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Exploratory Seismic Geophysical Study of the Khanuqah Structure Area

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Abstract

Khanuqah structure area carried as the geophysics exploration study of Jeribe Formation target, the area located in the north of Iraq within Salah Aldeen Governorate, has been used geophysical data represented by 2D seismic lines were executed as exploratory surveys of 27 seismic lines, the data interpretations used by Petrel software (version 2018) based on the required aims, which are determined to achieve an update the structural model in Jeribe Fn. as a gas reservoir.

The results show the Khanaqah structure includes five domes, the general direction of the structure axis is northwest-southeast, a gradient of its slope from the northwest structurally higher to the southwestern part structurally lower, the southeastern part of the study area is an open basin that increases the level of depth lines relative to the mentioned part.

Seismic sections showed at the locations of structural domes the phenomenon of inter-spacing of seismic reflectors as tuning phenomena in reservoirs within Jeribe Fn. reservoir which is a direct index of the gas presence. To ensure tracking of extensions phenomena as a director for a gas presence, the seismic interpretations used a new technique by convert 2D seismic lines to 3D seismic cube through the reflections specifications publication of the khanaqah area, that shows the concerning of gaseous presence in the Khanaouqa-1 well and its disappearance in the Khanaouqa-2 well, it indicates the relationship between the location of the two wells at the structure, since Khanaouqa-1 well is structurally shallower than the Khanaouqa-2 well, which means that the well of Khanaouqa-2 is outside the scope of the gas patch, this was confirmed by the 3D seismic cube derived that showed the phenomenon presence on the site of Khanoqa-1 and did not appear in Khanoqa-2.

Due to the importance of developing the Khanuqah structure as a worthy gas field, the research recommended drilling an exploratory well at the location of dome- B, whose coordinated in the study area penetrating the Euphrates Fn. bearing in mind that Khanuqa-1 did not locate on the center site of the domes nor on the center site of the direct phenomenon as evidence of the gas existence.

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Keywords: Khanaqah, Echos, Surveys, Dome- B, Tuning.

1. Introduction

The study area located in the north of Baiji district by distance (45)km within Salah al-Din governorate and on the administrative borders of the Kirkuk governorate in northern Iraq, the city of Tikrit is a distance (78)km to the south, the city of Kirkuk is a distance of (98)km to the east, the Tigris River passes along the middle of the study area. The Lower Zab River passes into the southeastern part of the region; the western side of the area is aligned with the international traffic line and the railway as shown in Figure (1). The area is characterized by rugged terrain, where the topographical elevation ranges between (360)m at the highest Khanouqa structure to (120)m at the eastern side of the structure that is adjacent to the Tigris River [1].

The Khanuqah structure was discovered in northern Iraq in the 1920s based on surface topography maps and from the results of drilling two exploration wells (Ku-1 and Ku-2) within the early Tertiary period in 1929 by Mosul Oil Company (MPC) [2], the study area was covered by reconnaissance seismic surveys in 1960 that was carried out by the Iraqi National Oil Company, and then in 1981, the seismic survey was carried out by the National Oil Company (INOC) based on a development plan from the North Oil Company, which included the survey of the Makhoul program. The results of previous seismic surveys interpretations gave the dimensions, depths, and shape of the subsurface structures and the distribution of faults systems, where the structure was shown at the Jeribi Formation with dimensions (25)km in length and (2.5)km in width within a longitudinal closure of (125)m in a northwest-southeast direction, The previous studies interpreted Khanuqah structure by manual picking the seismic reflectors and maps drawing, as mention below:

1. Seismic survey interpretations study of the western Tikrit in year 1960, Figure (2), [3].
2. Seismic survey interpretations study in the regions of western Tikrit and Makhoul Khanuqa, year/ 1986, Figure (3), [4].
3. Interpretation study of the evaluation seismic survey for the western region of Tikrit

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in year 1990, Figure (4), [5].

The current research used the new processing of the previous seismic records and interpretation the seismic reflectors with maps export by using new technique software ەn order to achieve the following objectives:

1. Updating the structural shape of the Khanuqah area within the required reservoir formation levels.
2. Interpret the reservoir ambiguity for the gas present between the two Khanaqa wells.
3. Determining the location of drilling exploratory or appraisal wells for the reservoir levels.

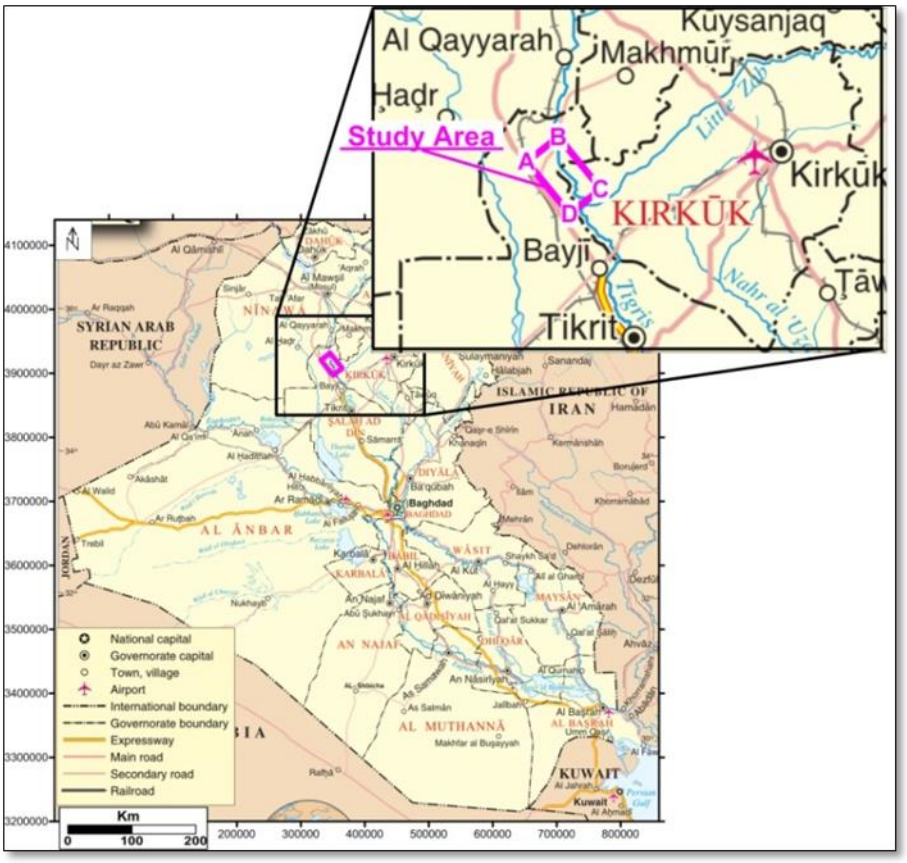

Fig. (1) Study area location [1]

