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Seismic Data Interpretation of the Upper Cretaceous Succession in the Karama SW Oil Field, Western Desert, Egypt

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Abstract: The northern part of the Western Desert seems to have passed through different phases of deformations in the late Cretaceous, post-middle Eocene and middle Miocene and the subsurface data indicated an early Mesozoic phase of normal faulting resulting of the tectonic evolution of the northern Western Desert where several hydrocarbon fields has been. Geophysical information in the form of seismic and well logging data are used to understand the structural elements, tectonic setting and stratigraphy of the upper Cretaceous rock units (Bahariya and Abu Roash Formations) in the Karama SW oil field, northern part of the Western Desert. The interpretation of the available seismic data led to the identification of the reflectors under investigation as well as to map and determine the structural elements on the tops of the evaluated lithostratigraphic units. 3D Seismic lines were used to construct four depth structure contour maps on the top of Abu Roash "C", Abu Roash "E", Abu Roash "G" and Upper Bahariya Formations reflecting the occurrence of major normal faults in various directions (mainly NW-SE) forming four way structural traps in shallow reservoirs in down thrown side from major fault and also there way dip closure.

Keywords: Seismic data, Upper Cretaceous, Karama SW Oil Field, Western Desert, Egypt

1. Introduction

North Western Desert in Egypt has the most prolificpetroleum province after the Red Sea region, it comprises aconsiderable number of significant petroleum basins such as Alamein Basin, Matruh- Shushan Basin, Faghur Basin, Gindi Basin, Abu Gharadig Basin Hydrocarbon occurrence in the Western Desert is closely related to the tectonic activities and stratigraphic history of the area which has created a series of reservoirs and seals. Most fields in the northern Western Desert are related to structures formed in Late Cretaceous-Eocene and are placed in or at the edge of early depo-centers that later became kitchen areas (Abu El Naga, 1984) (Said, 1990).

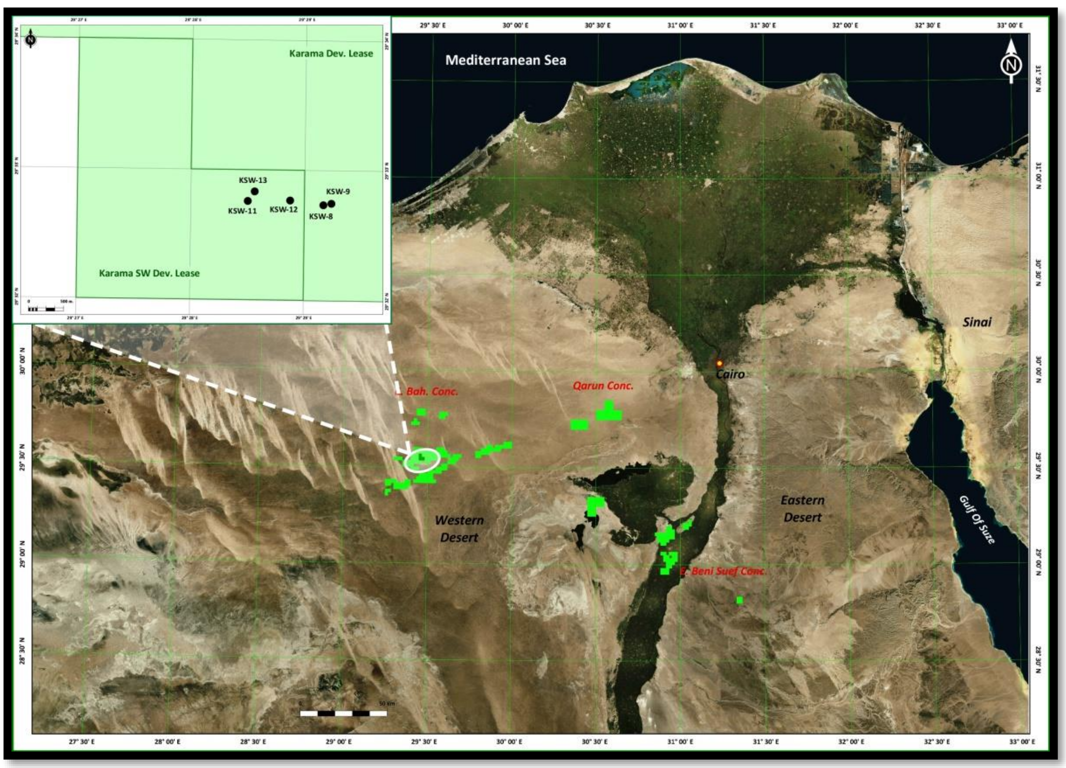

Figure 1: Location Map of Karama SW oil field in East Bahiriya Concession

Most of the sedimentary basins in Egypt are located in the northern Western Desert e.g. Matruh- Shushan basin, North Meleiha basin, Alamein basin, Abu Gharadig basin (of our interest), Gindi basin, Beni Suef basin, and Paleozoic Basins Abu Gharadig basin includes a huge number oil and gas fields in its depo-center and troughs; such as Abu Gharadig field, North Abu Gharadig field, Badr El-Din (BED) lease, GPT field, Wadi field (WD 33), Asala platform, Diyur field, , Raham lease, Karama -Karama SW leases in which Karama SW oil field exist(Fig-1:2). (Awad, 1984), (Schlumberger, 1984), (Bayoumi and Lotfy, 1989), (Bayoumi, 1996), (El Diasty, 2014), (El-Sherbiny, 2002), (Hendy et al., 1992), (Mahmoud et al.,2016), (Shahin et al., 1986),(Kamel, 2017) and (Mahmed, 2018) and others.

