithological and petrophysical characterizations in each zone in Mishrif Formation. The ultimate aim was to find, describe, and generate hydrocarbons from the formation. The study consists of two stages, the first one is that conducted before interpretation and the other one is the interpretation stage. The first stage includes determining effective porosity (corrected to effects of clay) and examining the Geoframe software's digitized results from well logs data and from the interpretation process parameters.

Materials and MethodsArea of study

The Amara oil field is located in Missan province, southeast Iraq, about 10 kilometers southwest Amara city, 20 km east of Al-Rafedain structure, and 20 km southeast Al-Kumait structure (Figure 1). Amara oil field was first discovered by seismic surveys conducted in late 1970s in Missan Province and recently further developed. Amara structure comprises a single anticline with a hub that is drifting northwest – southeast (Figure 2). Mishrif Formation (Cenomanian-Early Turonian) in the field of Amara consists of permeable limestone, chalky limestone, compact calcareous, and chert shale at the base of the formation .The thickness of Mishrif Formation in the examined wells ranges between 391 m in Am-1 [5] to 407 m in Am-2. The lower limit of the formation of Mishrif represents the change from basinal formation of Rumaila to shallow open marine facies. It is a conformable surface [6]. The upper boundary of the formation of Khassib is truncated by an unconformity surface dividing the middle from the late Cretaceous [4].