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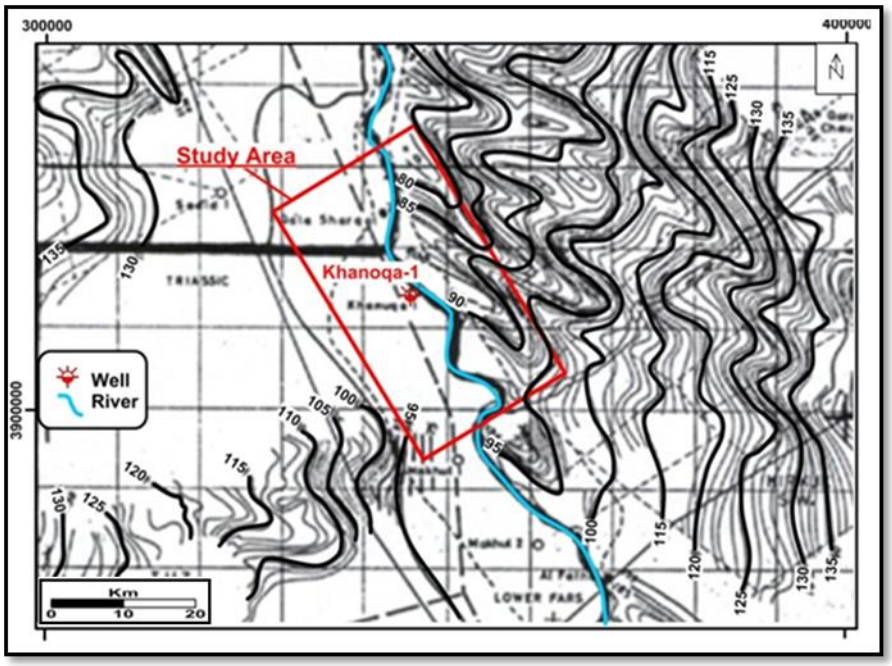

Fig. (2) Structural map in depth domain from the study results in year 1960 [3]

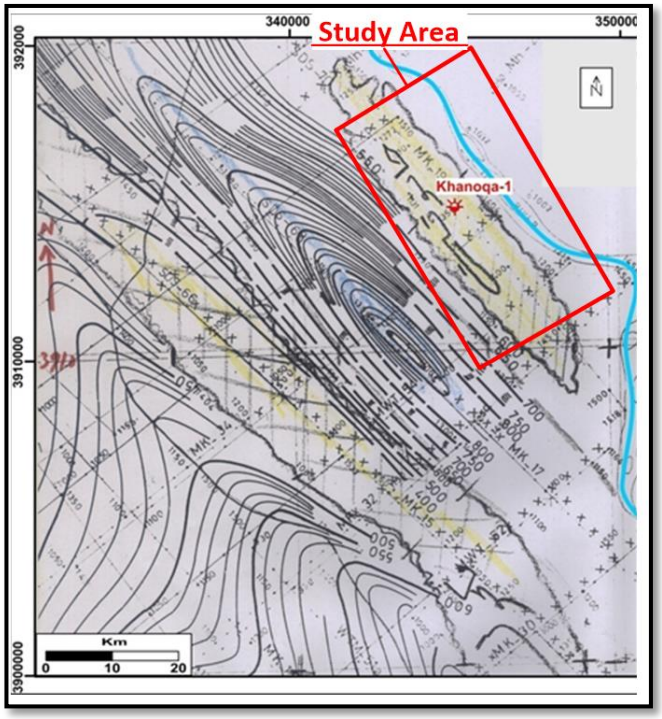

Fig. (3) Structural map in depth domain from the study results in year 1986 [4]

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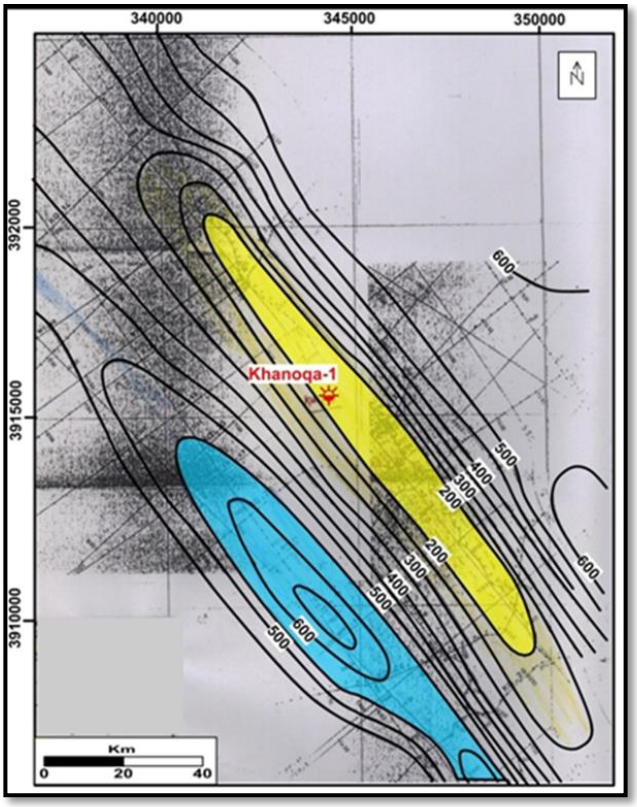

Fig. (4) Structural map in depth domain from the study results in year 1990 [5]

1. 1 Sub-Surface Geology and basin developments

The well drilling results of Khanuqa wells (Ku-1, Ku-2) and extrapolation study from surrounding areas which represented by Sidid well (Sd-1) northwest and Makhoul wells (Mk-1, Mk-2) southeast of the region and from the analysis of regional geological data, it is clear that the formations of the Upper Jurassic and the Early Cretaceous period is attenuation at the north side of the study area and lead to a great stratigraphic break, as for the Late Cretaceous and the Tertiary period's formations, they were deposited generally by a marine sedimentary system, except for the Upper Fars and Bakhtiari formations, which represent coastal or river movable rocks as shown in Figure (5) [6].

