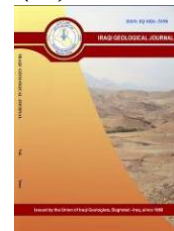




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Quantitative Interpretation of the Petrophysical Properties of Selected Wells for the Mishrif Formation in Nasiriyah Oilfield, Southern Part of Iraq

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Abstract

One of the oil field's main reservoirs is the Mishrif Formation, which is found in the Nasiriyah oilfield in the southern part of Iraq (Late Cenomanian-Early Turonian). It was one of the three oil wells selected for this study. To extract various petrophysical parameters for open wells indicated by gamma ray, density, neutron, self-potential, acoustic, and resistance, a variety of well logs were analyzed. The qualitative interpretation of the logs allowed for the identification of different types of rocks, the boundaries and thicknesses of the strata, the depths of the formation, and the zones that contained water and hydrocarbons. The quantitative interpretation, which assesses the reservoir's attributes by computing its porosity, the quantity and distribution of the shales, the levels of water and oil saturation, and other elements, that are necessary to evaluate the reservoir's units in the research wells. The features of the study wells and the used logs were reported, to make clear how these features were distributed among the sample wells. The collected petrophysical characteristics were handled and shown as charts. There are two types of units within the Mishrif Formation: reservoir-containing CR-I, MA, CR-II, and MB. In most wells, reservoir units are made up of hard, low-porous rocks that are positioned between highly porous reservoir units. For a few wells, the MA unit had low residual and mobile hydrocarbon percentages, whereas the MB unit had large percentages, while the hard rocks had significant percentages of water saturation.

Keywords: Quantitative interpretation; Petrophysical properties; Mishrif Formation; Nasiriyah oilfield

1. Introduction

The Mishrif Formation, which is a component of the Wasi'a Group, is a common Cenomanian-Early Turonian carbonate sequence found in the Arabian Gulf and its environs (Al-Sharhan and Narin, 1988).

The Mishrif Formation is one of the sedimentary strata of the Late Cenomanian-Early Turonian period, it is also one of the most important reservoirs in the Mesopotamian Basin of the central and southern parts of Iraq (Al-Naqib, 1967; Al-Ali et al., 2019). The Nasiriyah oil field is located in the Dhi Qar Governorate, about 30 km northwest of Nasiriyah City (Al-Khafaji, 2015). The topography of the study area is characterized by being a plain area including some swamps and marshy areas and covered by recent river deposits dating back to the Quaternary Period. Abbas et al. (2023); Al-Mashhdani and

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Al-Zaidy (2023) studied the Mishrif Formation in the southern part of Iraq and concluded that there are five environments within the Mishrif Formation, which are narrow marine environment, shallow marine environment, shallow open marine environment, biostrome, and deep marine environment. They also divided the formation into four units (CR-I, MA, CR-II, and MB).

In order to determine petrophysical parameters and analyze the Mishrif Formation reservoir's properties, this study uses wire line logs.



Fig. 1. Map of the study area Nasiriyah oilfield (Al-Khafaji, 2015)

2. Tectonic and Geologic Setting

The Mishrif Formation, corresponds to the Early Albian-Turonian series IV of the stratigraphic framework of the Iraqi Cretaceous Sequence, with the vast Megasequence AP8 deposited on the passive border of the Arabian Plate as a result of tectonic movement and eustatic movements. The Mishrif Formation was deposited in the second depositional cycle of the strata formerly known as the Middle Cretaceous and originated in the Mesopotamian Basin in southern and central parts of Iraq.

The study area is a portion of the Mesopotamian belt, which is further subdivided into the tectonic subzones of the Euphrates, Tigris, and Zubair. The Euphrates Sub-Zone provides geological evidence for this subdivision, which exhibits more significant rates of subsidence associated with the Thick Mishrif Formation. According to Jassim and Goff (2006), the Early Cenomanian-Turonian deformation of the northern Tethyan border of the Arabian Plate resulted in structural uplifts and depressions in various orientations that served as the boundaries for each of these subzones.

Between the Khasib Formation above and the Rumaila Formation below, the Mishrif Formation is situated in a stratigraphic position where the contact between them is an unconformity. In several wells in southern and central parts of Iraq, the Kifl anhydrite facies comfortably cover the Mishrif

Formation facies, suggesting the conclusion of the sedimentary cycle and the last stage of marine retreat (Abbas et al., 2023; Alsultan et al., 2022).

