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BUILDING A STRUCTURAL MODEL OF BELAYIM MARINE OIL FIELD, CENTRAL GULF OF SUEZ, EGYPT

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بناء نموذج تركيبي لحقل بترول بلاعيم البحري، وسط خليج السويس، مصر

الخلاصــة: يقع حقل بترول بلاعيم البحري في وسط خليج السويس. تم تفسير البيانات السيزمية لتحديد خصائص التراكيب التحتسطحية التي تتحكم بالشكل التركيبي لحقل بترول بلاعيم البحري المميز بطية محدبة يقطعها العديد من الصدوع العادية. الطية ثلاثية الاتجاهات مع كتل الصدوع المائلة تكون المصائد التركيبية الرئيسية في حقل بترول بلاعيم البحري و التي لها تأثير كبير في إمكانية تكون الهيدروكربون و توزيعه في تكوينات خزانات بلاعيم و كريم و روديس و نوبيا.

تم بناء نموذج تركيبي لحقل بلاعيم البحري في ثلاث خطوات وهم نموذج للصــدوع و نموذج شــبكي ثلاثي الأبعاد و نموذج للطبقات للحصــول علي نموذج تركيبي ثلاثي الأبعاد يدعم تحديد الأماكن المناسبة لتواجد الهيدروكربون في الحقل.

ABSTRACT: *Belayim Marine Oil Field is located in the central dip province of the Gulf of Suez. Seismic data interpretation was carried out to detect the subsurface structural features, which control the structural configuration of Belayim Marine Oil Field that are represented by an anticlinal fold dissected by several normal faults. Mostly three-way dip closure, with tilted fault blocks, forming a major structural trap has a great impact on hydrocarbon potentiality and its distribution in Belayim, Kareem, Rudies and Nubia reservoir Formations. Three steps for building a structural model, in terms of fault modeling, pillar gridding (3D gridding skeleton) and making horizons, were carried out to produce the final 3D structural model that supports the detection of suitable places for hydrocarbon potential in the field.*

INTRODUCTION

Belayim Marine Oil Field is one of the giant oil fields in the Gulf of Suez. It is located in the central part of the Gulf of Suez between latitudes 28˚ 34' 45" and 28˚ 38' 32"N and longitudes 33˚ 05' 17" and 33˚ 10' 38" E in the eastern side of the Gulf of Suez, 165 km southeast Suez City. The field is about 9 km to the west of the shoreline (Figure 1). The stratigraphic succession of Belayim Marine Field was divided into three main sequences (Bosworth and McCaly, 2001): 1) Pre-rift sequence extends from Precambrian to Eocene, 2) Syn-rift sequence represented by Miocene sediments, and 3) Post-rift sequence represented by Post-Miocene sediments.

The structural setting in the Belayim Marine Oil Field is complicated and dissected by a complex pattern of faults. Some of these faults are normal faults and trending in the NW-SE direction (clysmic faults), while the others are trending in the ENE-WSW direction (cross faults). The result of such intersection is the fracturing of the Gulf of Suez into numerous fault blocks (horsts and grabens) with variable throws and dimensions (Awni, et al., 1990).

The hydrocarbon reservoirs in Belayim Marine Oil Field can be classified into prerift reservoirs (Nubia Formation) and synrift reservoirs (Belayim, Kareem and Rudies Formations) (El Ayouty, 1990 and Alsharhan, 2003).

The main objectives of this study are:

1- Construct the depth maps of the Miocene and Pre-Miocene formations, using seismic interpretation.
2- Interpret these maps, in order to locate the high and low of structural features.
3- Describe the tectonic regime in the study area, in terms of tectonic elements (type, position, configuration (pattern) and orientation).
4- Build a structural model of the studied oil field.

To achieve these objectives in the study area, the following work methodology was followed:

1- Load the available data, which are twenty 2D seismic lines and well logs for five wells (BMNE-01, BM-17, Bel-113-M-34, BM-72 and BM-85), with check shots using Petrel 2015 Schlumberger’s software (Figure 2).
2- Perform Well-to-seismic tie for identification of geological formation tops, using vertical seismic profiles (VSP), check shots and sonic logs.
3- Pick and loop reflection horizons of the interested formation tops all over the vertical seismic sections.

Fig. (1): Location map of Belayim Marine Oil Field.