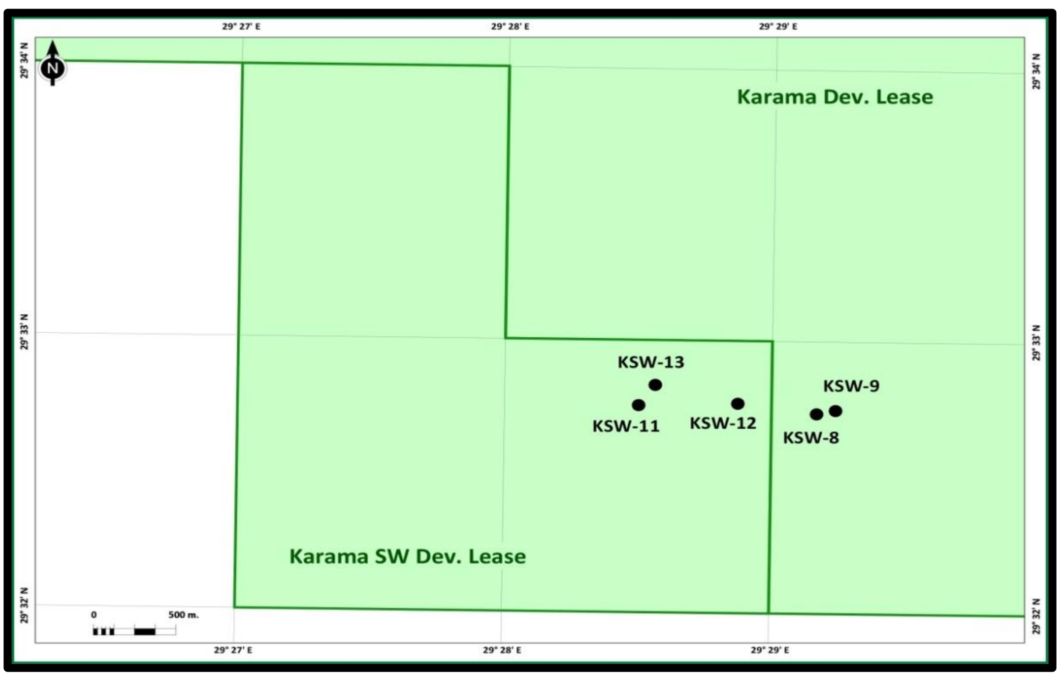

Figure 2: Well Location map of the Study area

2. Geological Settings

Abu Gharadig Basin is almost the largest basin in the northern Western Desert. Its structure has been recognized as a major rift basin in which there are numerous localized highs that in NE-SW oriented plunging anticlines that are believed to be fault-controlled folding (Schlumberger, 1995). The northern margin of this basin is marked by a major border fault zone which up- throws basement to about 10,000 feet forming Sharib-Sheiba ridge, and the southern boundary is called Sitra platform (Enayet, 2002). Abu Gharadig basin is considered as the most petroliferous basin in the Western Desert as far as hydrocarbon production and potential. The study area located SW from Aqsa, karama main, Karama NE, Karama SE fields and NE from Frash field and east from Amana field (Kamel, 2022) (Kamel, 2017) and (Mahmed, 2018) and others. The East Bahariya concession -where the study area exists- is an eastern extension of the Abu Gharadig basin, The eastern side of Abu Gharadig basin inclusive of the study area is defined on the south by the NE trending Asala Ridge (Fig-3), part of the regional Kattaniya Ridge, and to the north by a series of large-displacement, south-dipping normal faults define the northern edge of the Abu Gharadig basin as far west as the Badr El-Din fields (El-Sherbiny, 2022).

This area is structurally complex having undergone several periods of extension in the Jurassic and Cretaceous and at least one period of Late Cretaceous-Tertiary compression. Trap sizes are relatively small but in aggregate constitute a valuable resource (Pivnik et al, 2007). Especially the area of study is affected by this compressional sense.

2.1 Stratigraphic Settings

The stratigraphic succession of Abu Gharadig basin encountered more than one source rock e.g. Khatatba Fm., Alam El Bueib Fm., Alamein Fm. and Abu Roash F Mbr. Reservoir rock, as well as source rock, varies in lithology and age; Abu Gharadig basin encountered Khatatba sand as a reservoir rock, in addition to Alam El Bueib Fm., Alamein Fm., Kharita Fm., Bahariya Fm. and Abu Roash C, E, and G Mbrs.

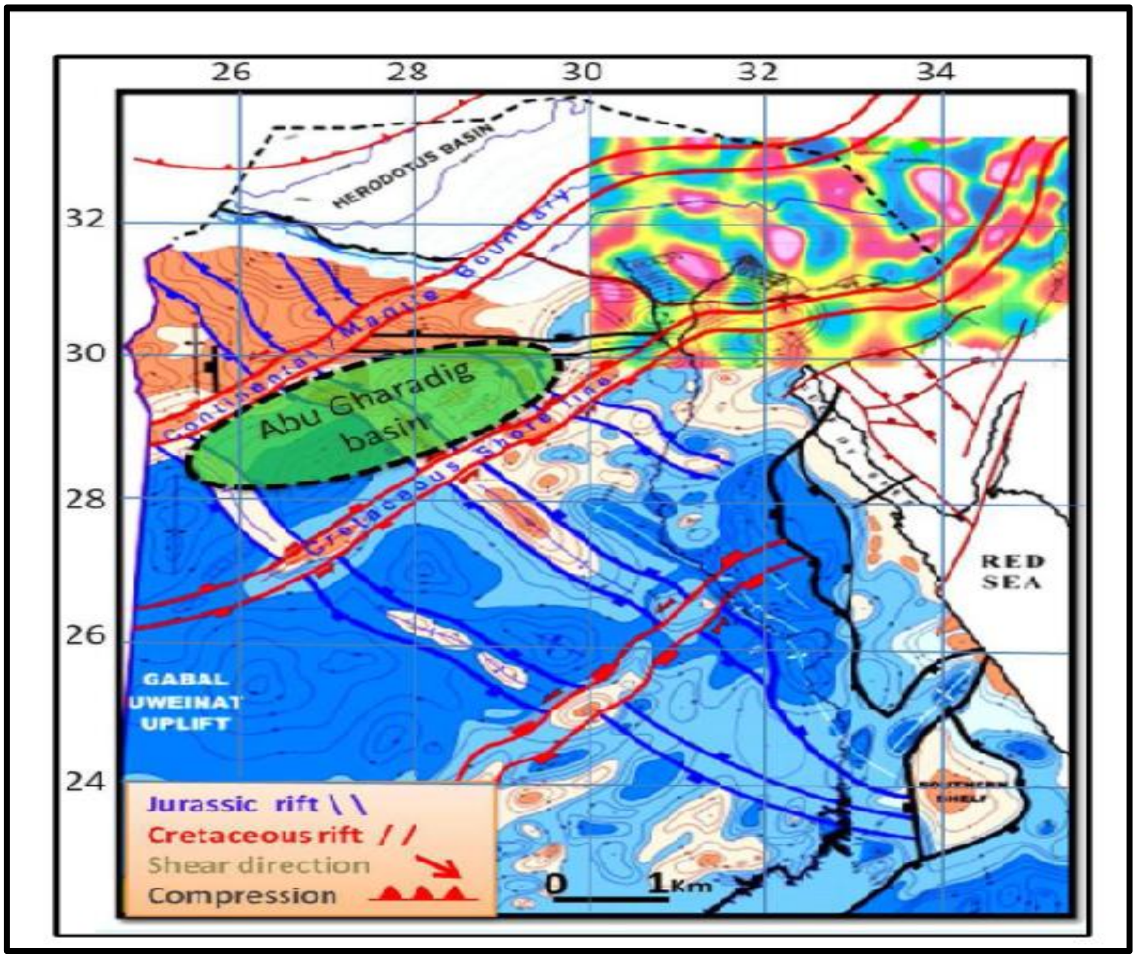

Figure 5: Tectonic framework of Egypt (modified after Meshref, 1988)

Along the whole stratigraphic column, there are several rock units play an important role in sealing the hydrocarbon and keeping it stay in reservoirs; these seal rock units are such as Khatatba shale, Alamein carbonates, Bahariya shale streaks, Abu Roash G shale and carbonates, Abu Roash F carbonate, Abu Roash D and B carbonates, Khoman chalk and Apollonia carbonate (Fig-4). The stratigraphic column in East.

