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Implementation of Seismic Inversion to Determine Porosity Distribution of Maysan in Amara Oil Field, Southern Iraq

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Abstract

The current research deals with studying the petrophysical properties represented by the porosity and its distribution on the level of all units of the top and bottom of the Kirkuk Formation Group. The study area is located in Maysan province in the south-eastern part of Iraq in the Amara field. The Kirkuk Group was deposited in the Tertiary Age. The post-stack method using seismic inversion and creating a relationship between seismic data was accomplished using Hampson-Russel software at well Am-1 and Seismic lines Ama 20 and 30. The research results indicate high porosity values on top of the formation with a decrease in acoustic impedance (Z) and, therefore, a reduction in the density. At the same time, low porosity values were indicated for the bottom of the formation with an increase in both acoustic impedance and density. The top of the formation contains clastic sediments with oil-sand of high porosity, which is considered hydrocarbon indication and low porosity carbonate materials at the bottom of the formation.

Keywords: Seismic Inversion, Porosity, Kirkuk Group, and Amara oil field, Iraq

تطبيق المعكوس الزلزالي للتنبؤ بالمسامية لمجموعة ميسان في حقل العمارة النفطي جنوب العراق

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الخلاصة

يتناول البحث الحالي دراسة الخواص البتروفيزيائية المتمثلة في المسامية وتوزيعها على مستوى جميع الوحدات العليا والسفلى لتكوين مجموعة كركوك. تقع منطقة الدراسة في الجزء الجنوبي الشرقي من العراق في حقل العمارة الذي ترسب في العصر الثلاثي. تم تطبيق طريقة ما بعد Post stack باستخدام برنامج Hampson Russel لمعالجة الانعكاسات الزلزالية وإنشاء علاقة بين البيانات الزلزالية وبيانات الآبار في البئر Am-1 والخط الزلزالي Ama20، 30). تشير نتائج البحث إلى قيم مسامية في أعلى التكوين مع انخفاض في الممانعة الصوتية (Z) وبالتالي انخفاض في الكثافة. بينما تمت الإشارة إلى قيم مسامية منخفضة لقاع التكوين مع زيادة في كل من الممانعة الصوتية والكثافة. وبالتالي، يحتوي التكوين على كربونات ذات مسامية منخفضة ومواد فتاتية مع رمل زيت ذي مسامية عالية والتي تعتبر مؤشرات هيدروكربونية.

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Introduction
Seismic inversion is defined as the identification of porosity, thickness, fluid content, hydrocarbon saturation, and rock properties using seismic data and well data [1]. They range from Acoustic Impedance (AI) to rock physical properties and estimate rock property information impedance property [2]. The seismic data represents the output of a convolution process between the earth's reflectivity and source wavelet, so most of the low and high-frequency components of the reflectivity are lost because of the convolution operation [3]. Therefore, inverting the seismic data to reflectivity and creating acoustic impedance would improve subsurface image quality and provide a physical parameter directly related to subsurface properties [4]. The inversion technique can be done in the time or the frequency domain and applied to post-stack seismic data, transforming as input seismic volume into a volume of acoustic impedance based on the oil well data. Seismic wavelet is helpful for geological properties interpretation [5]. It is used to turn a seismic trace to density and sonic logs, as well as the other way around, to turn those two logs into synthetic seismic at wells [6]. The previous studies had assessed the Amara oil field to evaluate the oil-bearing formations. The most important are Nahr Umr and Mishrif formations [7]. Evaluation of hydrocarbon occurrences in the Amara oil field included Khisab, Mishrif, Nahr Umr, Ratawi, and Yamama formations [8]. The study of microfacies in the main carbonate deposits (Mushrif Formation) in southern Iraq, together with interpretations of well wireline log data, shows lateral and vertical differences depending on the relative changes in sea level with tectonic deformation on the regional scale of the Arabian plate [9]. The study aims to deduce the hydrocarbon indicators from the acoustic impedance values and to form an opinion about the porosity distribution at the top and bottom of the Kirkuk group.

Location of the study area
The study area is located in the Maysan province in southeastern Iraq, which lies in the Mesopotamian basin on an unstable shelf. In the Al-Rafedain and Al-Kumait structure, the Noor field is located about 17 km SW of Amara field and 12 km away from NW of the Halfaya Field (Figure-1) [10]. The coordination determines the geographic coordinates of the study area as displayed in the corner symbols **A** (668000 E, 3540000 N), **B** (720000 E, 3540000 N), **C** (720000 E, 3506000N), D (668000E, 3506000 N).