The Nasiriyah oilfield is an anticline not faulted with dimensions of 30×10 km and extends northwest to southeast; with a structural closure of 65 meters at the highest surface of the Mishrif Formation. The region experienced significant tectonic activity from the Upper Jurassic to the Cenomanian periods, leading to lateral movements primarily directed towards the southwest. This geological dynamic status; played a pivotal role in shaping the landscape, giving rise to elongated, slender folds characterized by gentle undulations and a dominant northwest-southeast axial orientation. The far-reaching repercussions of these tectonic shifts were notably evident in the composition and deposition of sediments throughout the Mesozoic and Cenozoic eras in Iraq. These folds and their associated geological processes left a lasting imprint on the region's geological history (Alsultan, 2016; Al-Zaidy and Al-Shwaliay, 2018; Awad and Alsultan, 2020; Alsultan and Awad, 2021). It is possible that the formation at Nasiriyah vicinity may have been due to slight and recent lateral movements at a time dating back to the movement of the Alpine Orogeny in the Miocene Epoch, and this movement that occurred from the east and northeast of the western plate affected the long folds of the western plate. Small amplitude and its amplitude increased to form homogeneous folds in the northwest and southeast directions (Jassim and Goff, 2006).

3. Methodology

Involved the gathering of preliminary data from the wells in the research area's final reports, as well as the identification of the wells housing the needed study-related logs and their associated data. The petrophysical properties (Vsh, porosity, water, and hydrocarbon saturation) were interpreted using the interactive petrophysical software Techlog v.15 program. The Mishrif Formation was divided into many units following those petrophysical properties. Using the Neutron-Density cross plot for lithology identification, the Techlog software was also used to determine the lithology and mineralogy of the rocks of the Mishrif Formation.

4. Results

4.1. Qualitative Interpretation

The qualitative interpretation was done by studying the behavior of the open well logs (the curves) used in the current study. Through the SP-log, the permeable and impermeable layers were determined, as well as determining the thickness of the layers. Since the deviation of the SP-log depends on the contrast in the salinity between the drilling mud filtrate and the formation water, therefore, it gives a negative deviation in the case of the mud filter with less salinity than the formation water, while it gives a positive deviation when the formation water is fresh (Schlumberger, 1989). Since the studied formation is under great depth and its water content is salty, the SP deviates in a negative left direction against the permeable layers and towards the baseline against the impermeable layers.

We observed through the behavior of the GR-log in wells that radioactive elements tend to be concentrated in muds and shales, whereas clean formations have a low concentration of radioactive elements (Schlumberger, 1989). This is due to the GR-log, which measures the content of shales in the formation. In the studied area, the Mishrif Formation is regarded as one of the clean formations; since there aren't many log readings in areas that are covered by rocks including some shale layers.

As for the neutron log, it is used in qualitative and quantitative interpretations, mainly in deducing an image of the formation's pores and determining their porosity; directly. Since the neutron log is designed to specifically sense the hydrogen present in the formation therefore, it is possible to depend on this log to determine the porous areas in the formation by recording high values against the layers

containing oil or water, since these fluids contain a high amount of hydrogen. A resistivity log also can be used to confirm the type of fluid that fills the pores. The log records low values in front of the gas-containing layers in the pores of the rocks because it contains a small amount of hydrogen as compared to oil and water. Among other applications of neutron log, and in partnership with the density log, is the determination of the rockiness in the Mishrif Formation, which is represented by calcareous limestone with overlapping of dolomitic limestone at some depths.

As for resistivity logs, which are a function of the type of rock fluid (Asquith and Krowski, 2004), resistivity logs are used to determine the water-bearing and hydrocarbon-bearing regions, that is, they are used to indicate the permeable regions shown in Fig. 1 and Table 1.

