SUBSURFACE GEOLOGICAL AND PETROPHYSICAL ANALYSIS OF BAHARIYA RESERVIOR AT YOMNA FIELD, EAST BAHARIYA CONCESSION, NORTH WESTERN DESERT, EGYPT.

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ABSTRACT

Yomna field is located in the northern part of East Bahariya concession which is located in the northern part of the western desert. The aim of this study was to combine the different available data to understand the subsurface system and the characters of Late Cretaceous reservior (Bahariya Reservior) at Yomna field. Seismic interpretation was conducted on the available seismic lines concerned with the study area to provide a detailed structural interpretation to determine the structural geometry of Bahariya reservior for detecting the best localities for drilling new development wells within the study area. Five horizons have been identified and. A depth structure maps have been constructed on the

on the top of Khoman, Abu Roash A, Abu Roash E, Upper Bahariya and lower Bahariya. The structure contour maps and the 3D structural model showed that the area was affected by tectonic deformation system caused regional uplift. The principle structure responsible for hydrocarbon entrapment in the study area is the structure high which corresponds to the three way dip closure of NW-SE normal fault which was very clear on the seismic lines and structure contour maps. Petrophysical analysis has been established on the available wells within the study area to determine the reservior prosperities such as (Facies, clay volume, water saturation, effective porosity and reservior net thickness).

INTRODUCTION

Yomna Field is located at East Bahariya Concession in the eastern Abu El Gharadig Basin in the North Western Desert, Egypt. **Figure (1).**

AVAILABLE DATA

The present study is based on the data supplied by Qarun Petroleum Company (QPC) upon the approval of the Egyptian General Petroleum Corporation

(EGPC).The data used in the present study includes the following**: -** (1) Reflection 2D seismic profile of twenty lines created from both 2D and 3D surveys in multi-direction which have been used to trace and detect the seismic features of the Bahariya reservoir within the study Area. (2) Well-log data of five wells distributed in the study area. These wells are Yomna-2, 4, 11, 19 and Yomna-S-1X. The type of well logs available includes the following (Resistivity, SP, GR, Density and Neutron). **Figure (2).**

METHODOLOGY AND TECHNIQUES

The subsurface geologic setting is gained through the construction of seismic sections, structural cross sections, structure contour maps and 3D structural model. The Petrophysical evaluation is gained through the computer processed interpretation that passes through the quantitative interpretation technique. The Petrophysical characteristics are illustrated vertically (in the form of litho-saturation cross-plots). This study is carried out by using the computer software programs, such as Petrel 2009 software program, Interactive Petrophysics version 3.5 and Techlog software programs.
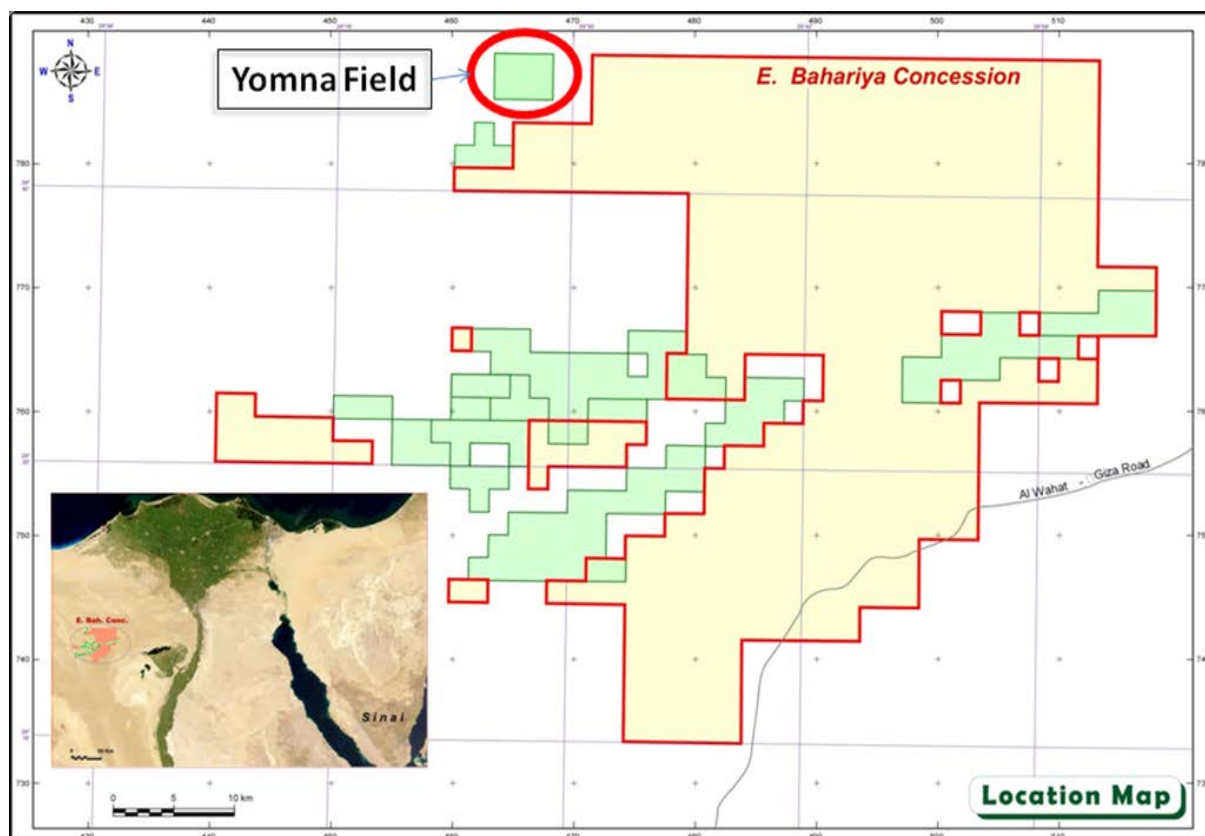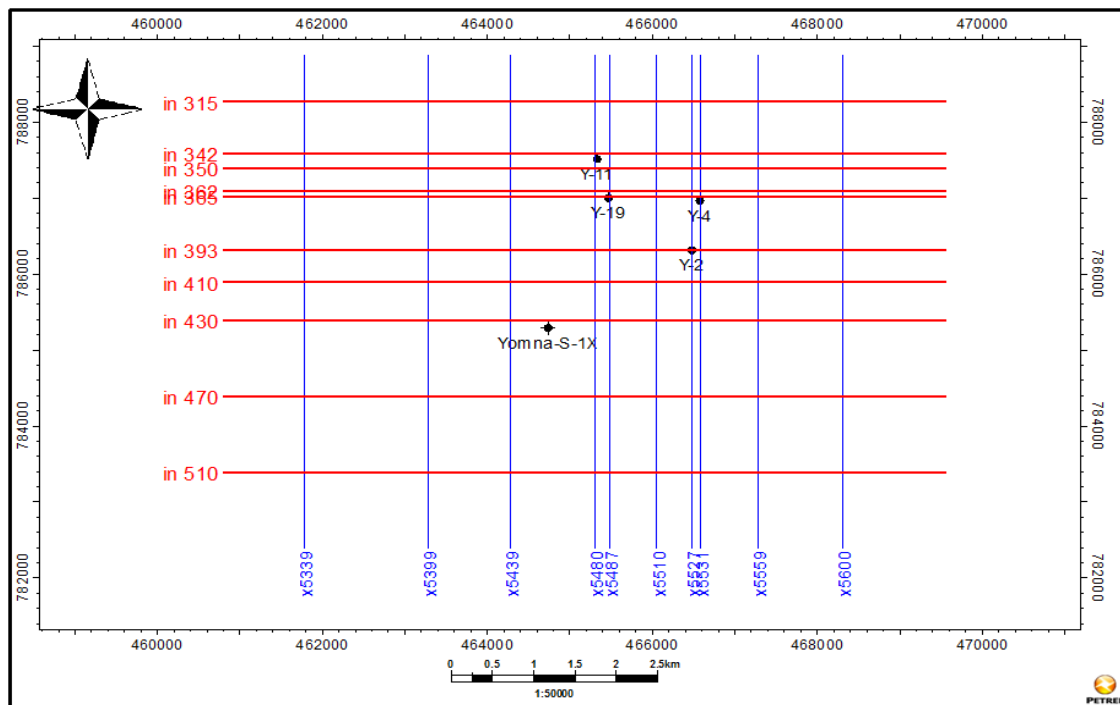
Figure (1) Location map of Yomna Field

Figure (2) Location map showing dataset used in this study (reflections seismic sections and petroleum Wells)

GENERAL GEOLOGIC SETTING

The structural history of the Western Desert is complex. Major rifting characterized the Jurassic through Early Cretaceous time, followed by a passive margin phase that persisted until the Syrian Arc event, Most of the productive fields lie within the Abu Gharadig, Shoushan and Matruh basins Figure (3).