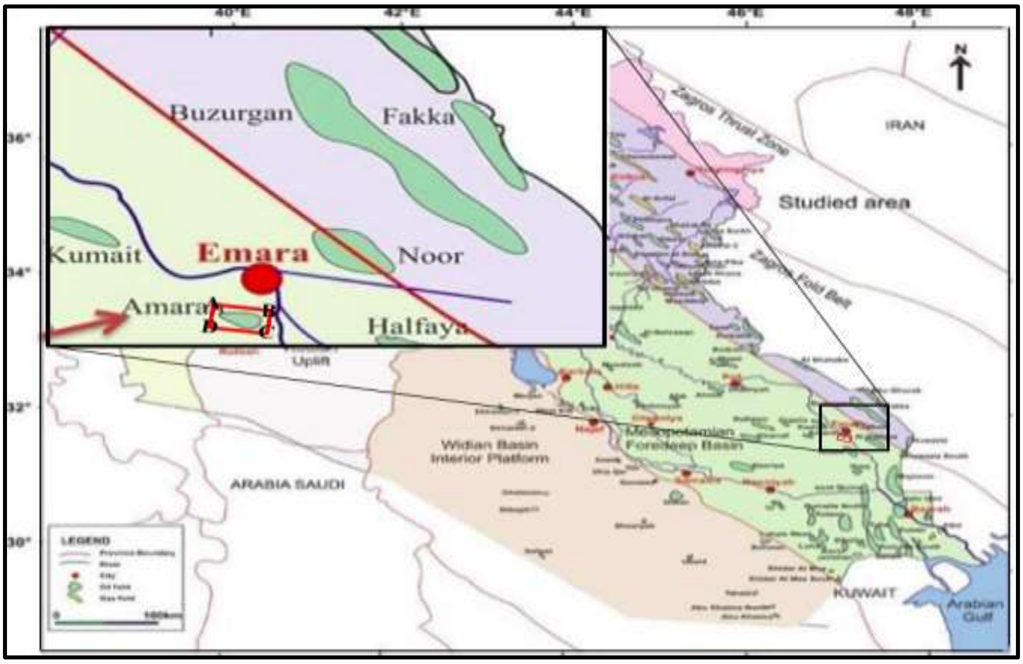

Figure 1- Location map of Iraq showing the study area [11]

Geological and Tectonic Setting

The study area rises several meters above sea level and is covered by Quaternary deposits (alluvial fans). It consists of grey sediments, soft sand and mud deposits from the dry marsh sediments. The Kirkuk group (Oligocene age) in SE Iraq are comprised mainly of calcite (Table-2). Tectonically, Foredeep contains several structures, including faults, folds, and diapiric structures almost entirely concealed beneath the Quaternary deposits. The interplate basin became narrower during the Oligocene period due to the direction of the folds (NW-SE, E-W, N-S) and the uplift movement of the High Folded Zone and the inclination in the west Arabian Plate [12]. The basin was affected by the compression along the Zagros margin and the rise along its Arabian margin due to the rifting onset in the Gulf of Aden and the Red Sea and the closure of the new Tethys River [13].

Synthetic Seismogram

The synthetic seismogram gave the best match between wells and seismic data. The Well Am-1 was chosen and compared with the seismic lines Ama20 and Ama30 to ultimately visualise the studied area. The picked reflectors (upper and lower Kirkuk formations) wavelets appeared as peaks on the synthetic trace in Figure-2 and 3. There are seven tracks from left to right representing reflecting tops, p-wave velocity, density log, acoustic reflectivity, and seismic trace**.**

