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# Petrophysical Evaluation of Mishrif Formation Using Well Logging in North Nasiriya Oil Field

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**Abstract**
The Mishrif Formation (Cenomanian – Early Turonian) is an important geologic formation in southern Iraq due to its petrophysical properties and geographic extensions, making it a good reservoir of hydrocarbons. Petrophysical properties of the Mishrif Formation in the current study at the Nasiriya oil field were determined from the interpretation of three open-hole logs data of (NS-1, NS-2, and NS-3) wells.
The results of the Mishrif petrophysical evaluation showed that the formation consists of five variable units (CRI, MA, CRII, MB1 and MB2), each one characterized by distinct petrophysical characteristics.
The upper (MA) and lower (MB) units were determined using electrical, porosity and gamma-ray logs. A shale seal separates the two units (CRI and CRII). The main reservoir units in the formation are MB1 and MB2 characterized by high moveable hydrocarbon compared with the residual hydrocarbon. These units are separated by barrier rocks (BR) consisting of marly limestone.

**Keywords:** Petrophysical Properties, Gamma-ray log, Mishrif Formation, Nasiriya oil Field.

# التقييم البتروفيزيائي لتكوين مشرف بإستخدام الجس البئري في حقل شمال الناصرية النفطي

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**الخلاصة**
نظراً لخصائصه البتروفيزيائية وامتداداته الجغرافية، فإن تكوين مشرف يعد من التكوينات الجيولوجية المهمة في جنوبي العراق، وهذا ما يجعله يُشكل مكمن هيدروكربوني جيد في جنوب العراق. حددت الدراسة الحالية الخصائص البتروفيزيائية لتكوين مشرف في حقل الناصرية النفطي وذلك من خلال تفسير البيانات الجسية لثلاثة ابار (NS-1،NS-2 وNS-3). وأظهرت النتائج البتروفيزيائية للدراسة الحالية أن تكوين مشرف، وفي الابار الثلاثة، يمتلك خمس وحدات متغايرة، حيث أن كل وحدة من هذه الوحدات لها خصائص بتروفيزيائية تميزها عن الوحدات الأخرى. وسُميت هذه الوحدات بـ (MB2, MB1, CRII, MA, CR1).
حُدِدت الوحدتين العليا (MA) والسفلى (MB) باستخدام المجسات الكهربائية ومجسات المسامية ومجس أشعة

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كاما. تُفصل هذه الوحدتين عن بعضها بصخور طفلية حاجزية تتمثل بـ (CRII, CRI). وتمثل الوحدتين MB1 و MB2 الوحدتين المكمنيتين الأساسيتين في التكوين، حيث تتسم بمحتواها الهيدروكربوني العالي فضلاً عن النسب العالية للهيدروكربونات المتحركة مقارنة بالهيدروكربونات المتبقية. وتنفصل هاتين الوحدتين عن بعضهما بصخور حاجزية (BR) تتألف من الحجر الجيري المارلي.

**Introduction**

The oil field studied is located in the Dhi-Qar governorate in southern Iraq, about 38 km to the northwest of Nasiriya city (Figure 1). Five exploratory oil wells were drilled in the field and showed the presence of oil in three reservoirs of Cretaceous age (Mishrif, Yamamah, and Nahr Omar formations) [1]. The Mishrif Formation (Cenomanian-Early Turonian) is an important formation in southern Iraq due to its petrophysical properties and geographic extensions, making it a good reservoir of hydrocarbons after the Zubair Formation that occupies the first order economically.

The Nasiriya oilfield is located within the stable shelf of the Arabian plate. The recent seismic surveys (1987-1988) indicate subsurface folds and domes. Folding is generally characterized by non-large extent (30 x 10 km) with N-S and NW-SE trending. These anticlines are unaffected by fractures, with a structural closure of 65 m at the top surface of the Mishrif Formation (the main reservoir formation in the field) with a slight inclination of 1-2 degrees dipping NE-SW, with the basement rocks of 9-10 km deep [2]. According to [3], the Nasiriya oil field represents an anticlinal fold that extends about 30 km long and about 10 km wide, located at the unstable platform Mesopotamian Basin zone [4].

The Mishrif Formation represents a heterogenous formation originally described as organic detrital limestones, with beds of algal, rudist, and coral-reef limestones, capped by limonitic freshwater limestones [5]. The Mishrif Formation reservoir comprises limestone, containing several zones and oil-producing units [1]. The Mishrif crude oils in the Nasiriya oil field can be classified as one group of oils, non-biodegraded and marine, non-waxy originating from organic matter deposited in anoxic marine environments [6].

The main aim of this study is to evaluate the petrophysical properties of the reservoir rocks in the Nasiriya oil field, such as shale volume, porosity, permeability, fluid saturation, and weight and movement of Hydrocarbons.


