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Structure Analysis of Sa’adi Reservoir in X Supergiant Oilfield, Southern Iraq

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Abstract

The study area is located in southern Iraq in Mesopotamia hydrocarbon province. It’s part of supergiant liner anticline that extends from south to north, South Rumaila, North Rumaila, West Qurna-1, and West Qurna-2. The major fold oriented north-northwest and extends approximately 120Km. All available data was integrated and used in this study to support a better image of the subsurface of the Sa'adi structure. The Sa'adi reservoir in the study area is considered as a secondary reservoir. Therefore, a three-dimensional seismic survey, and seven VSPs, in addition, to well tops that drive from a set of well logs are used in this study.

The three-dimensional seismic interpretation and subsurface structure maps of both Tops of Sa'adi and Tanuma formations were performed by Halliburton software (OpenWorks, DecisionSpace Geoscience, and Seismic Analysis). The structure maps of Lower Sa'adi_I and Lower Sa'adi_II have been created based on well tops. A set of well logs (Quad combo) were used to identify the well tops in more than four hundred wells that penetrated the Sa'adi reservoir and distributed over the study area using Geolog software. The structure maps of Lower Sa'adi_I and Lower Sa'adi_II in addition to the cross-sections were set up by Petrel 2018 (Schlumberger software). The study gives highly accurate structure maps of top of Upper Sa'adi, top of Lower Sa'adi_I, top of Lower Sa'adi_II, and top of Tanuma formations. The Sa'adi structure in study area is classified as asymmetrical, non-cylindrical, horizontal, antiform, brachy, gentle anticline.

Keywords: Seismic Interpretation; Structural Analysis; Fold Classification.

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1. Introduction

The Nameless oilfield is considered one of supergiant oilfield in Basra Provenance (Southern Iraq). Within this oilfield, several reservoirs that have been identified in the Cretaceous Period from youngest to oldest are Sa'adi, Khasib, Mishrif, Mauddud, Zubair, and Yammama reservoirs [1]. Figure (1) shows the Stratigraphic Column in the study area

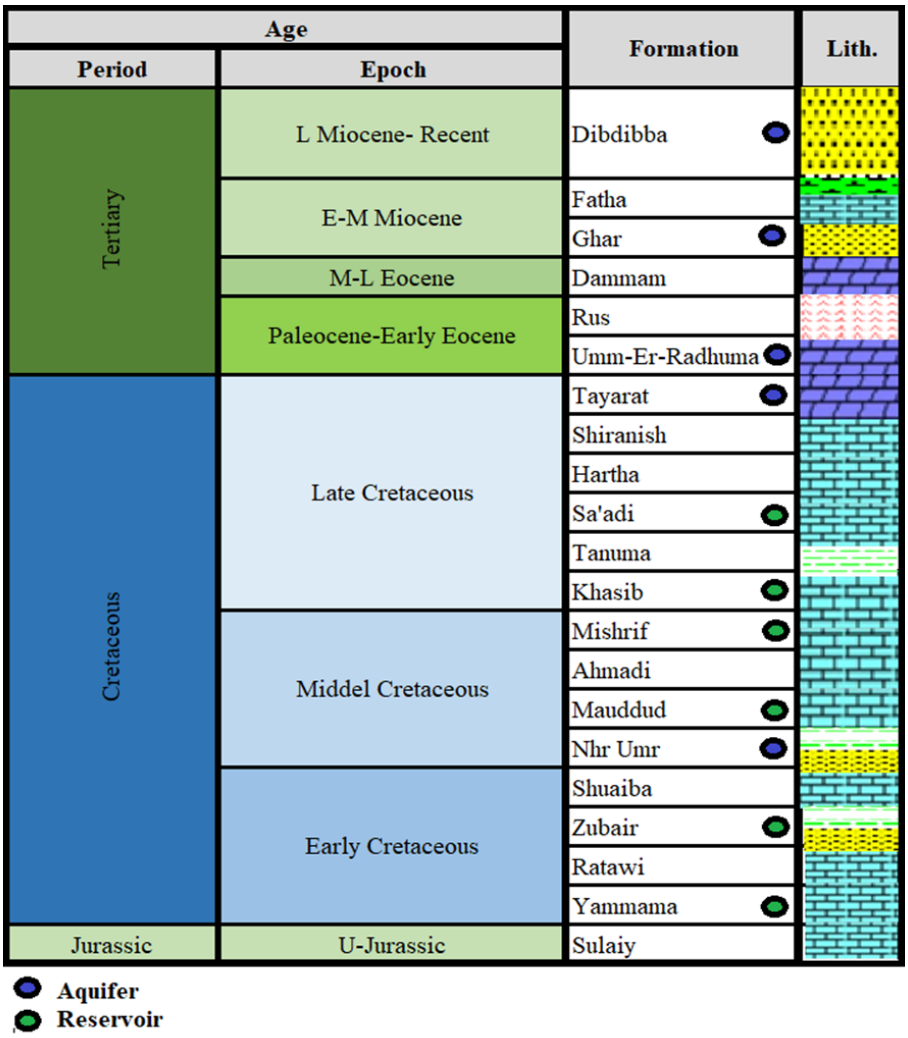

Fig. (1): Stratigraphic Column of X Oilfield. [1]

The first well in the study area was drilled in1973 after the first two-dimensional seismic survey in 1972 and then the drilling of appraisal and development wells was continued up to date [2]. A three-dimensional seismic survey is performed in 2012 by Western Geco/Schlumberger Company. Oil production commenced from this oilfield in 1990 by South Oil Company (SOC) mainly from Mishrif reservoir and little oil production from Zubair and Sa'adi reservoirs.

