 Iraqi Journal of Science, 2019, Vol. 60, No.2, pp: 321-329
DOI: 10.24996/ijs.2019.60.2.12

ISSN: 0067-2904

Evaluation of Petrophysical Characteristics of Carbonate Mishrif Reservoir in Ahdeb oil Field, Central Iraq

Buraq Adnan Al-Baldawi*, Madhat E. Nasser
Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

Ahdeb oil field is located in the central block of Mesopotamia plain in Iraq. It has three domes AD-1, AD-2, and AD-4.The current study represents characterization of carbonate Mishrif reservoir (Cenomanian-Early Turonian) in three wells (AD-A,AD-B,AD-C) at southern dome of Ahdeb oil field. Petrophysical properties were calculated using available well logs data such as neutron, density, sonic, gamma ray, resistivity and self-potential logs. These logs are digitized and then environmental corrections and interpretations were carried out using Techlog software. Petrophysical parameters such as shale volume, porosity, water saturation, hydrocarbon saturation, bulk water volume, etc. were determined and interpreted and illustrated in computer processing interpretation (CPI).Mishrif Formation was divided into five units according to reservoir properties (MI-1,MI-2,MI-3,MI-4 and MI-5). These units differ from each other's by reservoir properties. The unit MI-4 is the best reservoir unit in Mishrif Formation that has good petrophysical properties such as high porosity and low water saturation. The MI-4 unit represents the principle oil bearing unit in Mishrif Formation.The other units of Mishrif Formation are characterized by high water saturation with variations of effective porosity that indicated of these units are free oil shows.

Keywords: Ahdeb oil field, Mishrif Formation, Petrophysical Properties, Techlog.

تقييم الخصائص البتروفيزيائية لمكمن المشرف الجيري في حقل الاحدب النفطي ، وسط العراق

براق عدنان البلداوي*، مدحت عليوي ناصر
قسم علوم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

يقع حقل الاحدب النفطي في مركز السهل الرسوبي في العراق. يتكون الحقل من ثلاث قبب او طيات محدبة وهي AD-1,AD-2,AD-3. تمثل الدراسة الحالية ايجاد خواص مكمن المشرف الكاربوناتي ذو العمر السنوماني–التوروني المبكر في ثلاث ابار (AD-A,AD-B,AD-C) في القبة الجنوبية من حقل الاحدب. تم ايجاد الصفات البتروفيزيائية بأستخدام معلومات المجسات البئرية مثل مجس الكثافة والنيترون والصوتي واشعة كاما والمقاومية والجهد الذاتي. تم تحويل المجسات البئرية الى معلومات رقمية ومن ثم تم اجراء التصحيحات البئرية والتفسيرات باستخدام برنامج Techlog.تم حساب وتفسير المعاملات البتروفيزيائية مثل حجم السجيل والمسامية والتشبع المائي والنفطي وقد تم تمثيلها في التفسير والمعالج الحاسوبي (CPI).تم تقسيم تكوين المشرف الى خمس وحدات مكمنية بالاعتماد على الصفات البتروفيزيائية وهي (MI-1,MI-2,MI-3,MI-4 and MI-5) . تختلف هذه الوحدات فيما بينها بالصفات المكمنية. تعتبر الوحدة المكمنية الرابعة افضل وحدة في تكوين المشرف وذلك لتميزها بمسامية عالية وتشبع مائي منخفض. تعتبر الوحدة المكمنية الرابعة هي

*Email:buraqadnan81@scbaghdad.edu.iq

الوحدة المكمنية الرئيسة المنتجة للنفط في تكوين المشرف في حقل الاحدب النفطي. تتميز الوحدات المتبقية من تكوين المشرف بأرتفاع التشبع المائي وتغاير في المسامية الفعالة وهذا دليل على خلو هذه الوحدات من الشواهد نفطية.

