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Structural interpretation of 2D seismic reflection data of the Khabour Formation in the Upper West Euphrates, western Iraq

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Abstract

The seismic reflection method has a primary role in petroleum exploration. This research is a structural interpretation study of the 2D seismic reflection survey carried out in the Upper West Euphrates (Khan Al-Baghdadi area), which is located in the western part of Iraq, Al-Anbar governorate. The two objectives of this research are to interpret Base Akkas/Top Khabour reflector and to define potential hydrocarbon traps in the surveyed area. Based on the synthetic seismogram of Akk_3 well near the study area, the Akkas/Top Khabour reflector was identified on the seismic section. Also, the Silurian Akkas Hot_shale reflector was identified and followed up, which represents the source and seal rocks of the Paleozoic petroleum system in the Western Desert of Iraq. Time, velocity, depth, and isopach maps were drawn for Base Akkas/Top Khabour reflector and showed the presence of two anticline structures trending east-west and located on the west side of the study area. The first is termed as (A), represented by Tulul structure, and the second is termed as (B). The maps show the increase in time toward the eastern side of the study area. The general slope of the reflectors is toward the southeast of the study area, while the increase of the thickness of the Formation is gradual to the southwest as well as the northwest of the study area. The study area was affected by three transversal faults. Generally, the faults have northeast-southwest trends. The Ordovician Khabour sands are the primary reservoir in the study area. They are interpreted to be present throughout Akkas Field as gas/condensate accumulation located 100 km to the west of the study area.

Keywords: Upper West Euphrates, Structural interpretation, Paleozoic petroleum system, Khabour Formation.

تفسير تركيبي للبيانات الزلزالية الانعكاسية ثنائية الابعاد لتكوين الخابور في منطقة أعالي الفرات، غرب العراق

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الخلاصة

يمثل هذا البحث تفسير تركيبية للمسح الزلزالي الانعكاسي ثنائي الابعاد الذي تم إجراؤه في منطقة أعالي غرب الفرات (منطقة خان البغدادي) الواقعة في الجزء الغربي من العراق في محافظة الأنبار. لهذا البحث

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الهدفان هما تفسير عاكس أسفل عكاس / أعلى الخابور ضمن مسح خان البغدادي وتحديد المصائد الهيدروكربونية المحتملة في منطقة الدراسة. بالاعتماد على الأثر الزلزالي المصنع لبئر عكاس-3 القريب من منطقة الدراسة تم تعريف عاكس أسفل عكاس / أعلى الخابور على المقاطع الزلزالية، كذلك تم تعريف عاكس السجيل الحار (Hot Shale) وتتبعه في منطقة الدراسة الذي يمثل الصخور المصدرية وصخور الغطاء للنظام البترولي لحقب الحياة القديمة في الصحراء الغربية. تم رسم الخرائط الزمنية، السرعية، العمقية، وخرائط السمك لعاكس أسفل عكاس / أعلى الخابور وبينت هذه الخرائط 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 سمك التكوين تكون باتجاه الجنوب الغربي والشمال الغربي من منطقة الدراسة. ان منطقة الدراسة متأثرة بثلاث صدوع عرضية رئيسية، بشكل عام هذه الصدوع تمتد باتجاه شمال شرق-جنوب غرب. ان الصخور المكمنية في منطقة الدراسة متمثلة بالرمل ضمن تكوين الخابور فسرت على احتواها على تجمعات غازية/مكثفات المتراكم ضمن حقل عكاس الذي يبعد مسافة 100 كم في الجزء الغربي لمنطقة الدراسة.

