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Lithology Evaluation of Nahr Umr Formation Using AI with Vp/Vs relationship at Amara Oil Field, Southern Iraq

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Abstract

The litholog of Nahr Umr Formation was evaluated using the Acoustic Impedance (AI), Vp/Vs ratio cross plot colored by petrophysical properties (Vsh, PHIT, PHIE, and Sw) in Am-6-Am-10 wells. Bulk density is an important physical property that reflects matrix density and fluid density that exist in rocks pores. It is used as the main parameters to estimate physical characteristics (porosity, water saturation, shale volume, and others). AI was calculated using RHOB and VP logs. Shear velocity was calculated using Greenberg Castagna equations used for estimating the Vp/Vs ratio and the result Showed that theNahr Umr Formation iscomposed of two main lithological units. The upper unit (depth 3540m -3672m) iscomposed of limestone (limestone with low shale volume and low porosity high AI and limestone with high shale volume of high porosity and low AI), while the lower unit (depth 3672m-3740m composed of sandstone with ahigh volume of shale have the lower AI value. The type of fluid was high water saturation in the carbonate part with low effective porosity and hydrocarbons existing in the sandstone part with lower acoustic impedance value.

Keywords: Lithology, Vp/ Vs ratio, Nahr Umr Formation, Amara Oil Field, Iraq.

تقييم صخارية تكوين نهر عمر باستخدام العلاقة بين الممانعة الصوتية والنسبة لسرع الموجات الانضغاطية \ السرع للموجات القصية في حقل العماره النفطي , جنوب العراق

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الخلاصة

تقييم صخارية تكوين نهر عمر باستخدام العلاقة بين الممانعه الصوتية والنسبة للسرع الصوتيه ملونة بالخواص البتروفيزيائية المحسوبة (حجم الطين, المسامية الكلية والفعالة والشبع المائي)في بئرين عماره 6 و عمارة 10 .تعد الكثافة الكلية من اهم الخواص الفيزيائية التي تعكس كثافة الماده وكثافة السائل الموجود في فراغات الصخوروقد استخدمت كخاصية مهمة لحساب الخواص البتروفيزيائية المستخدمة في الدراسة. الممانعه الصوتية تم حسابها من الكثافة الكلية والسرع الانضغاطية . تم حساب السرع القصية من معادلة Castagna

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واستخدمت هذه السرع لحساب النسبة بين السرع الصوتيه الانضغاطية والقصية. وجد ان تكوين نهر عمر يتكون من وحدتين الوحدة العلوية تتكون من اللايمستون عالي الكثافة وقليل المسامية الفعالة وتمتد من الاعماق (3540–3672) ، في حين ان الوحدة السفلية والتي تمتد من العمق(3672–3740) فتتكون من الصخور الرملية المتتابعة مع صخور رملية عالية الاطيان السجيلية الوحدة العلوية تكون مشبعة بالماء ثم يتناقص الماء باتجاه الاسفل في الوحدة الرملية لتزداد الهيدروكربونات حيث تعتبر هذه الوحدة هي المكمن الرئيسي للتكوين في حقل العمارة النفطي.

1. Introduction

Nahr Umr Formation (NU) is one of the important production formations in Iraq, it extends alongwith Iraqi land [1], according to geological studies, Nahr Umr Formation is composed of two units the upper is limestone and the lower is sandstone [2]. The Amara oil field is located within the Mesopotamian basin unstable shelf [3]. This field is one of the small fields located in the region [4]. The field structure on the top of theNahr Umr Formation is an anticline with a length of 17km, a width of 4.5 km, and an enclosure of 90 m. This structure wasdiscovered by seismic exploration survey for thefirst time in 1958 [5]. Amara anticline axis trends NW-SE and the surface of the field is covered by clastic sedimentary rocks (-fine grained sand, gravels, and mud) from quaternary and recent ages [5][6]. The evaluation of NU Formation lithology and fluid content with depth is very important so in this study physical properties are used (shale volume that is calculated from ray-gamma log), (total and effective neutron-density porosity that is measured from both Neutron porosity and bulk density logs) and (water saturation that is calculated using Indonesian equation because NU Formation is rich with shale volume and this equation corrected water saturation according to the resistivity of shale volume) [7], as well as elastic physical properties (bulk density, compressional velocity, shear velocity, Vp/Vs and Acoustic impedance), as these relationships reflect the lithology type and fluid with depths [8]. Hydrocarbon content depends on lithology type and porosity percentage [9][10] and it affects bulk density by lowering the density and decreasing the value of AI and the ratio between Vp/Vs while the presence of water with anincrease in porosity will lead to the decrease in AI but increase in Vp/Vs [11].