Through a comprehensive study of the region [7], [8], the researchers list the stages of the geological development of the region as follows:

1- The area was covered by a deep-sea during the early Maastrichtian era, where the clay components belonging to the Shiranesh Fn. appear in the southern fold of the Qara Jok structure, and the Kirkuk (K- 119, K- 116) wells were deposited, and that in the valley of Iskand there is no trace of the Aliji Fn. layers, and that Shiranish Fn. is

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followed by the layers of Jadalah Fn.

2- The area was affected either by a regional uplift accompanied by erosion processes during the late Maastrichtian era until the end of the early Eocene age, or a rapid uplift and a rapid decline, which is explained by the absence of sediments of the Pliocene and early Eocene ages, It is assumed that the entire region was subjected to severe depression during the middle-late Eocene age, where the deposits of shallow marine formations such as limestone deposits can be considered to Avanah Fn.

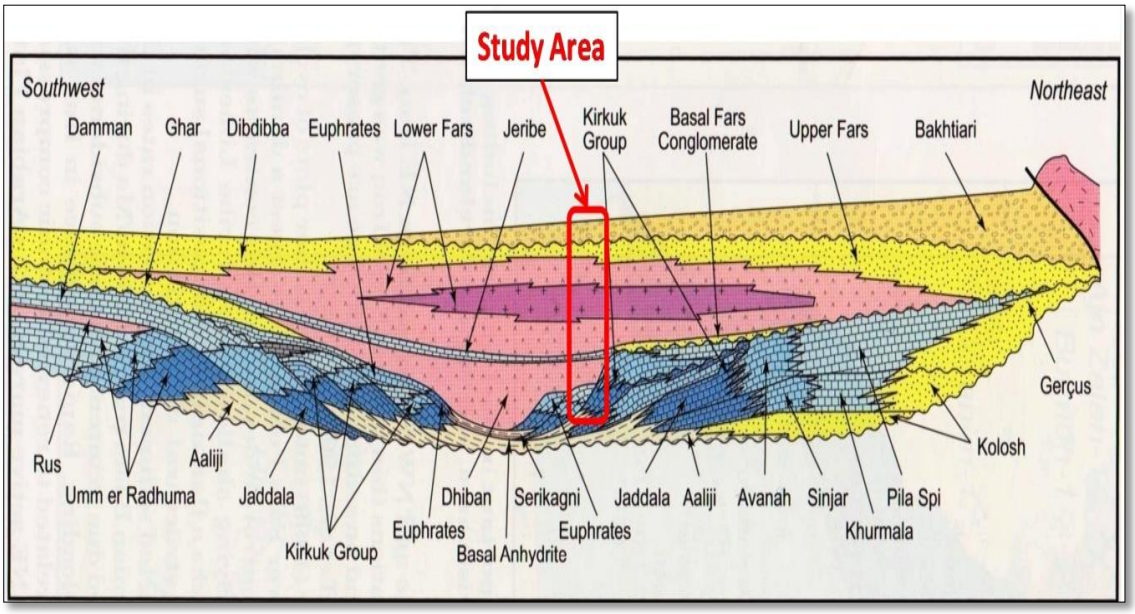

Fig. (5): Stratigraphy basin architectural in Tertiary era passing at the study area [8]

1. 2 Fold and Fault Systems

Study area located next to the sedimentary basin of Mesopotamia, and the results of seismic surveys indicate the presence of major faults in the NW-SE direction, these faults result primarily from the possibility of the region being affected by the alpine tectonic movement and during the Upper Miocene-Pleistocene period. It is noted that the direction of most structural axes is in the same direction (NW-SE), Khanuqah structure is considered one of the largest folds of the second-order (with a wavelength of less than (3)km and more than (200)m, with a length of about (30)km and a width of (3.5)km, and it extends in the same general direction, the structure is asymmetrical, as the slope of its north-eastern side ranges from (10-25)degrees and the slope of the south-western side ranges (30-60)degrees, [5].

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According to the tectonic division of Buday and Jassim, 1984 [9], as well as Al-Khadhimi et al., 1996 [10], the study area is located in the unstable zone within low folds sub-zone on the Hamrin- Makhoul belt, the surface folds are limited in an NW-SE direction and are affected by undefined faults neither in the sedimentary cover nor the crystalline basement.

The tectonic division of Jassim and Goff, 2006 [11], shows the study area is located within the Deir Al-Zor-Erbil block, on the western side; the Pre-Cambrian Rift system extends from the Nejd Rift, from the southeast side; the transverse fault system of Anah-Qalat Dizeh extends within the Cambrian era, Figure (6).

