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A Comparison of Mishrif Formation Characteristics in Kumait and Dujaila Oil Fields, Southern Iraq, Using Seismic Inversion Method and Petrophysical Properties Analysis

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Abstract

A comparison was conducted between two wells, Kt-1 and Kt-2, in Kumait and two wells, Du-1 and Du-2, in Dujaila oil fields that belong to Mishrif formation, southern Iraq. Seismic inversion method was employed to detect oil and water reservoirs. The comparison included the behavior of acoustic impedance (AI) of fluids and the lithology with related petrophysical properties. The values of water saturation, Shale volume (V_{sh}), and effective porosity were compared between the AI, two fluid reservoirs. It was found that the AI value for the oil reservoir unit is relatively low to medium, whereas it was relatively medium for the water reservoir. Effective porosity value showed, in general, an increase in the oil reservoir and a slightly decrease in the water reservoir. The V_{sh} and water saturation (S_w) values of the oil reservoir unit were in general lower than those in the water reservoir, which indicates the presence of hydrocarbons accumulation. The lithology and porosity are the main factors affecting the acoustic impedance values. Despite the small difference in density between oil and water, these two fluids still show perceptible variation in their properties.

Keywords: Mishrif Formation, Acoustic Impedance, Water saturation, Shale volume Southern Iraq, Kumait oil field, Dujaila oil field

مقارنة لخصائص تكوين المشرف في حقول كميث ودجيلة النفطيين باستخدام المعكوس الزلزالي وتحاليل الخصائص البتروفيزيائية، جنوبي العراق

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الخلاصه:

تم اجراء مقارنة لخصائص تكوين المشرف في اربع ابار، اثنان في حقول كميث واثنان في حقول دجيلة النفطيين من خلال دراسة طبيعية تصرف قيم الممانعة الصوتية في مكامن الابار الحاوية على النفط ومكامن الابار الحاوية على المياه وعلاقتها مع الخصائص البتروفيزيائية والتي تضمنت تحليل مجسات الابار (التشبع المائي، حجم تواجد الطين الصخري والمسامية الفعالة)، حيث وجد ان قيم الممانعة الصوتية لتكوين المشرف

في وحدات المكامن الحاوية على نفوط نسبيا من قليلة الى متوسطة ونسبيا متوسطة في المكامن الحاوية على مياه كما لوحظ قلة تواجد حجم الشيل والتشيع المائي في المكامن الحاوية على نفوط وزيادتها في المكامن الحاوية مياه، اما فيما يخص المسامية الفعالة بشكل عام لوحظ زيادتها في المكامن النفطية ونقصانها في المكامن المائية، ان الفروقات في الممانعة الصوتية تعود بشكل اساس الى الاختلاف في طبيعة السحنات الصخرية والمسامية في تكوين المشرف في منطقة الدراسة والتي اكدت تواجد المواد الهيدروكربونية ، ورغم ذلك ومن خلال المقارنة وجد اختلاف محسوس في قيم الممانعة الصوتية يرتبط بتغير طبيعة المحتوى السائل، حيث وبالرغم من قلة الفرق في الكثافة بين النفط والماء الا انه امكن تمييز بعض المواصفات للنفط او للماء .

1. Introduction

The results of reservoir characterization are obtained by various methods and usually cover parameters that include lithology, porosity and fluid saturation. Inverting seismic data to other rock properties implicitly assumes a relationship between the fundamental properties and the reflection of seismic waves from subsurface layers, for which the change in density and velocity reveals important information about the underlying materials and potential hydrocarbon accumulations. The integration of well-log and seismic data has been a consistent aim of geoscientists and become increasingly important (and successful) in recent years because of the shift from exploration to development of existing fields with large numbers of wells penetrating them [1]. One type of integration is the inverse modeling of logs from seismic data, which is called seismic inversion. The inversion process is nonlinear for waveforms with long wavelengths such as velocities, whereas it is linear for those with short wavelengths, such as impedance [2]. All types of inversion require some form of constraint and need to be calibrated by tying the result to real or simulated well data [3,4,5]. Relative acoustic impedance value is derived from seismic data and well logs (sonic and density). These results, well-derived and seismic, are combined together to produce absolute acoustic impedance results to predict the presence of accumulation of hydrocarbon and to distinguish between oil and water content in reservoir units. The different lithology and liquids' densities are affected by acoustic impedance value. The AI value is high in hard limestone layers with shale, while the value is low in porous sand layers. The lithology and fluid prediction from seismic data could delineate the boundary of carbonates from sandstone and shale. Therefore, integrating different data (seismic, impedance, well logs, and other geologic information) with different resolutions is the best tool to predict property value. Other data such as those of lithology, volume of shale, and effective porosity, and saturation, with best distribution, are utilized to improve the diagnosis type of fluid content. The integration of seismic attributes with petrophysical measurements from wells can significantly improve the spatial distribution of log properties [6]. This paper attempts to investigate the characteristics of Mishrif Formation in Kumait and Dujaila oil fields using the seismic inversion method and petrophysical properties' analysis depending on the available data.

2. The Mishrif Formation (Cretaceous- Cenomanian- early Turonian)

Mishrif Formation was described earlier by a number of studies [7,8]. It is divided into four zones, according to the variation in facies [9]. These zones from bottom upward are the sub-basin (MD), the open shelf (MC), the rudist build-up (MB) (which is the main reservoir rock in Mishrif Formation [10]), and the restricted shelf. The boundaries between these facies are not sharp [11, 12]. The thickness of Mishrif Formation ranges 350-400 meters in Amara, Majnoon area, southeastern Iraq, and is reduced to 157 meters in the well Zubair- 3, southern Iraq [7].

3. Location of Study Area

The study area which is represented by Kumait and Dujaila oil fields is located at the eastern parts of southern Iraq as part of the administrative border of the province of Maysan (Figure-1). Kumait and Dujaila oil fields lie within the Universal Transverse Markator (U.T.M) coordinates, as given in Table -1.

Table 1- Coordinates of the study area.

Point	Northern	Eastern
A	3560000	620000
B	3560000	682000
C	3525000	682000
D	3525000	620000