**Figure 1-** Location of the study area [7].

**Materials and Methods**

Petrophysical properties of the Mishrif Formation at Nasiriya oil field were determined from the interpretation of conventional logs data of NS-1, NS-2, and NS-3 wells. The petrophysical data were interpreted using the Interactive Petrophysics version 3.5 (IP). The data used in the present study consists of gamma-ray, neutron, density, resistivity and sonic logs, which are used in evaluating petrophysical properties including porosity (Ø), permeability (k), water saturation ($S_w$), and hydrocarbon saturation ($S_h$).

**1- Shale volume (Vsh) Calculation:**

To determine the volume of shale (Vsh) from a gamma-ray log, the following formula for older rocks from the gamma-ray index (GRI) equation is used:

$$I_{GR} = \frac{GRlog - GRmin}{GRmax - GRmin} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where: IGR = gamma-ray index, GRlog = gamma-ray reading by log (API), GRmin= minimum gamma (clean sand or carbonate), GRmax= maximum gamma-ray (shale).

The shale volume was computed by using the following formula for older rock [8]:

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

**2- Porosity Determination:**

The Mishrif Formation's porosity was calculated from neutron and density logs, and with regard to the density log, the following equation has been used:

$$ØD = \frac{(\rho ma - \rho b)}{(\rho ma - \rho f)} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where: ØD = porosity by density log, $\rho_{ma}$ = density of the dry rock (g/cm$^3$) in this study = 2.71(g/ cm$^3$) for limestone formation, $\rho_f$ = density of fluid (g/cm$^3$), $\rho_b$ = bulk density recorded by log.

When shale volume is more than 10%, the following equation [9] is used to remove the shale effect from porosity calculation:

$$ØDcor. = ØD - (Vsh \times ØD_{sh}) \quad \ldots\ldots\ldots\ldots\ldots (4)$$

The Neutron read is already in porosity units. If the shale volume is more than 10%, the following equation is used:

$$Ø NCor = ØN - (Vsh * ØN_{sh}) \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Where: $Ø D_{sh}$ = Density porosity for shale, $ØN_{sh}$ = Neutron porosity for shale, $\rho_{sh}$ = bulk density of shale.

To obtain porosity from the sonic log, a modified Wiley equation is used:

$$\phi_S = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

The following equation is used when the volume of shale is more than 10%:

$$Ø_{Scor.} = Ø_S - (Vsh \times Ø_S\text{-}sh) \quad \ldots\ldots\ldots\ldots\ldots (7)$$

Where: $Ø_S$= sonic-derived porosity, $\Delta t_{ma}$ = interval transit time in the matrix, $\Delta t_{log}$ = interval transit time in the formation, $\Delta t_{fl}$ = interval transit time in the fluid of the formation, $Ø_S$-sh = porosity of shale from the sonic log.

By a combination of Neutron-Density logs, the total porosity of the Mishrif Formation was determined. Schlumberger in1974 proposed an equation to compute the total porosity from neutron and density logs that expressed as:

$$ØT = \frac{\Phi Ncor + \Phi Dcor}{2} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

The effective porosity (Øe) can be determined by the following equation [9]:

$$\emptyset e = \emptyset t \times (1 - Vsh) \quad (9)$$

Finally, the secondary porosity is calculated using the following [9] formula

$$SPI = (\emptyset t - \emptyset_{Scor}) \quad (10)$$

**3- Permeability Calculation:**

The conventional method was used to correlate core permeability and porosity measurements, and to use the resulting porosity - permeability transform for the calculation of the permeability from porosity logs. Schlumberger chart (K3) is used to calculate the absolute permeability from porosity logs (Φ) and irreducible water saturation [10]

$$K = 10000\, \emptyset_e^{4.5} / S_{wi}^{2} \quad (11)$$

Where: k= permeability, $S_{wi}$ = irreducible water saturation, $\emptyset_e$ = effective porosity.

**4- Water and Hydrocarbon Saturation Estimation:**

The water saturation (SW) value is important in the well-log analysis to determine the movement of hydrocarbons from movable oil saturation. The water saturation of the wells of the study area was calculated using the following equations [11].

$$S_W = (FR_w/R_t)^{1/n} \quad (12)$$

$$S_{XO} = (FR_{mf}/R_{xo})^{1/n} \quad (13)$$

Where: $S_W$ = water saturation of the uninvaded zone (%), $S_{xo}$= water saturation of flushed zone (%), n= saturation exponent and its value is equal to 2 for carbonate rocks, F= Formation Factor, $R_w$ = formation water resistivity (Ωm.), $R_t$= the true resistivity of formation (Ωm.), $R_{mf}$ = mud filtrate resistivity (Ωm.), and $R_{xo}$= flushed zone resistance (Ωm.).