1. Introduction

Well log interpretation or reservoir characteristics represent a series of calculations in order to assess several reservoir properties that control the hydrocarbon productivity and storage. Porosity and water saturation are among the important petrophysical properties used to determine reservoir quality. The volume and distribution of pores control both parameters. Various logs can be used to determine porosity and water saturation, and to calculate reservoir compartmentalization.

Well logging is the technique of making reservoir properties measurements in the sub-surface earth formations through the drilled borehole in order to determine the physical and chemical properties of formations and the fluid they contain [1].

The Ahdeb oil field is located in the central section of Mesopotamia plain in Iraq, between Nomania and Kut towns, about 18km NW of Kut city, 180 km south east of Baghdad (Figure-1).

The main purpose of this study is to make use of all the available sets of well logs data acquired from Ahdeb wells (AD-A, AD-B, AD-C) to assess the petrophysical properties for each zones in Mishrif Formation. Well log understanding and assurance of the petrophysical properties for each units in Mishrif Formation as well as Assessment the petrophysical properties for each reservoir unit to perceive the vertical disseminations in Mishrif Formation utilizing accessible logs information. This study deals with pre-interpretation and the reservoir properties of Mishrif Formation. The study includes two steps, the pre-interpretation and the interpretation. The pre-interpretation represents the determination of effective porosity (corrected to shale effects) and all the parameters that are needed in the interpretation processes. The interpretations were carried out using **Techlog software (**an interactive program to carry out interpretations and log corrections for borehole environment and invasion effects).

2. Structure and Geologic Setting

Ahdeb structure is located on stable shelf in the Mesopotamian zone. Ahdeb oil field is an anticlinal structure elongated in NWW-SEE. It has three domes AD-1, AD-2, and AD-4. AD-1 is little higher than the other domes. There is no fault above Mauddud Formation in this field [2]. The two sides of the anticline are not steep, the dip angle of the south side is 0.7˚-0.9˚, the dip angle of the north side is 2˚, and the north limb is stepper than the south limb [2].

Mishrif Formation (Cenomanian-Early Turonian) in Ahdeb field comprises of porous permeable limestone, chalky limestone, tight limestone and shale at the base of development. The thickness of Mishrif Formation in the Ahdeb wells goes between 90-110m.

The lower limit of Mishrif Formation speaks to the change from basinal Rumaila Formation to shallow open marine facies .It is a comparable surface [3]. The upper limit with the Khasib Formation is truncated by an unconformity surface isolating the Middle from Late Cretaceous [4]. The equivalent formations of the Mishrif Formation are Gir-bir Formation in the North and the Balambo Formation of the more profound eastern and intrabasinal part of a similar basin of the Dokan Formation [3]. The top Mishrif truncation forms the AP9/AP8 megasequence boundary at ~92 Million years. The Mishrif is considered to be an overall progradational marine shelf sequence. Following the deposition of the transgressive shales and marly limestones of the Ahmadi and Rumaila formations, rudist reefs and other related build-ups represented the deposition of the Mishrif formation.The Cenomanian-Early Turonian Mishrif Formation reservoir of the Mesopotamian Basin accommodates more than one third of the proven Iraqi oil reserves within rudist-bearing stratigraphic units [3].

3. Methodology

1- Well logs are digitized using Neuralog software.

2- Techlog software was used to carry out the environmental corrections (hole-size, mud cake and invasion effects) that conform to the Schlumberger requirements for the application of required equations.

3- Well log interpretation and petrophysical analysis of Mishrif Formation are carried out using Techlog software.

