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Interpretation and analysis of Upper Cretaceous structural features at GPY Field, Western Desert, Egypt

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ABSTRACT : The present study is dealing with structural mapping and analysis of the GPY Concession which is located in the South of Abu Gharadig basin, Western Desert, Egypt. The work achieved based on 2D seismic survey and well data to evaluate the structural characteristics of the study area. Seismic analysis software was used for constructing time-structural maps which have been converted to depth structural maps. The interpreted structural features are represented by depth structural maps for four Upper Cretaceous horizons namely; Top Bahariya, Top Abu Roash "G", Top Abu Roash "D" and Top Khoman. Structural mapping revealed the presence of normal, dextral- oblique and reverse faults and one NE-SW trending fold. The trend analyses of the mapped faults show NW-SE, ENE-WSW and NW-SE orientations. Structural analysis revealed Late Cretaceous deformation due to deep seated dextral wrenching. The present findings can be used as analogues for correlation with the nearby oilfields that are located within Abu Gharadig Basin.

KEYWORDS: Western Desert; GPY field; wrench tectonics;Late Cretaceous deformation.

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I. INTRODUCTION

The western desert is considered one of the most important oil and gas provinces in Egypt. It extends 1000 km from the Mediterranean Sea to the Sudan border in the south and 600 to 800 km western from the Nile valley to the borders of Libya and covers an area of 681.000 Km² (69% of the Egyptian surface) about two-thirds of the area of Egypt. GPY oil and gas field lies in the northern Western Desert of Egypt. It is located directly to the east of the Qattara Depression and occupies about 54 Km^2 (Fig. 1). The drilling activity started in 1981 by drilling the exploratory well GPY-1 based on seismic interpretation. This well was bottomed in Kharita Formation at a total depth of 2519 m. It was tested with 200 BOPD of 40 API from the AR/G reservoir (EGPC, 1992). Till now General petroleum Company (GPC) drilled 13 wells till GPY-13, which drilled in 2019. All of them are hydrocarbon-bearing in different reservoirs horizon except GPY-11, which is classified as a dry hole. The main goal of this study is to determine the structural setting of GPY oil and gas field, Abu Gharadig Basin, northwestern Desert, Egypt using specific Seismic analysis programming which used in transforming these 2D seismic data into maps and structural seismic section.

II. GEOLOGIC SETTING

The Abu Gharadig basin is a deep E-W oriented asymmetric graben and one of the most important prolific basins in the northern part of the Egyptian Western Desert of Late Mesozoic age in which the basement depth exceeds10,000 m. It is delimited by the Qattara Ridge assured from the North and Sitra Platform from the South. Sinistral wrenching prevailed during the early Cretaceous, resulting in a NE-SW series of normal faults (Meshref, 1990). The region was controlled by dextral wrenching that represented by compressional structures with a NE-SW trend, such as the Mid Basin arch, the anticline of Abu Gharadig, and Mubarak High, at the end of the Cretaceous. It also resulted in a number of normal faults oriented WNW-ESE to NW-SE forming at the sub-horizontal Qattara Ridge and the central graben system forming a horsetail structure. The Santonian was represented as an uplift and erosion period, after which tectonic activity stopped around the end of the Khoman "A" time period (Abdel Aal and Moustafa, 1988). The Abu El-Gharadig basin has been studied structurally by numerous authors such as (Abu-Hashish et al., 2020, Kitchka et al., 2015 and Elmahdy et al., 2020). Structurally, GPY area is a pre-Khoman uplifted NE-SW trending block. The structure is dissected by a large number of minor faults (EGPC, 1992).

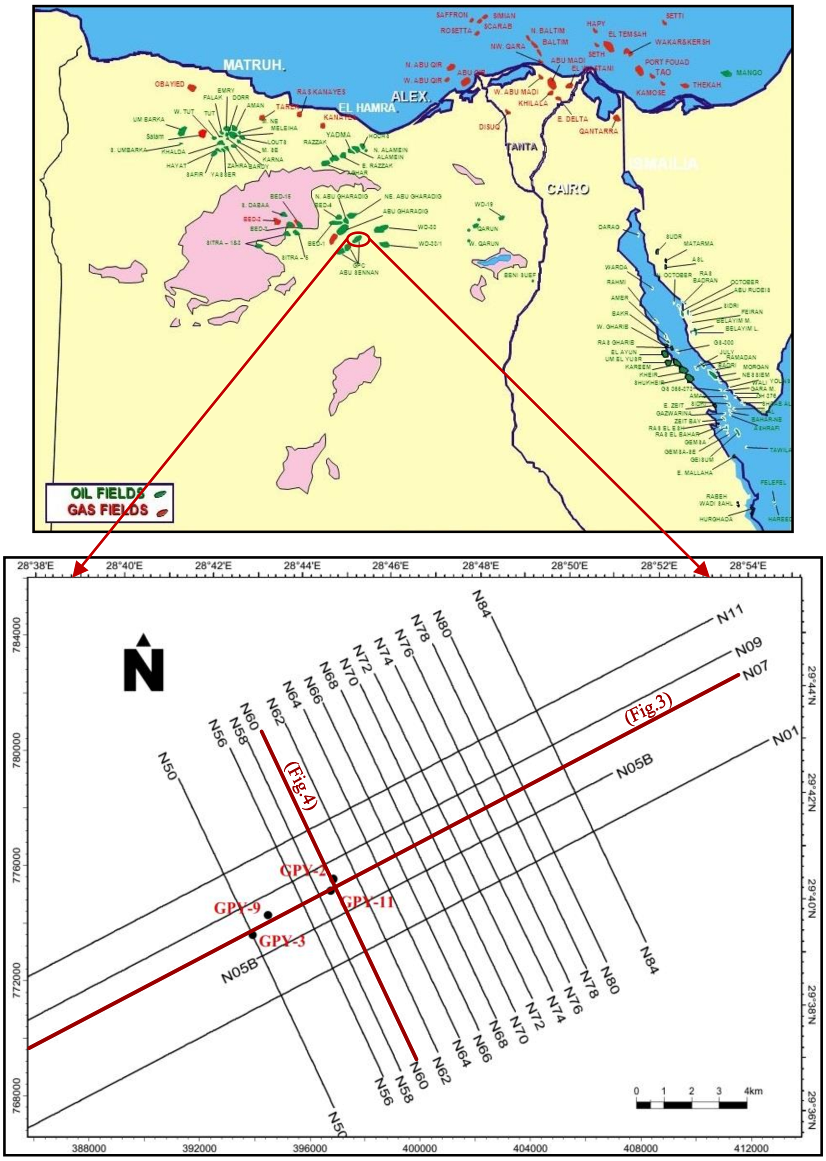

Fig. 1. Location map showing 2D seismic survey (five inline and fifteen xline) of GPY oil and gas vicinity in Abu Sennan Concession, Western Desert, Egypt.

