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Uncertainty Analysis to Assess Depth Conversion Accuracy: A Case Study of Subba Oilfield, Southern Iraq

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Abstract

The depth conversion process is a significant task in seismic interpretation to establish the link between the seismic data in the time domain and the drilled wells in the depth domain. To promote the exploration and development of the Subba oilfield, more accurate depth conversion is required. In this paper, three approaches of depth conversions: Models 1, 2, and 3 are applied from the simplest to the most complex on Nahr Umr Reservoir in Suba oilfield. This is to obtain the best approach, akes giving less mist with the actual depth at well locations and good inter/extrapolation between or away from well controls. The results of these approaches, together with the uncertainty analysis provide a reliable velocity model and more accurate predicted depth that reduced the ambiguity of the subsurface. The uncertainty analysis reveals that Model 3 is considered a more practical and most accurate approach because it gives a minimized standard deviation value of 14 with less residual and error values. The uncertainty of the depth conversion and the standard deviation values is raised towards the eastern part of the field due to an increase in the dipping depth in this region that affects the depth conversion results.

Keywords: Depth uncertainty; Depth conversion; Seismic interpretation

تحليل الموثوقية لتقييم دقة التحويل العمقي: دراسة حالة في حوض بلاد ما بين النهرين، جنوبي العراق

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الخلاصة

تعتبر عملية تحويل العمقي مسألة مهمة في التفسير الزلزالي لعمل صلة مترابطة بين البيانات الزلزالية في المجال الزمني والآبار المحفورة في المجال العمقي. ولتعزيز استكشاف وتطوير حقل نفط الصبة النفطية، لذا كان من اللازم إجراء طريقة أكثر دقة. في هذه الورقة البحثية، تم عمل ثلاث طرق للتحويل العمقي: موديل 1 و 2 و 3 تم تطبيقها من أبسطها إلى أكثرها تعقيداً على مكن نهر عمر في حقل صبة النفطية. وللحصول على أفضل طريقة من الممكن ان تعطي أقل فرق مع العمق الحقيقي عند مواقع الآبار واستقراء جيد بين او بعيدا عن مواقع الآبار. توفر نتائج هذه الطرق جنباً إلى جنب مع تحليل الموثوقية موديل سرعي موثوق وعمق متوقفاً أكثر دقة، مما قلل من مصاعب الاستكشاف التحت السطحي. يكشف تحليل الموثوقية أن الموديل 3

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يعتبر الطريقة الأكثر عملية والأكثر دقة في هذا الحقل لأنه يعطي ادنى قيمة انحراف معياري وتبلغ 14 مع قيم متبقي وخطأ أقل. تزداد موثوقية التحويل العمقي وقيم الانحراف المعياري نحو الجزء الشرقي من الحقل نتيجة لزيادة العمق في هذه المنطقة مما يؤثر على نتائج التحويل العمقي.

1. Introduction

Seismic reflection data involves subsurface images of geological features in the time domain, which geophysicists interpret to determine the subsurface geology structures, where hydrocarbon accumulations may be found. However, the initial interpretation and geological model must be in depth domain because wells are drilled in depth. Therefore, depth conversion is applied to reduce the structure ambiguity associated with structures in the time domain. In particular, areas that lacked geologic information due to the complexity in the subsurface [1] [2]. The velocity model is a significant step in converting seismic volumes or seismic events in time to depth. Many velocity models are built using different approaches to estimate a quantitative velocity and depth uncertainty [3]. The determination of the suitable approach of depth conversion is based on the level of geological complexity, the availability of the data, and the aim of depth conversion, whether detailed or regional. Some uncertainties in hydrocarbon exploration are linked to depth uncertainties. These uncertainties are the availability of geological and geophysical information, errors in horizons picking, facies, and property modelling [4].

There is a challenge in evaluating the accuracy of depth conversion approaches. The interpreter has a minor guide on potential depth errors, especially in regions away from well control or the factors that affect the accuracy of depth conversion [5]. Therefore, determining a proper seismic time-to-depth conversion approach and the accuracy of this conversion requires choosing the optimum velocity model, which is a subjective choice that the geophysicist makes. Previous studies on Subba oilfield in Iraq as in [6] and other fields in Iraq, e.g. Khashim Al-Ahmer gasfield; Merjan oilfield and Huwaiza oilfield Southeastern Iraq [7] [8] [9] generally, used the simple method of depth conversion to convert the two-way time map to depth map. However, this method cannot accurately evaluate the predicted depth of inter/extrapolation away from well controls.

Previous authors working on depth conversion [3] [10] [11] [12] [13] used more than one method of conversion to investigate the suitable velocity parameters like instantaneous velocity (V_0) and depth gradient (K) or to determine the level of velocity reference of V_0 for velocity model building [14]. However, these studies do not use these methods to decide which velocity model to be applied in the depth conversion process. Using more than one method for the depth conversion allows the interpreter to diagnose the causes behind increasing the difference (residual) between the actual depth and the calculated depth that led to an increase in the uncertainty of depth conversion. It is possible to determine the region with high uncertainty especially, away from well controls area by using the depth maps resulting from applying different methods of depth conversion to generate a standard deviation map. The purpose of this study is to determine the suitable approach for depth conversion with less depth uncertainty at or away from well controls. Hence, in this study, we investigate the extent depth conversion approaches and avoid anchoring on a single approach [15] [16] and evaluate uncertainties along complex regions. Three different common methods are applied in Nahr Umr Formation using the Subba oilfield 2D seismic dataset. Then, a standard deviation map is extracted, giving the amount of uncertainty in the study area. Analysis of these depth conversion approaches is used as a guide to evaluate the uncertainty of calculating depth at/away from well controls and choose the suitable approach for depth conversion in this field. The economic feasibility of this research is to reduce well drilling risk in the future, which is necessary to optimize the location of productive wells by obtaining the best tie between the predicted and the actual depth at well locations and get a better inter/extrapolation away from well control area within the boundary of Subba oilfield.

2. Location and Geology Setting

Subba oilfield lies in southern Iraq and is 72 km from Nasiriya City within the Mesopotamian Basin, as shown in Figure 1. The most significant hydrocarbon reservoir units are located in the Mesopotamian Basin in southern Iraq [17]. Lower Cretaceous succession contains 30% of Iraq's oil and gas reservoirs [18] [19] [20]. Hydrocarbon production in the Subba oilfield is predominantly from Nahr Umr, Zubair, and Yamama formations [21] [22]. This study concerned Nahr Umr Formation as a major clastic oil-producing reservoir in the Mesopotamian Basin in southern Iraq. It is composed of black shale interbedded with medium to fine-grained sandstone, including lignite, pyrite, and amber [23] [24] [25] [26]. The Nahr Umr Formation belongs to the Early Cretaceous (Albain cycle) is deposited in a clastic-carbonate inner shelf environment [27] [28] [29]. Nahr Umr Formation is composed of three main subsequence units, which are the upper subsequence (dominated by shale with a low rate of sand facies); the middle subsequence (dominated by sand with a low rate of shale facies), and the lower subsequence (dominated by sand facies). The middle subsequence is considered as the main productive subsequence in the Nahr Umr reservoir with good petrophysical properties in this field. However, the upper and lower subsequence reveal the low quality of reservoir properties [30].