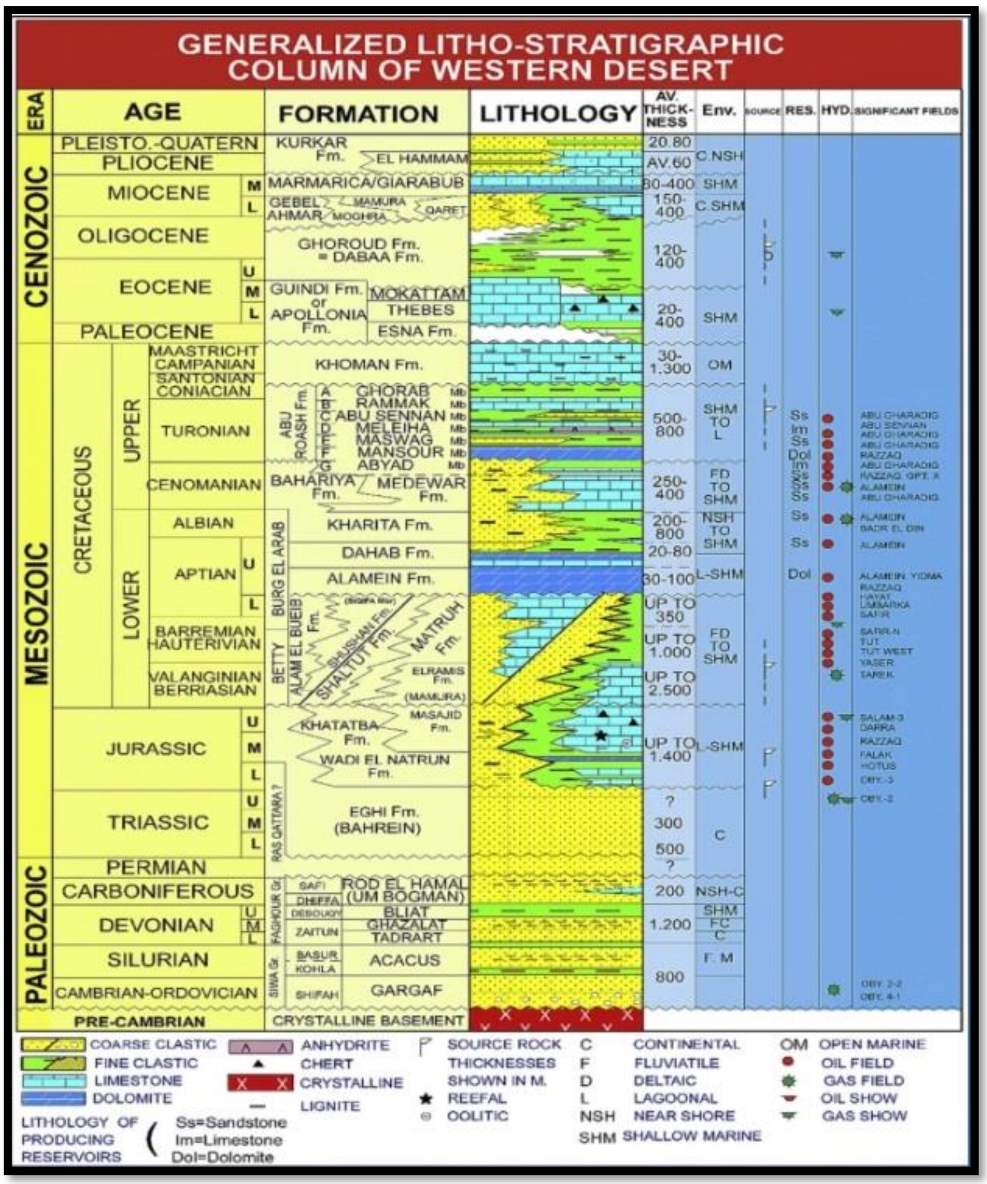

Figure 4: Generalized Litho-stratigraphic Column in the Northwestern Desert (After Schlumberger, 1995)

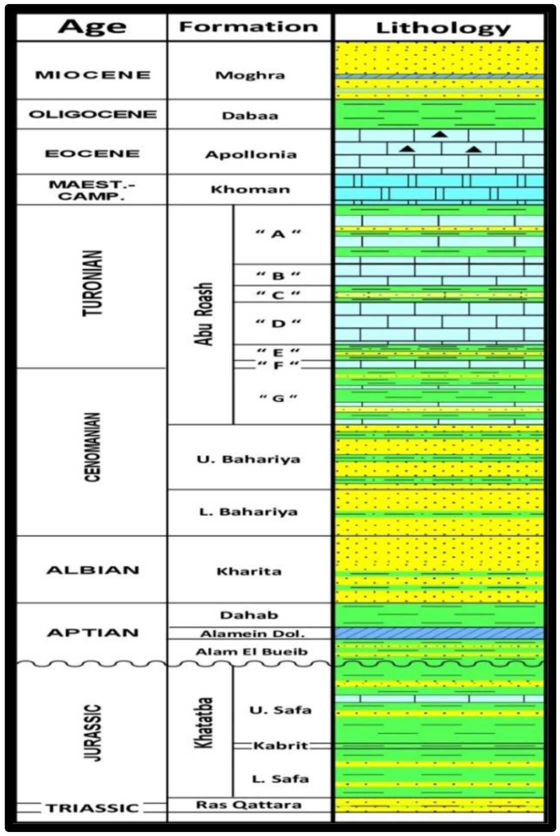

Figure 7: Lithological section in Karama SW Field

Bahariya Concession includes a sedimentary succession from Cretaceous to Miocene (Haq et al., 1988). The lower clastic unit from Cambrian to Pre-Cenomanian, the middle carbonates unit from Cenomanian to Eocene and the upper clastic unit from Oligocene to recent (Said, 1962), (Hantar, 1990), (Norton, 1967) and (Klitzsch and H. Schandelmeier, 1990) . These sequences rest unconformably over the Basement complex. Locally in the Field of the study area, the whole sections that penetrated through Karama SW Wells were reflected part of the global stratigraphic column of East Bahariya Which illustrated above. Therefore, the Lithological section of Karama SW Field is an example of each field indicated in (Fig-5). The Bahariya Reservoir in the study (upper Sands),

Lithological there is no definite thickness change in Upper Bahariya reservoir or any adjacent zones among Karama SW Wells, which shows - during deposition - a very stable structural status resulting in a steady conditions of deposition and consequently, the gross thickness of Upper Bahariya formation. Reveals a symmetrical appearance, Karama SW-9 Well bottomed in ARE member so when conducted map Ignores the thickens values of it (Fig-6). Isopach maps for Abu Roash formation which had been conducted (Fig-7) show that all thicknesses almost have the same value through Karama SW area, indicating the stability of structural activities during the time of deposition for Abu Roash formation, Karama SW-9 Well bottomed in ARE member so when conducted map Ignores the thickens values of it values of it.

