A 2D Seismic Reflection and Interpretation Study of the Khan Al-Baghdadi area within the Palaeozoic Era (western Iraq)

Ali M. Abdullah[*1], Ali M. Al-Rahim[1], Kanaan A. Jassem[2]
[1]Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq
[2]Oil Exploration Company (OEC), Ministry of Oil, Baghdad, Iraq

Abstract

This research deals with a 2D seismic structural and stratigraphic interpretation of Khan Al-Baghdadi area which is located in the western part of Iraq in Anbar governorate. Two main seismic reflectors are identified within the Silurian and Ordovician; these are the Hot_shale_1 within Akkas Formation and the Top Khabour Formation, which were deposited during the Paleozoic, based on synthetic seismogram of Akk_3 well near the study area. Time, depth, and velocity maps show the presence of two anticline structures trending east-west and located on the west side of the study area. The first is the Tulul structure (here denoted as A) and the second is denoted as B. Also, the maps show the increase in time towards the eastern side of the study area. The general slope of the reflectors is towards the southeast and the increase in the thickness of formations is gradually to the southwest and the northwest sides of the study area. The direct hydrocarbon indicator (DHI) was identified as sand lenses and flat spots on the studied reflectors, when applying seismic attributes like the instantaneous phase and the instantaneous Frequency), which give indicators of potential hydrocarbon accumulations. The primary reservoir in the study area is sandstone within the Khabour Formation, while the source and seal rocks are in the Hot_shale within Akkas Formation. They are interpreted to be present throughout Akkas Field, as gas-condensate accumulations, 100 km to the west of the study area and demonstrate the viability of the Paleozoic petroleum system in the Western Desert of Iraq.

Keywords: 2D interpretation, Khan Al-Baghdadi area, Hot_shale_1, Akkas Formation, Paleozoic petroleum system.

<div dir="rtl">

دراسة لتفسير البيانات الزلزالية الانعكاسية ثنائية الابعاد لمنطقة خان البغدادي ضمن حقبة الحياة القديمة (غرب العراق)

علي محمد عبدالله*[1]، علي مكي حسين الرحيم[2]، كنعان عبدالله جاسم [3]
[1]قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق
[2]شركة الاستكشافات النفطية، وزارة النفط، بغداد، العراق

الخلاصة

هذا البحث يتعامل مع التفسيرات التركيبية والطباقية للبيانات الزلزالية ثنائية الابعاد لمنطقة خان البغدادي الواقعة في غرب العراق ضمن محافظة الانبار. حيث تم التقاط عاكسين ضمن العصور (السلوري، الاوردفيشي) المتمثلة بالسجيل الحار ضمن تكوين عكاس واعلى الخابور والمترسبة ضمن حقبة الحياة القديمة.

</div>

_____
*Email: mali35898@gmail.com

والتي تم تعريفها من خلال الأثر الزلزالي المصنع لبئر عكاس–3 القريب من منطقة الدراسة. حيث بينت الخرائط الزمنية، العمقية والسرعية وجود تركيبين تحدبين باتجاه المحور وهما شرق–غرب ويقعان غرب منطقة الدراسة، التركيب الأول هو تلول(A) والثاني هو تركيب(B). كما أظهرت الخرائط ان الزيادة في قيم الزمن تكون باتجاه شرق منطقة الدراسة. وان الميل العام للطبقات يكون باتجاه الجنوب الشرقي للمنطقة. وان الزيادة في السمك تكون باتجاه شمال غرب وجنوب غرب من منطقة الدراسة. تم التوصل الى وجود الدلائل الهايدروكاربونية (DHI) والمتمثلة بالأجسام الرملية عدسية الشكل (Sand Lenses) والبقع المنبسطة (Flat Spot) والتي تعطي شواهد على تجمعات هايدروكاربونية محتملة في هذه الاماكن ضمن العواكس المدروسة وذلك بتطبيق السمات الزلزالية (الطور الاني والتردد الاني). ان الصخور المكمنية في منطقة الدراسة متمثلة بالرمل ضمن تكوين الخابور، وان الصخور المصدرية وصخور الغطاء متمثلة بالسجيل الحار ضمن تكوين عكاس. وهي فسرت على احتواها على تجمعات غازية/مكثفات المتراكم ضمن حقل عكاس الذي يبعد مسافة 100 كم في الجزء الغربي لمنطقة الدراسة. وتوضح جدوى النظام البترولي في الصحراء الغربية للعراق ضمن حقبة الحياة القديمة.

