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2D Seismic Structural Study of the Area Between Halfaya, Noor and Amara Oil Fields, Southeastern Iraq

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Abstract

The study area is located in the Missan government in southeastern Iraq, including oilfields (Halfaya, Noor, and Amara). The study area is about 966 Km². Based on the 2D seismic reflection interpretation, well-logs data (sonic and estimated density logs), and synthetic seismogram of well Am-2, two horizons were identified and picked (Nahr Umr and Shuaiba) within the Lower Cretaceous age. For the picked reflectors, two-way time and depth maps were created to display the subsurface's structural makeup. The structural interpretation shows two structural axes in the study area. The first is the Halfaya-Amara axis, whose direction is WNW-ESE corresponding with the Amara structure. This axis deviates southeast due to the tectonic effect at the Halfaya structure. Another tectonic force affected the Halfaya structure in the northwest-southeast direction leading to the appearance of a branch of a convex extension towards the north from the middle of the Halfaya structure, completing this branch to a structural closure as nose towards the Noor structure in the northern part of the study area. The second axis of Halfaya-Noor oilfields trending northwest-southeast direction.

Keywords: 2D seismic reflection data, structural interpretation, Halfaya-Noor-Amara oil fields, lower cretaceous formations.

دراسة تركيبية زلزالية ثنائية الأبعاد للمنطقة بين حقول نفط حلفاية ونور وعمارة، جنوب شرقي العراق

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الخلاصة

تقع منطقة الدراسة في محافظة ميسان جنوب شرق العراق وتشمل حقول نفط (حلفاية ونور وعمارة). تبلغ مساحة منطقة الدراسة حوالي 966 كم². اعتماداً على تفسير الانعكاس الزلزالي ثنائي الأبعاد، واستناداً إلى بيانات سجلات الآبار والآخر الزلزالي المصنع للبئر Am-2، تم تحديد واختيار عاكسي (نهر عمر وشعبية) في العصر الطباشيري السفلي. تم رسم الخرائط الزمنية والعمقية للعوامس المختارة لإظهار الصورة التركيبية تحت السطح. يبين التفسير التركيبي أن هناك محورين تركيبيين في منطقة الدراسة، الأول هو محور حلفاية - عمارة الذي يكون اتجاهه غرب شمال غرب - شرق جنوب شرق متطابق مع تركيب العمارة. ينحرف هذا المحور إلى

الاتجاه الجنوبي الشرقي بسبب التأثير التكتوني في تركيب حلفاية. أثرت قوة تكتونية أخرى على تركيب حلفاية في الاتجاه شمال غرب - جنوب شرق مما أدى إلى ظهور تفرع من امتداد محذب باتجاه الشمال من منتصف تركيب حلفاية ، مما أكمل هذا التفرع إلى انغلاق تركيب كخشم باتجاه تركيب نور في الجزء الشمالي من منطقة الدراسة. المحور الثاني لحقول نفط حلفاية - نور يتجه باتجاه شمال غرب - جنوب شرق.

1. Introduction

Seismic reflection exploration is used to investigate the subsurface image of the oilfields since the turn of the 20th century [1]. There are several reasons for the seismic method's superiority to geophysical approaches, the most significant of which are its high accuracy, high resolution, and great penetration [2]. Numerous seismic investigations were carried out to investigate the underlying geology of numerous oilfields in Iraq. Those who conducted the research concluded that the seismic reflection method offers a clear picture of the stratigraphy and structure of the subsurface, which aids in understanding subsurface geology and offers solid proof of oil accumulation [3-6]. The basic idea in seismic methods is a hit on the surface to create a seismic wave that travels underground. This wave is reflected when it reaches a boundary between different layers. By using the travel time, the geological boundaries can be determined [7]. The time it takes for sound to travel from its source to the reflecting interface and back to the surface provides information about the reflector's depth, and the intensity of the reflected signal provides information about any differences in the properties of the rocks at the interface [8]. The two steps before the interpretation stage are data acquisition and data processing. Seismic data interpretation is the third and last step of any seismic exploration work. Structural seismic interpretation aims to provide structural maps of the subsurface [9]. Since the Cretaceous sequence in Iraq is the greatest-producing reservoir and holds over 80% of the country's oil reserves, much research has concentrated on this region [10]. This research aims to study the structural axes of the Lower Cretaceous formations in the Halfaya, Noor, and Amara oilfields in southeastern Iraq in one study, where each field has been studied independently, where the A 2D seismic survey covers the area.

2. Location of the Study Area

The study area is located in southeastern Iraq in Missan Governorate, as shown in Figure-1. The study area is about 966 km², and the Tigris River penetrates the study area. The study area included three oil fields, the Halfaya in the southeast, Noor in the north, and Amara in the west.