**5- Weight and Movement of Hydrocarbons Calculation:**

The calculation of the water saturation ($S_w$) is not sufficient for fully evaluating the oil-range productivity, so one must calculate:

**A-** The total water volume in the flushed and uninvaded zones of the drilling mud according to the following equations [12]

$$BVW = Sw\emptyset \quad (14)$$

$$BVxo = Sxo\emptyset \quad (15)$$

Where: BVW= Total water volume of the uninvaded zone and BVXO= Total water volume of the flushed area.

**B-** Volume of total hydrocarbons (movable and non-movable) from the equation:

$$BVO = Sh * \emptyset \quad (16)$$

Where: BVO=Total volume of hydrocarbons.

3- The oil saturation of the movable hydrocarbons from equation [13]:

$$MOS = Sxo - Sw \quad (17)$$

Where: MOS = movable oil saturation

4- Saturation of oil waste (non-movable): calculated by the following equation:

$$ROS = 1 - Sxo \quad (18)$$

Where: ROS=Saturation of oil reducible.

**Results**

Based on the Interactive Petrophysics (IP) software (V.3.5), the current study interpreted the petrophysical properties of the Mishrif Formation. The results of mathematical averaging calculations of the shale volume show that the shale volume is varied with the depth of all wells, where the maximum shale volume is observed in zone-3. Other zones have variable values of volume and the minimum values were observed in zone-2 (Figure 2).

In addition to that, the mathematical calculation of porosity results also shows that porosity varies with depth. It can be seen from Figure 3 that the porosity in the wells is varied from unit to another, where the maximum effective porosity is observed in zones 2, 4, and 6. The minimum effective porosity is observed in zone 3. Secondary porosity is not significant and can be neglected.

According to [14], there are four permeability classes (Table-1). The permeability was classified in the study area as very high and high, and it was classified as fair in a few locations (Figure 4). The Permeability is different from well to other, and zone 6 has higher values. The oil could be accumulated in zones 2, 4, and 6, while most water is accumulated in zones 2, as shown in Figure 5.

The area between ($Phie$) and ($B$Vxo) represents the residual hydrocarbon. The area between ($B$Vxo) and ($B$VW) represents the movable hydrocarbon, as shown in (Figure 6).