Tectonically, this field is located in the western boundary of the Mesopotamian Basin within the Zubair subzone in the unstable shelf as a part of the Arabian platform [31]. The Subba oilfield geometry is an asymmetrical anticlinal structure with the southern and northern domes, discrete via the shallow saddle.

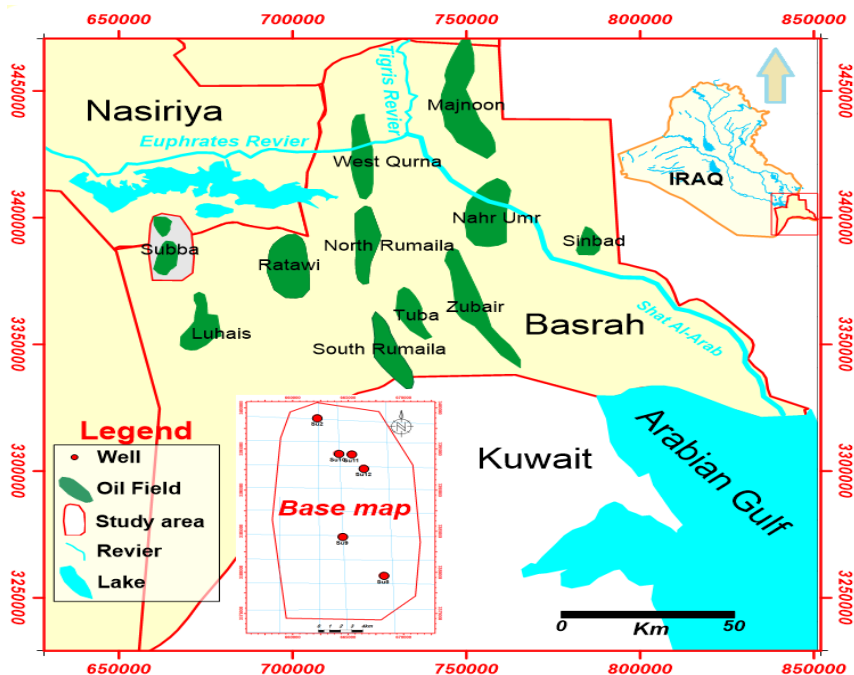


Figure 1-Location map shows the Subba oilfield and the base map that includes six wells within the 2D seismic survey.

3. Data and Methodology

3.1 Dataset

Mapping subsurface structures on flat areas can be constructed only if the subsurface data are obtainable; well data and seismic reflection sections provide different information from the subsurface such as changes in the lithology and the existence of hydrocarbon accumulation [32]. 2D seismic sections are used in this study (e.g. Figure 1) along the Subba-Luhais survey (SL) in addition to sonic and density logs from six wells and all of these wells penetrated

Nahr Umr Formation. All these data were obtained from an oil exploration company (O.E.C). The quality of seismic data is good to use in this study. In this paper, the source of the velocity data can be obtained from 1. well velocity directly from check shots of Su2, Su8, and Su10; 2. hybrid velocity, which is derived from the pseudo-velocity (i.e. the time from seismic and depth from well) of Su9, Su11, and Su12 wells; 3. a mix of these two sources according to the availability of the velocity data. Figure 2 shows the workflow of seismic interpretation and depth conversion uncertainty used in the Subba oilfield.

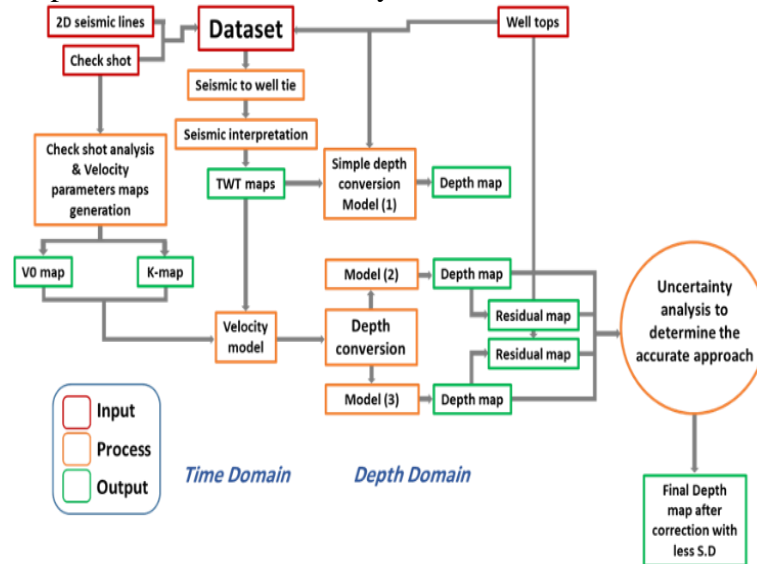


Figure 2-Workflow for seismic interpretation and depth conversion uncertainty [33]

3.2 Methodology

3.2.1 Seismic Interpretation

In this study, three key seismic horizons were interpreted, representing the tops of Nahr Umr, Shauiba, and Zubair formations using a 2D seismic survey of SL oilfield, Figure 3. These top formations were assigned from the check shots and the synthetic seismograms together and calibrated with the well velocity information. Then TWT grid surfaces are extracted as illustrated in Figure 4. High-to-intermediate continuous seismic reflectors within the Subba oilfield characterize the interpreted horizons; therefore, auto-tracking was used in the picking process. While in regions with weak reflectors, the horizons were interpreted manually. The accuracy of depth conversion depends on the number of TWT surfaces, so utilizing more TWT surfaces in the velocity model enhances the predictability of the outcomes of depth conversion [2].

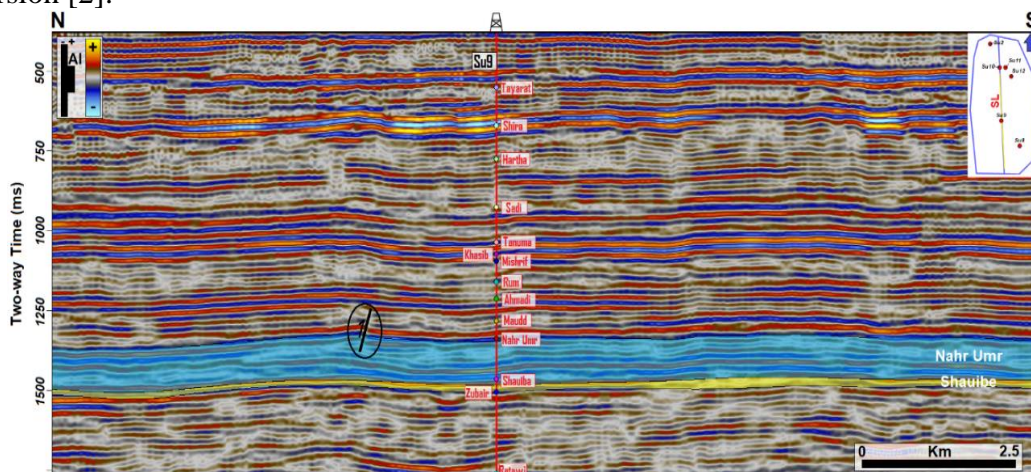


Figure 3-2D interpreted seismic (SL) two-way time across Subba oilfield.