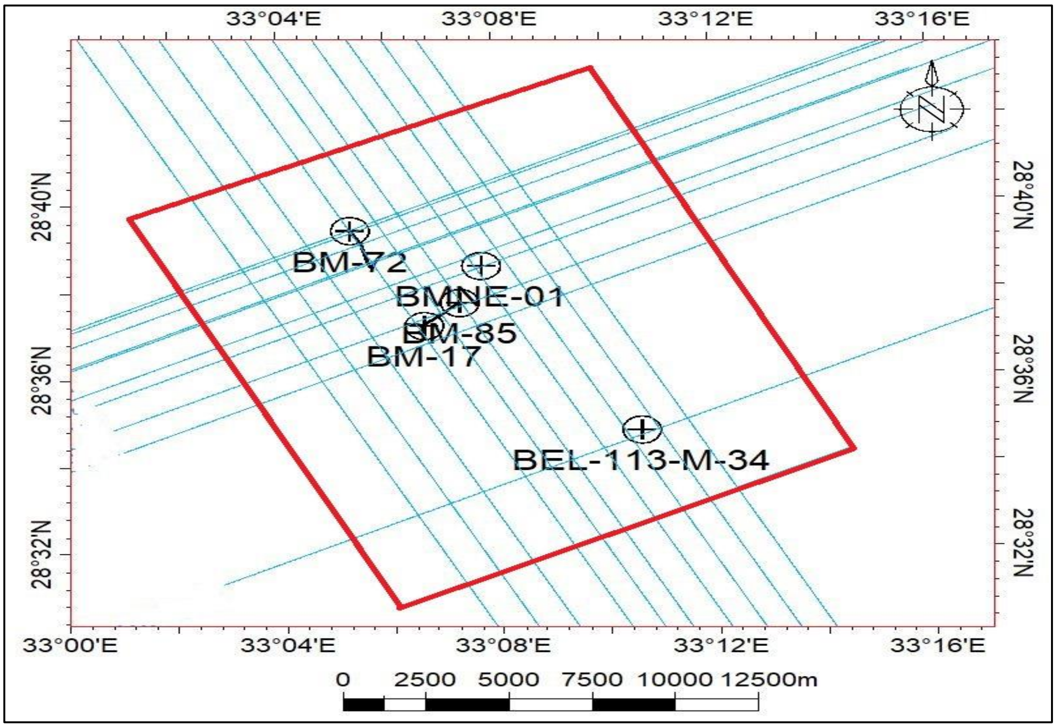

Fig. (2): Seismic lines and boreholes location map.

4- Depth structural mapping on the tops of four reflection horizons (Nubia, Rudeis, Kareem and Belayim).

5- Construct isochore maps for the Rudeis, Kareem and Belayim Formations.

6- Construct the fault structural framework of the study area.

7- Integrate all the previous results, to build the structural model of the study area.

SEISMIC DATA INTERPRETATION

The interpretation of seismic data was done, using Petrel 2015 software. Seismic data were integrated with well data (VSP and check shots), to achieve well-to-seismic tie step, that is to identify the geological formation tops on the seismic sections. Then, start the picking of three different Miocene horizons (Belayim, Kareem and Rudies Formations) in addition to Pre-Miocene Nubia Formation horizon, using the manual tracking technique, according to the reflection character of each horizon. Then, the fault picking was carried out on the seismic sections, according to Dobrin and Savit (1988), based on the discontinuities in reflection falling along an essentially linear pattern, disclosures in tying reflections around loops, divergence in dip not related to stratigraphy, diffraction patterns and distortion or disappearance of reflections below suspected fault lines, to construct the fault polygon of each horizon.

The time maps and average velocity maps were constructed on the tops of the seven horizons. The depth maps were generated through a depth conversion process of the time values multiplied by the corresponding average velocity values for each horizon, and divided by two; this produces depth values of the interested horizons.

Isochore maps were constructed for the Pre-Miocene, Rudeis, Kareem and Belayim, South Gharib and Zeit Formations, by subtracting the depth values of each two sequential formational tops.

Interpreted Seismic Sections

Figure (3) shows the seismic inline (L2853) that is located at the northern part of the field. This section illustrates the structural configuration of Belayim Marine Field where the main horst defining the field is very small in the northern part. None of the faults dissect the Zeit or South Gharib Formations. The Kareem, Rudeis and Nubia Formations have a complex structure, as they are dissected by several normal faults.

Figure (4) shows the seismic inline (L2678) that is located in the central part of the field. This section shows the disappearance of the fault (F10) and the appearance of the Miocene fault (F8). The main horst of the field became wider than the northern part.

Figure (5) shows the seismic inline (L2384) that is located in the southern part of the field. This section shows similarity to the central part, except for the main horst of the field, which became wider.

Depth Maps:

Figure (6) shows the depth structure map on the top Belayim Formation, which indicates the structural high represented by a NW-SE trending anticline. This fold is dissected by NW-SE normal faults throwing to the SW and NE directions forming a horst at the centre of the field and cross faults trending in the ENE-WSW direction and throwing in the northern and southern directions. The depth ranges from 2000 m to 2900 m.

Figure (7) shows the depth structure map on the top of Kareem Formation. This map shows similarity to the structure of Belayim Formation, but with more faults. The depth ranges from 2250 m to 3125 m.

Figure (8) shows the depth structure map on the top of Rudies Formation. This map shows similarity to the structure of Kareem Formation. The depth ranges from 2375 m to 3375 m.

Figure (9) shows the depth structure map on the top of Nubia Formation. The structure of this horizon is represented by a three-way dip closure dissected by some normal faults throw to the SW and NE directions. The depth ranges from 3000 m to 4250 m. This map shows the maximum throw of the main field-bounding fault, which is about 800 m at the western side of the field.

1) Isochore Maps:

Isochore maps are usually constructed by subtracting the depth values of each two sequential top formations projecting on them their dissecting faults.

Figure (10) shows the Belayim isochore map. The thickness above the field horst is very small and become thicker on the western and eastern sides, which indicate that, the faults were active during deposition of the Belayim Formation.

Figures (11 and 12) show the isochore maps of Kareem and Rudies Formations, where the thicknesses of these two formations are slightly homogeneous in the eastern side, while they increase toward the western down thrown area.