Introduction

The seismic reflection method is the most widely applied of any well-known geophysical technique [1] and gives a more direct and detailed picture of the subsurface geological features [2]. It is more suitable in areas where the oil is in structural traps, but it is also useful for locating and detailing certain types of stratigraphic features [3]. Seismic data interpretation is the third and last stage in any seismic exploration project. In the two preceding stages (fieldwork and data processing), seismic reflected waves are first generated and then processed to give the stacked seismic sections, whereas the interpretation is the end product of the seismic work. Thus, the accuracy of the interpretation stage depends on the accuracy of previous works [4]. Khan Al-Baghdadi area is located approximately 150 km to the west of Baghdad in the Western Desert province of Iraq in Anbar governorate, as shown in Figure-1. Tectonically, the study area lies within the Salamn zone on the stable Arabian Platform [5]. It is located about 100 km to the east of Akkas Field. It represents a gas-condensate accumulation in which the principal reservoir is the upper portion of the Ordovician Khabour Formation. The lower Silurian Akkas shales are the seal and source for this accumulation and are thought to be present throughout western Iraq. Fine-grained sandstones within the Silurian Akkas Formation provide an additional reservoir [6]. Thus, in certain regions of the study area, such as Akkas Field, the key to hydrocarbon accumulations is the presence of Akkas and Khabour Formations. Akkas and Khabour Formations constitute the primary source, seal, and reservoir triplet of the Paleozoic play of Western Iraq. This research aims to interpret the 2D seismic data for surveys carried out in Khan Al-Baghdadi area for determining the structure picture of the study area within the Palaeozoic Era for the two reflectors, which are Hot_shale_1 within Akkas Formation (Silurian) and Top Khabour Formation (Ordovician). Also, a stratigraphic picture was generated by applying seismic attributes to predict hydrocarbon accumulations that might be present within the formations, using Petrel-2017 as interpretation software [7].
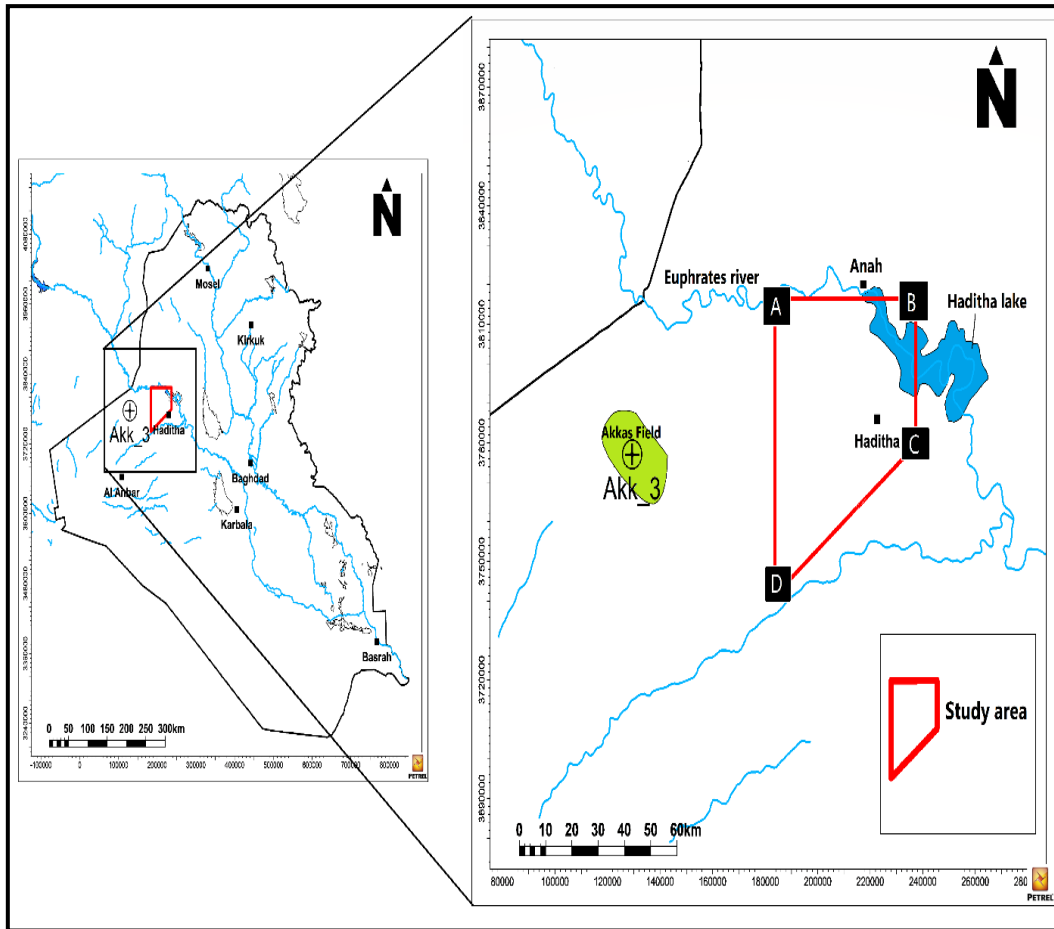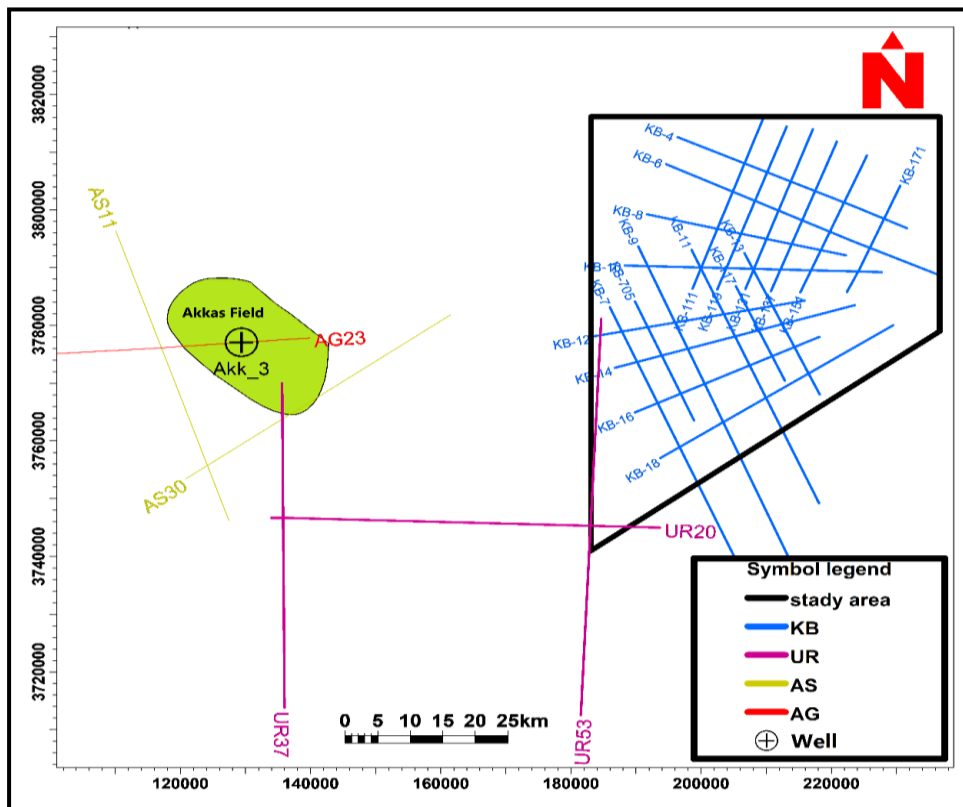
Figure 1- Location map of the study area

Figure 2- The base map of the study area.

Base map preparation

   The study area is covered by 25 2D seismic reflection lines (Figure-2). The total accumulative length of these seismic lines is 1252 Km, covering an area of 3007.5 km^2 [8]. These 25 lines were acquired during four surveys conducted between 1980 and 1990. These are represented by Khan Al-Baghdadi survey (KB), which consisted of twenty lines, as well as Anah_Ghadah survey (AG), Akkas survey (AS), and Um-Rashif survey (UR). The latter three sets (AG, AS, and UR) are located in the west of the study area and used to connect with the Akk_3 well, which is 100 km far from the study area. The 2D seismic data were loaded to the interactive workstation of the interpretations department at the Iraqi Oil Exploration Company (O.E.C) (using Petrel 2017 and Hampson-Russell 10 software suits) in a SEG-Y format. After that, the base map of the study area was constructed as shown in Figure-2, which also includes a definition of the geographic coordinates for the study area in the UTM coordinates system.