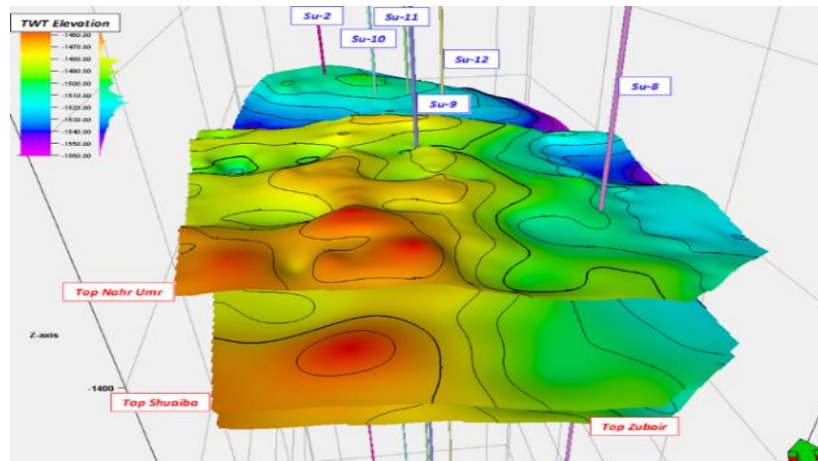


Figure 4-Three time horizons mapped from 2D seismic time sections. Contours are in two-way time (TWT). The vertical axis (Z) is TWT in ms.

3.2.2 Depth Conversion Approaches

In the current study, three approaches 1, 2, and 3 Models were applied for depth conversion, which are:

Model 1: In this approach, the depth conversion was carried out using a simple approach. This approach is one of the most common methods in seismic interpretation to convert the geological features in the time domain into the depth domain, which is also called the direct or pseudo-velocity approach [34]. The predicted depth from this approach should match the actual depth at each well location, and this approach is only applied at certain depth locations (i.e. only at well locations) [1]. Many previous studies were used this method in Iraq, such as in [6] [7] [8] [9]. This approach was involved in this study to show the limitation of this approach.

To apply this simple depth conversion, the average velocity was calculated by dividing the actual depth by one-way time to the corresponding seismic horizon of Top Nahr Umr at well locations. The average velocity map of Top Nahr Umr Horizon is computed by using a mix of two velocity sources: the actual velocity information of check-shot (Su2, Su8, and Su10) and the pseudo-velocity of wells (Su9, Su11, and Su12). Then, convert to (X, Y) grid surface to construct an average velocity map from six well points (Figure 5a). This average velocity map was multiplied by the one-way time surface in Figure 4 that was divided by two to give one-way time of the Nahr Umr horizon to generate a depth map, Figure 5b.

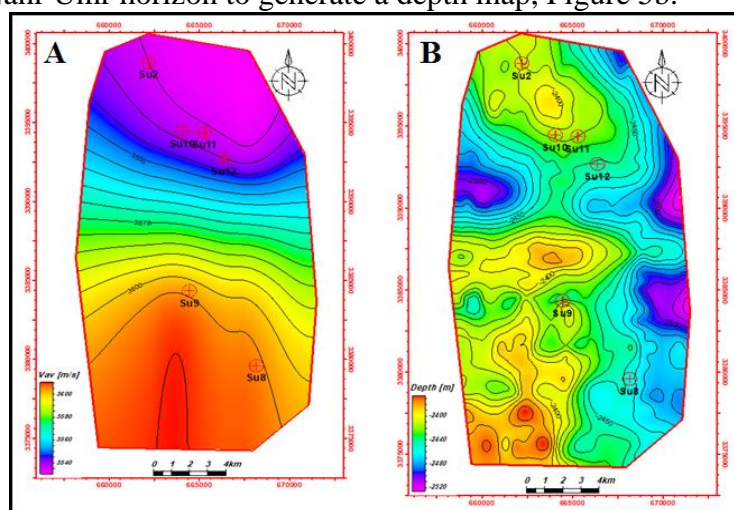


Figure 5-a) Average velocity map of Top Nahr Umr Reservoir generated from 6 well points, b) Depth map of Nahr Umr Reservoir using simple approach Model 1.

Model 2: In this approach, at each (X, Y) location, the velocity is varied with depth in the vertical direction by a factor of depth gradient (K). The velocity is varied in the horizontal direction by instantaneous velocity (V₀). According to this approach, the relationship between the average velocities can be computed by the following equation:

$$V_{av} = V_0 + KZ \dots \dots \dots (1)$$

V_{av} is the average velocity; V₀ is the instantaneous velocity; K is a depth gradient, and Z is the well depth. This approach was applied in [2] [5] [30] [32]. In the current study, the velocity parameters (instantaneous velocity (V₀) and depth gradient (K)) are cross-plotted against the corresponding actual depth values from the check-shots of three wells Su2, Su8, and Su10, as shown in Figure 6. A best-matching straight line that passes through these points represents the depth gradient (K). Then V₀ of Top Nahr Umr Horizon at well locations is calculated by using the following equation:

$$V_0 = V_{av} - KZ \dots \dots \dots (2)$$

Velocity parameters (V₀ and K) are then converted into (X, Y) grid surface to generate V₀ and depth gradient (K) maps from three well points, as shown in Figure 7. The correlation value from the cross-plot in Figure 6 between the average velocity and the depth reflect the quality and the degree of the linear function between them. If the linear function has a wide scatter of points and low regression, then this function represents unsuitable relation to applied in this area because this function doesn't represent the velocity-depth relation therefore, another function should be used.