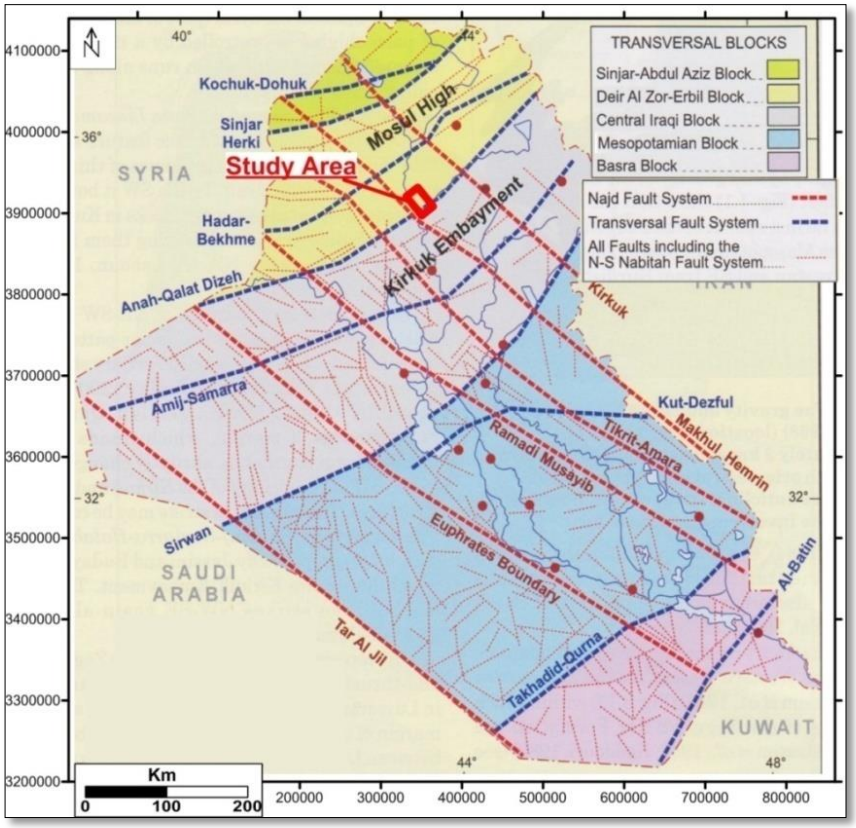

Fig. (6): Tectonic division of study area [11]

2. Material and Methods

This research used the geophysical data interpretation represented by the implemented 2D seismic lines as exploration and detailed surveys, which numbered (27) seismic lines as shown in covered the structure area. The data of the neighboring wells was relied upon due to the lack of wells velocity survey in Khanuqah wells, as the identification was made from Makhmour well (Mm-1), which contains velocity survey

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recordings and through which was identification the seismic reflectors represented the Lower Fars, Jeribe and Euphrates formations.

The seismic lines were re-processed to post-stack migration by Echos software [12] in the Processing Department/ Iraq OEC. The seismic interpretation works were applied by Petrel software [13] starting from the project construction and data loading to the structural maps output processes, as follows:

- Wells data loading included Formations tops and well velocity survey, which are two wells were drilled in year/1929 according to structure surface show and pierced the formations of the Lower Fars, Jeribe and Euphrates.
- Seismic lines loading as SEGY format in time domain a reference level (300) m above sea level.
- Unifying the time arrival record differences between seismic lines intersections due to the diversity of seismic surveys parameters differences of each seismic survey, where the time differences were eliminated during the full by using bulk shift of the seismic section in the vertical field to the extent of matching with the seismic lines defined from the wells.
- Definition of seismic reflectors and tracking (Picking) that represent each of the formations (Lower Faris, Jeribi, and the Euphrates), Figure (7).
- Study and trace the faults systems and their directions to the study area.
- Gridding the structural maps in time domain as a cell (250) m^2 for each seismic horizon picked and the direction angle (Azimuth) is (55°), which was determined on the basis of the regional orientation of the structures and the general sedimentary basin.
- Calculated the formations velocity from wells velocity survey, structural maps in time domain surfaces, and extracting the best relation between time and depth, thus the output of velocity distribution in three dimensions of the study area, Figure (8).
- Gridding the structural maps in depth domain as a cell (250) m^2 extracting from the 3D velocity model and extracting thickness maps by preparing a 3D structural model that is qualified for volumetric calculations, from which the thickness and distribution of the mentioned formations were calculated.
- Applying Seismic attributes at some seismic sections for enhancement of the quality and continuity to the reflector, continuity and determined the direct hydrocarbon

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indicator.

- Converting (2D) seismic data to (3D) seismic cube by the publication of reflective specifications.