Introduction

The seismic reflection method absorbs more than 90% of the money spent worldwide on applied geophysics. Most surveys are aimed at defining oil-bearing structures at depths of thousands of meters using hundreds or even thousands of detectors [1]. The basic idea in seismic methods is a hit on the surface (a controlled source) to create a seismic wave that travels underground. This wave is reflected and refracted when it reaches a boundary between different layers. Using the travel-time (time required for the wave to travel to the surface), the different geological boundaries can be determined [2]. The velocity value of the waves carries information on the type of rocks and is important to locating and mapping features, such as anticlines, reefs, faults, and salt domes, many of which are associated with oil and gas accumulation [3]. Seismic interpretation is the science and art of inferring the geology from the processed seismic sections [4]. Geological description is the primary aim of seismic interpretation. The accuracy of the interpretation depends on the quality of seismic data, where the higher quality gives a more accurate interpretation [5]. The structural interpretation aims to draw time, velocity, depth, and isopach maps which represent the variation between two seismic events or reflections of the studied formations in the depth domain [6]. The first objective of this research is to interpret Base Akkas/Top Khabour reflector over the Khan Al-Baghdadi surveyed area and tie this interpretation to Akk_3 well. The second objective is to define potential hydrocarbon traps in the study area. The Upper West Euphrates (Khan Al-Baghdadi) area is located approximately 150 km west of Baghdad in the Western Desert province of Iraq, bordered by the Euphrates River. The study area is approximately 3007.5 km^2 [7], as shown in Figure 1. Khan Al-Baghdadi area lies within the Salman zone on the stable Arabian Platform in western Iraq and is tectonically quiescent [8]. The stratigraphic correlations of wells across Iraq demonstrate the westward regional thinning and erosion of the Mesozoic rocks from the edge of the Mesopotamian Basin toward the Arabian Platform [9]. Continuous down-warping of the Mesopotamian Basin accommodated a thick accumulation of Mesozoic and Tertiary sediments that are not present in Western Iraq [10], as demonstrated in Figure 2. As a result, the Western Desert lies in a hydrocarbon province that is quite distinct from the highly prolific Mesopotamian Basin. The well-known Tertiary, Cretaceous, and Jurassic hydrocarbon systems of central and eastern Iraq are absent near the study area. The potential of the Ordovician Khabour sands in the study area comes from the Paleozoic hydrocarbon system. The commercially viable accumulations of hydrocarbons that are closest to the study area consist of the Akkas gas field (about 100 km west of the Khan Al-Baghdadi area) and two other noteworthy hydrocarbon accumulations that are pertinent to the exploration potential; these are the Risha Field (Jordan) and the Kahf discovery (Saudi

Arabia). Akkas Field is a gas and 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 [11], as illustrated in Figure 3.