2. Study area

Amara oil field is located in Messan Governorate in the southeast of Iraq, (Figure 1) and the south edge of the field extends to the south of Amara city- about 361 km south Baghdad,180 km north Basra, and 20 km southeast of Kumait structure [12]. Table 1 shows thecoordinates of two wells within theAmara oil field.

Table 1- The coordinates of Am-6 and Am-10 wells

well	E	N
Am-6	699 045	351 8582
Am-10	697 150	351 9250

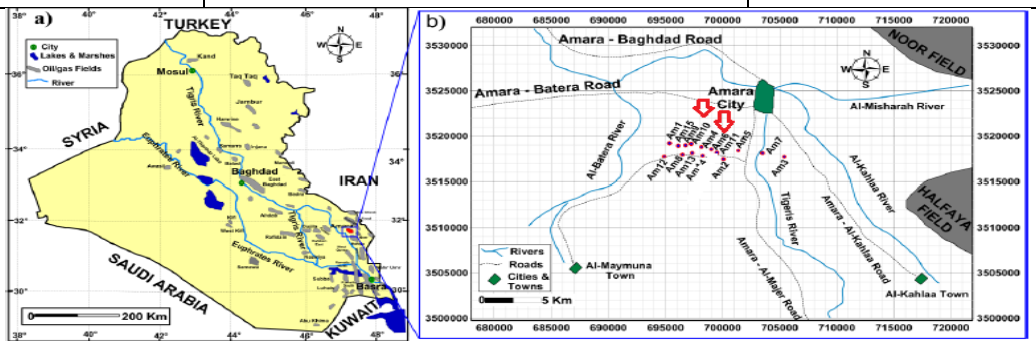

Figure1-(a) The Iraqi map showing the Amara oil field location [13], (b) location of the the well (adapted from MOC. 2001Maps)

Nahr Umr Formation is a part of theAlbian sedimentary cycle, the average thickness is approximately 250m, the lower sand part of the formation is the important part because it contains the hydrocarbon accumulation which has good reservoir properties, the thickness of this part is different according to the well location in the field with an average thickness approximate 55-75 m [14]. Table 2 shows the top of formation at Am-10 and Am-6.

Table 2- The Top depths of the formation at studied wells

formation	Top well Am6	Top well Am10
Nahr Umr	3540	3535

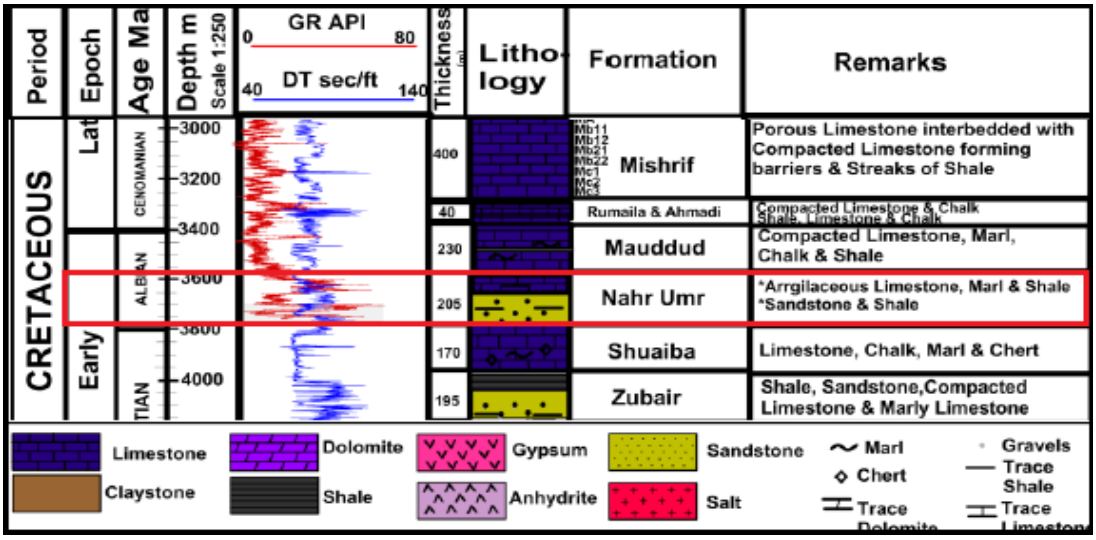

Figure 2-The stratigraphic Column of the Amara oil field (average thickness for each formation) Based on the availability of logs data, the sonic log was taken from depth 1800 – 4300 from Am3 well, GR from 1800 – 3730 from Am4 well, Sonic and GR from 1180 – 1800 from Am12 well**.** [15] The red rectangle highlighted to Nahr Umr Formation

3. Materials and Methods

The work procedures which are used to achieve the results pass throw many steps;