1. Surface Geology

The surface Geology reflects the final network of the accumulated litho-stratigraphic units on the earth surface. The Western Desert is essentially a plateau desert with numerous enclosed depressions. The Northern part of the Western Desert is a plateau covered with Neogene Sediments and occupying an area about 216,000 Km2 (**Abu El Naga, 1984).**

The northern basins of the western desert initially formed as a single rift, perhaps during the Permo-Trassic, which have been developed into a Pull apart structure. Marine conditions are first recorded in the Jurassic and cretaceous sequences. Later tectonic events are presumed to split the original basin into a series of smaller

compartments. The Northern part of the Western Desert forms the major part of the unstable shelf as defined by **(Said, 1962)**.
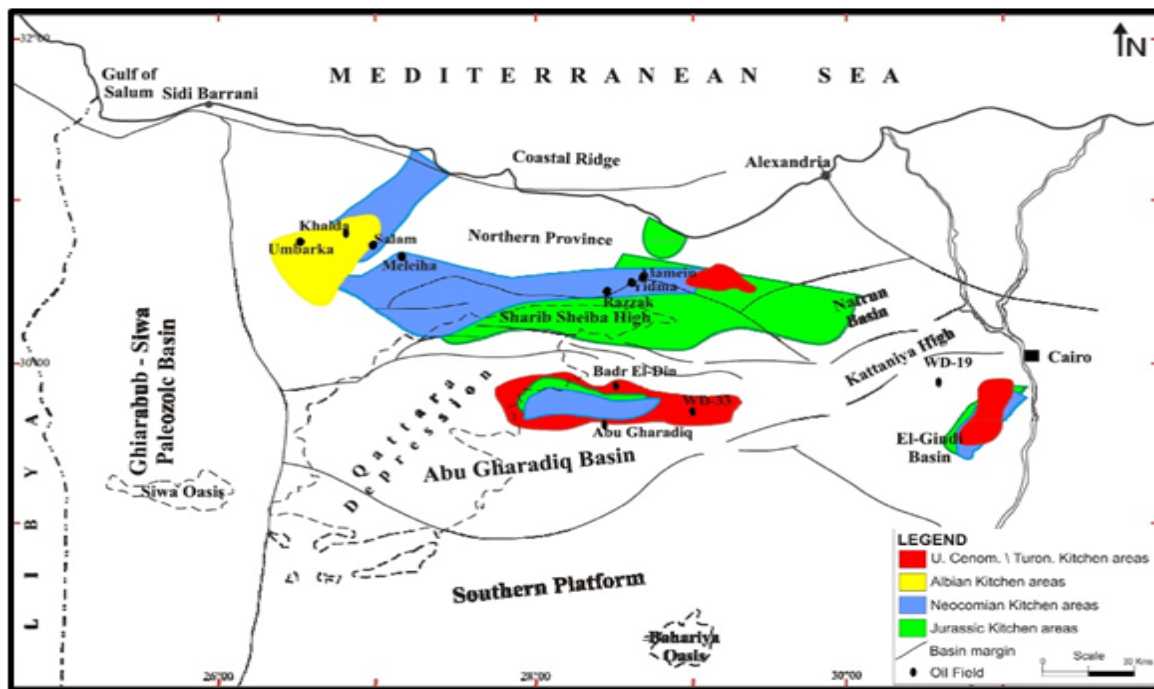

Figure (3) Basins within the North Western Desert of Egypt

2. Stratigraphy

The stratigraphic column of the north western desert is thick and includes most of the sedimentary succession from Pre-Cambrian Basement Complex to Recent. Figure (4).

The total thickness, despite some anomalies increases progressively from about 600 ft in the south to reach about 25,000 ft to the north and northeast along the coastal area.

The main part of the North Western Desert is covered by thin blanket deposits of Miocene rocks which unconformable overlie old Strata **(Said, 1962)**

Said (1962) subdivided the entire range of sedimentary sequence, from base upwardly, into three main cycles:-

- Lower Clastic division: From Cambrian to Cenomanian, predominantly Clastic

- Middle calcareous division: From Cenomanian to top Eocene, predominantly Calcareous.

- Upper Clastic division: From Oligocene to Recent, predominantly Clastic.

    Bahariya Formation is the main producing horizon in the study area. The type locality of which is situated in Gebel El-Dist, Bahariya Oasis, where its base

not exposed **Said (1962). Norton (1967)** designated the lower part in the nearby Bahariya-1 well.

Bahariya Formation was deposited under shallow marine conditions.

El- Sheikh (1990) classified the Bahariya formation into four units as the following:-

- The lowermost consist of thick sandstone inter-bedded with shale.
- The second consist of sandstone but with marked difference in thickness.
- The third consist of limestone and shales.
- The upper is made of thinly inter-bedded sand stone and lime stone.

In the study area Bahariya formation was penetrated by all the studied wells. It lies on Kharita formation and it is overlain with Abu Roash formation G Member
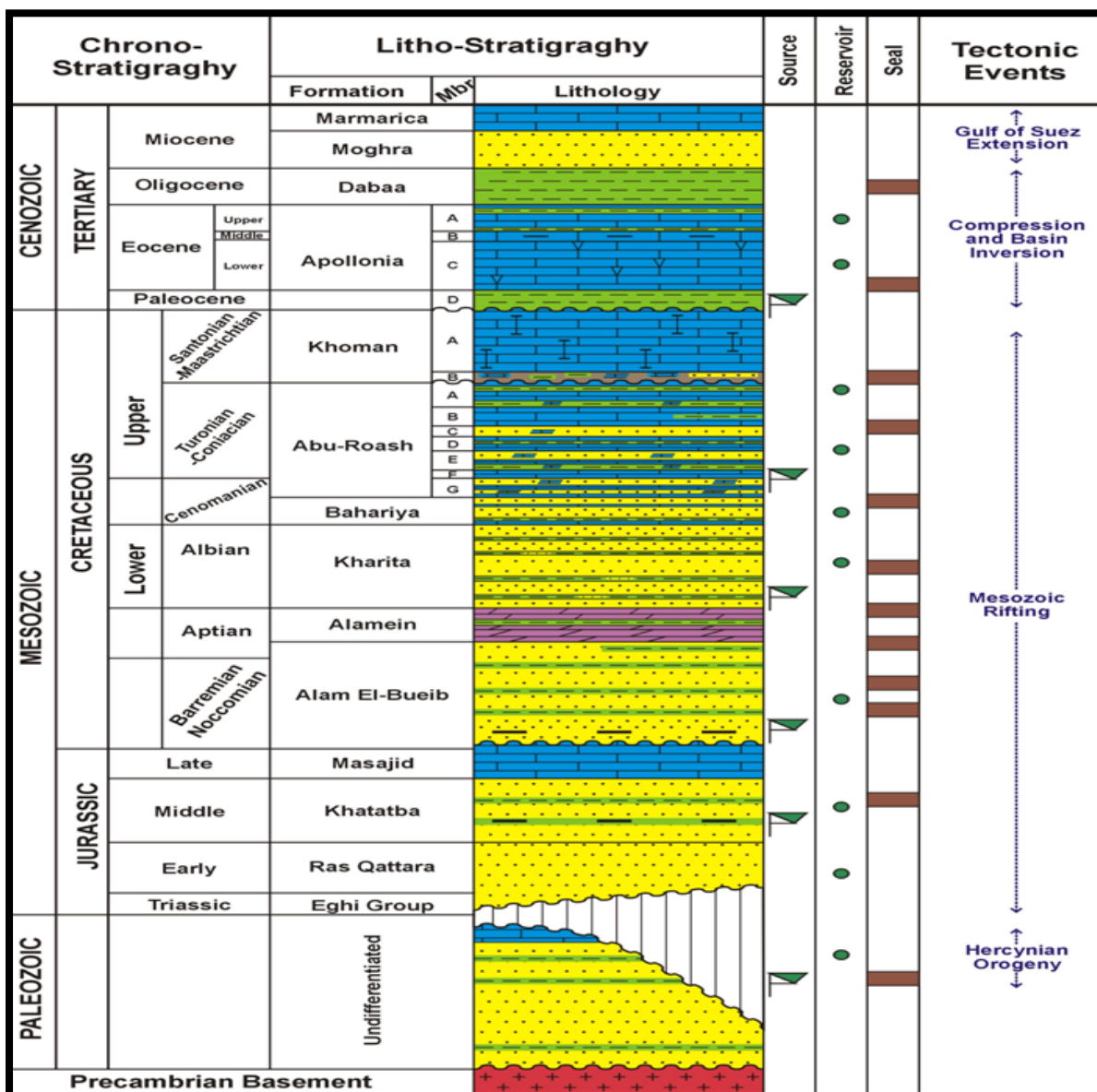
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Figure (4) Generalized Stratigraphic column of the North Western Desert of Egypt. (After, Moustafa, et al., 2003)

STRUCTURAL SETTING OF YOMNA FIELD

The Northern Part of the Western Desert of Egypt forms features-less plain with some exceptions of small folds and faults of Abu Roash complex that reflects its geological history **(Said, 1990).**

Structures result primarily from vertical movements of basement blocks, and consist mainly of draped over and/or fauanticlinal features **(Schlumberger, 1984)**.

