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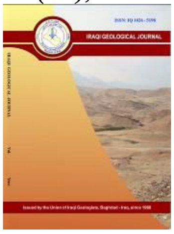

Structural Geometry Analysis of Khasib Formation in West Qurna I and II Supergiant Oilfields, Southern Iraq

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Abstract

The West Qurna I and II supergiant oilfields are one of the largest oil-producing fields, southern Iraq. They are parts of a supergiant anticline that extends more than 120 km. This anticline is oriented north-northwest and it's included the South Rumaila, North Rumaila, West Qurna I, and West Qurna II. The aim of this study is to integrate all available data to provide a better understanding of the subsurface structure for both West Qurna I and II. 3-D high-quality seismic data (in SEGY format) that executed for both oilfields independently were used as a key tool to supply perfect structural images. In addition to Zero-Offset Vertical Seismic Profile, set of well logs and well tops from 569 wells that distributed over the study area, 423 wells are located in West Qurna I, 146 wells situated in West Qurna II. OpenWorks, DecisionSpace G1 10ep and Seismic Analysis 10ep software of Halliburton were used to perform the 3D seismic interpretation and create structure maps (in-depth domain). While the cross-sections were done by Schlumberger software (Petrel 2018). Finally, the well tops were picked using Geolog 8.0. The study concludes that the structure of West Qurna I and II can be classified as an antiform, non-cylindrical, horizontal, gentle, brachy, asymmetrical anticline.

Keywords: West Qurna Oilfield; Structural analysis; Geometric analysis; Fold classification; Seismic interpretation

1.Introduction

The supergiant West Qurna I (WQI) and West Qurna II (WQII) oilfields are located in Mesopotamia hydrocarbon province (Abdullah et al., 2018). Within these oilfields, there are several hydrocarbon-bearing zones have been identified in the Cretaceous period. These are from oldest to youngest: Yamama, Zubair, Mauddud, Mishrif, Khasib, Sa'adi formations, and Yamama, Mauddud, Ahmedi, Mishrif, Khasib, Sa'adi formations in West Qurna I and West Qurna II respectively (Abdullah et al., 2018). Also, most of the oil production in the West Qurna I oilfield is from the Middle Cretaceous Mishrif reservoir and from the Early Cretaceous Zubair reservoir and minor oil production from Late Cretaceous Sa'adi reservoir while, In West Qurna II the oil production is only from Middle Cretaceous Mishrif reservoir. The first 2D seismic survey in West Qurna I & II was done in 1972 and the first well was not drilled until 1973 and then 12 exploration and appraisal wells were drilled starting from 1983 (Kunakbayeva and Gauder, 2019). Recently, high-quality 3D seismic surveys were executed in West

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Qurna I by Western Geco/Schlumberger while Terra Seis and Oil Exploration Company carried out the 3D seismic survey of West Qurna II. Numerous classifications of the folds could be used to define one specific fold (Al-Kubaisi and Ahmed, 2017). In this study, certain engineering parameters were used to perform the classification. The engineering parameters used in this study are the facing of the fold, fold orientation, fold tightness, the symmetry of the fold, and fold dimensions. (Fig. 1).

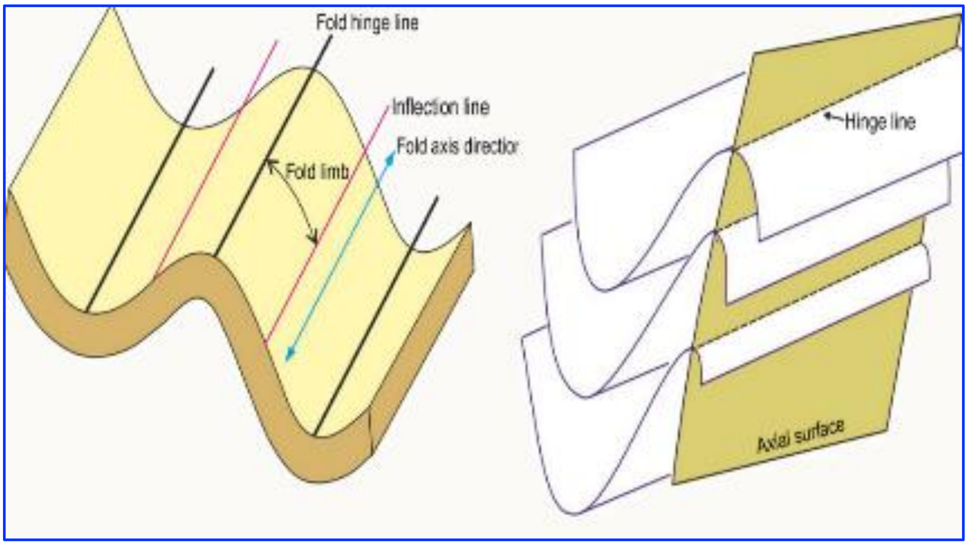

Fig. 1. The geometric parameters of a fold (Lisle, 2020)

The Khasib Formation of Late Cretaceous (Upper Turonian – Lower Coniacian) (Mohammed, 2018) in WQI and WQII has been a subject to very few studies because most studies in this area were focused only on the main reservoirs (Mishrif, Yamama and Zubair reservoirs). This study focuses on the Khasib Formation that was divided into the upper Khasib member and the lower Khasib member (Mohammed, 2018) and the main objective is to provide highly precise structure maps of the three reflectors (top of the Khasib Formation, top of the Lower Khasib, and top of the Mishrif Formation) in order to provide an accurate horizontal and vertical extension of WQI and WQII structure using all available and reliable data (well logs, well tops, 3D seismic surveys, check shot, and Vertical Seismic Profile (VSP)). In addition to analyze and classify the fold systems according to different geometric parameters.