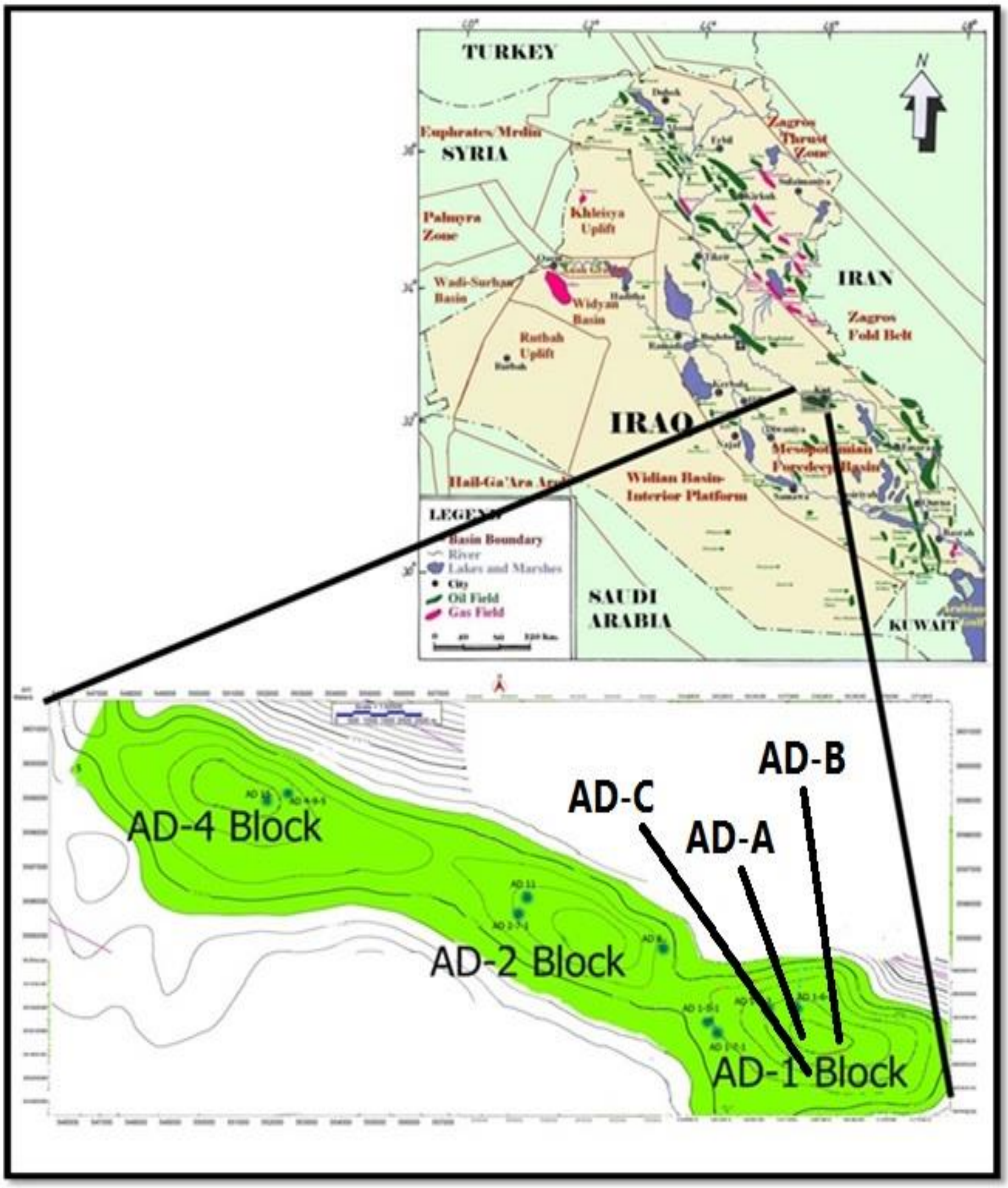

Figure 1- Location map of Ahdeb oil Field showing the studied wells (modified from [2]).

4. Petrophysical Properties

For determining reservoir properties of Mishrif Formation, petrophysical parameters must be obtained and evaluated. These parameters include:

A- Volume of shale (Vsh): To get Vsh from gamma ray (GR Log), it is basic that the gamma ray index (IGR), controlled by utilizing equation of Schlumberger (1974) [5]

IGR= (GRlog- GRmin) / (GRmax – GRmin) (1)

Where: GRlog = gamma ray reading of formation; GRmin = minimum gamma ray reading (clean sand or carbonate): GRmax = maximum gamma ray reading (shale).