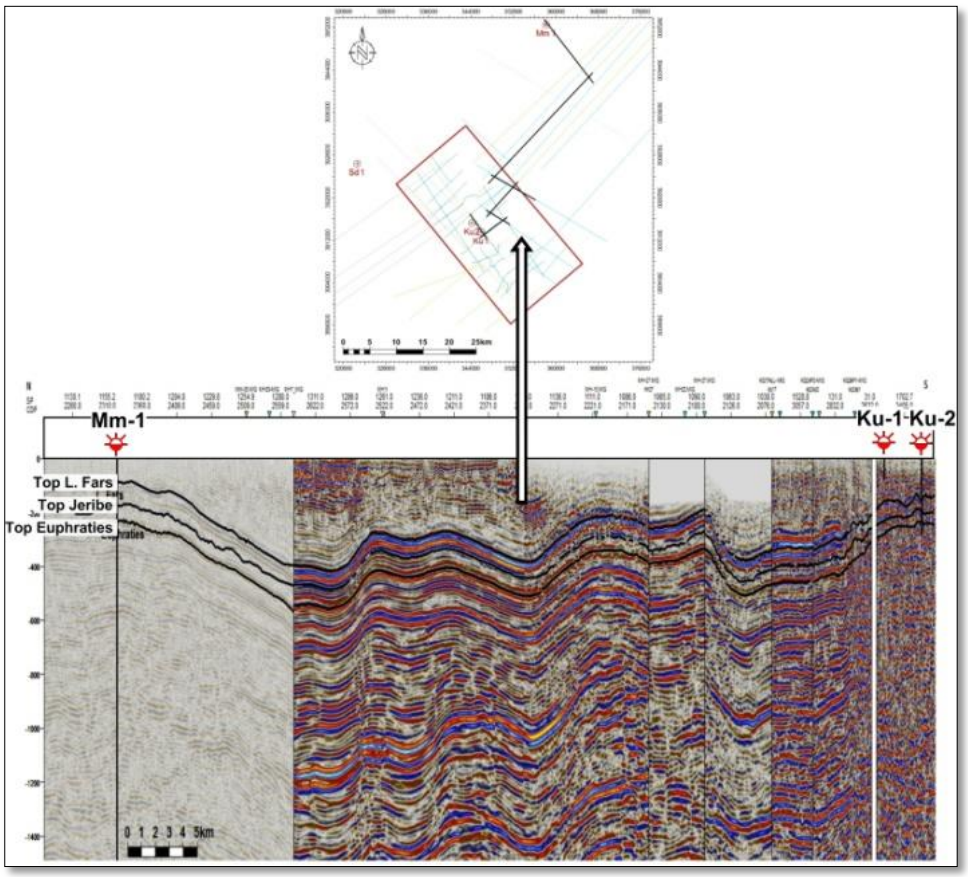

Fig. (7): Definition of seismic reflectors by the tie line to Makhmour- 1 well

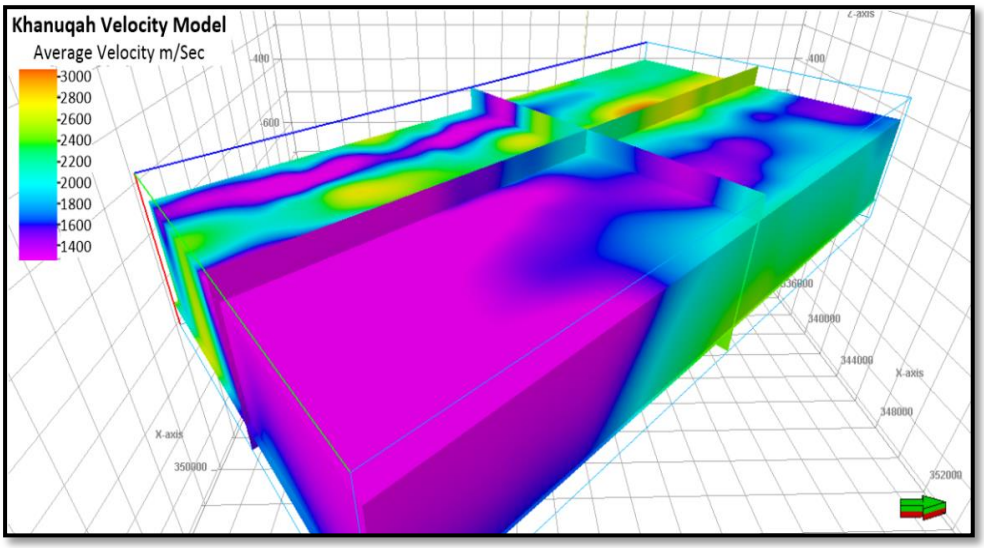

Fig. (8): Velocity distribution in three dimensions in the study area

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3. Results

Both structural maps in time and depth domain is the same shape, because the velocity distribution obtained gentle contrast in lateral and vertical vectors, that showed Khanuqah structure is a large enclosure includes small domes (5 domes) and the direction of the structure axis are NW-SE, the dimensions and structural closures amount shown in Figure (9), Table (1).

The location of the Khanuqah wells (Ku-1 and Ku-2) shows that outside the aforementioned structural closures, the study area was affected by two main fault systems, the first system towards NW-SE and the second toward NE-SW.

Thickness distribution map for the Jeribe Fn. showed the decrease in thickness on the slopes of Khanuqah structure and its increase gradually toward the structure. It is noted that the thickness of the eastern side is higher than the western side, Figure (10).

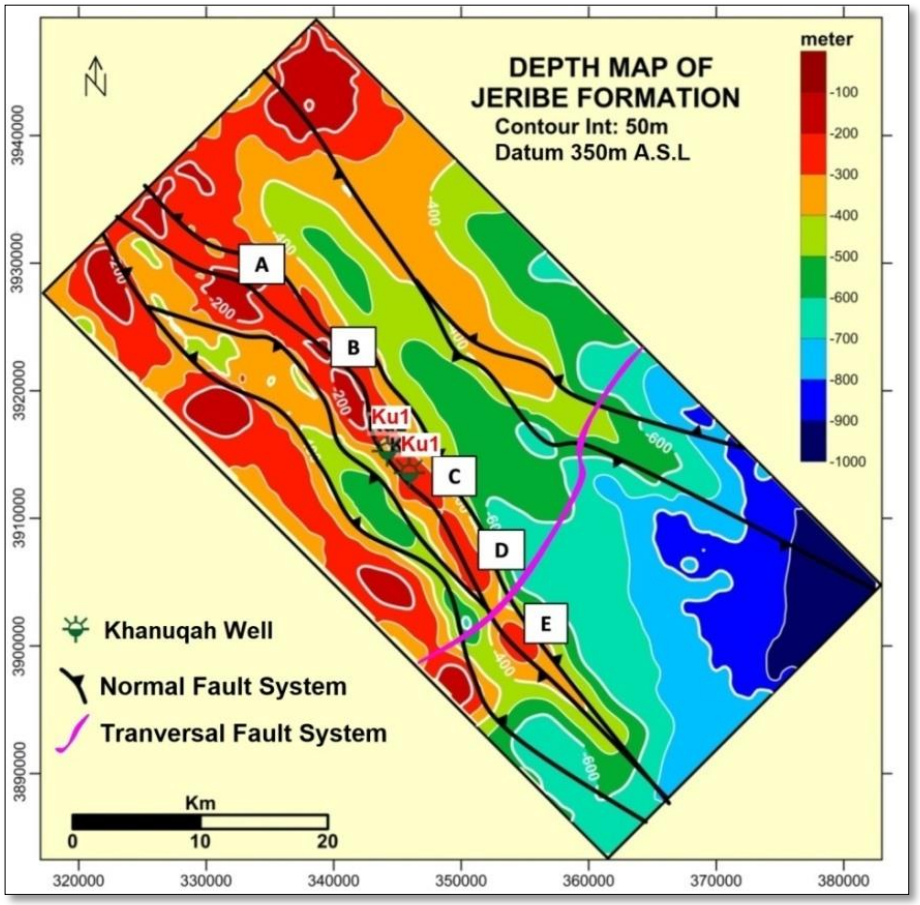

Fig. (9): Jeribe Fn. Depth map shows the structural domes, faults systems, and the Khanqah wells (Ku1, Ku2) located out of the area of the dome

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Table (1) Dimensions and amount of domes closures in Khanuqah structure formations

Formation	Closure Id.	Length (Km)	Width (Km)	Closure (m)
L. Fars	A	5	4.5	35
	B	10	2.5	25
	C	5	1.5	15
	D	6	1.5	20
	E	7.5	3.5	45
Jeribe	A	5.5	4.5	60
	B	8	2	45
	C	5.5	2.5	65
	D	6	2	60
	E	8	3	145
Euphraties	A	4.5	3	30
	B	7.5	2	30
	C	5	2.5	50
	D	6	2	65
	E	9	3.5	145