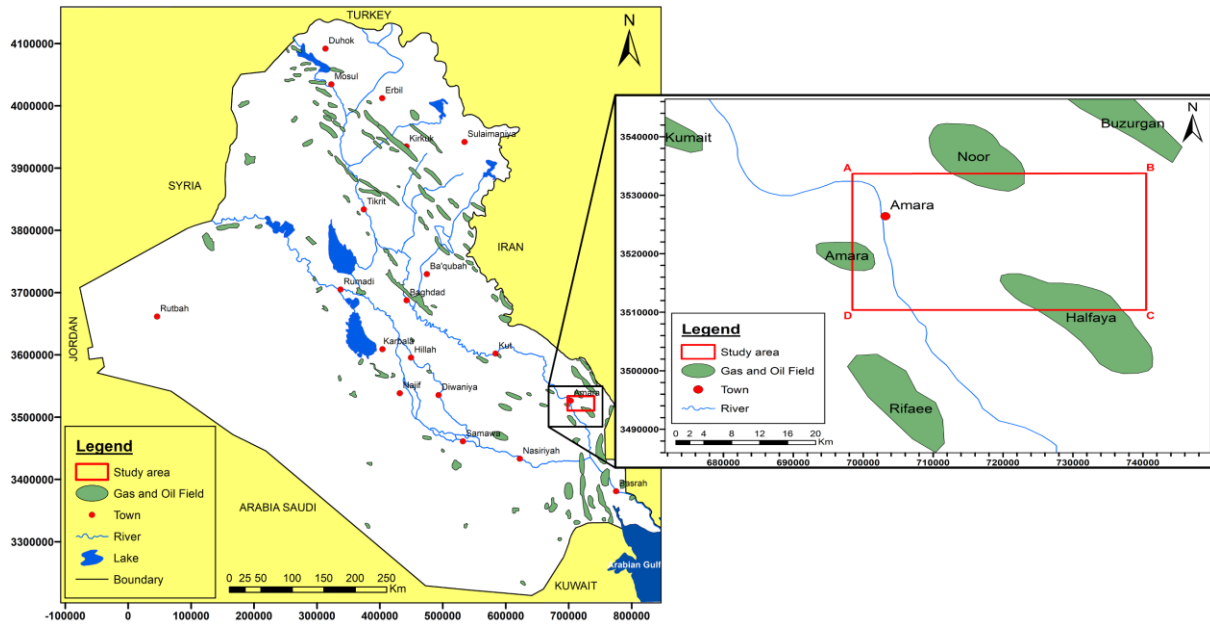


Figure 1: Map of Iraq showing the location of the study area.

3. Geology of the Study Area

Topographically, this region belongs to the typical Quaternary area with no exposure to the older bedrock. Lithologically the sediments filling the Mesopotamian plain are represented by gravels, sands, silts, and clay [11]. The subsurface geology of the study area is identified from the data obtained from Am-2 well drilled within the Amara oil field, Am-2 well reaches to Yamama Formation at a depth (4692 m). This study concerns the Lower Cretaceous formations: Nahr Umr and Shuaiba Formations. Figure-2 is a stratigraphic column of Am-2 well with a brief description of the formations included in this study [12]. The Mesopotamian can be subdivided into three subzones, Euphrates, Tigris, and Zubair. The study area is located within the unstable shelf of the Mesopotamian zone and precisely in the Tigris subzone. The Tigris Subzone is the largest and most mobile unit in the Mesopotamian Zone. It contains two NW-SE trending groups of relatively low amplitude buried anticlines associated with longitudinal faults and an E-W transversal trend [13].

