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Studying the Statistical and Petrophysical of the Mishrif Formation in the Nasiriya Oilfield, Southern Iraq

Fahad M. Al-Najm[1], Mayssa N. Shehab[2], Heba A. Al-Samer [1,*], Mohammed H. Hafiz[2]

[1] Department of Geology, College of Science, University of Basra, Basra, Iraq
[2] Department of Oil and GasEngineering , College of Oil and Gas Engineering, Basrah University for Oil and Gas, Basrah, Iraq
* **Correspondence**: hibaalsamir@gmail.com

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Abstract

The Mishrif Formation was studied in seven wells that were distributed in the Nasiriya Oil-field, southern Iraq, well logs were obtained for these wells and included: Gamma ray, Neutron, Density and Resistivity log. The Nasiriya Oil field is located at the unstable platform Mesopotamian zone. The Mishrif Formation was divided into two rock units, the upper MA and lower MB, separated by insulating shale rocks based on the gamma ray log. Furthemore, the lower rock unit was also divided into two reservoir units MB1 and MB2. The petrophysical properties of the formation were studied using various logs and through realationships between the logs. The petrophysical study of the water and hydrocarbon saturations showed that the formation contains varying proportions and quantities of water and hydrocarbons that can be produced. The research also included a statistical study and calculation of reservoir heterogeneity using two methods: first using the Dykstra-Parsons Coefficient, where the results showed that is, the Lateral extension of the reservoir units of the study wells are heterogeneous, and second using the Lorenz coefficient, where the results showed that wells heterogeneous distribution, while Ns-9 and Ns-16 wells a homogeneous distribution.

Keywords: Mishrif Formation; Nasiriya Oil-field; Statistical; Heterogeneity.

1. Introduction

The Nasiriya Oil-field is located in Dhi Qar Governorate, approximately 38 km northwest of Nasiriya City (Fig.1), between latitude 61° 10´- 57° 50´ and longitude 34° 80´- 34° 60´. The Nasiriya Oil-field located at the stable platform Mesopotamian zone (Jassem and Goff, 2006). The Mushrif Formation deposited during the Cretaceous Period, is one of the important geological formations containing oil in southern Iraq and it represents the second formation from the economic aspect after the Zubair Formation in southern Iraq (Aqrawi et al., 1998). It is considered a major hydrocarbon reservoir in some fields (Awadeesian et al., 2018). The Mishrif Formation contains about 30% of Iraq's total oil reserves (Abdula, 2020).

2. Geological Setting

The Mishrif Formation is one of the formations of the Early Cenomanian – Late Turonian sedimentary cycle within the Megasequence AP8 (Late Tithonian - Early Turonian) (Jassim and Goff, 2006). The Mishrif Formation consists of carbonate rocks deposited in shallow marine environments.

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The thickness of the formation in southern Iraq ranges between 150-200 m, as it increases towards the Iraqi-Iranian border until the thickness of the formation reaches more than 350 m. Its thickness in the study area is between 150-180 m. The stratigraphic seals in Nasiriya Oil-field are based on lithostratigraphic sections Bellen et al. (1959- 2005), as illustrated in Fig.2.