2. Study Area

West Qurna I and II are situated in the southeast part of the Republic of Iraq in Mesopotamia hydrocarbon province. The WQI and WQII geographically located approximately 50 & 70 Km respectively northwest of the Basra City (Fig. 2). The surface area of WQI and WQII are 442 and 340 Km2 respectively. The study area was flooded with Al-Hamar marsh water where dams were constructed for the purpose of developing the fields. The area covers by alluvial deposits and modern clay materials (Dawd and Hussein, 1992). The Khasib Formation in the study area consists mainly of limestone at an average depth of 2200 meters (subsea) and the average formation thickness is approximately 70 meters. The Khasib Formation subdivided into two members which are upper Khasib and lower Khasib, a thin layer of shale separates them.

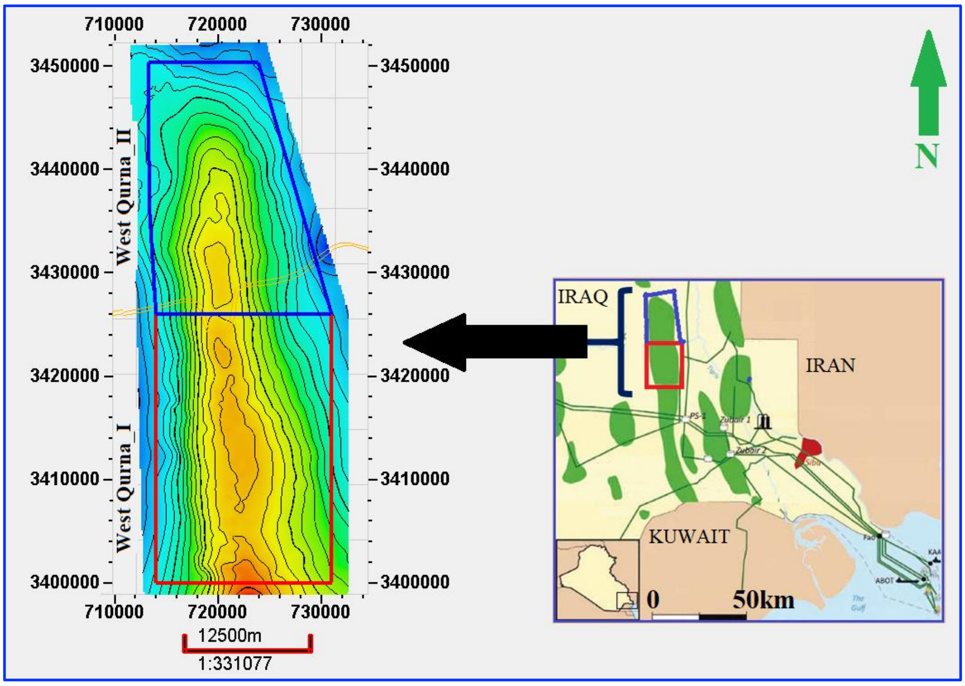

Fig. 2. Location map of study area and wells locations

3. Methodology

The three-dimensional structure maps of the top Khasib Formation, top of the Lower Khasib, and top of the Mishrif Formation were created based on 3D seismic interpretation with utilizing well tops according to the workflow illustrated in Fig. 3. The structure maps based on 3D seismic data were used for the purpose of studying geometry analysis of the WQI and WQII oilfields. Unfortunately, the 3D seismic survey was not conducted in the northwest region of the WQ1 and south region of WQII Due to the highly populated area (Medina city). The essential first step in seismic dataset interpretation is to establish the relationship between 3D seismic reflections and subsurface geology by comparing marker beds or any correlation points which are selected on well logs with main reflections on the seismic sections (Bacon, 2007). In order to achieve the aim of the work, a synthetic seismogram should be generated and try to make the best fit with actual seismic sections by correlating and matching the synthetic seismogram. The troughs and peaks of the synthetic generated from density and sonic logs ought to match similar characteristics of seismic data. The seismic well tie process was done using Halliburton software (Seismic Analysis 10ep software). The digitized well logs were recorded in-depth domain whereas the reprocessed 3D seismic data is in the time domain, therefore the acoustic impedance log must be converted from the log as a function of depth, into a log as a function of two-way travel time (TWT).

3.1. Seismic Well Tie (SWT)

This can be done if we know the time-depth (T–Z) relation for the well, which theoretically can be achieved by using the sonic log. However, some issues could arise. For example, errors resulting from miss calibration of the acoustic log, tend to be accumulated when the log is running over numerous thousands of meters (Bacon, 2007). Therefore, the acoustic log is generally calibrated with a time-depth relationship from VSP or check-shot before combining with the density log to produce acoustic impedance (Al-Ali, 2019). Finally, the synthetic seismogram is generated by convolving the reflection coefficients spikes using well log data with the wavelet extracted from the seismic data. As a result, it is produced the synthetic seismic response that would be expected from subsurface geology (Bacon, 2007).

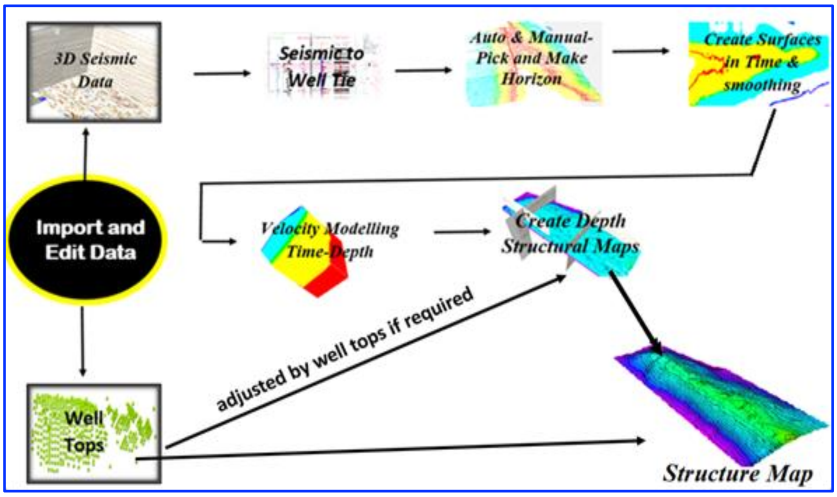

Fig. 3. The workflow of creating three-dimensional structure maps

The seismic wavelet is the important link between seismic data and subsurface rock properties in addition to stratigraphy (Henry, 2001). In this study, a seismic wavelet was estimated (using extracted wavelet) to create the synthetic seismogram and then tie the well log to the seismic data. The well-to-seismic tie was generated for eleven vertical wells, seven of these eleven wells are located in WQI Oilfield while the remaining four are located in WQII Oilfield as shown in (Fig. 4). Fig. 5 shows an example of well-to-seismic.