For the purpose of this work, the formula of Dresser Atlas (1979) [6] for older rocks was used to determine the shale volume

Vsh = 0.33 * [2 (2*IGR) – 1] (2)

B- Porosity: Total porosity within Mishrif Formation was calculated from Neutron – Density derived porosities. Neutron log calculate the direct porosity after corrected according to on the equation of Tiab & Donaldson (1996) **[7]**

ØNcorr = ØN – (Vsh * ØNsh) (3)

Where ØNcorr. = corrected porosity is derived from Neutron log for no clean rocks**:** ØNsh = Neutron porosity for shale.

Density porosity is determined from the bulk density of clean liquid filled formations when the matrix density (ρma) and the density of the saturating fluids (ρf) are known, using Wyllie *et al.*, (1958) **[8]** equation

ØD = (ρma – ρb) / (ρma – ρf) (4)

Where ρma = density of matrix (2.71 gm/cm3 for limestone, 2.87 gm / cm3 for dolomite, 2.61 gm / cm3 for sandstone), ρf = density of fluid (1 gm/ cm3 for fresh water, 1.1 gm/ cm3 for saline water).

When shale volume is more than 10%, we used equation (5) to remove shale effect from porosity calculation

ØDcorr = ØD – (Vsh * ØDsh) (5)

Where ØDcorr. = corrected porosity is derived from Density log for no clean rocks**:** ØDsh = density porosity for shale.

Total porosity (Øt) is then determined as follows

Øt = (ØN + ØD) / 2 (6)

The effective porosity (Øe) is then determined, by equation of [9]

Øe = Øt * (1-Vsh) (7)

Sonic log (Δt) according to Wyllie time- average equation (8) was used to determine primary porosity

ØS = (Δtlog - Δtma) / (Δtfl - Δtma) (8)

Δt is increased due to the presence of hydrocarbon. To correct for hydrocarbon effect, Hilchie (1978) **[10]** proposed the following empirical equations:

Ø = ØS * 0.7 (gas) (9)

Ø = ØS * 0.9 (oil) (10)

Keeping in mind the end goal to rectify sonic porosity from shale impact inside formation, the following equation is used

ØScorr = ØS – (Vsh* ØSsh) (11)

Where ØS = sonic derived porosity: Δtlog = interval tansit time in the formation; Δtma = interval transit time in the matrix; Δtfl = interval transit time in the fluid in the formation; ØSsh = apparent porosity of the shale; ØScorr = corrected sonic porosity.

C- Water and hydrocarbon saturation:

Water saturation for the uninvaded zone was calculated according to [11]:

Sw = {(a * Rw) / (Rt * _m)}1/n (12)

Water saturation in the invaded zone (Sxo) can be simply calculated from the same equation above by replacing Rw with Rmf (mud filtrate resistivity available from well log headers) and Rt with Rxo (measured resistivity of the invaded zone):

Sxo = {(a * Rmf) / (Rxo * _m)}1/n (13)

Where: Rw = Resistivity of water formation that is previously determined from SP log. a = tortuosity factor=1; m = cementation factor=2; n = saturation exponent=2.

The hydrocarbon saturation can be calculated by using the following equation:

Sh = 1 – Sw (14)

Moveable hydrocarbon saturation was calculated based on Schlumberger (1998) [9] equation

MOS = Sxo - Sw (15)

Whereas residual oil saturation was calculated from [12] as follows equation; **ROS = 1 - Sxo (16)**

D- Bulk Volume Analysis

Bulk volume of water (BVW) is the product of formation water saturation (Sw) and its porosity [13].

BVw = Sw * Ø (17)

Also the bulk volume of water in the invaded zone is calculated as follow: **BVxo = Sxo * Ø (18)**

5. Results and Discussions:

Figures-(2, 3 and 4) represent computer processed interpretation (CPI) of wells AD-A,AD-B and AD-C respectively, that have been deduced using Techlog software. The Figures show the full interpretation process as following:

1. The lithology track: This represents the effective porosity (PHIE), percentage of shale (Vshale), and percentage of Matrix (limestone bed).