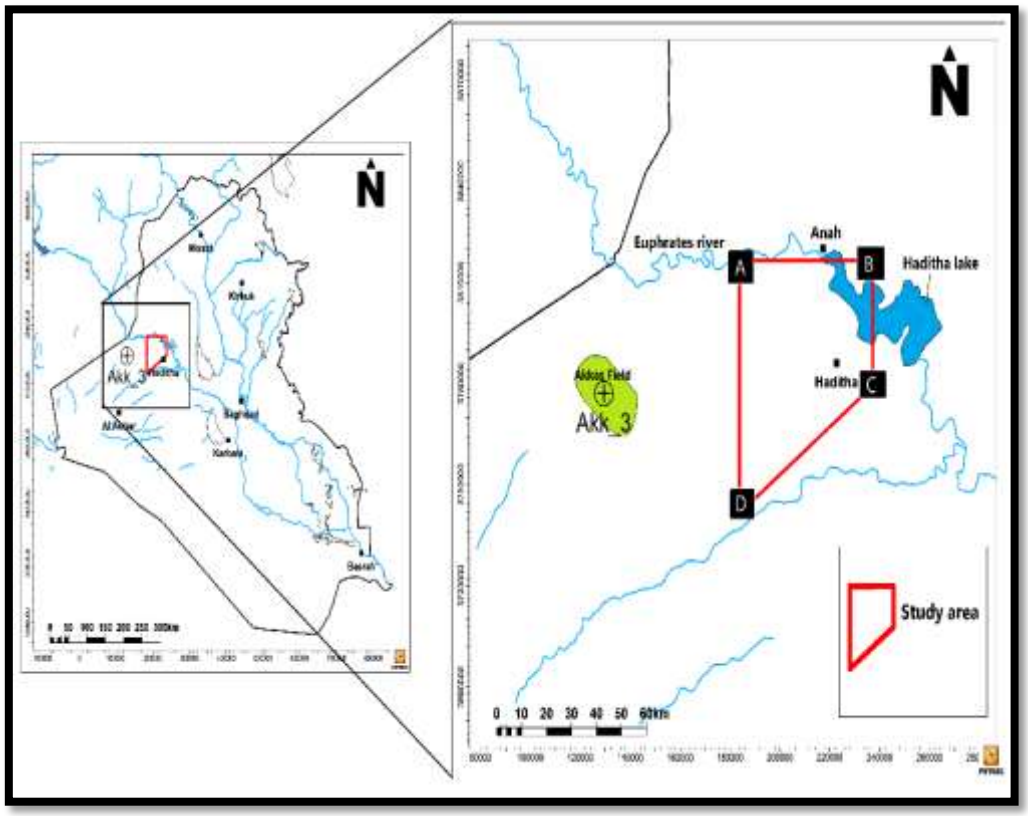

Figure 1- Location map of the study area

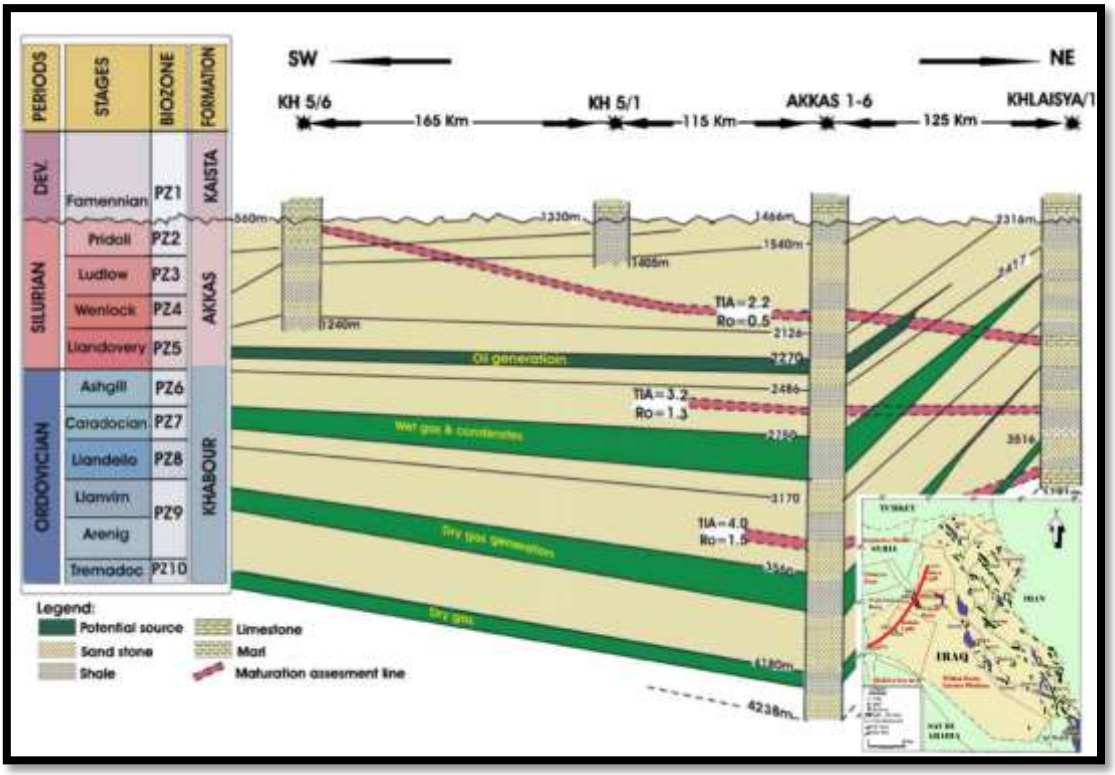

Figure 2- Stratigraphic cross-section of Akkas wells and their surrounding wells [10].

Materials and methods

Two types of data were used in this study; well data include the sonic log, density log, check-shot survey, and well tops of Akk_3; seismic data include sets of 2D seismic lines, which were acquired during four check-shot surveys conducted between 1980 and 1990 [7]; these are the Khan Al-Baghdadi survey (KB), consists of twenty lines, Anah_Ghadah survey (AG), Akkas survey (AS), and Um-Rashif survey (UR). The three sets of seismic lines (AG, AS, and UR) are located in the west of the study area. They are used to connect with the Akk_3 well, which is 100 km far from the study area. All of these sets were imported into the interactive workstation. The base map of the study area is shown in Figure 4. The interpretation was carried out using Petrel 2017 and Hampson-Russel 10 software. The synthetic seismic traces were generated from the sonic and density logs. These were tied to check-shot data of Akk_3 well and are shown in Figure 5. The correlation and well-tie to line AG23 are shown in Figure 6. This tie formed the first step in the picking events [12], which corresponded to the top of the hydrocarbon reservoir sand of the Khabour Formation. This reflector, within the logs of Akkas wells that show hydrocarbon prospects, was selected for mapping. The identified Base Akkas/Top Khabour reflector was tracked on the reflections on the seismic sections of the study area to produce the time structure (isochron) map. The time map was converted to a depth structure map using the velocity model. Also, in this study, the Hot_shale within Akkas Formation was identified on the seismic section, which represents the source and seal rocks in the study area. Major faults were identified, based mainly on break-in reflection events or abrupt termination of reflection events, and marked on the seismic lines.