The basic structural elements of the Western Desert are oriented NE to ENE, EW and WNW to NW, to some extent reflecting the two dominant WNW-ESE, ENE-WSW trends in the basement, where ENE-WSW depressions and ridges alternate **(Meshref 1990)**.

The dominant structural style of the Western Desert comprises two systems: a deeper series of low relief horst and graben belts separated by master faults of large throw, and broad Late Tertiary folds at shallower depth **(Sestini 1984).**

Abu Gharadig basin is a rift basin bounded to the north and south by two right-lateral shears and from the east and west by northwest trending normal faults **(Meshref 1990)** Figure (5).

It was formed during the Albian, reached maximum subsidence in the Late Cretaceous (Maastrichtian) and was subsequently inverted during the Paleocene-Eocene **(Lüning et al.2004).** It seems to be a continuous basin with a major uplift along its center that divides it into north Abu Gharadig Basin and south Abu Gharadig Basin **(Meshref 1990).**

The structural pattern of Abu Gharadig Basin is dominated by NE-SW oriented faults coupled with a strong pattern of NW–SE conjugate faults. These fault patterns suggest regional wrench movement **(Abd El Aal 1988).**
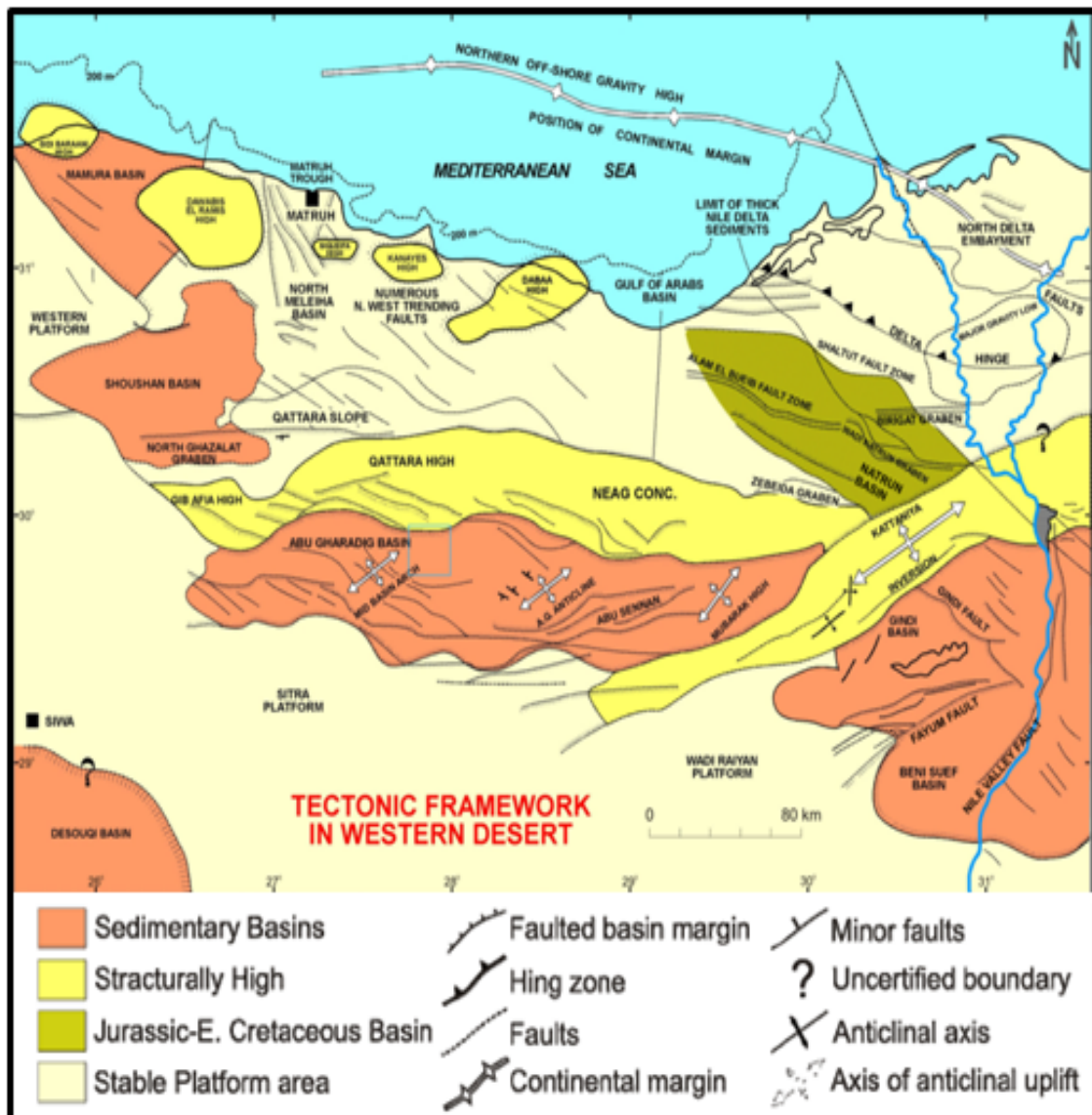
Figure (5) Tectonic Framework in the western desert, Egypt modified after **(Bayoumi 1996).**

Seismic Interpretation

The seismic method is very important for petroleum exploration to detect the locations of the exploratory wells, as well as for the development and evaluation of the oil fields. The main target of the seismic data involves determination of the geologic significances from the seismic data **(Sheriff and Geldart, 1995).**

The interpretation of seismic reflection 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. In order to perform such process, knowledge about the velocity of propagation of the seismic waves is needed. Such seismic velocities, as shown earlier, are diversified

into average velocities and interval velocities, as derived from the basic time-depth relationship of the given wells.

The structural interpretation and modeling of the Upper Cretaceous rocks (Abu Roash and Bahariya formations) at Yomna Field which lies at Abu Gharadig Basin, guides us to the best localities for drilling developmental wells in this field.

This goal was achieved through the interpretation of 2D seismic data of twenty seismic reflection lines take N-S and W-S trends.

The interpreted seismic sections X5527 and X5531 are shown in figure (6), which are dip seismic sections and take the N-S trend and seismic section In430 is shown in figure (7).

The structural and stratigraphic features of these reflectors can be recognized. Khoman reflector appears as a strong and continuous as it may be deposited after the uplift occurred in the area, so there was a large accommodation space in the down thrown side of the major faults causes the large thickness of Khoman. On the other hand, the other reflectors are affected by main normal faults appear. The major fault in Khoman may be due to the rejuvenation occurred to these major faults after Khoman deposition.