Synthetic seismograms and reflector definition

   Synthetic seismogram is a plot that compares between synthetic and composite traces [9]. The studied reflectors were defined using the synthetic seismogram from Akk_3 well, which lies on the seismic line AG-23 on the western side of the study area. In this process, the sonic log, density log, check-shot survey, and well tops of Akk_3 were utilized. A synthetic seismogram was generated using Hampson-Russel 10 software. The main step of the generation of synthetic seismograms was computing the acoustic impedance (AI = v x ρ), where v is seismic velocity and ρ is density measured from log, after the calibration by calibrating the sonic log of Akk_3 with the check-shot survey to reach the highest matching rates of calibrated Time Depth Relation (TDR) to produce acoustic impedance and reflection coefficient logs (RC= AI (2) – AI (1) / AI (2) + AI (1)). The synthetic seismogram was generated by convolving with a deterministic wavelet [10]. This wavelet was used for the convolution process to transform the reflection coefficients to the best seismic signal and to determine the reflectivity that was resulted from the acoustic impedance difference. Figure-3 represents the seismic sections Ag23 passing through the Akk_3 well locations, where the synthetic traces of reflectors are also displayed. The figure shows that the matching between the seismic and synthetic traces was good. Figure-4 represents a part of the KB-117 seismic line, showing the picked horizons as well as its location on the base map, which is marked by the red arrow. The picked reflectors appeared as peaks or troughs on the seismic section (positive or negative reflections) in different intensities. The Hot_shale_1 corresponds to a peak, while the Top Khabour corresponds to a trough.
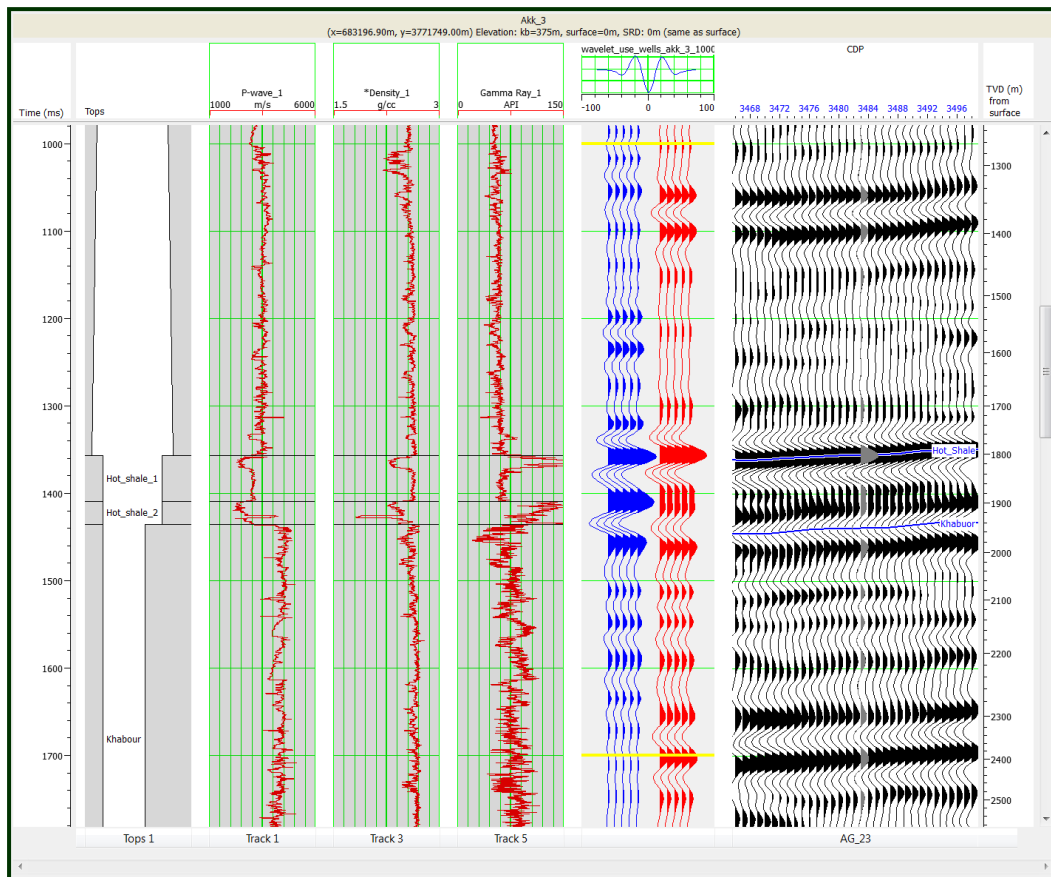
Figure 3- Synthetic seismogram of Akk_3 well which shows a good tie with seismic data.
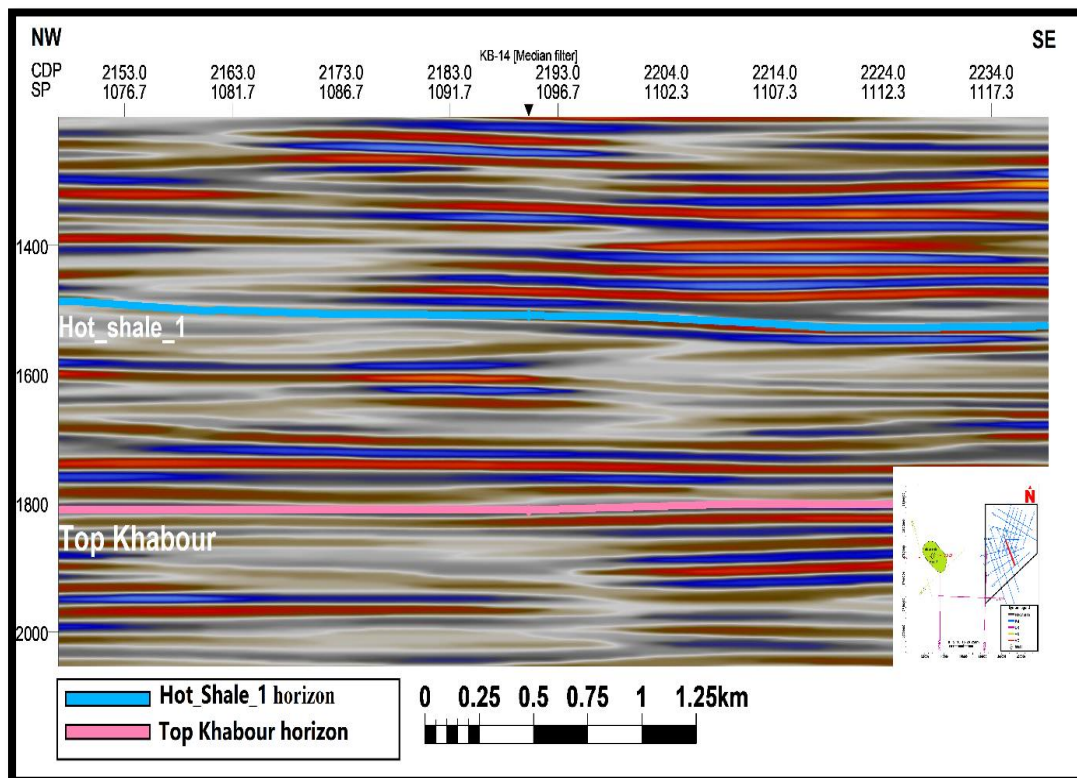

Figure 4- Part of the KB-117 seismic line showing the picked horizons, where its location on the base maps is marked by the red arrow.

Structural Picture of the Picked Horizon

After the definition of the reflectors by synthetic seismogram of Akk_3 on the seismic section AG23, the reflectors, represented by Hot_Shale_1 and Top Khabour Formations, were picked and followed up in all seismic lines of the study area. This step was performed to prepare the time maps which were converted later to structural maps in depth domains by using the velocity model of these reflectors.