Fig.1. Location map of the Nasiriya Oil-field

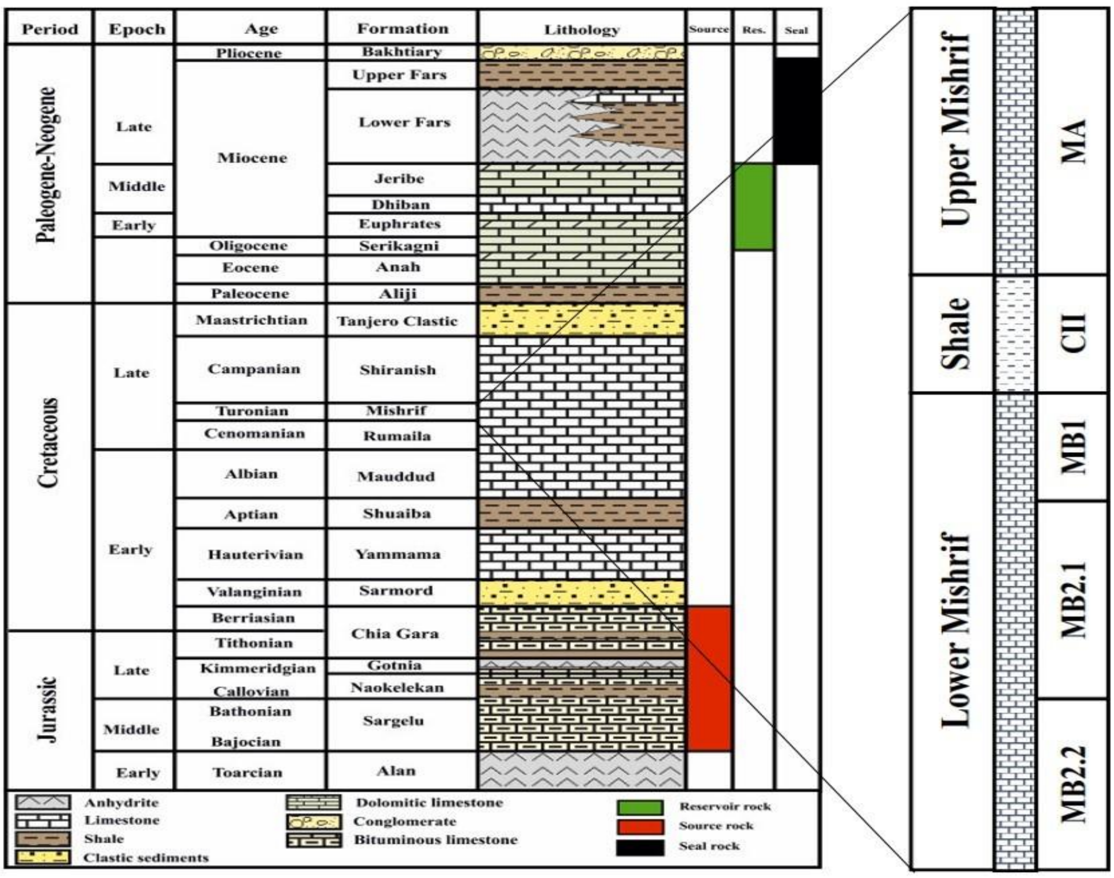


Fig.2. Stratigraphic column of Nasiriya Oil-field

3. Materials and Methods

In this study, seven wells were selected in the Nasiriya Oil-field in southern Iraq (Ns-6, Ns-8, Ns-9, Ns-14, Ns-15, Ns-16 and Ns-20), as shown in the Table.1 and the Fig.3. The statistical analysis of the study wells was conducted by drawing a histogram of gamma-ray, density and neutron log for each of the wells using the Minitab program and representation of the relationships between logs, it is called qualitative interpretation.

Then the petrophysical properties were calculated using the Excel software and represented using the Techlog software Fig.5, it is called the quantitative interpretation. Later, the reservoir heterogeneity was calculated using the Dykstra parson index.

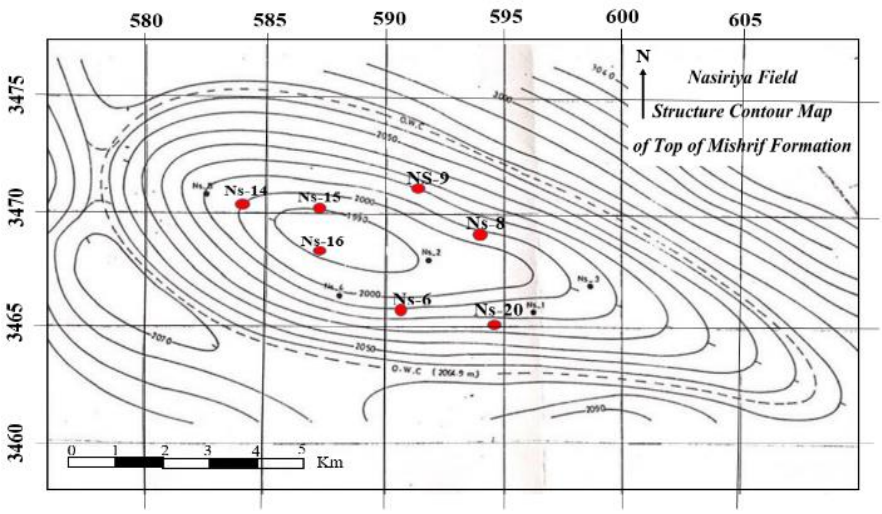


Fig.3. Structure contour map of the location of the study wells of Mishrif Formation in Nasiriya Oil-field

Table 1. The depths and coordinates of the study area wells

Well	Top (m)	Bottom (m)	Thickness (m)	Eastern (m)	Northern (m)	RTKB (m)
Ns-6	1921	2095	174.0	590761	3466471	14.14
Ns-8	1911	2092	181.0	593577	3469783	12.94
Ns-9	1910	2078	168.0	591856	3470315	13.10
Ns-14	1917	2075	158.0	584543	3470654	7.65
Ns-15	1903	2092	189.0	587755	3470783	11.75
Ns-16	1921	2093	172.5	587164	3468607	17.00
Ns-20	1928	2098	169.5	593891	3466609	12.56

4. Results and Discussion

4.1. Qualitative Interpretation

The qualitative interpretation was performed in two different ways: first, by the relationships between Rt & NPHI, second by drawing a statistical histogram of the GR, NPHI, RHOB logs for each well of the study wells to identify the best well in terms of shale content and porosity, the purpose of construction of histograms is to evaluate the petrophysical characteristics (Shale Volume and Porosity) of the wells (Figs. 6,7, 8). Through the relationship between the neutron log NPHI and resistivity log

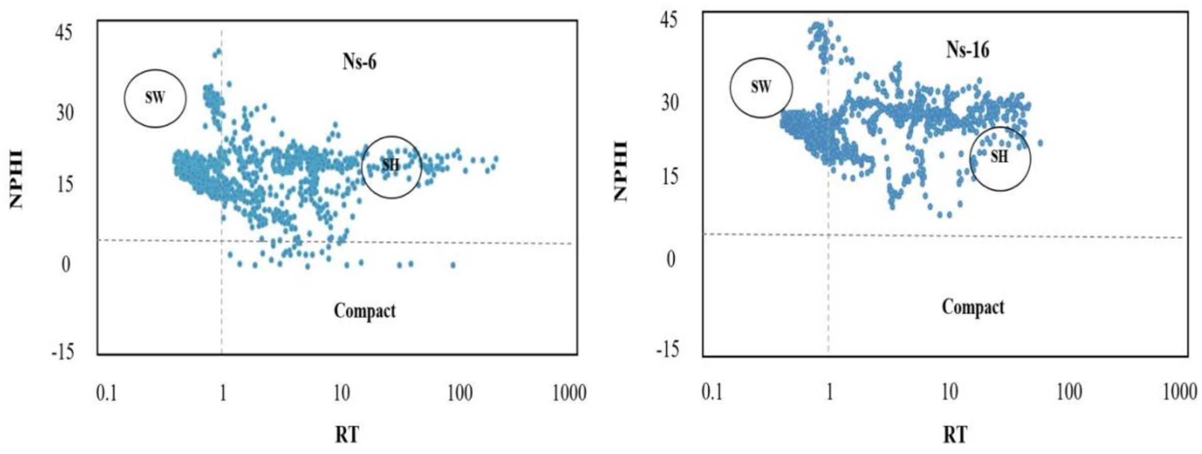
RT, that the wells indicate that they contain of water saturation more than the hydrocarbon saturation, except for the well Ns-6, as shown in the Fig.4.