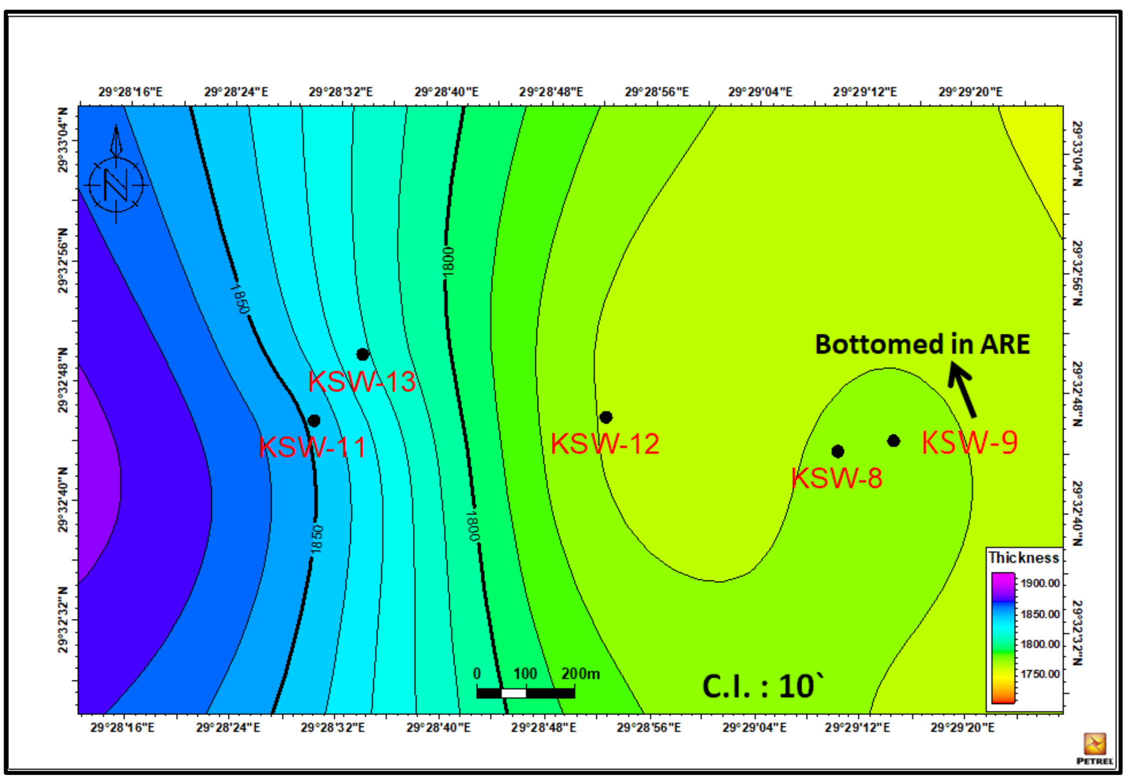

Figure 6: Isopach map of Upper Bahariya in Karama SW field

After conducting isopach map for Khoman Fm. it had been found that there is variation in thickness (from 1600 ft to 1525ft) because of the presence of some low and high lands in Karama SW field during the time of Khoman deposition indicating that the structural activities were highly developed during the age of Maestrichtian (time of Khoman deposition), the map explained that the Khoman Formation was thickening in the central part direction so Khoman Formation is unconformably overlying Abu Roash formation (Fig-8).

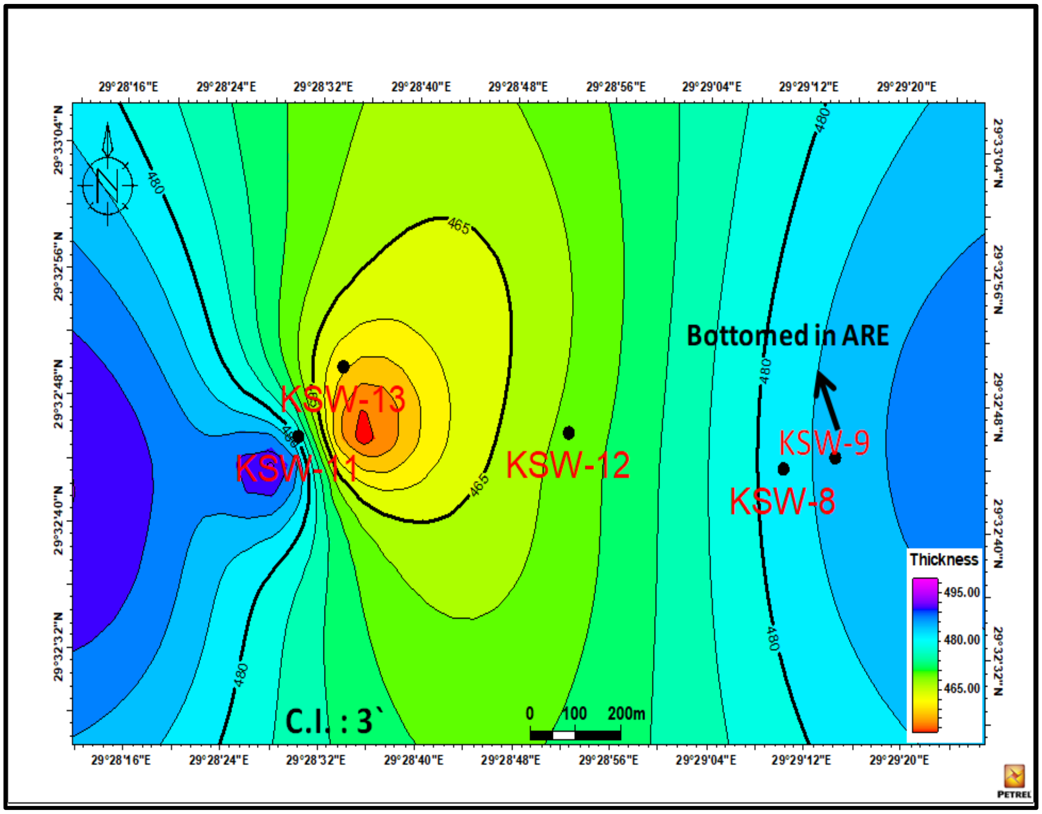

Figure 7: Isopach map of Abu Roash Formation in Karama SW field.