Time Maps

Two way time (TWT) maps were constructed using Petrel 2017 software for the picked horizons, with a contour interval of 20 ms (Figures-5 and 6). Figure-5 represents the TWT map for Hot_shale_1, with a contour interval of 20 ms, while the TWT value ranges from -1240 to -1720 ms. Figure- 6 represents the TWT map for Top Khaboure Formation, a with contour interval of 20) ms from sea level, while the TWT value range 1600 - 1960 ms. The two maps show in general a dominance of two structural phenomena as anticline structures. The first is the Tulul structure (A), located in the northwest side of the study area and trending E-W, whereas the second is named B structure, located in the southwestern side of the study area, trending E-W, and extending out the study area. They represent structurally the highest area with the lowest value of TWT, compared with the lower area on the east side (basin) with the highest value of TWT. Also, these Figures-5 and 6 show the general dip towards the southeast.
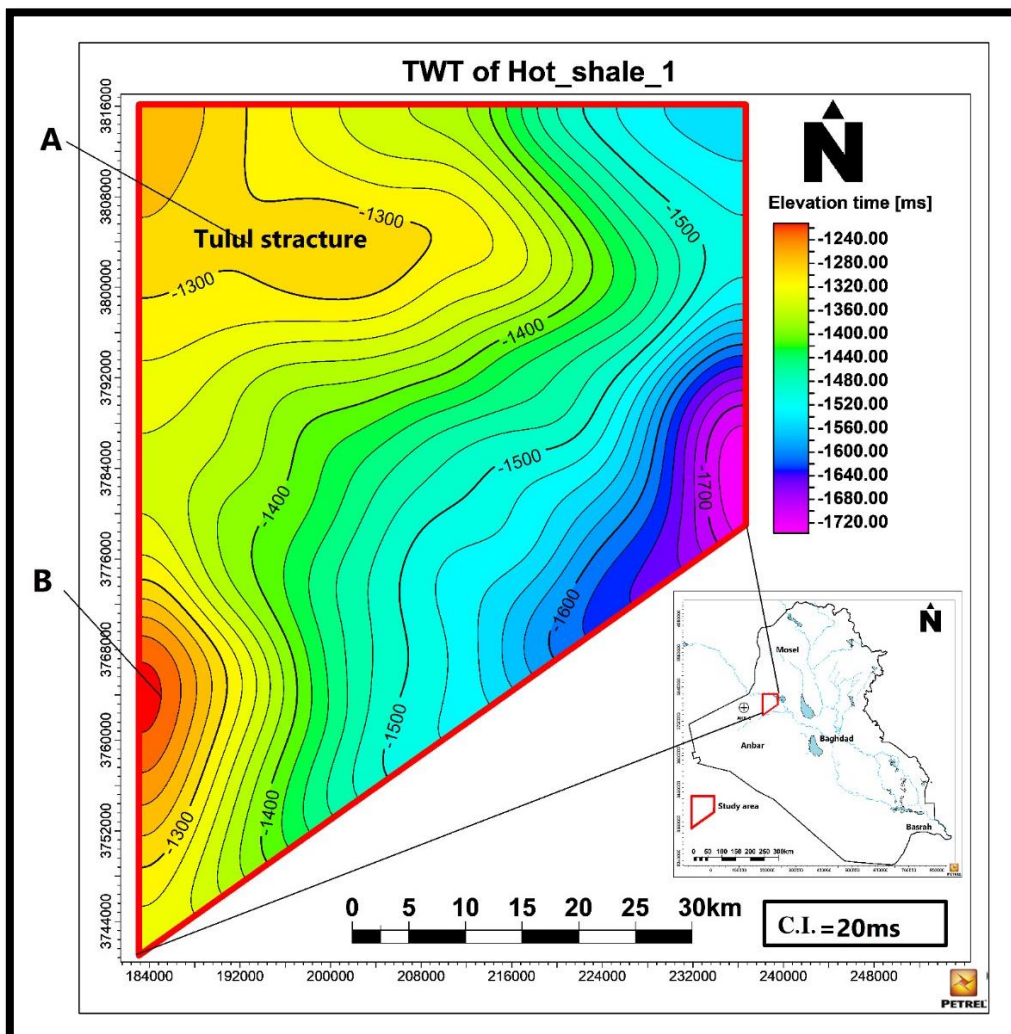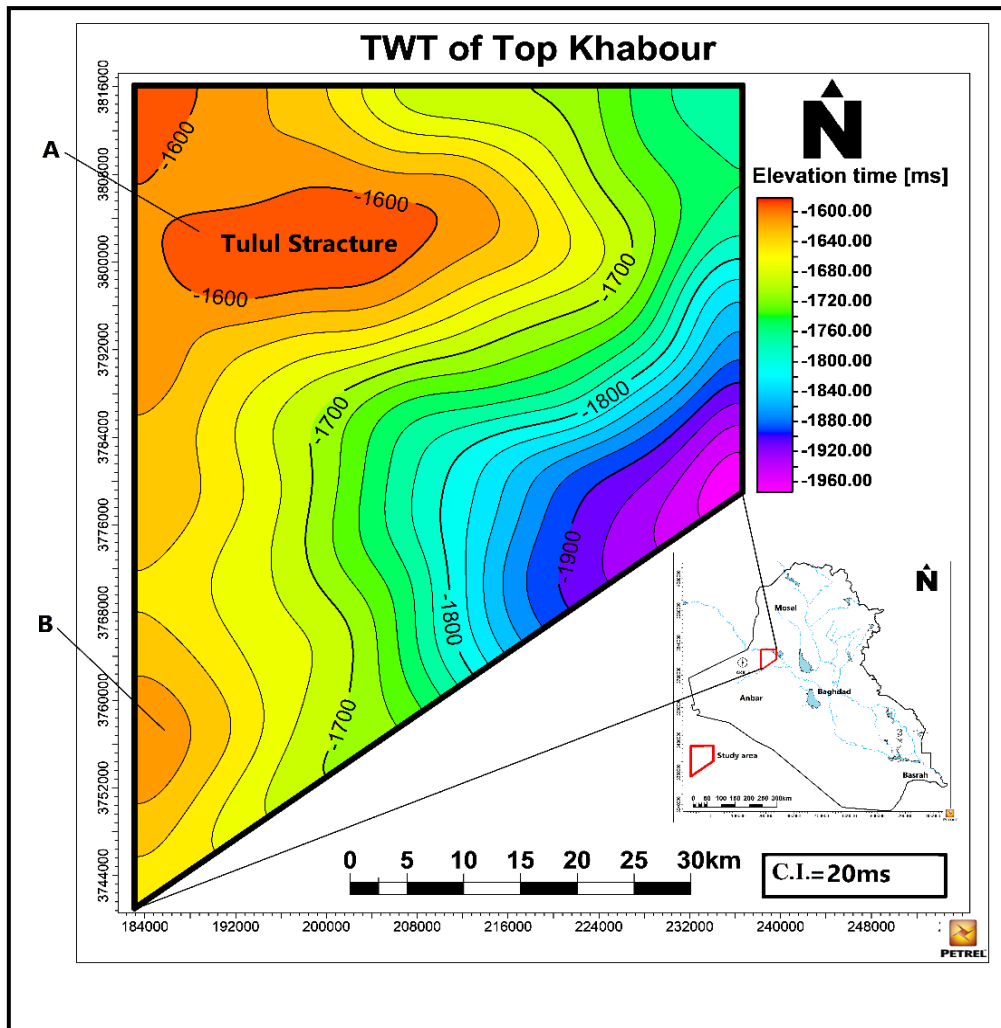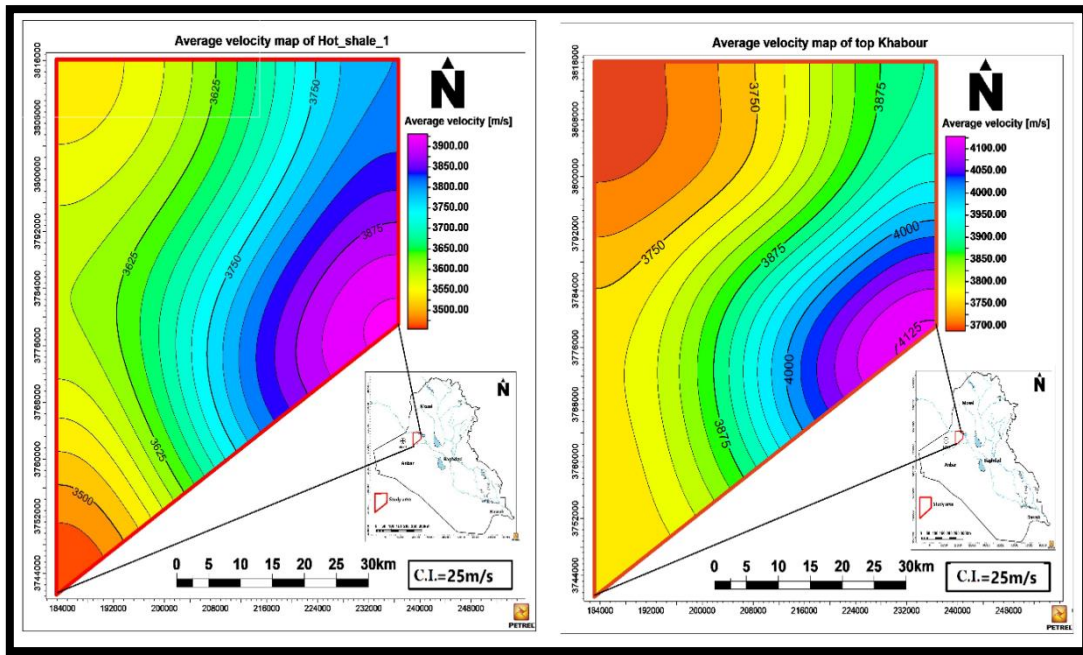