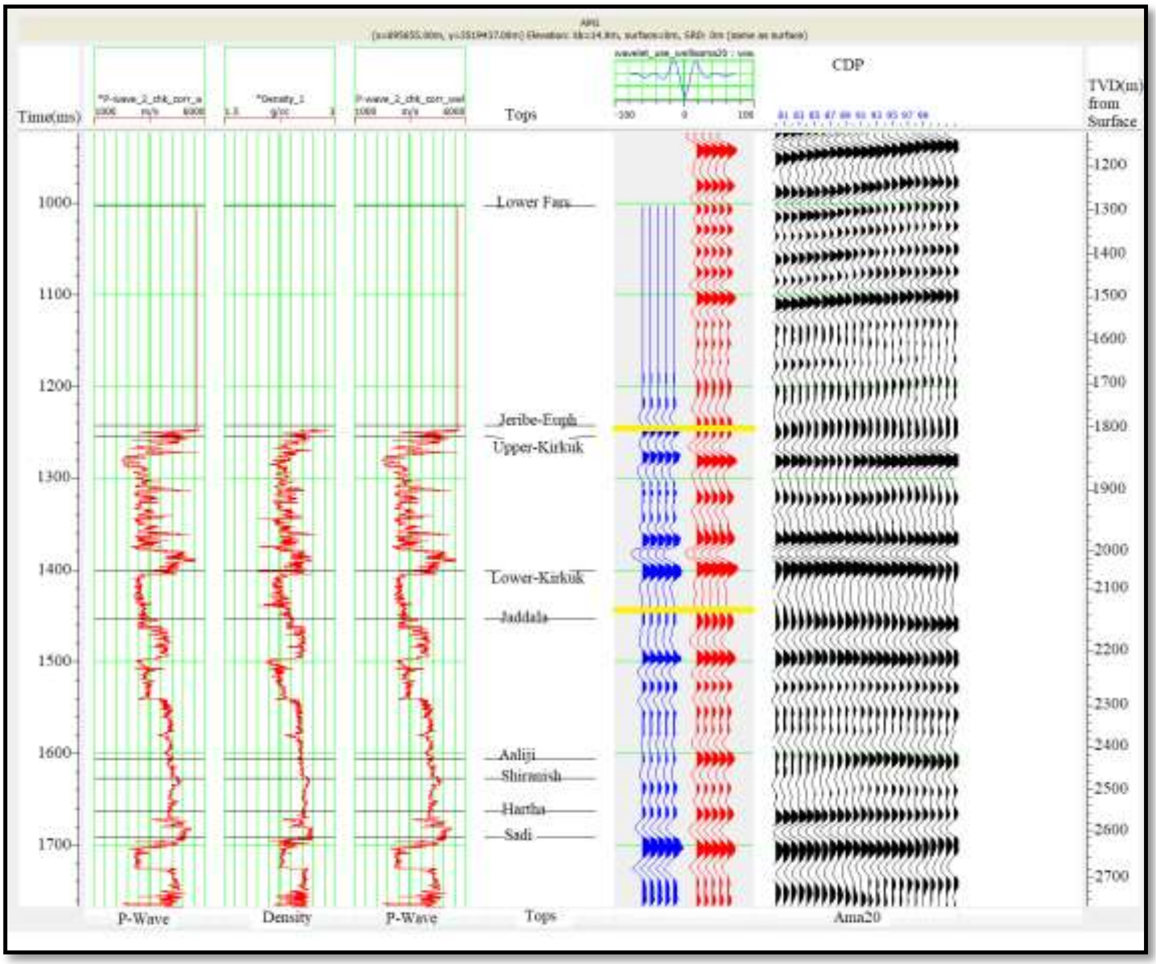

Figure 2-Synthetic seismogram at well Am-1 in Ama20.