- Shale volume (Vsh) was calculated from thecorrected ray-gamma log which is used as lithology identification to recognize the permeable zones.
- Neutron porosity (NPHI) was read directly from the field that depends on the fluid amount in the pores and the percentage of hydrogen concentration.
- Bulk density (RHOB) log reflects the density of matrix and saturated fluid density.
- TheDensity–Neutron porosity ND PHIT and ND PHIE (total porosity and effective porosity) was determined using neutron and bulk density logs.
- Water saturation (Sw) is calculated using Archie's equation after having the water resistivity from thesalinity method and a, n, and m parameters from thePickett plot.
- (Vsh, RHOB, NPHI, Sw, ND PHIT, and ND PHIE) logs data were used to evaluate the depth lithology type connected with cross plot of AI &Vp/Vs.
- Evaluate the lithology of formations using Density and NPHI logs cross plot between (RHOB-NPHI) cross plot.
- The VP is calculated from DT and then Green Castagna 1992 equation [16] was used to calculate Vs from Vp, this method used many equations for each lithology type and depends on VP data.

For limestone Vs = - 0,05508VP2+ 1.01677VP-1.03049
For sandstones Vs = 0.8042 VP – 855.88
For shale Vs = 0.76969Vp – 867.35

- The Fluid mixing Rock model was used to evaluate fluid density distributed with depth for each formation using the petrophysical parameters as input especially thewater saturation log, the estimated fluid density log was used to evaluate our final result.
- According to the relation between bulk density and velocity with rock physics that depend on lithology type, fluid type, porosity percentage, and fluid saturation the formation can be evaluated and the hydrocarbon depths can be measured [9].
- Acoustic impedance and the ratio between VP/VS were used to determine lithology and fluid types, where the decrease in AI value and the VP/VS ratio indicate the presence of hydrocarbon fluid, while the increase in AI with the decrease in the VP/VS ratio reflects the increase in cement value, and the decrease of AI with anincrease in VP/VS indicates porosity with water saturation.
- The Vp/Vs, AI cross plot were drawn colored with shale volume, effective porosity, total porosity, and water saturation to evaluate formations lithology type and fluid type with depth according to the distribution of formation points around limestone, sandstone, and shale line.

4. Result and discussions

The lithology of Nahr Umr formations is evaluated using Schlumberger, 2005-2010-RHOB, NPHI cross plot after applying all needed corrections to remove the effect of external condition on the readings like change in hole caliber and hydrocarbons effect. In Figure 3 Nahr Umr Formation consists of points around limestone and points concentrate around the sand line that means NU formation consist of two main lithology parts; carbonate rocks and sandstone rocks with ahigh volume of shale which affects the distribution of points so that it deviates towards the sand area on the upper left corner of the cross plots.

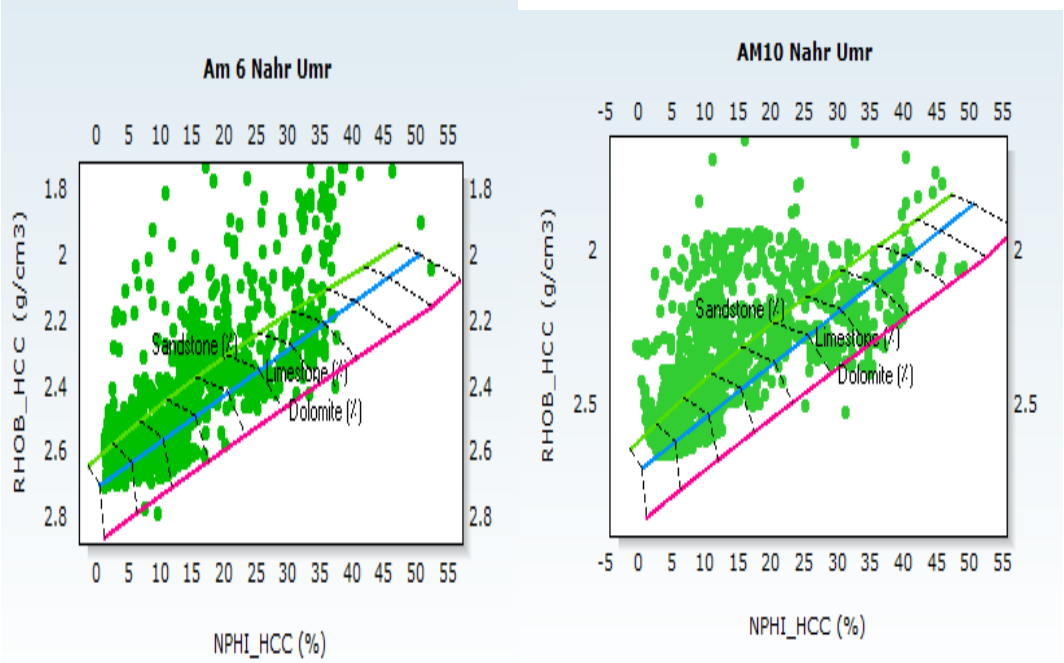

Figure3-Nahr Umr Formation lithology cross plot from using NPHI with RHOB logs data
Figures 4, 5, 6, 7, and 8 show the cross plot between Acoustic impedance and Vp/Vs ratio.