Stratigraphically, the Abu Gharadig basin comprises rock units that range in age from Precambrian to Recent (Fig. 2). At GPY area, the rock units are represented by the Kharita Formation (Albian) with 390 m thick, which is composed of sand and shale intercalations. It is unconformably overlain by the Cenomanian Bahariya Formation which is composed mainly of fine- to medium- grained quartzitic sandstone, colorless to pink, medium to coarse grained with thin streaks of shales, interbeds and carbonate inclusions (Soliman, 1970). Abu Roash Formation was named by Norton (1967) rests conformably on the Bahariya Formation. It represents the marine neritic to open basinal facies. The lithology of the Abu Roash Formation reflects alternation of transgressive and regressive phase's characteristics respectively by cyclic to deep marine carbonates and shallower deposits of alternating shales and sandstones. El Gezeery et al., (1972) subdivided the Abu Roash Formation into seven members from bottom to top (G, F, E, D, C, B, A). The Abu Roash Formation is of Turonian-Coniacian age and has thickness of 420-670 m in the GPY area and is overlain by the Khoman Formation of Santonian to Maastrichtian age (Demerdash et al., 1984). It is composed of two-members: Khoman "A" member (Upper part) consists of cherty limestone, whereas Khoman "B" member (the Lower part) consists of Shale, silt, and argillaceous limestone and is absent in the over high areas. The total thickness of the Khoman Formation is 230-420 m.

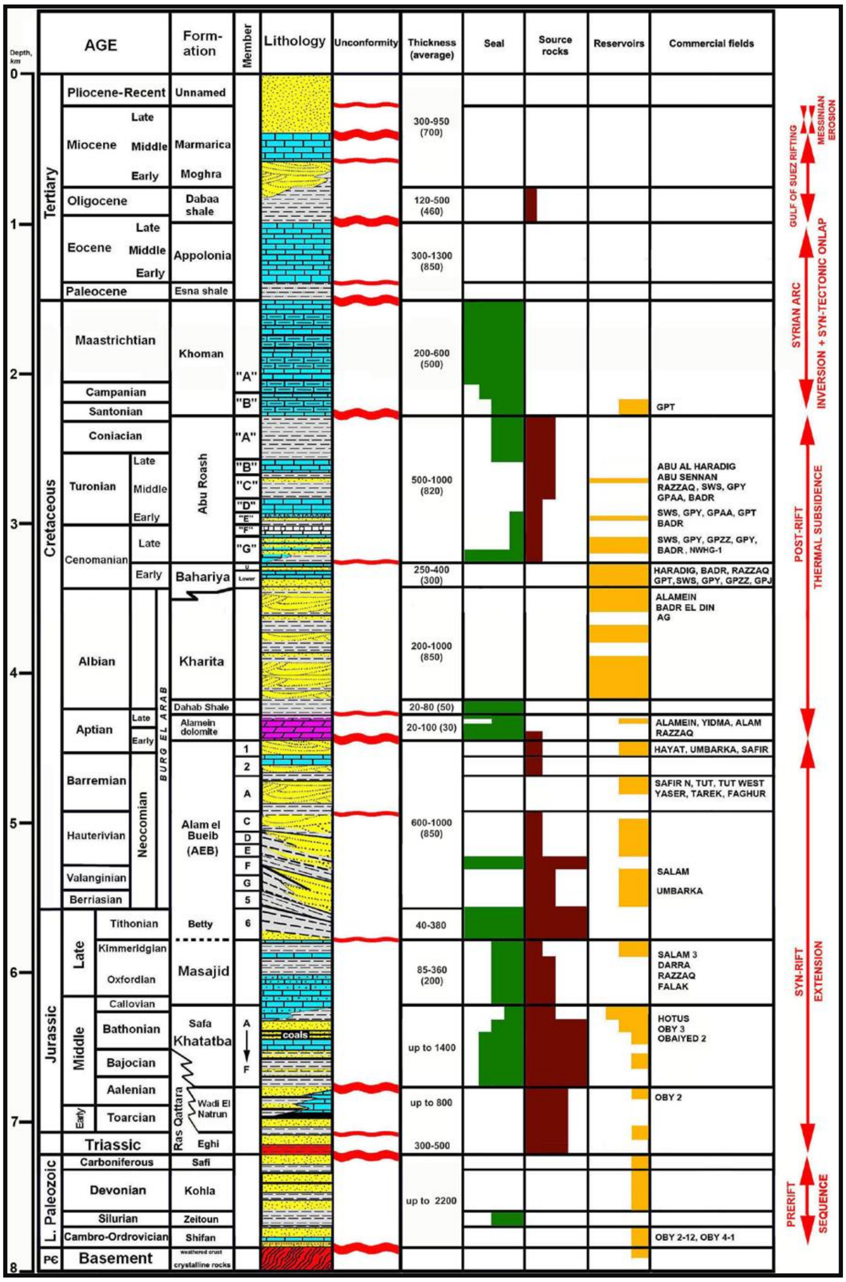

Fig. 2. Generalized Stratigraphic column of the Abu Gharadig basin petroleum system elements, stratigraphic control of hydrocarbon fields and main stages of tectonic development for the Western Desert petroleum province (Wescott et al., 2011).

III. DATA AND METHODOLOGY

This study based on twenty seismic lines and check shot data. Four wells are used: GPY-2, GPY-11, GPY-9, and GPY-3 (from north to south). The GPY-3 was the only well with check shot data (Fig. 1). Top Khoman Formation, Abu Roash D Member, Abu Roash G Member, and Bahariya Formation are picked from top to bottom. Time-structural maps have been converted to depth and used to study the area's structural setting. Schlumberger TM Petrel software was used for seismic interpretation.

IV. RESULTS AND DISCUSSION

Formation Tops Maps and Structural Geometry

Four Cretaceous horizons were picked (i.e., Top Bahariya, Top Abu Roash "G", Top Abu Roash "D" and Top Khoman) and the resulting two-way-time (TWT) structural maps were, later, converted to depth maps. Two chosen dip and strike sections are presented (Figs. 3 and 4) to demonstrate the structural geometry of the mapped area. The seismic interpretation shows oblique (with dextral component) and normal faults which have NE-SW and ENE-WSW trends in addition to some faults having NW-SE trend. Some faults dissect all upper Cretaceous rock units from Bahariya to top Khoman Formation whereas other faults die out within the Khoman Formation. (Figure 4) shows a SW-NE oriented seismic inline (strike) through GPY-3, GPY-9 and GPY-11 wells which displays the horsts and grabens in the GPY area. The first horst bounded by two faults F2 & F10 and the second horst bounded by F13 & F8. The first graben bounded by F1 (strike fault) &F8 and the second graben bounded by F14 & F15, showing gradual thickening of the upper cretaceous sediments toward the NE in the down dip direction toward the first graben. Figure (4) is NW-SE trending dip seismic section that passes through GPY-2 well. It displays a main asymmetrical fold trending NW-SE of pre-Khoman age dissected by a reverse fault (F1) which is parallel to the nearby fold axis.