Table 1. Tops of reservoir and cap units for the Nasiriyah oilfield

Well I.D.	Kifil (m)	CR-I (m)	MA (m)	CR-II (m)	MB (m)	Rumaila (m)
NS-19	1894.879	1905.233	1919.877	1985.29	1995.587	2052.905
NS-25	1883.095	1894.95	1910.553	1982.056	1997.386	2059.339
NS-32	1882.483	1902.619	1918.979	1980.525	1991.165	2053.809

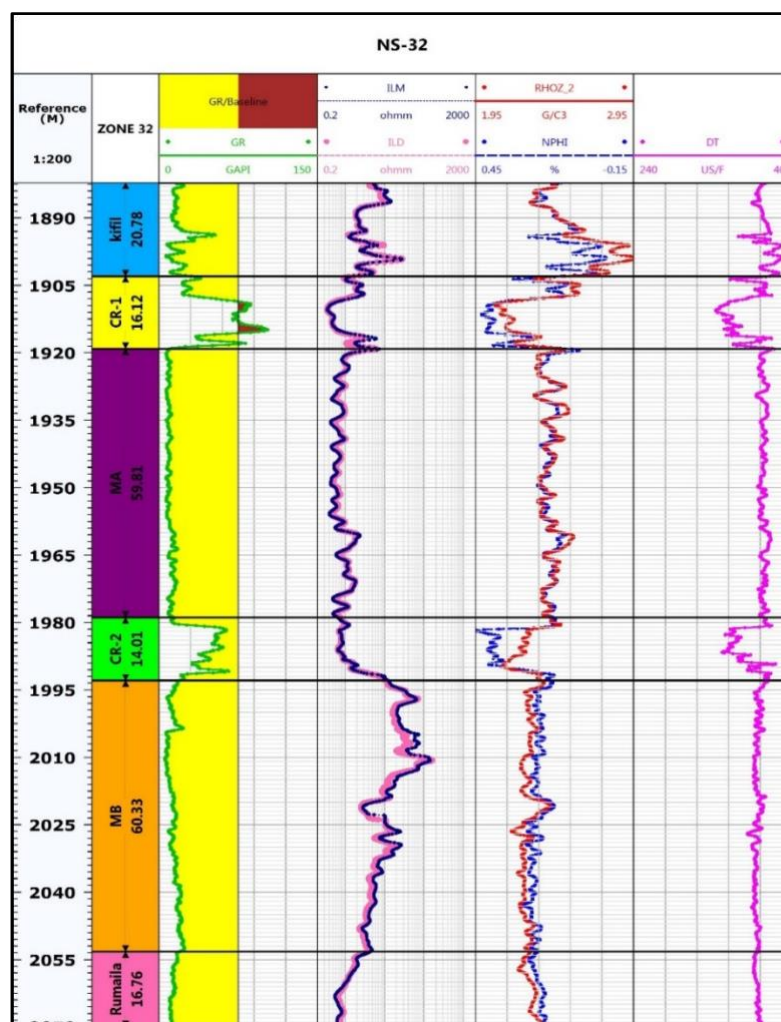


Fig.1. Qualitative interpretation of the Mishrif Formation in the well NS-32

4.2. Inclosures of Quantitative Interpretation

The study of rock characteristics and how they interact with fluids (such as gases, liquid hydrocarbons, and aqueous solutions) is known as Petrophysics.

The following petrophysical characteristics are covered in this research:

Shale volume,
Porosity, and
Water saturation.

4.2.1. Shale volume determination from GR log:

The gamma-ray log measures the strength of the natural radioactivity present in the formation. It is particularly useful in distinguishing sand from shale in siliciclastic environment (Darling, 2005). Since the GR tool measures any radiation emitted by the rocks, therefore, rocks with low amounts of radiation are called clean rocks such as limestone and sandstone, these are more likely to contain hydrocarbons than dirty rocks. Clean sandstone may also produce a high gamma-ray response if the sandstone contains potassium, feldspar, mica, or uranium-rich waters (Asquith and Krygowski, 2004). GR-log has been used for:

Formations in correlation in which the curves are examined for similarity in gross lithology and magnitude Reservoirs often have a lower radioactivity level than shale. When estimating the amount of shale, the concentration of shale in the formation affects the amplitude of the gamma-ray ~~there~~ in comparison to surrounding clean zones. The first step in determining the volume of shale from a gamma-ray log is to calculate the gamma-ray index (Asquith and Krygowski, 2004).

$$I_{GR} = \frac{GR_{Log} - GR_{min}}{GR_{mix} - GR_{min}} \quad (1)$$

IGR = gamma ray index

GRlog = gamma ray reading by log (API units)

GRmin= minimum gamma (clean sand or carbonate)

GRmax= maximum gamma ray (shale)

As the Mishrif Formation is considered to include old rock, therefore, the shale volume (V) used in this study is the Larionov (1969) older rocks (Asquith and Krygowski, 2004):

$$V_{Sh} = 0.33 \times (2^{(2 \times IGR)} - 1) \quad (2)$$

4.2.2. Porosity

4.2.2.1. Calculation of Porosity

The calculation of the porosity is the most crucial feature of a reservoir rock because it provides a gauge for the ability to store hydrocarbons (Lucia, 2007). It may be calculated in a variety of ways, including by examining the underlying data or using investigative data.