2- Fluid analysis track: that represents the effective porosity (PHIE), water filled porosity in the invaded zone (BVWXO), and water filled porosity in the un-invaded zone (BVW). Notice that:
- The zone between (PHIE) and (BVWXo) represents the residual hydrocarbons.
-The zone between (BVWXo) and (BVW) represents the movable hydrocarbons.
-The zone between (PHIE) and (BVW) represents the total hydrocarbons.
3- Saturation track: represents the water saturation in the flushed and un-invaded zone.
Based on porosity classification of [14] that appears in Table-1, the effective porosity of Mishrif Formation in studied wells ranges from negligible and reaches to very good with the mean is fair porosity.

Table 1- The classification of porosity according to [14]

Type of porosity	%	Type of porosity	%
Negligible	**0-5**	**Good**	**15-20**
Poor	**5-10**	**Very good**	**20-25**
Fair	**10-15**	**perfect**	**>25**

Mishrif Formation in Ahdeb oil field, was divided into five reservoir units or zones according to porosity measured data and from log analysis from top to bottom (Mi-1, Mi-2, Mi-3,Mi-4 and Mi-5). Unit (Mi-4) is the best porosity unit in the Mishrif Formation.

The reservoir characteristics of Mishrif units are clarified in the following description from top to bottom:

First unit (Mi-1):

The unit represents top of Mishrif Formation. The porosity is negligible with mean about 4.2% so this unit is cap rock for Mishrif reservoir but water saturation ranging (0.06-1) with mean 0.47.

Second Unit (Mi-2):

Porosity ranging (0-23.4) but water saturation about (0.28-1) with means 0.66. This unit may contain some few oil shows but not considered reservoir pay unit in Mishrif Formation.

Third Unit (Mi-3):

The porosity increases towards top of unit and may reach to negligible porosity towards lower zone of unit which is about (0-26.6%) with poor porosity mean about (6.8%) while water saturation ranging (0.06-1) with mean 0.64.

Forth Unit (Mi-4):

This unit represents the principle oil bearing unit in Mishrif Formation which is characterized by porosity ranges (0-23.5%) with good mean about (15%) as well as water saturation (0.13-1) with mean (0.58). The CPI figures of studied wells indicated that the unit (Mi-4) produces hydrocarbons in the wells when the reservoir properties is improvement especially decreasing in water saturation whereas porosity is almost characterized good in all wells of Ahdeb oil field.

Fifth Unit (Mi-5)

The unit represents the lower unit at bottom of Mishrif Formation which is characterized by porosity ranges (0-15%) with negligible porosity mean about (3.5%) and water saturation ranges (0.24-1) with mean 0.57.

6. Conclusions

The logging data studied comprises gamma ray, electric (spontaneous potential, laterolog deep and shallow, formation density and neutron log). These logs are digitized using Neuralog Software and then the environmental corrections and the interpretations have been carried out using Techlog software. Density and neutron log are used to calculate total porosity, and then corrected by clay volume and hydrocarbon fluid content to calculate the effective porosity. Water saturation was calculated using Archie equation.

The computer processes interpretation (CPI) of wells AD-A, AD-B and AD-C of Ahdeb oil field have been deduced using Techlog software. The computer processes interpretation shows that the Mishrif Formation in the Ahdeb field can be divided into five reservoir units .These units are; MI-1,MI-2,MI-3,MI-4 and MI-5.The reservoir unit MI-4 is the most important unit in Ahdeb field because it is characterized by good reservoir properties and represents the principle oil bearing units in Mishrif Formation. Mishrif Formation in Ahdeb oil field has good reservoir properties in AD-1 dome (southern dome) as shown in studied wells but it is characterized by bad reservoir properties toward other domes (northern dome) of Ahdeb field.