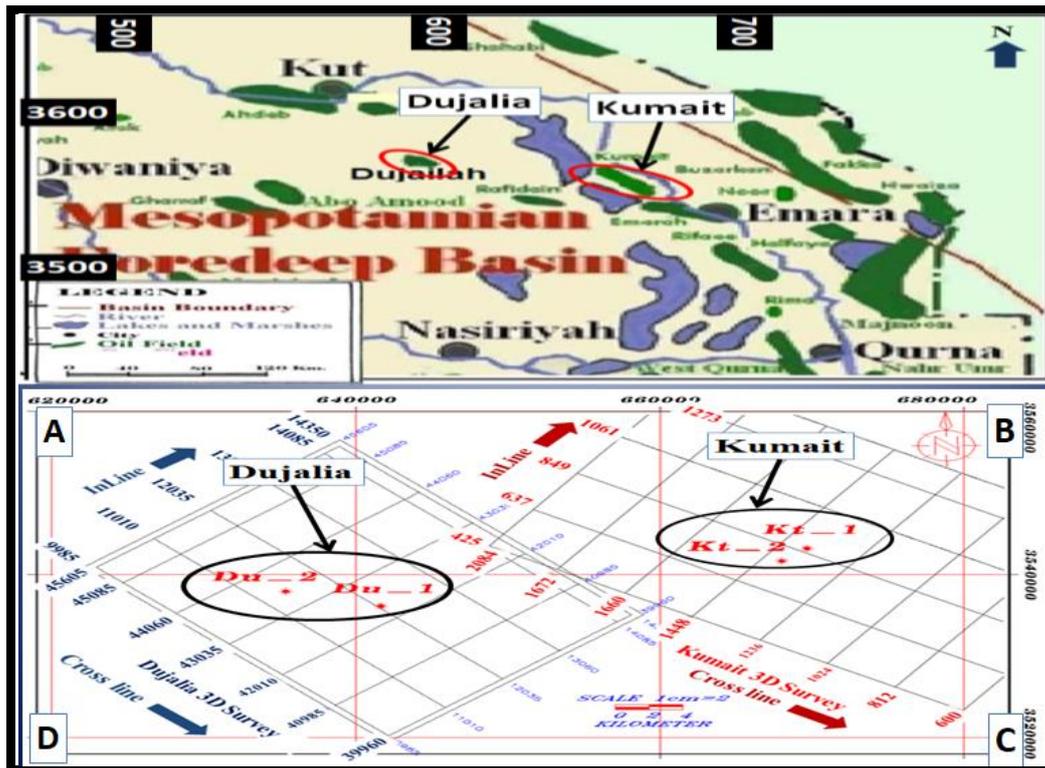


Figure1- Location map and base map of the study area covered by the 3D survey [13].

The well geological formation of Kumait-1 (Kt-1) reaches Sulaiy Formation (4410m depth) which belongs to the Cretaceous age, while Kumait-2 (Kt-2) reaches to Shuaiba Formation (3874 depth) (Figures-(2 and 3, respectively) [8].

Mishrif Formation is divided into two main sections: the high Mishrif and the low Mishrif. The high Mishrif is divided into three main units separated by nonporous limestone barriers. Mishrif is divided into three sections:

First reservoir unit (MA): In the well Kt-1, this unit is located within the depth range of 3071 - 3079 m, whereas in Kt-2, it is located within the depth range of 3088 - 3095 m, consisting of limestone and wackstone.

Second reservoir unit MB: In the well Kt-1, this unit is located within the depth range of 3085-3110 m, whereas in the well Kt-2, it is located within the depth range of 3097- 3124 m, consisting of calcareous limestone and wackstone rocks.

Third reservoir unit MC: In the well Kt-1, this unit is located within the depth range of 3116-3121 m, whereas in the well Kt-2, it is located within the depth range of 3128-3135 m, consisting of calcareous limestone and wackstone rocks [14].

The Lower Mishrif

The well Kt-2, the lower Mishrif is located within the depth range of 3183-3360 m, whereas in the well Kt-2, it is located within the depth range of 3187 - 3373 m.

The rocks of the upper part of the lower Mishrif Formation consist of limestone rocks with good reservoir properties. It is considered as a part of the main reservoirs of the Mishrif Formation in the southern fields.

The underside of the lower part of the reservoir is characterized by poor reservoir characteristics because it contains mud materials and, therefore, it is considered as having non-reservoir rocks.

On the other side, two wells were drilled in Dujaila Oil field. The deepest drilling was in well Du-1 at a depth of 4124 m at the top of Ratawi Formation, while the drilling in well Du-2 was finished at depth 4589 m, as shown in Figures-(4 and 5).

The well Dujaila-1 is located within the depth range of 2839 - 3162 m. The well Dujaila -2 is located within the deep range of 2816 - 3125 m. The upper Mishrif is divided into three sections:

First reservoir unit (MA)

In the well Dujalia -1, this unit is located within the depth range of 2850 – 2903, m whereas in the well 2 it is located within the depth range of 2Du-1825 - 2869 m, consisting of limestone.

Second reservoir unit (MB): In the well Dujalia -1, this unit is located within the depth area between (2918 - 3086) m, while in the well Dujalia. 2 it is located within the depth area between (2887 - 3058) m, and consists of calcareous limestone and clay [15].

The third reservoir unit (MC): In the well Dujalia -1, it is located within the depth area between (3116 - 3162) m while in the well Dujalia -2 it is located within the depth area between (3085 - 3125) m and consists of calcareous limestone and clay [15].

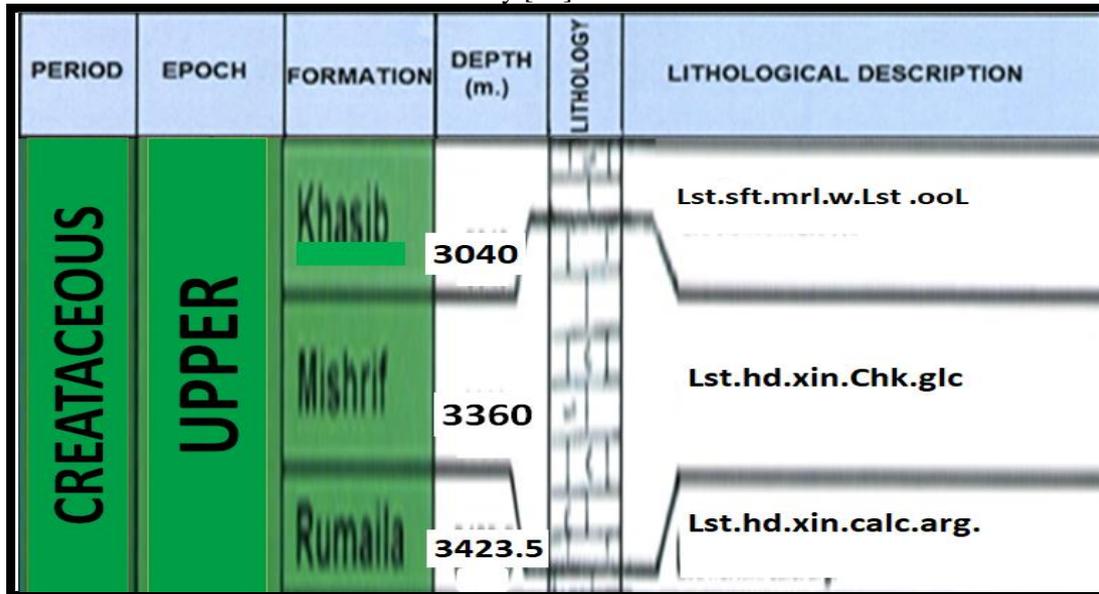


Figure 2-Geological column in Kt-1 well [14]