Through the neutron and density logs, preceive that the correspondence of the density log with the porosity $Ø_N$ is evidence of the presence of limestone. While positive separation, an increase in the value of the density log with porosity $Ø_N$, is evidence of the presence of shale, as explained in Fig.5. Through the statistical histogram charts, it was found that the value of the GR log for the study wells at most depths is less than 20 or 30 API indicates clean limestone, some depths are between 30 – 70 API indicates dirty limestone and depths is more than 70 API indicates shale (Fig. 6).

Based on the reading of the logs for the wells, determined the depths and thicknesses of the Mishrif Formation in the Nasiriya field (Table 2).

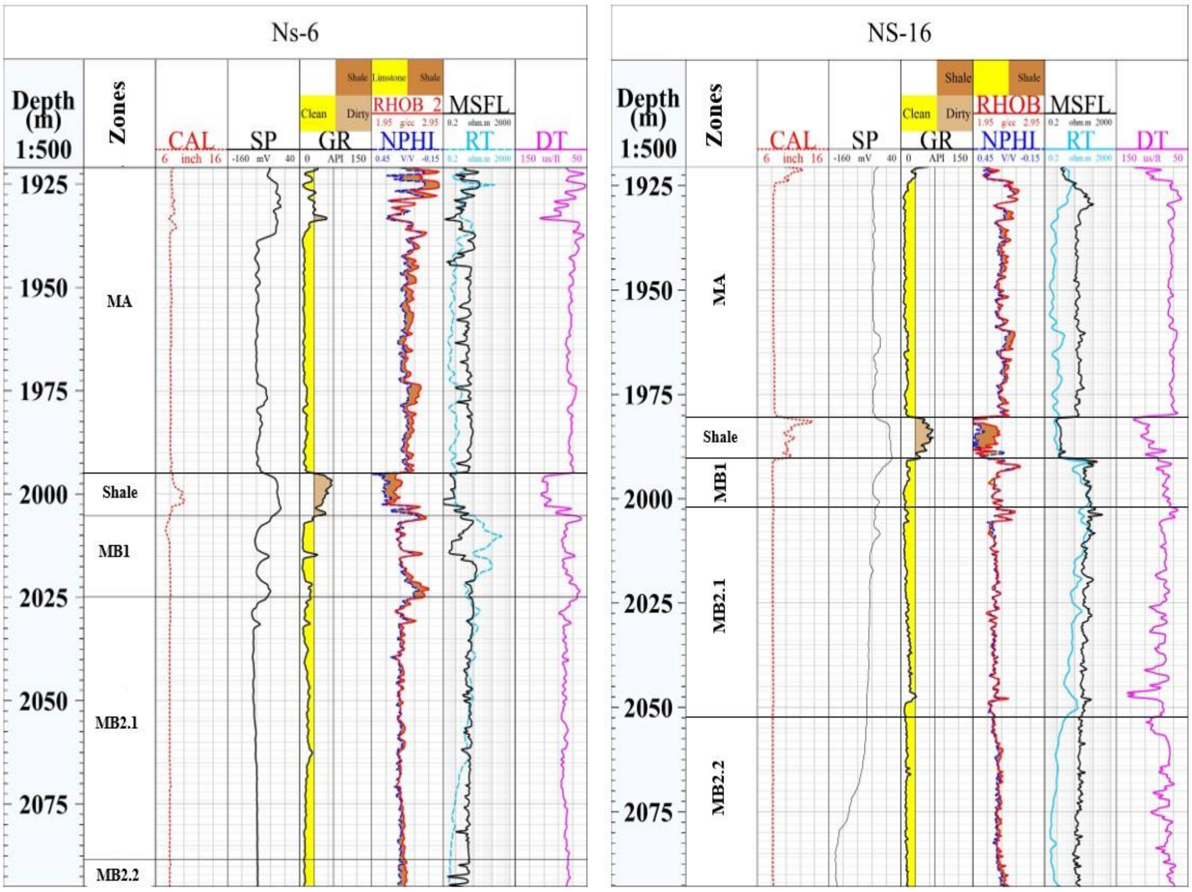
Table 2. The top and thickness for the reservoir units of the study area wells.