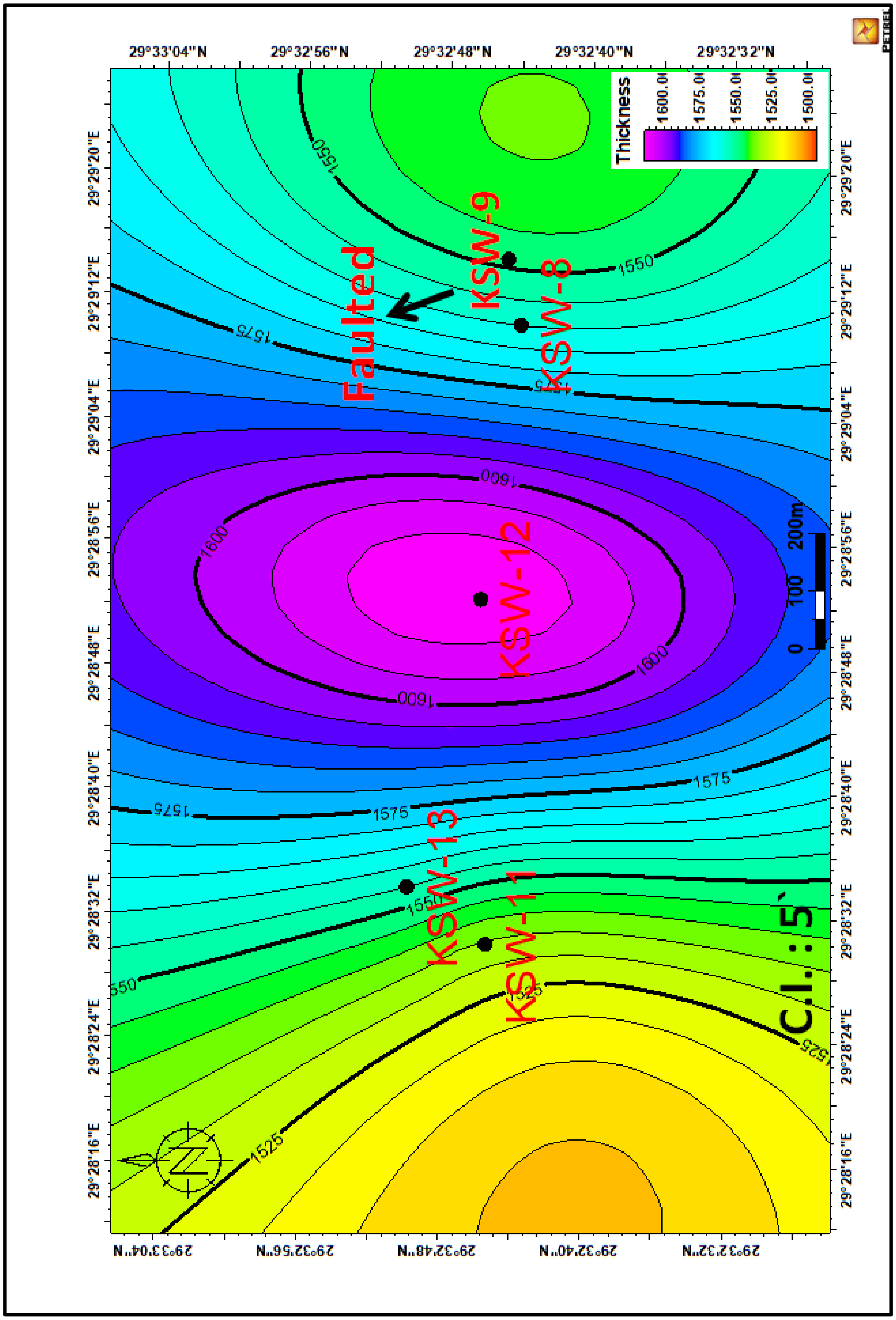

Figure 8: Isopach map of Khoman Formation in Karama SW field

3. Materials and Methods

The available data for this work include:

- Thirty 3D Seismic lines (11 cross-lines, 9 in-lines and 10 random -line).
- Well logs for Five wells as below: -
- Gamma-Ray Logs (GR).
- Resistivity Logs (R).
- Neutron Porosity Logs (Φ).
- Density Porosity Logs (ρ).
- Photo Electric Effect Logs (PEF).
- Mud Logs.
- Drilling parameters logs (ROP, WOB, etc.).

The methodology used in this study included the most common step for this work is seismic interpretation by picking on seismic data, there are two modules of interpretation; Horizon interpretation which is carried out on the horizons of interest, and Fault interpretation for the interesting section, and then, all seismic interpretations are used to construction structure Maps using petrel 2017.Also well log interpretation to extract formation tops to tie it on seismic to help in seismic interpretation (Fig-9).

4. Seismic Data Analysis

It is the important step in seismic exploration in which we extract the subsurface geologic information from seismic data by transforming the physical responses of interfaces between beds displayed by the seismic lines into geologic information of interest, such as structural features, bedding plane continuity or termination and geometry of the sequences (Gadallah et al., 2009) .

Structural interpretation in particular is usually the foremost objectives for detecting faults, folds and unconformities (Abu El Ata et al., 1988). 3D seismic interpretations have become the mainstay of onshore and offshore hydrocarbon exploration over the last 25 years.

Most of the interpretation steps in the current study were done by Petrel seismic and simulation software (Petrel 2017) which is one of the Schlumberger products. Seismic interpretations began with picking and tracking of horizons and faults on a 3 D seismic lines then followed by creating a subsurface structure maps. Interpretation of reflection seismic data is a process of transforming the physical responses displayed by the seismic lines into geologic information of interest, concerning either the structural style or the stratigraphic regime. On the other hand, the initial step in the seismic data interpretation process is to correlate the major geological structures with reflectors. The process of tracing reflectors within a given seismic line, and from line to line at tie points, requires careful phase correlation of the events. During this process the seismic horizons and the structural elements (faults and folds) were picked. The structural features can be differentiated into folds, faults and unconformities. Therefore, seismic expressions and criteria for recognizing these structural elements have to be established, to facilitate the interpretation of the given seismic data (Abedi and El-Toukhy, 1990).

In the presented study, the seismic interpretation was conducted on thirty 3D seismic sections (Fig-10), and the following are the selected seismic lines for revealing the structure style within the study area.

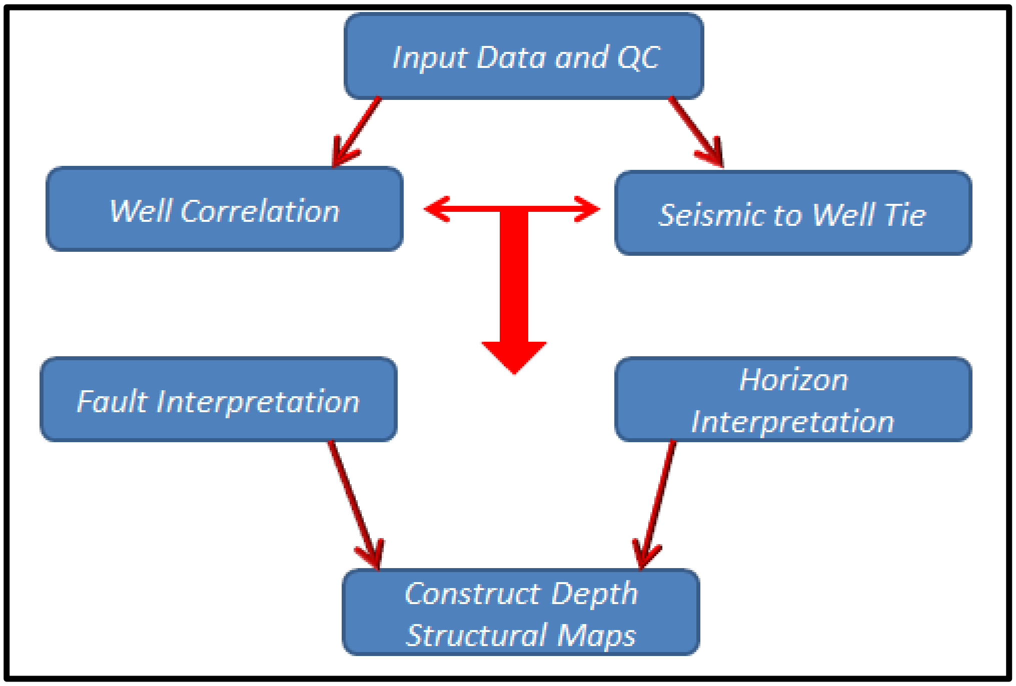

Figure 9: The Workflow applied on the study area.