Figure 4 shows the distribution points colored by shale volume where the increase of shale volume leads to low acoustic impedance and high Vp/Vs ratio. Figure 5 colored by Neutron-Density (ND) total porosity, Figure 6 colored by ND effective porosity in these two figures the increase in the total and effective porosities leads to low acoustic impedance and high Vp/Vs ratio., Figure 7 colored by water saturation and Figure 8 represent the formation points colored to the interpretation of this study result for Nahr Umr Formation. From Figure 8 Am-6 could be classified for three colored points areas the blue area with low Vsh, PHIT, PHIE,

and high Sw the AI ranged between (11500 to 16385)g.m/cm3.s and Vp/Vs from (1.64-1.96) and it indicates low porosity limestone with water fluid. In the green area with higher Vsh, PHIT, PHIE, and low Sw, the AI ranged approximately from (8500 - 11500) g.m/cm3.s and Vp/Vs from (1.7-2) and it indicates high porosity limestone with water fluid. In the yellow area with higher PHIT, PHIE, and low Sw, the AI ranged approximately between (4300 to 7500)g.m/cm3.s and Vp/Vs from (1.61-2.14) and it indicates Sandstone with high Vsh, the points with alow value of both AI and Vp/Vs represent oil as fluid exist and the points with high value of Vp/Vs indicate the presence of water as fluid in this area.

At Am-10 the NU Formation is classified into three colored areas, the blue area with Low Vsh, PHIT, PHIE, and high Sw in which the AI ranged between (11000 to 15718)gm/cm3.s and Vp/Vs from (1.64-1.97) and it indicates low porosity limestone with water fluid. In the yellow area with higher Vsh, PHIT, PHIE, and low Sw, the AI ranged approximately from (8300 - 11500) g.m/cm3.s and Vp/Vs from (1.7-1.94) and it indicates high porosity limestone with water fluid. In the green area with higher PHIT, PHIE, and low Sw, the AI ranged approximately between (5380 to8300)g.m/cm3.s and Vp/Vs from (1.61-2.14) and it indicates Sandstone, the points with alow value of both AI and Vp/Vs represent the presence of oil as the existing fluid. It seems that the density of Nahr Umr in Am-6 is higher than in that of Am-10 Figure 4. At the same time, the porosity and effective porosity of Nahr Umr is also higher in Am-6 than Am-10, (Figure 5 and Figure 6). Finally, the water saturation (Sw) of Nahr Umr Formation in Am-6 is very low relative to that at Am-10, Figure 7. From the interpretation of the above figures, we can conclude that lithology in Am-6 well is better than the lithology in Am-10 as a hydrocarbon reservoir.