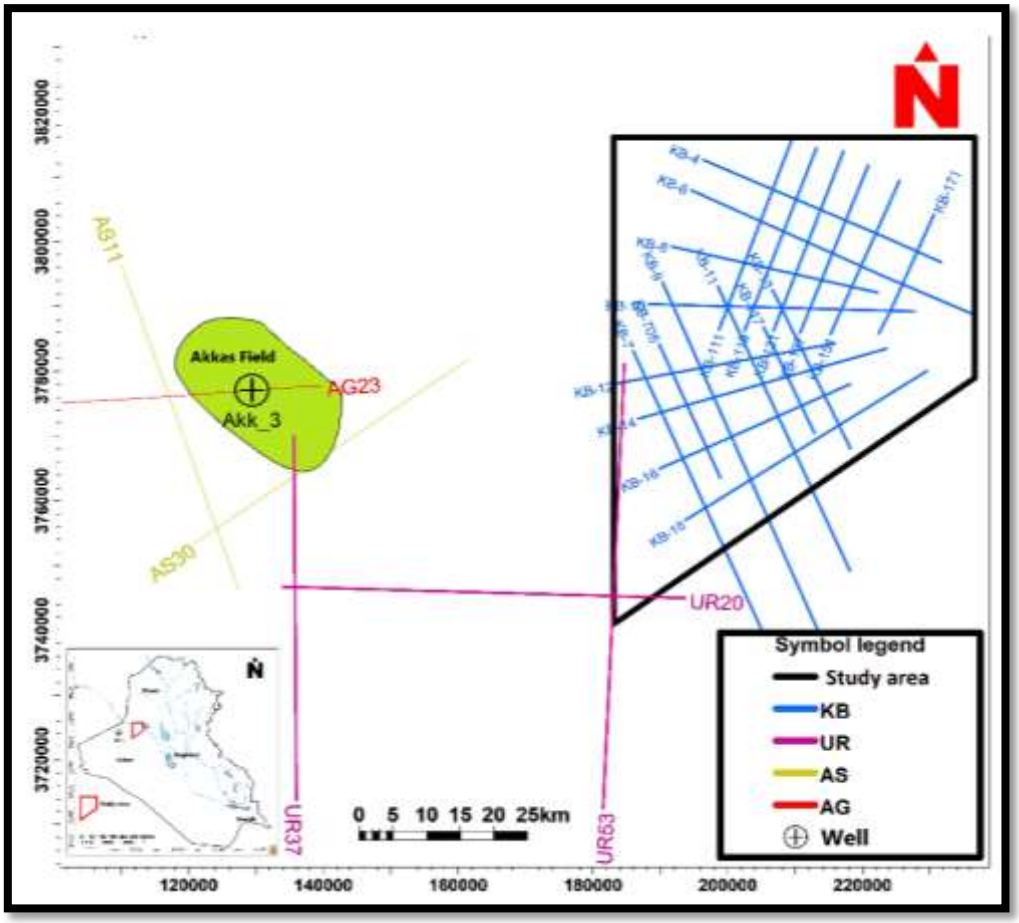

Figure 3- The type section of Akkas Formation (left), showing the Hot_shale beds, and the type section of Khabour Formation (right), showing the sweet gas/condensate accumulation in the Akkas-1 well [11].