The TWT structure contour map on the top of the Bahariya Formation based on the 2D seismic data (Fig. 5) shows an irregular distribution pattern with a maximum value of 2614 msec increases at the northeast and eastern parts of the study area. On the other hand, the time decreases at the western and southwestern parts of the study area, recording the minimum time of 1432 msec. Also, the TWT structure contour map on the top of the Abu Roash "G" Member (Fig. 6) shows an irregular distribution pattern with a maximum value of 2335 msec increases towards the northeastern and eastern parts of the study area. Alternatively, the time decreases at the western and southeastern parts of the study area, recording the minimum time of 1324 msec. Additionally, the TWT structure contour map on the top of the Abu Roash "D" (Fig. 7) shows an irregular distribution pattern with a maximum value of 2163 msec increases at the northeastern and eastern parts of the study area. Conversely, the time decreases at the western and southeastern parts of the study area, recording the minimum time of 1287 msec. The TWT map on the top of the Khoman Formation (Fig. 8) shows an irregular distribution pattern with a maximum value of 1596 msec increases towards the north and northeastern parts of the study area. The time decreases west and south wards recording the minimum time of 1001 msec.

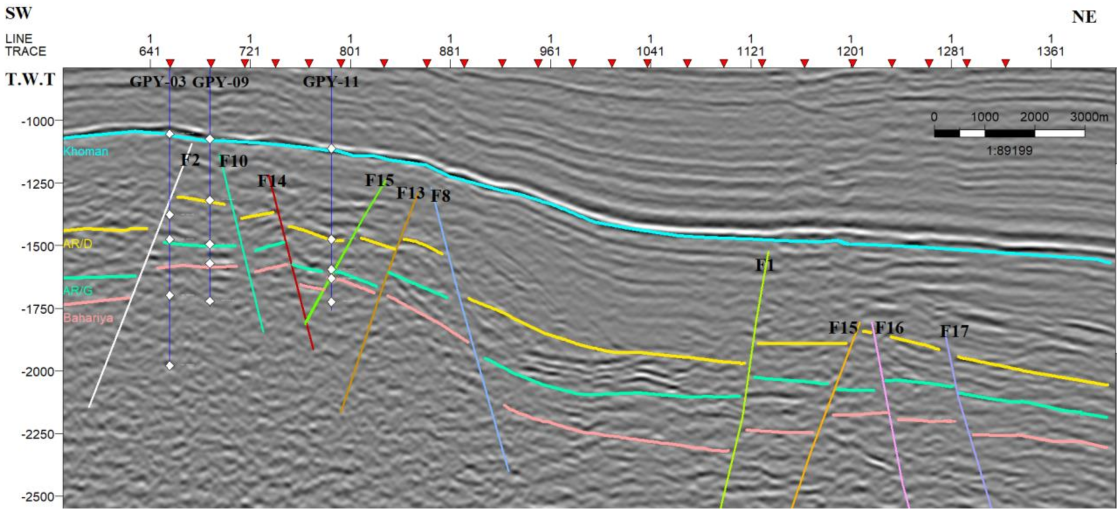

Fig. 3. Interpreted SW-NE seismic inline (strike) N07 displays the horsts and grabens in the GPY area. Note exhibits a clear raised fault block bounded by two normal faults for GPY-9 Well relative to the surroundings wells (GPY-3 Well and GPY-11Well).

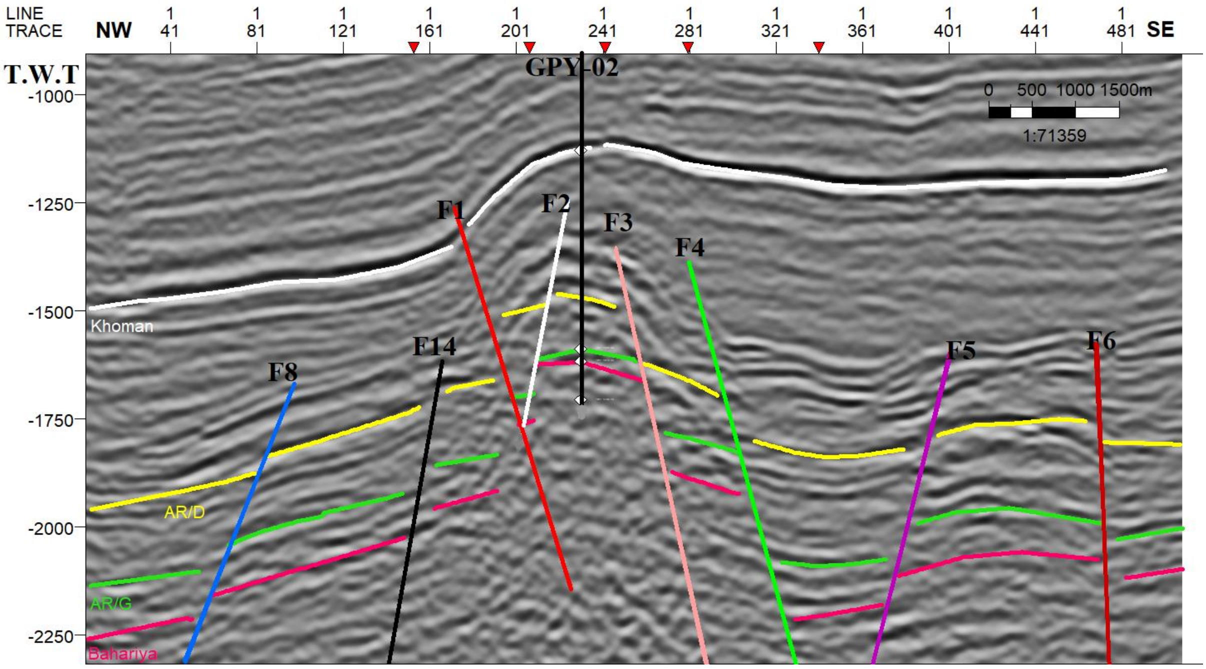

Fig. 4. Interpreted NW-SE seismic cross line (dip) N60 displays the main asymmetrical fold (NW-SE) of pre-Khoman age dissected by set of reverse fault (F1) and normal faults (F2 antithetic on F1), F3 and F4 all of them parallel to the fold axe and have the trend NE-SW in the GPY area.