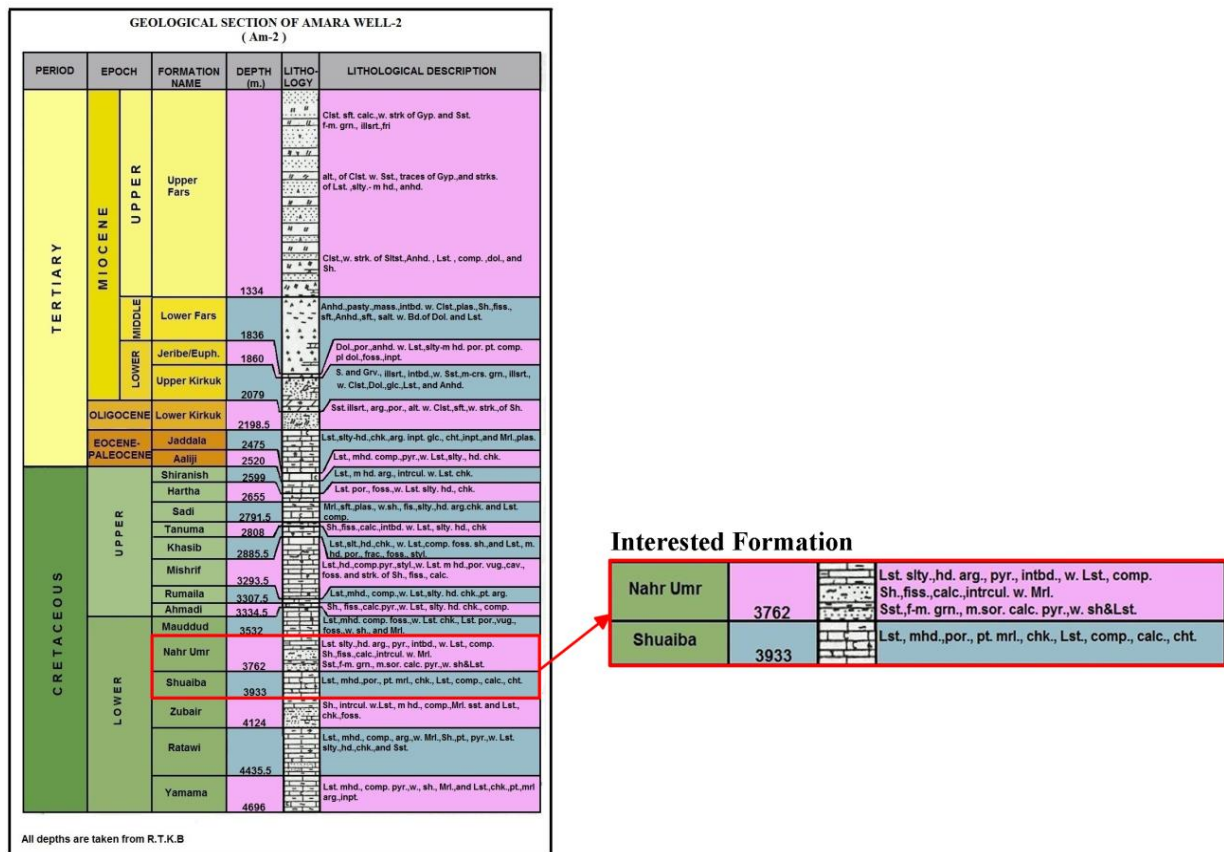


Figure 2: Stratigraphic column for Amara oil field (Am-2 well) with a brief description of the formations included in this study.

4. Data and Methodology

Three types of data were used in the current study (Obtained from the Iraqi Ministry of Oil, Oil Exploration Company), which include:

- 1-Well data: Including well tops, sonic log, and the coordinates of the well (Am-2) of the Amara oilfield in the study area.
- 2-Well seismic data: Check-shot (One-way time) for well Am-2.
- 3-Seismic data: Twenty-six 2D seismic lines cover almost all the study area.

The base map was constructed using Petrel software (Figure-3). Before the interpretation process, seismic data improvement was carried out by using attributes as follows: structural smoothing attribute (to increase the continuity of the seismic reflectors and decrease noise). Then, the second derivative attribute (used to help in picking the reflectors by providing continuity in areas where reflections are poorly resolved on the raw amplitude). The calculated seismic data will be shifted to 180° phase. So, the phase shift attribute is applied (to recover the original phase). As a result of these improvements, the seismic data will lose some of the amplitude range. So, we must re-inventory the original seismic section values. Finally, for better improvement, the trace AGC attribute was applied (used for enhancing low-amplitude sections to improve horizon interpretation) [14, 15]. Also, the mis-tie correction was applied because the 2D seismic lines were implemented at different times and directions. The interpretation process was carried out on the Petrel software, where first, the reflectors were picked in all seismic sections, then time and depth maps were drawn, velocity model was constructed to convert the time map into a depth map to obtain the structural image. The input data required to generate the velocity model of the current study are: two-time surfaces (top of Nahr Umr and Shuaiba), well tops and time-depth relationship.

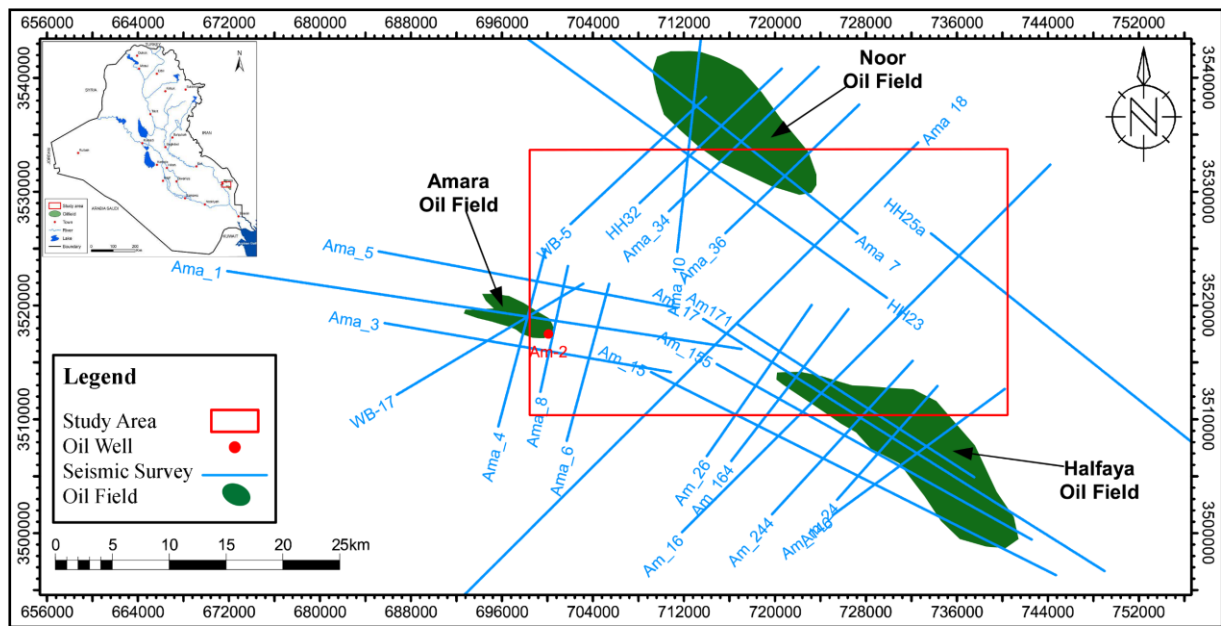


Figure 3: Base map of the study area, shows the in-between area within the Halfaya-Noor-Amara oil fields and seismic survey lines.