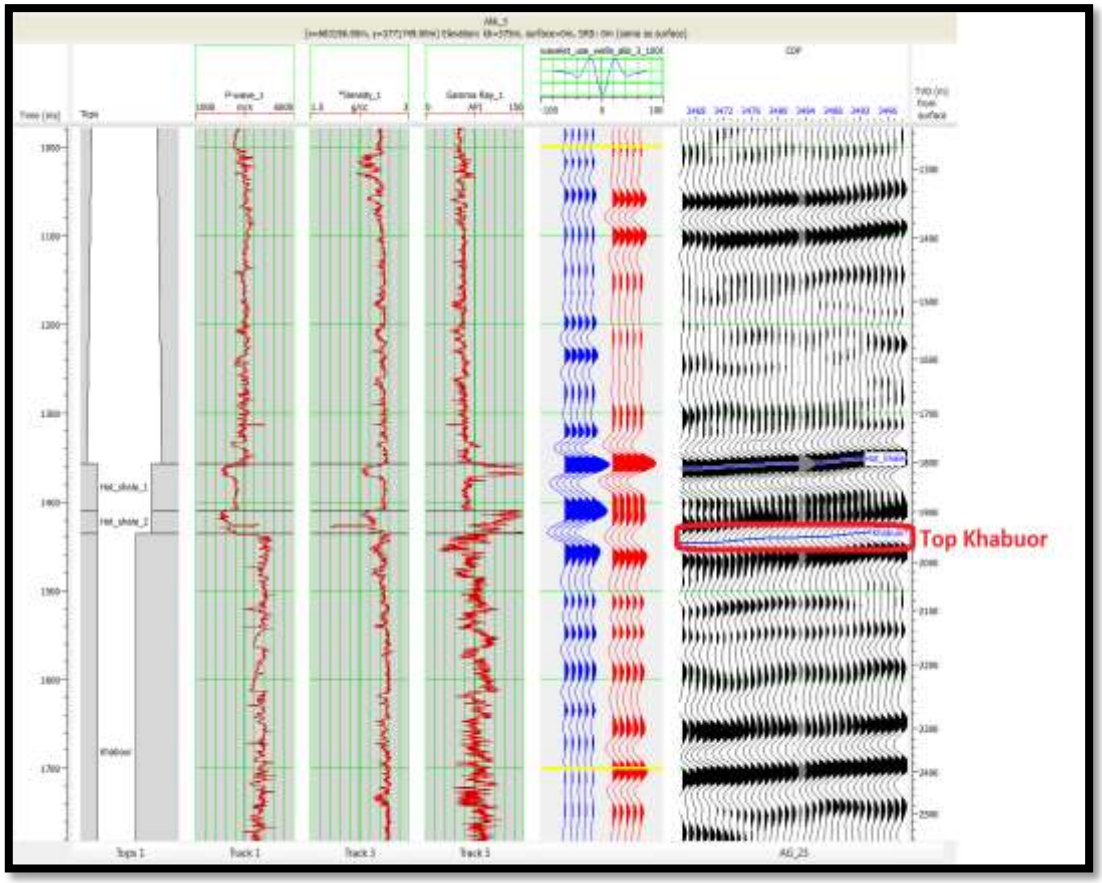

Figure 4- The base map of the study area, showing the seismic lines of the study area and location of Akk_3 well.

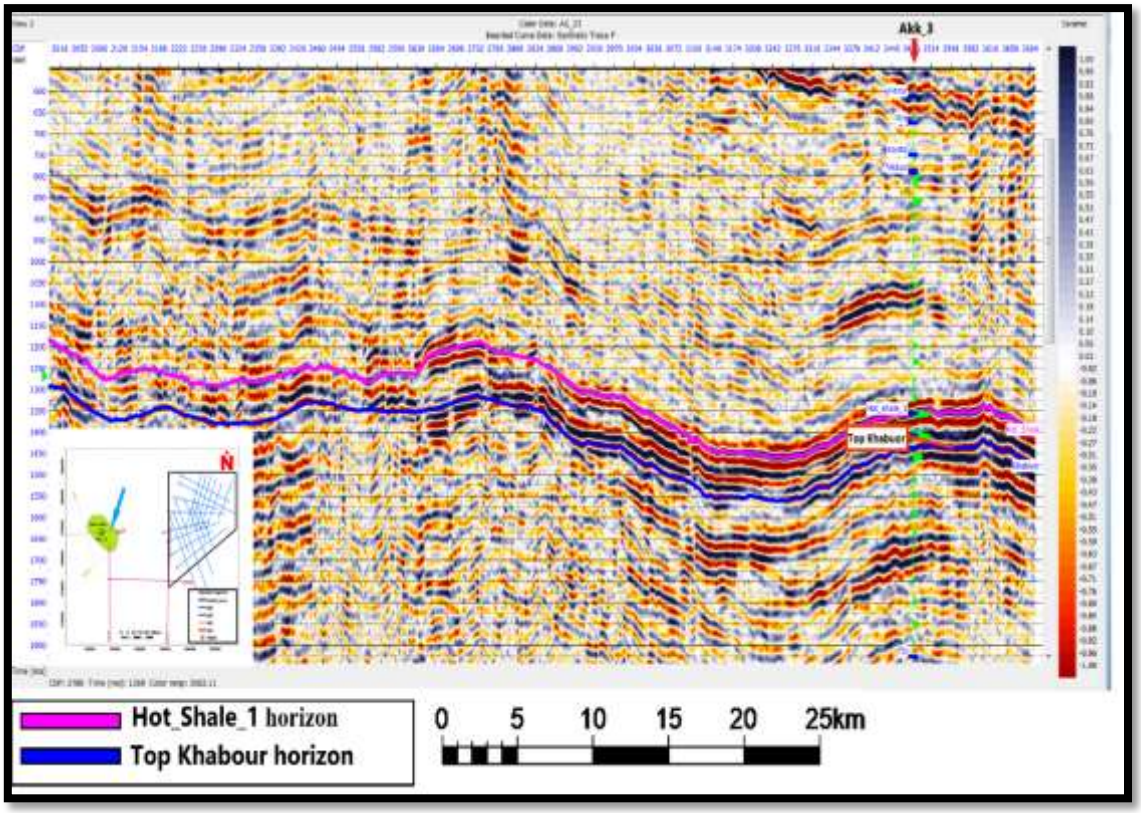

Figure 5- Synthetic seismogram of Akk_3 well which shows a good tie with seismic data.