Well	Member	Top	Thickness	Well	Member	Top	Thickness
Ns-6	MA	1921.00	73.5	Ns-8	MA	1911.00	65.4
	MB1	2005.32	19.5		MB1	1985.73	19.3
	MB2.1	2024.82	63.6		MB2.1	2005.06	48.1
	MB2.2	2088.45	6.6		MB2.2	2053.18	38.8
Ns-9	MA	1910.03	66.2	Ns-14	MA	1917.00	64.1
	MB1	1987.72	15.1		MB1	1992.47	28.7
	MB2.1	2002.85	47.1		MB2.1	2021.52	31.8
	MB2.2	2049.96	28.2		MB2.2	2053.37	21.6
Ns-15	MA	1903.00	67.7	Ns-16	MA	1922.19	58.2
	MB1	1982.16	14.6		MB1	1990.59	12.1
	MB2.1	1996.75	49.6		MB2.1	2002.67	50.7
	MB2.2	2046.34	45.7		MB2.2	2053.24	39.8
Ns-20	MA	1928.00	59.4				
	MB1	1997.48	14.7				
	MB2.1	2012.22	44.4				
	MB2.2	2056.64	40.9				



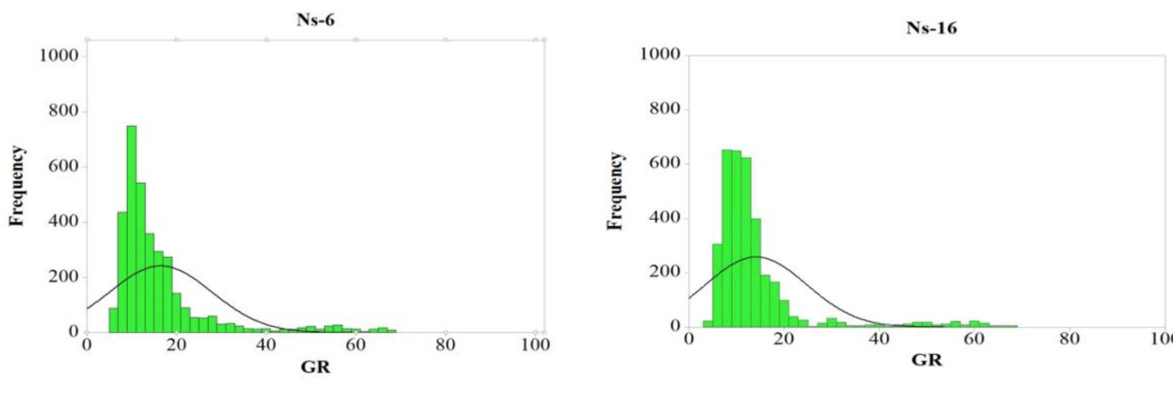
(**a**) (**b**)

Fig.4. (a) Relationship between neutron log (NPHI) & resistivity log (RT) for the well Ns-6; (b) Relationship between neutron log (NPHI) & resistivity log (RT) for the well Ns-16 to determine the hydrocarbon saturation SH rate and water saturation SW rate



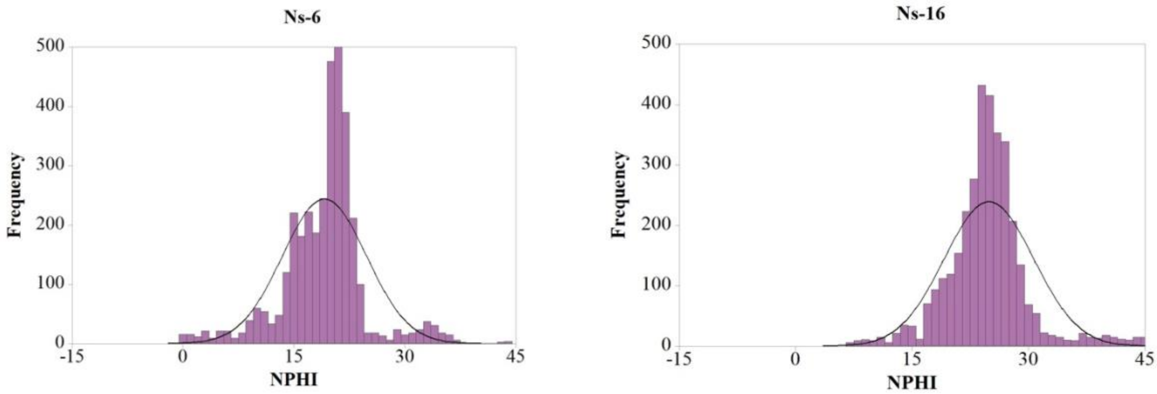
(**a**) (**b**)

Fig.5. (a) It explains the behavior of the well logs for the study well Ns-6; (b) It explains the behavior of the well logs for the study well Ns-16.



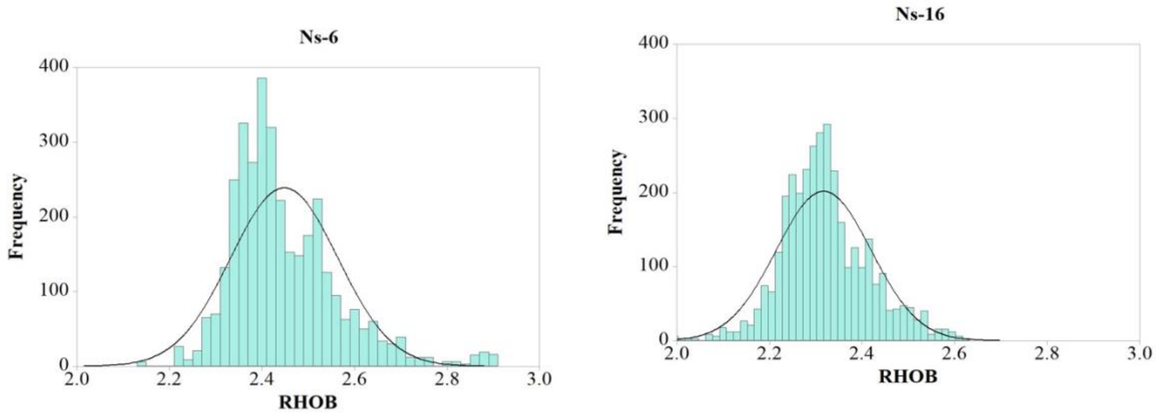
(**a**) (**b**)

Fig.6. (a) Histogram analysis of gamma ray (GR) in Ns-6 well; (b) Histogram analysis of gamma ray (GR) in Ns-16 well.