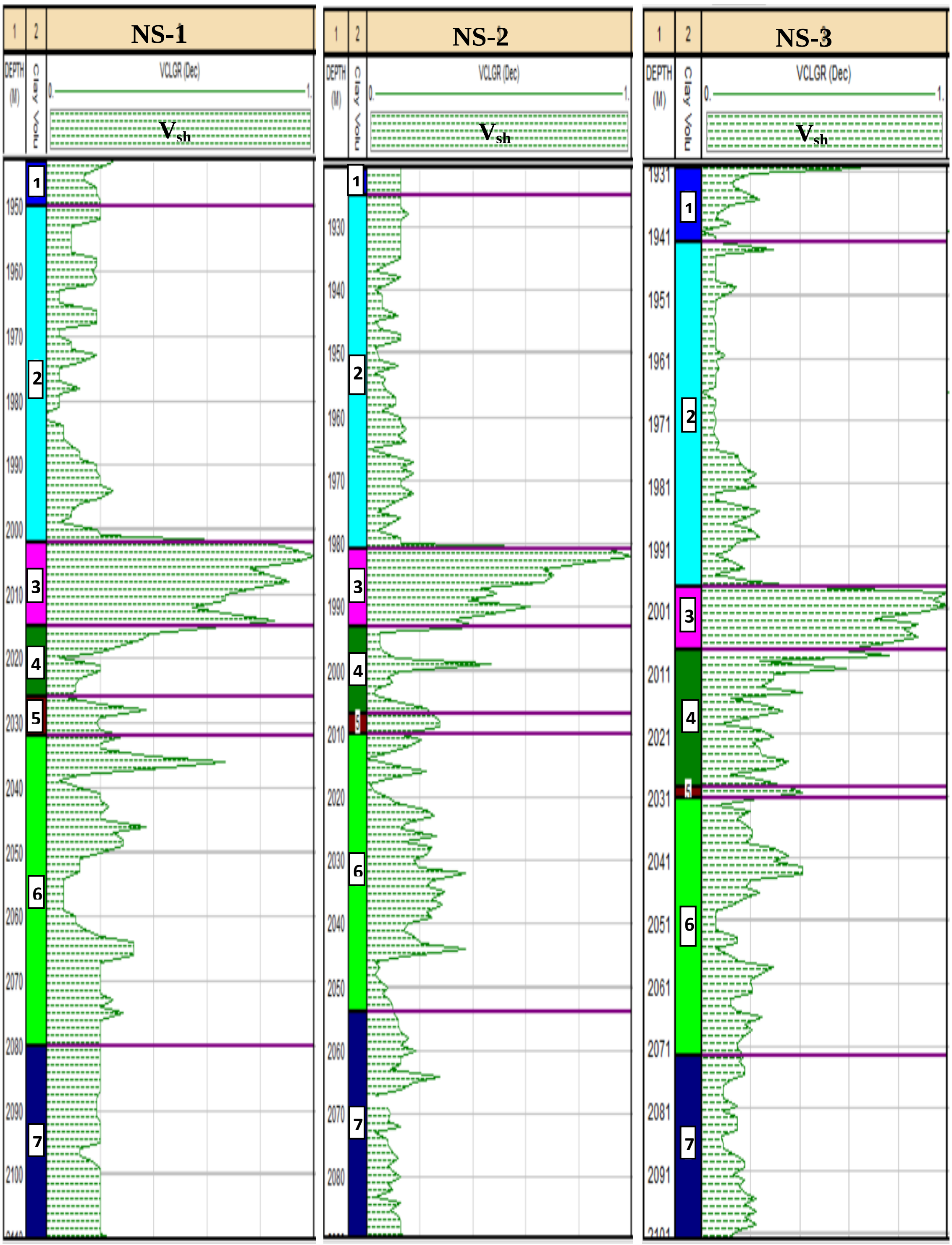


**Figure 2-** Volume of shale curves for Mishrif Formation in studied wells

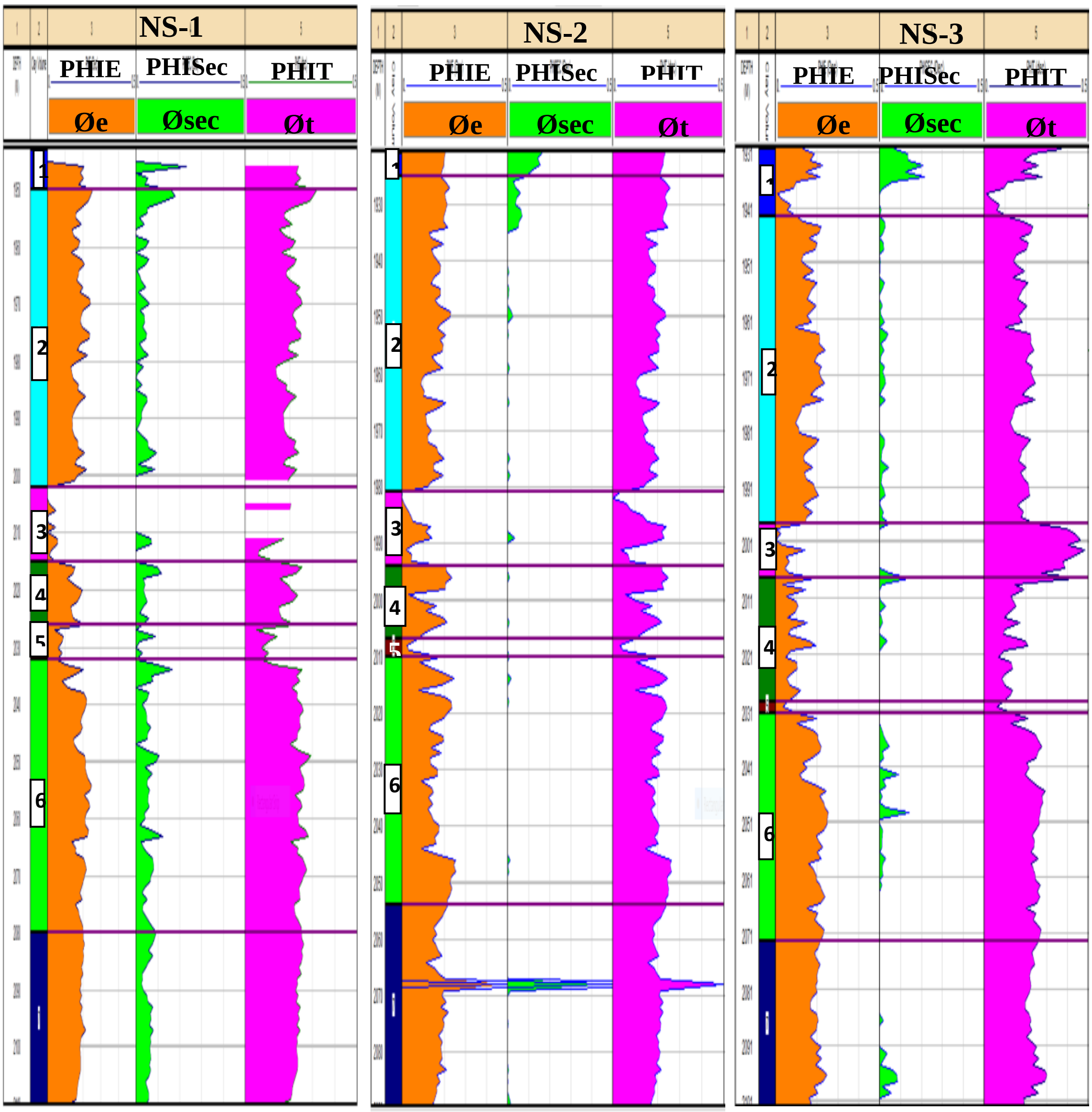


**Figure 3-** Effective porosity, secondary porosity and total porosity for Mishrif Formation in studied wells

**Table 1-** Permeability Classification after [14 ]

| Permeability value (md) | Classification |
|---|---|
| < 10 | Fair |
| 10 - 100 | High |
| 100 - 1000 | Very high |
| > 1000 | Exceptional |