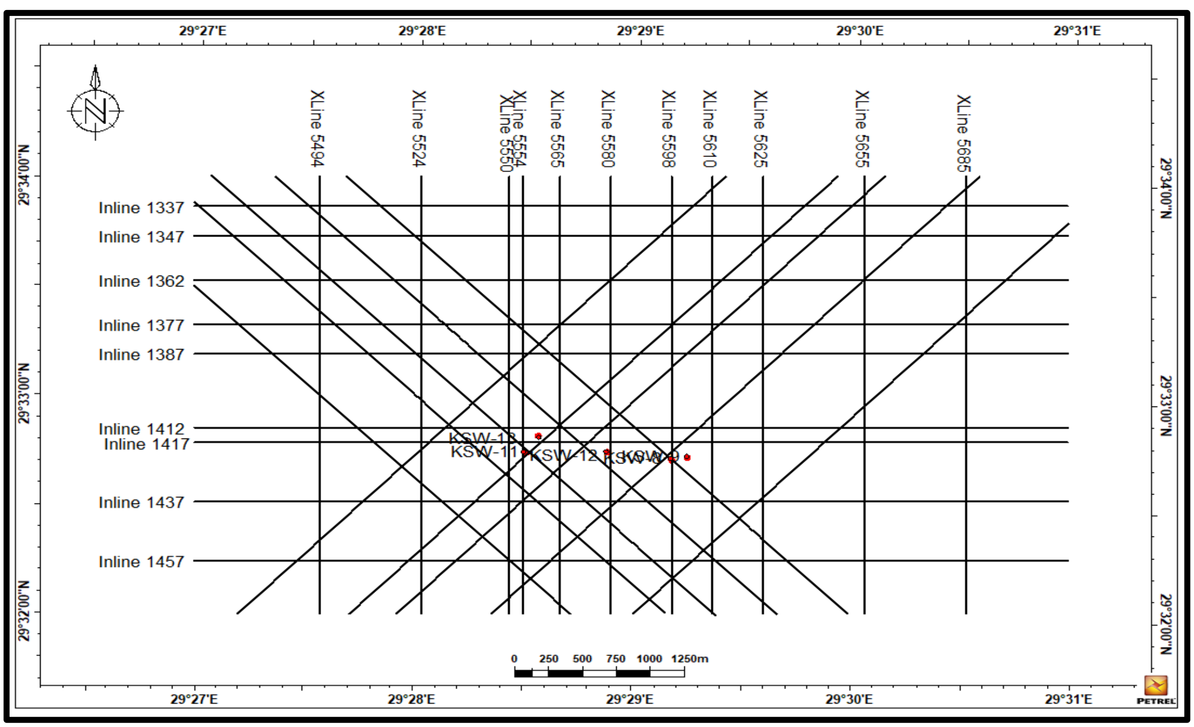

Figure 10: Base map of 3D seismic line among Karama SW field.

4.1.1 N-S seismic Cross line (X Line section 5581):

The seismic cross section 5581among KSW-12 well directed to north-south, has about 4 kilometer long, which showing seismic reflectors (Apollonia Formation, Khoman Formation, Abu Roash "A" Member, Abu Roash "C" Member, Abu Roash "G" Member, Upper Bahariya Formation, Khatatba Formation, Ras Qattara Formation). Reflectors parallel to semi-parallel and dipping to the north direction (Fig-11).

The karama SW area is affected by N-S extension force resulted in E-W shortening structural feature which forming the major normal fault (F1) trending East –West direction and as differences in fault in fault angle there are some fault related fold (rollover anticline) affected on shallow horizons (ARE Member, ARD Member and ARC Member) in the down throne side of major noramal fault (F1), This is in agreement with (Moustafa, 2008) who mentioned that, during the late Cretaceous-Early Tertiary, a strong folding phase took place along the northern territories of the Western Desert as a result, an indicated crustal-shortening took place due to the development of NE-SW oriented doubly plunging anticlinal folds affected the Jurassic and Cretaceous rocks in the northern Western Desert. The major fault (F1) has a thrown about +700-800 feet, cut down below Ras Qattara formation to Khoman Formation , and the dip angle increased upward Khoman Formation with maximum dip angle about 30o. Moreover, (F1) fault has a growth thickness criterion, because the sediments thickness of Khoman Formation on the hanging wall is greater than those of the foot-wall. This criterion is indicating to the presence of an active tectonic movement during the sedimentation time of Khoman Formation at the Late Cretaceous (from Campanian to Maastrichtian time). In addition, the fault (F2) is an antithetic fault on (F1), which has a thrown about +300-400 feet, dip angle about 25o from U.Bahariya Formation to Khoman.

There is other normal faults (F3, F4, F5, F6 and F7) trending NW-SE also an antithetic fault on (F1).

4.1.2 N-S seismic Cross line (X Line section 5550):

This is also a 3-D cross section 5581among KSW-13 well projection directed to north-south, has about 4 kilometer long, where eight reflectors were identified (Apollonia Formation, Khoman Formation, Abu Roash "A" Member, Abu Roash "C" Member, Abu Roash "G" Member , Upper Bahariya Formation, Khatatba Formation, Ras Qattara Formation)(Fig-12). The main phenomena on this line are the normal faults that are present in the study area either deep-seated (F1, F2, F3) or shallow (F4, F5). F1 is the Major normal fault that has E-W strike, which dip toward south, cut reflectors from Khoman formation to below Ras Qattara formation. The investigation of seismic section shows that the study area subjected to three stages of deformation. The first phase related to the early cretaceous resulted in deposition of Jurassic section represented by khatatba formation on tilted faulted blocks showing the Jurassic thickness to word down dip faulted block. The second stage at the end of cretaceous resulting on forming plunging anticline on the down thrown side of major normal fault (F1) this deformation beyond the fault tip lead to displacement of ARC,ARE members in the down thrown side to juxtaposed above uplifted foot blocks and growth thickness on the hanging wall side, by Abu Roash G section oil bearing reservoir in upper thrown side of the major normal fault (F1) which leading to form reserve oil through four way closure combined with three way closure on the down thrown side of shallow horizons ARE, ARC members this reflect atypical example of fault related folds which defined according to (Billings,1972) . The third stage resulted on deposition of khoman on the late cretaceous (Campanian - Maastrichtian time) with thinning