- *Neutron log porosity*

The neutron log is used in qualitative and quantitative interpretations, mainly in deducing an idea about the pores of the formation and determining their porosity directly. Since the neutron log is designed to specifically sense the hydrogen present in the formation therefore, it is possible to rely on this log to determine the porous areas in the formation by recording high values against the layers containing oil or water, since these fluids contain a high amount of hydrogen. A resistivity log can also be used to confirm the type of fluid that fills the pores. The neutron log records low values in the gas-containing layers in the pores of the rocks because it contains a small amount of hydrogen as compared to oil and water. Among its other applications, and in partnership with the density log, is the

determination of the rockiness in the Mishrif Formation, which is represented by calcareous limestone with the overlapping of dolomitic limestone at some depths.

As for resistivity logs, which are a function of the type of rock's fluid, the resistivity logs are used to determine the water-bearing and hydrocarbon-bearing regions, ~~that is~~, they are used to indicate the permeable regions.

The neutron log directly measures the porosity of the shale-free depths. As for the shale-containing depths, the following equation (Tiab and Donaldson, 1996) was used:

$$\phi_{Nc} = \phi_N - (\phi_{N(sh)} \times V_{sh}) \quad (3)$$

ϕ_N : 'porosity derived from neutron Log'

ϕ_{Nc} : 'porosity derived from neutron Log and corrected by the effect of the shale'

$\phi_{N(sh)}$: 'Neutron porosity of the adjacent shale'

V_{sh} : 'is the shale volume'

- *Density log porosity*

The Greek letter ρ , which stands for density, is used to represent grams per cubic centimeter or g/cm³. The matrix density (ρ_{ma}) and the bulk density (b or RHOB) are the two different density values that the density log uses. According to the logging tool's measurements, the bulk density is the density of the whole formation's solid and liquid components. The rock's sturdy framework's density is known as the matrix density.

When the matrix density (ρ_{ma}) and the density of the liquid-filled (ρ_f) are known, porosity may be calculated from the bulk density of clean liquid-filled formations (Asquith and Krygowski, 2004). One of the porosity logs, such as density, can be used to calculate porosity as well according to Wiley's equation (1958, Wiley et al.)

$$\phi_D = \frac{(\rho_{ma} - \rho_b)}{(\rho_{ma} - \rho_f)} \quad (4)$$

ϕ_D = porosity measured from Density log.

ρ_{ma} = Density of the dry rock (g/cm³)

ρ_f = Density of fluid (g/cm³)

ρ_b = 'The total density of a formation is taken from the log values and measured in unit (g/cm³)'.

Taking into consideration that the porosity of the fill is equal to 2.71 g/cm³ because in this study the formation is limestone and the value equals 1 g/cm³ for freshwater or 1.1 g/cm³ for salt clay.

- *Neutron-Density cross plot for lithology identification*

Neutron-Density crossplots help to determine the lithology of pure lithology such as sandstone, limestone, or dolomite, which are oil- or water-filled formations. If the formation is heterogeneous, such as dolomitic cemented sandstone, then the density-neutron cross plot analysis can be misleading.

Neutron-Density multi-crossing plots for many wells, were marked with red dots, showing the best match for the set of points (Figs. 2, 3, and 4), most of which lie on the limestone curve in units of CRI, MA, CRII, and MB, which are the main components of the lithology of the Mishrif Formation. There are a few points distributed on the dolomite and sandstone curves in the Nasiriyah oilfield.