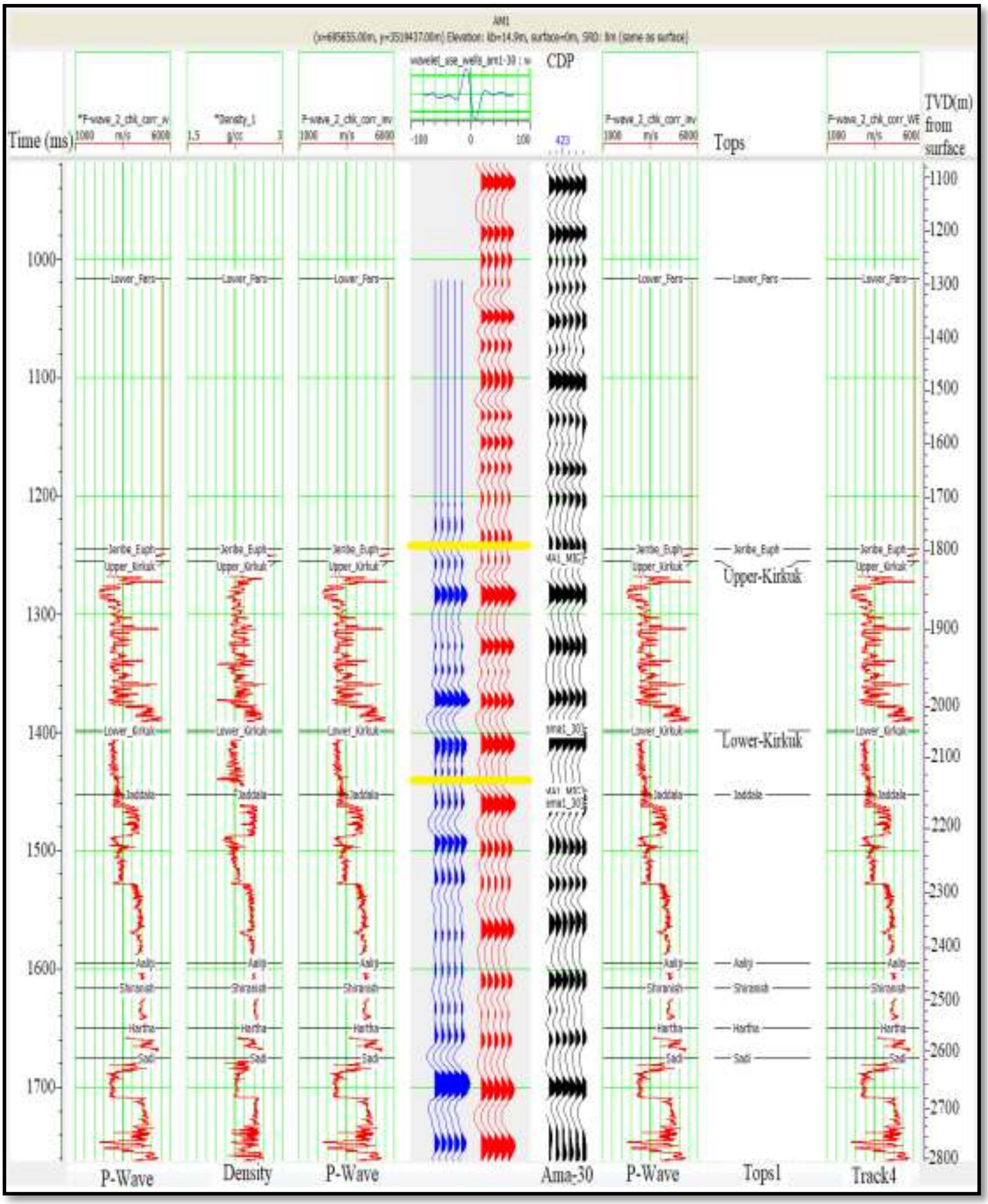

Figure 3- Synthetic seismogram at well Am-1 in Ama30.

Synthetic Trace

This synthetic trace matches the seismic trace (Figure-4), an inverted impedance overlay on the original impedance at (Am-1) well and at the two seismic lines Ama20. The best match was obtained between the synthetic trace (trace red) and the seismic trace (black trace) to determine the topes of the Kirkuk Group.