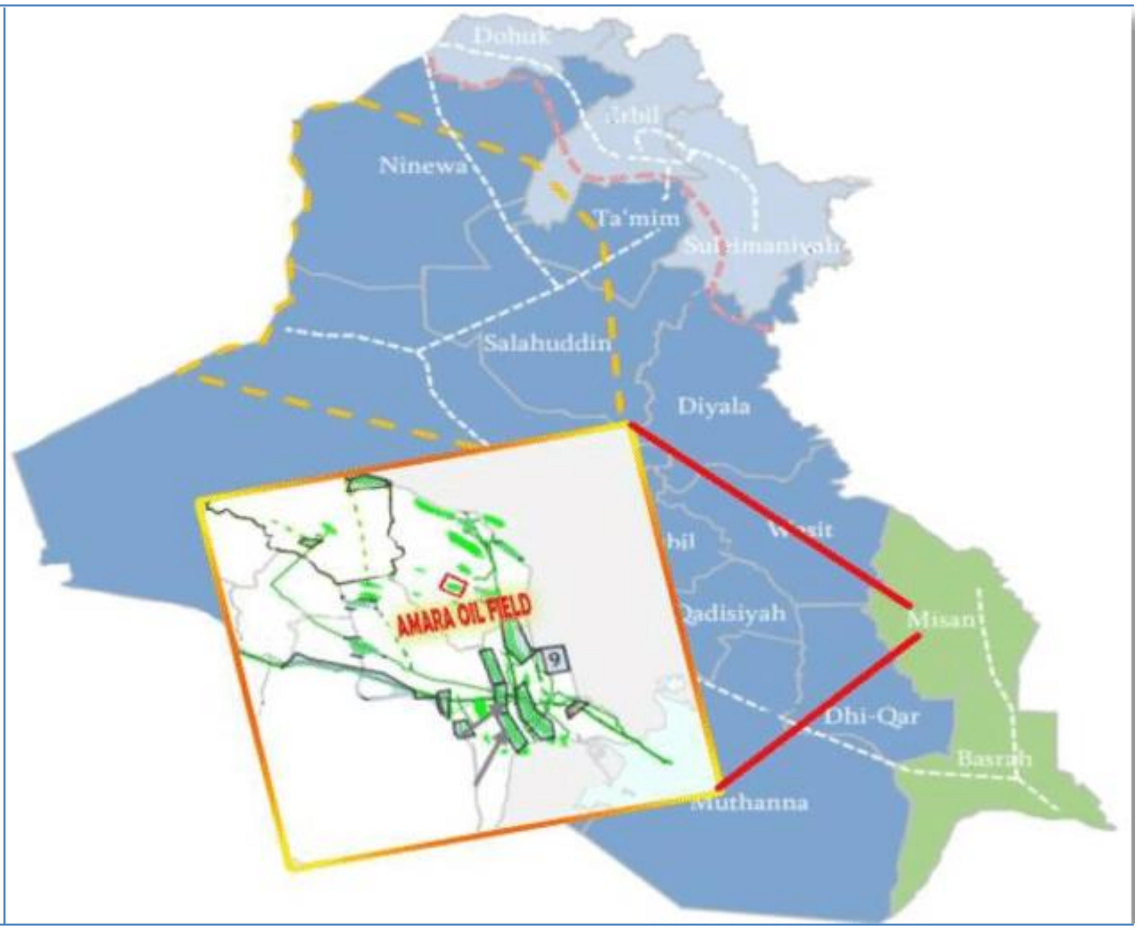

Figure 1-Location map of the study area [3].