5. Horizon Picking

A synthetic seismogram is generated by multiplying calibrated sonic and estimated density logs to generate an acoustic impedance log, derive reflection coefficients, and convolve with a deterministic wavelet. A synthetic seismogram is developed to determine the reflector more precisely on the seismic section at the well site to begin the process of horizon picking. Horizon picking is marking the reflection on a seismic section. It involves deciding what wiggles from trace to trace are from the same reflection [16]. One then follows the path of that specific reflector on a set of seismic lines that cross orthogonally in planar view, producing a result that correlates on every line. By linking particular horizons on a seismic line, one may subsequently generate a (TWT) map [17]. The identification of the tops of Nahr Umr and Shuaiba horizons in this study was carried out depending on well tops and the well-seismic velocity survey data (check shot) of well Am-2 and more precisely by using a synthetic seismogram of this well as shown in Figure-4. The picked reflectors appeared as troughs on the synthetic trace.

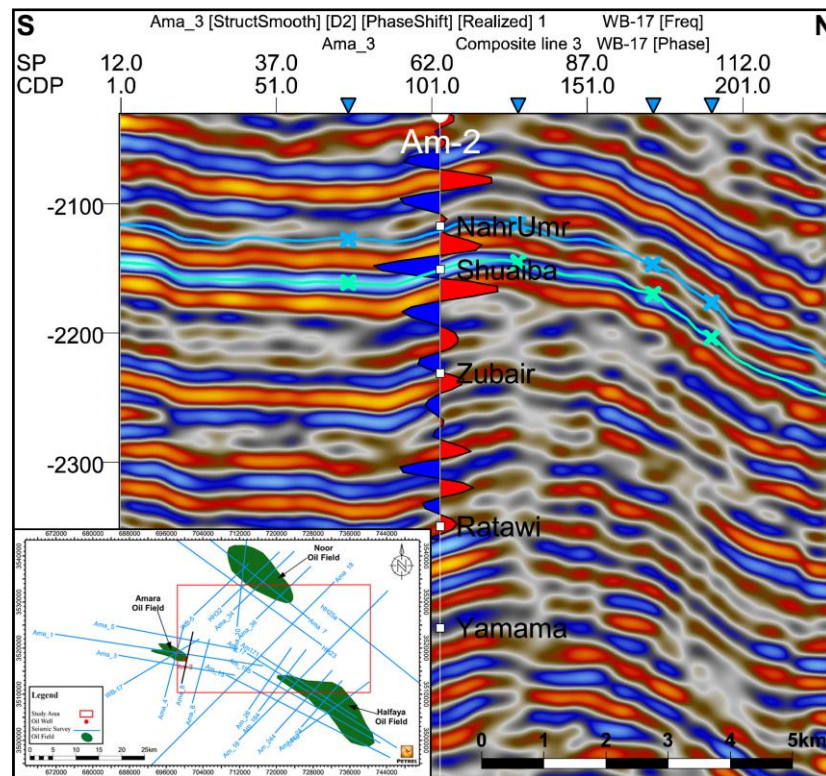


Figure 4: Shows horizons picking from well Am-2 in Ama_8 seismic section, the base map (in the lower left corner) shows the location of the section (black line) in the study area near the Amara oilfield.

6. Structural Interpretation

The top reflectors of the Nahr Umr and Shuaiba Formations were picked in all the study area to prepare the TWT maps, which are later converted to depth maps using these reflectors' velocity models. Structurally, all structural maps (time & depth map) show the highest area is located on the southwest and southeast side, representing an anticline folded structure extending out of the study area, while the lower area on the northeast side represents the basin. The slope is steep on both sides of the anticline (it may describe a trend of faults) and then gradually decreases towards the NE. A saddle separates Halfaya and Amara structures with a general direction of NW-SE with a slight difference for each structure. The Halfaya, Noor, and Amara structures appear as closures with the axis running about along N60°W, N65°W, and N75°W trending, respectively, corresponding to results in the previous study [18]. In this study, it was found that there are two structural axes, as shown in Figures 5-6 and 9-10. The first is the Halfaya-Amara axis, whose direction is WNW-ESE at the Amara structure. Then the axis deviates in the southeast direction due to the tectonic effect at the Halfaya structure, as explained by [19]. Another tectonic force affected the Halfaya structure in the northwest-southeast direction leading to the appearance of a branch of a convex extension towards the north from the middle of the Halfaya structure, completing this branch to a structural closure as nose towards the Noor structure. The second axis of Halfaya-Noor was formed in the direction of northwest-southeast. Below is a detailed interpretation of all maps of interested formations:

6.1 Two-Way Time (TWT) Maps

Two TWT maps were constructed for the picked horizons (Top Nahr Umr and Top Shuaiba Formations) to show the values and changes on the map in the time domain. A contour interval of 10 ms was basically used, while the sea level is considered a reference datum for all maps.

The increase in the TWT means the seismic wave took extra time to reach the reflector's surface because the reflector is getting deeper. There is excellent correspondence between the two TWT maps of the two horizons regarding higher and lower values and the location of structural closures.

6.1.1 Two-Way Time Map of Top Nahr Umr Formation

The TWT map of Nahr Umr (Figure-5) shows that the lowest value of TWT is at the west and southwest (2100 ms), representing the Amara structure and at the southeast (2130 ms), representing the Halfaya structure, while the highest value of TWT is at the northeast of the study area (2525 ms). In addition, the minimum value in the Noor structure is (2327 ms) within the study area. The contour value of the enclosure of the structures is (2170, 2350, 2170) ms, with closure amounts of 40, 23, and 70 ms for Halfaya, Noor, and Amara, respectively, within the study area.