(**a**) (**b**)

Fig.7. (a) Histogram analysis of neutron log (NPHI) in Ns-6 Well; (b) Histogram analysis neutron log (NPHI) in Ns-16 Well



(**b**)

(**a**)

Fig.8. (a) Histogram analysis of density log (RHOB) in Ns-6 Well; (b) Histogram analysis density log (RHOB) in Ns-16 Well

4.2. Quantitative Interpretation

Using Excell software (2010) for calculation petrophysical properties of Mishrif Formation, then representation by using the Techlog software (2015), is obtained as below equations:

Calculation of Shale Volume (Vsh): Calculated from the gamma ray log (Asquith and Krygowski, 2004).

$$Vsh = (2^{(2*IGR)} - 1)/3, \quad (1)$$

Vsh = shale volume, IGR= gamma ray index.

$$IGR = (GR\ log - GR\ min)/(GR\ max - GR\ min), \quad (2)$$

GR_{log} = log reading (API), GR_{min} = minimum GR, GR_{max} = maximum gamma GR.

Porosity Calculation: Sonic log used to calculate primary porosity (Wyllie *et at* ., 1958).

$$Øs = (\Delta t\ log - \Delta t\ ma)/(\Delta t\ f - \Delta t\ ma), \quad (3)$$

Øs = Sonic – derived porosity, *Δt log* = formation measured by the log, *Δt ma* = the interval transit time in the rock matrix., *Δt f* = the interval transit time in the formation (induction=189).

The density used for determining total porosity using the equation 4 (Wyllie *et al.*, 1958) and equation 5 (Dewan, 1983 in Asquith and Krygowski, 2004):

$$\varnothing D = (\rho\ ma - \rho b)/(\rho\ ma - \rho f)\ , \qquad (4)$$

$$\varnothing De = \varnothing D - Vsh \times \varnothing Dsh, \qquad (5)$$

ØD = density derived porosity, *ρ ma* = matrix density (2.65), *ρ b* = the log reading, *ρ f* = fluid density (1), ØDe = Shale-corrected density porosity.

The neutron log used for determining total porosity by using equation 5 (Dewan, 1983 in Asquith and Krygowski,2004).

$$\varnothing Ne = \varnothing N - (\varnothing Nsh \times Vsh), \qquad (6)$$

ØN = neutron porosity, *ØNe* = Shale-corrected porosity, *ØNsh* = neutron porosity of nearby shale.

The total porosity or effective porosity was calculated by equation 8 in clean zones and equation 9 in shale zones (Schlumberger, 1997).

$$\varnothing N.D = (\varnothing N + \varnothing D)/2, \qquad (7)$$

$$\varnothing N.De = (\varnothing Ne + \varnothing De)/2, \qquad (8)$$

The secondary porosity was calculated (Schlumberger, 1997).

$$SPI = \varnothing N.D - \varnothing S \qquad (9)$$

Calculation of water and hydrocarbon saturation: Water saturation was calculated by using Archie's equation (1944).

$$S_W = \sqrt{\frac{F * Rw}{Rt}}, \qquad (10)$$

S_W = water saturation, Rt = true resistivity recorded by log (Ωm), Rw = formation water resistivity, F = formation factor.

The hydrocarbon saturation (S_h), it is determined by equation (Schlumberger, 1987)

$$S_h = 1 - S_w, \qquad (11)$$

$$BV_W = S_W * \varnothing_{N.D}, \qquad (12)$$

$$BV_h = S_h * \varnothing_{N.D}, \qquad (13)$$

BVw = bulk volume water in the uninvaded zone, BVh = The total volume hydrocarbon.

MOS (movable oil saturation) using the equation (Spain, 1992):

$$MOS = S_{XO} - S_W, \qquad (14)$$

The residual oil saturation (Schlumberger, 1998):

$$ROS = 1 - S_{XO,} \qquad (15)$$

4.2.1. Reservoir units of Mishrif Formation

It was observed that the lithology of the Mishrif Formation in the Nasiriya oil field consists, in general, of clean limestone characterized by low gamma ray log response (Ali et al., 2022), and it was compared with the reading of the logs and the results of the petrophysical calculations, and on its basis the Mishrif Formation was divided into:

- MA Unit (Upper Mishrif) : This part consists of granular carbonate and chalky carbonate rocks , and the rocks of this part are characterized by high porosity ranging between 0.13 and 0.20, The thickness of this part ranges between 58.2 m and 73.5 m, as shown in the Table. 3. It does not contain oil due to the very fine grained nature of its rocks (Exploration, 1989).

Table 3. The petrophysical results of the reservoir unit (MA)

Average			
Well	**Vsh**	**ΦN.D e**	**Sh**
Ns-6	0.08	0.13	0.08
Ns-8	0.05	0.17	0.01
Ns-9	0.04	0.19	0.00
Ns-14	0.03	0.17	0.00
Ns-15	0.04	0.19	0.00
Ns-16	0.12	0.20	0.02
Ns-20	0.06	0.18	0.02

- MB Unit (Lower Mishrif): It is an important reservoir part of the Mishrif Formation because it contains granular limstone rocks, which are considered good reservoir rocks. This type of rock is characterized by high porosity. This part is divided into two subunits, MB1 and MB2:
- MB1 subunit: It is characterized by good reservoir specifications, its thickness ranges between 12.1 m and 28.7 m, and increases towards the well Ns-14 due to an improvement in porosity as shown in Table. 4.