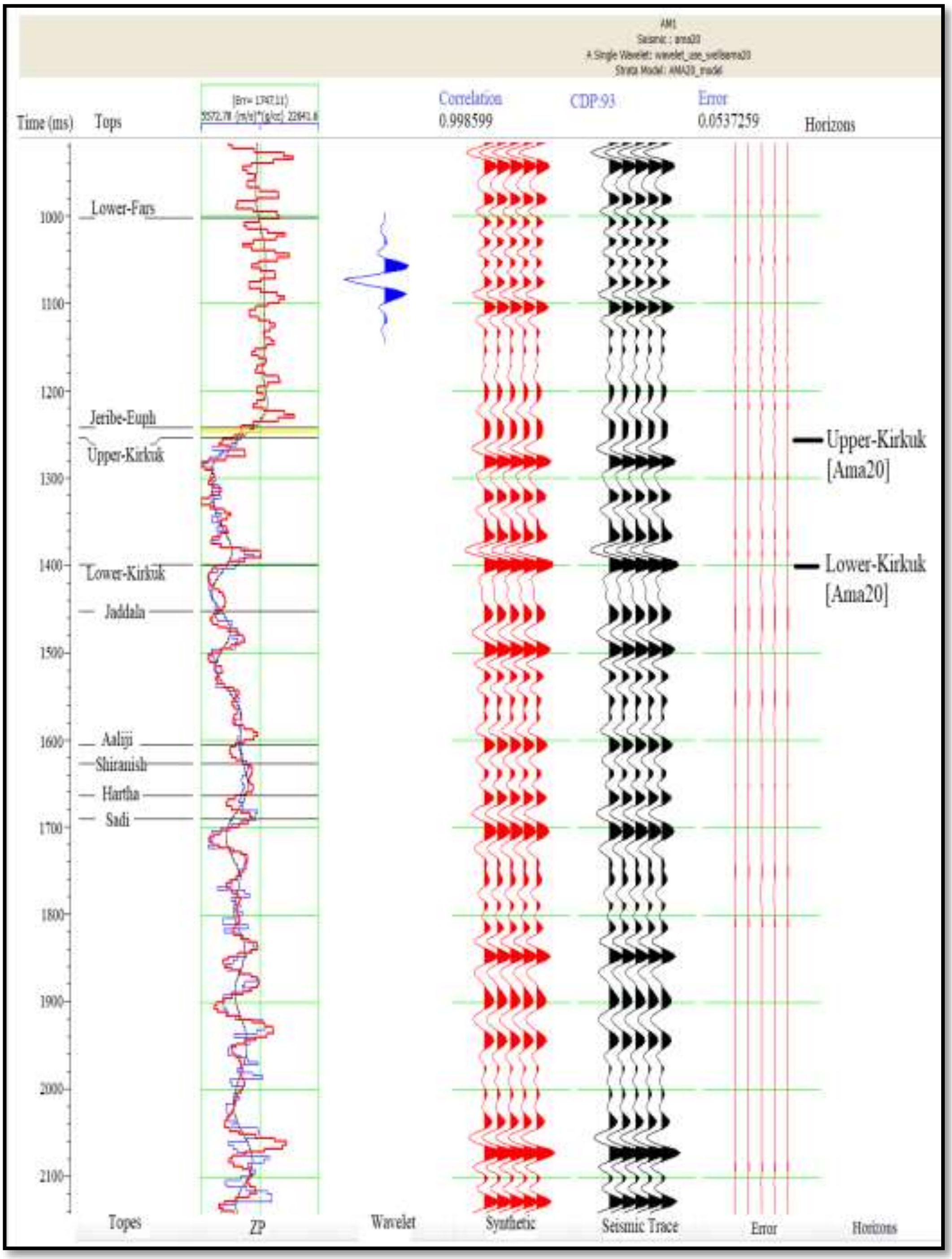

Figure 4-Inversion analysis window.

Inversion Analysis

The study aims to determine the acoustic impedance values of the top and bottom of the Kirkuk Group between the site of the Am-1 well and the two seismic lines Ama20 and 30 to cover the study area. A constant variation in acoustic impedance between the decrease (Z), density, and increase porosity in the top of the Kirkuk Group and the increase (Z), density, and decrease porosity in the bottom (Figure-5). This results from a change in the lithology or the fluids present in the formation, indicating the possibility of the presence of hydrocarbons.