Figure 5-TWT map of Hot_shale_1

Figure 6-TWT map of Top Khaboure Formation.

Velocity Maps

The average Velocity maps were acquired from the velocity model for the piked reflectors using Petrel 2017 software to convert TWT maps that were measured in time domain to depth maps in depth domain [11]. The maps were prepared with contour intervals of 25 ms. Figure- 7 represents the average velocity maps of Hot_shale_1 (left) and Top Khaboure Formation (right). The two maps show that the velocity increases irregularly with depth because of the heterogeneity of sedimentary layers as a result of differing facies and depositional environments. The velocity value for each reflector increases towards the east and decreases towards the northwest and southwest of the study area.

Depth Maps

By using the velocity model that was constructed by Petrel software, two depth maps were prepared for the two studied reflectors, with a contour interval of 30m. Figures- 8 and 9 show the depth maps for Hot_shale_1 and Top Khaboure Formations, respectively. These depth maps give the same shape as the time map and show the same structural picture of the studied formations. Depth maps show that the depth increases in the southeast direction and decreases towards the northwest and southwest directions within the study area. Depth maps showed the presence of two structures; the first is Tulul Structure (A) located in the NW part of the area, 2550 m in Hot_shale_1 Formation and 3300 m in Top Khabour Formation. The second is B structure located at the SW part of the area and extending out of the study area. The general direction of this structure is in the E-W.

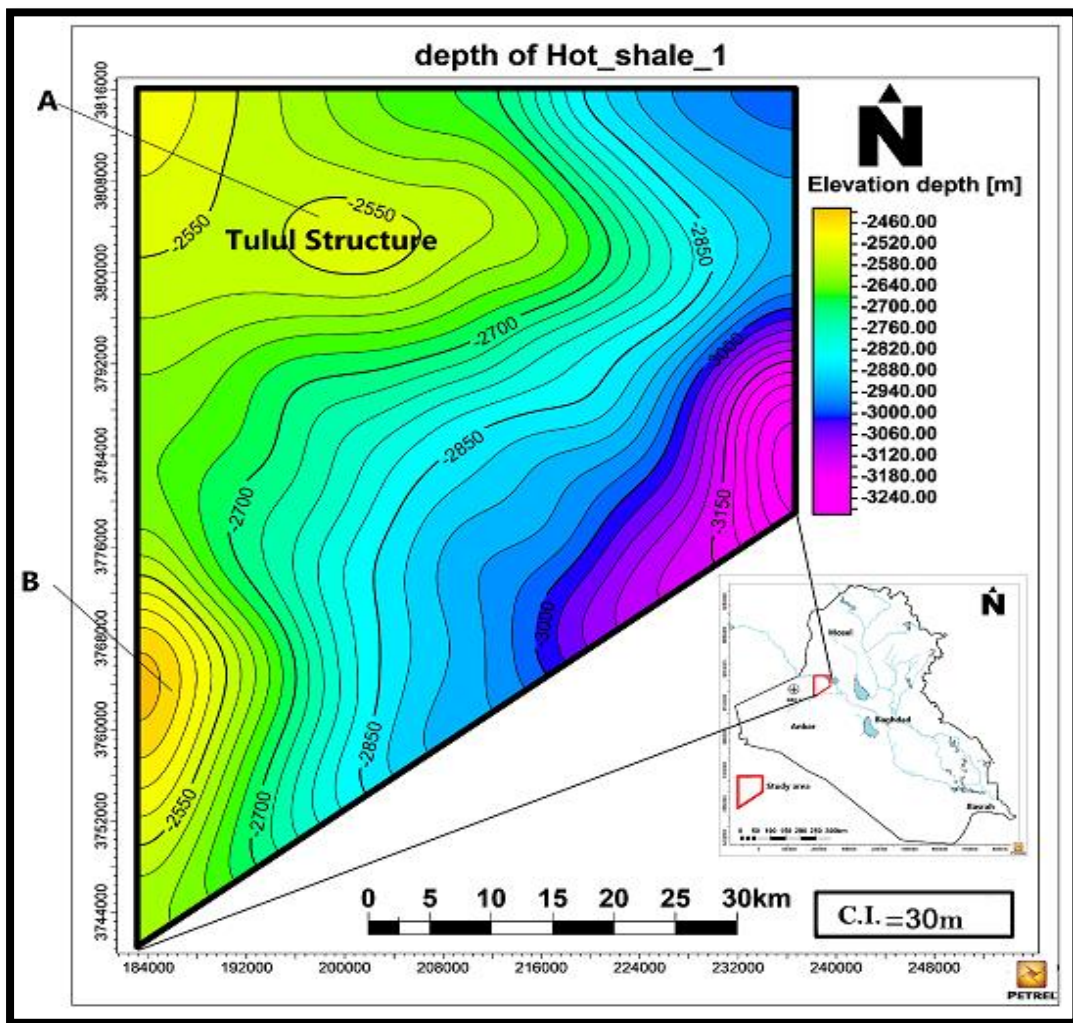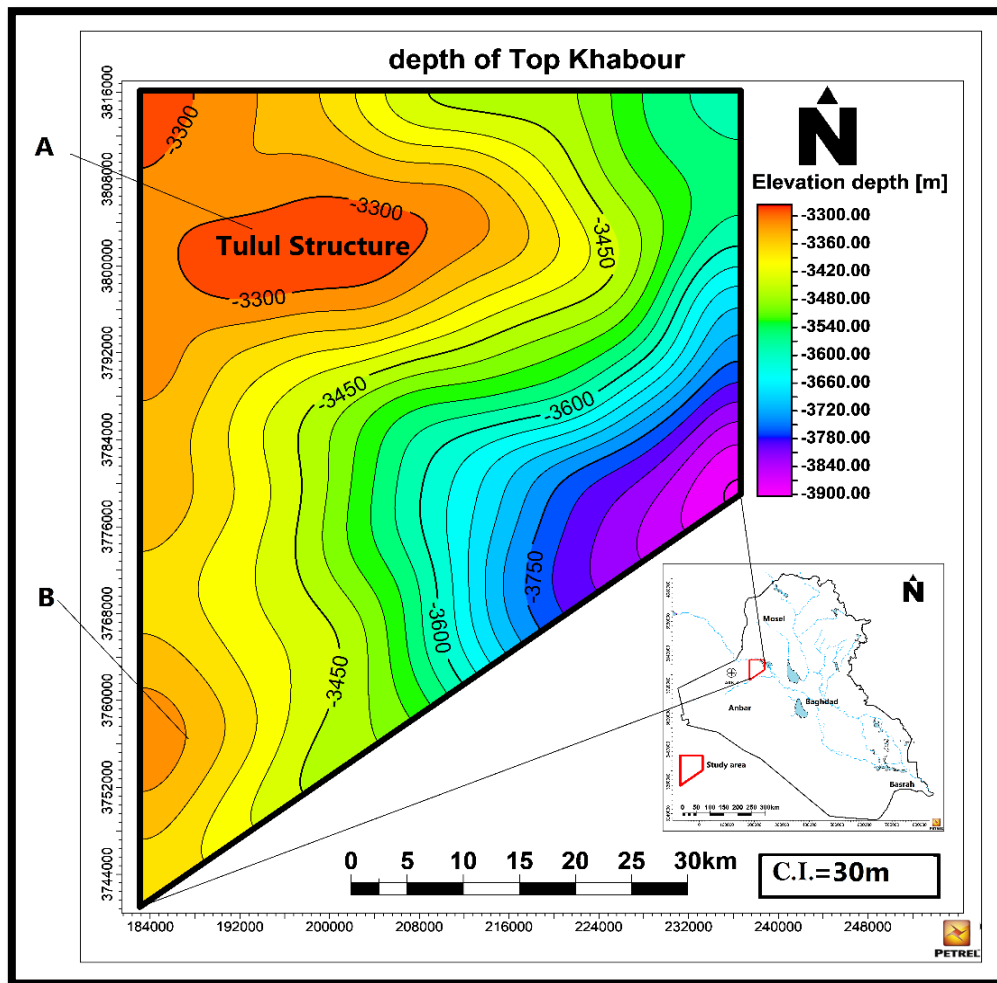**Figures 7**-Average velocity maps of Hot_shale_1 (left) and Top Khaboure (right)