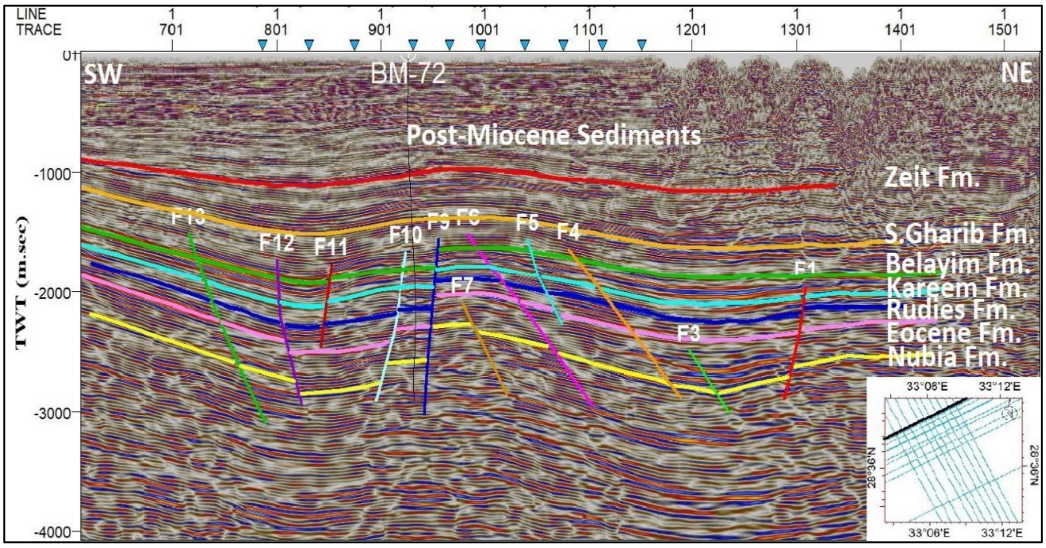

Fig. (3): Interpreted seismic inline (L2853).

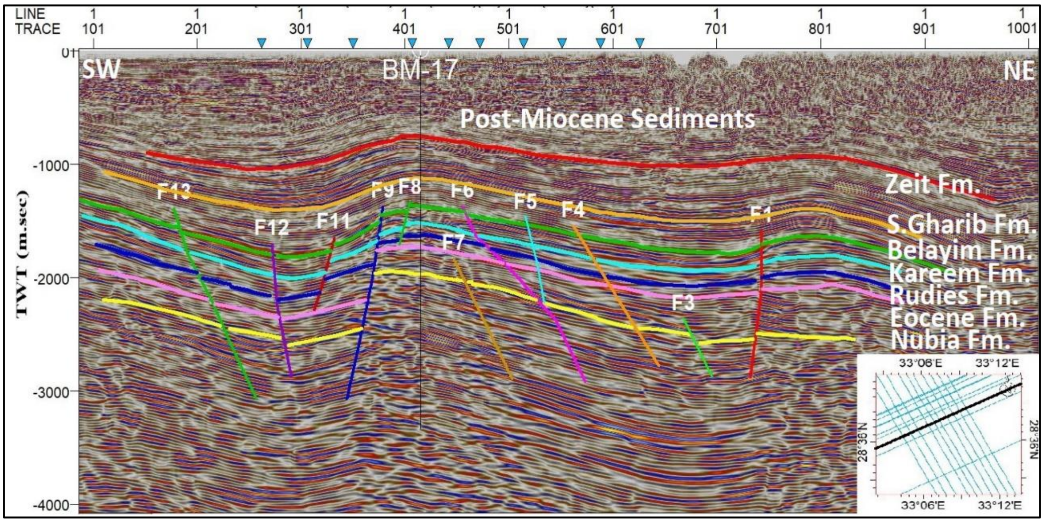

Fig. (4): Interpreted seismic inline (L2678).

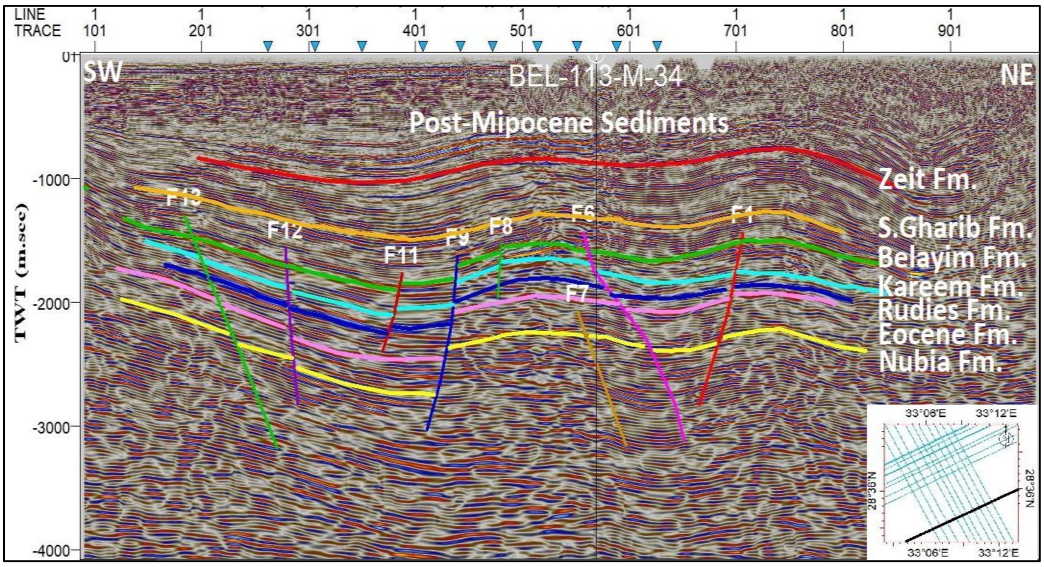

Fig. (5): Interpreted seismic inline (L2384).