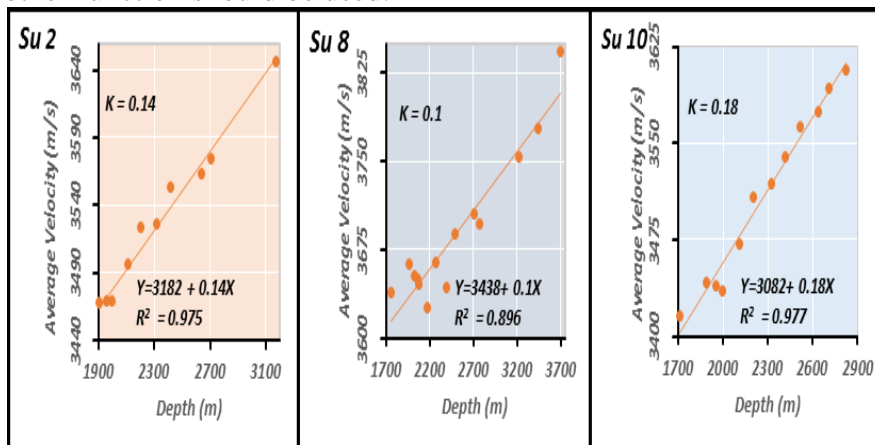


Figure 6-Check-shot analysis to derive the velocity parameters V₀ and K of Su2, Su8 and Su 10 wells.

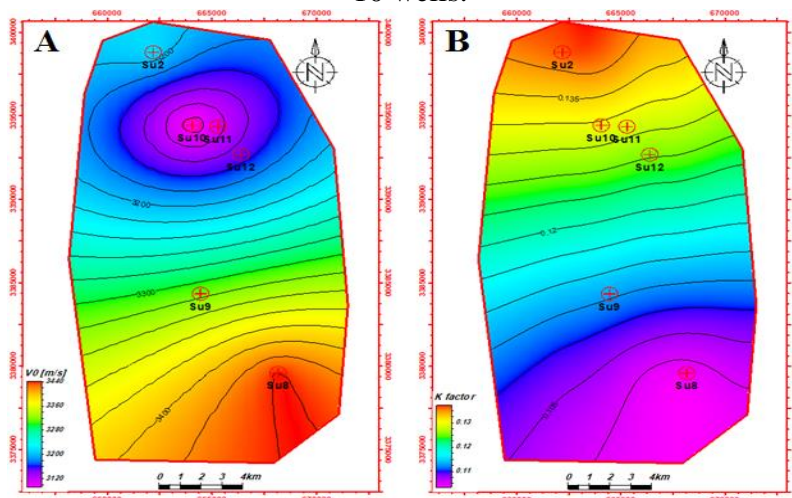


Figure 7-The maps of velocity parameters of three well points on Top Nahr Umr Reservoir a) instantaneous velocity map and b) depth gradient (K) map.

In this approach, the average velocity map (Figure 8a) of the Nahr Umr horizon is computed by equation 1, where V_0 and K are used as shown in Figure 7a and b, respectively, Z represents the actual depth for each well location. This average velocity was used to convert the TWT map of Top Nahr by multiplying the one-way time surface in Figure 4 that divided by two to obtain the one way time by the average velocity map in Figure 8a to generate the depth map at Nahr Umr Formation as in Figure 8b.

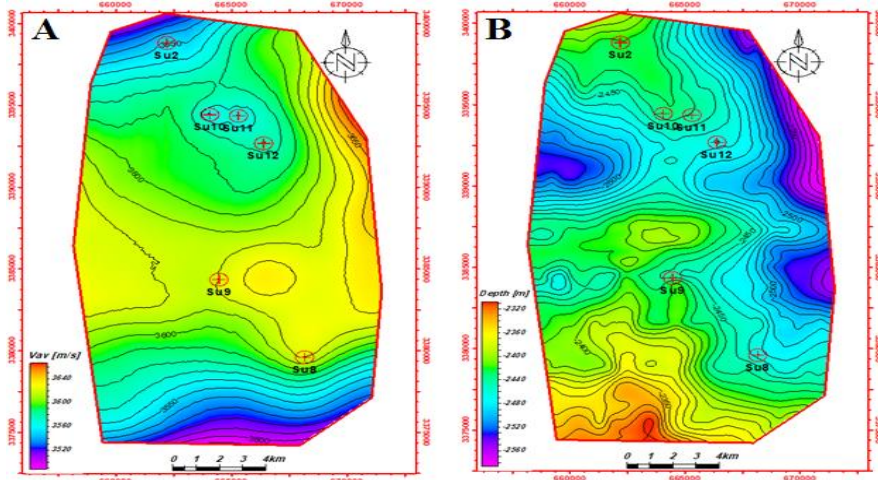


Figure-8 a) average velocity map and b) Depth map of Nahr Umr Reservoir using Model (2).

Model 3: As in the preceding approach, at each (X, Y) location, the velocity change in the vertical direction by depth gradient (K) and in the horizontal direction by instantaneous velocity (V_0). Therefore, this approach is similar to the previous approach, but we use time rather than real depth to compute the average velocity using the following equation:

$$V_{av} = V_0 + KT \dots\dots\dots (3)$$

V_{av} is the average velocity; V_0 and K are velocity parameters of the Nahr Umr horizon, which were calculated the same way as in the previous approach (Figure 7); T represents the travel time of the picked surface. The average velocity (Figure 9a) was computed by using equation 3, which is used in depth conversion to extract the depth map for Nahr Umr Formation by multiplying the one-way time surface in Figure 4 by the average velocity map in Figure 9a to generate a depth map at Nahr Umr Formation, Figure 9b. This approach was applied [3] [4] [5].

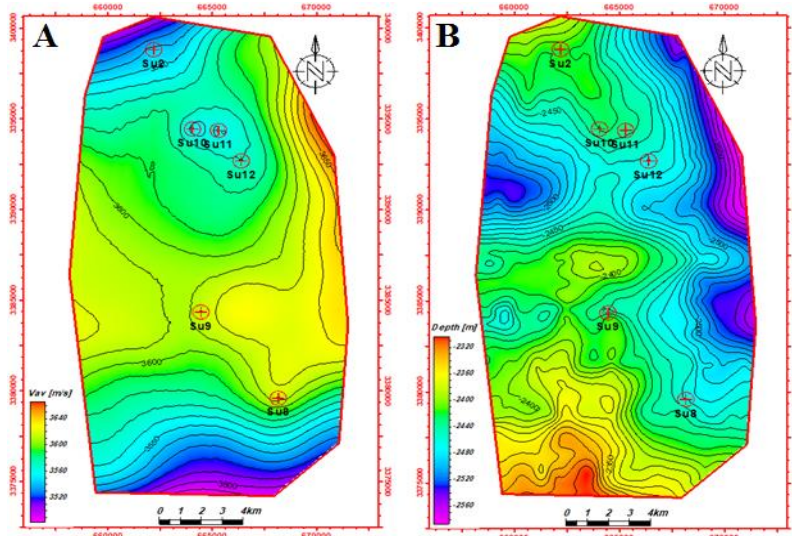


Figure 9-a) average velocity map. b) Depth map of Nahr Umr Reservoir using Model (3).