The cross-sectional view reveals a system of fault-bounded blocks, and the bounding faults are all normal slip faults. The main faults affect the Lower and Upper cretaceous sequences trending northwest southeast and dipping towards the north-northeast, south-southwest and west directions. Some of the faults seen in the Upper Cretaceous section do not extend into the Lower Cretaceous and Jurassic sections. However, there are some additional deep-seated faults present in the deeper horizons that are probably, Jurassic in age. These faults are normal faults forming small horst producing traps. The reflectors of all sequence are dipping gradually to northwestern direction due to the tilted fault blocks.
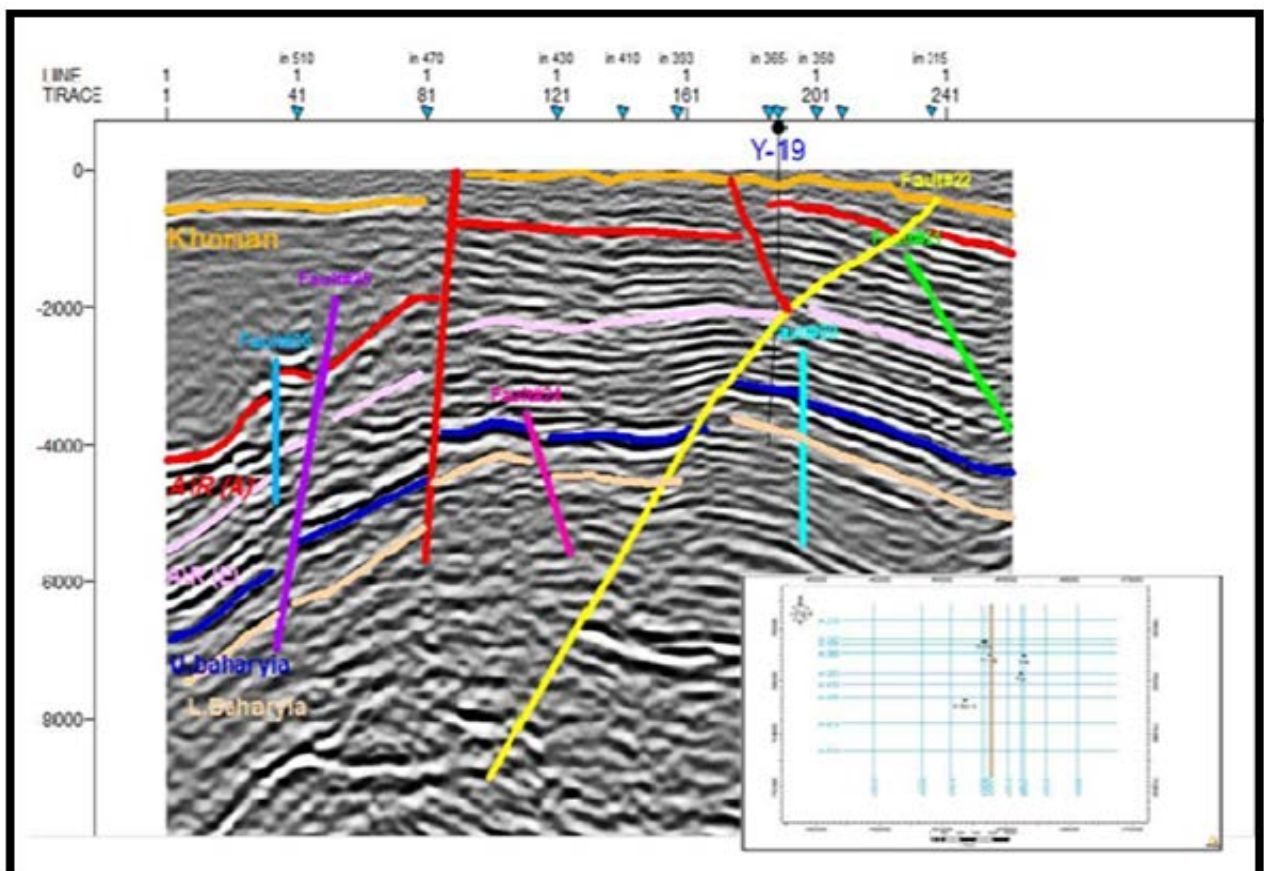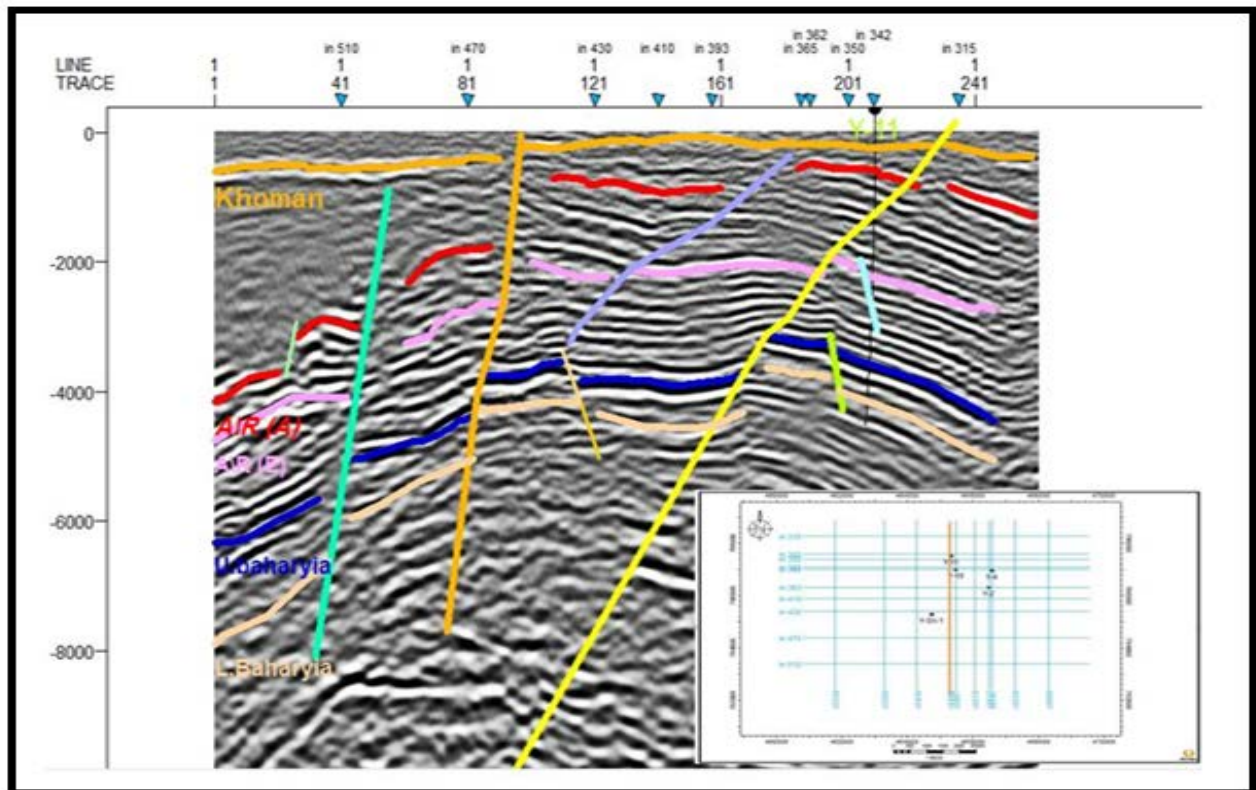
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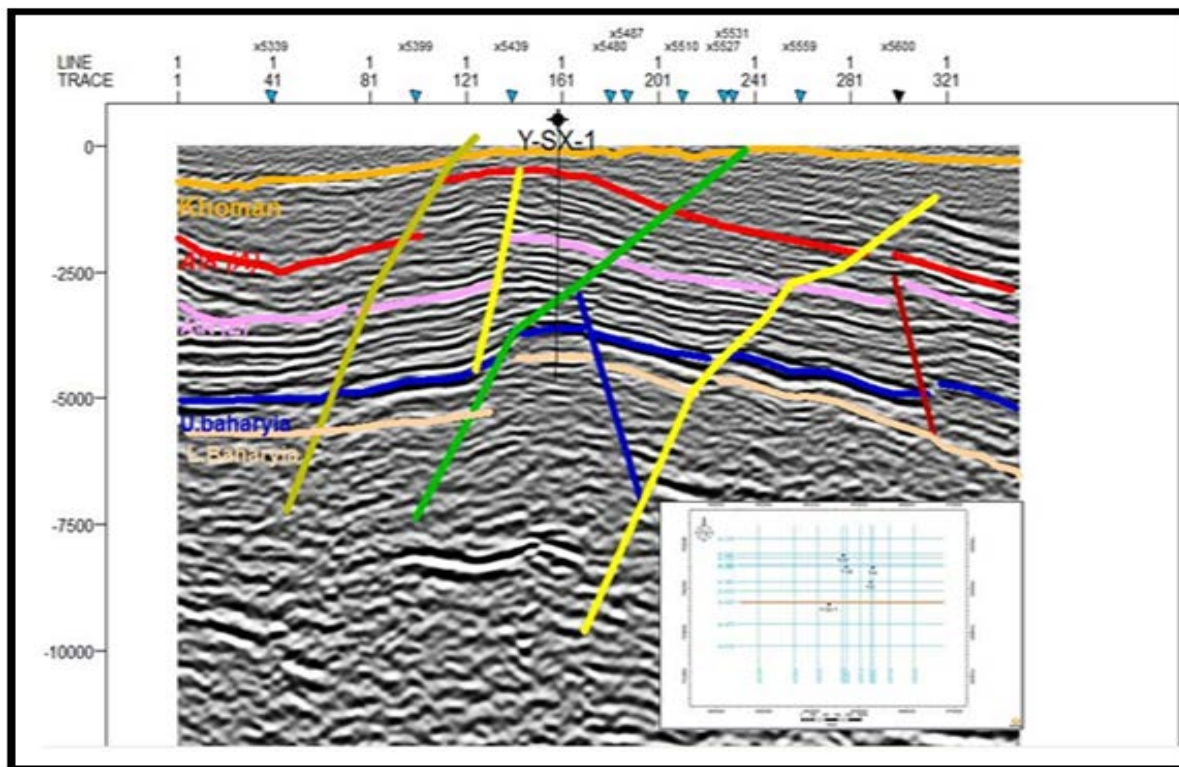**Figure (6):** N-S interpreted seismic sections.

Figure (7): E-W interpreted seismic sections

Structure contour maps

After the interpretation of the seismic sections we construct structure contour maps for each of the selected stratigraphic horizons by using Petrel 2009 software program (@ Schlumberger, 2009). To illustrate the subsurface structural configuration of the study area, five structure contour maps are constructed on top of five horizons with in the area of study which are (Khoman formation, Abu Roash (A) Formation, Abu Roash (E) Formation, Upper Bahariya Formation and Lower Bahariya Formation. Figure (8).

According to the structure depth map that was constructed on Upper Bahariya horizon and Lower Bahariya horizon,the Yomna structure is interpreted to be a three-way dip faulted closure along the northwest– southeast trending normal fault.