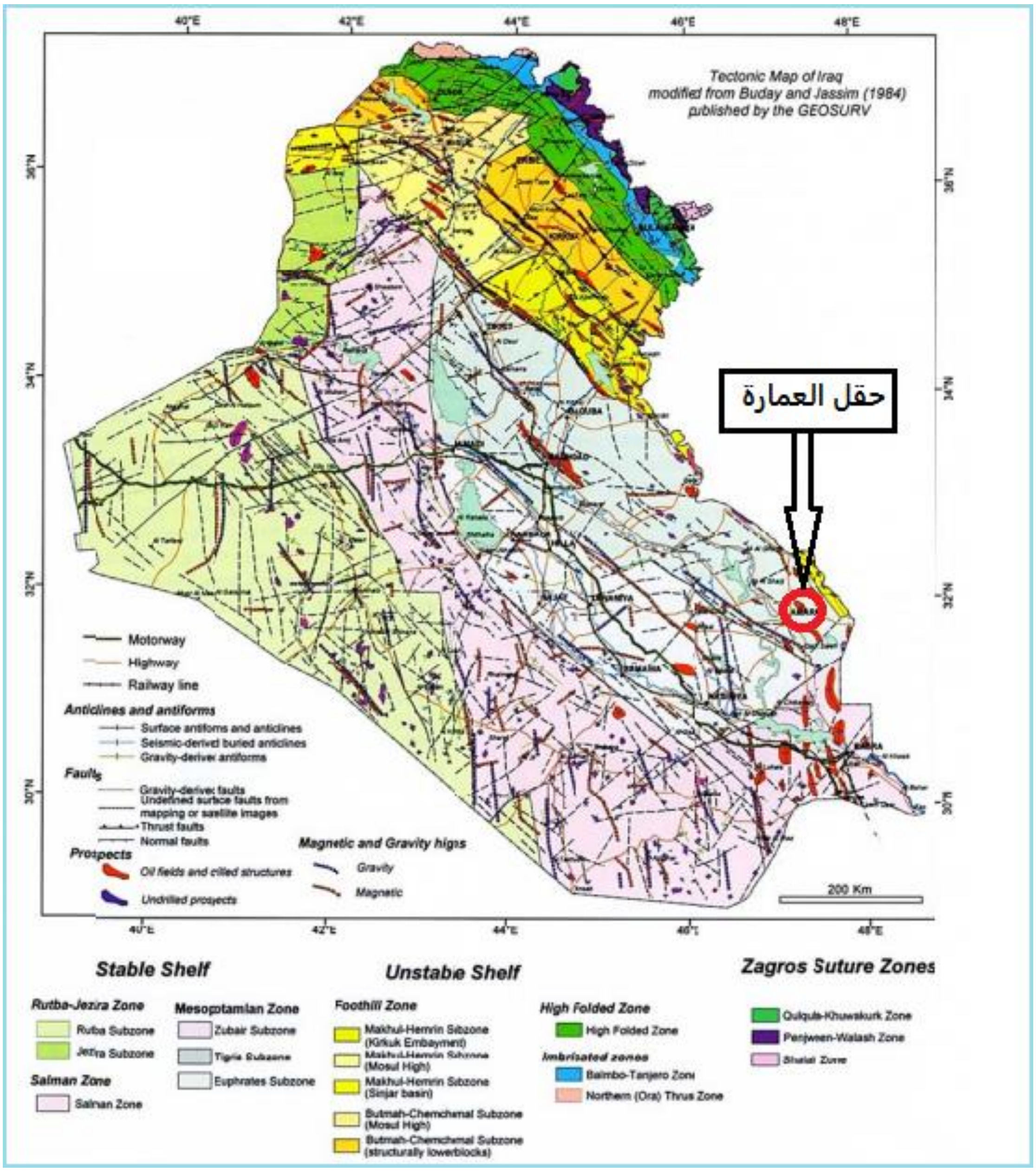

Figure 2-Tectonic map of Iraq [4].

Methodology

This research involves the analysis of petrophysical properties using data from the available open hole geophysical logs of the studied well (e.g. spontaneous potential, gamma ray, density, sonic, neutron, and resistivity logs). In addition, well logs interpretation and petrophysical analysis (Computer Processing Interpretation; CPI) of Mishrif formation in Amara oil field were performed using GeoFrame software. The lithology of Mishrif Formation was determined using density-neutron crossplot and the porosity and water saturation were calculated from Amara-1 logs cut-off. Also, the water resistivity (Rw) value in the Formation's reservoir was calculated using Pickett-Plot method. Table 1 presents unit tops and barrier beds of Mishrif formation.

Table 1-Top of Mishrif Formation units

WELLS / UNITS	Am-1			Am-3			Am-8			Am-11			Am-14		
	R.T.K.B	S.L	Thick	R.T.K.B	S.L	Thick	R.T.K.B	S.L	Thick	R.T.K.B	S.L	Thick	R.T.K.B	S.L	Thick
Top of Mishrif CR1	2880	2865	9	2909	2896.35	2	2873	2859	9	2877	2865	4	2867	2853	12
MA	2889	2874	33	2911	2898.3	40	2882	2868	37	2881	2869	33	2879	2865	35
CR2	2922	2907	23	2951	2938.35	23	2919	2905	23	2914	2902	22	2920	2906	54
MB1	2945	2930	67.5	2974	2961.35	49	2942	2928	61	2936	2924	58	2974	2960	38
CR3	3012.5	2997.5	14.5	3023	3010.35	63	3003	2989	53	2994	2982	56	3012	2998	28
MB2	3027	3012	22	3086	3073.35	54	3056	3042	58	3050	3038	62	3040	3026	68
CR4	3115	3100	29	3140	3127.35	70	3114	3100	72	3112	3100	67.5	3108	3094	69
MC1	3144	3129	102	3210	3197.35	65	3186	3172	51	3179.5	3167.5	68	3177	3163	53
CR5	3216	3201	24	3275	3262.35	7	3237	3223	10	3237.5	3222.5	6.5	3230	3216	20
MC2	3240	3225	37	3282	3269.35	20	3247	3233	27	3244	3232	28	3250	3236	
Rumila Formation	3277	3262		3302	3289.35		3274	3260		3272	3260		3278	3264	

Porosity logs

Porosity values will be determined based on the results obtained from the other logs described below.

Density log

Density log value is obtained from the bulk density of the formation, which is filled with mud filtrate, where the density of the matrix (*Pma*) and the density of the mud filtrate are known. The formula used is [7]:

$$\Phi D = \frac{(\rho ma - \rho b)}{(\rho ma - \rho f)} \quad (1)$$

where ΦD = porosity by density log, ρma = dry rock density for limestone formation (for this study = 2.71g/cm3) ; Pf = fluid density = 1 g/cm3 for fresh water or 1.1 g/cm3 for salt mud; Pb= bulk density log reader.

Neutron log

Neutron log is used principally for the delineation of porous formation and determination of its porosity. It responds primarily to the amount of hydrogen present in the formation. Thus, in clean formations whose pores are filled with water or oil, the neutron log reflects the amount of the liquid-filled porosity.