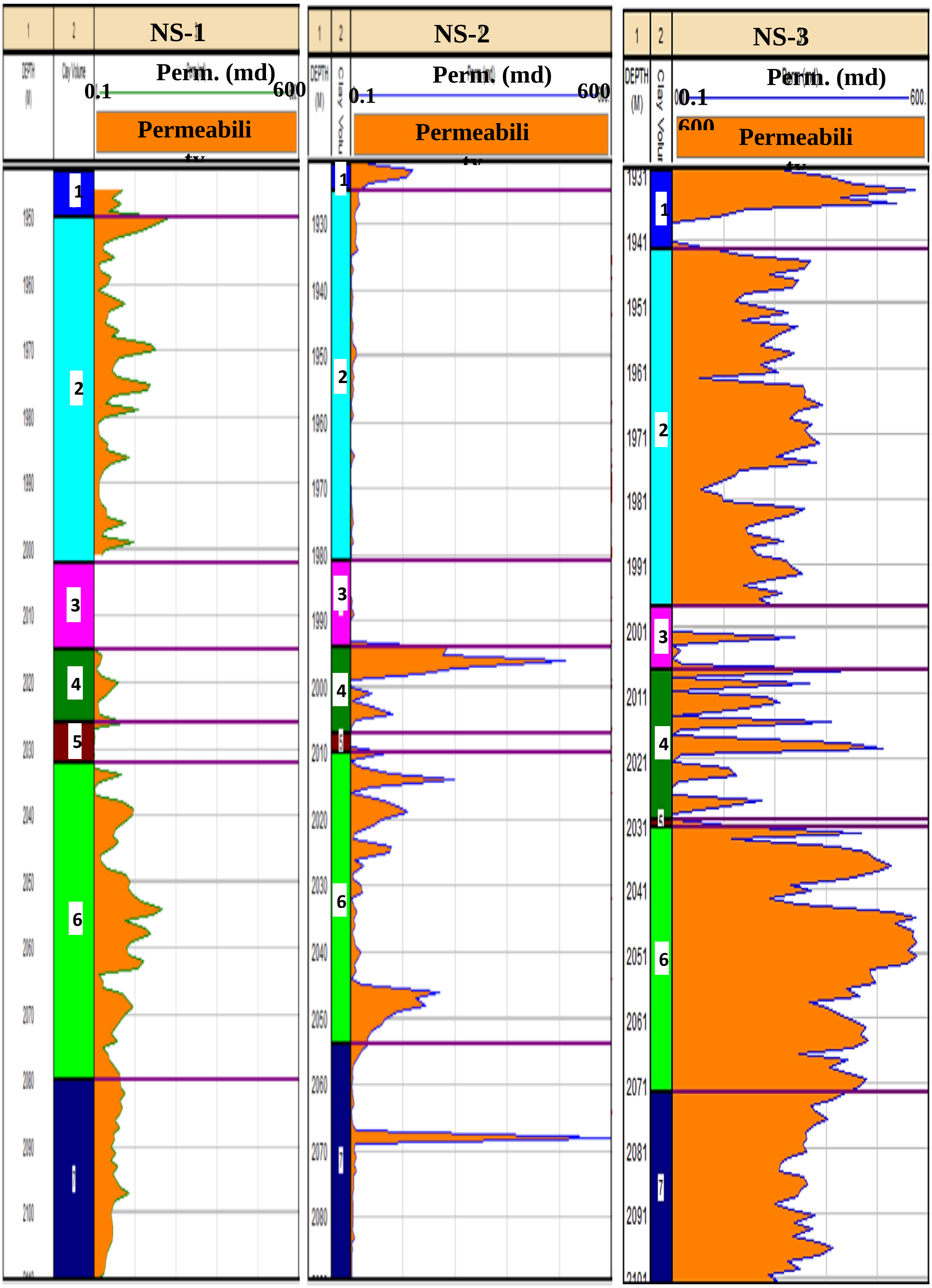


**Figure 4-** Permeability curves of the Mishrif Formation in studied wells

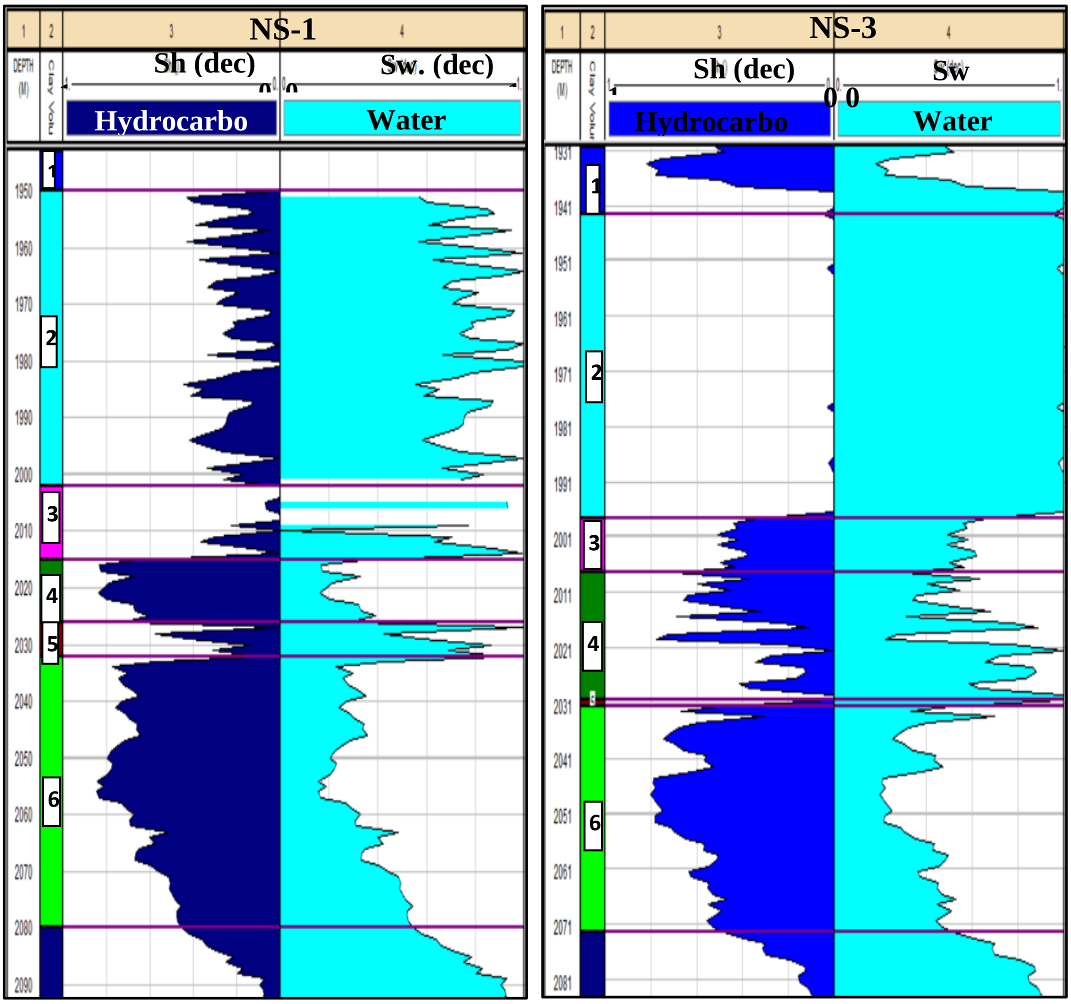


**Figure 5-** Water and hydrocarbon saturation curves for Mishrif Formation in studied wells

## Discussion

The results of the petrophysical evaluation of the current study revealed that the Mishrif Formation in the three wells has five variable units (CRI, MA, CRII, MB1 and MB2). Each unit has special characteristics different from the others.