Figure- 8 Depth map of Hot_shale_1.

Figures 9- Depth map of Top Khaboure Formation.

Isochron and Isopach Maps

Thickness maps are a fundamental tool in structural interpretation. They assist to study the variation in thickness of studied formations. Isochrones and isopach maps are two different types of thickness maps which were created using Petrel 2017 software to construct the two maps for the picked reflectors by subtracting the map of the top reflector from the map of the bottom reflector.

Isochron map

The isochrones map represents the variation in time between two seismic events or reflections of the studied formations in the time domain. The isochron map between Hot_shale_1 and top Khabour horizons shows that the differences in time values range between 240 and 360 ms, which increase towards the southwest of the study area, with a contour time interval of 10 ms (Figure-10, left). The isochron map between top Khabour and Burj reflectors shows that the differences in time values range between 1440and 1980 ms, which increases towards the southwest of the study area, with a contour time interval of 30 ms (Figure-10, right).

Isopach map

The isopach map represents the variation between two seismic events or reflections of the studied formations in the depth domain [11]. The isopach map of Hot_shale_1 (Figure-11, left) shows that the thickness values have a range of 40-480 m. It is noted that there is an increase of thickness towards the SW of the study area, reaching about 480 m. The map was prepared with a contour interval of 20 m. The isopach map of Top Khabour (Figure-11, right) shows that the thickness values range between 2900 and 3900 m. It is noted that there is an increase of thickness towards the SW of the study area, reaching about 3000m. The map was prepared with a contour interval of 25 m.
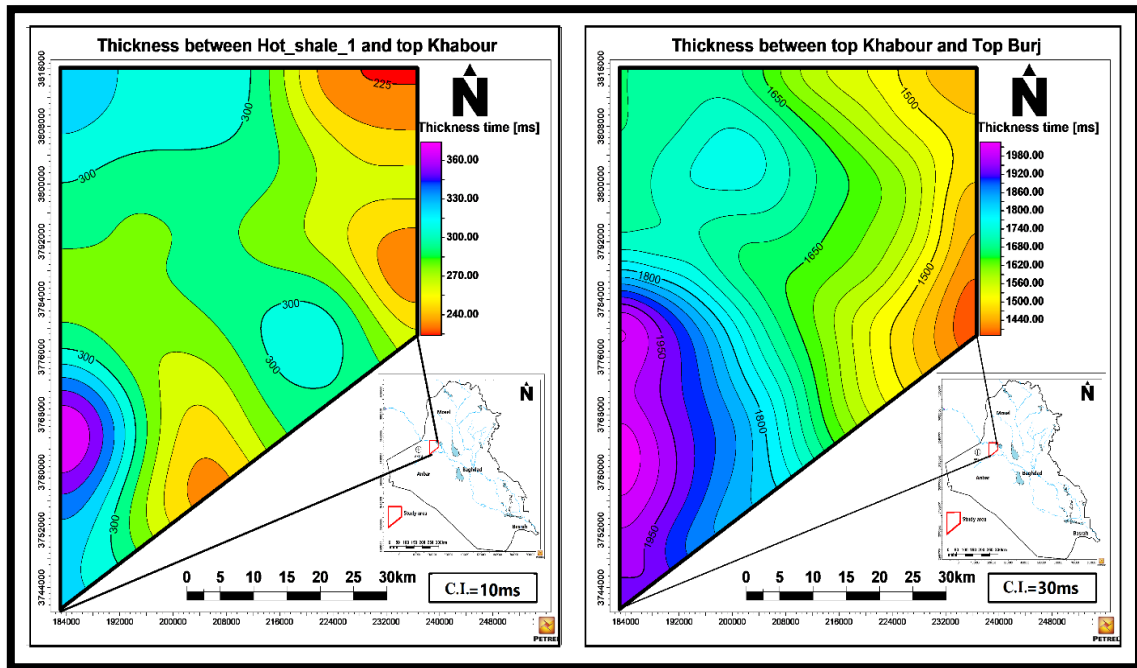
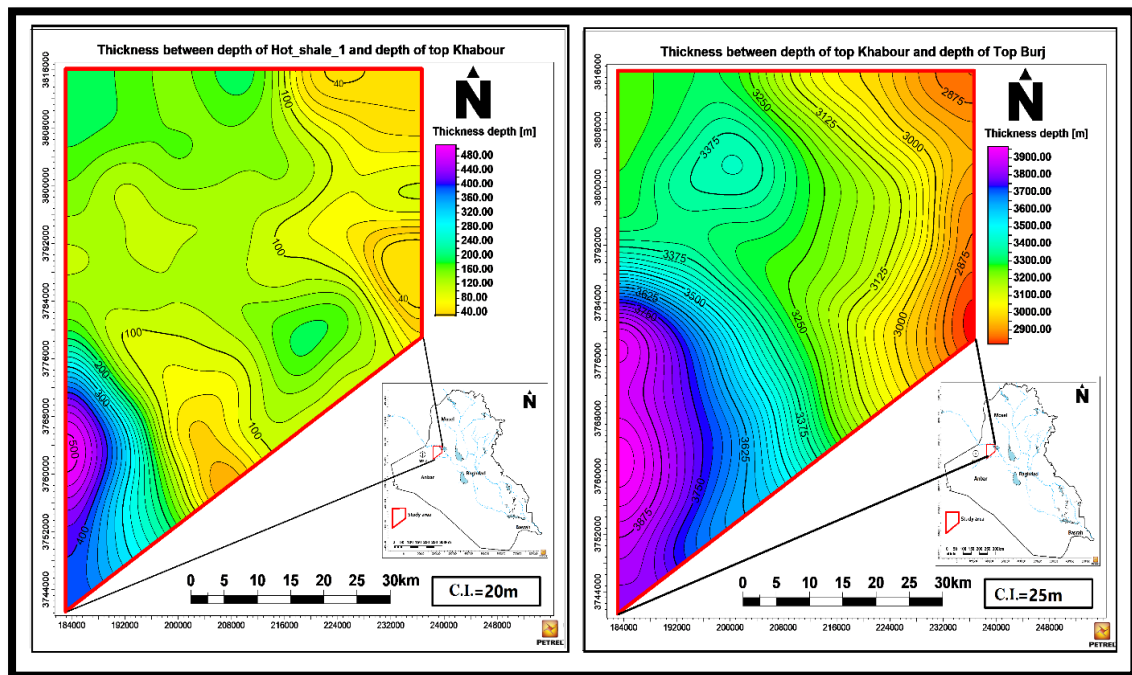**Figure-10** Isochrones maps of Hot_shale_1 (left) and Top Khabour (right)