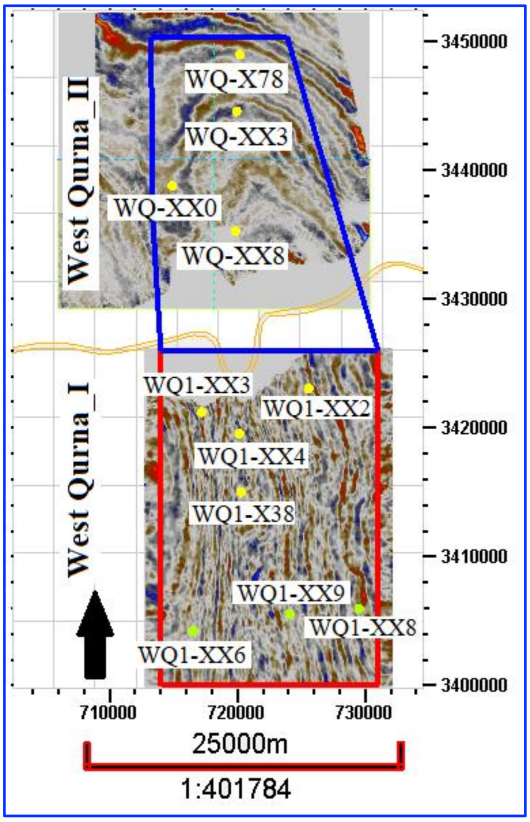

Fig. 4. Well sites that used in the Seismic Well Tie

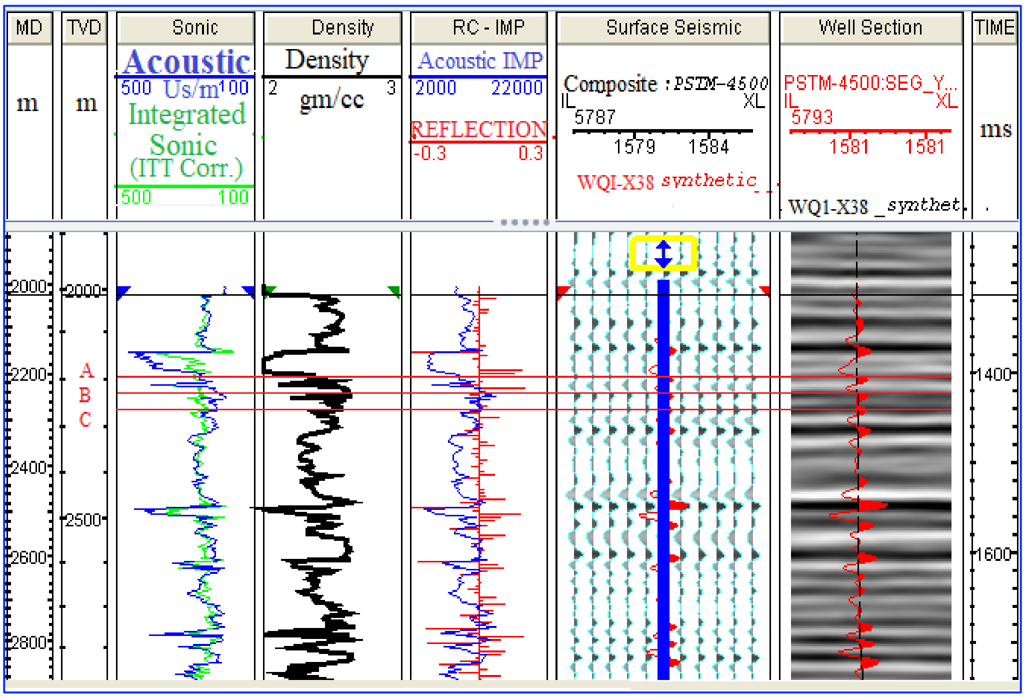

Fig. 5. Example of well-to-seismic in WQI

All eleven wells contained sonic and density logs opposite the interesting interval. There are seven wells in West Qurna I Oilfield that have Zero offset VSP but unfortunately, we have only one well (WQII-XX3) that contains a check shot in West Qurna II. Wells details illustrated in Table 1.

Table 1. Details of the wells used in the Seismic Well Tie

No.	Field	Well name	Sonic log	Density log	VSP	Checkshot
1	WQI	WQ1-XX4	AVL	AVL	AVL	
2	WQI	WQ1-XX6	AVL	AVL	AVL	
3	WQI	WQ1-XX8	AVL	AVL	AVL	
4	WQI	WQ1-XX3	AVL	AVL	AVL	
5	WQI	WQ1-XX2	AVL	AVL	AVL	
6	WQI	WQ1-XX9	AVL	AVL	AVL	
7	WQI	WQ1-X38	AVL	AVL	AVL	
8	WQII	WQ-XX3	AVL	AVL		AVL
9	WQII	WQ-XX8	AVL	AVL		
10	WQII	WQ-X78	AVL	AVL		
11	WQII	WQ-XX0	AVL	AVL		

AVL – Available

A seismic horizon can be defined as a contact between two bodies of rock having different densities, porosity, seismic velocity, fluid content, or all of those that may be represented by a seismic reflection) (Bacon, 2007). After the definition of the reflectors by utilizing synthetic seismograms for eleven wells in the time domain and made the appropriate correlation with the seismic section by applying reasonable shift, three reflectors have been picked and mapped in all study areas. Fig. 6 illustrate the three reflectors (top of Khasib Formation, top of Lower Khasib, and top of Mishrif Formation).