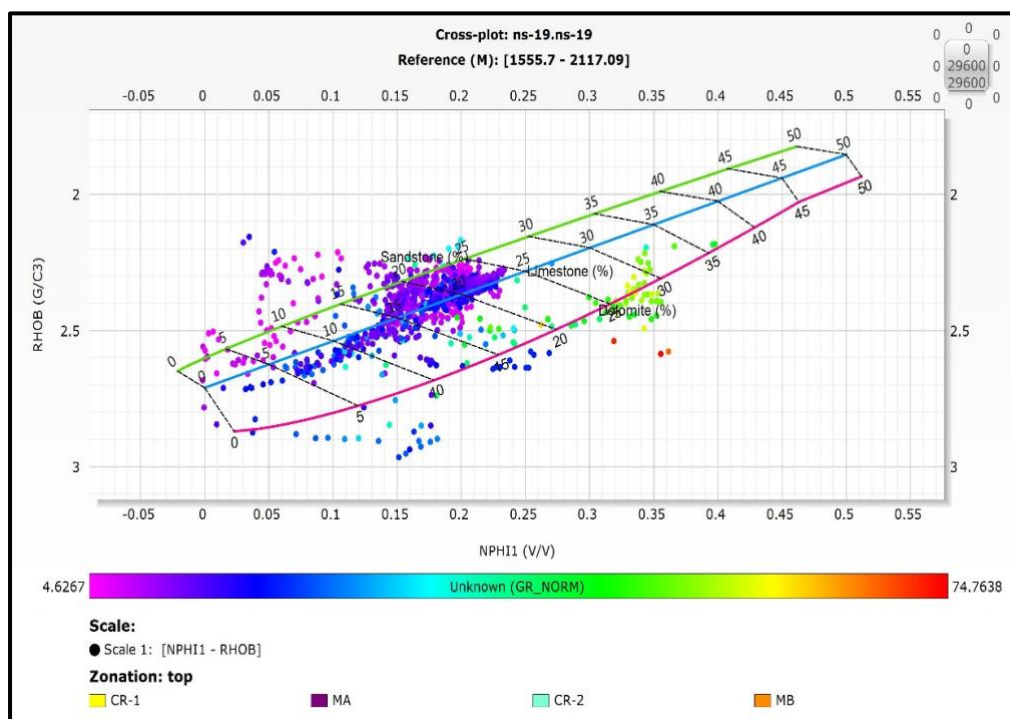


Fig.2. Cross plot of Neutron porosity and Density porosity for the well NS-19

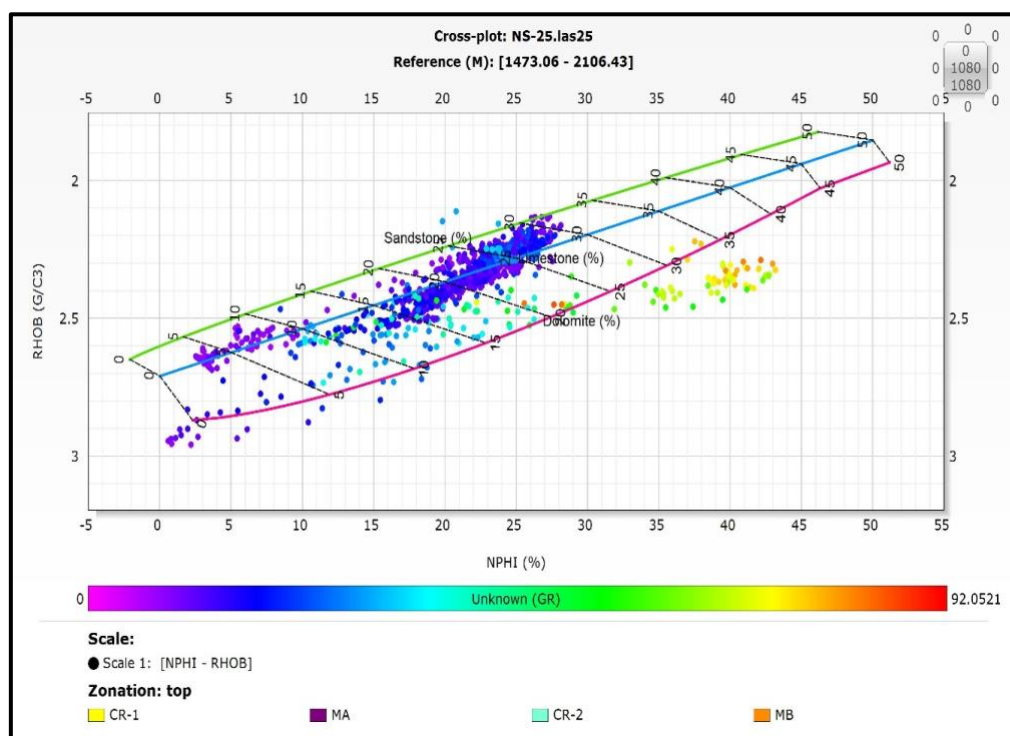


Fig.3. Cross plot of Neutron porosity and Density porosity for the well NS-25

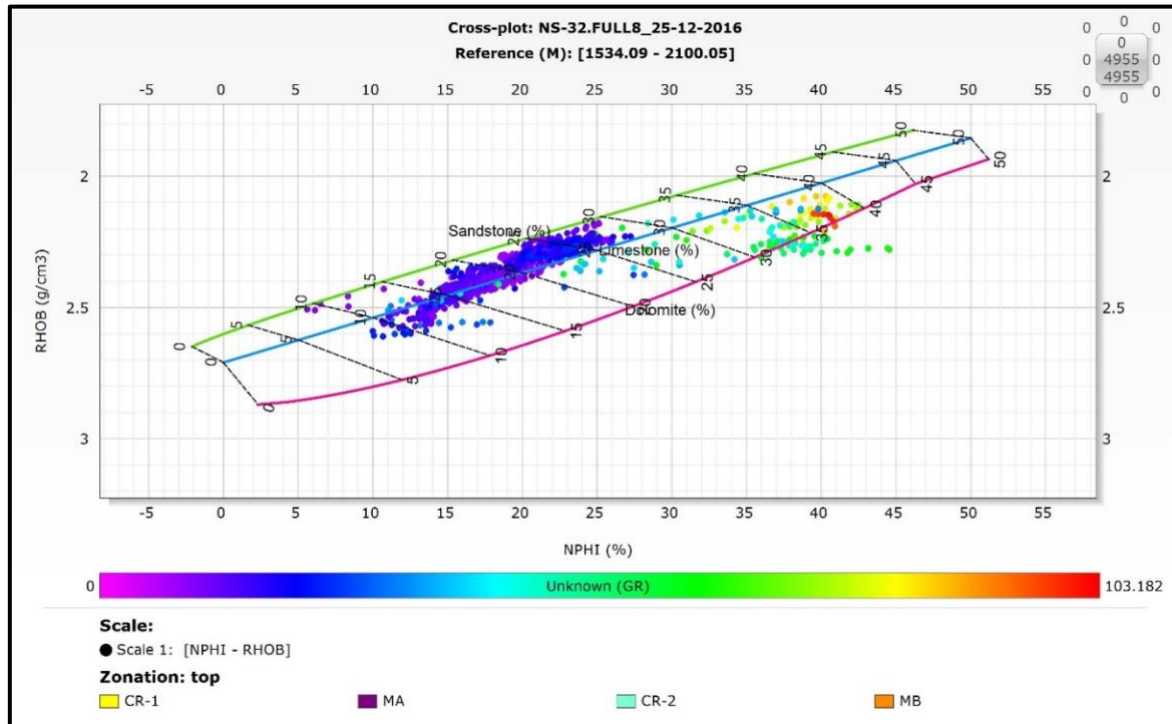


Fig.4. Cross plot of Neutron porosity and Density porosity for the well NS-32

4.2.3. Porosity determination

The porosity of a reservoir affects how much oil it can hold; hence, the petroleum engineer considers measuring the porosity to be crucial. Differentiating between various forms of porosity is required (Bowen, 2003).

The percentage difference between the pore volume and the reservoir rock's bulk volume is known as the porosity of a rock.

$$\text{Percentage porosity} = \frac{\text{pore volume}}{\text{bulk volume}} \times 100 \quad (5)$$

Where:

Bulk volume= the total volume of the rock

Pore volume= the volume of the pores between the grains

4.2.3.1. Total porosity

Total porosity is the proportion of a rock's total pore space to its bulk volume. The equation provided by Schlumberger (1974) can be used to calculate the total porosity from the density and neutron porosities:

$$\phi_T = \frac{\phi_N + \phi_{ND}}{2} \quad (6)$$

ϕ_T : The total porosity, calculated from the density and neutron logs, for the oil and gas carrier regions.

4.2.3.2. Effective porosity

According to Bowen (2003), effective porosity is defined as the ratio of the volume of linked pores to the total volume of reservoir rocks.

$$\phi_E = \phi_T \times (1 - V_{SH}) \quad (7)$$

ϕ_T : The total porosity

ϕ_E : The effective porosity

V_{sh} : Volume of shale

4.2.4. Determination of Archie's parameters

Applying Archie's equation requires figuring out the parameters or coefficients that are affected by the kind of pore. Numerous inaccuracies in the assessment of saturation, particularly in the estimation of the volume of oil in situ, are brought on by uncertainty over the values of these factors. According to (Al-Khafaji et al., 2022), the cementation exponent (m) is the primary variable that contributes to errors in calculating saturation.