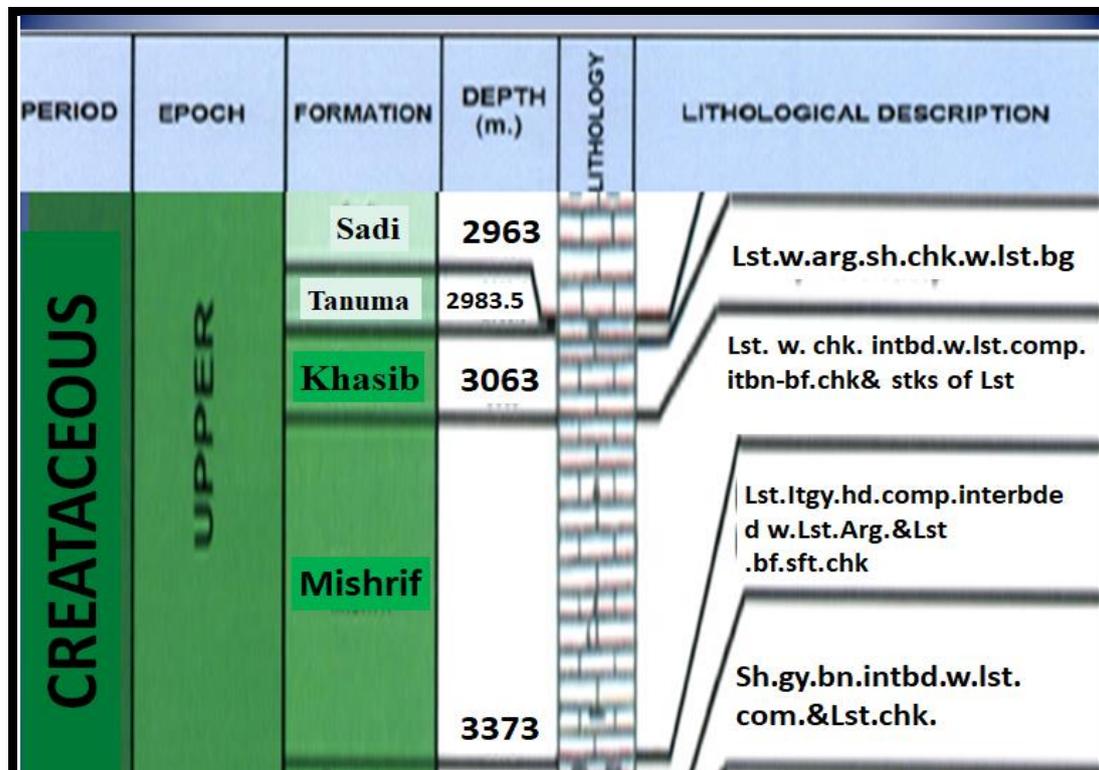


Figure 3- Geological columns in Kt-2 well [14].

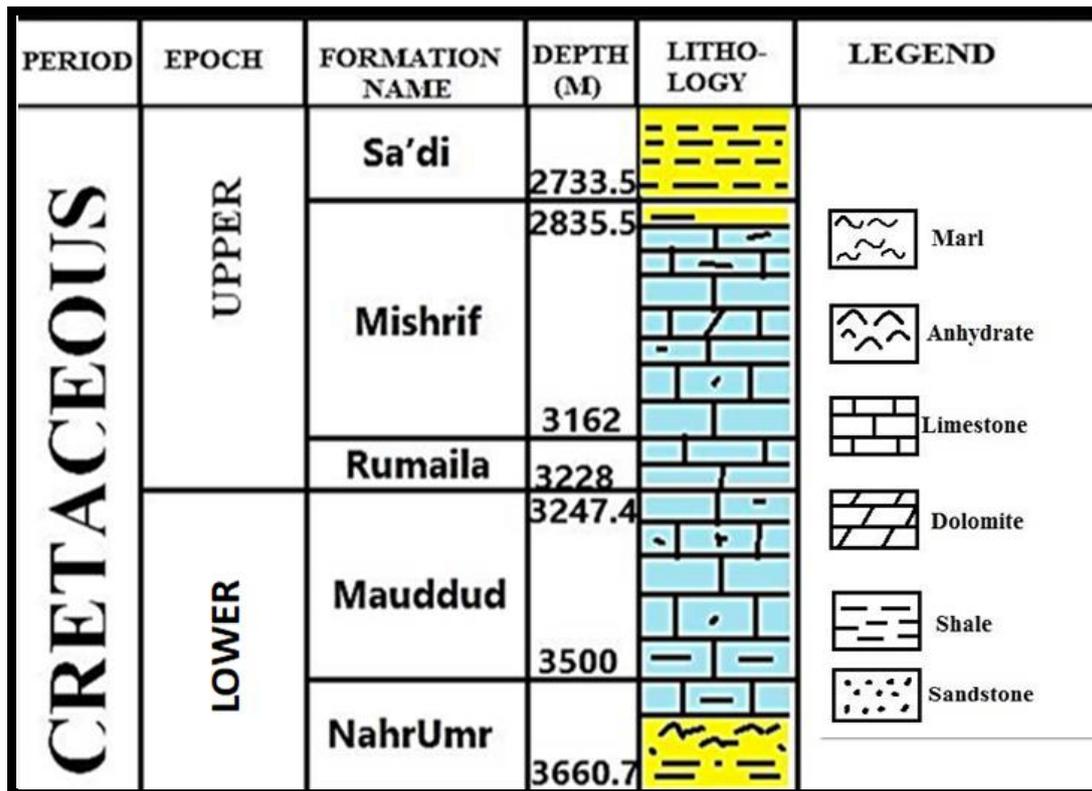


Figure 4- Geological column in Du-1 well [15].

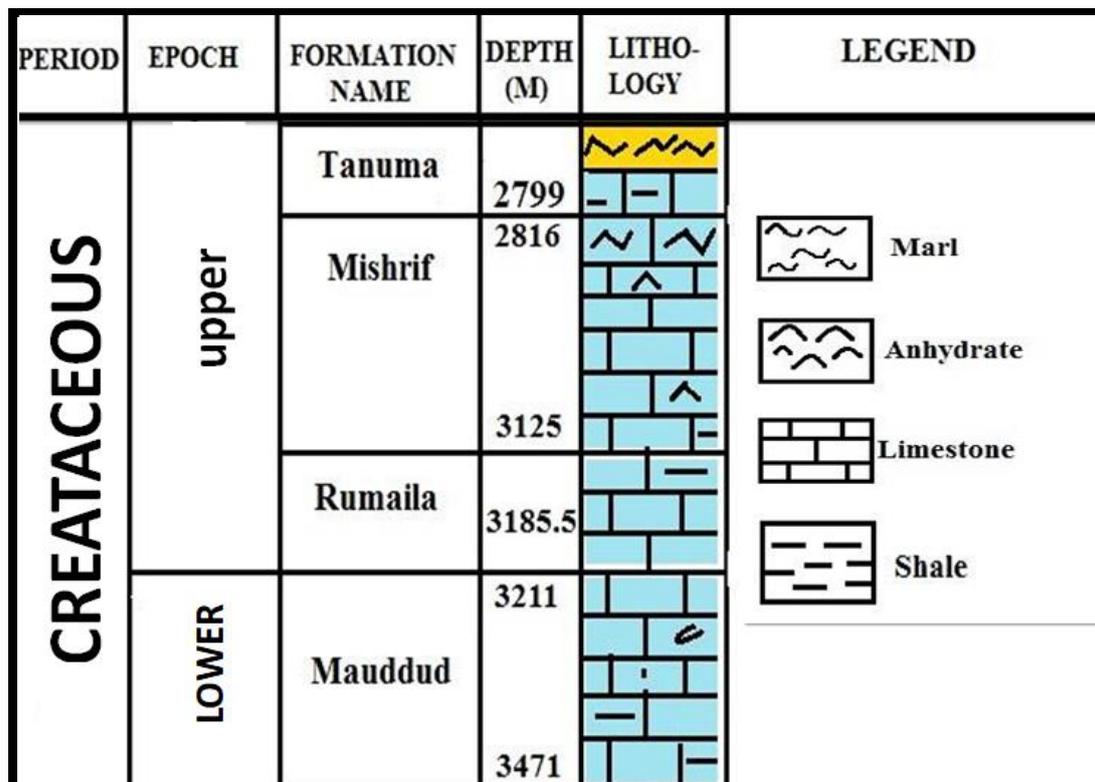


Figure 5- Geological column in Du-2 well [15].