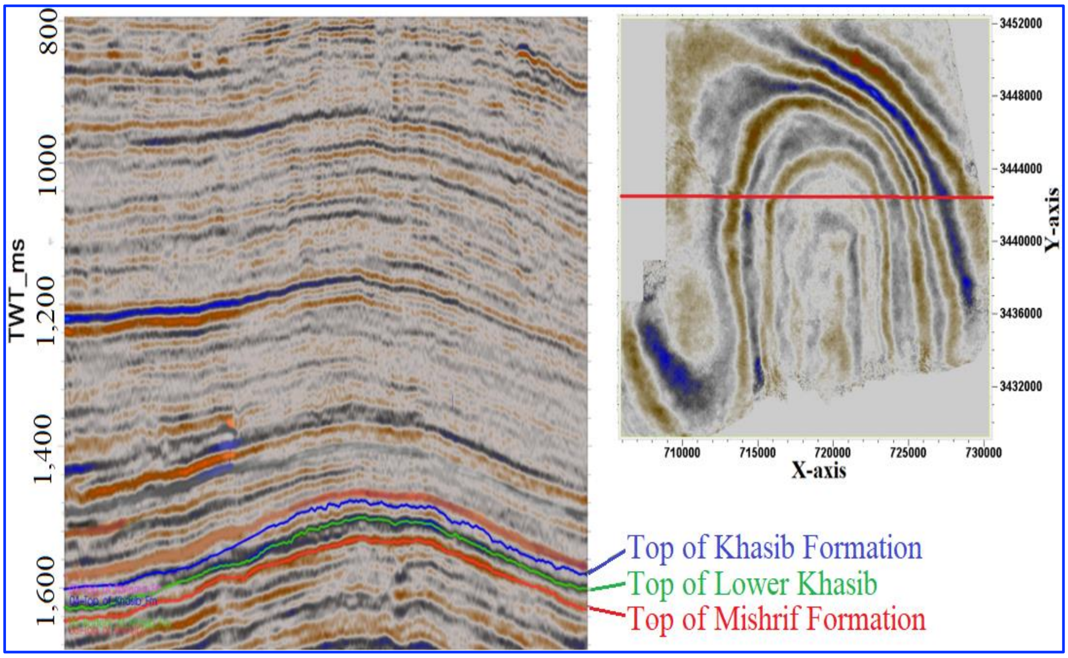

Fig. 6. The identified horizons along WQII from east to west

The studied seismic horizons have been picked using DecisionSpace Geoscience 10ep software (DSG 1oep) on multiple inlines and xlines in section editor or cup editor. Fig. 7 contains the three-dimensional visualization of the three interpreted horizons. A number of QC tools are included in this software to aid the interpretation such as ezValidator and correlation polygon. After interpreting required horizons, seismic calculator gives the operation available to easily refine or edit multiple horizons (Halliburton, 2017).

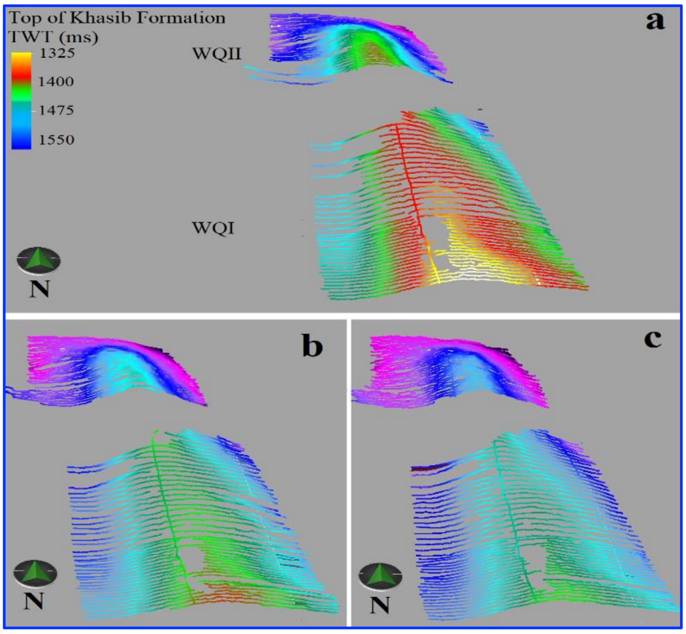

Fig. 7. The three interpreted horizons in time domain velocity model and depth conversion

A seismic velocity model gives ability to employ a combination of geophysical information (in the time domain) and geological information (in-depth domain) to build an accurate estimation of the geological depth structure (Halliburton, 2017), therefore it is indispensable to map depth and thickness of subsurface layers that interpreted from 3D seismic reflection. Depth conversion generally is used to remove the structural ambiguity in time and verify subsurface structure (Pandey, 2013). The velocity model which has been created can be used for depth conversion. Objects which can be converted include seismic data, subsurface horizons, and faults (Schlumberger, 2007). Once the velocity model is created and validated, it used to initiate depth conversion and output the structure maps in-depth domain for three surfaces Fig. 8 and Fig. 9 shows a structure map of the top of Khasib Formation and seismic sections in the depth domain.