Figure-11 Isopach maps of Hot_shale_1 (left) and Top Khabour (right)

Seismic Attributes

Attributes are a mathematical analysis tool of the basic attributes of seismic traces (time, amplitude, frequency, attenuation, phase). Seismic attributes extract information from seismic data that is otherwise hidden in the data [12]. This information can be used for predicting, characterizing, and monitoring hydrocarbon reservoirs. Seismic attributes were applied to the 2D seismic line of Khan Al-Baghdadi survey to study the stratigraphic features. The instantaneous phase is important in structural and stratigraphic interpretation studies to detect reflector terminations, such as faults, on lap, top lap, down lap, flatspot, and sand lens. The instantaneous phase attribute section is very important for the

distinction of the termination of the reflector surface's continuity, because it does not depend on the reflection strength. It is measured in radian between $-\pi$ to π [13-14].

Instantaneous Phase

The instantaneous phase attribute shows the continuity and discontinuity of events and it is very important to study faults [15, 16], flat spots, and sand lenses that are used in the computation of instantaneous frequency. Figures-12 and 14 illustrate the instantaneous phase sections and show the stratigraphic features, represented by flat spots on of KB10 and sand lenses on the seismic section of KB8, which demonstrated indicators of potential hydrocarbon accumulations. Figure-13 illustrates the seismic line of KB8 before applying the instantaneous phase attribute.
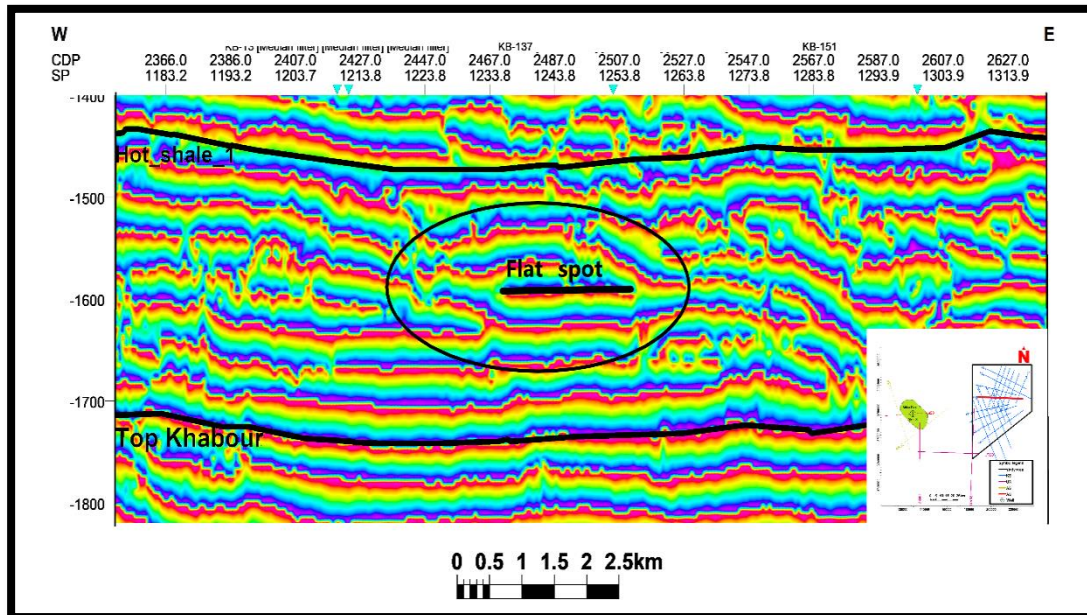

Figure 12-The instantaneous phase sections on KB10 seismic line showing the picked horizons, with flat spots as a direct hydrocarbon indicator (DHI).
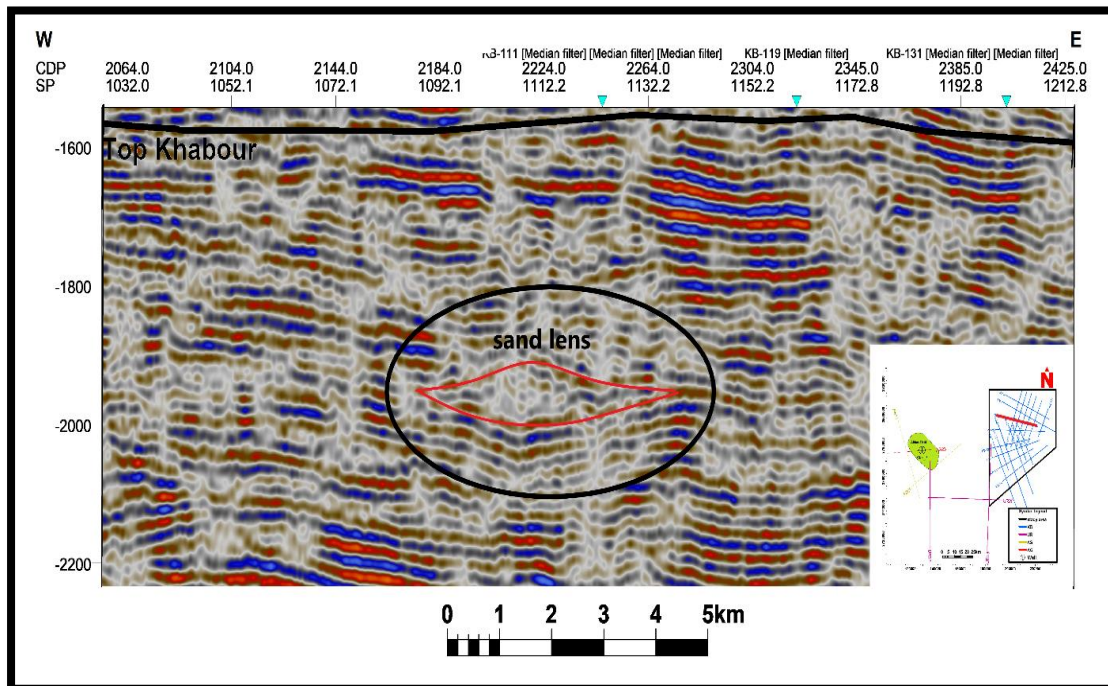