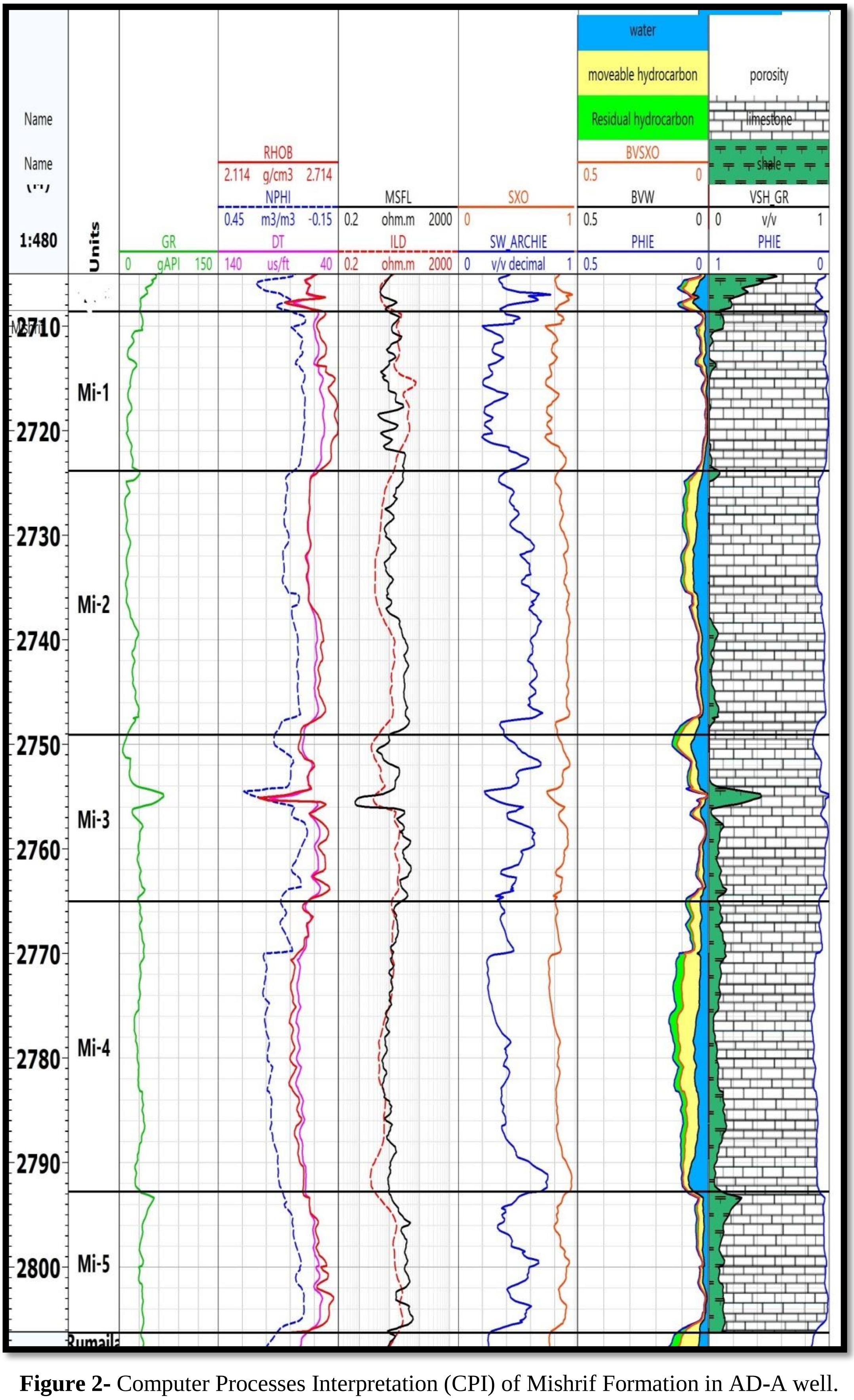

Figure 2- Computer Processes Interpretation (CPI) of Mishrif Formation in AD-A well.