The structure has a high relief and is a part of the large Mubarak ridge, adjacent to the eastern trough of the Abu Gharadig Basin,

The deeper structural picture is much the same but some of the faults seen in the Upper Cretaceous section do not extend into the Lower Cretaceous and Jurassic sections. However, there are some additional deep-seated faults present in the deeper horizons that are probably, Jurassic in age. This map shows that the Bahariya Formation was penetrated in the horst and step-fault blocks in most wells

with good hydrocarbon bearing-zone parameters detected by Yomna-2 well to the south based on higher productivity.
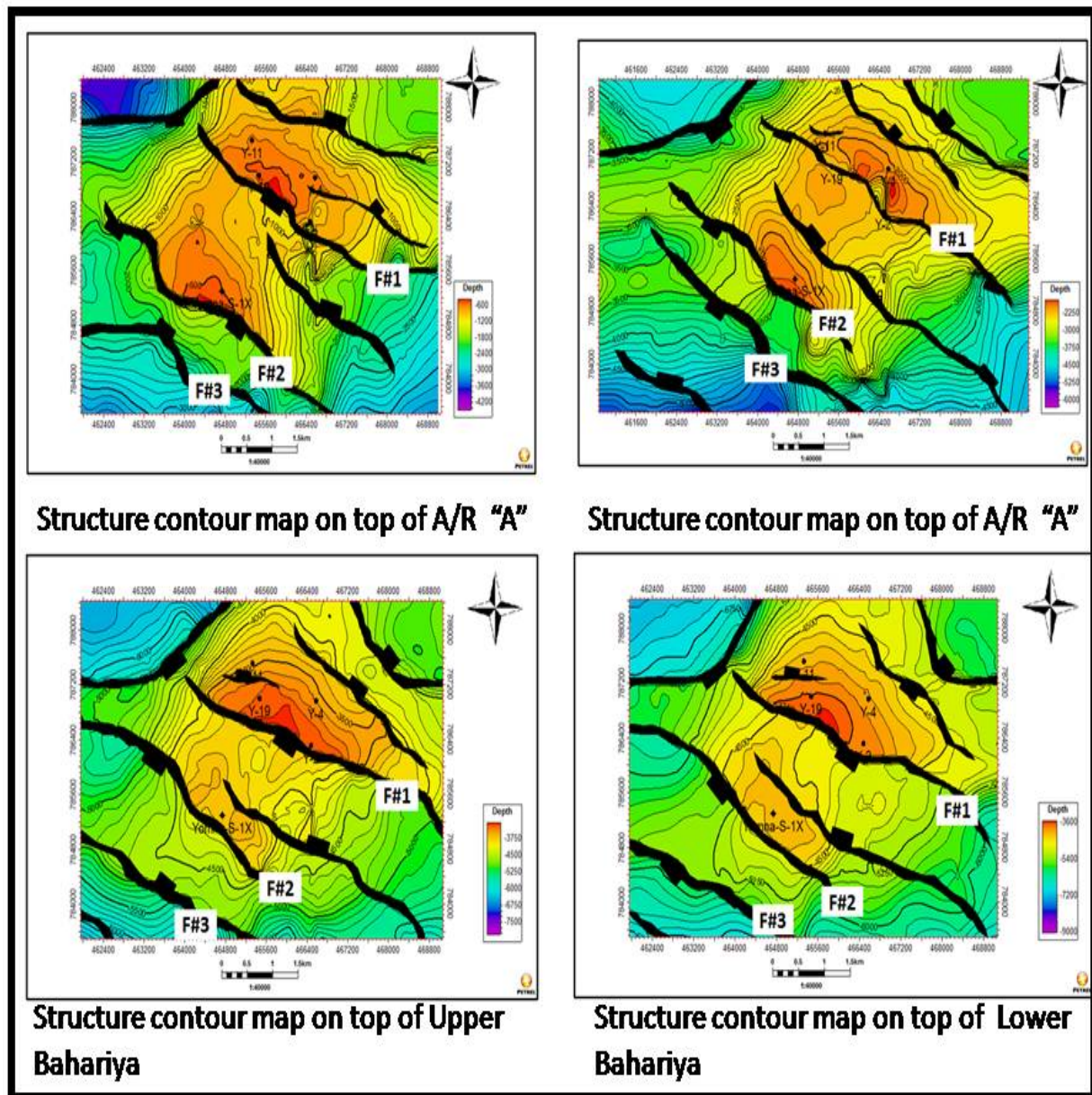

Figure (9): Structure contour maps on top of selected rock units in Yomna Filed

STRUCTURE MODEL OF THE STUDY AREA

Identifying and recovering hydrocarbons requires accurate, high resolution geological modeling of the reservior structure, stratigraphy and rock properties to enhance the geological understanding and provide accuracy throughout the exploration, development and production cycles. The Three-dimensional (3D)

modeling of complex structures requires incorporation of all available   data and interpretations **(Mirta and Leslie 2003)**

In the present study, structural framework modeling is applied in order to construct 3D model consist of horizons and faults. Each are modeled as individual surfaces from their interpretations, and then assembled into a volumetric model of zones.

This (3D) structural model as done through the following steps:-

1. Fault Modeling

The process of fault modeling defines the faults in the geological model which will form the basis for generating the 3D grid. These faults will define break in the grid. The purpose of this step is to define   the shape of each of the faults should be modeled; this is done by generating the "key pillars" which describe the fault.

In the study area only the main faults where selected during the construction of the 3D structural model using the Petrel Software.

The obtained 3D structural model confirms the interpreted structure from the seismic. The 3D Structural model shows that the regional uplift occurred in the study area, it shows the typical tilted fault block in the area which is affected by the mapped faults figure (10).
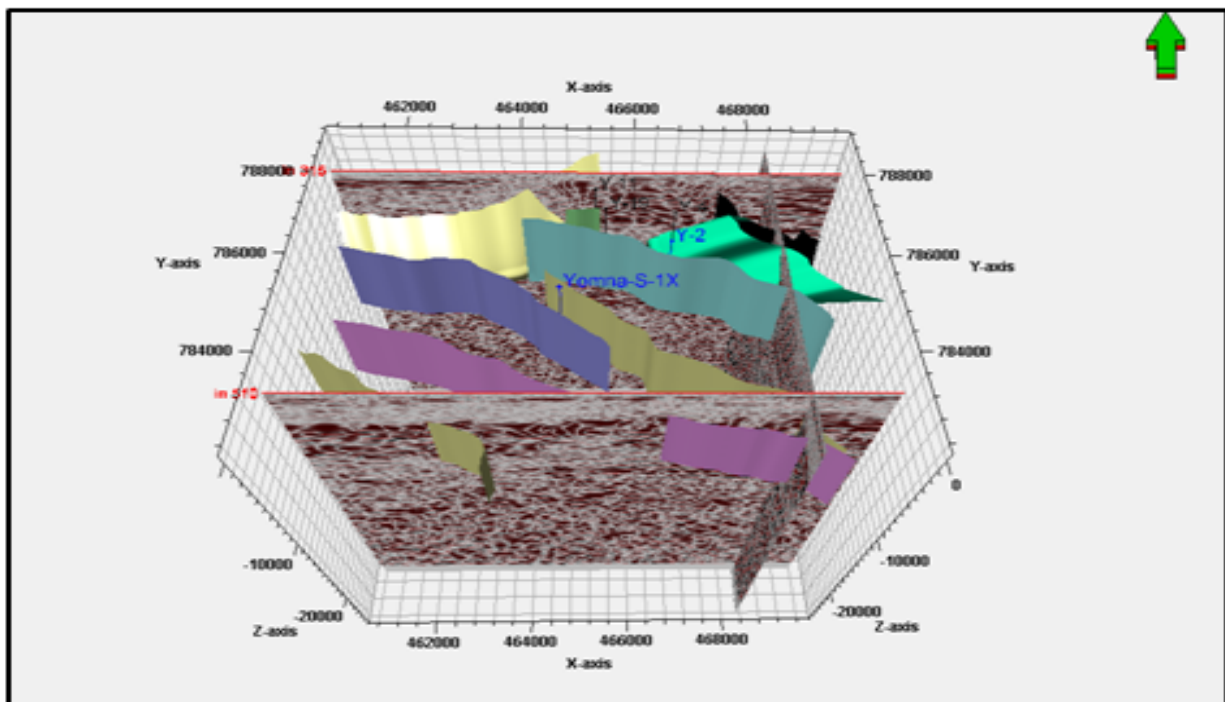