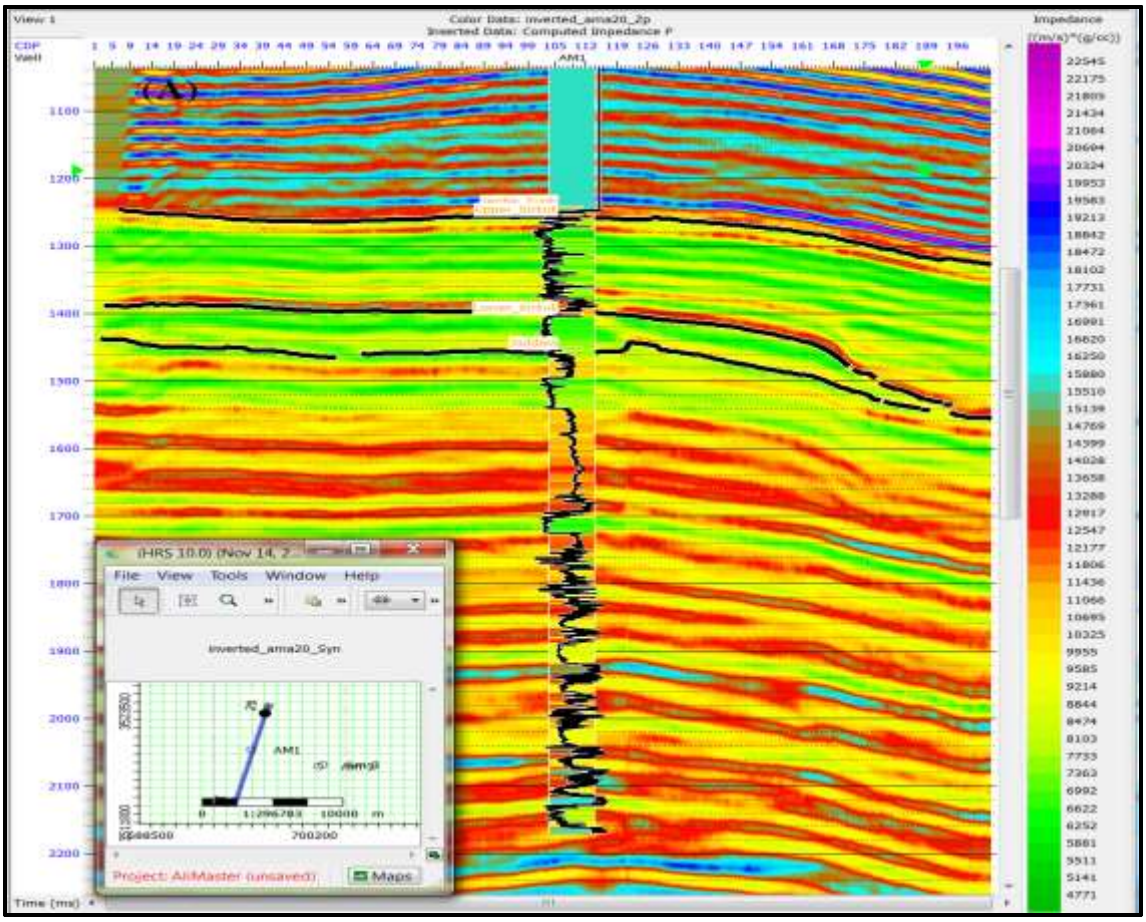

Figure 5-Inverted acoustic impedance passing through well (Am-1) at inline section (A)- Am20, (B)- Am30.

Porosity of the Kirkuk Group

Seismic and well data (porosity and neutron log) from an acoustic (Am-1) detecting-well lithology and hydrocarbon exploration using the Hampson-Russell EMERGE module [14] were compared with the impedance values.

The cross plot shows that there is a good and direct relationship between acoustic impedance (x-axis) and density (y-axis) while reversing with porosity-NPHI (y-axis). The cross-plotting displays that the formation contains carbonate of low porosity with a high value of the acoustic impedance (Z) and density. It includes clastic sediments (sand, silt, and shale) of moderately low Z and density, with a high porosity value. It is observed that the sand's porosity is lower than the shale's. In comparison, the density of the sand is higher than the shale. The cross plotting shows the presence of isolated points that represent (Oil-Sand) values (moderately-low Z, density, and high porosity in formation, which refers to a hydrocarbon indicator (Figures 6 and 7).