The thickness of Mishrif Formation in Kumait oil field's wells at the eastern side of the study area is about 310 meters, while it is ranges between 327-309 meters in Dujaila oil field's wells at the western side of the study area.

4. The Tectonic Situation in study area

The study area is located on the Mesopotamian basin near the north-east slope of the Arabian-African platform, which is located between Zagros Mountain in the east and the Arabian Shield in the west [16, 17]. The structures in the Mesopotamian tectonic subzone are trending NW-SE, mostly due to the stresses of the collision between Arabian and Iranian plates [18,19]. A set of small fold closures, such as Dujalia, Abu Amoud, East Abu Amoud, and Kumait fields, are examples of those structures in the study area [19, 20], as shown in Figure-6.

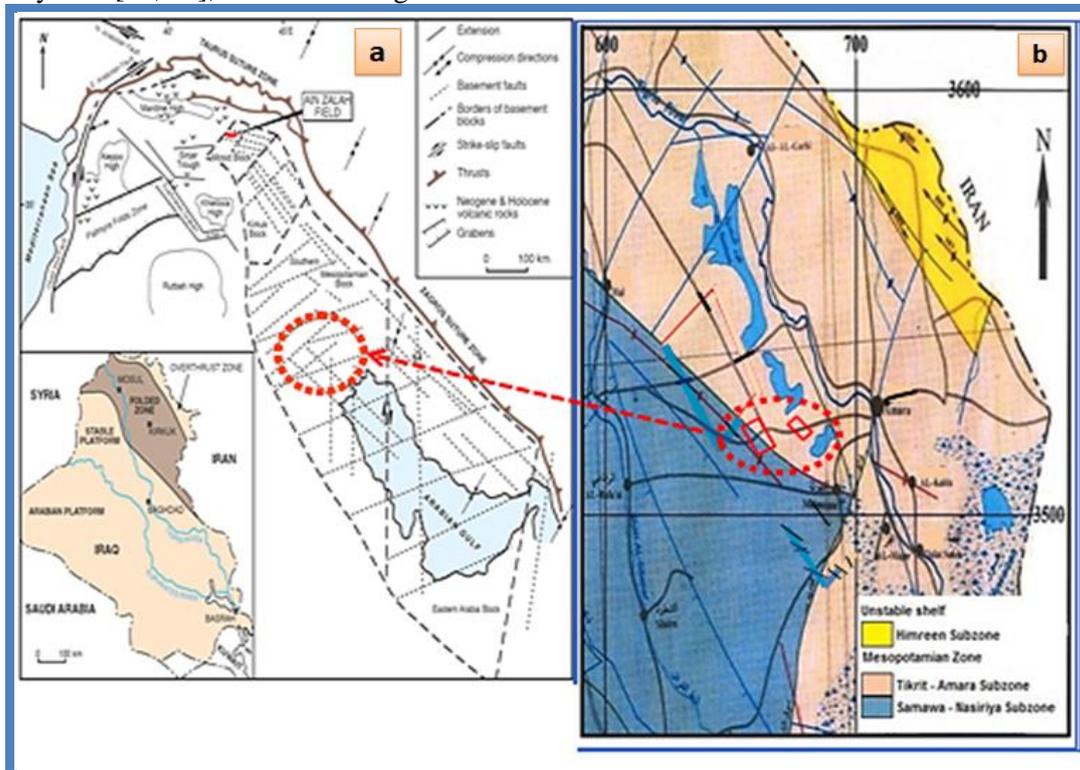


Figure 6-(a) Tectonic elements and basement fault trends for the NE Arabian Plate [20]. The inset map shows the tectonic zones of Iraq. **(b)** Tectonic map of the study area [21].

5. Well log analysis of reservoir characteristics

The simulation of the inversion matrix was started by building an initial model of acoustic impedance, which is extractable by multiplying sonic and bulk density (RHOB) well logs. Well log data is considered as the most fundamental method for reservoir characterization in oil and gas industry. This method is very useful to detect hydrocarbon bearing zones, and calculate hydrocarbon volume. The well logs data is considered as a good tool for the characterization of subsurface formations depending on physical properties of rocks. Many characteristic properties can be obtained, such as shale volume (V_{sh}), water saturation (S_w), porosity (ϕ), permeability (k), elasticity (σ , AI, SI, etc.), and reflectivity coefficient (R).

Basically, there are two types of characterization that are used in reservoir evaluation; these are: petrophysical properties (shale volume, water saturation, permeability, etc.), which are more geology-related, and rock physics (elasticity, wave velocity, etc.) which are more geophysics-related. Every property is related to each other. Many techniques are used to find a hydrocarbon bearing zone, such as NPHI, neutron log and reflectivity coefficient. It is better to use standard data to obtain better characterization.

5.1. Shale Volume

Shale volume distribution is one of the most important factors that have to be considered in formation evaluation, since the existence of shale reduces effective porosity and permeability of the reservoir [22]. Shale is typically more radioactive than sand and carbonate; Gamma ray log can be used for estimating shale volumes in porous reservoirs. The volume of shale is expressed as a decimal fraction or percentage. Equations 1 and 2 show gamma ray index computation which is necessary to determine the volume of shale from the gamma ray log. The data available for copying and pasting to

the LogMath window is derived from the Hampson-Russell portion of the LogMath. There are several nonlinear responses to the gamma ray log, depending on the position and age of formation [23]. The nonlinear relationships are more optimistic as they produce a lower shale volume value than that produced by the linear equation [2].

$$\text{Linear response Vsh} = 0.33(22 * 1GR - 1) \dots\dots\dots(1)$$

$$1GR = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \dots\dots\dots(2)$$

where:

IGR = Gamma ray index.

GRlog = The actual gamma ray value.

GRmin = Minimum gamma ray value of formation without shale.

GR max = The maximum response of gamma ray corresponding to shale layer response.

Vsh = Volume of shale.

Vsh value which represents the accumulation of hydrocarbon in Kumiati oil field is shown in Figure- 7. The seismic inversion section passing through Kt-1 and Kt-2 wells shows the variation of Vsh value along the seismic inversion section. The volumetric shale values relative to the Mishrif units were found to be as follows:

The MA unit of Mishrif Formation (blue color) in the seismic section is represented compacted limestone. The Vsh log in this layer shows a low value and the compact limestone reduces the probability of hydrocarbon accumulation.

The MB unit (reddish-yellow) on the seismic inversion section has a relatively low acoustic impedance at the site of Kt-1 well, which confirms the low Vsh value (clean reservoir unit), which indicates a high probability of an accumulation of hydrocarbon. This unit in Kt-2 well is represented by relatively medium acoustic impedance, which may indicate a decreased probability of hydrocarbon accumulation with an increased water reservoir, as shown in Figure-7.

The MC unit of Mishrif Formation can be distinguished in the seismic inversion section by the blue color. The Vsh log value in this is layer increased, indicating the presences of shale which decreases the probability of the accumulation of hydrocarbons.