Results and discussion

After the definition of the reflectors by synthetic seismogram of Akk_3 well on the seismic section AG23, the Base Akkas/Top Khabour reflector was picked and followed in all seismic lines of the study area. This was performed to prepare the structural time map which will be converted later to a structural depth map by using the velocity model of this reflector. The specifications of the seismic signal and the continuity of the reflectors are intermediate to acceptable in terms of the stability of frequency and amplitude, while there are changes in the reflectivity. Three types of seismic attributes (structural smoothing, trace AGC (iterative), median filter) were applied to the seismic line to enhance the continuity of the picked reflectors and increase the signal-to-noise ratio. The structural interpretations of the 2D seismic reflection data are presented in figures 7, 8, and 9. The fault analysis was carried out in the sets of seismic liens that include KB (4, 6, 8, 10, 12); because the quality of the seismic sections ranged from acceptable to intermediate, we selected the clearest seismic sections to detect and pick the faults. These seismic sections show that the study area is affected by three transversal faults. Generally, the faults have NE-SW trends, as shown in Figure 7. Several small mine faults are found in the studied seismic sections, but the three mentioned faults are the main faults that affected the study area, from the surface to all reflectors beneath it. The depth structural map of Base Akkas/Top Khabour reflector was generated from the time structural map, with the aid of the velocity map obtained from the velocity model. The analysis of the depth structural map shows that the depth increases in the south-east direction and decreases toward the north-west and south-west directions within the study area. The depth map (Figure 8, lower) shows that the contours have perfect closure in the northwestern and southwestern sides of the study area, which highly implies the existence of reservoirs. The first structure or closure is Tulul, teremd as (A), located in the northwestern part of the area (3300 m). The second structure, termed as (B), is located at the southwestern part of the area and extends out the study area. The general direction of the anticline structures is to the E-W. The average velocity map (Figure 9, left) was prepared with contour intervals of 25 m/s. It shows that the velocity value increases toward the east and decreases toward the northwest and southwest of the study area. While figure 9 (right) represents the isopach map and shows that the thickness values range between 2900 and 3900 m. It is noted that there is an increase of thickness towards the southwestern part of the study area, reaching about 3900 m. The map was prepared with a contour interval of 25 m.

The structural interpretation of the 2D seismic reflection survey of the Khan Al-Baghdadi area showed the presence of two traps for hydrocarbon accumulation within the sandstone reservoir of the Ordovician Khabour Formation. In the study area, the source and seal rocks form the the Silurian Akkas Hot_shale, while the Ordovician Khabour sands form the primary reservoir. They are interpreted to be present throughout Akkas Field, as gas/condensate accumulation located at 100 km to the west of the study area, demonstrating the viability of the Paleozoic petroleum system in the Western Desert of Iraq.