Figure 13- The seismic line of KB8 before applying instantaneous phase attribute, with sand lenses that may contain hydrocarbon accumulations, as well as the location of KB8 on the base map.
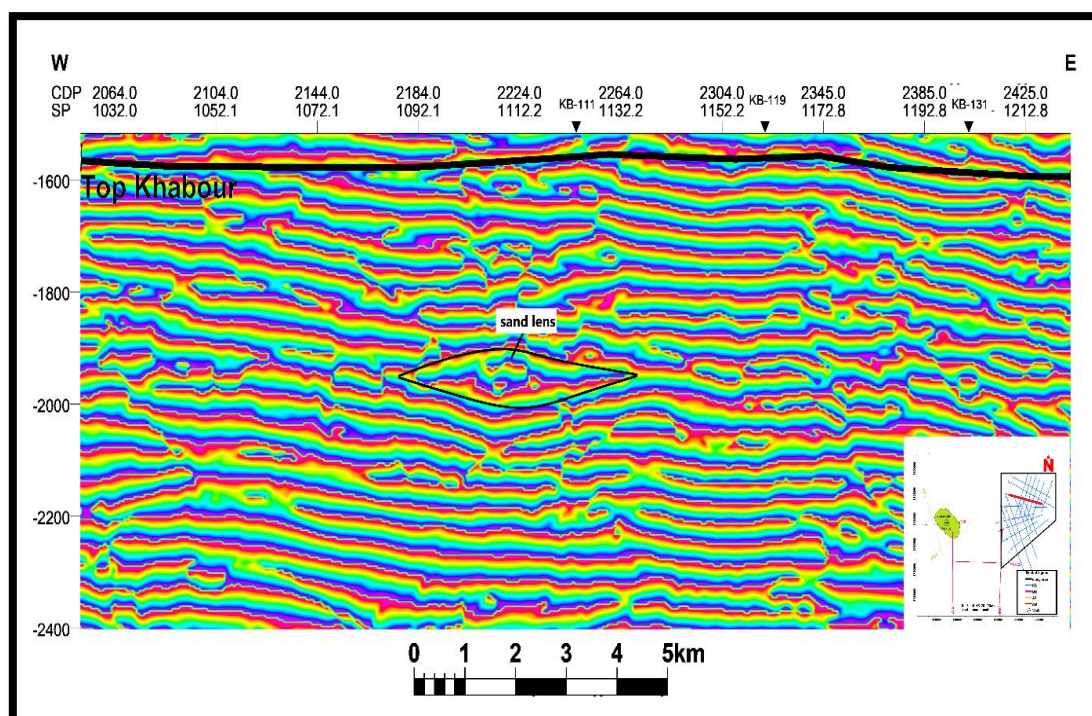
Figure 14- The instantaneous phase sections on KB8 seismic line showing the picked horizons, with sand lenses that may contain hydrocarbon accumulations, as well as the location of KB8 on the base map.

Conclusions

The Hot_shale and Ordovician Khabour sands of the Silurian Akkas are the primary reservoir, seal, and source rocks in the study area. They are interpreted to be present throughout Akkas Field, as gas-condensate accumulations located 100 km to the west of the study area. They demonstrate the viability of the Paleozoic petroleum system in the Western Desert of Iraq. Two phenomena appear as anticline structures on the time and depth maps of these two reflectors. These are the Tulul stricture (A) in addition to a second structure (B). Generally, the trending of the two structural features is towards east-west and the thickness of the reflectors increases towards the southwestern side of the study area. Flat spot and sand lens stratigraphic features appeared within the studied reflectors, by using seismic attribute techniques. These features may contain hydrocarbon accumulations in Khabour sands that represent the reservoir of the Paleozoic petroleum system in the Western Desert of Iraq.

References

1. Kearey, P., Brooks, M. and Lan H., **2002**. *An Introduction to Geophysical Exploration*, 3rd ed., Blackwell Science Ltd., 256p.
2. Milsom, John . **2003**, *Field Geophysics*, 3rd. Ed. University College London, 232 p.
3. Al-Sinawi .**1981**. *Introduction to Applied Geophysics*, first ed., Printed at Mosul University .142 p.
4. Telford, W. M., Telford, W. M., Geldart, L. P., Sheriff, R. E., & Sheriff, R. E. **1990**. *Applied geophysics*. Cambridge university press.
5. Jassim S. Z., and Goff J. C., **2006**. *Geology of Iraq*. Dolin, Prague and Moravian Museum, Brno, 486p.
6. Al – Hadidy, H-A-, **2007**. *Paleozoic stratigraphic lexicon and hydrocarbon habitat of Iraq*, Geo Arabia, vol.12.no.1. Gulf Petrolink, Bahrain, 68p.
7. Schlumberger. **2018**. *Overview of Petrel E&P Software Platform*. Retrieved 513,
8. 2108, from https://www.software.slb.com/products/petrel?tab=Overview.
9. Oil Exploration Company (O.E.C). **2001**. Oil Exploration Company. *Re-interpretation of seismic information study of Khan Al-Baghdadi*, 30 p, Unpublished study.

10. Al-Rahim, A. M., & Hashem, H. A. **2015**. Enhancing the indication of ancient geologic features by using Seismic Attributes technique extracted along picked horizons of seismic and flattened data. *Iraqi Journal of Science*, 56(3C): 2640-2647.
11. Dobrin, M. **1976**. *Introduction to Geophysical Prospecting*, 3rd ed., McGraw Hill. Int. co., International Student Edition 386 p.
12. McQuillin, R., Bacon, M, and Barclay, W. **1984.** *An Introduction to Seismic Interpretation, Graham and Trotman*, 287 p.
13. Alsadi, H. N. **2017**. *Seismic Hydrocarbon Exploration-2D and 3D Techniques*. Switzerland: Springer, 341p.
14. Taner, M. T., Koehler, F., and Sheriff, R. E., **1979.** Complex seismic trace analysis. *Geophysics*, **44**:1041–1063.
15. Alridha, N. A. and Muhsin S. U. **2015**. Seismic attributes analysis in Balad oil field – center of Iraq, *Arabian Jornal of Geosciences* ISSN 1866-7511, **8**(5): 2785-2798.
16. Ali, K. K., Al-Sharaa, G. H., & Rasheed, A. H. **2018**. 3D Seismic Structural and Stratigraphy Study of Shuaiba Formation in Kumait Oil Field-Southern Iraq. *Iraqi Journal of Science*, 1665-1672.