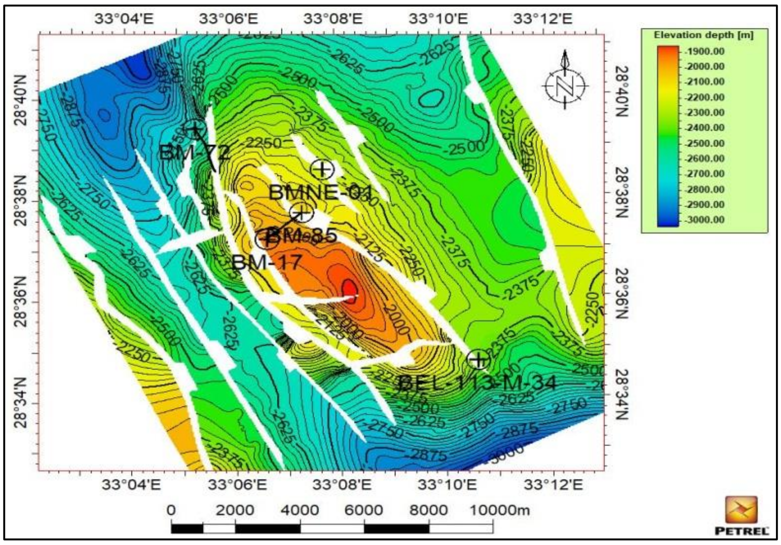

Fig. (6): Depth structure map on the top Belayim Formation (CI=25 m).

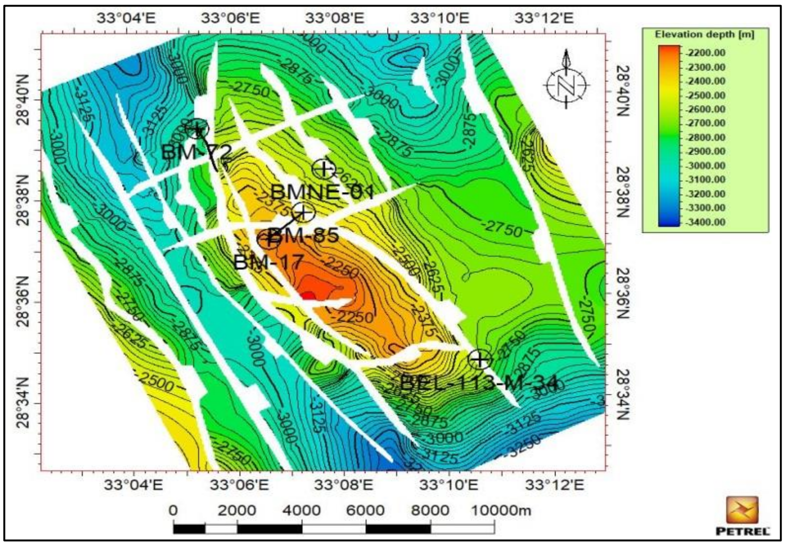

Fig. (7): Depth structure map on the top Kareem Formation (CI=25 m).

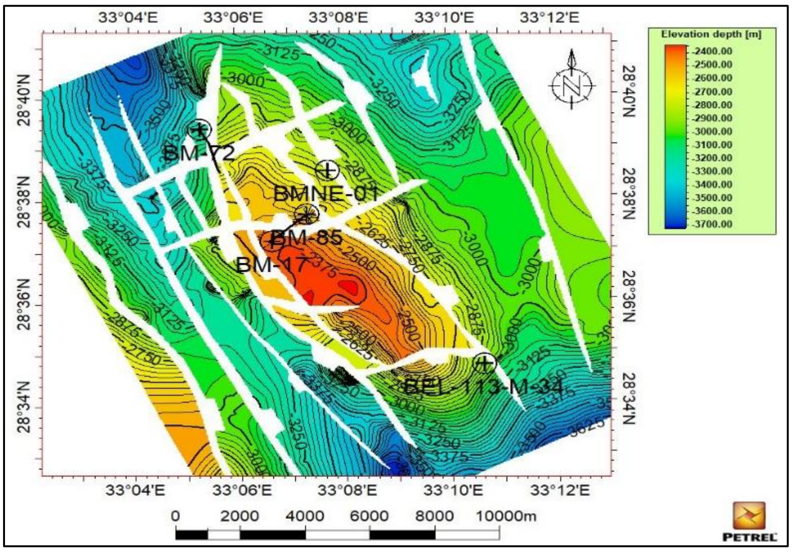

Fig. (8): Depth structure map on the top Rudies Formation (CI=25 m).