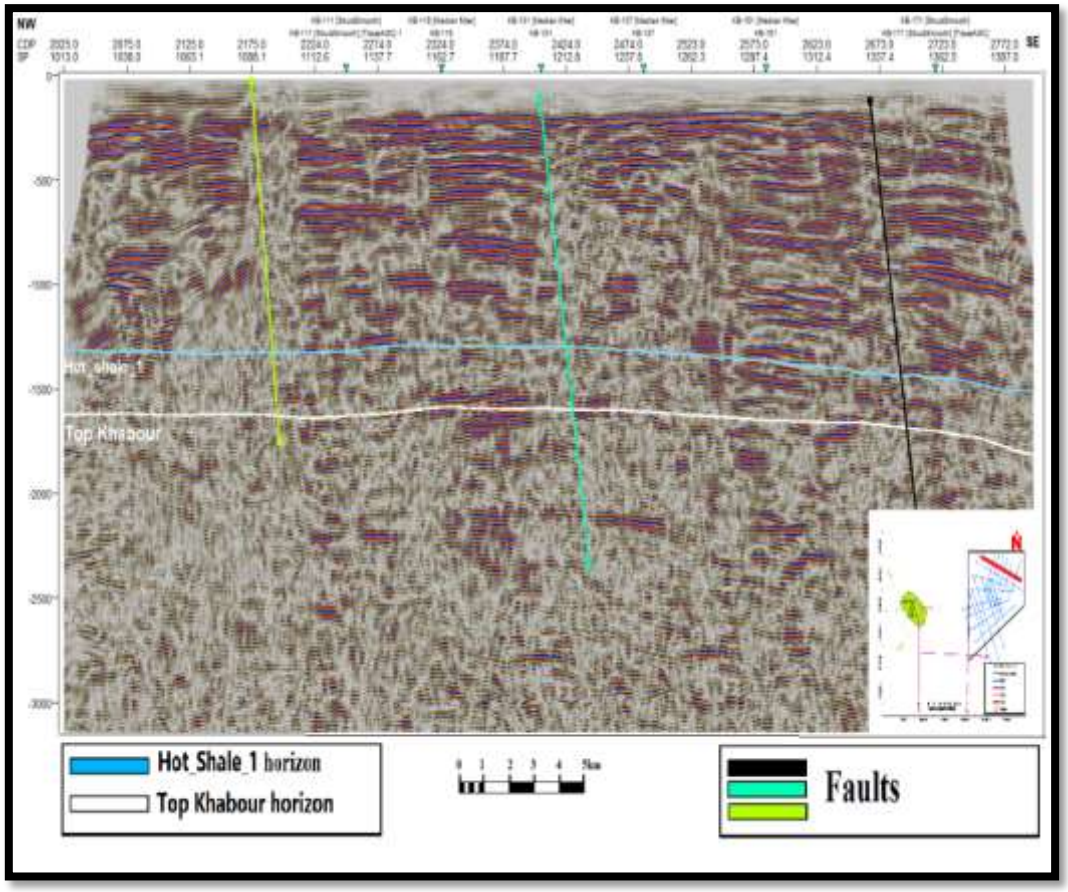

Figure 6- Seismic Ag23 sections passing through the Akk_3 well. Locations and synthetic traces of reflectors are displayed. The matching between the seismic and synthetic traces is shown.

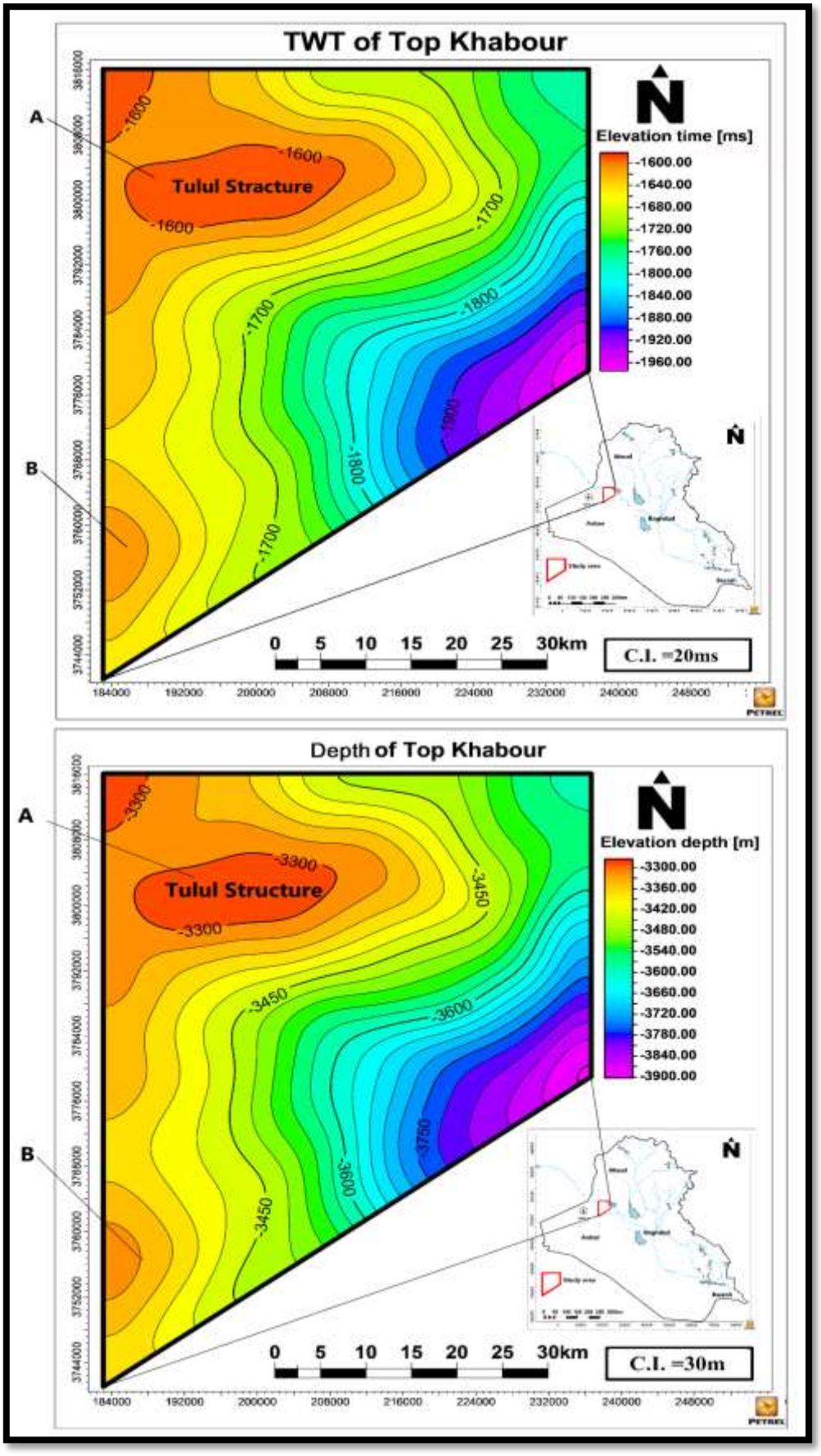

Figure 7- Three picked faults and seismic horizons on seismic section KB4.