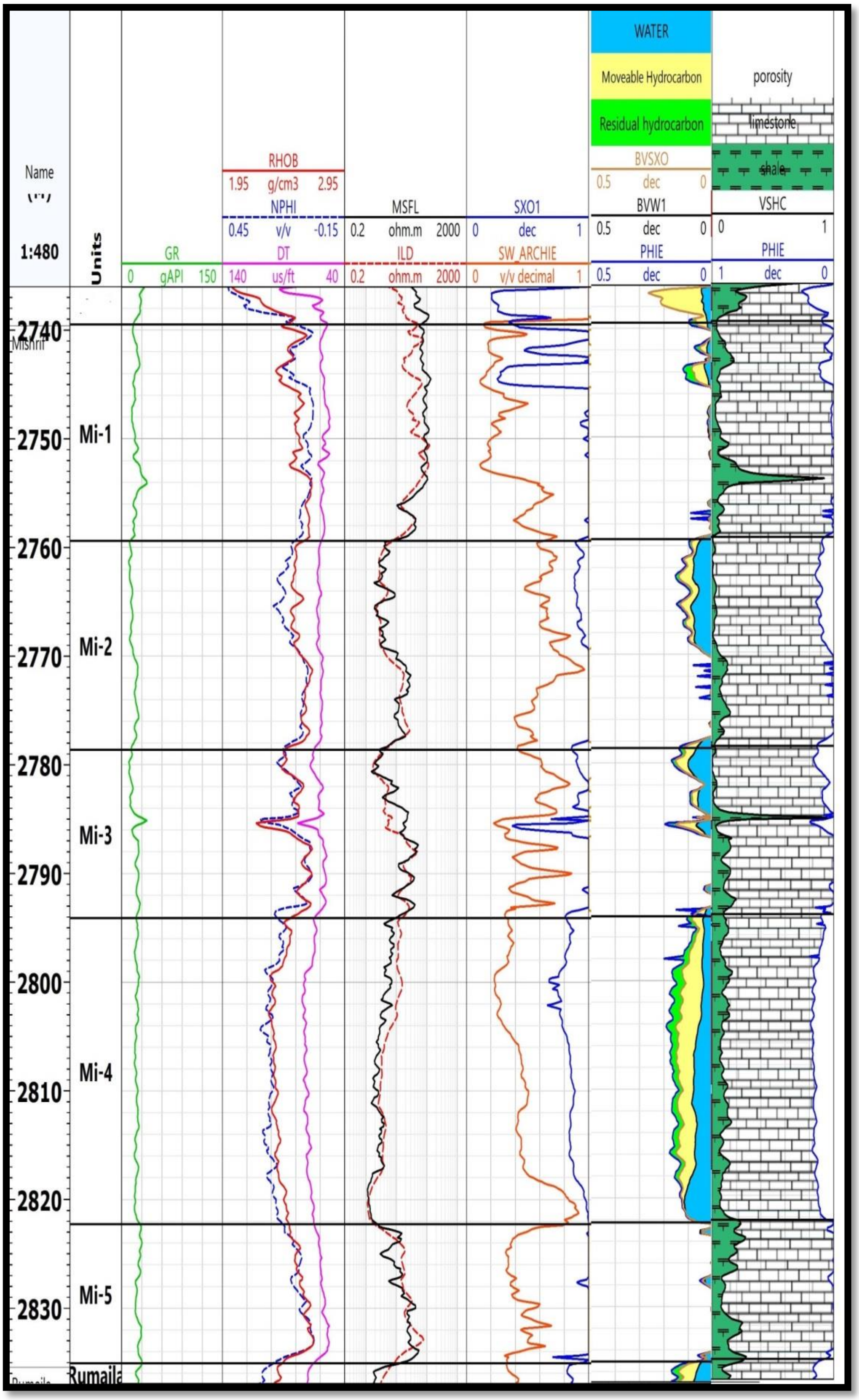

Figure 3- Computer Processes Interpretation (CPI) of Mishrif Formation in AD-B well.