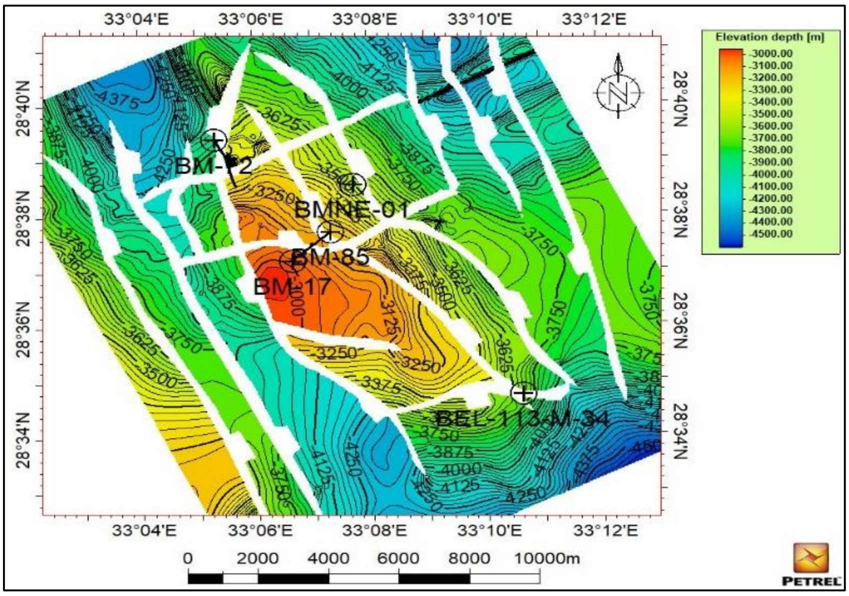

Fig. (9): Depth structure map on the top Nubia Formation (CI=25 m).

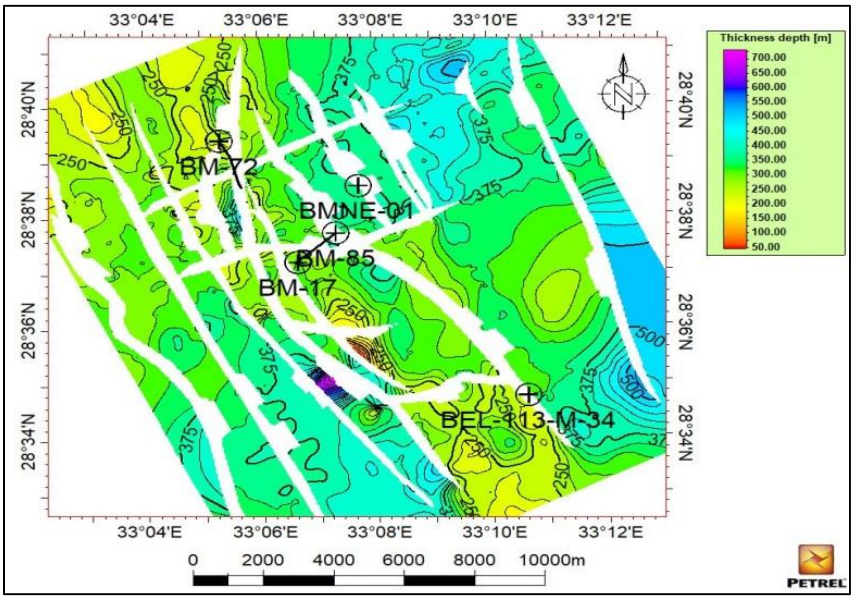

Fig. (10): Belayim isochore map (CI=25 m).

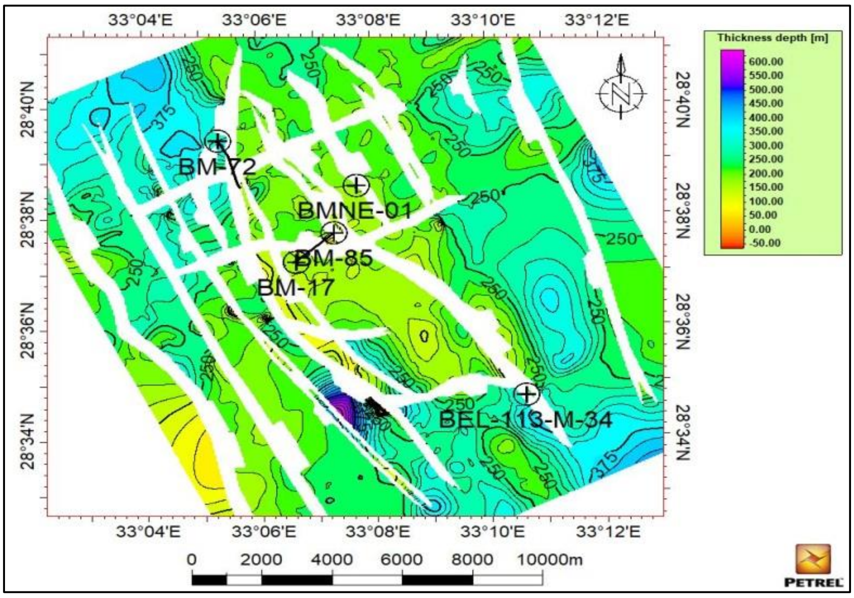

Fig. (11): Kareem isochore map (CI=25 m).