A combination of the neutron log with one or two other porosity logs yields even more accurate porosity values and lithologic identification, including evolution of shale content [8].

Sonic log

Based on Wyllie [9], the time-average equation (2) for the calculation of primary porosity was used, as follows:

$$\Phi s = \frac{(\Delta t - \Delta tma)}{(\Delta tf - \Delta tma)} \quad (2)$$

The presence of hydrocarbon increases the Δt. In a previous work, Hilchie [10] suggested the following empirical equations to correct for hydrocarbon effect:

$$\Phi scorr = \Phi s * 0.7 \quad \text{-----} \quad gas \quad (3)$$

$$\Phi scorr = \Phi s * 0.9 \quad \text{-----} \quad oil \quad (4)$$

Then, the following equation is used to remove the porosity, derived from the impact of sonic log of shale in the formation:

$$\Phi Scorr = \Phi S - (Vsh * \Phi Ssh)^2 \quad (5)$$

where ΦS = sonic dependent porosity, Δt = interval tansit time within formation, Δt_f = interval transit time in the matrix, Δt_f = interval transit time in the formation fluid, ΦSsh = apparent shale porosity, and ØScorr = corrected sonic porosity.

Volume of clay (Vclay)

In order to obtain V clay from the gamma ray (GR Log), gamma ray index (IGR) must be computed by the use of the equation of Schlumberger [11]:

$$IGR = \frac{(GRlog - GRmin)}{(GRmax - GRmin)} \quad (6)$$

where GRlog = formation gamma ray reading; GRmin = minimum reading of gamma rays (shale-free sand or carbonate), and GRmax = maximum reading of the gamma rays(shale). The formula of Dresser Atlas [12] for older rocks was used for the purpose of this study to estimate the shale volume, as follows:

$$Vsh = 0.33 * (2^{2 * IGR}) \quad (7)$$

Determination of Porosity

Total porosity: The value of total porosity within the Mishrif formation was computed by a combination of neutron and density logs [11]:

$$\Phi\ total = \Phi N + \Phi D / 2 \quad (8)$$

Effective porosity: The value of effective porosity (PHIE) was estimated from total porosity after subtracting the filled clay volume. For this reason, it is always lower or equal to total porosity depending on the volume of shale [13]. The effective porosity can be measured by applying Schlumberger formula [14]:

$$\Phi\ e = \Phi\ t \times (1 - VSh) \quad (9)$$

where Φ e= effective porosity, Φ t= total porosity, Vsh = volume of shale.

Primary and secondary porosity

Primary porosity is the ratio of voids space to the total volume of the rock contained in the pores made during deposition [15]. The sonic log reflects of the primary (intergranular) porosity [7].

The secondary porosity index (SPI) is the contrast between total porosity that is computed by the neutron-density log and porosity which is computed by the sonic log, as follows:

$$SPI = \phi\ total - \phi\ primary \quad (10)$$

$$SPI = (\Phi\ N.\ D - \Phi S) \quad (11)$$

Where Φ N. D = neutron-density log and SPI =secondary porosity index.

Water Resistivity

The value of water resistivity (Rw) may vary widely from one well to another in some reservoirs due to the impact of certain parameters, such as salinity, temperature, and fresh water invasion. However, several methods have been developed to assess reservoir resistivity, including chemical analysis of the formulated water sample, self potential (SP curve), water catalogs, and various analytical methods [16]. In Mishrif Formation, there was no data available for formation water analysis. Thus, an application named the Archie's Parameters Estimation from Log Pickett Cross plot was used (Figure 3). This analysis depends on the relationship between the deep induction log (ILD) and the total porosity in the clean water zone of limestone rocks. On the plot, there will be a zone with constant Rw, m, and Sw =100% as plotted data points in a straight line pattern [17].