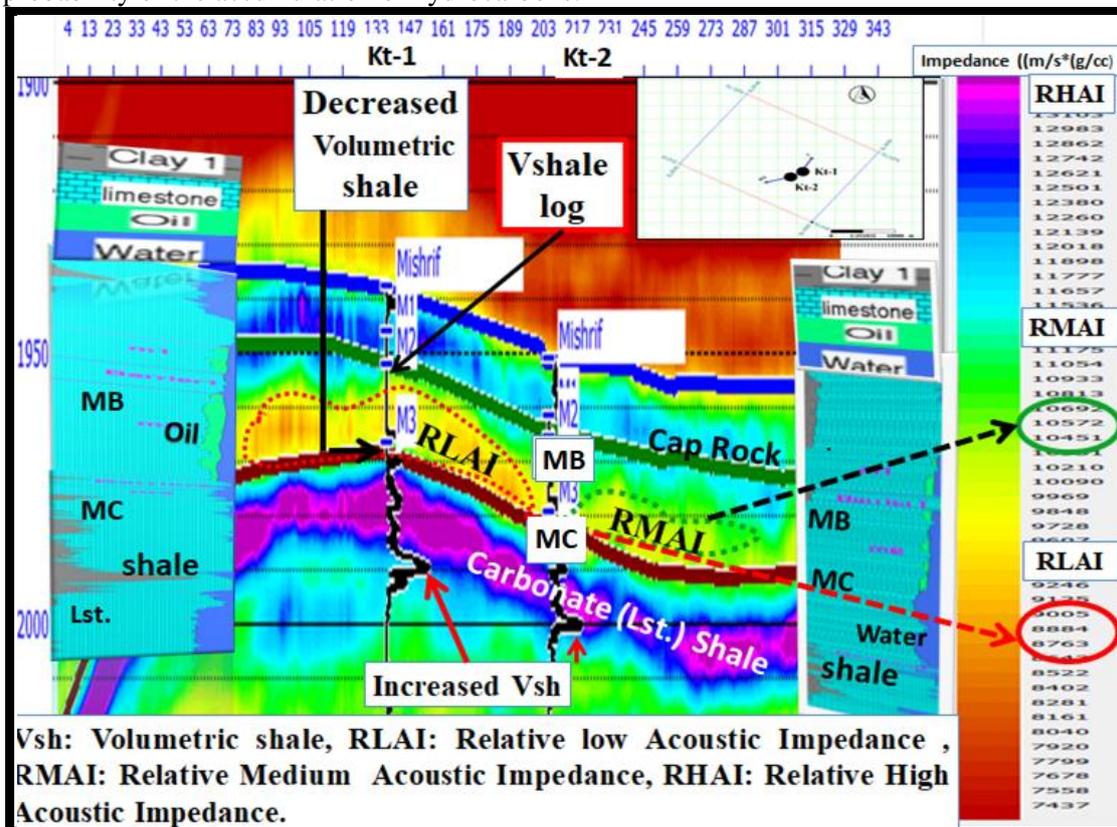


Figure 7- Arbitrary section of inverted Relative Acoustic Impedance (RAI) with volumetric shale logs in Mishrif Formation passing through wells Kt-1 and Kt-2.

The relative RAI value coincided with the decrease of the volumetric shale from log in MA unit, as observed around the Du-1 and Du-2 wells at the level of Mishrif Formation (Figure-8) which is probably the area of oil reservoirs. The Oil –Water Contact (OWC) passing through the unit in Du-1 well, also few oil proved in Du-2 well in this unit from interpretation logs. The different colors indicate different results of acoustic impedance between MA, MB and MC units. A relatively low acoustic impedance value can be observed in the MB unit, with a relatively medium value in the MC unit, associated with the increased volumetric shale. The porous limestone with shale indicates a more decreased acoustic impedance value as compared to that of the limestone in MA unit. The presence of water reservoirs was proven in MB and MC units in Dujaila field, depending on log data interpretation.

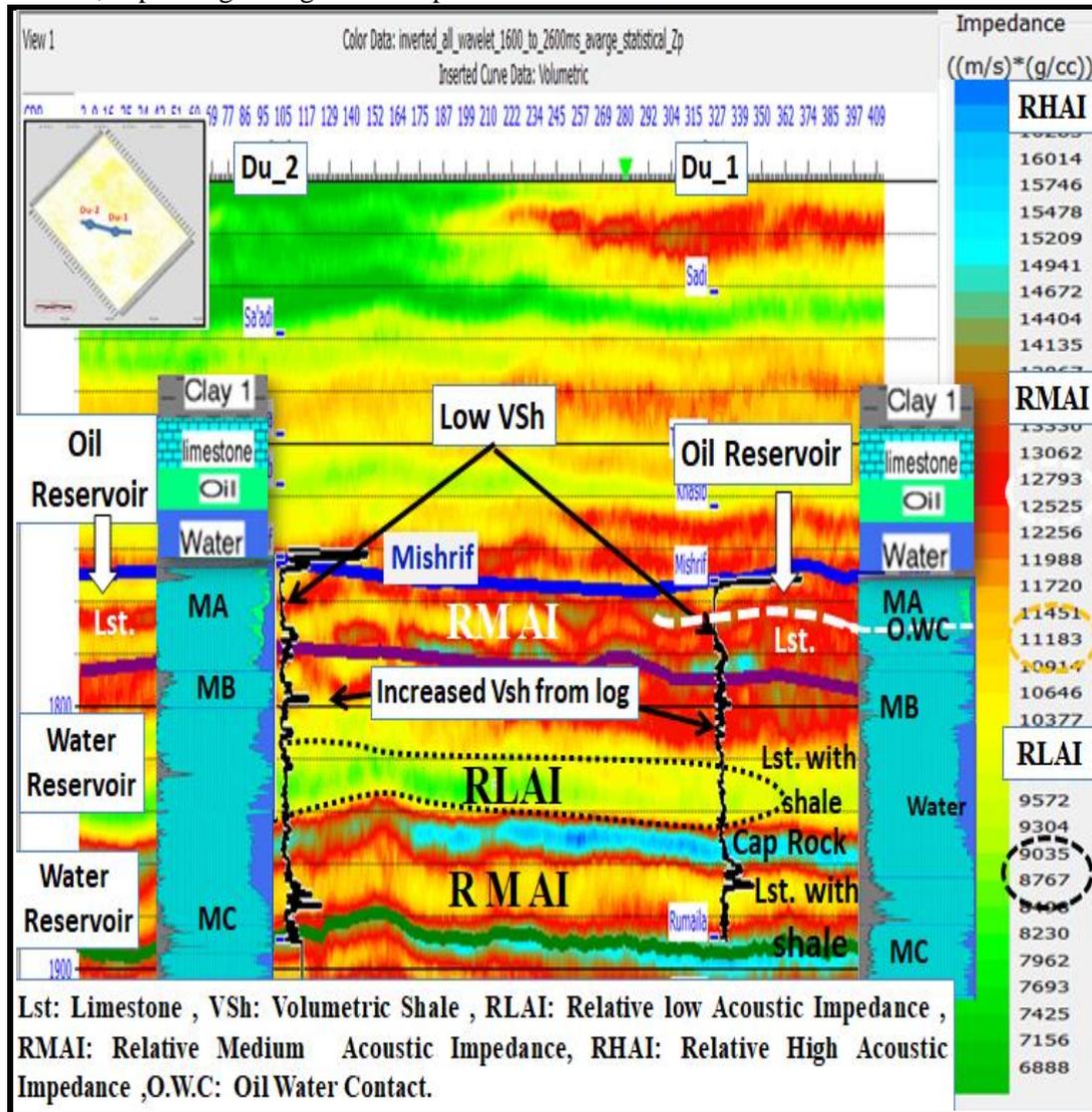


Figure 8- Arbitrary section of inverted Relative Acoustic Impedance (RAI) with volumetric shale logs in Mishrif Formation passing through wells Du-1 and Du-2.