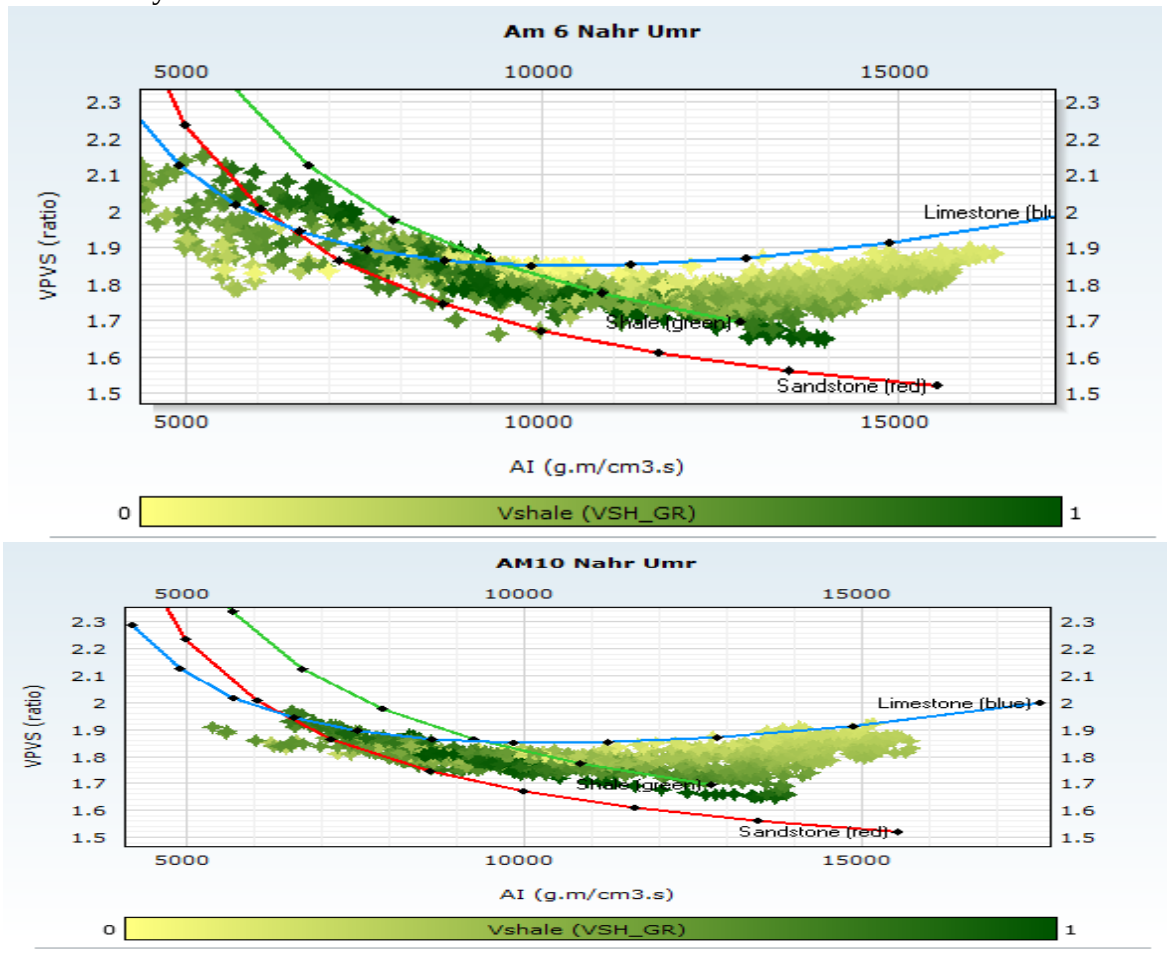

Figure 4-AI, Vp/Vs cross plot for Nahr Umr formation colored by Vsh at Am-6 and Am-10 in thesouth of Iraq

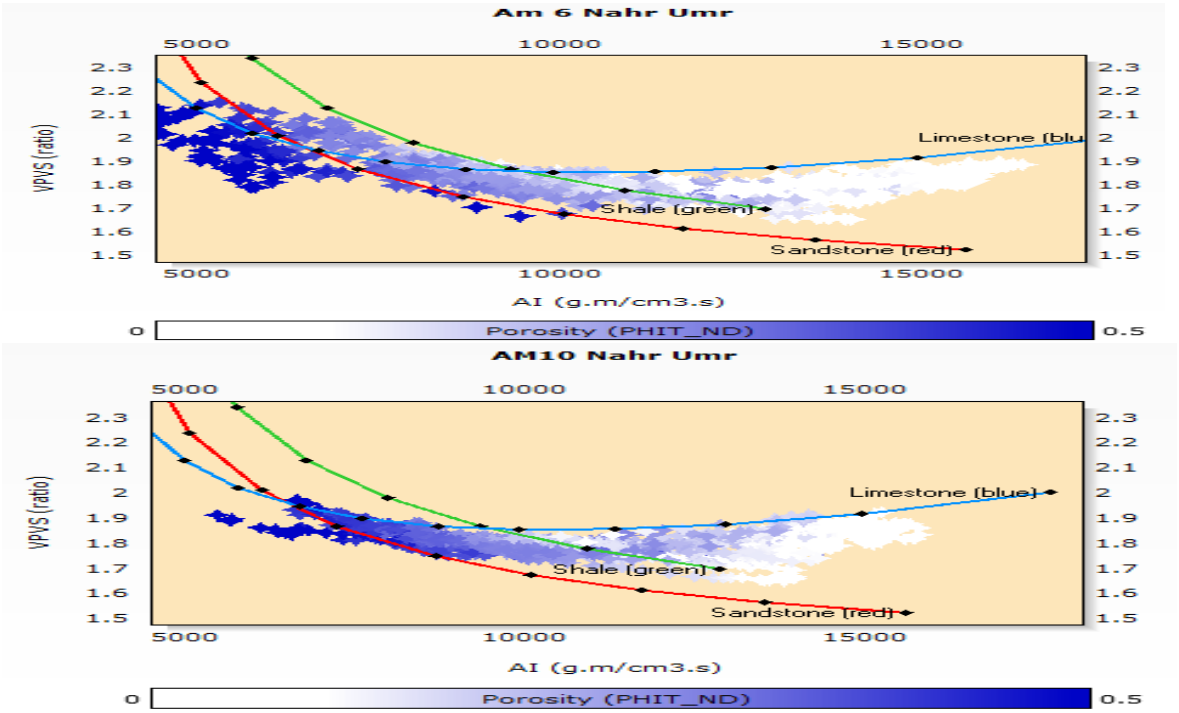

Figure 5-AI, Vp/Vs cross plot for Nahr Umr Formation colored by total porosity at Am-6 and Am-10 in thesouth of Iraq