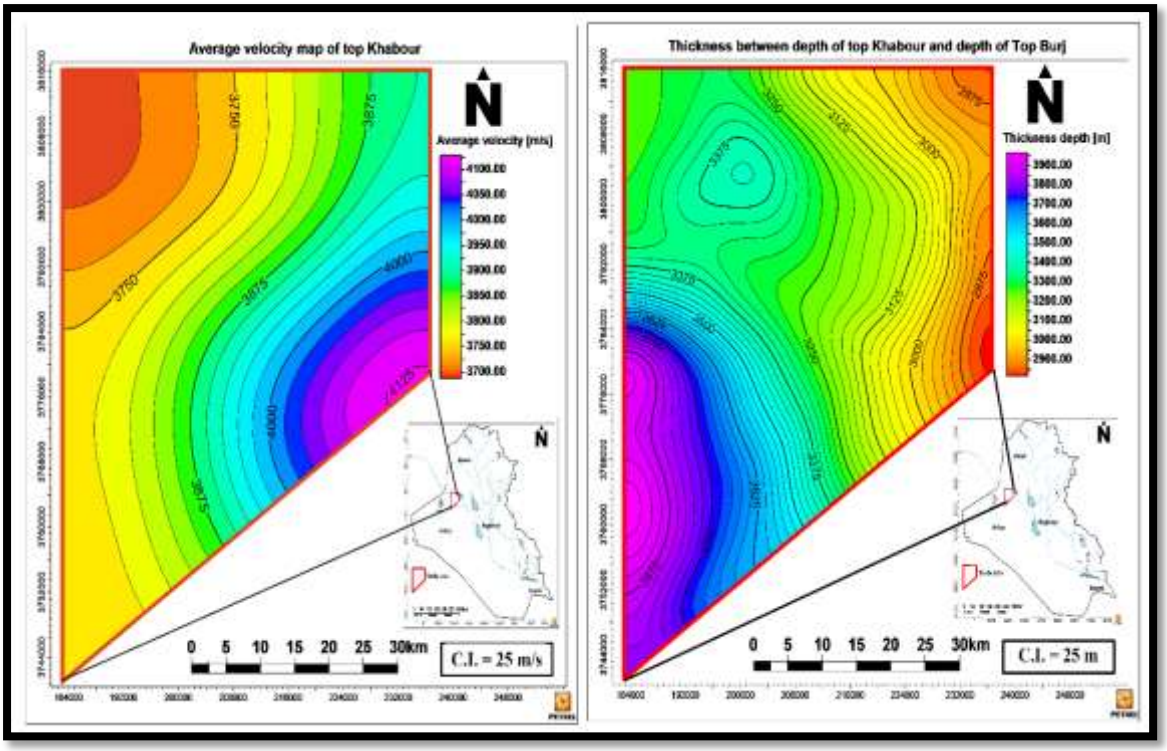

Figure 8- Structural map with an identified prospect hydrocarbon closure for Base Akkas/Top Khabour reflector; time map (upper) and depth map (lower).

Figure 9- The average velocity map (left) and the isopach map (right) for Base Akkas/Top Khabour reflector.

Conclusions

In this study, the hydrocarbon-bearing reservoir of Ordovician Khabour Formation in the Khan Al-Baghdadi area was delineated and mapped from 2D seismic lines and well logs data. Base Akkas/Top Khabour reflector was identified on the seismic section as a trough. The structural interpretation showed that there are two antithetic structures; these are Tulul structure (A) at a depth of 3300 m and the structure (B) at a depth of 3360 m. These two structures are responsible for hydrocarbon entrapment in the study area. Generally, the trending of the two structural features is toward the eastwest and the thickness of the reflectors increases toward the southwestern side of the study area. Furthermore, the structural interpretation showed that the study area was affected by three transversal faults, which have NE-SW trends. Hydrocarbon prospect areas were delineated in the depth structured maps (A, B). Finally, the information obtained from the structural seismic interpretation resulted in more understanding of the structures and hydrocarbon potentials of Khan Al-Baghdadi area in the western desert.

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