To calculate m and/or a from well logs, Pickett (1966) proposed a technique based on a cross plot between resistivity vs. porosity. This strategy is explained using the logic below. Pickett (1966) asserts that.

$$R_t = \frac{a}{\phi^m} \times \frac{R_w}{S_w^n} \quad (8)$$

S_w : water saturation (fraction)

R_w : water resistivity (ohm-m)

ϕ^m : is the porosity (fraction)

R_t : Resistivity of the uninvaded zone (ohm-m), and, a , n , and m are Archie's parameters (dimensionless).

In a water-bearing zone, $S_w = 1$; Equation (8) where m is the slope and $(a.R_w)$ is the intercept at $\phi = 1$, is an equation of a straight line on a log-log plot. R_w is known from other sources; therefore, a can be discovered quickly.

$$\log R_t = -m \log(\phi) + \log(a \times R_w) - n \log(S_w) \quad (9)$$

In a water-bearing zone, $S_w = 1$; thus Eq. (9) can be reduced to:

$$\log R_t = -m \log(\phi) + \log(a \times R_w) \quad (10)$$

Archie's parameters were obtained by Pickett's plot for wells NS-19, NS-25, and NS-32 ($a=1$, $m=1.94$, $n=2$) either value ($R_w=0.027$).

4.3. Evaluation of the Mishrif Formation's Zonation

The main reservoir in the Nasiriyah oilfield is composed of limestone distributed alternatively in the formation, which plays a role in improving the petrophysical properties.

Lithologically, the Nasiriyah oilfield is divided from top to bottom into the following units (CR-I, mA, CR-II, and MB) by following the regional divisions in the region.

Fig. 5, represents the distribution of petrophysical properties in the studied wells of the Nasiriyah oilfields elucidating shale volume calculation, total and effective porosity, and water saturation. All these factors affect the quality and quantity of oil in each reservoir unit, where the higher the porosity and the less water saturation; the unit will be more productive.

4.3.1. Cap rock (CR-1)

The thickness of this unit is around 14-15 m in the studied wells of the Nasiriyah oilfield and it is composed of limestone rocks with a high shale percentage, with extremely poor reservoir properties, but shows oil stains in oil well NS-19. This unit can be found in all of the studied wells. The studied 3

oil wells have a porosity that ranges between 0.11–0.27 and water saturation ranges between 0.92–1 (Table 2 and Fig. 5).

4.3.2. Reservoir unit (ma)

The reservoir unit has a thickness of 61-71 m in the studied wells of the Nasiriyah oilfield, and it is composed of limestone, with minor clay content in certain wells and pure in others. During this time, weak oil evidence and oil occurred, and the results of the analysis and interpretation of the logs revealed that it contained reservoir water in the Nasiriyah oilfield. A porosity ranges between 0.16–0.19 for the Nasiriyah oilfield, and the water saturation ranges between 0.80-0.87 (Table 2 and Fig. 5)

4.3.3. Cap rock (CR-2)

The thickness of this unit is around 10-14 m in the wells of the Nasiriyah oilfield and it is composed of limestone with a high shale percentage, with extremely poor reservoir properties, but shows oil in well NS-32. This unit can be found in all of the studied wells. The 3 studied wells have porosity ranges between 0.24-0.30 and water saturation ranges between 0.83-0.98 (Table 2 and Fig. 5).

4.3.4. Reservoir unit (mb)

In the studied wells of the Nasiriyah oilfield, the thickness of this unit ranges between 57–62 m. This section of the formation is defined by the rocks of the Rumaila Formation, which are below the reservoir unit, and the Ma layer, which is above it. This unit can be found in all of the studied wells. The studied 3 wells have porosity ranges between 0.18–0.25 and water saturation ranges between 0.20–0.43. This unit is thought to be the most significant part of the Mishrif Formation and is also thought to have favorable properties for the reservoir (Table 2 and Fig. 5).