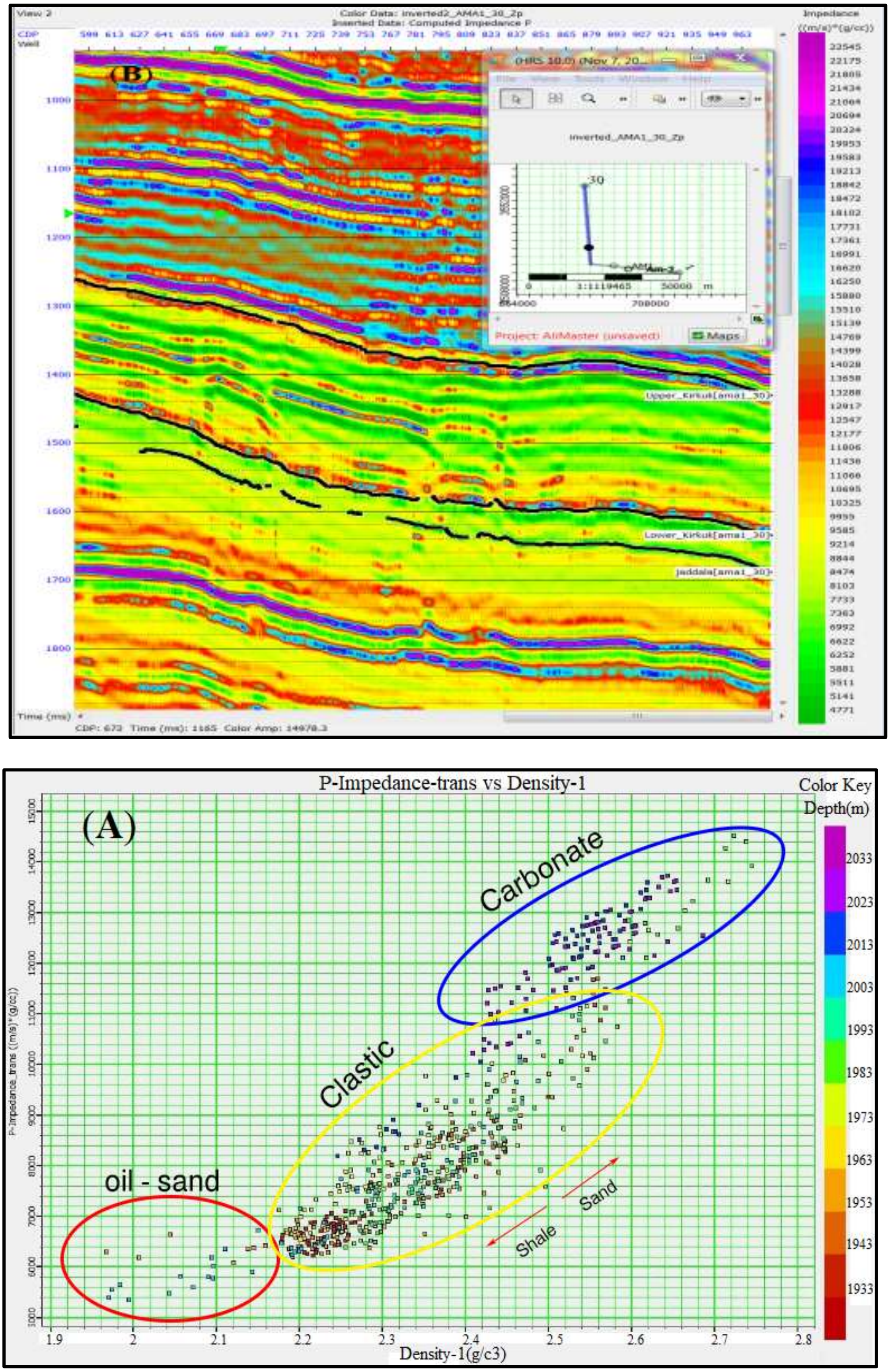

Figure 6-Cross plot at Density-Acoustic impedance at (A) Top and (B) Bottom.