3.2.3 Residual Maps

The most standard approach to apply the residual corrections is by matching the predicted depth of a particular horizon, at each well location in the study area, with the actual depth, at the exact well location. This is done by founding the difference between the predicted depth and the true depth at well locations and converted into (X, Y) grid surface to generate a residual depth map. The main aims of the residual calculation are to improve the depth conversion accuracy and get a general view of depth conversion performance [35]. The residual map is used as quality control (Q.C.) to immediately diagnose any residual values of considerable magnitude. This help to review and verify the data and the interpretation near the well area, where the residual value is high. Two residual maps were computed for Nahr Umr Formation by subtracting the actual depth from the predicted depth at well location, as shown in Figure 10, representing the residual maps using Models 2 and 3.

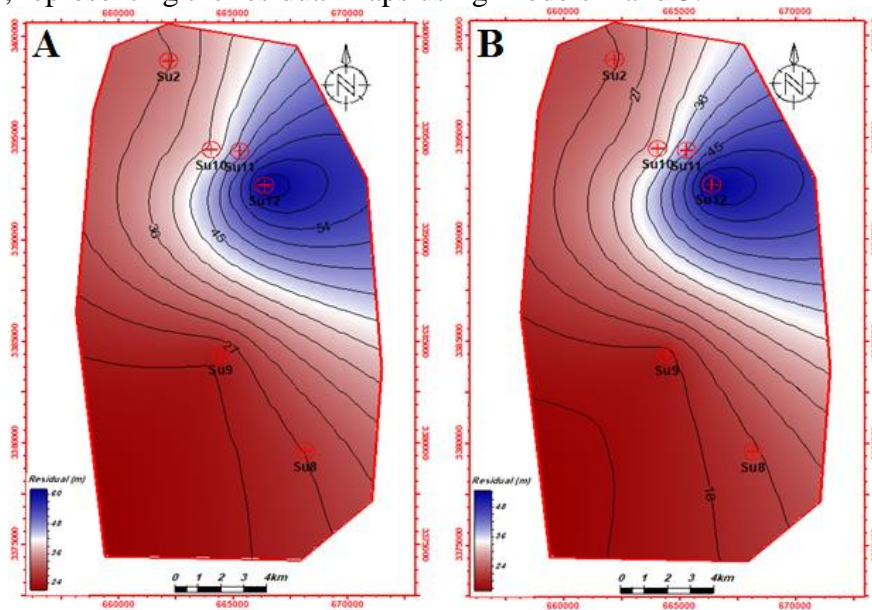


Figure 10-Contoured well residual map produced by subtracting the actual depth from predicted depth at well location. a) Residual map resultant from Model 2, b) Residual map resultant from Model 3

3.2.4 Correction and Uncertainty Analysis of Depth Conversion

The computation of the residual map was carried out to correct the depth map and remove the mistie between the predicted depth and the actual depth at the well location. The depth map produced from Model 1 does not correct because the predicted depth match exactly the actual depth at well locations. The residual maps show that the range of the residual values produced by Model 2 is higher than the residual map produced from Model 3. The depth map was corrected by subtracting the residual map (Figure 10 a and b) from the calculated depth map resultant from the depth conversion (Figures. 8b and 9b) of Nahr Umr Formation (Figure 11). These corrected depth maps show that the actual and predicted depth difference is zero at each well location, and errors are removed.

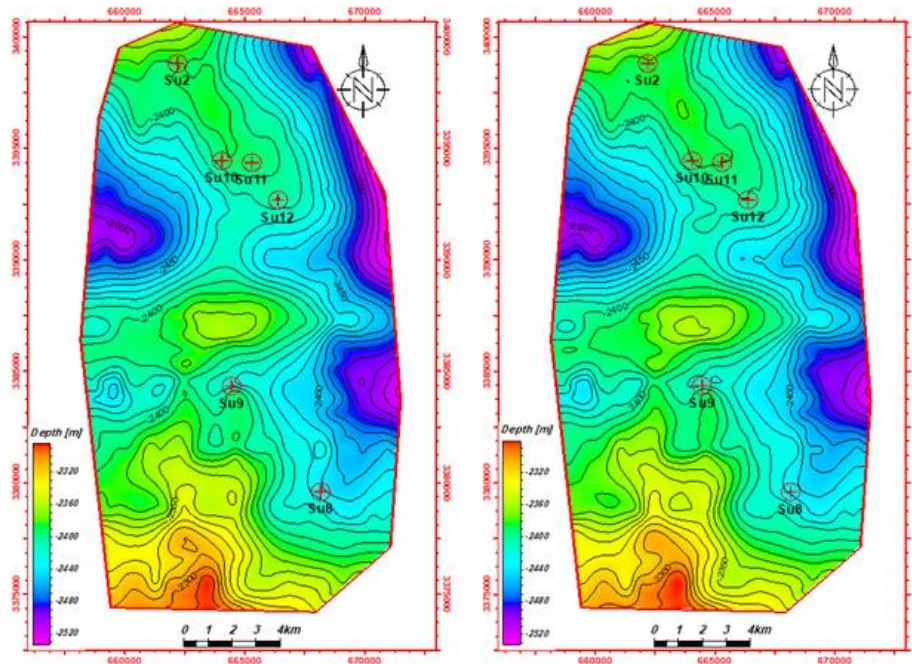


Figure 11-The corrected depth map was produced by subtracting the residual map from the predicted depth map a) corrected depth map using Model (2) b) corrected depth map using Model (3).

Statistically, the depth map that gives a minimum standard deviation is considered a more accurate depth map [32]. The current method of assessing the depth uncertainty depends on using the standard deviation of three depth maps. These depth maps were tied and corrected at well locations of different depth conversion approaches except the depth map produced from Model 1 to determine the predicted depth accuracy away from well controls. Figure 12 shows the standard deviation of the corrected depth map at the top Nahr Umr Formation because of three depth conversion approaches.

The standard deviation values are nearly zero at each well location because the depth map is tied and corrected to the actual depth at well locations. While, in areas away from well locations, the standard deviation map shows the bull's eye (for illustration purposes, zoom in was carried out at each well location) which are formed due to the high values of the standard deviation around to well locations and hence, it reduces the accuracy in measuring the predicted depth. As shown in Figure 12, the maximum value of the standard deviation is 37m in the southern part of the study area. Figure 13 illustrates an arbitrary cross-section of different scenarios of the predicted depth between the well locations of the three approaches of depth conversion through the Subba oilfield along the Top Nahr Umr Formation. These approaches are Model 1 (yellow line), Model 2 before correction (red line), Model 2 after correction (in green line), Model (3) before correction (in blue line), and Model 3 after correction (black line). This cross-section displays the variation in the predicted depth on the Top Nahr Umr Formation surface for the three different depth conversions. The variation and the inconsistency in the predicted depth surface are increasing between or away from well controls and the difference is becoming more significant towards the flank of Subba Structure's across the eastern part of the field. This helps to determine the most accurate approach of the well tie. Table 1 shows the analysis of depth conversion uncertainty for the two approaches in Models 2 and 3 at well locations. Model 3 gives low residual values and fewer errors compared with Model 2. The highest error value for the two approaches is located at well Su 12.