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This study integrated high-quality three-dimensional seismic interpretation, seven Vertical Seismic Profiles (VSP), and a set of well logs to provide high accurate subsurface structure maps of the Sa'adi Formation. Four structure maps have been created. Structure maps of the top of Sa'adi and Mishrif reservoir are created based on 3D seismic interpretation, while the structure maps of the top of Lower Sa'adi_I and Lower Sa'adi_II are created based on well logs. Specific geometric parameters in this study are used to make the fold classification Figure (2).

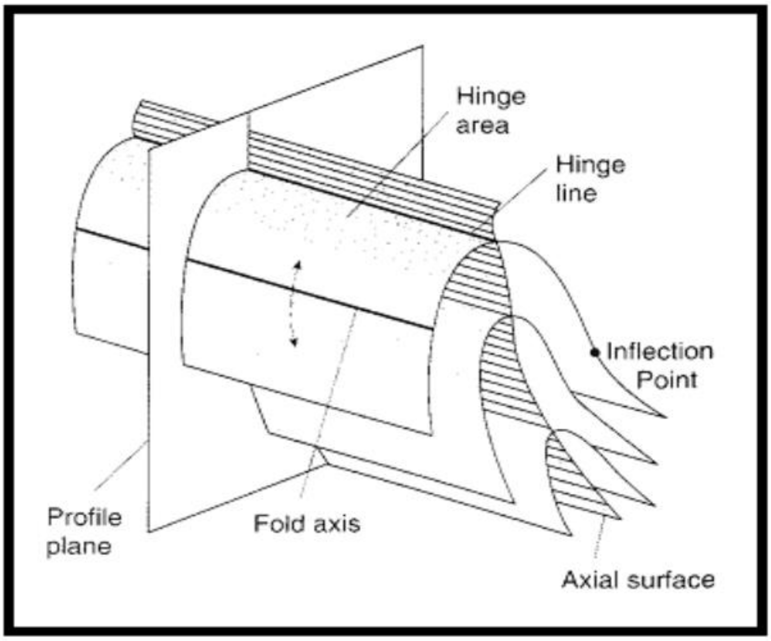

Fig. (2): The geometric parameters of a fold [3].

2. Study Area

The X oilfield is located in Mesopotamia hydrocarbon province, geographically about 50 kilometers northwest of Basra city (southern Iraq). The study area was flooded with Al-Hamar marsh water. The surface area of the field is approximately 442 square kilometers and it covers by alluvial deposits and modern clay materials [4].

3. Methodology

Sa'adi reservoir in study area is considered as a tight reservoir. Sa'adi's permeability range between 2 to 10 mD and the average porosity is about 13%. It consists mainly of clean limestone. The Sa'adi Formation is divided into two main members (Upper Sa'adi and Lower

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Sa'adi) and then the Lower Sa'adi member has been subdivided according to the reservoir quality into two parts (Lower Sa'adi_I and Lower Sa'adi_II). Figure (3) shows example of well logs interpretation using Geolog software in order to divide Sa'adi reservoir into members and units according to the reservoir quality.

In this oilfield, the high-quality 3D seismic survey was executed in 2012 by WesternGeco Company, but unfortunately, the seismic survey does not cover the whole study area. The 3D seismic survey didn't execute in the northwest area due to the high population density [5]. The structure maps of the top of the Sa'adi and Tanuma formations were created using the OpenWorks, DecisionSpace Geoscience, and Seismic Analysis software. While the structure maps of Lower Sa'adi_I and Lower Sa'ad_II have been created based on well tops using Petrel 2018 software. These all structure maps were used to study structure analysis of the study area according to the workflow shown in Figure (4).

The first step in 3D seismic interpretation is to do a Seismic Well Tie (SWT) to find the relationship between subsurface geology and three-dimensional seismic reflectors by comparing main reflectors with well logs [6]. This process has been done by Seismic Analysis software. As known, the processed three-dimensional seismic data is in time, while the well log records are an in-depth domain, thus the acoustic impedance has to be converted from depth domain into a time-domain (the acoustic impedance log should be a function of TWT (two way travel time) [7]. This process can be achieved by using a Time - Depth Relationship from chock shot or VSPs to calibrate the sonic logs [8].