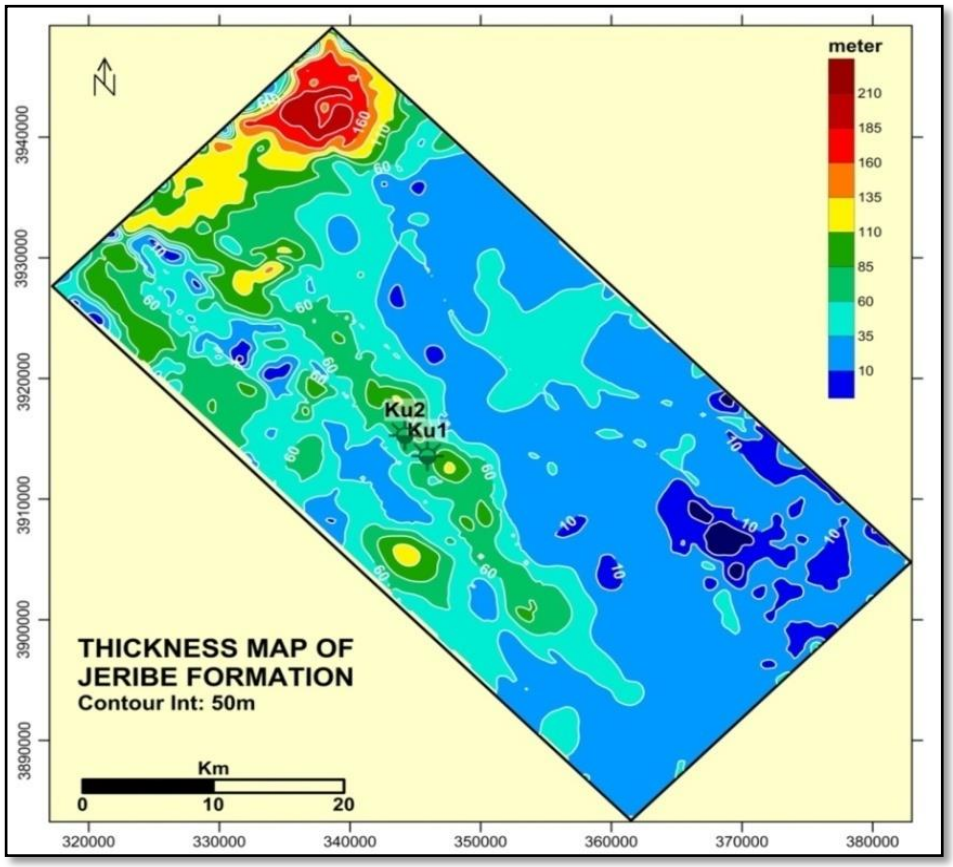

Fig. (10): Jeribe Fn. Isopach map shows thickness increase to the north-western parts, while decrease to the south-eastern

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Direct indications of hydrocarbons appearing on seismic profiles are a feature that gives clues to their presence and is particularly useful in reducing the risks associated with exploratory drilling, the most important indicator of hydrocarbons presence in Khanuqah structure area is the phenomenon of the inter-divergence of seismic reflectors at the sites of structural domes, as this phenomenon is called (tuning phenomena in reservoirs), in which the amplitude of the wave is in the same time level and then the time range varies in a distinctive way between two successive reflectors, one of which is in contact with oil and gas and the deeper one when in contact with water [14], as shown in Figures (11) and (12).

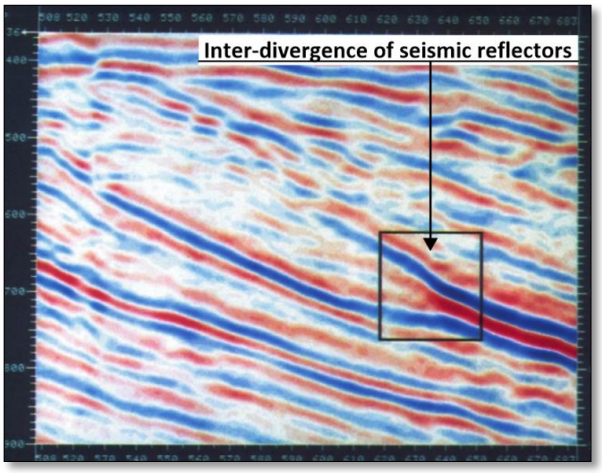

Fig. (11) The direct hydrocarbon indicator (DHI) shows the tuning phenomena in reservoirs behavior by the inter-divergence of seismic reflectors [14]

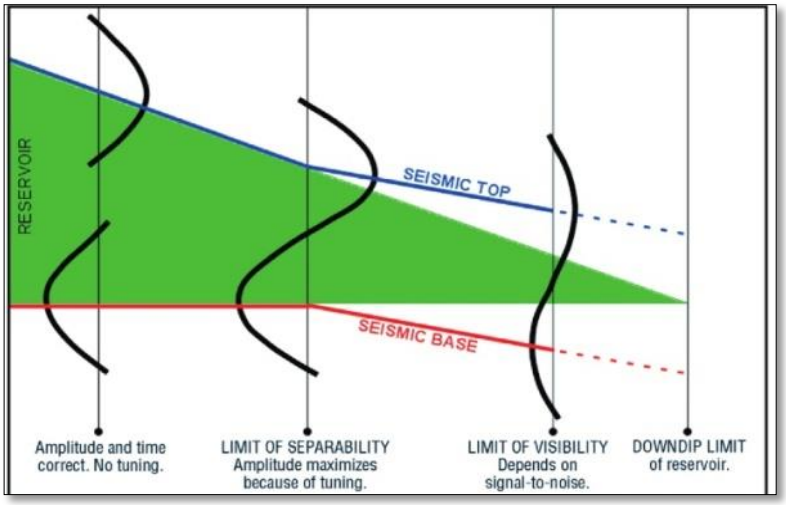

Fig. (12) The behavior of amplitude and time at the zero phase reflectors within the reservoir due to fluid effective [14]

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The seismic sections showed the tuning phenomena in reservoirs at the Jeribi Fn. reservoir, was applied the seismic attribute of the instantaneous phase change, which shows the extension of this phenomenon on the section of the seismic line (Kq-20) despite the presence of a gap on the mid of seismic sections due to the lack of the recording coverage, as the phenomenon extends by about (4) km in length as shown in (Fig. 13), is also evident on the parallel seismic line (Kq-18) intermittently due to the deterioration of seismic reflectors quality, which extends about (3) km in length.