5.2. Water saturation

Water saturation is an important parameter in petrophysical studies. The complexities of the calculation of water saturation arise because of the use of various independent approaches. These different approaches lead to different S_w values, which may result in significant differences in the volumes of Original Oil In Place (OOIP) or Original Gas In Place (OGIP). It was reported that 10% Pore Volume (PV) change in S_w has the same impact as a 2% Bulk Volume (BV) change in porosity in a 20% BV porosity reservoir [24].

The formation's clean and shale free water saturation was calculated using the Archie method. Archie formula is based on the fact that the only conductive material in the formation is salt water; but ions which are released along with shale are also responsible for conducting electrical current in sandy shale formations. The presence of shale in the SP chart can decrease distortion and increase actual conductivity. It should be noted that the exchange capacity of ions, which reflects the potential of shale's electrical conductivity, may show a significant impact on the evaluation of hydrocarbon formations.

The value of the Sw log of the MB unit in well Kt-1 was low, coinciding with relatively low acoustic impedance, which indicates an oil reservoir unit. While a relatively low value of Sw log was shown in the upper part of the MB unit in K-2, suggesting that oil is not found in this well (Figure-9).

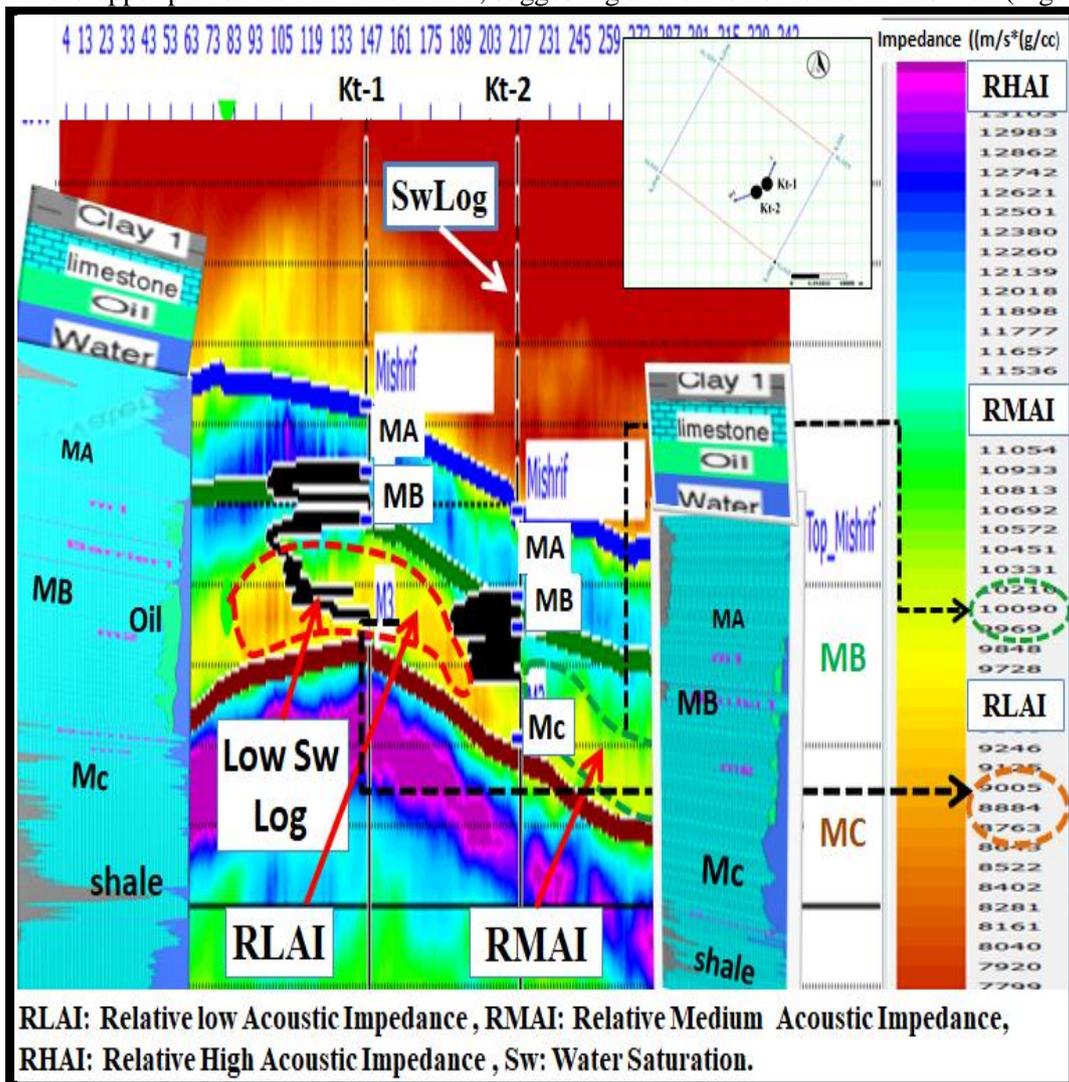


Figure 9- Arbitrary section of inverted Relative Acoustic Impedance (RAI) with Sw logs in Mishrif Formation passing through wells Kt-1 and Kt-2.

The MA unit of within Mishrif Formation in Dujaila field shows a variation in Sw value in the middle part, which confirms an oil-water contact in Du-1 well, as shown in Figure-10. The upper part of the MA unit represents the oil reservoir, which coincides with low Sw and medium acoustic impedance. Also, Du-2 well in MA unit shows low Sw and relatively medium AI values. The MB and MC units at Dujaila oil field are characterized by high Sw and relatively low to medium acoustic impedance values, as shown in Figure-10.