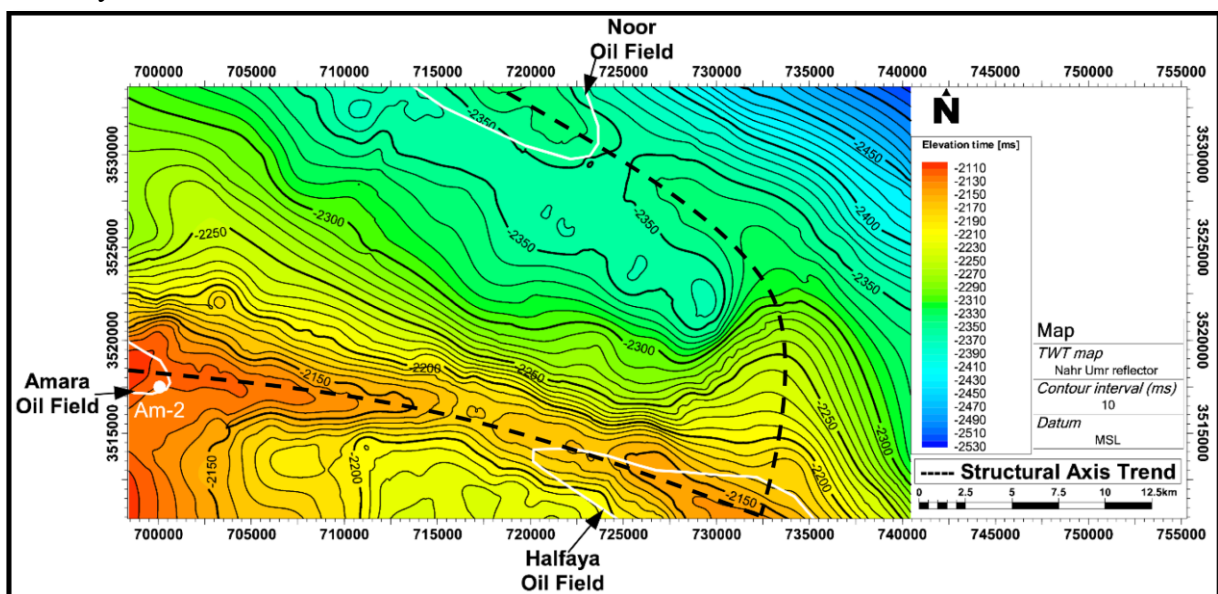


Figure 5: TWT map of the top Nahr Umr Formation.

6.1.2 Two-Way Time Map of Top Shuaiba Formation

The TWT map of Shuaiba (Figure-6) shows that the lowest value of TWT is at the west and southwest (2129 ms), representing the Amara structure and at the southeast (2173 ms), representing the Halfaya structure, while the highest value of TWT is at the northeast of the study area (2580 ms). In addition, the minimum value in the Noor structure is (2364 ms) within the study area. The contour value of the enclosure of the structures is (2190, 2390, 2190) ms with closure amounts (17, 26, 61) ms for Halfaya, Noor, and Amara, respectively, within the study area.

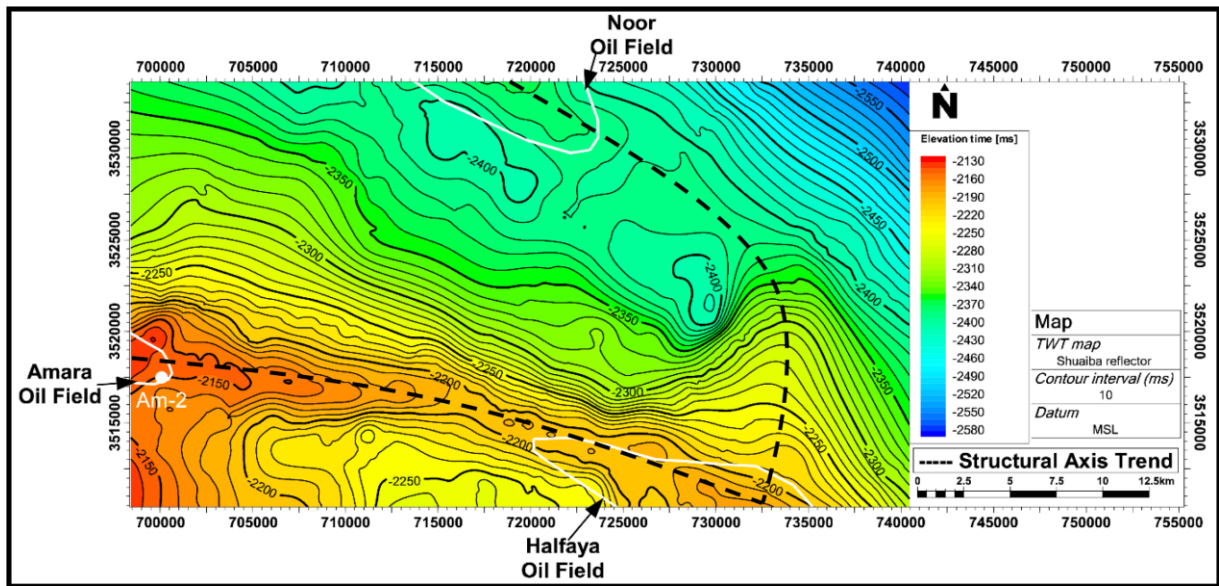


Figure 6: TWT map of the top Shuaiba Formation.

6.2 Average Velocity Maps

The average velocity was calculated using the time horizons of the two formations (top Nahr Umr and top Shuaiba). Velocity maps of the reflectors showed increased velocity values with depth.