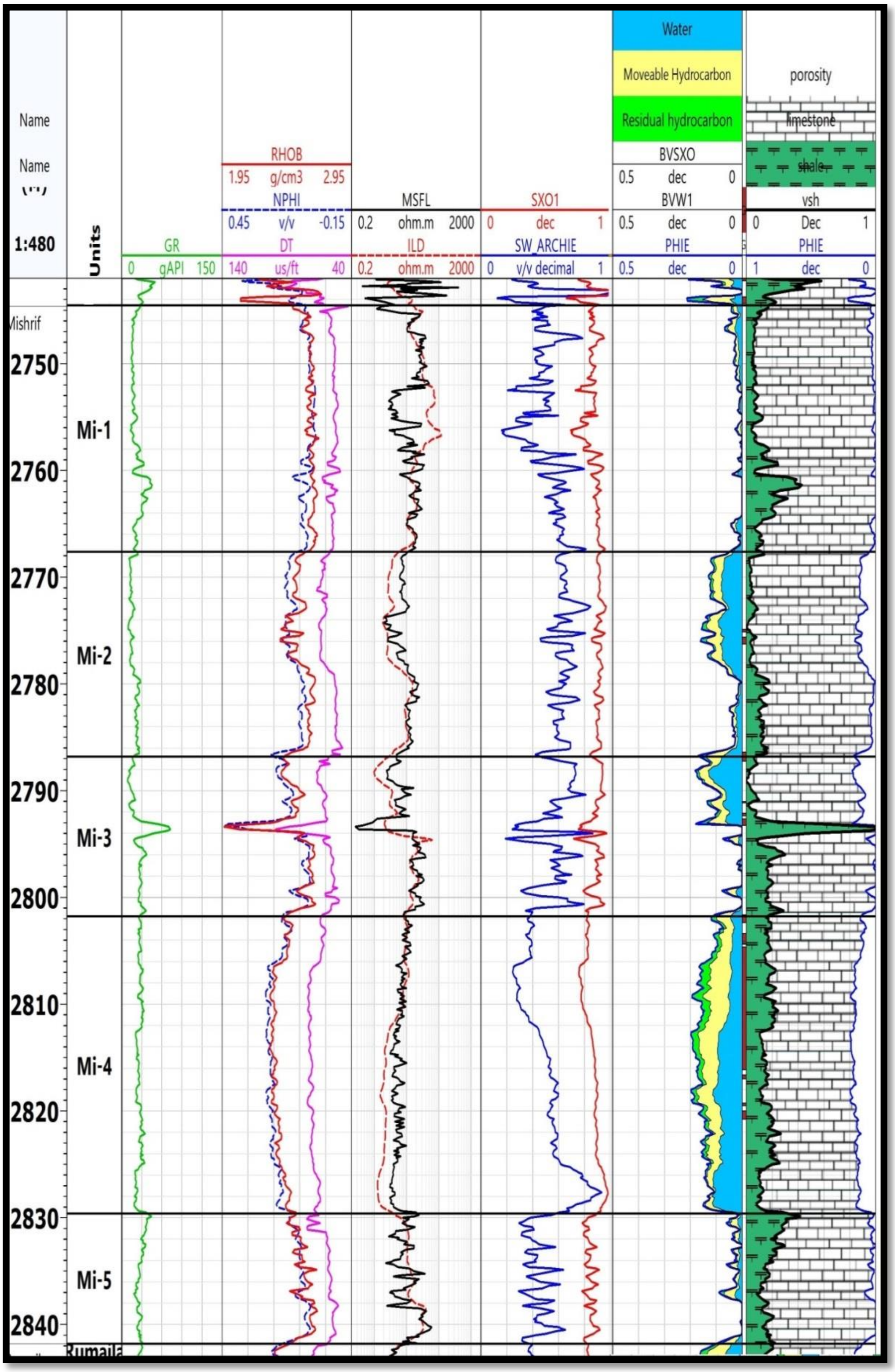

Figure 4- Computer Processes Interpretation (CPI) of Mishrif Formation in AD-C well.

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