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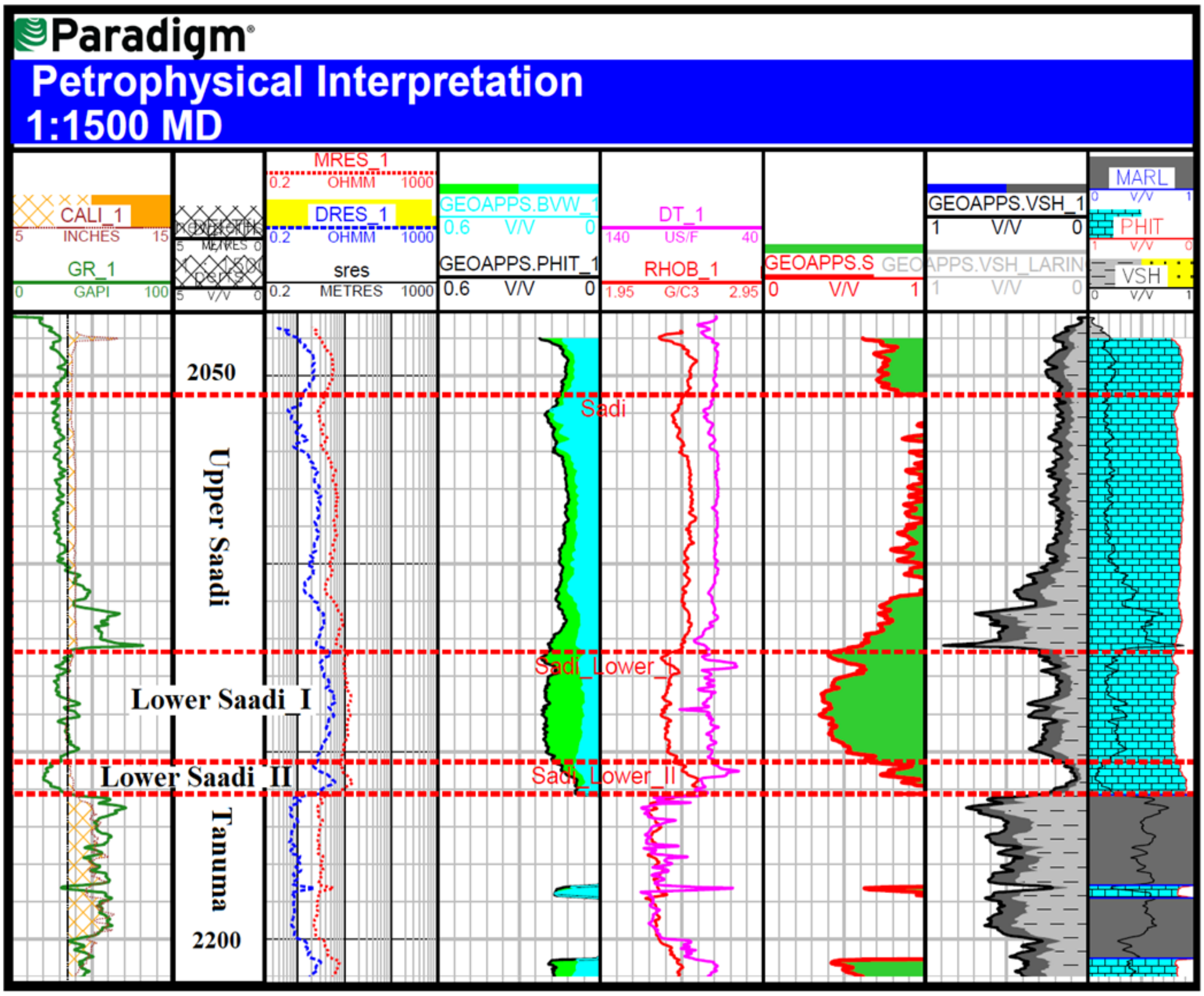

Fig. (3): Sa'adi Formation Subdivisions.

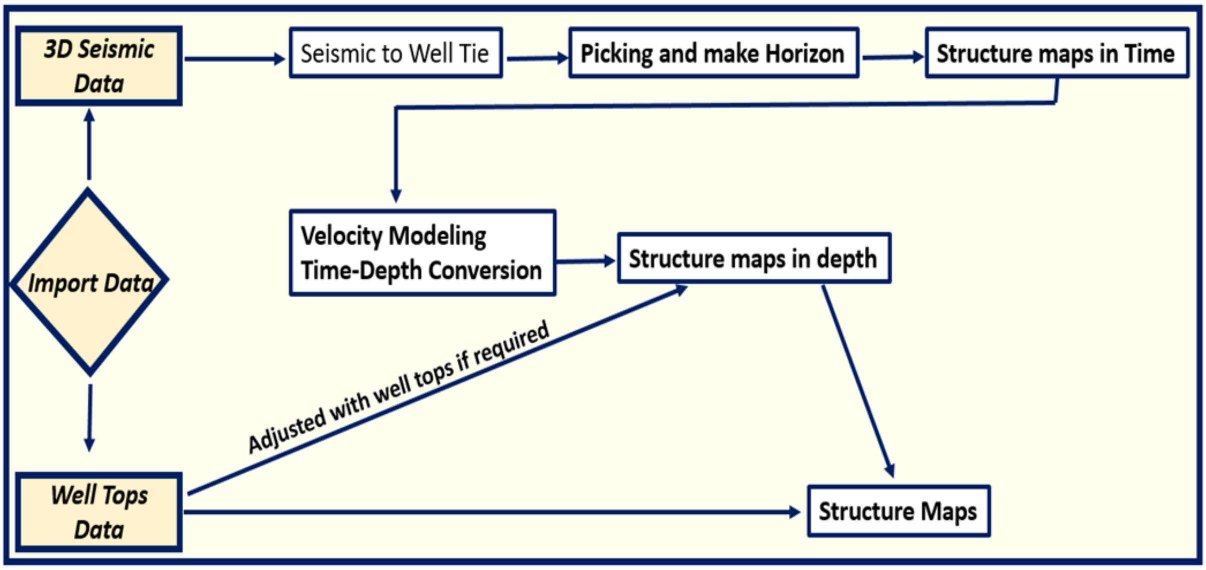

Fig. (4): The workflow of creating three-dimensional structure maps.

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The acoustic impedance is derived from multiplication of the sonic log by density log. The synthetic seismogram is created by convolving the reflection coefficients with the wavelet which has been extracted from the seismic survey. The wavelet is the link between the properties of formation rock and seismic data [9]. The extracted wavelet has been used in this study to generate the synthetic seismogram Figure (5), to have a good fit between generated synthetic seismogram with the seismic section. Commonly wavelet is chosen according to the source of the seismic signal [10].