6.2.1 Average Velocity Map of Top Nahr Umr Formation

The average velocity map (Figure-7) shows a range of 3160 - 3500 m/s values. Velocity value increases toward the southwest direction and decreases toward the southeast direction. Contour interval (20 m/s).

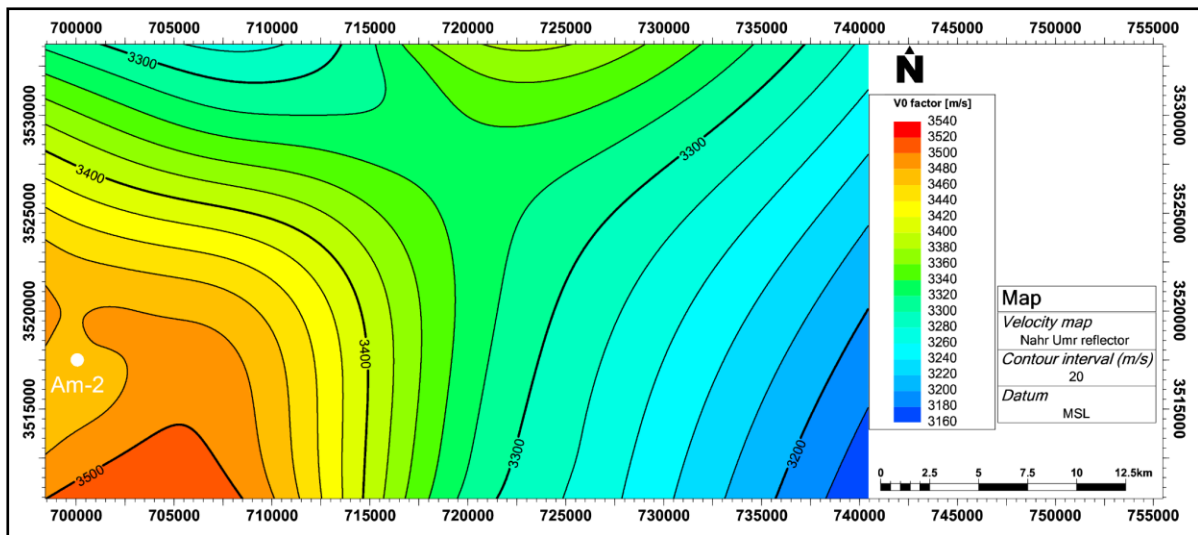


Figure 7: Average Velocity Map of top Nahr Umr Formation.

6.2.2 Average Velocity Map of Top Shuaiba Formation

The average velocity map (Figure-8) shows a range of 3435 - 3520 m/s. Velocity value increases toward the southwest direction and decreases toward the northwest direction in the east with a contour interval of 5 m/s.

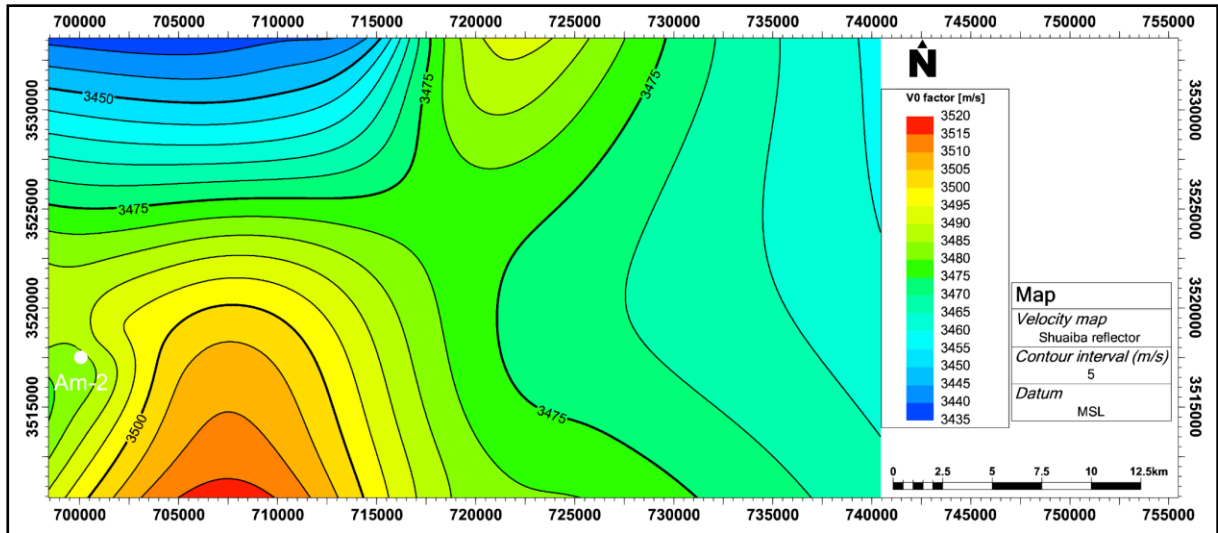


Figure 8: Average Velocity Map of the top Shuaiba Formation.

6.3 Depth Maps

The shape of the depth map looks like a TWT map and shows the same picture of the studied formations. It is obtained by using the velocity map and one-way time from the time map of the given reflector by dividing the values in the TWT map by two (to convert it to a one-way time map because the depth map is measured by one direction only). In general, the structural depth map illustrates the locations and shapes of the main structural features in the study area based on the geometrical shape of contour lines and is displayed a real picture of the structural subsurface setting. These maps depend on sea level as a reference level.