The CRI unit, cap Rocks-I (zone-1) , represents the Mishrif Formation's top zone in the Nasiriya oil field. It is composed of low porous and low permeable muddy limestone rock 7-11 m thick. High porosity and permeability appeared in the MA unit (zone-2). The thickness of this unit ranges from 52 – 56 m composed of chalky, marly limestone with high water saturation. The CRII (Cap Rocks-II) (zone-3) comprises black-grey-greenish shale rock of thickness ranges between 10 and 13 m. It is a good seal rock, which prevents the hydrocarbon migration from bottom MB to top MA units. MB unit were divided into two units, MB1 (zone-4) and MB2 (zone-6), separated by a barrier unit (zone-5). The MB1 unit has good porosity, permeability, and hydrocarbon saturation; it has MOS higher than ROS. The barrier unit consists of marly limestone 3.5-7m thick. The best and most thick reservoir unit in the Nasiriya oil field is MB2. It mainly consists of high porous limestone ranging in thickness between 70 and 78 m. This unit is characterized by good reservoir properties, particularly movable hydrocarbon, representing the principle oil-bearing units in Mishrif Formation. Based on [15] study, the main reservoir unit of the Mishrif Formation is MB1. [16] subdivided the Mishrif Formation in the Halfaya oil field into five teams and mentioned that the MB1 and MB2 are the most important units in the formation as main oil-bearing units due to the good reservoir properties

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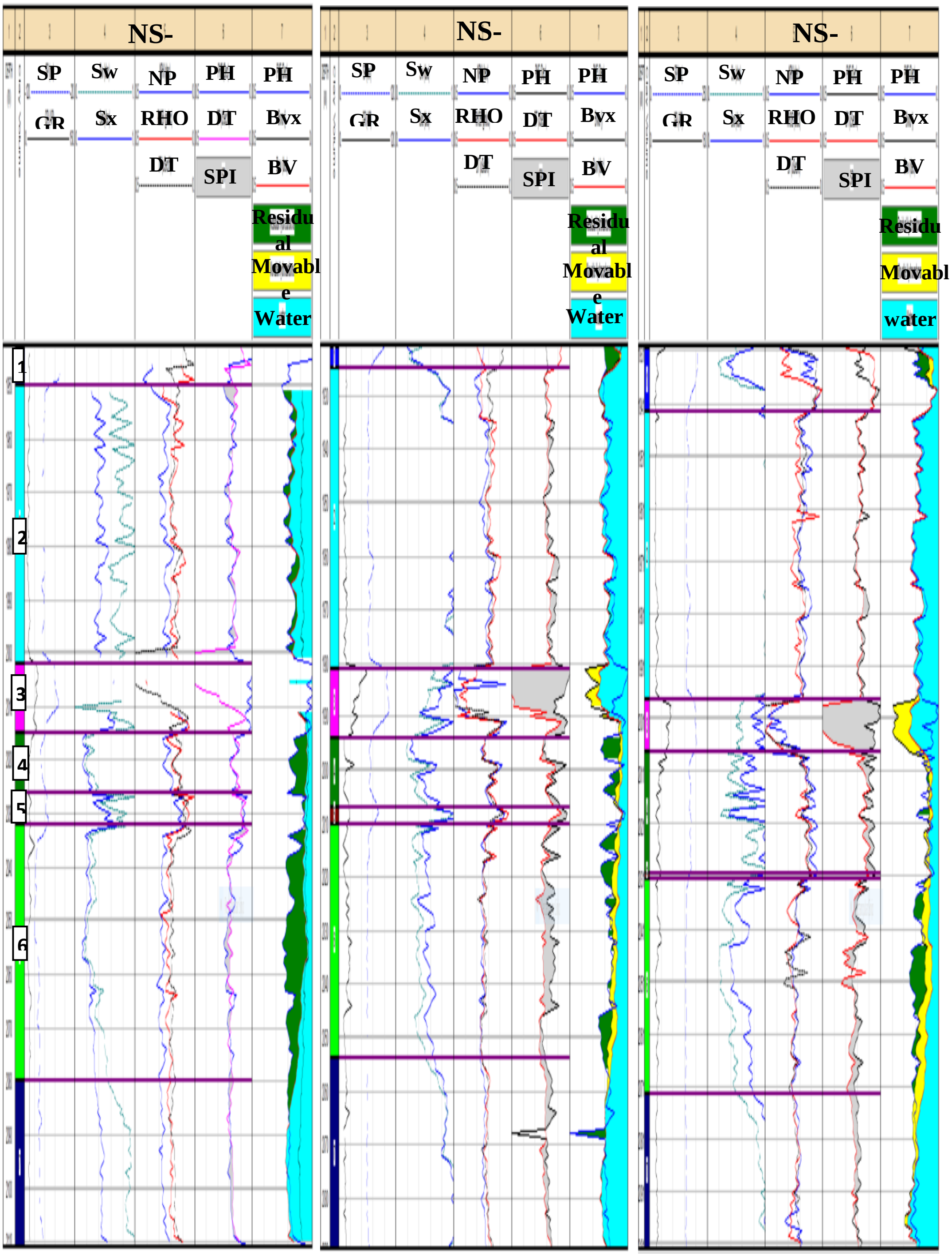