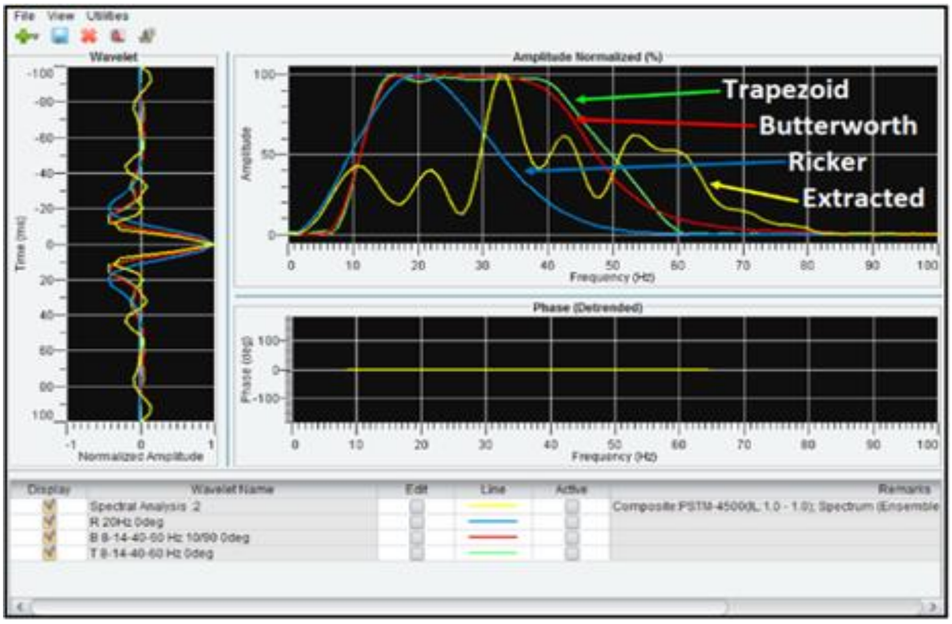

Fig. (5): Wavelet viewer displays the four types of wavelets which are available in DecisionSpace Geophysics software (DSG 10pe).

In this study, Seismic to Well Tie (SWT) was done for seven wells inside the study area. Fortunately, all these seven wells have Acoustic log, Density log, and VSP for Sa'adi Formation. Figure (6) shows the location of these seven wells. Figure (7) shows an example of SWT.

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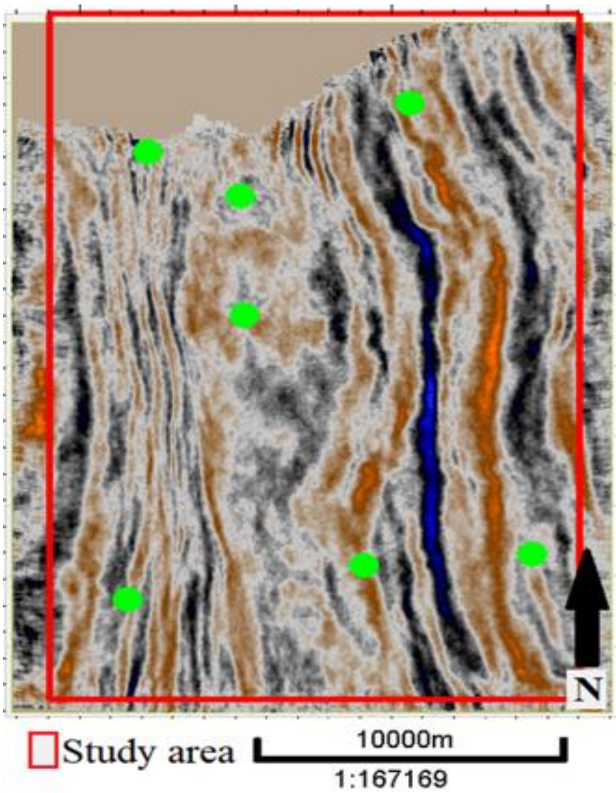

Fig. (6): Well location that used in the SWT.