To confirm the tracing of the inter-diversity phenomenon of the aforementioned seismic reflectors, the seismic 2D lines data were converted to the 3D cube by the publication of the reflective specifications using the Petrel software within an applied process (Workflow), which requires creating a model with homogeneous physical properties (Anisotropic) **[15]**, prepared to spread seismic reflectors in three directions (X, Y, Z) after cropping within a unified time domain of the 2D seismic lines, in which the lines of the study area were cropped between (50 - 1000) mSec as it is a limitation to the Jeribe Fn. reservoir, and then designing an area for a 3D seismic area with specific controls for the numbering and dimensions of the (In-Line, X-Line) interspaces, which resulted in the transfer of the mentioned model that contains the seismic reflective properties to the seismic (3D) cube formatted, as shown in (Fig. 14), (Fig. 15).

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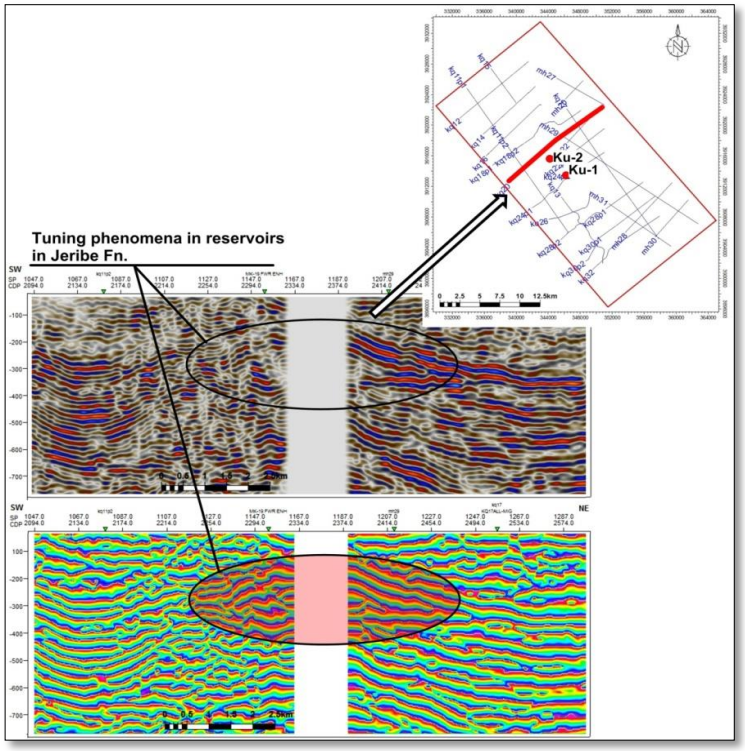

Fig. (13): Tuning phenomena in reservoirs at the seismic section Kq-20 converting to the instantaneous phase, which indicates direct detection of the hydrocarbon presence

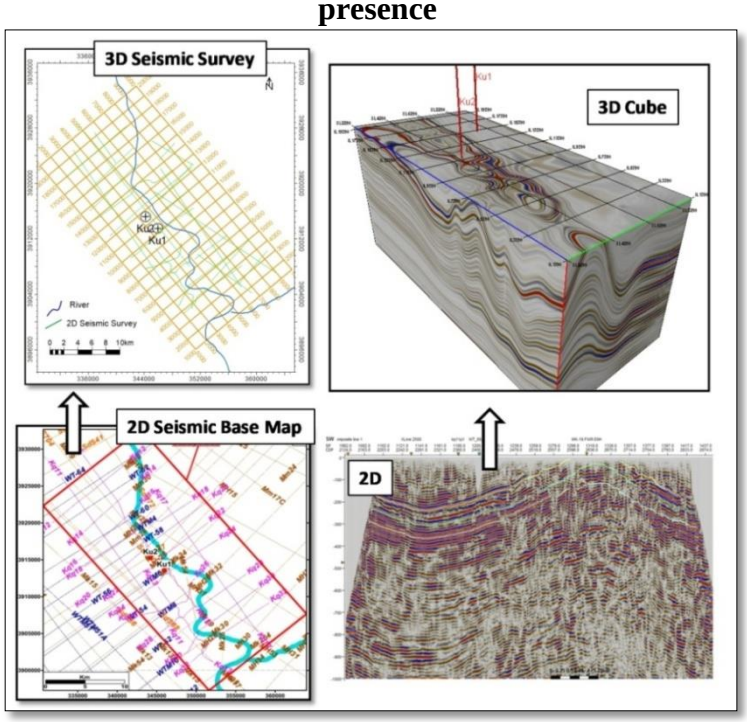

Fig. (14): Inferred 3D seismic cube from 2D seismic lines through the publication of the reflective specifications

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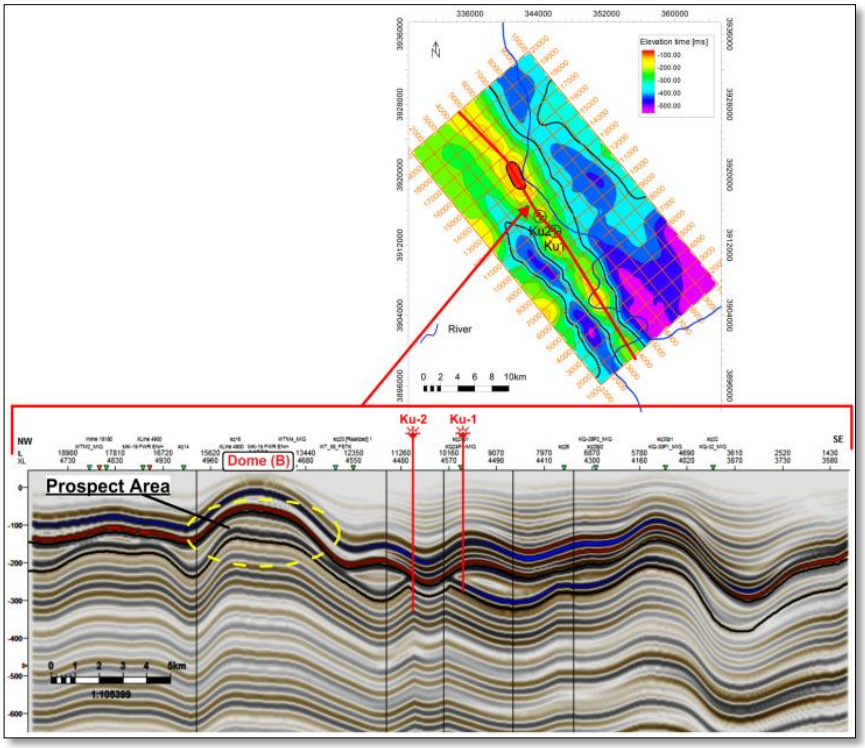