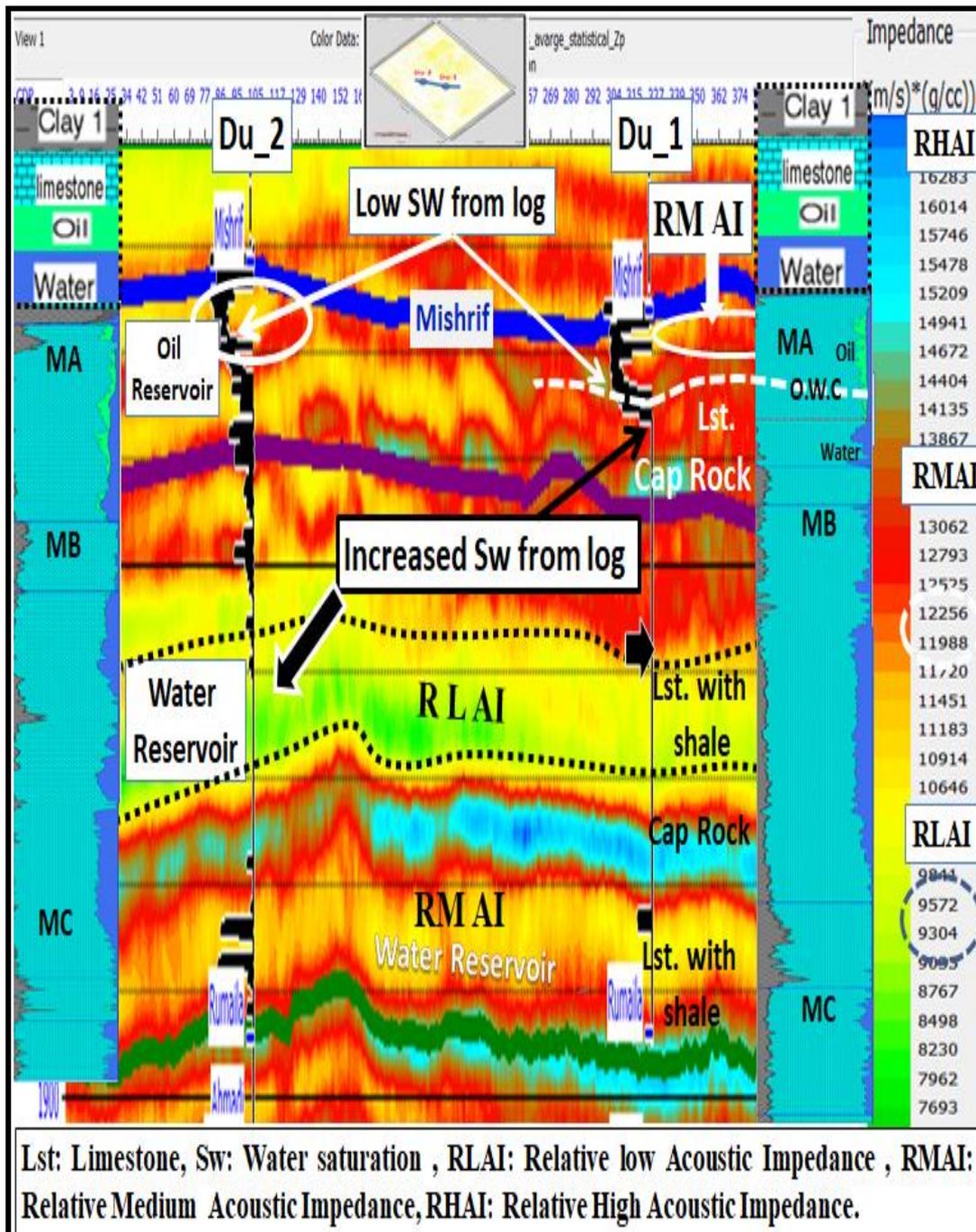


Figure 10- Arbitrary section of inverted Relative Acoustic Impedance (RAI) with Sw logs in Mishrif Formation passing through wells Du-1 and Du-2.

5.3. Effective porosity

The effective porosity is mostly considered to reflect the capability of fluid to flow through rocks or sediments. The ineffective porosity includes water bound to clay particles, called Clay Bound Water (CBW) and isolated porosity. The isolated pores (those bounded by clay) are excluded from the effective porosity [25].

Clay surfaces and interlayers consist of electrochemically bound water (CBW), varying in volume depending on the type of clay and the salinity of the forming water [26].

The most common definition of effective sandstone porosity excludes CBW as part of porosity while CBW as part of total porosity [27].

The log derivation of effective porosity includes CBW as a part of the V_{sh} . V_{sh} is greater than V_{cl} 's (Caly volume not bounded by water), not only because it contains CBW, but also because it includes quartz (and other mineral) grains of clay and silt size, rather than pure clay [27].

The effective porosity in Kt-1 well of Kumait oil field shows high values in MB unit within Mishrif Formation, with relatively low acoustic impedance values that indicate the presence of pore fluid in this unit. On the other side, the effective porosity in well K-2 is decreased slightly in the MB unit, with relatively medium acoustic impedance (RMAI), as demonstrated in Figure-11.

The MA unit at Du-1 and Du-2 wells showed similar characteristics, represented by an increased effective porosity and relatively medium acoustic impedance, indicating the presence of hydrocarbons. The MB and MC units in Du-1 and Du-2 wells also showed an increase of porosity with relatively medium to low acoustic impedance. Hence, it may be difficult to distinguish oil from water reservoirs. In spite of that, the acoustic impedance values in unit MA was higher than those in MB and MC units, as illustrated in Figure-12.

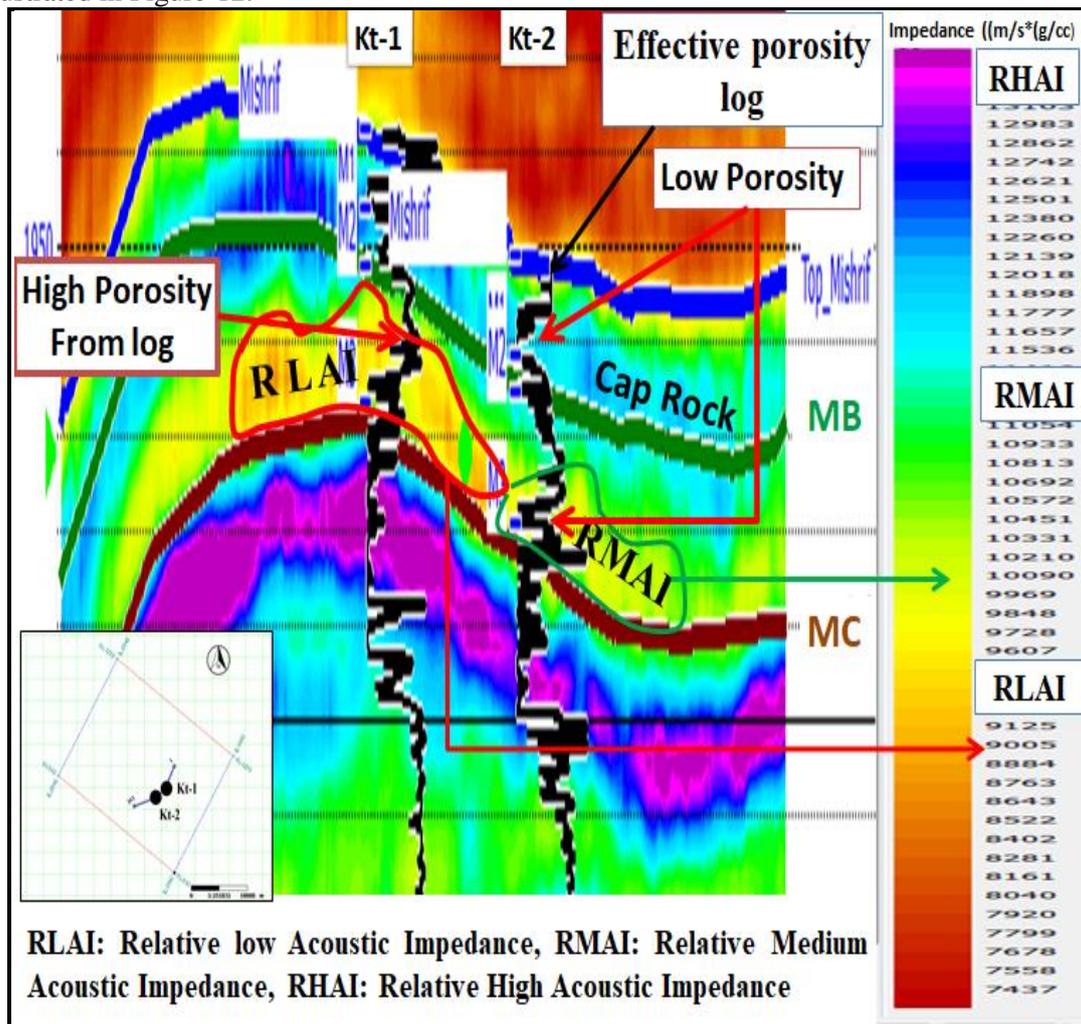


Figure 11- Arbitrary section of inverted Relative Acoustic Impedance (RAI) with effective porosity logs in Mishrif Formation passing through wells Kt_1 and Kt_2.