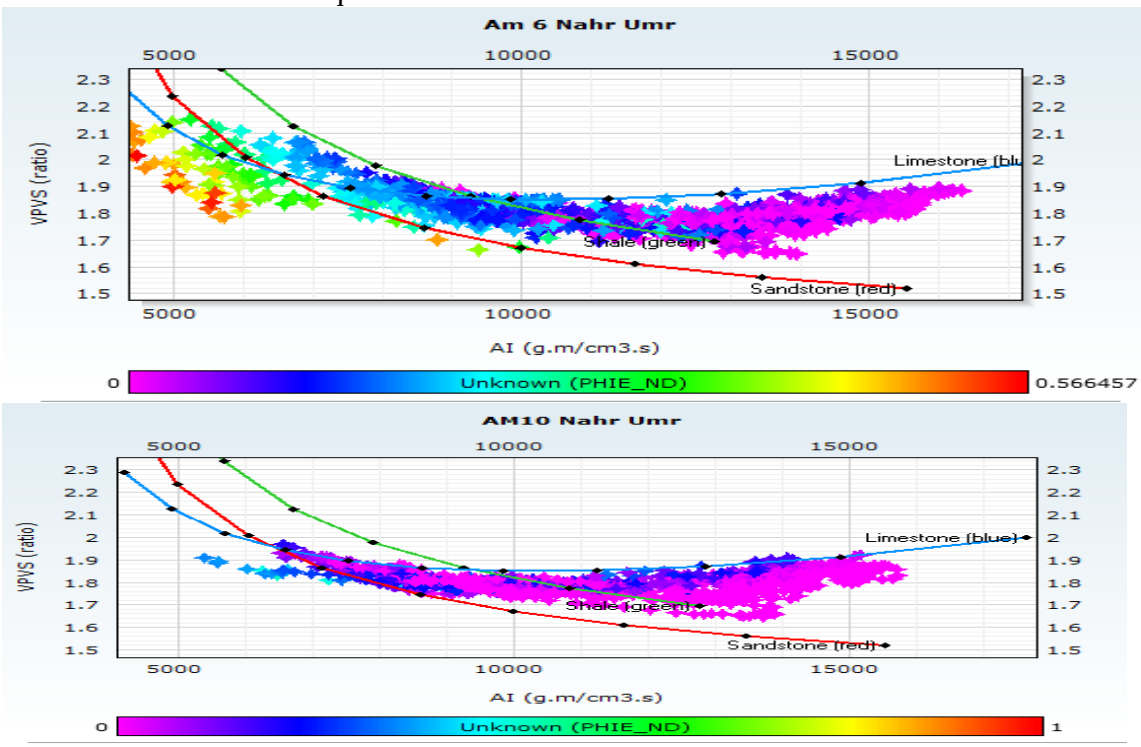

Figure 6-AI, Vp/Vs cross plot for Nahr Umr Formation colored by effective porosity at Am-6 and Am-10 in thesouth of Iraq