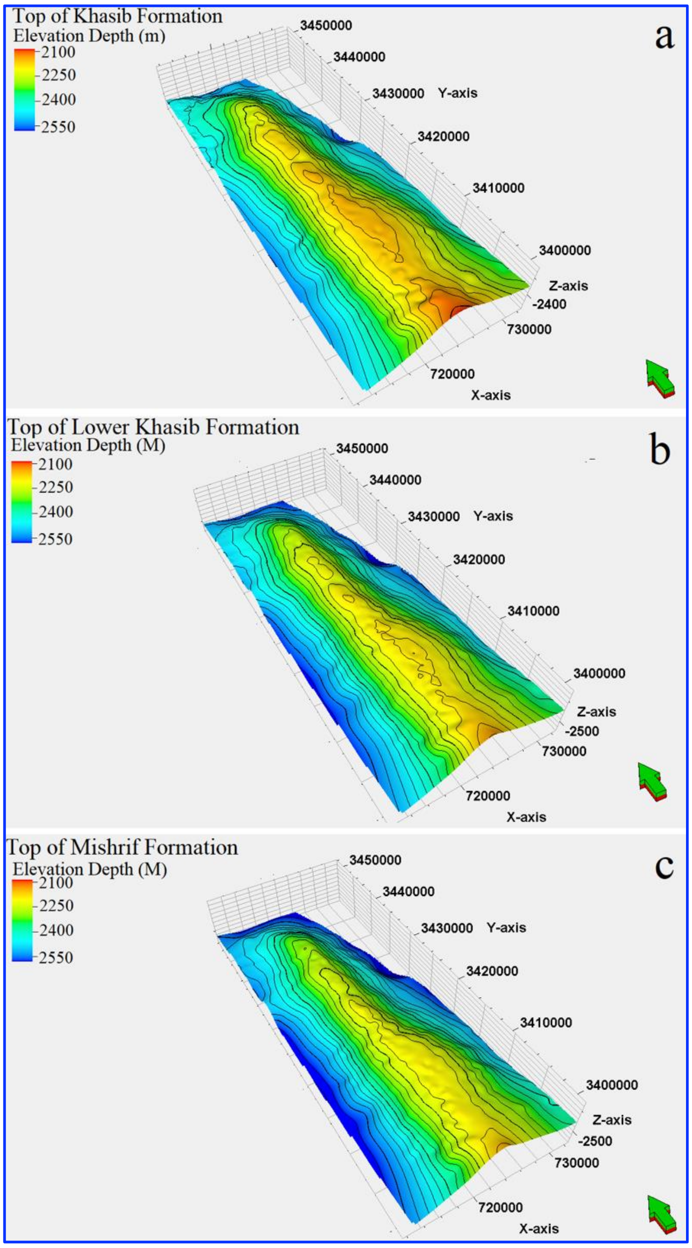

Fig. 8. Three depth structural maps derive from the interpretation of 3D seismic surveys, (a) top of Khasib Formation (b) top of Lower Khasib (c) top of the Mishrif Formation

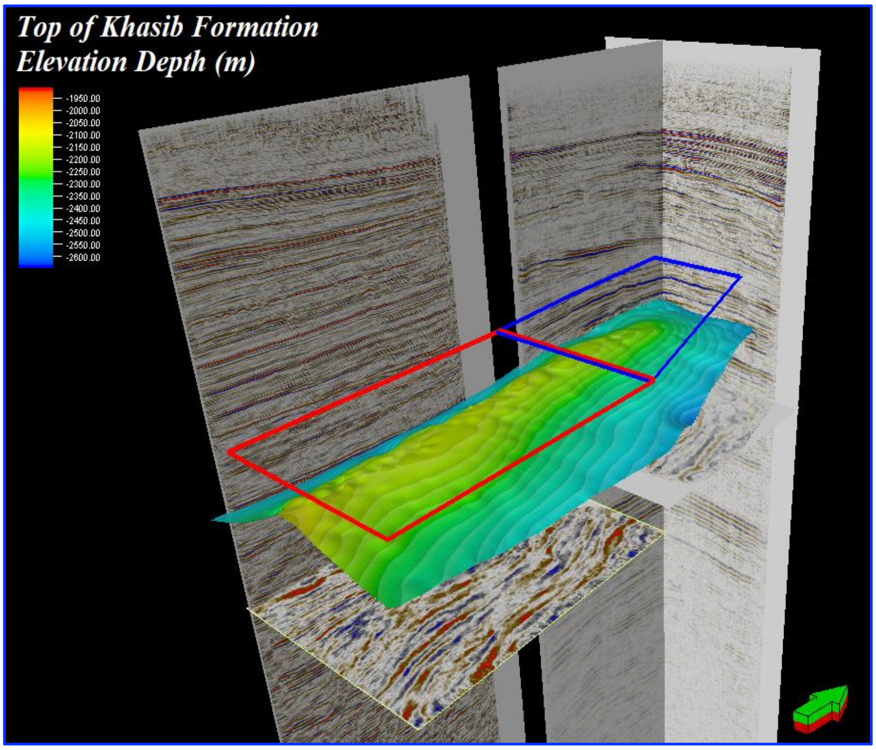

Fig. 9. The structural map of top of Khasib Formation in the depth domain extracted from the 3D seismic survey

4. Results

The three-dimensional structure maps of the Khasib Formation, lower Khasib Member and top Mishrif Formation (base of Khasib Formation) can be used for the purpose of studying geometry analysis of the WQI and WQII. Fig. 10 illustrates that the plunge angle of the West Qurna structure is small and the hinge line of the fold structure is not quite straight. Obviously shown in Fig. 10 that the dip angles of the eastern and western limbs are not equal in all three structure maps (top of Khasib, lower Khasib, and Mishrif). The dip angle of the eastern limb approximately ranges from 1.2 to 2.1 degrees, while the dip angle of the western limb of the fold approximately ranges from 2 to 3.5 degrees. Numerous classifications of the folds could be used to define one specific fold. Each of them uses certain geometric parameters to perform the classification (Al-kubaisi and Lazim, 2016). In this study, the geometrical fold classifications have been done based on fold facing, fold orientation (According to the dip of axial surface).