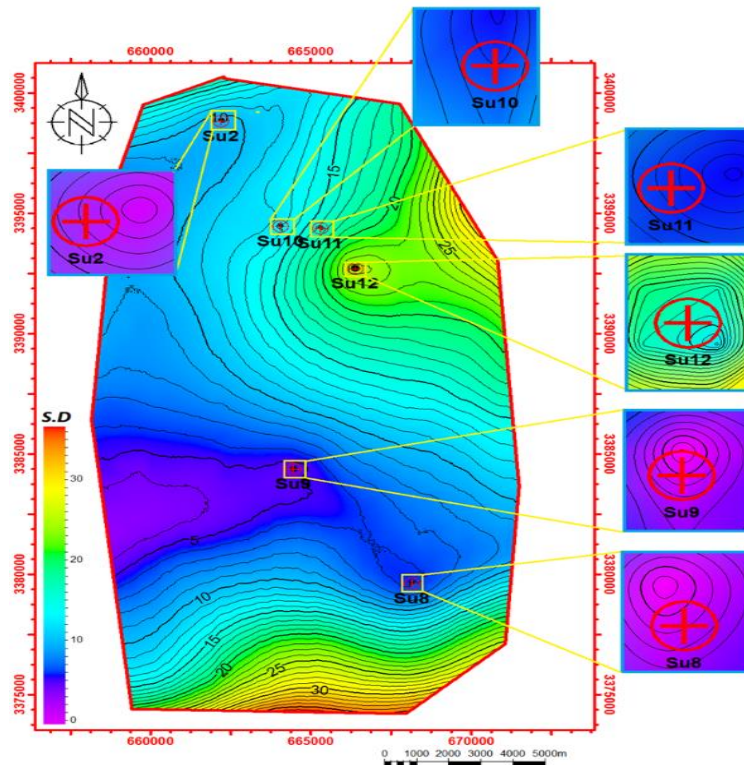


Figure 12-Standard deviation map of three approaches Model 1, 2, and 3. The values of the standard deviation is zero at well positions because all of the predicted depth were tied and corrected according to the actual depth at wells.

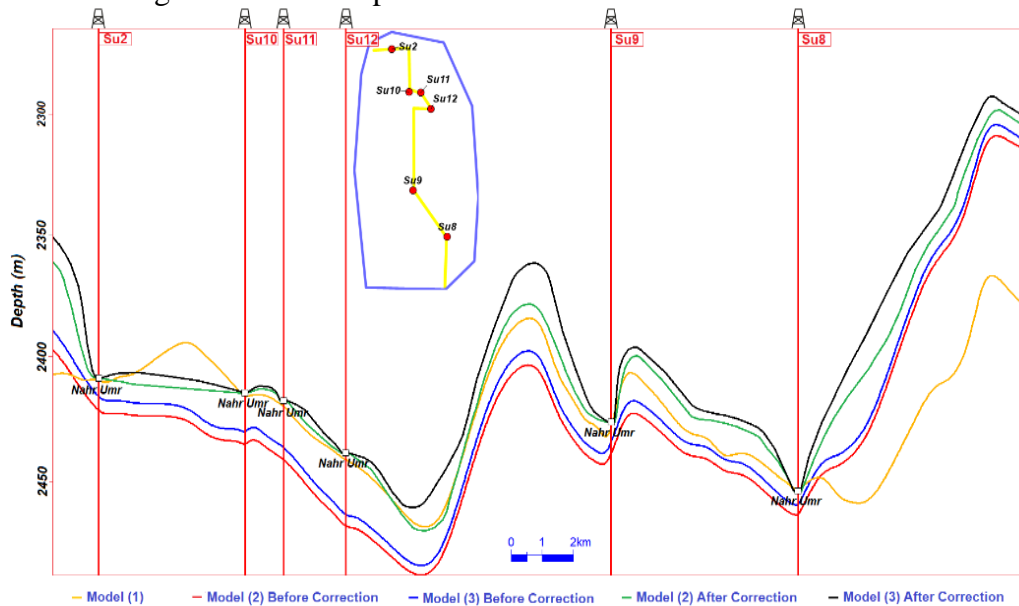


Figure 13-Arbitrary cross section through Su2, Su10, Su11, Su12, Su9 and Su8 wells, illustrate the different scenarios of different depth conversion approaches on Top Nahr Umr Formation along Subba oilfield.

4. Results and Discussion

The comparison between the depth map of Nahr Umr Formation, which products from this study and the previous studies shows a difference in the structural shape image than the previous studies. The current interpretation illustrates that the structure consists of several enclosures, while the previous interpretations demonstrates that the structure is one enclosure.

The contoured maps for the velocity parameters (V_0 and K) on the Top Nahr Umr Formation were generated from three well points. The V_0 map (Figure 7a) shows non-constant values with a range of velocity variation from 3100 to 3440 m/s because of changing the depth gradient (K), as presented in Figure 7b.

The comparison between these calculated depth maps (Figures. 8b and 9b) shows the effectiveness and accuracy of the velocity model used for each depth conversion approach. The three predicted depth maps Figures. 5b, 8b, and 9b show similar subsurface structural images with slight differences in the size and shape of the enclosures. The depth map from Model 1 was tying exactly at well locations, but the Q.C. of the contour line of the interpolation and the extrapolation rely only on the interpreted time surface. Thus, the residual calculation is considered a Q.C of depth conversion results, and the distinction can be made immediately for any significant value of the residual. This conclusion leads us to investigate and revise the data and reconsider the interpretation of the regions around this well. As mentioned earlier, all depth conversion approaches except Model 1, don't show exact matching at well location. The magnitude of the residual maps illustrates how the depth map extracted from the depth conversion process is accurate. It gives us a realistic visualization for general performance for the depth conversion process. The depth maps from Models 2, and 3 give mistie (residual) between the predicted and the actual depth at each well control. Therefore these predicted depth maps should be corrected by computing the residual values at each well location and converted into a grid surface and then subtracted from the predicted depth map to remove these errors. The residual map from Model 2 gave a greater values range than those in the residual map from Model 3. The corrected depth map of Nahr Umr Formation from the Model 2 shows a slight difference away in predicted depth from well controls compared to the corrected depth map from the Model 3 as seen in Figures. 8b and 9b. Models 2 and 3 show positive errors at each well location and the highest errors were at Su12 well. The more accurate depth conversion results considered one of the main factors to minimize the residual value, guided by determining the main factors that are responsible for the residual value. Also, the residual values produce because the interpreter might pick the wrong reflector or the depth value at well location was inaccurate. A depth cross-section was extracted along the Su2, Su10, Su11, Su12, Su9, and Su8 wells to show the differences among Model 1, Model 2 (before and after correction), and the Model 3 (before and after correction). As expected, the simple approach Model 1 and the corrected predicted depth map of Models 2 and 3 tie exactly at well locations, but the mistie increase away or between well controls. To decide which depth conversion approach could be considered as an accurate approach; uncertainty analysis of depth map, modeled by different approaches should be applied on the depth map to detect the suitable approach. According to the uncertainty analysis (Table 1), Model 3 gives minimum standard deviation, and this means that this approach could be considered as a better approach to use in this field. The corrected depth maps (Figure 11) tie all the wells exactly but have a slight resemblance. Figure 14 shows the difference between two corrected depth maps of Figure 11.