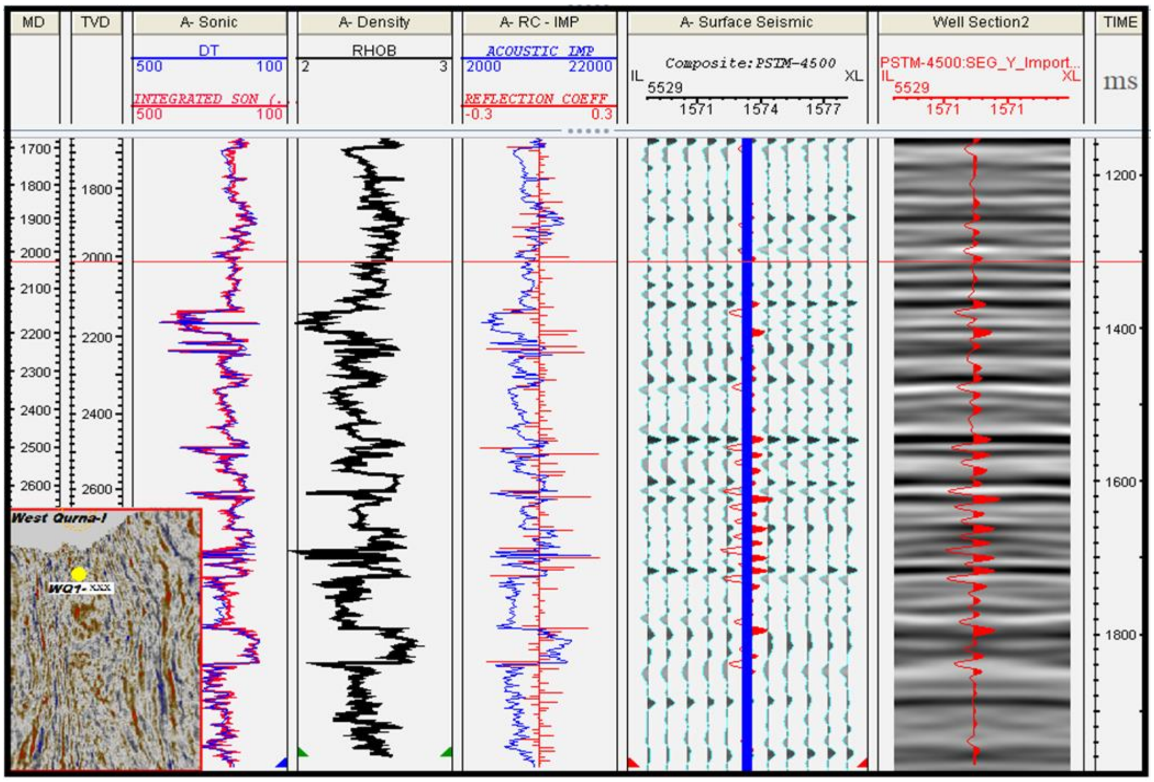

Fig. (7): SWT Example.

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Seismic reflectors of the top of Sa'adi and Tanuma formations were picked in seismic sections by correlating the synthetic seismograms of seven wells with the seismic data using DecisionSpace Geoscience 10ep software Figure (8).

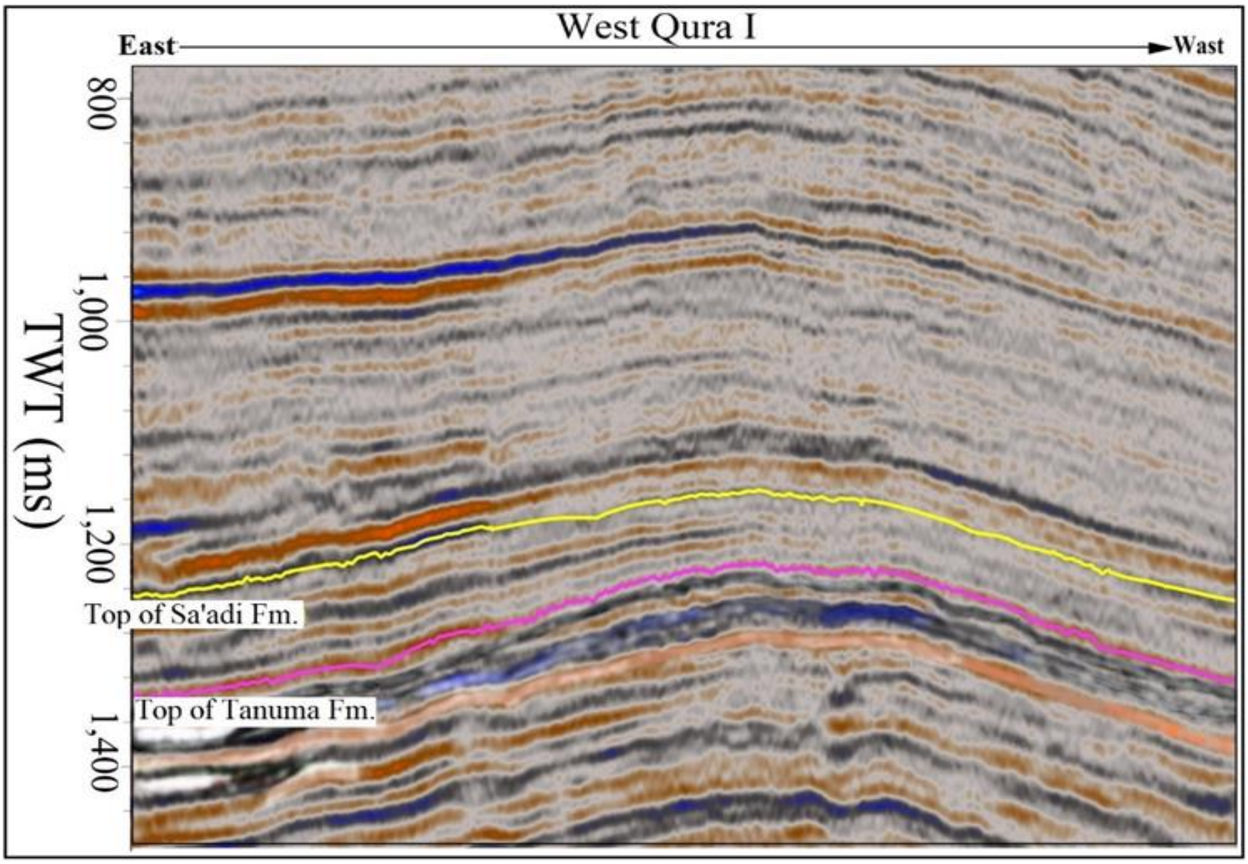

Fig. (8): East-West Seismic Cross-Section.