Table 4. The petrophysical results of the reservoir unit (MB1)

Average			
Well	**Vsh**	**ΦN.D e**	**Sh**
Ns-6	0.08	0.15	0.66
Ns-8	0.12	0.15	0.33
Ns-9	0.06	0.20	0.45
Ns-14	0.06	0.22	0.61
Ns-15	0.04	0.23	0.73
Ns-16	0.03	0.25	0.69
Ns-20	0.44	0.13	0.13

- MB2 subunit : This unit has good reservoir specifications in Nasiriya Oilfield wells. It is divided into two reservoir zones: 1) a reservoir zone of high hydrocarbon saturation MB2.1 (Al-Zubaidi et al., 2022), the thickness ranges between 31.8 m and 63.6 m, 2) and a reservoir zone of high water saturation MB2.2, the thickness ranges between 6.6 m and 45.7 m.

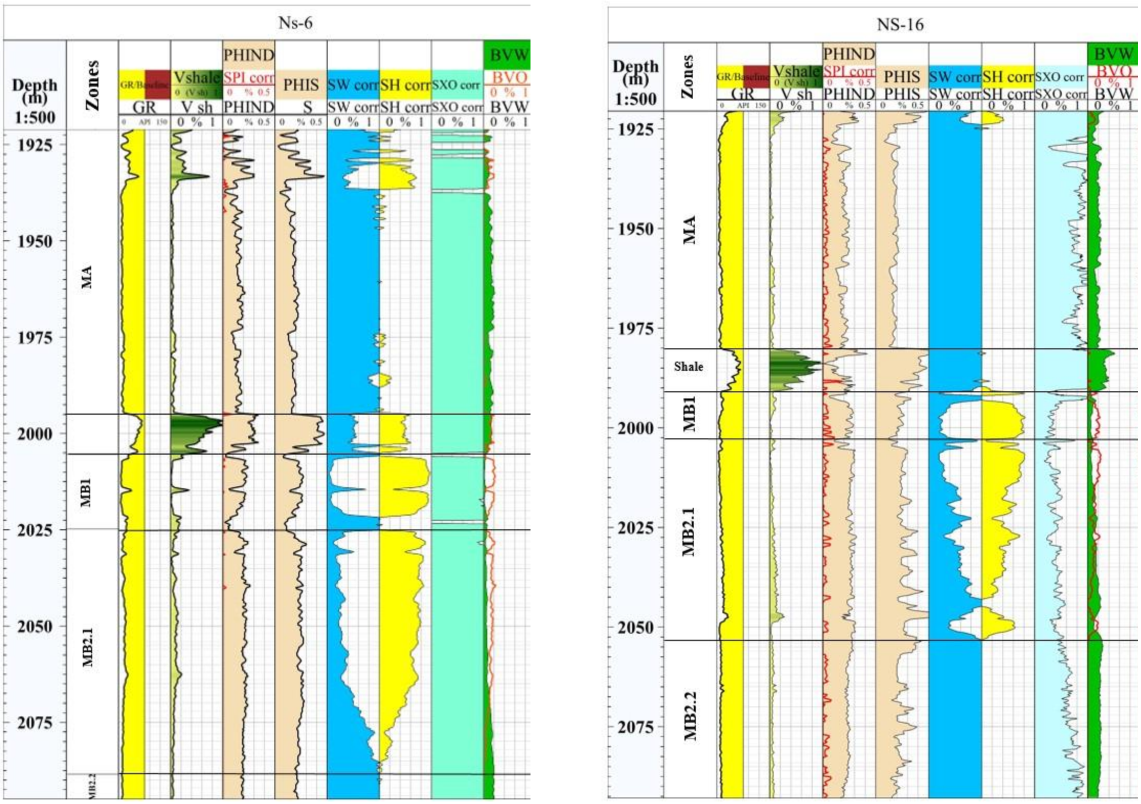
Table 5. The petrophysical results of the reservoir unit (MB2.1)

Average			
Well	**Vsh**	**ΦN.D e**	**Sh**
Ns-6	0.08	0.20	0.56
Ns-8	0.09	0.24	0.46
Ns-9	0.08	0.25	0.40
Ns-14	0.07	0.24	0.31
Ns-15	0.07	0.26	0.42
Ns-16	0.08	0.25	0.37
Ns-20	0.13	0.19	0.26

Table 6. The petrophysical results of the reservoir unit (MB2.2)

Average			
Well	**Vsh**	**ΦN.D e**	**Sh**
Ns-6	0.04	0.19	0.00
Ns-8	0.07	0.21	0.00
Ns-9	0.07	0.23	0.00
Ns-14	0.04	0.23	0.00
Ns-15	0.06	0.22	0.00
Ns-16	0.06	0.23	0.00
Ns-20	0.04	0.22	0.02

The Fig. 9 showed that the effective porosity values of the Mushrif Formation ranged from good to excellent and the primary porosity was equal in all wells of the study. Due to the low influence of diagenesis processes on the formation, such as dolomitization and dissolution, the secondary porosity was observed in the study wells as low or non-existent at some depths. The movable oil saturation and the residual oil saturation were calculated for the study wells, as it was noted in the well Ns-15, Ns-16 and Ns-20 that a percentage of the residual oil saturation higher than the movable oil saturation and this indicates that the permeability is low. As for the wells Ns-6, Ns-8 and Ns-9 the movable oil saturation is higher than the residual oil saturation and this is evidence of a low permeability. As for the well Ns-14 some depths have high permeability and some depths have low permeability.