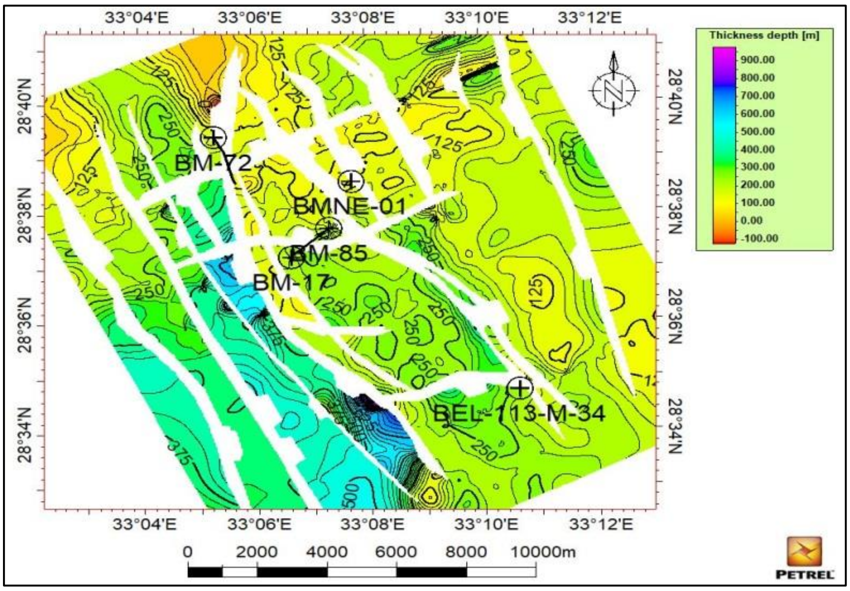

Fig. (12): Rudies isochore map (CI=25 m).

BUILDING STRUCTURAL MODEL

Structural modelling means a construction of geometrical and structural properties of the reservoir by defining a map of its structural top and the set of faults running through it. This stage of work is carried out by integrating interpretations of geophysical surveys (seismic) with available well data (Cosentino, 2001).

The building of the 3D structural model has been completed in the following three steps: Fault Modelling, Pillar Gridding and Making Horizons.

1- Fault Modeling:

The fault modeling starts with picking the faults on the 2D seismic sections to create the fault sticks (Figure 13). Then, the fault sticks are grouped by Petrel software to construct the fault surfaces (Figure 14). These fault surfaces indicate the dip, azimuth, length, orientation and trend of the interpreted faults.

The fault model of Belayim Marine Oil Field indicates that the predominant fault trend is the NW-SE direction with some faults trending in the ENE-WSW direction.

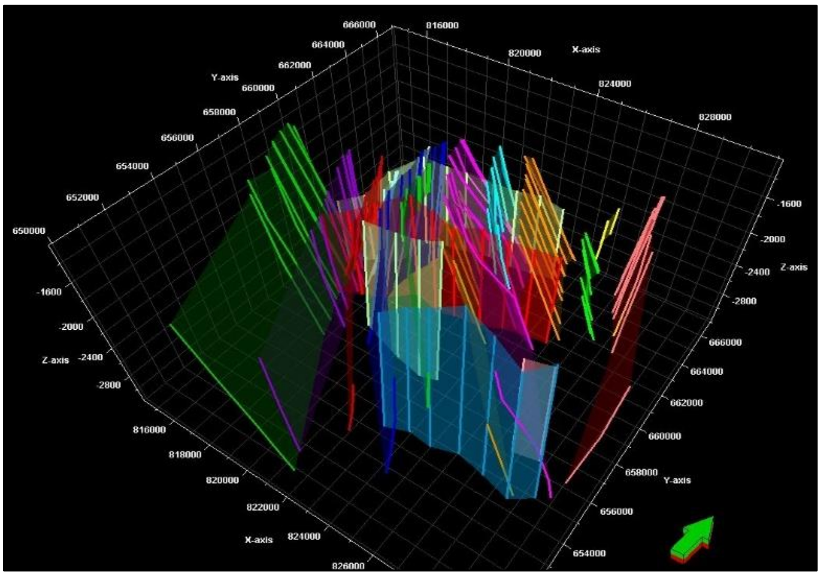

Fig. (13): The interpreted fault sticks collected from the 2D seismic sections, before they are converted to fault surfaces.

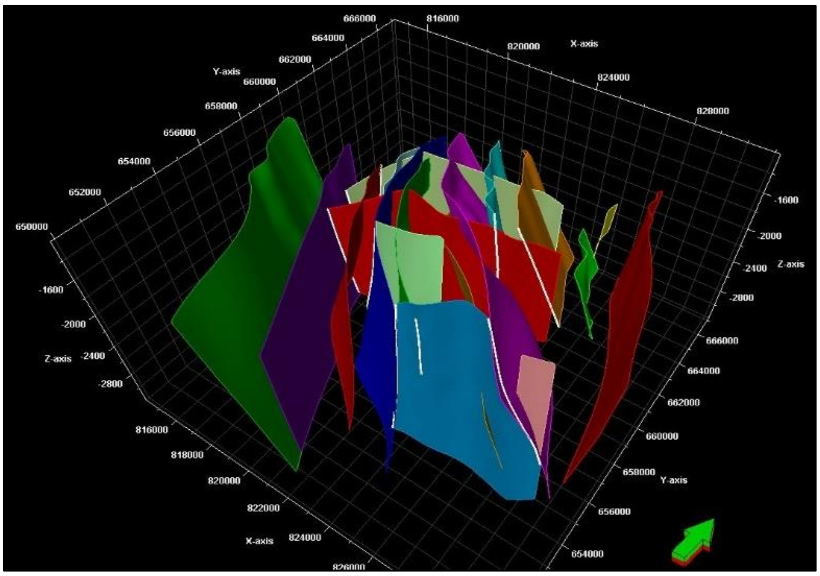

Fig. (14): The fault model of Belayim Marine Oil Field.