Depth conversion was done using the seismic velocity model to convert the two seismic horizons (in-time domain) to geological structure maps (in-depth domain). The structure ambiguity (in-time domain) generally can be removed by doing the depth conversion [11]. The structure maps of the top of Sa'adi and Tanuma formations were adjusted by well tops especially in places where the 3D seismic survey was not executed. The well tops extracted from well logs have been used to build accurate structure maps of Lower Sa'adi_I and Lower Sa'adi_II. (Fugure_9) shows the four subsurface structure maps, top of Sa'adi and top of Tanuma formations that were generated based on 3D seismic interpretation and the other structure maps of Lower Sa'adi_I and Lower Sa'adi_II that were created based on well tops. Figure (10) shows the location of the wells that were used to create the structure maps of Lower sa'adi_I and Lower Sa'adi_II.

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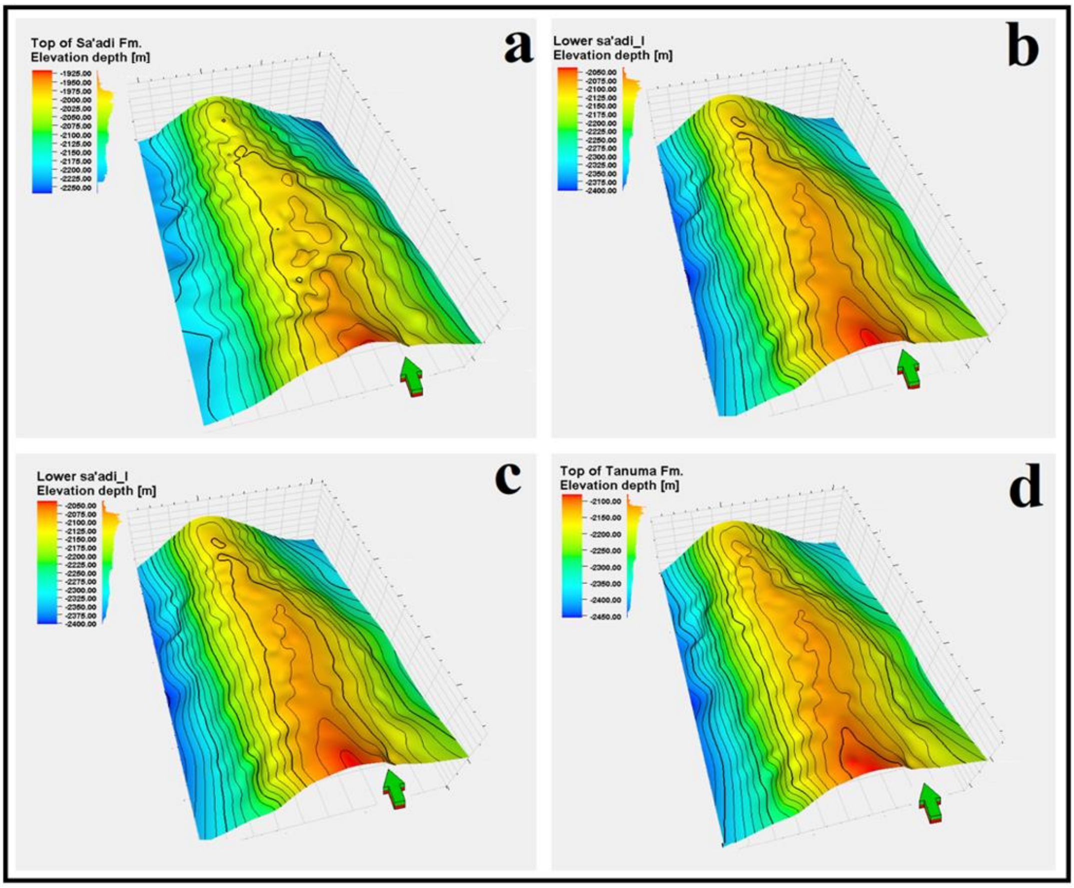

Fig. (9): Structure Maps. a- Top of Sa'adi Formation; b- Top of Lower Sa'adi_I; c- Top of Lower Sa'adi_II; and d- Top of Tanuma Formation.

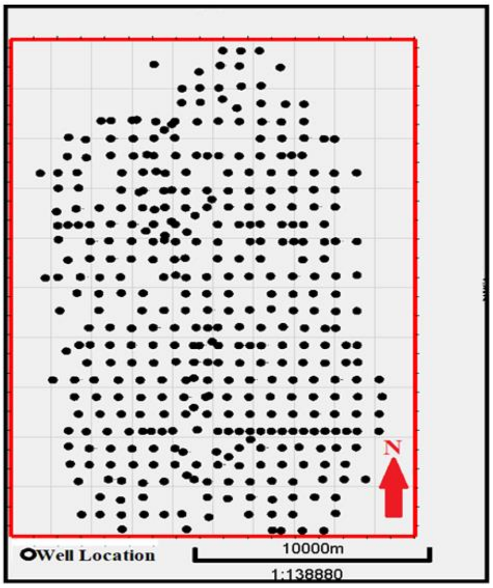

Fig. (10): The location of the wells that were used to create the structure maps of Lower Sa'adi I and Lower Sa'adi_II.

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4. Results and Discussion

The structure maps of top of Upper Sa'adi, Lower Sa'adi_I, Lower Sa'adi_II, and Tanuma created could be used to analyze the structure of the study area. The hinge line of the Sa'adi structure is not fully straight. The unequal dip angle of the western and eastern flank in all structure maps (Top of Upper Sa'adi, Lower Sa'adi_I, Lower Sa'adi_II, and Tanuma) and the plunge angle of the structure of the Sa'adi Formation is quite little as shown in Figure (11).