(**a**) (**b**)

Fig.9. (a) It explains the petrophysical result of the study well Ns-6; (b) It explains the petrophysical result of the study well Ns-16

4.3. Pore Throat Radius (R35)

It can be used to support the flow unit data base as it directly comes from capillary pressure tests or is estimated from log readings (Martin et al., 1997; Gunter et al., 1997). It describes the diameter of the pore throat radius at mercury saturation 35. They discussed about the value of and method for supporting reservoir flow units using R-35. It directly calculates R-35 using Winland's equation (Kolodzie, 1980):

$$\text{Log R35} = 0.732 + 0.588 \text{ Log Ka} - 0.864 \text{ Log } \Phi \,, \qquad (16)$$

Table 7. Classification of porous systems (Pittman, 1992).

Pore Type	Size range (μ)
Mega	>10
Macro	2-10
Meso	0.5-2
Micro	0.1-0.5
Nano	<0.1

R35 was calculated for the MB1 and MB2 reservoir subunits for the formation of the Lower Mishrif for all the wells of the study area through the porosity and permeability that were calculated using the data of the logs, it was discovered to have very large to medium (22.3-1.7 μ) sized pores.

4.4. Permeability Calculation

The ability of a porous medium to transmit fluids is indicated by its permeability (Peters, 2006). A rock's permeability is determined by its effective porosity, which is affected by the grain size, grain shape, grain sorting, cementation, degree of consolidation, shale content, and other characteristics of the rock (Tiab and Donaldson, 2011), the equation of Willie et al.'s (1958) to calculate the permeability:

$$K=[C*(\emptyset^3/Swirr)]^2, \qquad (17)$$

Where: K = permeability (mD), C = constant, its value equal 250 for medium oil and 79 for dry gas, Ø = porosity, Swirr = irreducible water saturation.

Table 8. The values of each R35, K and Ø of the wells of the Nasiriya Oilfield

Well No.	Reservoir Units	Pore type	R-35	Φ	K
Ns-6	MB1	Mega	22.3	15.16	604.3
	MB2	Macro	4.6	20.13	62.3
Ns-8	MB1	Mega	17.9	15.32	423.6
	MB2	Macro	4.7	22.52	77.7
Ns-9	MB1	Macro	5.1	19.75	73.4
	MB2	Macro	3.0	24.44	40.9
Ns-14	MB1	Macro	5.9	21.81	109.4
	MB2	Macro	2.8	23.67	35.1
Ns-15	MB1	Mega	12.3	22.67	398.5
	MB2	Macro	3.8	24.24	58.3
Ns-16	MB1	Mega	11.8	25.18	434.1
	MB2	Macro	2.4	25.13	28.7
Ns-20	MB1	Macro	3.8	13.18	24.8
	MB2	Meso	1.7	20.77	11.5

4.5. Degree of Heterogeneity Calculation

4.5.1. Dykstra Parson Coefficient V_k

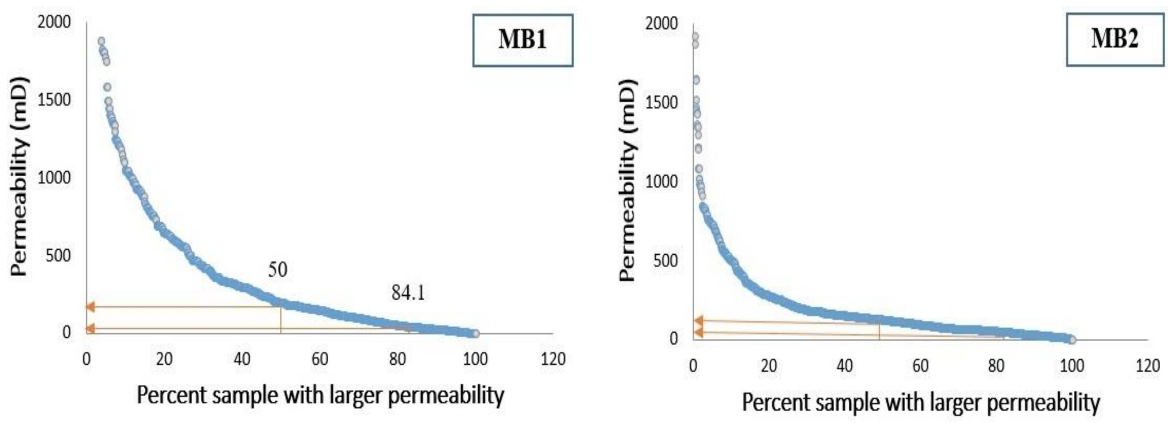
Permeability heterogeneity was quantified using Coefficient of Permeability Variation of Dykstra and Parsons (1950) as explained by Jensen et al. (2000). The Dykstra-Parsons Coefficient is an excellent tool for characterizing the degree of reservoir heterogeneity. The term Vk is also called the Reservoir Heterogeneity Index (RHI). A log probability graph with the cumulative probability values shown in Fig. 10, the initial permeability values are displayed. The 50th and 84th probability percentiles are then determined from this plot's slope and intercept, which are used in equation to derive Vk for all data. The Dykstra Parsons Coefficient has the following definitions. The Dykstra-Parsons coefficient ranges from a minimum of 0 (homogeneous) to a maximum of 1.0 (heterogeneous). Abbas and Mahdi (2020) mentioned that the petrophysical heterogeneity of the reservoir units within the Mishrif Formation is due to variations in porosity, water saturation and fluid volume. $K50$: Permeability value at the 50 percentile, K84.1: Permeability value at the 84.1 percentile.