2- Pillar Gridding:

Generating the grid is considered as the base of all modeling. This step includes a creation of the 3D skeleton (cells) of the structural model and the fault pillars of the study area. The skeleton is either comprised of three grids of cells of the top, mid and base skeleton grids (Figure 15A) or hold on horizons and layer surfaces (Figure 15B) of the structure model and they are referred to the points of the fault pillars (Figure 16).

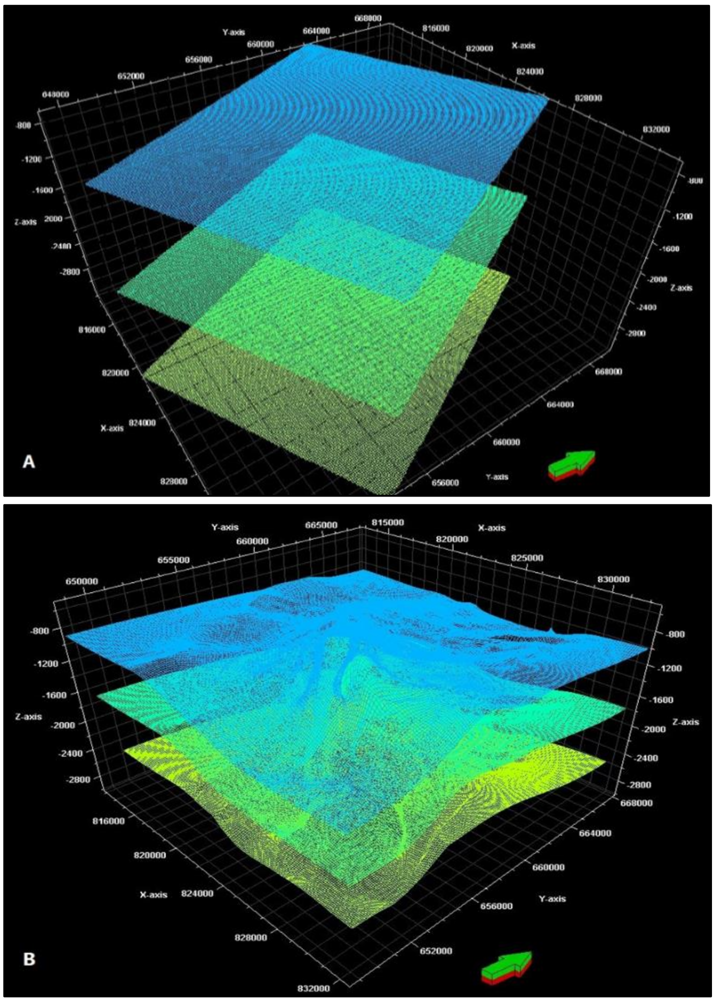

Fig. (15): The skeleton grid of top, mid and base (A) of structural model and horizons (B) in the study area.

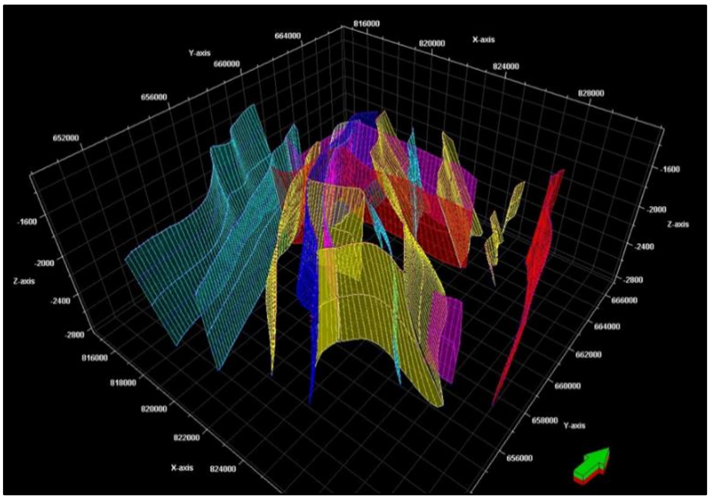

Fig. (16): The fault pillars of the study area in 3D view.

3- Horizon Modelling:

Once the fault model and pillar gridding process are completed, adding horizons is the next step in the workflow. The making horizons process generates independent geological horizons from XYZ input data, then building the vertical layering in the model. Figure (17) represent the horizon model of the seven interested formations of Belayim Marine Oil Field.

To generate additional horizons using relative distance to existing horizons (for example, isochores) use the make zones process. These two processes (Make horizons and Make zones) are used to create the geological zones within the model. It is expected that each zone will have similar petrophysical properties and can therefore be modeled using a single set of input data.

The process of 3D structural modelling includes the import of stratigraphic horizons in the study area. At this stage seven different formations have been integrated into the presented final 3D structural model (Figure 18).

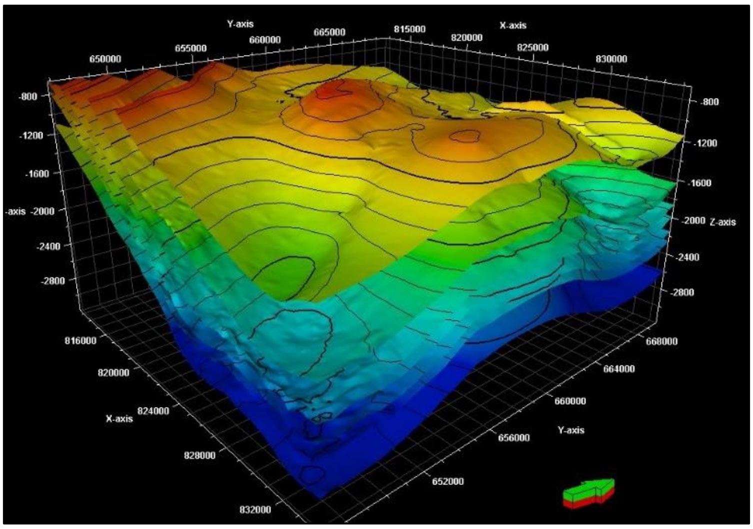

Fig. (17): Horizons model of Belayim Marine Oil Field.