Table 1-Depth conversion uncertainty analysis using Models (2) and (3)

Well	Actual depth (m)	Model 2			Model 3		
		Calculate depth (m)	Difference (m)	Error %	Calculate depth (m)	Difference (m)	Error %
Su 2	2408.5	2441.2	32.7	1.6%	2432	23.5	0.97%
Su 8	2454.3	2481.5	27.1	1.1%	2474.9	20.6	0.83
Su 9	2432.8	2457.3	24.48	1%	2449.9	17	0.7%
Su 10	2414.4	2453.8	39.4	1.6%	2445.5	31	1.3%
Su 11	2417.6	2464.2	46.5	1.9%	2456.1	38.5	1.59%
Su 12	2438.8	2501.4	62.6	2.6%	2494	55	2.26%
S.D		14.2			14		

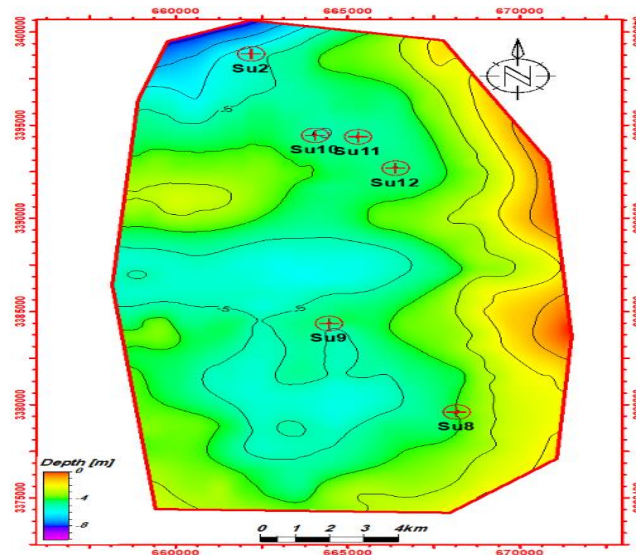


Figure 14-Difference map among depth maps of Fig. 10a, generated using Model 2, and of Fig. 10b, generated using Model 3.

5. Conclusions

The simulation of the depth grid surfaces depends on a non-stationary model by combining all available sources of uncertainties, from the processing stage to the data themselves (horizons, seismic velocities, well tops, and time-depth relation). This study determines the suitable depth conversion approach in Subba oilfield that helps to obtain the most accurate depth map with low potential depth error in Top Nahr Umr Reservoir. These approaches are supported by the standard deviation to give more strength and reliability in our interpretation and help to understand the subsurface of Subba oilfield.

Determination of suitable velocity parameters (V_0 and K) allows the development of various models to check the accuracy of the depth conversion over the study area. The instantaneous velocity (V_0) map shows the lateral variations of velocity, while the vertical velocity variations showed by depth gradient (K) map. In current study, the lateral velocity variations are more than the vertical variations. This is because instantaneous velocity values ranged from 3060 to 3340 ms, while depth gradient map values ranged from 0.104 to 0.135. Therefore, the lithology effect on velocity model and depth conversion results in more than the velocity increasing with depth.

The uncertainty analysis of depth conversion is considered the most significant step in seismic interpretation to investigate the predicted depth in all directions away from well controls, especially when a few or no well markers are available. The depth uncertainty was clearly a challenge in the Subba oilfield due to lack of well information (only six wells). To manage this uncertainty, three of the most common approaches of depth conversion were performed, ranging from the simple to more complex approaches, Models 1, 2, and 3. Each approach gives slight differences in the structure depth map on top Nahr Umr Reservoir. However, the uncertainty analysis revealed that Model (3) is more practical than the other approaches (Model 1 and 3) in this field. This is attributed to the depth map derived from this approach, which gives a minimized standard deviation with lower residual values. In addition, the simple approach (Model 1) shows no mistie at well location but performed poorly outside well control area, whereas Model (2) gives higher residual value in this field. The residual values between the predicted and the actual depth at well location represent a diagnostic factor in determining the accuracy of depth conversion. The consistent errors from different depth conversion approaches raised the accuracy in the results and reduced the uncertainty. The depth uncertainty was raised towards the structure's flank (eastern part of the field) due to

the increase in the standard deviation values on the map (Figure 12) and recorded the highest value, 37m. This is because the increase in the dipping depth in this region leads to an increase in the standard deviation values in the map.