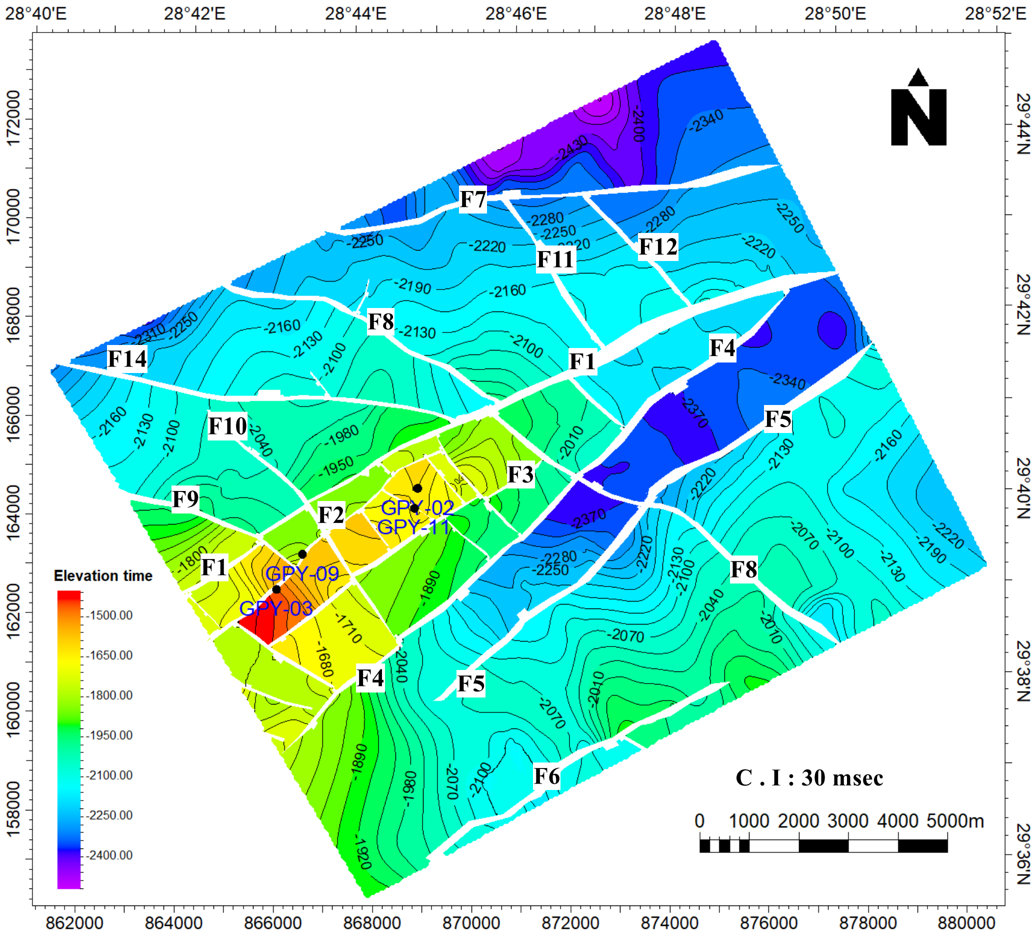

Fig. 5. TWT structural contour map on the top of Bahariya Formation.

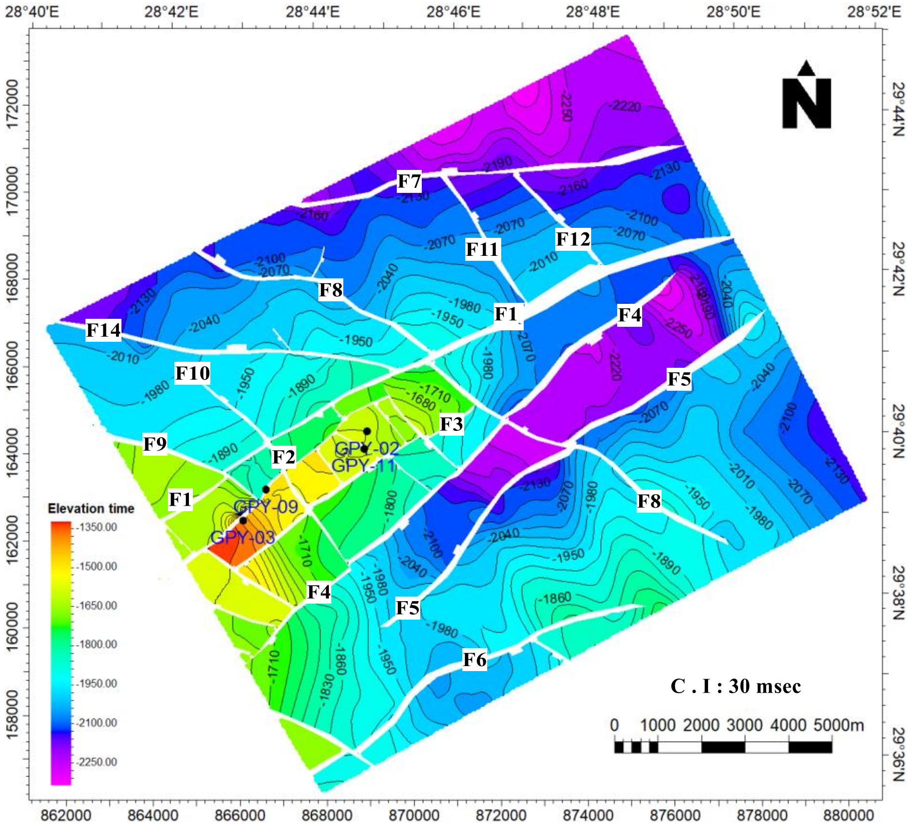

Fig. 6. TWT structural contour map on the top of Abu Roash G Member.

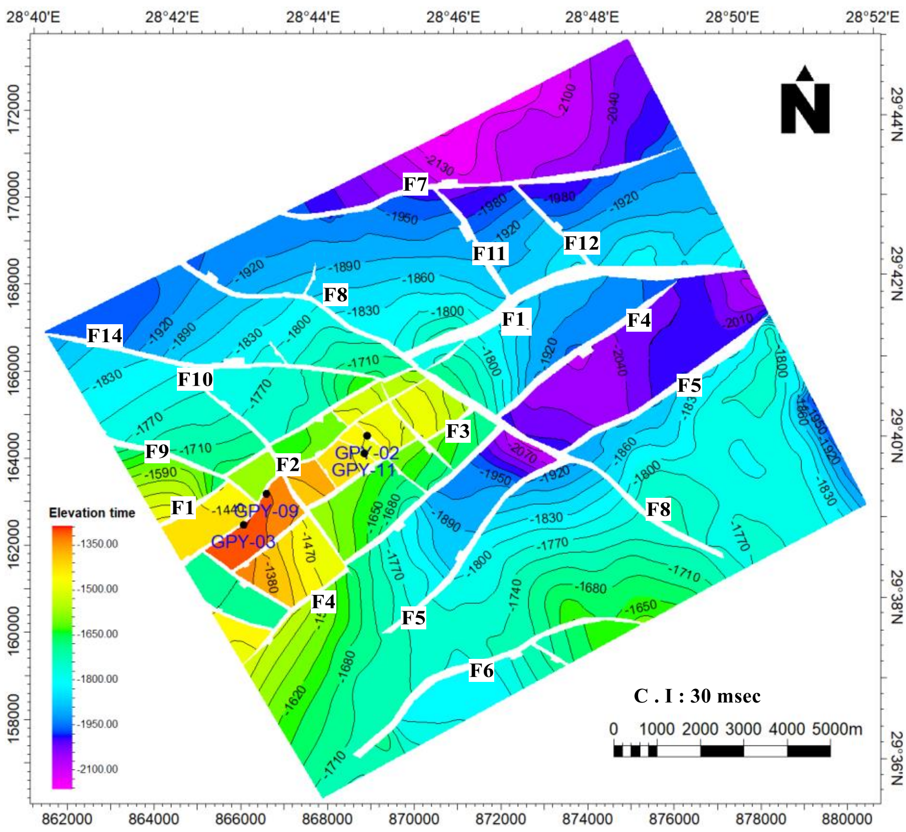

Fig.7. TWT structural contour map on the top of Abu Roash D Member.