Figure 11 shows that the dip angle of the western flank in all four structure maps ranges roughly from 2 to 4 degrees however the dip angle of the eastern flank ranges roughly from 0.9 to 2.0 degrees. There is several-fold classification using different geometric parameters that could be used [12]. Different structural classifications were performed in this research.

4.1. Classification according to the symmetry of the fold:

According to the cross-sections in Figure (12) the X oilfield is an asymmetrical fold.

4.2. Classification according to the tightness of folding:

The interlimb angle is the angle between the limbs of the fold which assesses the intensity of the fold, the tight interlimb, the large fold intensity, and vice versa. The folds classify into six types based on interlimb (open, close, gentle, isocline, tight, and fan). Figure (12) illustrates that the interlimb angle of X oilfield (Sa'adi Formation) is quite wide approximately range between 172 and 177; therefore, the X oilfield is a gentle fold.

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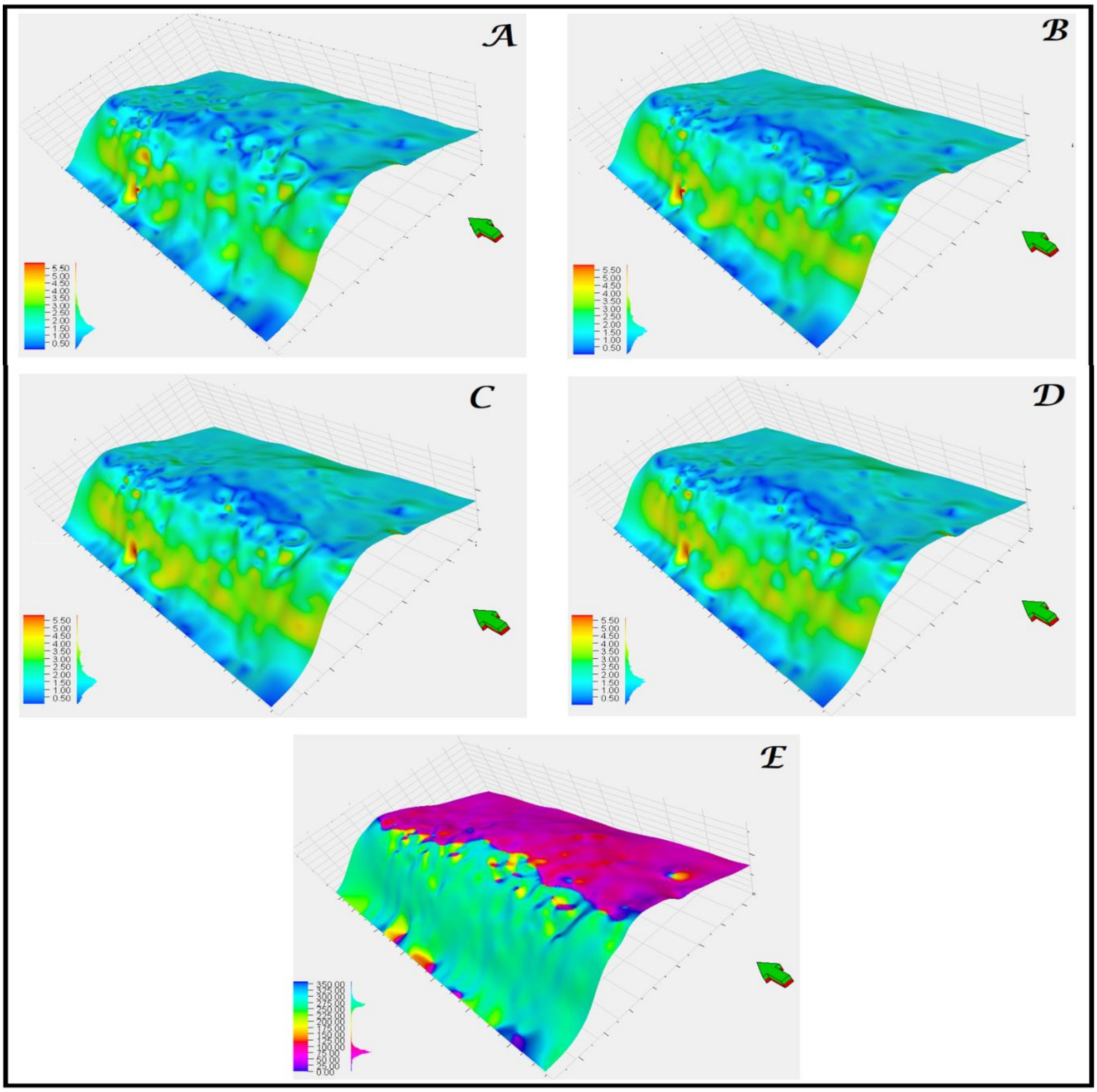

Fig. (11): Formation dip angle and azimuth. A- The dib angle at top of Upper Sa’adi; B- The dib angle at top of Lower Sa’adi_I; C- The dib angle at top of Lower Sa’adi_I; D- The dip angle at top of Tanuma Formation; E-The dib azimuth (Top of Lower Sa’adi_II).

4.3. Classification according to the plunge of hinge line:

The folds can be classified into five classes according to the plunging angle of the hinge line: 1) non-plunging or horizontal fold when the plunging angle is less than 10 degrees; 2) shallow fold when the plunging angle is between 10 to 30 degrees; 3) moderate fold when the plunging angle is between 30 to 60 degrees; 4) steep fold when the plunging angle is between 60 to 80 degrees; 5) and finally vertical angle when the plunging angle is between 30 to 80 degrees [13].