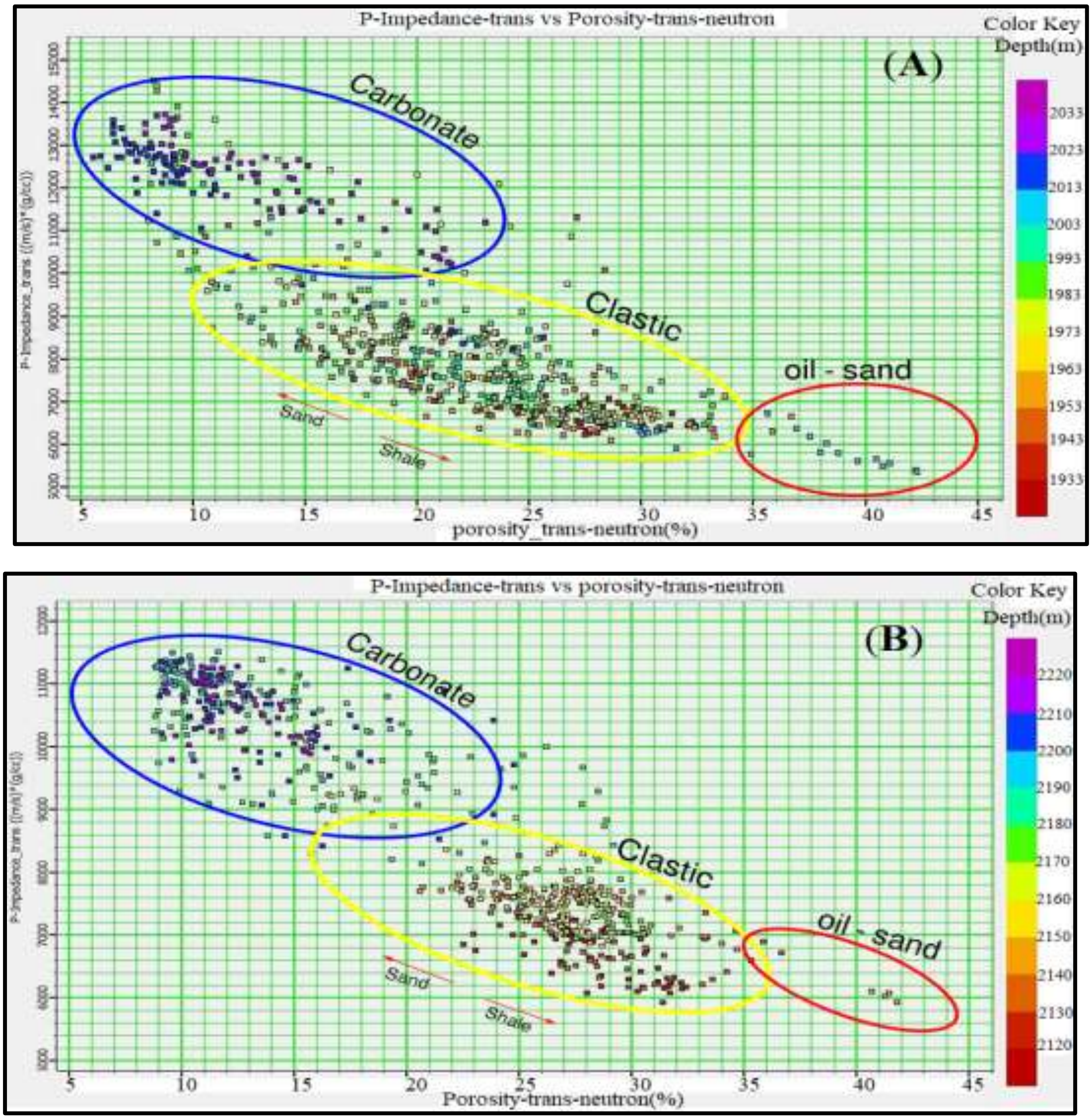

Figure 7-Cross plot at porosity trans neutron -acoustic impedance at (A)Top, (B)Bottom.

Discussion

A seismic inversion technique was performed on seismic data by utilising Hampson-Russell Software and the (post stack) method to invert the seismic data into acoustic impedance. The output results were used to predict porosity distribution on vertical and horizontal scales to cover the formation in all study areas. Acoustic impedance analysis with porosity shows that the Z value increases with decreasing porosity at the bottom of the formation. In contrast, the porosity increases with decreasing Z at the top of the formation. This is attributed to the lithological changes in the formation’s upper and lower part, which was determined by comparing the porosity and density with the acoustic impedance in the cross plots. The formation consists mainly of limestone and dolomite with a high to the medium proportion of sand, a small amount of shale and very little silt, with a rare amount of oil- sand. The rock content can be inferred by comparing the acoustic impedance with the density and porosity of the formation, as shown in Table 3.

Table 3- General log responses to various rocks in the Kirkuk Group

Lithology	**Acoustic impedance (Z)**	**Density (RHOB)**	**Porosity (NPHI)**
Limestone	Very High	Very High	Very Low
Dolomite	High	High	Low
Sandstone	High-Moderately	High-Moderately	Low-Moderately
Shale	Low- Moderately	Low- Moderately	Very High

Silt	Low	Low	High
Oil-Sand	Very Low	Very Low	Very High

Conclusions

The decrease in acoustic impedance values in the Amara field indicates the reduction in density and increase in porosity at the top of the Kirkuk Group. The increase in density and the decrease in porosity values in the bottom of the Kirkuk Group indicate an increase in acoustic impedance. The cross-plot displays that the formation has a very high Z, high density, and low porosity for carbonates; and moderately-low Z, density and high porosity for clastics and oil-sand. Such values are considered as hydrocarbon indications. The clastic sediments a high Z, density, and low porosity, representing sand type; and high Z, density, and low porosity representing shale type.

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