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References

- [1] Etris, E.L., Crabtree, N.J. and Dewar, J., "True depth conversion: more than a pretty picture," *CSEG Recorder*, vol. 26, p. 11–22, 2001 .
- [2] N. Crabtree, "Ranking velocity models for depth conversion, closure confidence and volumetric," *Frist Break*, vol. 35, pp. 39-49, 2017 .
- [3] Bartel, D.C., Busby, M., Nealon, J. & Zaskie, J., "Time to depth conversion and uncertainty assessment using average velocity modeling," in 76th SEG Annual Meeting, 2006 .
- [4] Radzi, A., Bazleigh, Y. & Khalil, A., "Quantifying the uncertainty of Gross Rock Volume: a decade of time-to-depth conversion in Sepat Field, Malay Basin," *Frist Break*, vol. 34, pp. 73-77, 2016 .
- [5] Kulikowski, D., Hochwald, C. & Amrouch, K. , "An automated cross-validation method to assess seismic time-to-depth conversion accuracy: A case study on the Cooper and Eromanga basins," *Australia. Geophysical Prospecting*, vol. 66, pp. 1521-1534, 2018 .
- [6] Al-Ridha, N., and Al-Khafaji, H. , "Stratigraphic and Structural Study of Khlesia Region Using 2D Seismic Data - North Western Iraq". *Iraqi Journal of Science*, vol. 60, no. 2, pp. 277-289, 2019 .
- [7] Khorshid, S.Z. & Owiad, J.I., " Sub-Surface Investigation of Khashim Al-Ahmer Gas Field Using Seismic Reflection Data," *Iraqi Journal of Science*, vol. 56, pp. 774-784, 2015 .
- [8] Khorshid, S.Z., Alki, H.D. & Zaid, A.M. , "Subsurface Investigation of Merjan oil field Depending on 3D Seismic Reflection Central Iraq," *Iraqi Journal of Science*, vol. 57, pp. 2457-2469, 2016 .
- [9] Al-Ridha, N. & Yousif, H.M., "Seismic structural study of Mishrif and Nahr Umr Formations in Huwaiza oilfield south-eastern Iraq," *Iraqi Journal of Science*, vol. 60, pp. 554-567, 2019 .
- [10] Hwang, L. & Mccorkindale, D., Trol Field depth conversion using geostatistically derived average velocities, *The Leading Edge*, 1994 .
- [11] Dalfsen, W.V., Doornenbal, J.C., Dortland, S. & Gunnink, J.L., "A comprehensive seismic velocity model for the Netherlands based on lithostratigraphic layers," *Netherlands Journal of Geosciences* , vol. 85, pp. 277-292, 2006 .
- [12] M. Al-Chalabi, "Instantaneous slowness versus depth functions," *Geophysics*, vol. 62, no. 1, pp. 270-273, 1997a .
- [13] M. Al-Chalabi, "Parameter nonuniqueness in velocity versus depth functions," *Geophysics*, vol. 62, no. 3, p. 970-979, 1997b .
- [14] J. Smallwood, Use of V0-K depth conversion from shelf to deep-water: how deep is that bright spot, *First Break*, 2002 .
- [15] Chellingsworth, L., Bentley, M. & Wynn, T., "Human factors in seismic uncertainty — restoring a realistic uncertainty range. Interpretation," *Seismic uncertainties*, vol. Special section, pp. 21-32, 2015 .
- [16] Al-Khazraji, O. N. A. Idan, Rami M. Salih, A. L. M. Hussein, R. K.,, "Quantitative Implementation of Acoustic Impedance Inversion to Porosity and Lithology Prediction of Clastic Reservoir, Luhais Oil Field, Southern Iraq," *Civil and Environmental Research*, vol. 10, no. 6, pp. 10-18, 2018 .
- [17] Al-Khafaji, A. J., Hakimi, M. H., Mohialdeen, I. M. J., Idan, R. M., Afify, W. E., & Lashin, A. A., "Geochemical characteristics of crude oils and basin modelling of the probable source rocks in the Southern Mesopotamian Basin, South Iraq," *Journal of Petroleum Science and Engineering*, vol. 196, no. 107641, pp. 1-23, 2021 .

- [18] Aqrawi, A.A.M., Goff, J.C., Horbury, A.D. & Sadooni, F.M., The Petroleum Geology of Iraq, Scientific Press Ltd., 2010, p. 424.
- [19] Idan, R.M., Al-Rawi, D., Nasser, M.E., AlMashaekhy, D., , "Reservoir properties and seal efficiency in the Zubair Formation in Euphrates Subzone, Southern Iraq," *Arabian Journal of Geosciences*, vol. 8, no. 2, pp. 773-780, 2015 .
- [20] Idan, R.M., FAISAL, R.F., NASSER, M.E., AL-AMERI, T.K. and AL-RAWI, D.,, "Hydrocarbon potential of Zubair Formation in the south of Iraq," *Arabian Journal of Geosciences*, vol. 8, no. 7, p. 4805–4817, 2015 .
- [21] Idan, Rami M. and Faisal, Rasha F., "Application of Geophysical Logs to Estimate the Source Rock Quantity of Ratawi Formation, Southern Iraq: A Comparison Study," in 1st International Conference on Petroleum Technology and Petrochemicals, 2019 .
- [22] R. M. Idan, "Total organic carbon (TOC) prediction from resistivity and porosity logs: a case study from Iraq," *Bull. Iraq nat. Hist. Mus.* , vol. 14, no. 3, pp. 185-195, 2017 .
- [23] Owen, R.M.S. & Nasr, S.N. , "Stratigraphy of the Kuwait Basrah area," *AAPG*, pp. 1252-1278, 1958 .
- [24] Bellen, R.C.V., Dunnington, H.V., Wetzel, R. & Morton, D., *Lexique Stratigraphique*, vol. 3c, Iraq: Internal. Asie., 1959, p. 333.
- [25] Idan, R. M., Salih, A. L. M., Al-Khazraji, O. N. A., & Khudhair, M. H. , "Depositional environments, facies distribution, and porosity analysis of Yamama Formation in majnoon oilfield. Sequence stratigraphic approach," *Iraqi Geological Journal*, vol. 53, no. 1, p. 38–52, 2020 .
- [26] Al-Musawi, F. A., Idan, Rami M., Salih, A. L. M., 2019, "Reservoir properties and Facies distribution of Mishrif Formation in Ratawi oilfield, Southern Iraq," in The Structural Geology Contribution to the Africa-Eurasia Geology: Basement and Reservoir Structure, Ore Mineralisation and Tectonic Modelling, Tunisia, 2018 .
- [27] Jassim, S.Z., and Goff, J.C., *Geology of Iraq*, Brno: Dolin, Prague and Muravian Museum, 2006, p. 341.
- [28] Faisal, R. F., Idan, R. M., Salih, A. L. M.,, "Assessment of the Lower Cretaceous source rock using PetroMod approach in West Qurna Oilfield- Southern Iraq," *Iraqi Journal of Sciences*, vol. 57, no. 3c, pp. 2258-2269, 2016 .
- [29] Al-Ameri, T. K., Al-Jubouri, N. M., Isa, M. J., and, Al-Azzawi, Rami E., , "Hydrocarbons generation potential of the Jurassic–Lower Cretaceous Formation, Ajeel field, Iraq," *Arabian Journal of Geosciences*, vol. 6, no. 10, pp. 3725-3735, 2013 .
- [30] Al-Musawi, Furat A., Idan, Rami M., and Salih, Amani L. M., , "Reservoir characterization, Facies distribution, and sequence stratigraphy of Mishrif Formation in a selected oilfield, South of Iraq," in 1st International Conference on Pure Science (ISCPS-2020), 2020 .
- [31] Idan, Rami M. Al-Musawi, Furat A. , Salih, Amani L. M., Al-Qaraghuli Shahad A. F., , "The Petroleum System of Zubair Formation in Zubair Subzone, Southern Iraq," *Journal of Petroleum Research and Studies*, no. 25, pp. E57-E73, 2019 .
- [32] A. Brown, "Interpretation of Three-Dimensional Seismic Data," *SEG Investigations in Geophysics*, vol. Memoir 42, no. 9, p. 368, 2011 .
- [33] Al-Khazraji, O.N.A., Al-Karadaghi, S.S.H.,, "Reducing the risk and residual errors by uncertainty analysis of depth conversion in Nasiriya Oil Field, Iraq," *Arabian Journal of Geoscience*, vol. 13, no. 498, 2020 .
- [34] J. Baerg, "Traveltime in media with linear velocity-depth functions," Consortium for Research in Elastic Wave Exploration Seismology Research Report, vol. 27, pp. 461-466, 1991 .
- [35] M. Al-Chalabi, Principles of seismic velocities and Time-to-Depth Conversion, Houten: EAGE publications bv, 2014, p. 491.