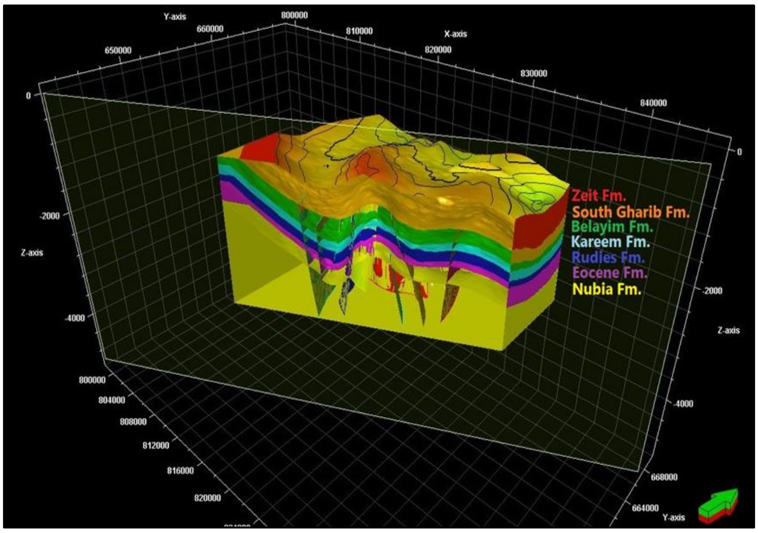

Fig. (18): Final 3D structural model of Belayim Marine Oil Field.

3D structural modelling provides information at each point of the model within the defined z-range. The uncertainty of models can be reduced by the calibration with borehole data. However, the most accurate models with the highest resolution can only be achieved by using additional information such as high resolution 3D seismic reflection data.

A geological cross-section has been constructed from the final 3D structural model mentioned above to show the lateral and vertical extensions of the studied formations and their dissecting faults (Figure 19).

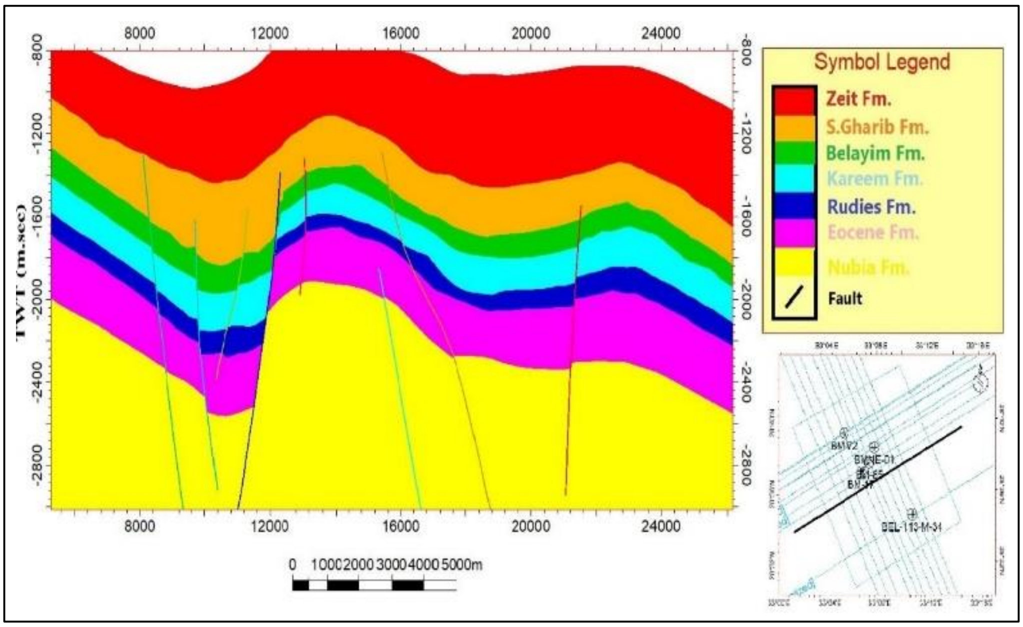

Fig. (19): Geological cross section of Belayim Marine Oil Field.

CONCLUSION

The final 3D structural model of Belayim Marine Oil Field has been built. The predominant fault trend is the NW-SE direction. Zeit and South Gharib Formations have a NW-SE doubly plunging anticlinal structure with a clear difference in dip of the flanks of the anticline with no dissecting faults. Belayim, Kareem and Rudies Formations have an anticlinal structure dissected by normal faults thrown in the SW and NE directions. The interested hydrocarbon reservoirs are Miocene (Belayim, Kareem and Rudies Formations) and Pre-Miocene (Nubia) Formation.

This final 3D structural model supports the detection of suitable prospects for hydrocarbon potentiality in the studied oil field at the three-way dip closure of the field.

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