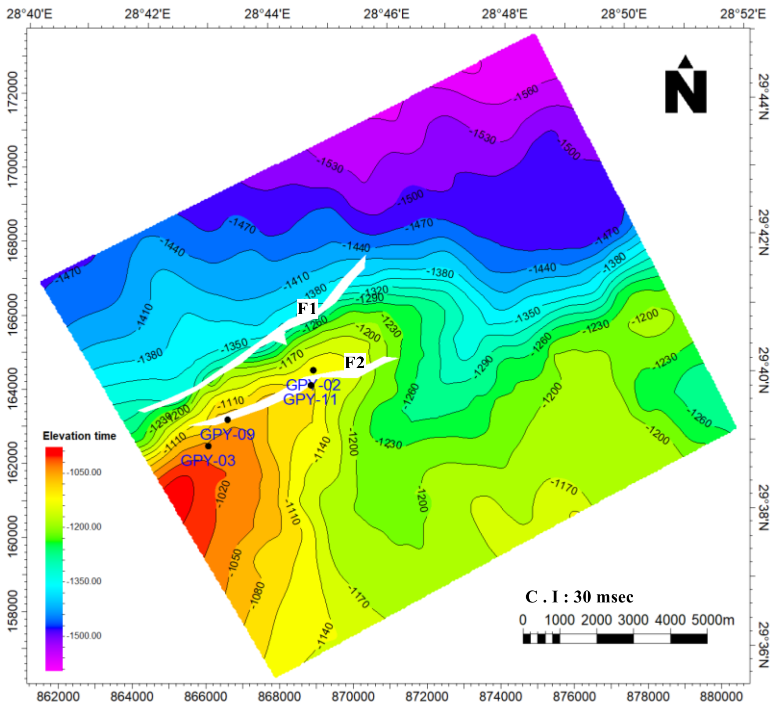

Fig. 8. TWT structural contour map on the top of Khoman Formation.

The velocity of Bahariya Formation (Fig. 9) increases on the central part of the study area recoding the maximum value up to 1.459 m/sec. Alternatively, the velocity decreases on the eastern part of the study area, recording the minimum value down to 1.154 m/sec. The velocity of Abu Roash G Member (Fig. 10) increases on the central part of the study area recoding the maximum value up to 1.456 m/sec. Conversely, the velocity decreases on the southwestern part of the study area, recording the minimum value down to 1.205m/sec. The velocity of Abu Roash D Member (Fig. 11) increases on the northern and eastern parts of the study area recoding the maximum value up to 1.33m/sec. On the other hand, the velocity decreases on the southwestern parts of the study area, recording the minimum value down to 1.185m/sec. The velocity of Khoman Formation (Fig. 12) increases on the central part of the study area recoding the maximum value up to 1.163m/sec. Moreover, the velocity decreases on the western and southwestern part of the study area, recording the minimum value down to 1.035 m/sec.

The constructed depth structure contour maps on top of the Bahariya Formation (Fig. 13), the Abu Roash "G" Member (Fig. 14), the Abu Roash "D" Member (Fig. 15) and Khoman Formation (Fig. 16) show two major fault trends which are the ENE-WSW and NW-SE directions. According to the mapped faults, it can be related to the major tectonic movements which give Abu Gharadig basin present shape. Extensional structures in the form of grabens and horsts have been recorded in the northeast, east, west, and central parts of the study area. On the contrary, compressional structures in the form of a reverse fault (F1) and its related fold is well represented on the top of the Khoman Formation at the western part of the area (Fig. 16).

The general configurations of the mapped horizons (i.e., the Bahariya Formation, the Abu Roash "G" Member, the Abu Roash "D" Member and Khoman Formation) are thus structurally controlled. The interpreted depth values on the top of the Bahariya Formation ranging from 3412 m in their deepest location to 1795 m in their shallowest location. The thickness of the Bahariya Formation changes considerably in the GPY area. The ideal thickness of Bahariya Formation in this area ranging from 159 m to 376m. The interpreted depth values on the top of the Abu Roash "G" Member range from 3243m in the deepest location to 1715m in the shallowest one. The thickness of the Abu Roash " G " Member changes considerably in the GPY area. Ideal thickness of Abu Roash "G" in this area ranging from 46mto 135m then almost the faults affecting Abu Roash "G" Member. The interpreted depth values on the top of the Abu Roash "D" Member range from 2818m in the deepest location to 1570m in the shallowest one. The thickness of the Abu Roash " D " Member changes considerably in the GPY area. Ideal thickness of Abu Roash "D" in this area ranging from zero to 111m. The interpreted depth values on the top of the Khoman Formation range from 1595m in the deepest location to 977 m in the shallowest one. The thickness of the Khoman Formation changes considerably in the GPY area. Ideal thickness of Khoman Formation in this area ranging from 234 to 415m.

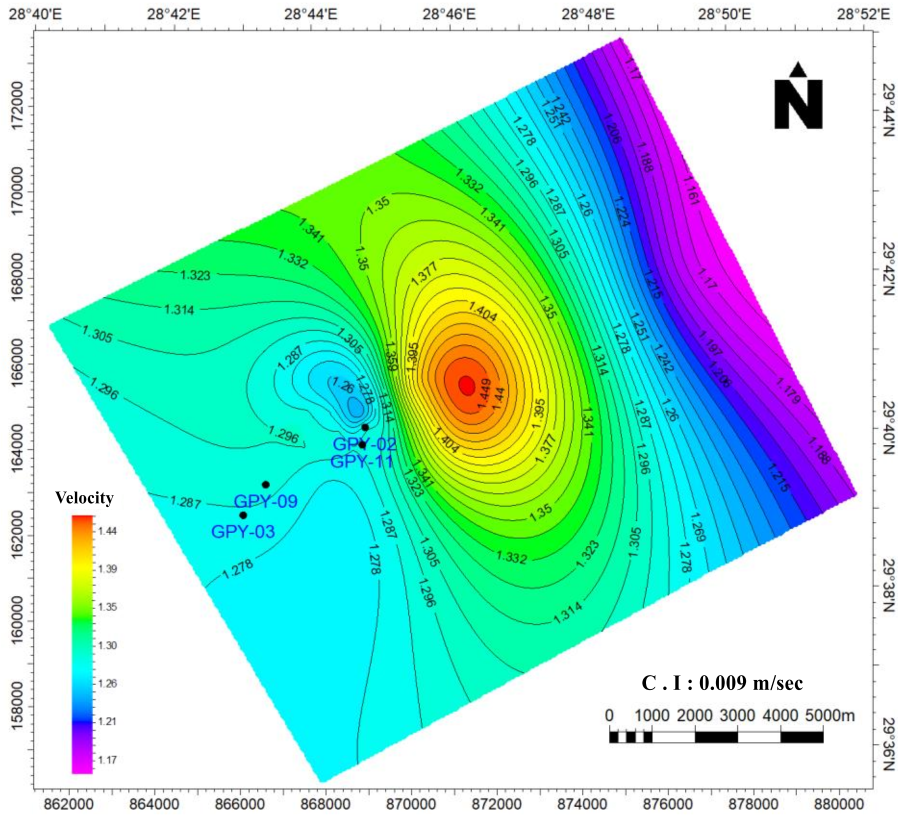

Fig. 9. Velocity map on the top of Bahariya Formation.