4.1. Fold Facing Classification

If the hinge line of the fold is straight, the fold is called a cylindrical fold. The folds with curved hinge line are called non-cylindrical folds. The folds can be classified based on the fold facing into syniform when the hinge line is at the bottom of the structure and antiform when the hinge line is at the top of the structure (Pluijm and Marshak, 1997). Based on the foregoing, the West Qurna structure is a non-cylindrical antiform fold. face and plunge of hinge line), fold tightness, the symmetry of the fold and fold dimensions.

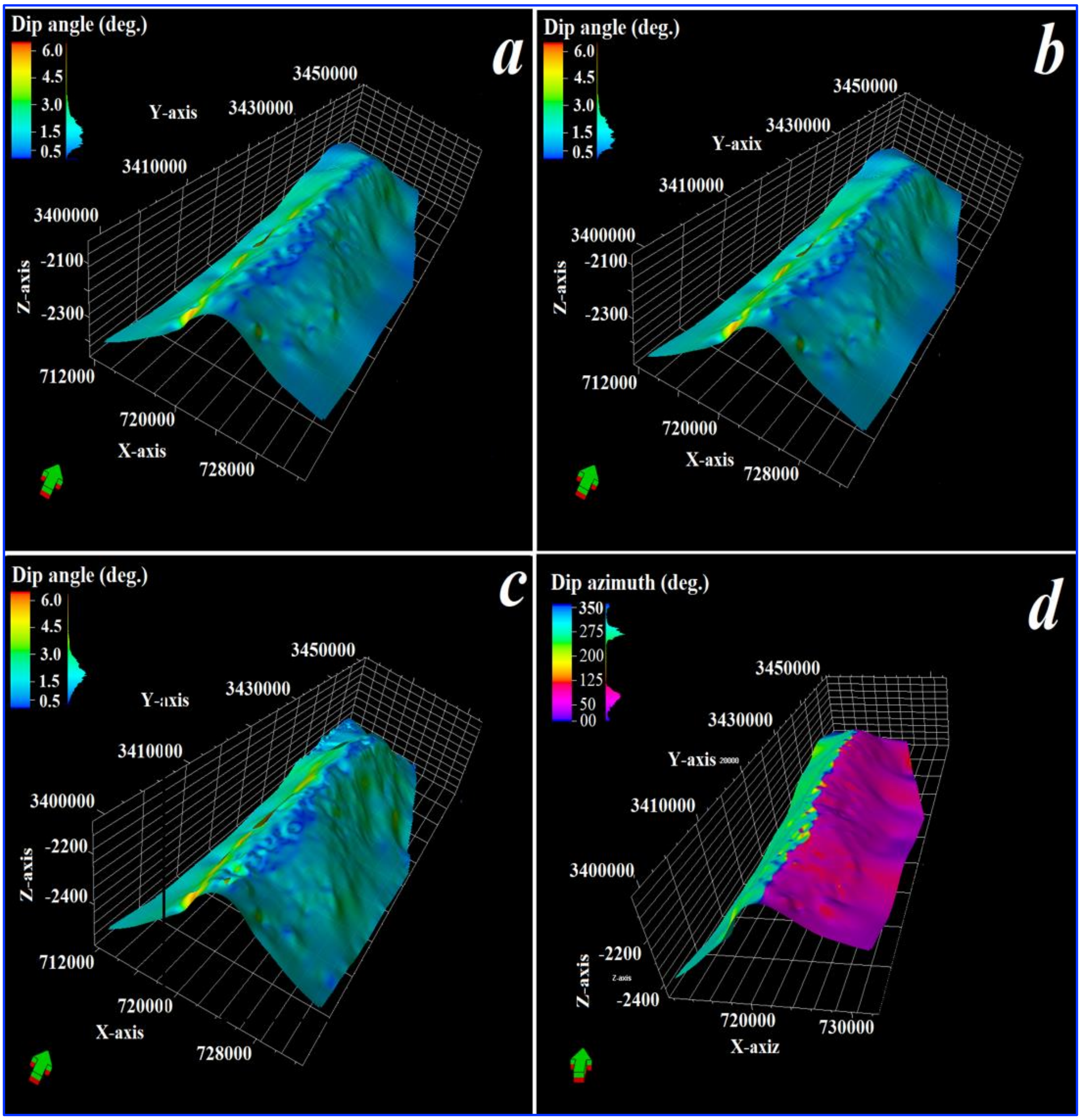

Fig. 10. Formation dip angle and azimuth a- The dip angle at top of Khasib Formation, b-The dip angle at top of lower Khasib Member. c-The dip angle at top of Mishrif Formation, d-The dip azimuth of top of Khasib Formation

4.2. Fold Orientation Classification

4.2.1. According to the dip of axial surface:

The folds can be classified into three types, according to the dipping of the axial surface, which are recumbent, inclined and upright (Fig. 11). Therefore, the West Qurna structure is classified as an upright fold.

4.2.2.. According to the plunge of hinge line

Folds can be classified based on the angle of a plunge into horizontal or non-plunging when the plunge angle of the hinge line is less than 10 degrees, however it can be classified as a vertical fold if the plunge angle is between 80 to 90 degrees (Pluijm and Marshak, 1997). The plunging angle of the West Qurna structure is very low (less than one degree). Therefore, the fold of the West Qurna is classified as a non-plunging or horizontal anticline (Fig. 11).