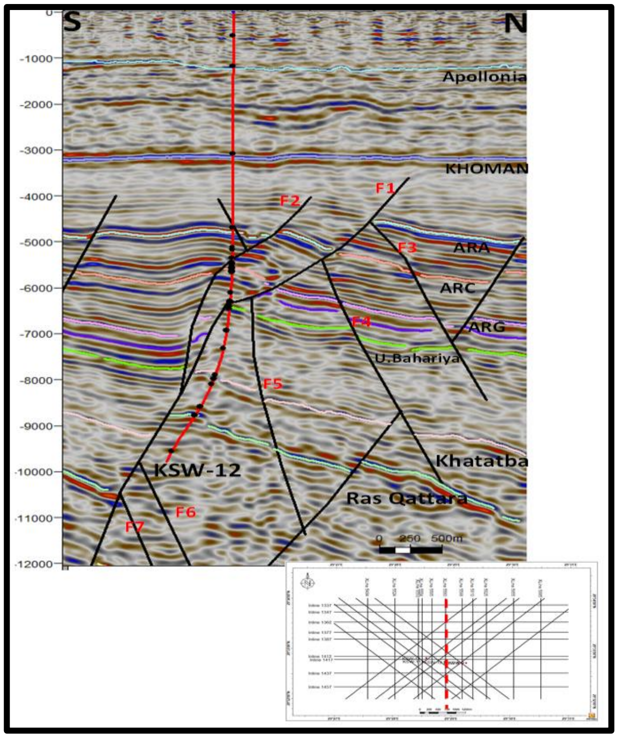

Figure 11: N-S Seismic Cross Line 5581

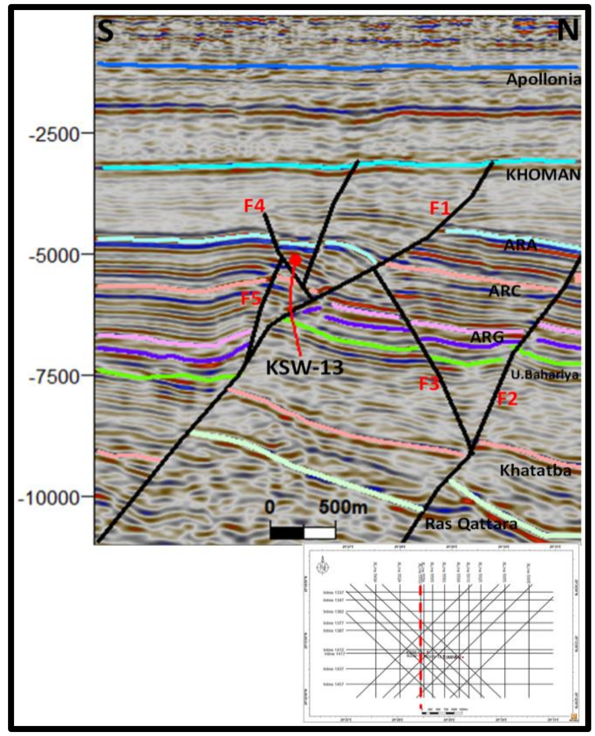

Figure 12: N-S Seismic Cross Line 5550

4.2 Subsurface depth structure mapping

Depth structure contour maps are a common way of representing the elevations for a certain surface and its geometry. The contours are shown at regular intervals across structure the map, it is important that all the depths are referenced to the mean sea level (True Vertical Depth Sub Sea). Some of the previously interpreted horizons mapped, and we will focus here on the Late Cretaceous formations especially Uper Bahariya Formation, Abu Roash "G", "E","C" Members which represent the different structure styles of the Late Cretaceous time interval in the study area.

4.2.1 Depth Structure Contour map of the Upper Bahariya Formation

The depth structure contour map of the top Upper Bahariya based on 3D seismic data in the area of the Karama SW Field (Fig-13) shows the major fault trends E-w, and other faults trend NE-SW and NW-SE. The E-W trending faults form the dominant fault trend and hydrocarbon fault traps encountered along which related to Jurassic and late Cretaceous trends respectively.

The normal faults were formed by NE-SW oriented lengthening associated with the NW-SE shortening resulting from basin inversion. Such NW-SE oriented normal faults are abundant in the Upper Cretaceous rocks but are fewer in number in the Jurassic rocks which are mildly affected by inversion-related folds (Mostafa, 2008).

The study area is structurally low areas exist in the Northeast and in the Northeastern parts of the study area recording values between -7250 ft. to -7500 ft. and structurally high recording values in the center from 6750 ft. to 6500 ft, The contouring interval every 50 feet and the dipping of the map in the north direction in the up thrown side.

4.2.2 Depth Structure Contour map of the Abu Roash "G" Member

The depth structure contour map of the Cenomanian Abu Roash "G" Member exhibited the same structural features of Upper Bahariya Formation (Fig-14). The Abu Roash “G” Formation depth structure contour map which constructed from 3D seismic interpretation explained as Three-way dip closure bounded by the major normal faults E-W direction and some minor ones, structurally high recording values in the center from -6000 ft. to -6250 ft and structurally low recording values in the north direction from -6750 ft, To -7000 ft The contouring interval every 50 feet and the dipping of the map in the north direction in the up thrown side.

4.2.3 Depth Structure Contour map of the Abu Roash "E" Member

The depth structure contour map of the Cenomanian Abu Roash "E" Member exhibited the same structural features of Abu Roash "G" Member but has shown the effect of faults related fold in down thrown side as mentioned before (Fig-15). The Abu Roash “E” Formation depth structure contour map which constructed from 3 D Model Based on seismic data interpretation explained as Three- way dip closure bounded by the major normal faults E-W direction and some minor ones in up thrown side And in the down thrown side four way closure combined with three way closure bounded by the major normal faults E-W direction and some minor ones. Structurally high recording values in the center from -5850 ft. to -5750 ft, in the up thrown side and from -6050 ft. to -6250 in the down thrown side and low values in up thrown side from -6500 ft. to -6600 ft and from -6500 ft. to -6600 in the down thrown side, exhibited contouring interval every 50 feet and the dipping of the map in the north direction in the up thrown side.

4.2.4 Depth Structure Contour map of the Abu Roash "C" Member

The depth structure contour map of the Cenomanian Abu Roash "C" Member exhibited the same structural features of Abu Roash "E" Member (Fig-16). The Abu Roash “C” member depth structure contour map which constructed from 3D seismic interpretation explained as Three- way dip closure bounded by the major normal faults E-W direction and some minor ones in up thrown side And in the down thrown side four way closure combined with three way closure bounded by the major normal faults E-W direction and some minor ones. Structurally high recording values in the center from -5250 ft. to -5150 ft, in the up thrown side and from -5500 ft. to -5450 in the down thrown side and low values in up thrown side from -5750 ft. to -5850 ft and from -5750 ft. to -6000 in the down thrown side, exhibited contouring interval every 50 feet and the dipping of the map in the north direction in the up thrown side.

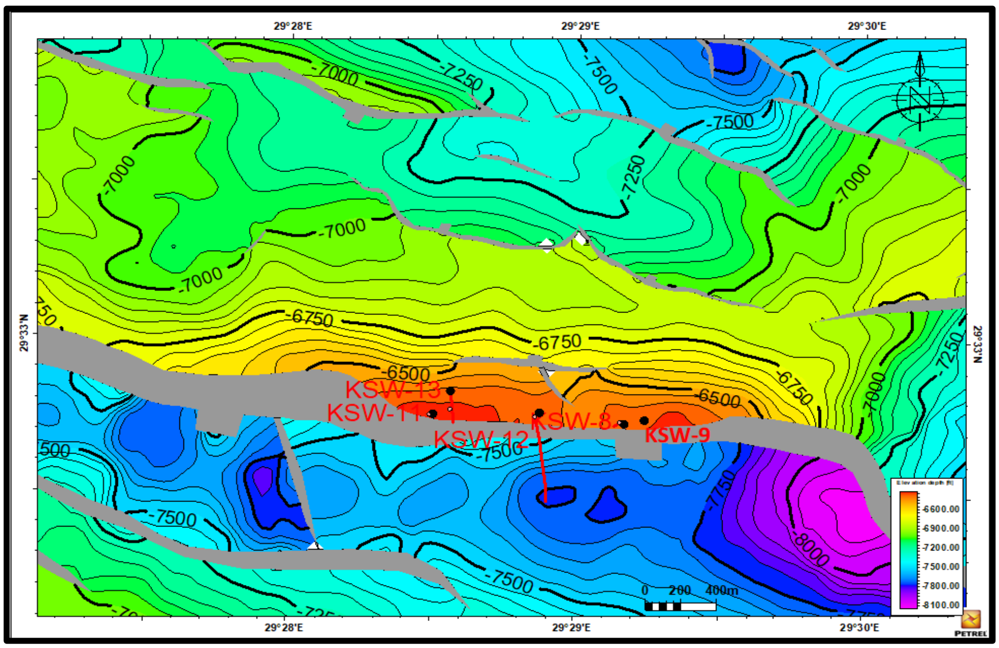

Figure 13: Depth Structure Contour map on top Upper Bahariya Formation.