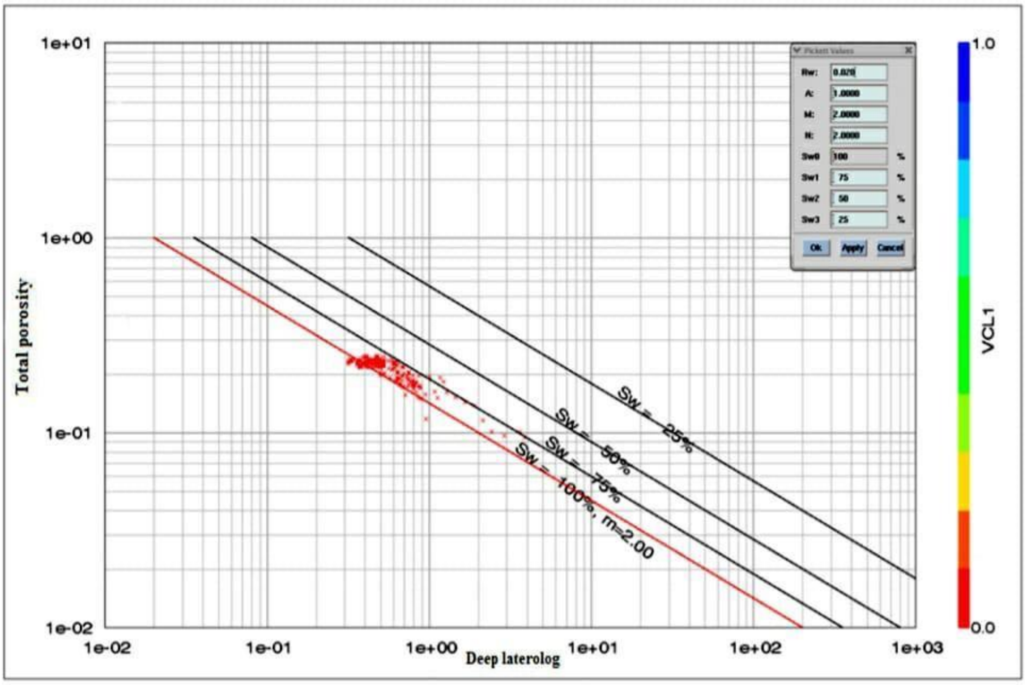

Figure 3-Pickett cross plot in well Am-1, showing total porosity and deep laterolog

Density-Neutron Cross Plot For Lithology

This type of plots was used to calculate the lithology and total porosity [6] in Well Am-1 of Mishrif Foration, Unit MA, as illustrated in Figures 4 and 5.

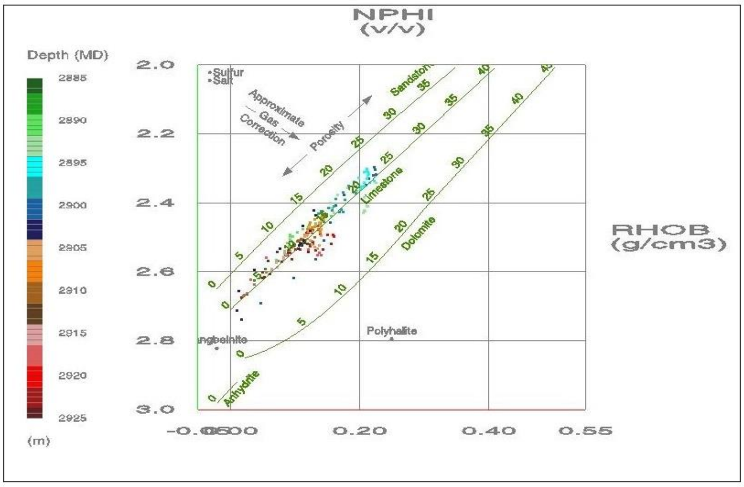

Figure 4-Neutron – Density cross–plot for Mishrif Formation unit MA in Am1.