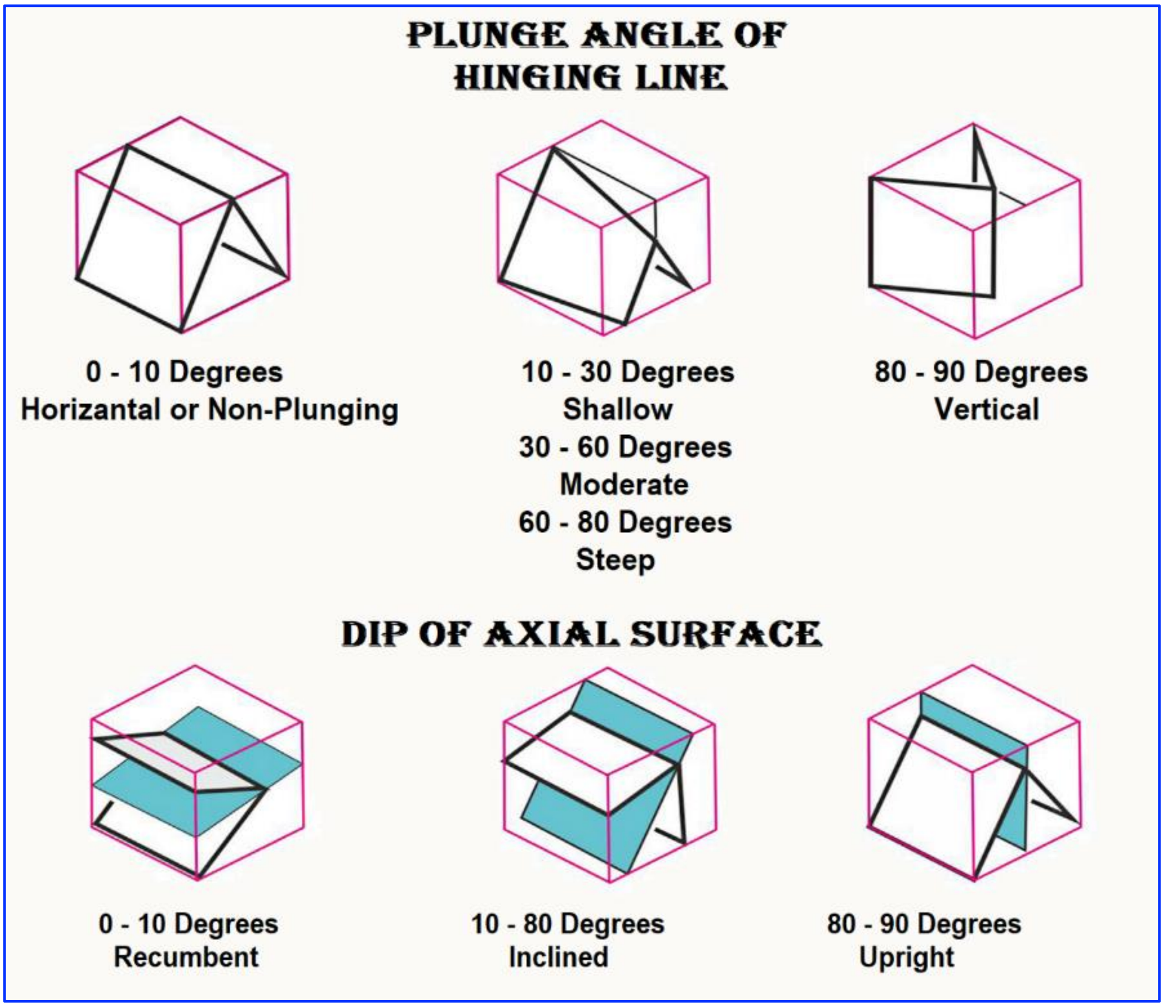

Fig. 11. Folds classification according to their orientation (Lisle, 2020)

4.3. Tightness of Folding Classification

The angle measured between fold limbs is called the interlimb angle. The interlimb angle gives an estimation of the folding intensity, the larger interlimb angle, the smaller intensity of folding, and vice versa. According to the interlimb angle, the folds can be classified into six classes: gentle, open, close, tight, isoclinal, and fan fold (Fig. 12) (Lisle, 2020). The interlimb angle of the West Qurna structure is wide (approximately 170-175 degrees). Therefore, according to this classification, the West Qurna structure is a gentle fold.

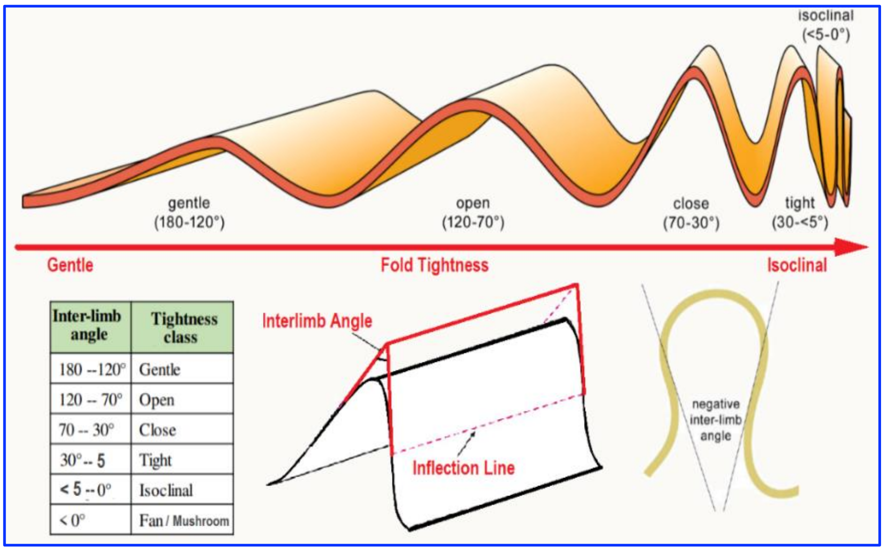

Fig. 12. Folds types according to the interlimb angle (Pluijm and Marshak, 1997)

4.4. Fold Symmetry Classification

The fold can be called a symmetrical fold if one flank of the fold is the mirror image of the other (Lisle, 2020). A symmetrical fold must have limbs of equal length, on the other hand, if the limbs of the fold are unequal the fold is called asymmetric fold (Al-kubaisi and Lazim, 2016). The cross-sections of the West Qurna structure show clearly that the eastern limb is longer than the western limb which leads to that the West Qurna structure is asymmetrical fold (Fig. 13).