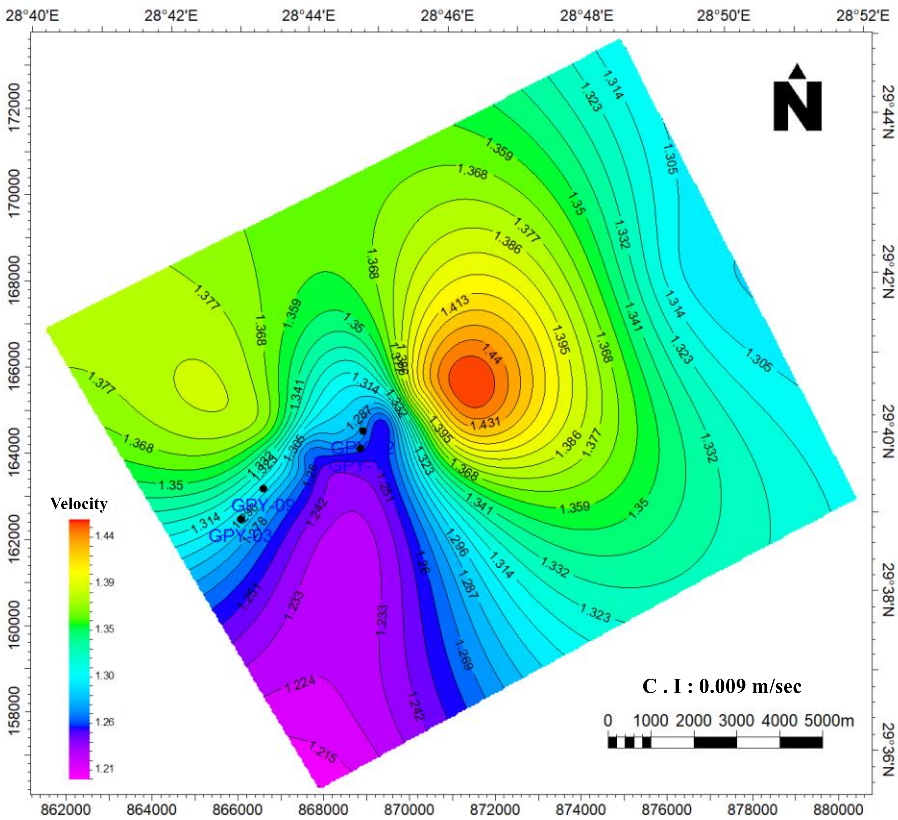

Fig. 10. Velocity map on the top of Abu Roash G Member.

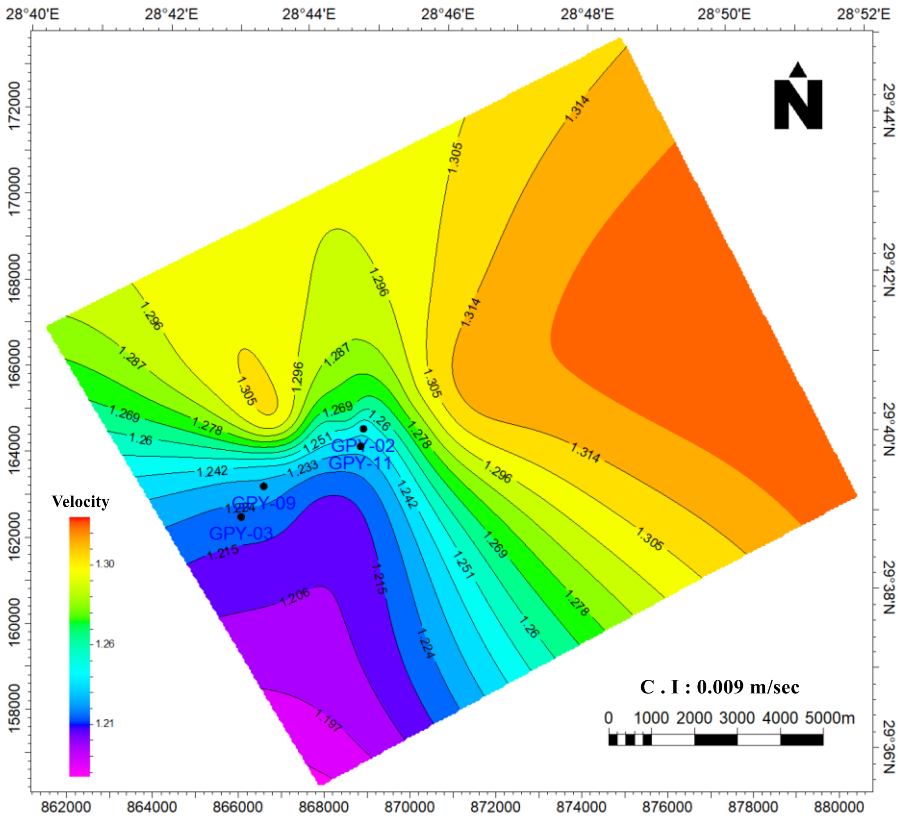

Fig. 11. Velocity map on the top of Abu Roash D Member.