Table 2. Interpretation values of Mishrif Formation in the Nasiriyah oilfield

Well NA.	Units	PHIE	PHIT	SW	VSH
NS-19	CR-1	0.06	0.11	0.92	0.17
	MA	0.17	0.19	0.87	0.01
	CR-2	0.11	0.24	0.98	0.41
	MB	0.15	0.18	0.43	0.05
NS-25	CR-1	0.04	0.11	1	0.24
	MA	0.02	0.17	0.8	0.02
	CR-2	0.07	0.24	0.9	0.54
	MB	0.23	0.25	0.2	0.07
NS-32	CR-1	0.11	0.27	0.9	0.53
	MA	0.16	0.16	0.96	0.01
	CR-2	0.18	0.3	0.83	0.44
	MB	0.21	0.23	0.23	0.05

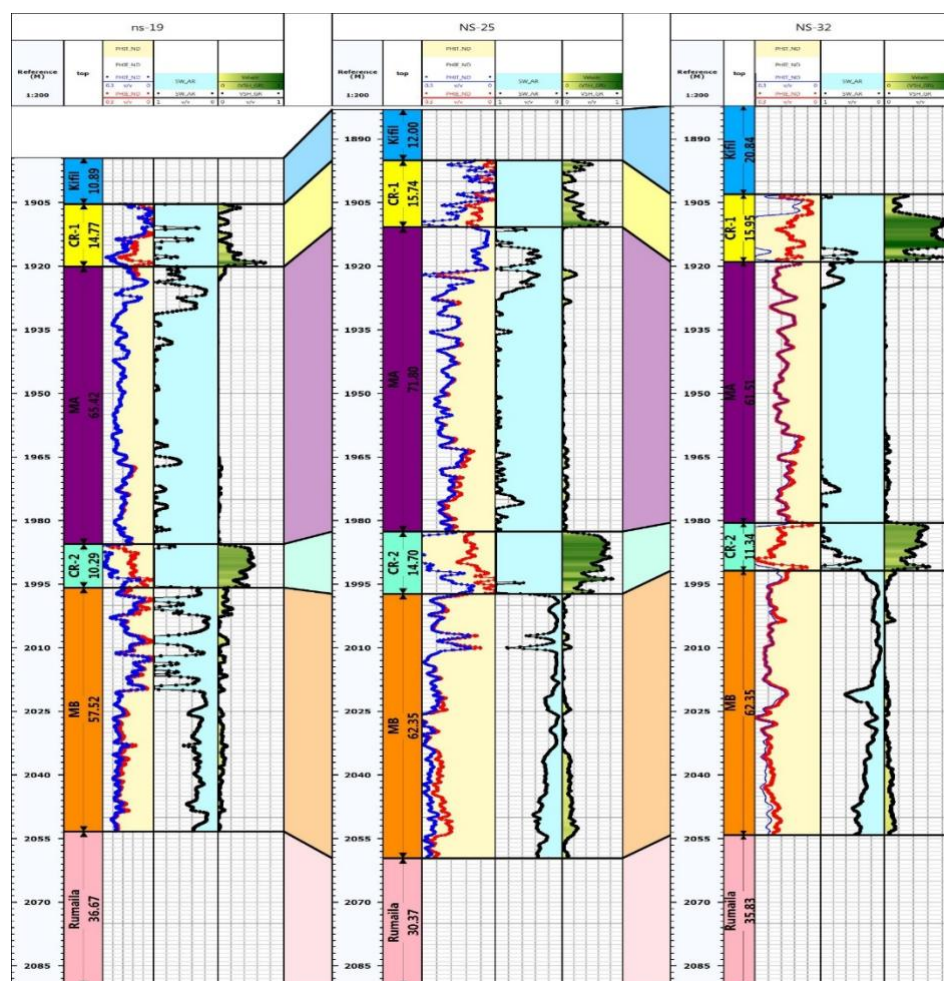


Fig.2. Vertical Cross section in direction N-S shows a correlation of the Mishrif Formation in the Nasiriyah oilfield in wells NS-19, NS-25, and NS-32

5. Conclusions

In the current research, the Techlog v.15 program and available logs such as (gamma radiation log, density log, neutron log, acoustic log, and resistivity logs), were used to indicate the petrophysical characteristics of the Mishrif Formation, which include calculating and studying the volume of oil shale, porosity of all kinds, and water saturation. The Mishrif Formation is divided into four units (CR-I, MA, CR-II, and MB) including reservoir and non-reservoir units. Reservoir units are highly porous in most of the studied wells and are separated by hard rocks with low porosity. The percentage of residual and mobile hydrocarbons was low in the MA unit and high in the MB unit for selected wells, while the percentage of water saturation was high in the hard rocks.

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