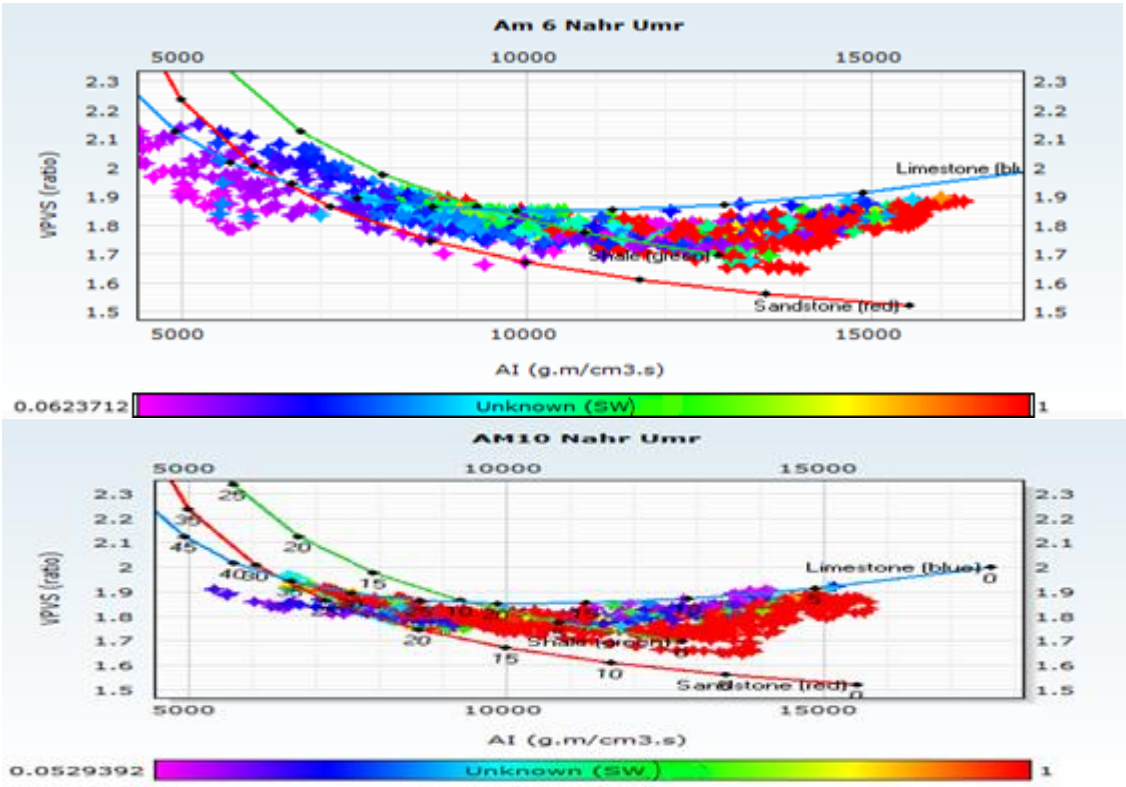

Figure 7-AI, Vp/Vs cross plot for Nahr Umr Formation colored by water saturation at Am-6 and Am-10 in thesouth of Iraq

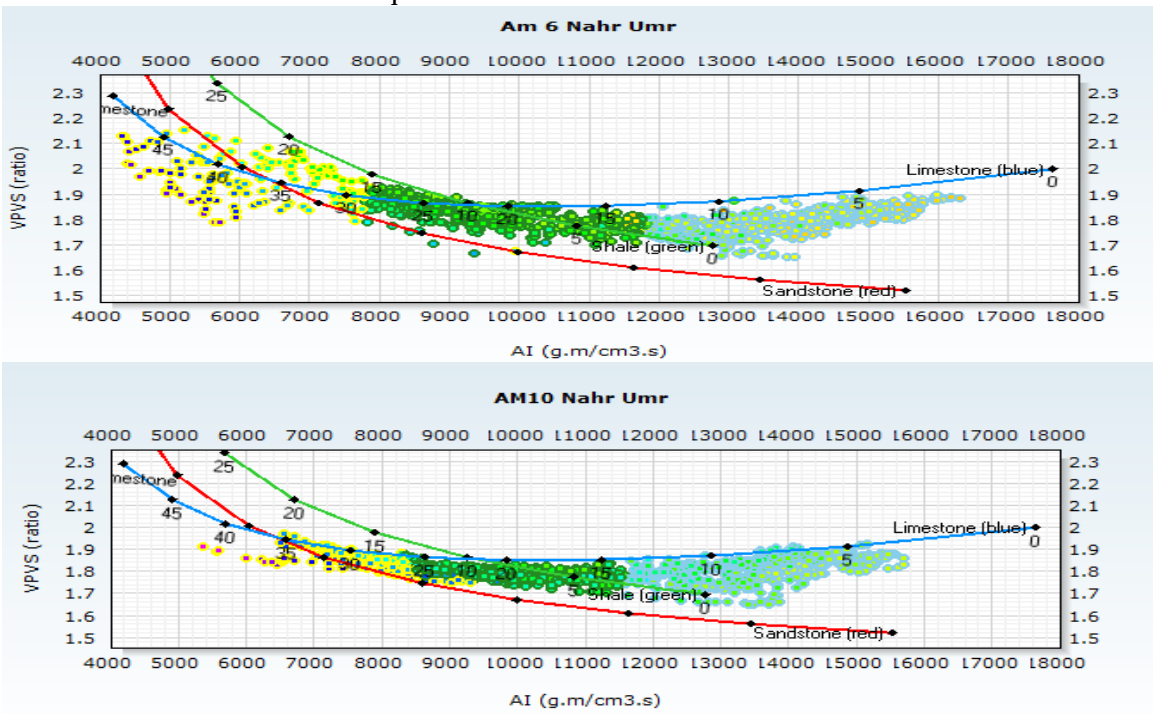

Figure 8-AI, Vp/Vs cross plot for Nahr Umr Formation colored as aninterpretation of this study according to the physical properties differential at Am-6 and Am-10 in thesouth of Iraq

4.1 The Log Interpretation

The most effective parameter in the results of this study is density; the change in this parameter will lead to adramatic change in all logs readings. From Figures 9 and 10 the final interpretation images reflect the change in physical properties concerning depth. According to

this relation, the study formation was divided into three zones depending on similarities in physical properties. The blue depths represent high bulk density (matrix and fluid) with high sonic velocities and high acoustic impedance but it has low porosity (effective and total) the fluid type is water and this appears in thefluid density log so these blue zones reflects low porosity high water saturation limestone with low Vsh amount. The green depths represent lower density than the blue one and so that less velocity and more porosity with arange of water saturation. The yellow depths represent much lower density and velocity with the highest porosity and shale volume which reflects the sand part of the formation interbedded with shale volume, This depth contains the hydrocarbons and isconsidered as agood reservoir characterized by low AI and Vp / Vs ratio.