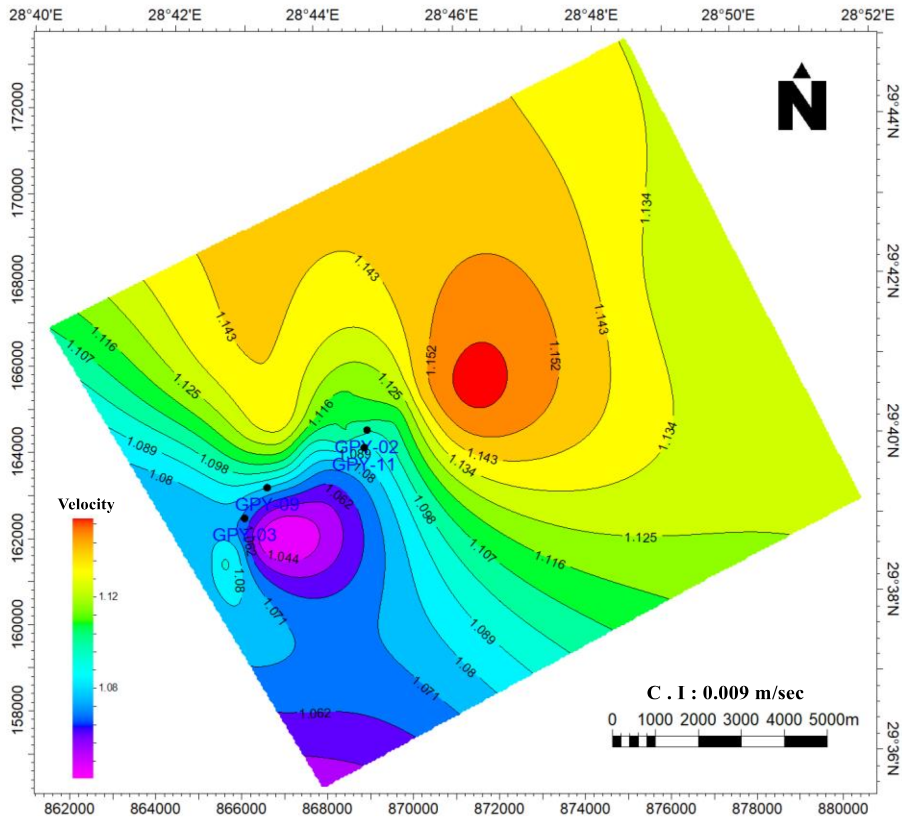

Fig. 12. Velocity map on the top of Khoman Formation.

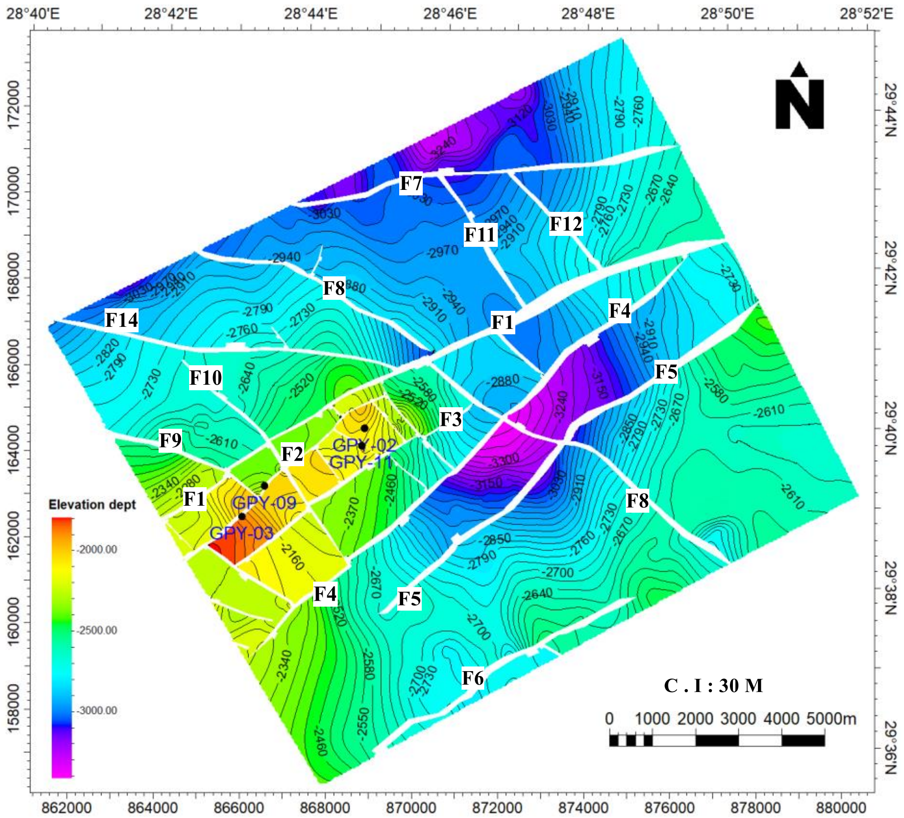

Fig. 13. Depth structural contour map on the top of Bahariya formation.

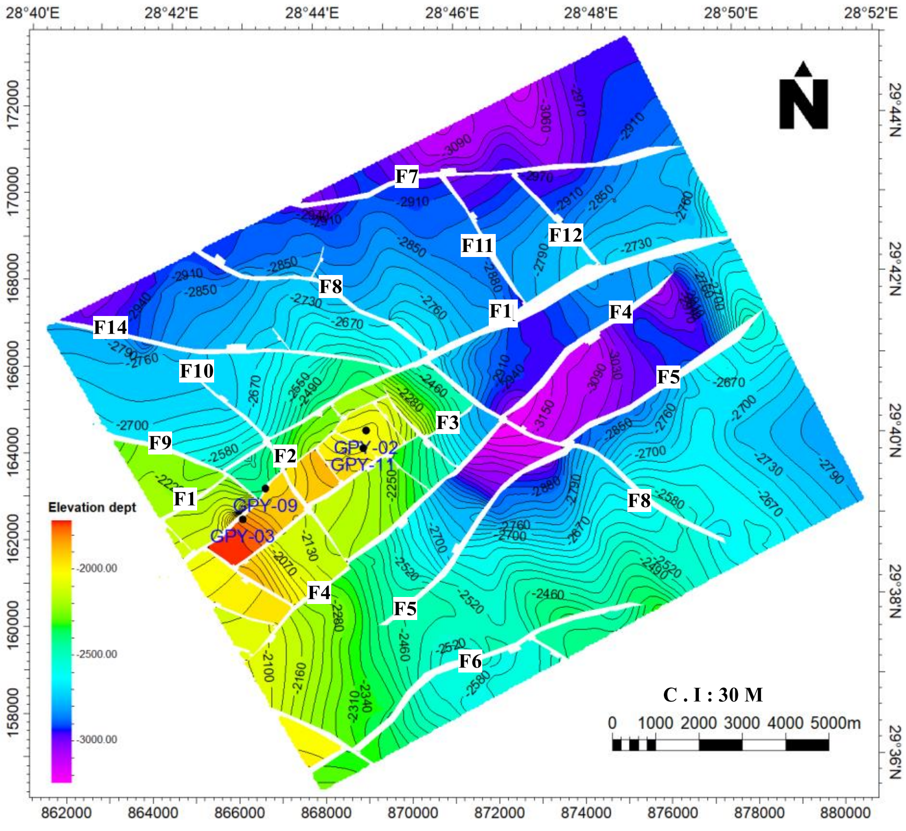

Fig. 14. Depth structural contour map on the top of Abu Roash G Member.