Fig. (15) Seismic arbitrary line from the inferred 3D seismic cube passing through Khanuqah wells (Ku1, Ku2) by the direction NW-SE, shows the tuning phenomena in reservoirs which can be seen in larger extension at the dome site (B) where located NW of Khanuqah wells.

4. Discussion

The results of seismic interpretations in all structural maps showed that the Khanuqah structure is located on an anticline structural axis in the direction of its NW-SW axis, which is formed by the influence of the lifting alpine movement at the end of the Mediterranean era. The NW side is structurally higher than the SW side; the inclination degree of the layers is higher at the SW side than the NE side due to the sum of the tectonic forces driving from the SW side.

The image of depth maps did not differ in general from its image in the time domain due to the somewhat homogeneity of the velocity used, the difference was only revealed by the increase in the structural closures at the depth domain.

The Khanuqah structure appeared generally at the Formations level of lower Fars, Jeribe and the Euphrates in the form of a fold with five relatively small closures, affected by four normal faults in the direction of NW-SE, with the influence of the transverse fault system towards SW-NE, the southeastern part of Khanukah structure shows an open basin area, where the values of depth levels are increasing towards the aforementioned

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part.

As well the current interpretations of the study area showed a difference in the structural shape image than the previous interpretations, where the current interpretations showed that the structure consists of several domes, while the previous interpretations showed that the structure has one dome, Figure (16).

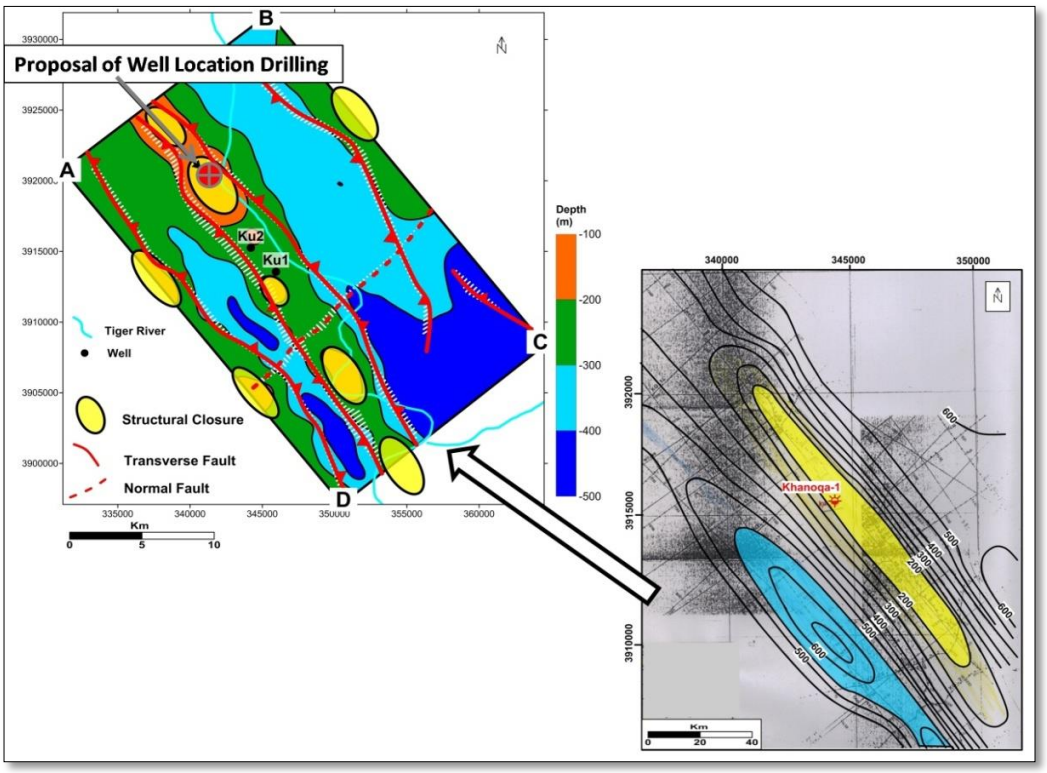

Fig. (16): Khanqah structural of Jeribe Formation shows the comparison between the current study results and the old study results in 1990 (Interpretation study of the evaluation seismic survey for the western region of Tikrit).

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5. Conclusions

1. The study area is structurally complex and was subjected to tectonic movements during the Cretaceous and Tertiary eras, which resulted from fault systems in different directions that led to the distortion of the structures, the fold axis of an irregular structure is observed as a result of the impact of the fault systems, which shows their effect in two main systems; the first one in the direction of the regional fault (Makhul - Himreen) and the second system is transversal faults in the direction of the regional fault (Anah - Qalaat Deiza).
2. With regard to the presence of gas in the Khanuqa-1 well and its disappearance in the Khanuqa-2 well, it indicates the relationship between the location of the two wells in terms of structure, as the Khanuqa-2 well is structurally lower than the Khanuqa-1 well, which means that the Khanuqa-2 well is outside the scope of the gas patch, which was confirmed by (3D) seismic cube deduced from (2D) seismic lines, that showed the inter-dispersion phenomenon of seismic reflectors as direct evidence for gas presence, as it appeared on the site of the Khanuqa well-1 more than the site of the Khanuqa-2 well.
3. Because of the importance of the reservoir exploration, the study recommends drilling an exploratory well at the dome site (B) penetrating the Euphrates formation, noting that the two sites drilled for the Khanuqah wells-1 and -2 were not located on the center of a structural phenomenon, as they were drilled before the seismic surveys.

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