4.5. Fold Dimensions Classification

The structure length (L) to width (W) ratio can be used to classify the folds. Depending on this classification, three types of folds can be distinguished as follows (Haider, 2018):

- Liner fold when the ratio (L/W >5)
- Brachy fold when the ratio (5 > L/W > 2)
- Domes and Basin fold when the ratio (L/W < 2)

From the structure maps, the length of the West Qurna structure is approximately 52 km, while t

5. Discussion

This is a case study provides the practical approach for creating structural maps by interpreting 3D seismic surveys, in addition, to use certain engineering parameters to classify the fold systems. Numerous geometrical fold classifications of the Khasib Formation in both WQI and WQII oil fields have been done using highly precise structure maps of the three reflectors (top of Khasib Formation, top of Lower Khasib Member, and top of Mishrif Formation) using the high quality of the 3D seismic survey, precise time-depth relationship drives from seven VSPs and one check shot, in addition, to use well tops from well logs to make some necessary adjustments to the structure maps. The interpretation of three-dimensional seismic data in WQI and WQII indicates that there is no clear evidence of faults in the Khasib Formation. The WQI and WQII fold can be classified as an upright, non-cylindrical, horizontal, asymmetrical, brachy, and gentle anticline according to fold facing, fold orientation (According to the dip of axial surface and plunge of hinge line), fold tightness, the symmetry of the fold, and fold dimensions.The width of the structure is about 13.5 km, therefore the West Qurna structure is Brachy fold.

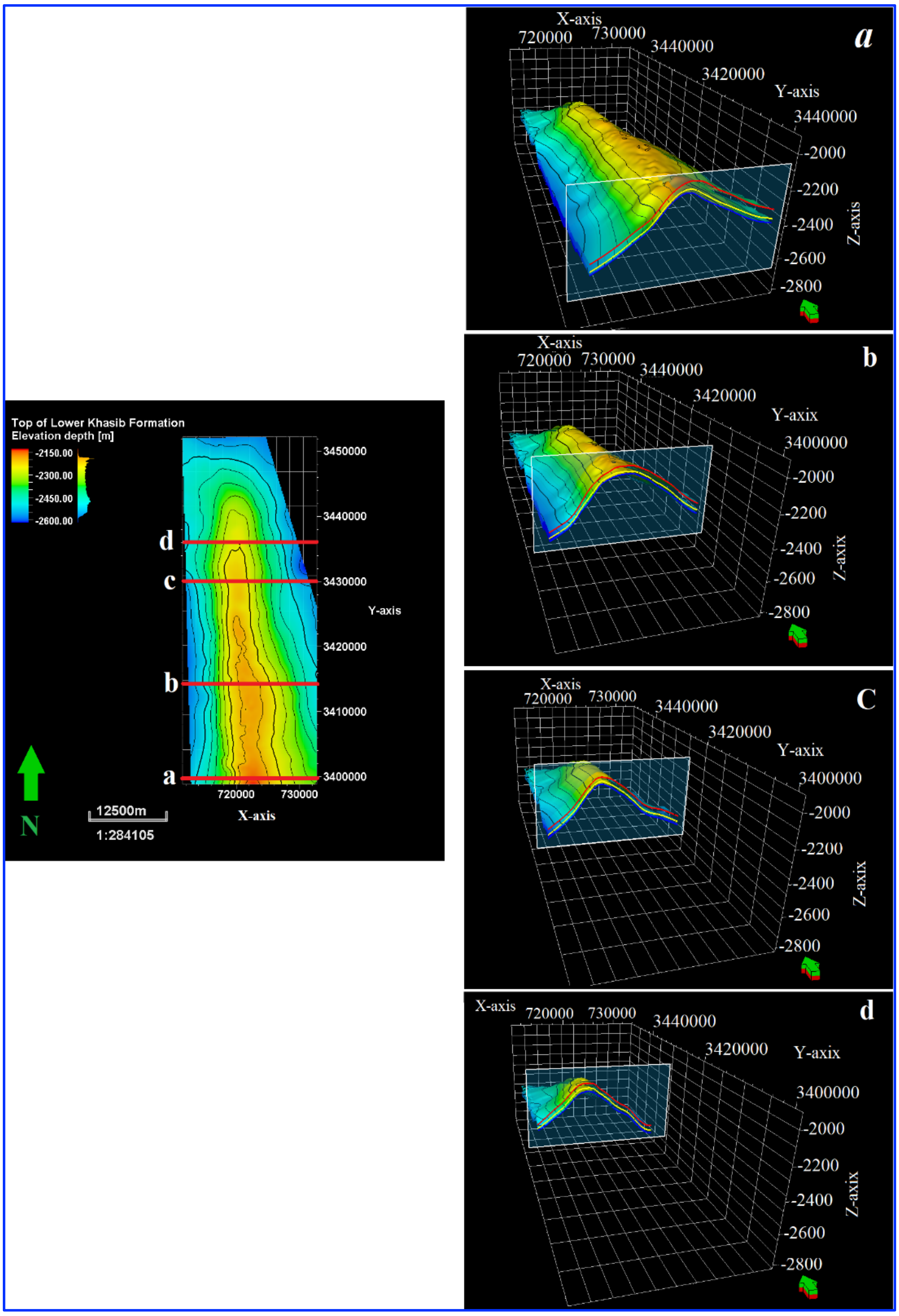

Fig. 13. East-West cross sections of the WQI and WQII oilfields

6. Conclusions

The study provided highly precise structure maps of the three reflectors Khasib, Lower Khasib, and Mishrif due to using the high quality of 3D seismic survey in WQI and WQII in addition to precise time-depth relationship drives from seven VSP and one check shot. Well tops from well logs were very useful to make some necessary adjustments to the structure maps especially in places where the 3D seismic survey is missing. The 3D seismic interpretation of WQI and WQII indicates that there is no clear evidence of faulting in Khasib Formation in both oilfields. Finally, the study concludes that the West Qurna structure is the upright, horizontal, gentle, non-cylindrical, brachy, asymmetrical anticline.

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