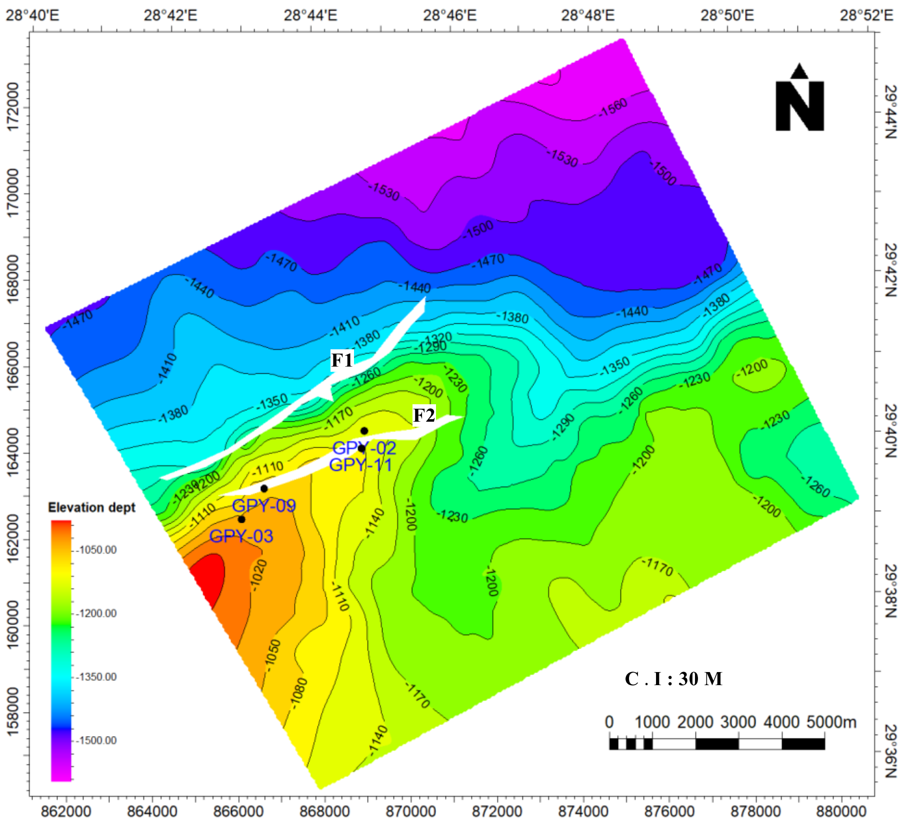

Fig. 15. Depth structural contour map on the top of Abu Roash D Member.

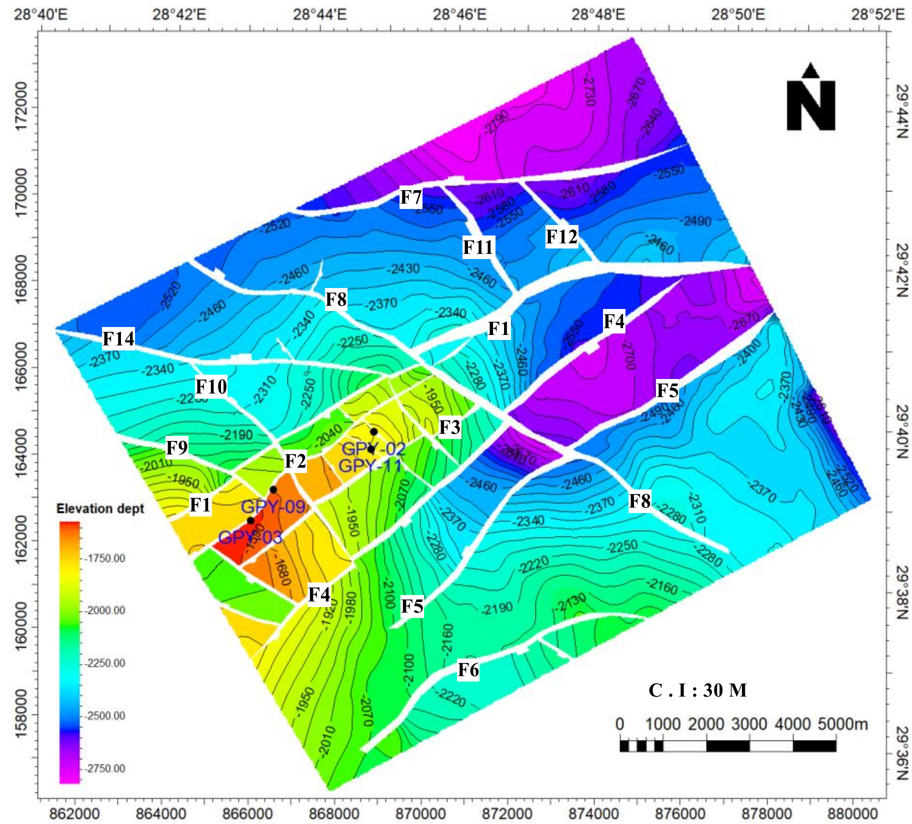

Fig. 16. Depth structural contour map on the top of Khoman Formation.

Structural Analysis

Structural analysis of the interpreted and mapped structures associated with Upper Cretaceous sediments revealed that the NE-trending folds and the reverse fault in the study area (F1) are shaped at right angle to a horizontal NW-SE oriented maximum principal stress ($\sigma 1$) in the light of the wrench model of Wilcox et al. (1973). The NW-SE normal faults are formed perpendicular to horizontal NE-SW oriented minimum principal stress ($\sigma 3$). The NE and ENE oriented oblique faults represent the Y-shears and P-shears, respectively, whereas, the R′ is absent in the study area. It is worth mentioning that Moustafa (1988) concluded the R′ is not common or absent in northern Egypt, because of the increase in the sedimentary cover. This structural system may symbolize the expression of a deep seated E-W oriented principle strike slip deformation zone (Fig. 17).

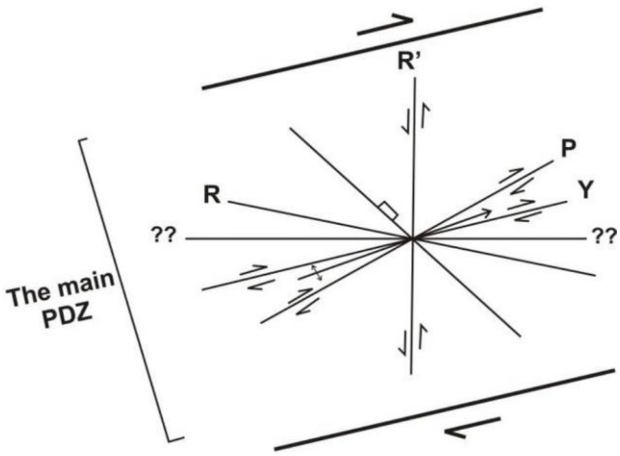

Fig. 17. Wrench model as applied to the study area.

V. CONCLUSION

Using the interpretation of 2D seismic data, detailed structural mapping of GPY fields was accomplished in the light of four picked Upper Cretaceous horizons. The interpretation indicates a main asymmetrical fold (NE-SW) of pre-Khoman age that is dissected by a reverse fault (F1). Also, the interpretation indicates three major fault trends oriented NE-SW, ENE-WSW and NW-SE based on the constructed structural contour depth maps for each horizon. Structural analysis revealed that the interpreted structures are related to the Upper Cretaceous tectonics at which it formed due to deep seated dextral wrenching.

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