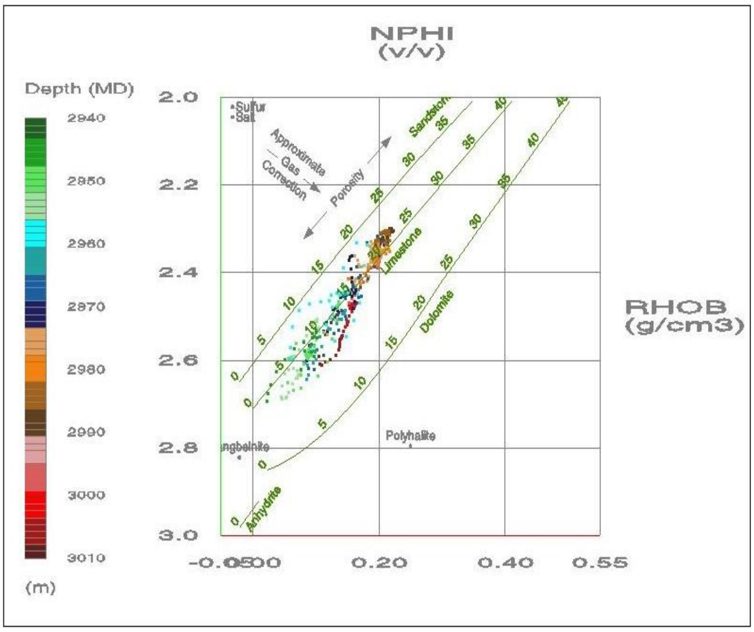

Figure 5- Neutron – Density cross–plot for Mishrif Formation unit MB1 in Am1.

The cross-plot shown in Figure 4 indicates that unit MA consists of mainly limestone with some dolomitic limestone at depths of 2905–2925 m. Figure 5 indicates that unit MB1 consists of mainly limestone with some dolomitic limestone at depths of 2940-2950 m and 3000-3010 m.

Interpretation of well-logging

Figure 6 presents the computer processing interpretation (CPI) of well Am-1, which was achieved by using Geoframe software.

The figure shows that Mishrif Formation is divided into three units (MA, MB, MC). The unit MB is divided into two secondary units (MB1, MB2), while the unit MC is also divided into two secondary units (MC1, MC2). The reservoir units have high porosity, low water saturation, and variable quality. They are separated by tight muddy limestone layers that have high water saturation and missing porosity.

The Mishrif Formation consists of two principal oil-bearing units. The study focuses mainly on the oil-bearing units (MA, MB1) for the presence of good hydrocarbon complex, whereas the unit MC will be regarded as a container of water in the Formation. The units MB2, MC1, and MC2 do not represent reservoirs in the study area, but they may have moderately good reservoir properties, with higher porosity and higher water saturation. Because of the high porosity and low water saturation, MA reservoir unit represents the richest oil-bearing unit of the Mishrif Formation.

Mishrif Formation units of MB2, MC1, and MC2 are characterized by the highest water saturation in Amara wells. They do not have any hydrocarbon indicators. In spite of being characterized by relatively high porosity, they have low permeability. Table 2 shows the petrophysical characteristics of reservoir units in Mishrif Formation.