$$Vk = (K50 - K84.1) / k50, \qquad (18)$$

Table 9. The value of Dykstra-Parsons Coefficient in reservoir units of the study wells

Well	Vk of MB1	Vk of MB2
Ns-6	0.98	0.59
Ns-8	0.77	0.50
Ns-9	0.37	0.33
Ns-14	0.76	0.49
Ns-15	0.76	0.47
Ns-16	0.49	0.43
Ns-20	0.56	0.58

The heterogeneity in the reservoir was determined for the extension of the unit MB1 and MB2 for the wells of the study as shown in the Fig.10. The results showed that the value of the cofficient of the unit extension MB1 is 0.57 for the study wells and the value of the coefficient of the unit MB2 is 0.64. That is, the lateral extension of the reservoir units of the study wells are heterogeneous.



(**a**) (**b**)

Fig.10. (a) The Dykstra-Parson Coefficient of Permeability Variation (mD) for reservoir unit MB1 of the study wells; (b) The Dykstra-Parson Coefficient of Permeability Variation (mD) for reservoir unit MB2 of the wells

4.5.2. Lorenz coefficient L_k

The cumulative storage capacity and the cumulative flow capacity are used to calculate L_k, a statistical measure of heterogeneity (Handhal et al., 2019). The distribution of reservoir permeability is homogeneous if L_K=0, but the distribution of reservoir permeability is heterogeneous if L_K = 1 (Tiab and Donaldson, 2015). Homogeneous wells for Lk< 0.5 obtained a 0 code, whereas heterogeneous wells for Lk > 0.5 obtained a 1 code.

Table 10. The value of Lorenz Coefficient Lk for the study wells

Well	K (md)	Ø	Lk	Status
Ns-6	95.50	0.16	0.78	1
Ns-8	81.74	0.19	0.63	1
Ns-9	24.91	0.22	0.32	0
Ns-14	31.96	0.20	0.59	1
Ns-15	60.16	0.22	0.51	1
Ns-16	174.30	0.23	0.41	0
Ns-20	8.67	0.19	0.60	1

0 means homogeneous; 1 means heterogeneous.

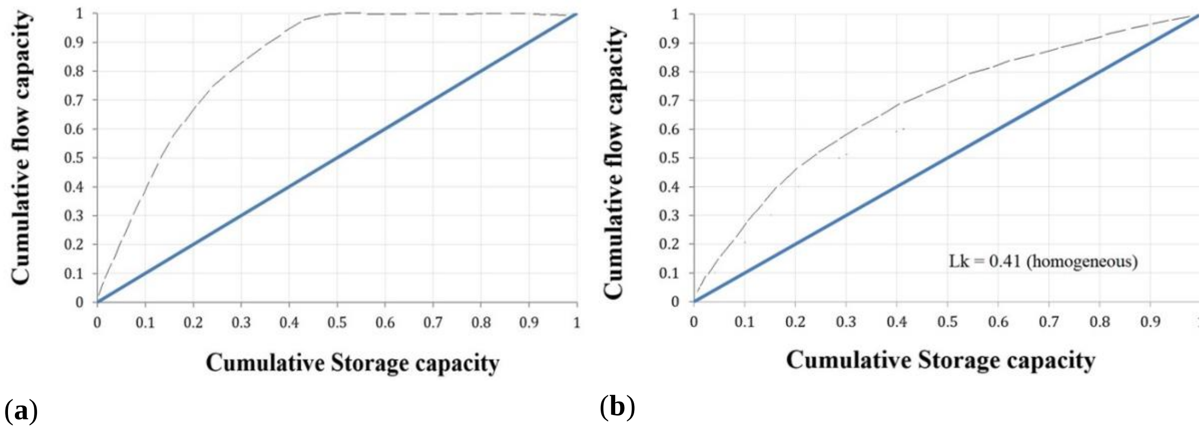


Fig.9. (a) Lorenz coefficient *Lk* for Ns-6; (b) Lorenz coefficient *Lk* for Ns-16.

5. Conclusions

The Mishrif Formation in the Nasiriya oil field is mainly composed of clean limstone, dirty and a few percentage of shale in all study wells, which was determined using well logs. It was possible to divide the Mushrif Formation into two units (MA and MB) using CPI through various petrophysical properties such as shale valume , effective porosity, water saturation and hydrocarbon saturation, the upper MA and lower MB, separated by insulating shale rocks, based on the gamma ray log, the lower unit MB was divided into two reservoir units MB1 and MB2. The wells indicate that they contain of water saturation more than the hydrocarbon saturation, except for the well Ns-6. Using the data of the logs and R35 calculated, it was discovered to have very large to medium (22.3-1.7µ) sized pores. The results showed that the value of the Dykstra-Parsons cofficient of the unit extension MB1 is 0.57 for the study wells and the value of the coefficient of the unit MB2 is 0.64, and the value of the Lorenz coefficient for (Ns-6, Ns-8, Ns-14, Ns-15 and Ns-20) wells had a heterogeneous distribution, while (Ns-9 and Ns-16) wells had a homogeneous distribution.

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