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It can be said that the X oilfield is horizontal (non- plunging) fold (very low plunging angle).

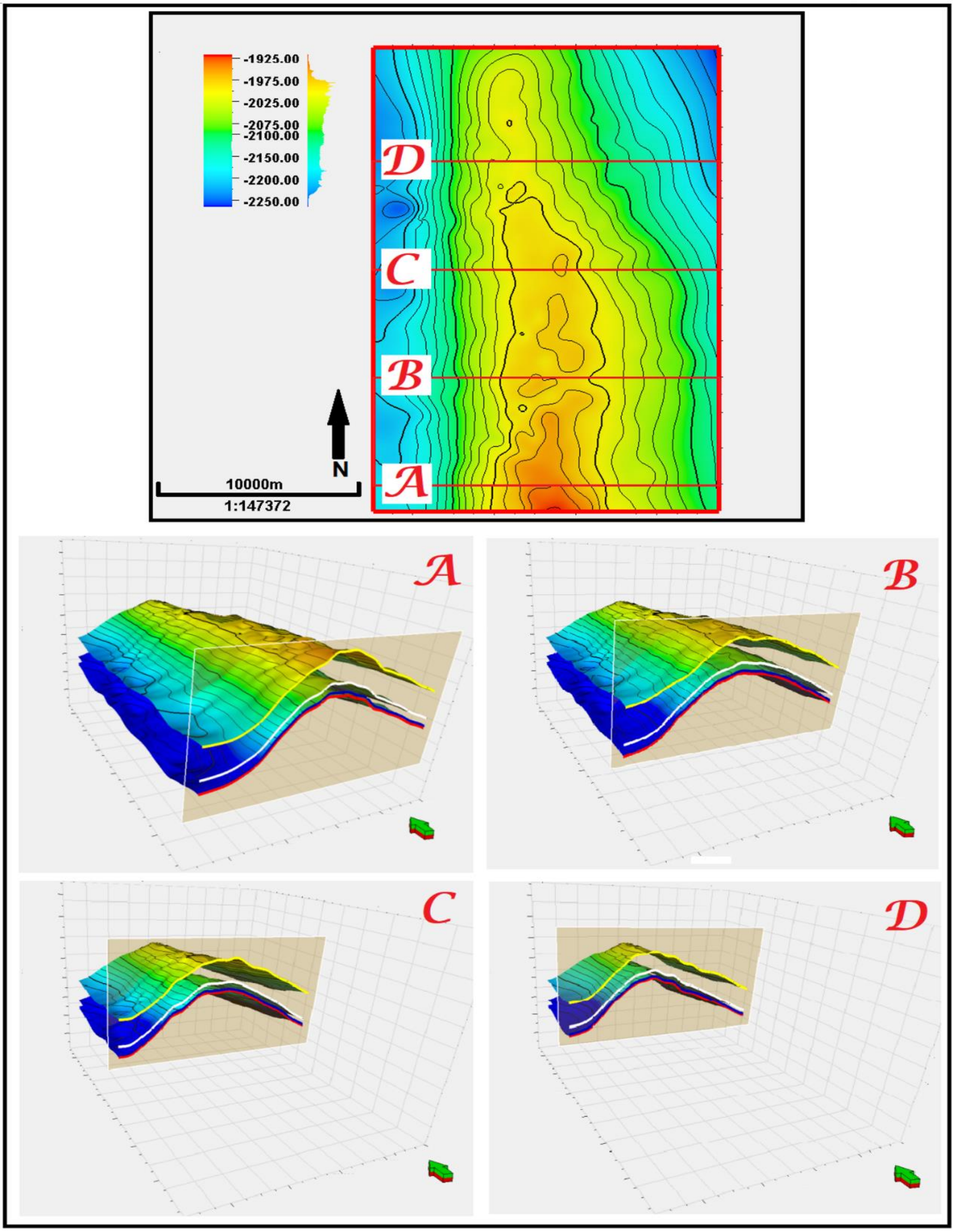

Fig. (12): East-West, Cross-sections of the study area.

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4.4. Classification according to the dip of axial surface:

X oilfield structure is upright fold based on dipping of the axial surface. It can be said that the fold is upright when the dip of the axial surface is between 80 to 90 degrees, inclined fold when the dip of the axial surface is between 10 to 80 degrees, and recumbent fold when the dip of the axial surface is between 0 to 10 degrees.

4.5. Classification according to fold facing:

The fold can be called cylindrical if it has a straight hinge line otherwise it is called non-cylindrical. Also, it can be called antiform if the hinge line is located at the top of the structure. Therefore, the structure of X oilfield is an antiform cylindrical fold.

5. Conclusions

This study gives highly accurate structure maps of top of Upper Sa'adi, top of Lower Sa'adi_I, top of Lower Sa'adi_II, and top of Tanuma formations. This is due to the high-resolution 3D seismic survey and 7 VSPs in the study area in addition to more than 500 wells penetrated Sa’adi Formation in this field. The well tops that derived from well logs were used to create the structure maps of Lower Sa’adi-I and Lower Sa'adi-II and also they were used to make some adjustments for structure maps of the two reflectors which derive from seismic interpretation. Finally, the conclusion of this study is that X oilfield is asymmetrical, upright, brachy, non-cylindrical, gentle, horizontal anticline.

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