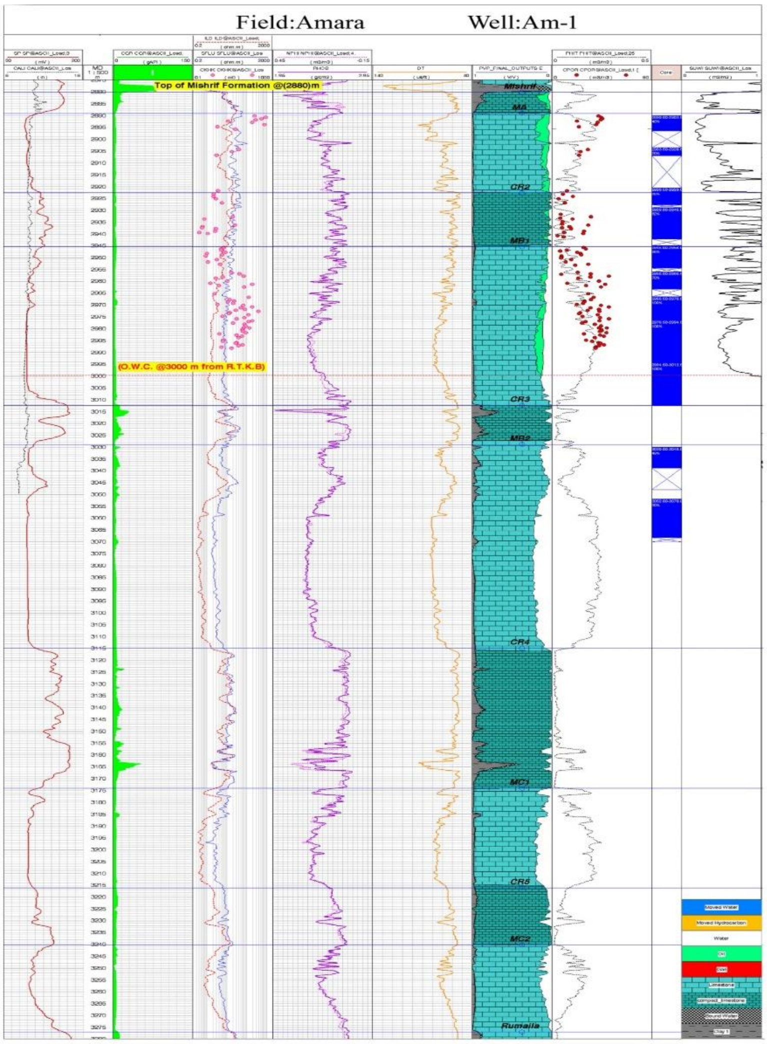

Figure 6- Computer Processes Interpretation of Mishrif Formation in Am-1.

Table 2-Petrophysical characteristics of reservoir units in Mishrif Formation

Borehle Name	Name	Top MD (m)	Bottom MD (m)	Gross Thickness (m)	Net Pay Thickness (md)	Net Pay Gross Thickness Ratio	Net Pay Porosity %	Net Pay Water Saturation %
Am_1	MA	2889	2922	33	25	0.76	0.143	0.287
	MB1	2945	3012.5	67.5	8.5	0.13	0.189	0.463
Am_3	MA	2910.5	2951	40.5	15.460	0.38	0.103	0.318
	MB1	2974	3023	49	2	0.04	0.126	0.376
Am_8	MA	2882	2919	37	36.595	0.99	0.148	0.210
	MB1	2942	3003.3	61.3	38.5	0.63	0.148	0.375
Am_11	MA	2881	2914	33	32.471	0.98	0.170	0.272
	MB1	2936	2994	58	27.75	0.48	0.155	0.428
Am_14	MA	2879	2920	41	37.375	0.91	0.147	0.238
	MB1	2974	3012	38	20.5	0.54	0.130	0.391

Conclusions

Computer processes interpretation showed that the Mishrif Formation in the Amara field can be divided into three units (MA, MB, MC). The MB unit was divided into two sub units units (MB1, MB2) and the MC unit was divided into two secondary units (MC1, MC2), depending on petrophysical properties and well data. The Mishrif Formation consists of two principal oil-bearing units. This study is focused on the oil-bearing units (MA, MB1) with the presence of good hydrocarbon complexes. While units MB2, MC1, and MC2 do not represent a reservoir in the study area, but they may have moderately good reservoir properties such as high porosity and high water saturation.

The unit MA of Mishrif formation is not considered to be fully evaluated because it has been assessed to last prove oil (the contact between the reservoir units and the barrier below it) as L.P.O. (last prove oil), because the oil water contact (OWC) level not determined in Amara wells the oil in place considered prove oil so that the possible oil extended from last prove oil to spill point which can calculated after drilling delineation wells to determine oil water contact.

By using Pickett plot, Archie's parameters were determined. The range values of tortuosity factor, saturation exponent, and cementation factor were found to be 1, 2, and 2, respectively.

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