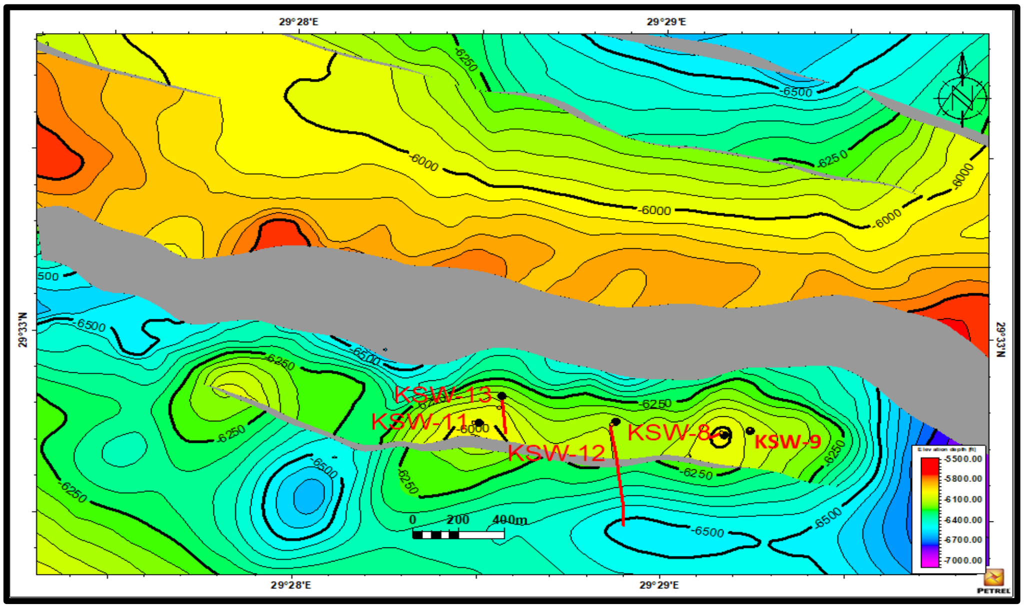

Figure 14: Depth Structure Contour map on top Abu Roash "G" Member.

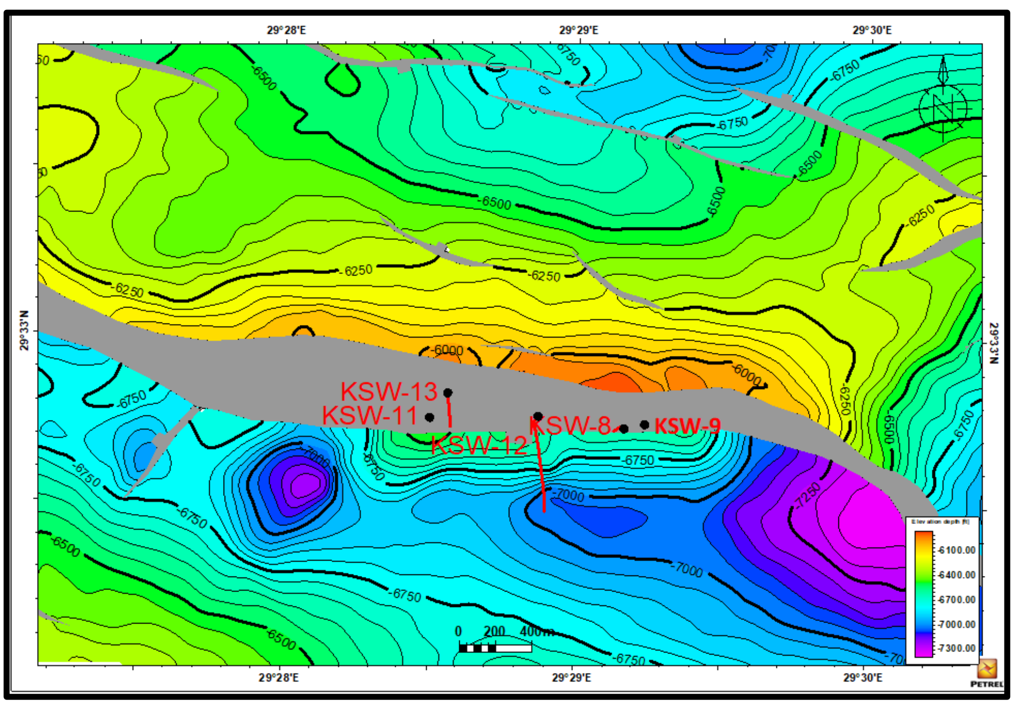

Figure 15: Depth Structure Contour map on top Abu Roash "E" Member.

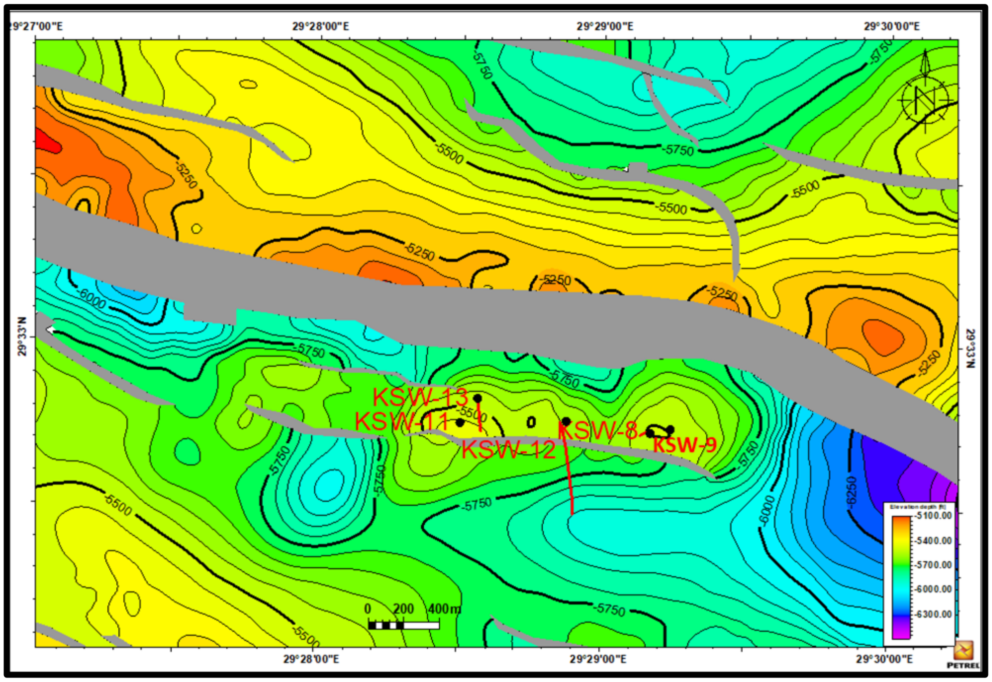

Figure 16: Depth Structure Contour map on top Abu Roash "C" Member.

5. Conclusions

The karama SW area is affected by N-S extension force resulted in E-W shortening structural feature which forming the major normal fault (F1) trending East –West direction and as differences in fault angle there are some fault related fold (rollover anticline) affected on shallow horizons (ARE Member, ARD Member and ARC Member) in the down throne side of major normal fault. The principal structure responsible for hydrocarbon entrapment in the study area was a structural high which corresponds to the three-way dip closure of east-west major normal fault and the northeast-southwest normal fault up thrown side of major normal and a structural high which corresponds to four-way dip closure of east-west major normal fault and the northeast-southwest normal fault down thrown side of major normal fault in Karama SW oil field area. Four depth structure contour maps constructed on top (ARC, ARE, ARG and upper Bahariya formation).

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