6.3.1 Depth Map of Top Nahr Umr Formation

The depth map (Figure-9) shows that the lowest depth is at the southeast (3443 m), representing the Halfaya structure, while the highest depth is at the northeast of the study area (4135 m). In addition, the minimum depth in the Amara structure (3654 m), while in the Noor structure is (3895 m) within the study area. The contour value of the enclosure of the structures is (3705, 3925, 3705) m with closure amounts (262, 30, 51) m for Halfaya, Noor, and Amara, respectively, within the study area. This map was drawn with a contour interval of (5 m) to illustrate the closure in the Noor structure.

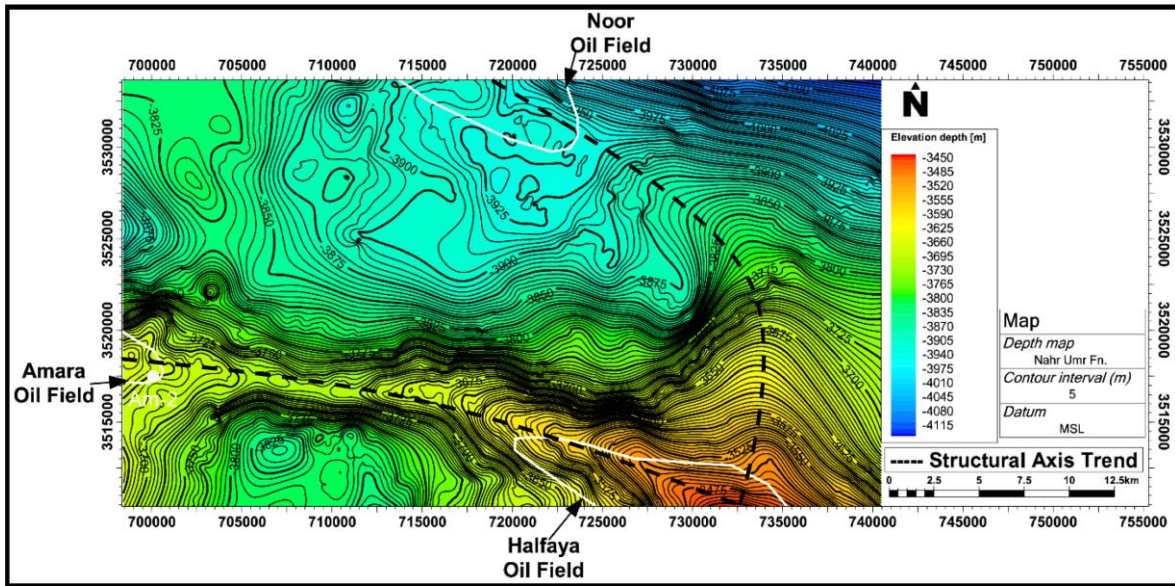


Figure 9: Depth Map of top Nahr Umr Formation.

6.3.2 Depth Map of Top Shuaiba Formation

The depth map shown in (Figure-10) appears that the lowest depth is at the west and southwest (3713 m), representing the Amara structure, and at the southeast (3775 m), representing the Halfaya structure, while the highest depth is at the northeast of the study area (4462 m). In addition, the minimum depth in the Noor structure is (4109 m) within the study area. The contour value of the enclosure of the structures is 3825, 4155, and 3825 m, with closure amounts is 50, 46, and 112 m for Halfaya, Noor, and Amara, respectively, within the study area. A contour interval of 15 m was used.

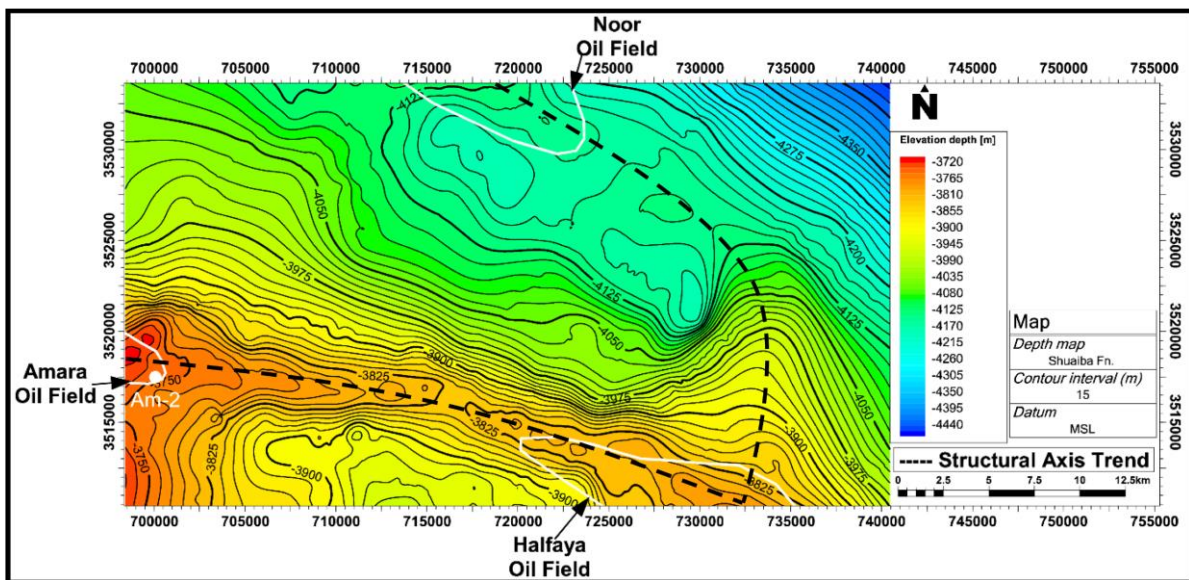


Figure 10: Depth Map of top Shuaiba Formation.