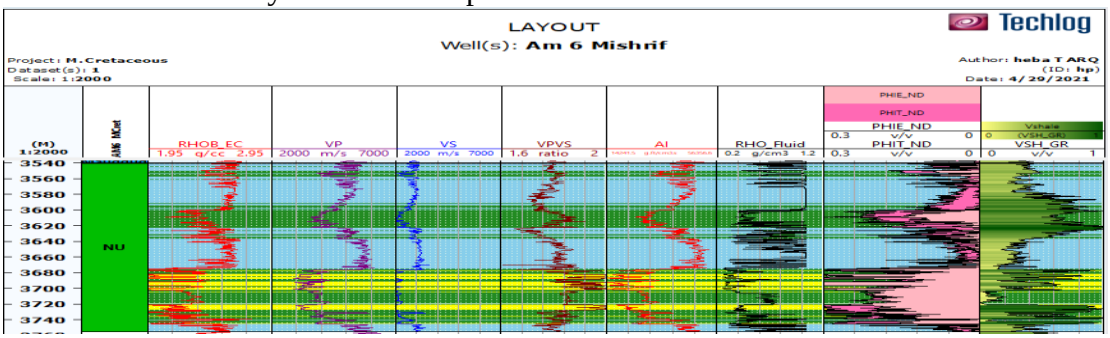

Figure 9- the interpretation of logs of Am-10 well in Amara oil field, Southern Iraq

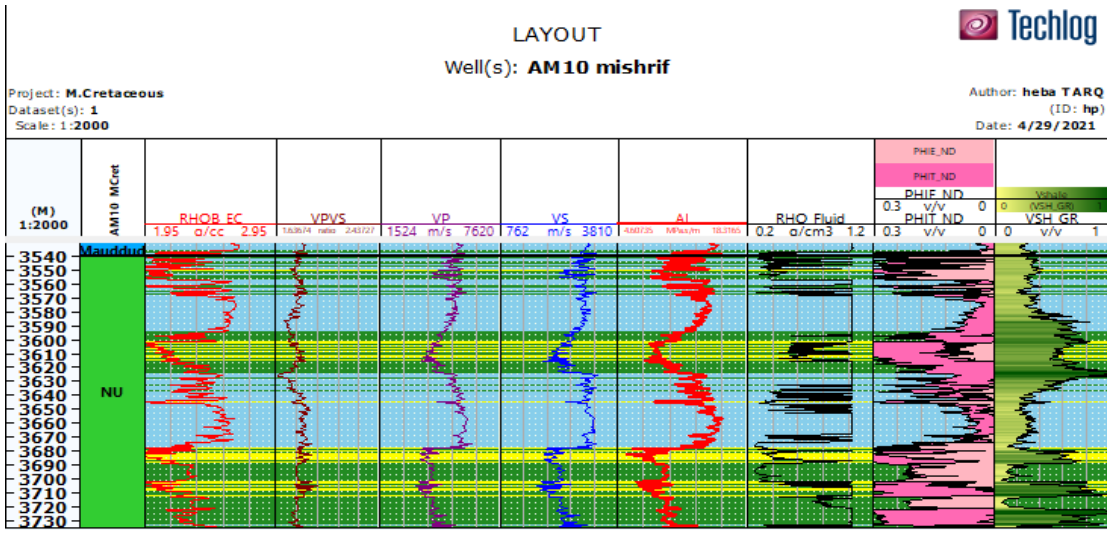

Figure 10-The interpretation of logs of Am-6 well in Amara oil field, Southern Iraq

5. Conclusions

The results show that thelithology of theNahr Umr Formation is composed of two main parts; the first is limestone with shale and the second is sandstone interbedded with shaly sand. The fluid type is indicated according to the values of both VP/VS and AI. The zone with high VP/VS and high AI indicates low porosity limestone with water fluid while low AI with high VP/VS indicates high porosity rocks with water saturation and that exists almost in the shaly layers of the formation. The low amount of both AI and VP/VS indicates azone of hydrocarbon fluid that exists in the sand part of Nahr Umr.

6. Acknowledgements

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