The slight changes in densities between oil and water are difficult to distinguish using acoustic impedance values, so the relative change of the rock property effect of acoustic impedance value. Therefore, the hardness of the limestone in the MA unit causes high acoustic impedance and a higher increase in velocity than that caused by limestone with shale in MB and MC units (Figure-12).

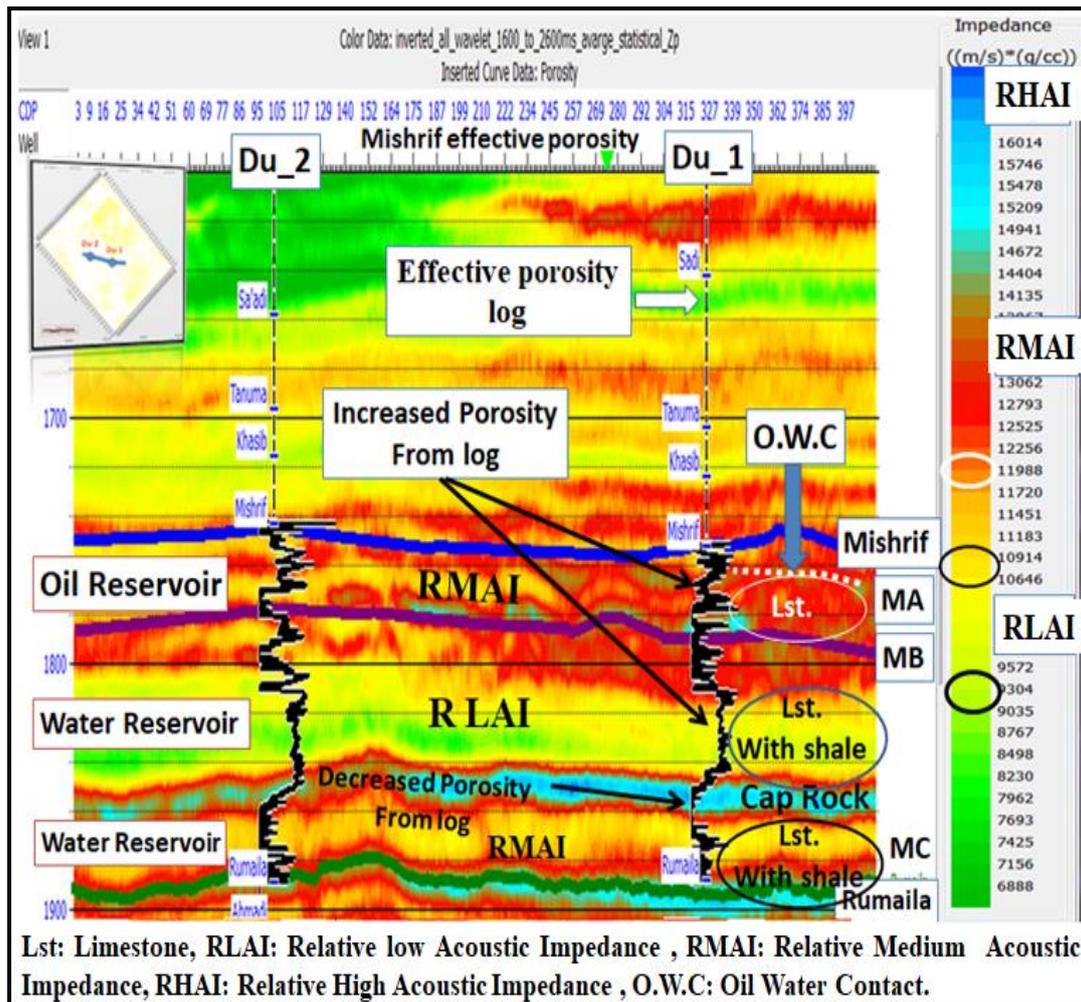


Figure 12- Arbitrary section of inverted Relative Acoustic Impedance (RAI) with effective porosity logs in Mishrif Formation passing through wells Du-1 and Du-2.

6. Results and discussion

This study attempts to investigate the relationship between the petrophysical properties and the behavior of the acoustic impedance and detect some characteristics necessary for defining oil and water reservoirs in Mishrif Formation in Kumait and Dujaila oil fields, southern Iraq.

The final results of the study are summarized in Table -2

Table 2-The results of acoustic impedance and well log analysis for reservoir characterization in Mishrif Formation in the study area.

Physical and geological characterization	MB oil reservoir unit of Mishrif Formation		MA oil reservoir unit of Mishrif Formation	
	Kt-1	Kt-2	Du-1	Du-2
Shale Volume(Vshale)	Low	Low	Low	Low to Medium
Water Saturation (Sw)	Low	Low	Low	Low
Effective Porosity	Medium	Medium	Medium	Medium
Acoustic Impedance(AI)	Relatively Low	Relatively Medium	Relatively medium	Relatively medium

The well log analysis results showed that the values of volumetric shale and water saturation are reduced in Kt-1, 2, Du-1 and Du-2 wells. In the well of K-1: In general the result of well log analysis for second reservoir unit MB, we noticed the reservoir characterization in volumetric shale and water saturation reduced on site Kt-1 and Kt-2. The effective of porosity is medium in the two wells. Well Kumait-1 showed the presence of oil. As for the well Kumait-2, the intermediate tests showed the presence of reservoir water contained in the first and second reservoir units (MA, MB). The analysis of seismic inversion section in the two wells showed relatively low acoustic impedance values in Kt-1 well (oil reservoir) and relatively medium acoustic impedance in Kt-2 well (water with oil reservoir). The first period MA unit in Dujaila field, which is relatively more important depending on the oil shows and the analysis of the logs, MA unite the most important characteristic of this period is that the water saturation indicate low value of the oil reservoir in Du-1 well, and the reservoir properties of the reservoir were not determined of the well Dujaila-2 because the only oil shows exist during the layers tests well which found to contain small amounts of oils with water through the analysis of logs, the effective of porosity is give medium value in two wells, and through the analysis seismic inversion section in two wells showed relative medium acoustic impedance value each on site of Du-1 and Du-2 wells).

The lithology and porosity have remarkable effects on acoustic impedance values. Because of the relatively low difference between the density of oil and water, it seems difficult to distinguish oil from water reservoirs in the study area. The types of oil and water and their relation to the facies variation in the sedimentary formation may be making the acoustic impedance achieved better successfulness in other areas.

7. Conclusions

Many factors affect the process of distinguishing the accumulation of hydrocarbon zones, such as petrophysical properties, acoustic impedance values, water saturation, and volumetric shale in oil reservoir. The variation of AI value, from low to medium, in Kt-1 well (oil reservoir) and Kt-2 well (water reservoir) indicates the effects of fluid content on AI value. The similarity in the values of AI and effective porosity in each of Du-1 and Du-2 wells, in the Mb unit, is due to the presence of heavy oil. Also, the almost similar density of oil and water resulted in a difficulty to find a distinction between the AI values. Moreover, the compact limestone and secondary pores caused an increase in AI value and a decrease in effective porosity. The reservoir characterization using well log data in the two oil fields showed low values of Vsh and Sw logs, as well as low to medium acoustic impedance value with a slight increase in the effective porosity log value in the oil zone. On the other side, low to medium values of the shale volume, water saturation, effective porosity, and acoustic impedance in water reservoirs were observed. The lithology, porosity, and geometry of pores system, percentage of shale volume, and types of shale may represent the main controlling factors on acoustic impedance values.

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