Figure (10): 3D fault model of the study area with the seismic lines

2. Pillar Giddings

The generation of the structural model is done in a process called pillar gridding. Pillar grading is a unique concept in petrel where the faults in the fault model are used as a basis for generating the 3D grid. Several options are available to customize the 3D grid for either geomodeling or flow simulation purposes. Pillar gridding is the process of making the Skeleton Framework or 2D Grid. Figure (11)
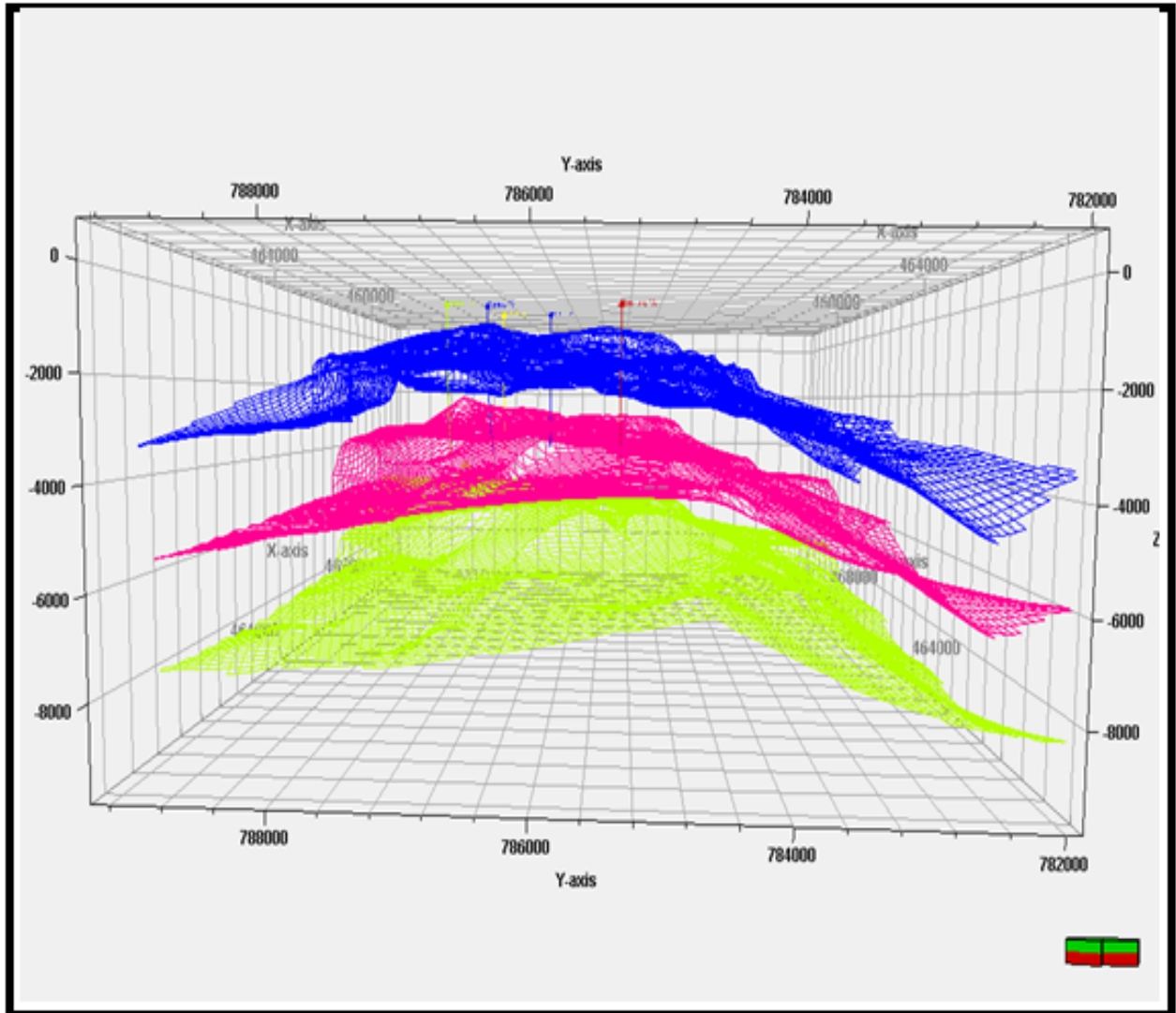

Figure (11): 3D model of the celluler gridding used in the study area

3. Make Horizons

Make horizons is the final step in structural modeling. This process is a fully automatic procedure once the input data and some setting have been specified such as the relationships between the surfaces taken in to account (erosion, discontinuity or conformable). To put stratigraphic horizons in the model, the first step is to make horizons which honor the grid increment and the faults defined in the previous step. The five studied horizons, Khoman, Abu Roash"A", Abu Roash "E", Upper Bahariya and Lower Bahariya are used in building the 3D Structural model figure (3.12 and 13).

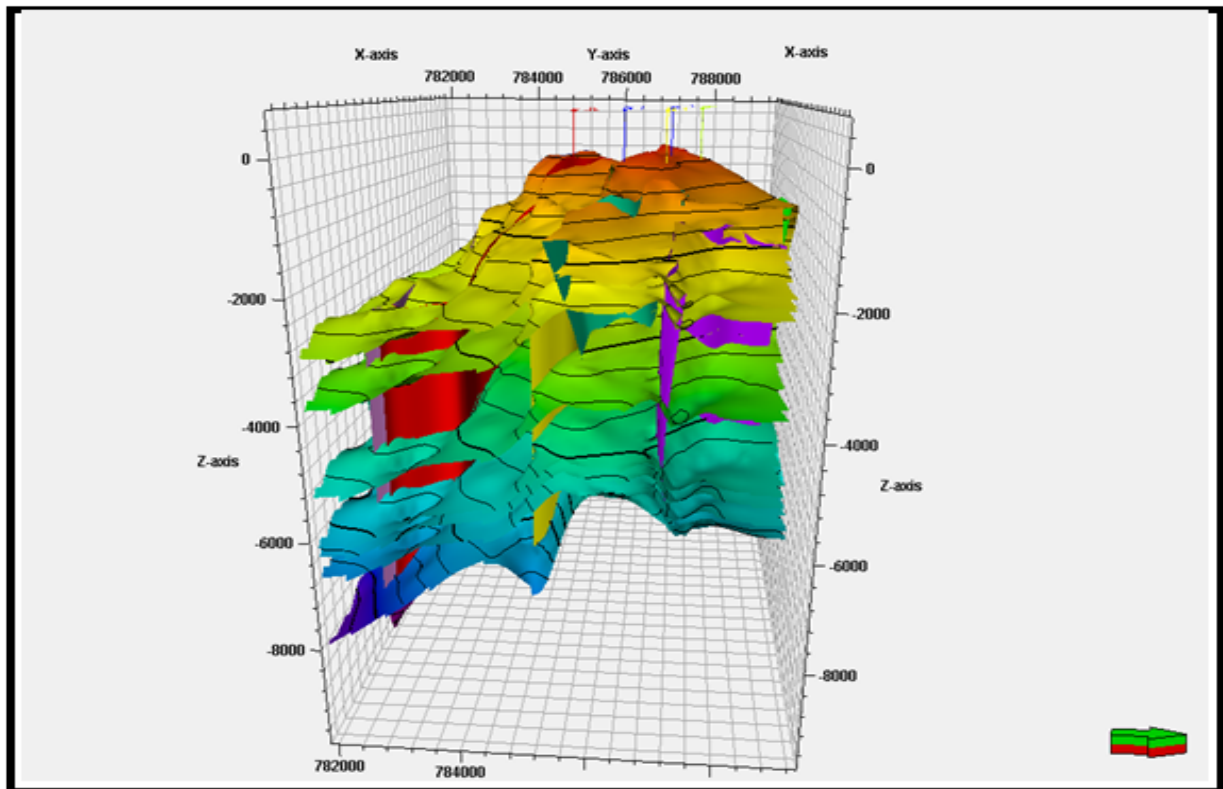*International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-6,June 2016*
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Figure (12): 3D structural gridded surfaces of the model with the faults with in the study area .
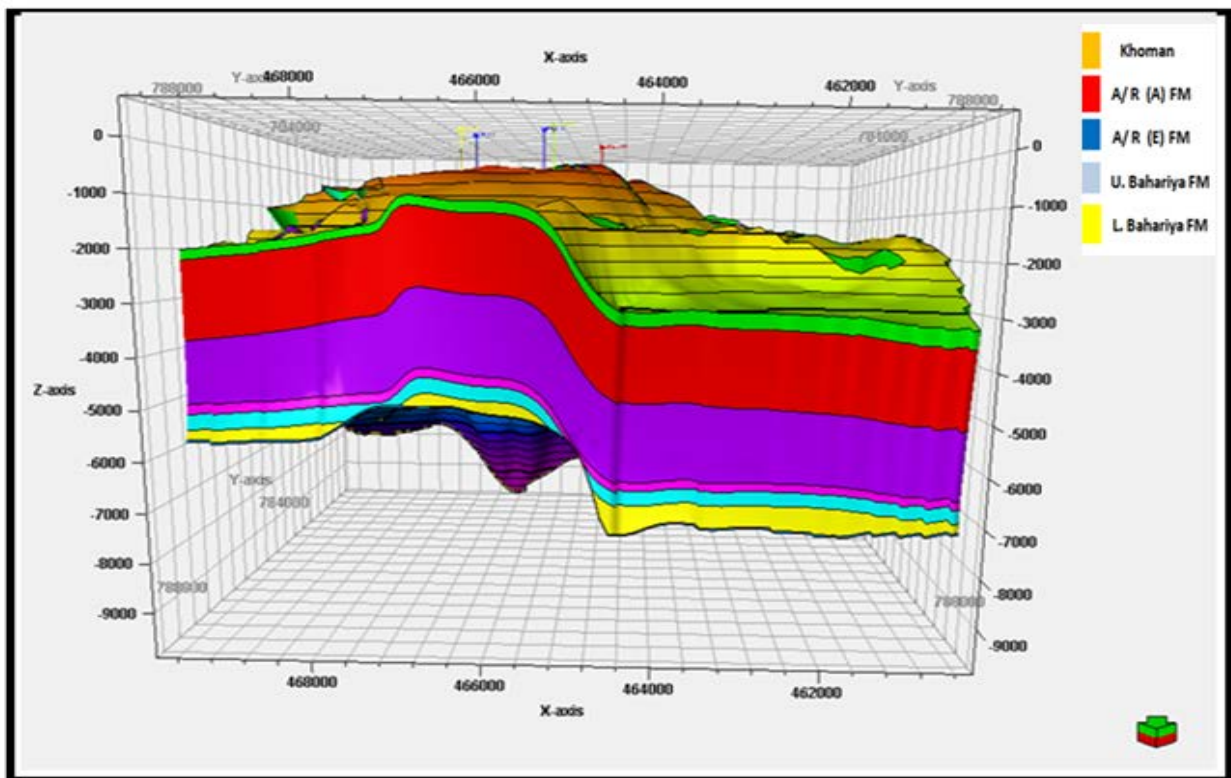
Figure (13): 3D structural model with the wells in the study area .