7. Conclusions

1- The top of the Nahr Umr and Shuaiba Formations were picked. TWT and depth maps showed that the values of (time & depth) are decreased towards the southeast, represented by the Halfaya structure, and decreased towards the southwest, represented by the Amara structure.

These structures represent anticline folded structures extending out of the study area, so the values in time and depth decrease. At the same time, values increase to the northeast side representing the basin. The velocity map of the Nahr Umr Formation shows that the value rises toward the southwest direction and decreases toward the southeast direction. The velocity map of the Shuaiba Formation shows value increases toward the southwest direction and decreases toward the northwest direction in the east. The difference in velocity is due to the difference in lithology, geological age and compaction of formations.

2- The study revealed three separate structures representing the three oil fields (Halfaya, Noor, and Amara) affected by different tectonic forces in other geological times with two structural axes in the study area. The first one is the Halfaya-Amara axis (which is separated by a saddle), and its direction is WNW-ESE at the Amara structure. Then this axis deviates in the southeast due to the tectonic effect on the Halfaya structure. Another tectonic force affected the Halfaya structure in the northwest-southeast direction leading to the appearance of a branch of a convex extension towards the north from the middle of the Halfaya structure, completing this branch to a structural closure as nose towards the Noor structure. The second axis of Halfaya-Noor was formed in the direction of northwest-southeast.

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References

- [1] O. R. Berg, "Seismic Detection and Evaluation of Delta and Turbidite Sequences: Their Application to Exploration for the Subtle Trap," *AAPG Bulletin*, vol. 66, no. 9, pp. 1271-1288, 1982.
- [2] W. M. Telford, L. P. Geldart and R. E. Sheriff, "Applied Geophysics," *Cambridge University Press Cambridge, United Kingdom*, p. 770, 1990.
- [3] M. H. Shehab and K. K. Ali, "2D Seismic Reflection Study of the Cretaceous-Tertiary Period in Qasab-Jawan Area in Northwestern Iraq," *Iraqi Journal of Science*, vol. 62, no. 9, pp. 2983-2994, 2021.
- [4] A.S.A. Majeed and K.K. Ali, "3D Seismic Structural Study of Zubair Formation in Najaf-Karbala Area-Central Iraq," *Iraqi Journal of Science*, vol. 64, no. 5, pp.2342-2353, 2023.
- [5] A.M. Abdullah and A.M. Al-Rahim, "Structural interpretation of 2D seismic reflection data of the Khabour Formation in the Upper West Euphrates, western Iraq," *Iraqi Journal of Science*, vol. 63, no. 1, pp. 191-201, 2022.
- [6] N. Abd Al-Ridha and H.M. Yousif, "Seismic structural study of Mishrif and Nahr Umr Formations in Huwaiza oilfield southeastern Iraq," *Iraqi Journal of Science*, vol. 60, no. 3, pp. 554-567, 2019.
- [7] S. A. Al-Sinawi, "Introduction to Applied Geophysics," first ed., *Printed at Mosul University*, p. 142, 1982.
- [8] M. Bacon, R. Simm and T. Redshaw, 3-D seismic interpretation, *Cambridge University Press*, p. 221, 2003.
- [9] H. N. Al-Sadi, "Seismic Hydrocarbon Exploration. 2D and 3D Techniques, Seismic waves," *Cambridge University Press*, p. 331, 2017.
- [10] S. Z. Khorshid and A. D. Kadhm, "Subsurface Investigation of Oligocene Geologic Formations Age, East Baghdad Oil Field," *Iraqi Journal of Science*, vol. 56, no. 4C, pp. 3441-3451, 2015.

- [11] T. Buday, "The regional geology of Iraq: stratigraphy and paleogeography (Vol. 1)," *State Organization for Minerals, Directorate General for Geological Survey and Mineral Investigations*, p. 445, 1980.
- [12] Oil Exploration Company (O.E.C.), "Reinterpretation seismic data of Amara Field," 2010.
- [13] T. Buday and S.Z. Jassim, "Tectonic Map of Iraq, scale 1: 1000 000, 1st edit," *GEOSURV, Baghdad, Iraq*, 1984.
- [14] Petrel help, "Volume attribute library," 2018.
- [15] M. A. Albakr, "Integration Seismic and Earthquakes Data Interpretation for Reservoirs Characterization in Kumate and Dhafriyah oil fields, Southern Iraq," M.Sc. Thesis, *University of Baghdad, Iraq*, p. 150, 2021.
- [16] offeen, "Interpreting Seismic Data," *Tulsa. Oklahoma: PennWell books*, p. 260, 1983.
- [17] O. L. Anderson and J.D. Pigott, "Seismic technology and law: partners or adversaries," *Energy and Mineral Law Institute*, 24, p. 285, 2004.
- [18] A. E. K. Al-Hachem and M.R.S. Al-Obaidi, "Determination of the Paleostress Orientations and Magnitudes for Missan Structures, Southeastern Iraq," *Journal of University of Babylon for Pure and Applied Sciences*, vol. 26, no. 10, pp. 213-233, 2018.
- [19] A. A. Aqrawi, J. C. Goff, A. D. Horbury and F. N. Sadooni, "The petroleum geology of Iraq," *Scientific Press*, p. 560, 2010.