**Figure 6-** GR, SP, bulk volume water, movable and residual hydrocarbon and porosity for the Mishrif Formation in studied wells

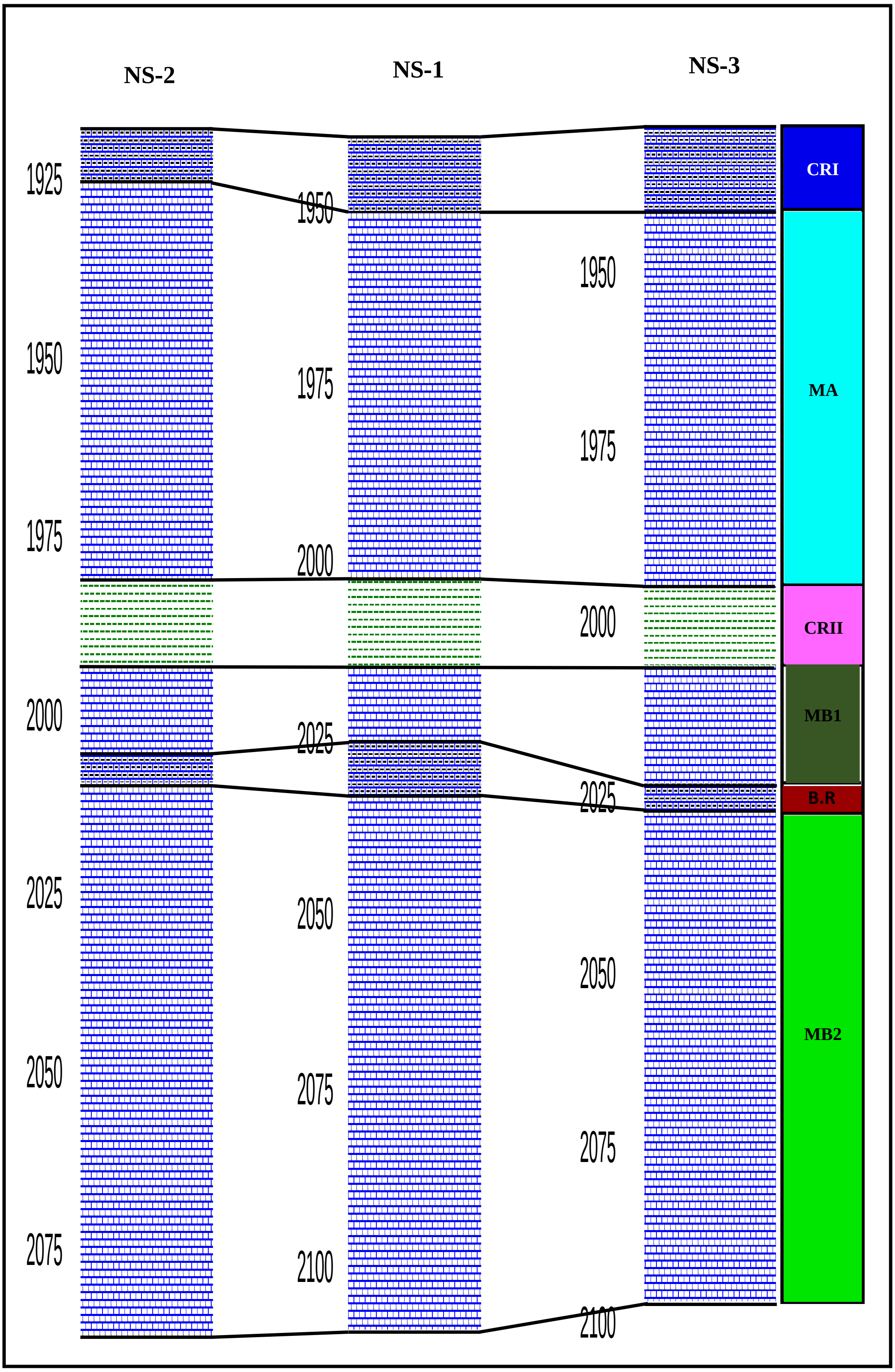


**Figure 7:-** The correlation between the main units in the Mishrif Formation.

## Conclusion

The Mishrif Formation in the Nasiriya oil field is divided into five units CRI, MA, CRII, MB1 and MB2. Depending on the well-logging, the Mishrif formation was divided into two main units, upper Mishrif and lower Mishrif. The lower Mishrif were divided into two reservoir units separated by a barrier composed of compacted limestone that appeared in all wells.

The primary porosity is more than secondary (vugs and fractures). Zone-3 (CRII) represents the main seal in the formation. The MA, MB1 and MB2 units have relatively high effective porosity and good permeability. The MB2 is the main oil-bearing unit in the Mishrif Formation characterized by containing movable hydrocarbon.

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