Structural Cross Sections

Structural cross sections have been constructed using the interpreted seismic lines. Figure (14) shows NW-SE structural cross sections which reflect that the study area was affected by a set of normal faults forming a horst and graben blocks. The two main faults forming the traps is F1 and F2, F1 is directed towards the NW-SE trend and its downthrown side is directed towards the SW trend. F2 is also directed towards the NW-SE trend and its downthrown side is directed towards the SW trend.

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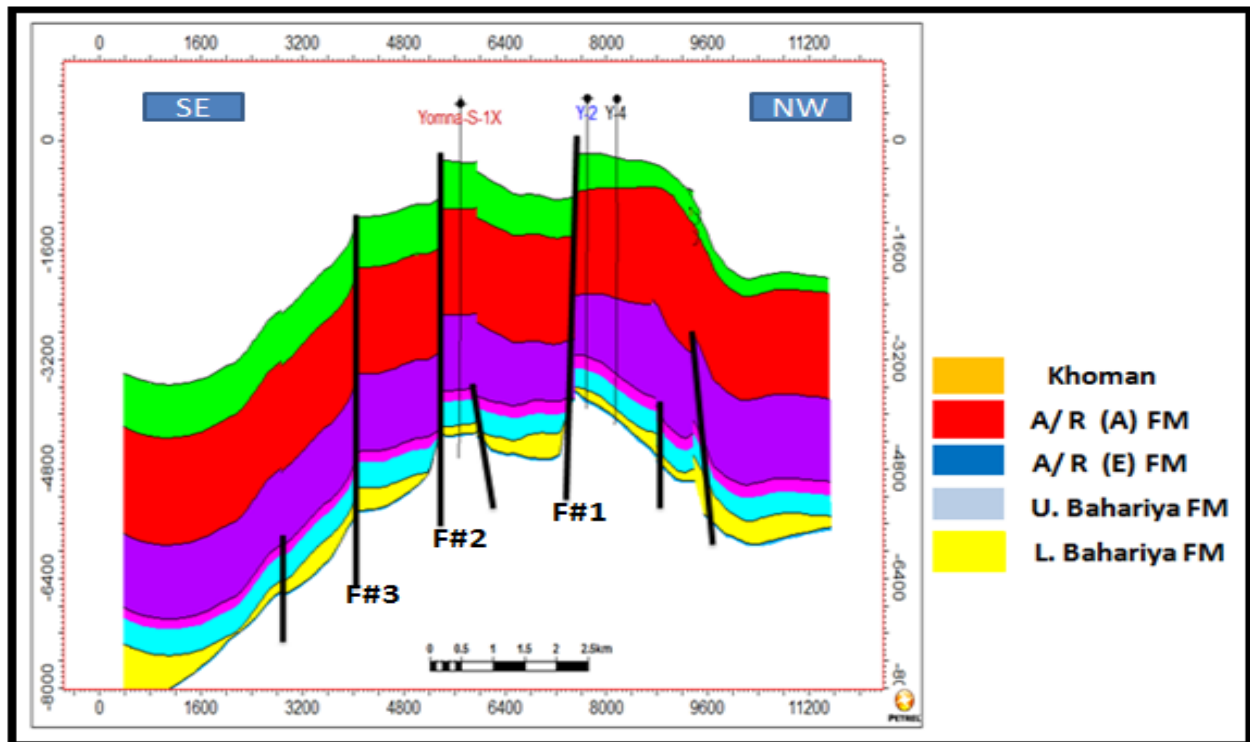**Figure (14):** Structure cross section within Yomna Field

PETROPHYSICAL EVALUATION

This part of the study is concerned with the Petrophysical characteristic of Bahariya reservior at Yomna field, North Western Desert, Egypt. We need to evaluate the reservoir in the term of petrophysical parameters of both rock and fluid constituents. In order to assess possible petroleum reservoir, the porosity and hydrocarbon saturation are required to be evaluated, which together define the amount of hydrocarbons per unit volume of rock. Petrophysics, in its simplest form, is the calculation of porosity and fluid saturations as a function of depth in a well (**Luthi, 2001).**

In this study, the petrophysical analysis was performed for five wells in the study area (Yomna-2, Yomna-4, Yomna-11, Yomna-19 and Yomna South 1X).

The value of formation water resistivity (Rw) for Bahariya Formation is obtained from the composite-log data at Sw equals 100%, by using the Archie's water saturation equation (Schlumberger, 1987). Another method for determining Rw is the using of "Pickett plot", which is developed by plotting porosity values with deep resistivity values on two-by-three cycle log-log paper (**Asquith and Gibson, 1982).**

Upper Bahariya formation have been subdivided into three zones depending on the sea energy regression and transgression,

The calculated net pay, Effective porosity, water saturation and hydrocarbon saturation values were tabulated for Bahariya Formation (table 1). The cutoffs used are as follows: Effective porosity 10%, Volume of shale 35%, Water saturation 65%.

Well log analysis

Well-log analysis represents the most important stage in the evaluation of petrophysical characteristics (effective porosity, shale content, water saturation, and hydrocarbon saturation).

Lithological Identification cross-plot

Identification of lithology is of a particular importance in formation evaluation process. Logs can be used as indicators of lithology. The most useful logs for this purpose are density, neutron, sonic and gamma-ray logs. Figure (15) shows the neutron density cross plot of the different zones which shows that zone one it is mainly characterized by the predominance of sandstone and siltstone with shale and limestone, while zone two and three are mainly characterized by the predominance of siltstone and shale with small percentage of sandstone and lower Bahariya zone are mainly characterized with sandstone.

Shale Types and Clay Minerals

Techlog software can be used to determine the shale type based on Thomas-Stieber plots (Shale Volume Versus Porosity and Neutron Versus Density) plots were used to identify the shale types

Clays are usually distributed in the formation in 3 ways:

- Laminated shale: Continuous bands of shale layers interbedded with sand layers

- Dispersed shale: Clays found in pore spaces or coating sand grains

- Structural shale: Clays that are part of the formation matrix

The Module which used is Thomas-Stieber Shaly Sand Model was originally invented to resolve the problem of laminated shaly-sand sequences, In the conventional methods, the correlation between the Gamma ray parameter and the shale volume is usually presented as one direct relationship. Because the shale can exist in three different forms in the sand: dispersed, laminated and structural, the method expects a correlation between the varying gamma ray responses and the shale geometry **(Thomas & Stieber, 1975).**

Upper Bahariya zone one and two shows that is mainly characterized with sandstone and laminated shale, zone three shows that is mainly characterized with laminated and dispersed shale and lower Bahariya zone is characterized with sandstone with complete absence of shale figure (16).

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Well	Zones	Top	Bottom	Gross	Net	Net to Gross	Av_PORE	Av_SWE	Av_VSH
		(ft)	(ft)	(ft)	(ft)	%	%	%	%
Yomna-2	U.Baharaiya Zone#1	3787	3987	200	40.5	0.203	0.162	0.313	0.302
Yomna-2	U.Baharaiya Zone#2	3987	4267	280	26.5	0.095	0.164	0.393	0.353
Yomna-2	U.Baharaiya Zone#3	4267	4418	151	18	0.119	0.177	0.401	0.293
Yomna-2	L.Baharaiya	4418	4566	148	0	0	0	0	0
Yomna-4	U.Baharaiya Zone#1	4089	4219	130	30.75	0.237	0.159	0.415	0.297
Yomna-4	U.Baharaiya Zone#2	4219	4619	400	0	0	0	0	0
Yomna-4	U.Baharaiya Zone#3	4619	4726	107	0	0	0	0	0
Yomna-4	L.Baharaiya	4726	4831	105	0	0	0	0	0
Yomna-11	U.Baharaiya Zone#1	4216	4400	184	34.5	0.188	0.199	0.436	0.352
Yomna-11	U.Baharaiya Zone#2	4400	4697	297	3.25	0.011	0.197	0.455	0.333
Yomna-11	U.Baharaiya Zone#3	4697	4874	177	1.5	0.008	0.172	0.422	0.437
Yomna-11	L.Baharaiya	4874	5186	312	0	0	0	0	0
Yomna-19	U.Baharaiya Zone#1	3875	4053	178	35	0.197	0.203	0.199	0.304
Yomna-19	U.Baharaiya Zone#2	4053	4332	279	25	0.09	0.196	0.36	0.344
Yomna-19	U.Baharaiya Zone#3	4332	4466	134	5.5	0.041	0.177	0.48	0.429
Yomna-19	L.Baharaiya	4466	4672	206	0	0	0	0	0
Yomna-S-1X	U.Baharaiya Zone#1	4196	4361	165	13.25	0.08	0.154	0.46	0.146
Yomna-S-1X	U.Baharaiya Zone#2	4361	4724	363	0	0	0	0	0
Yomna-S-1X	U.Baharaiya Zone#3	4724	4855	131	0	0	0	0	0
Yomna-S-1X	L.Baharaiya	4855	5220	365	0	0	0	0	0

Table (1) Summary of the petrophysical parameters composing the Bahariya reservoir within the studied wells.

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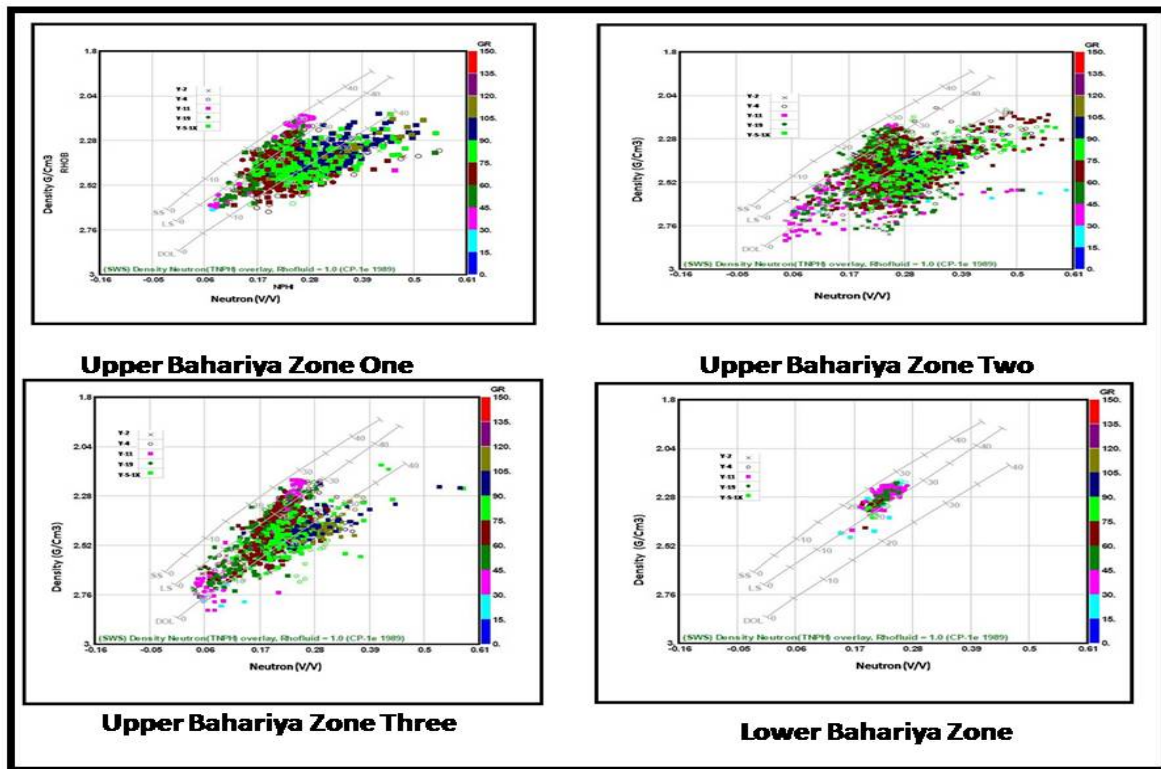*ISSN: 2395-3470*
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Figure (15): Lithological identification cross plots of Bahariya Formation in all available wells
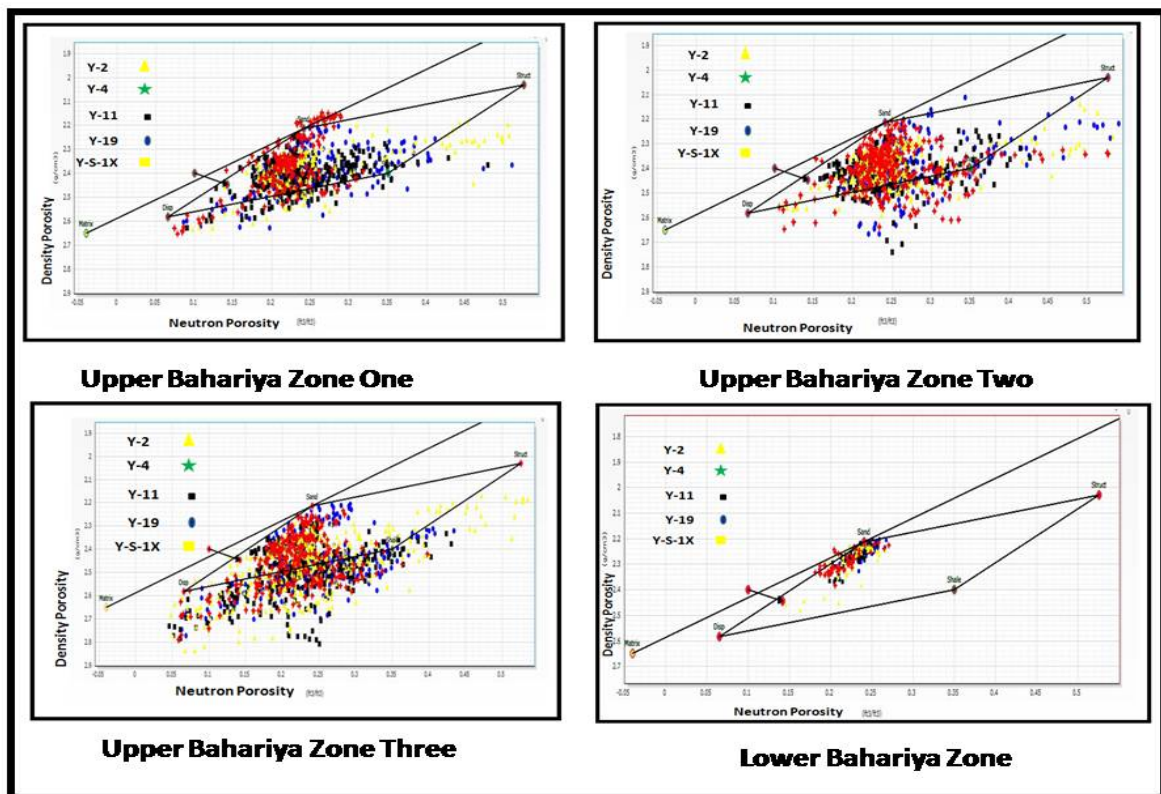
Figure (16): Shale Type cross plots of Bahariya Formation in all available wells

Vertical Distribution of Petrophysical Characteristics

The vertical variation of hydrocarbon occurrence can be represented through the litho–saturation logs. The results of cross-plots show the effective porosity, shale volume, matrix contents, and water and hydrocarbon saturations **(El Kadi, 1978).**A Litho–saturation log is a representation, zone-wise, for the electrical logs with equivalent contents of rocks and fluids by depth through wells using PC software. The following is a summarized discussion for these litho-saturation cross-plots.

Figure (17) represents the litho-saturation log of Bahariya formation at Yomna-2 well which indicates that there are three productive zones with in the Upper Bahariya, the most productive zone is zone one and two as the sand increase and it is characterized by the presence of good hydrocarbon saturation as the pay zone is 40.5ft for zone one and 26.5 ft for zone two and zone three is less productivity than the others as the net pay reaches to 18ft, The effective porosity ranges between 10% to 30% but the mean value is16.8%, the water saturation ranges between 0% to 100% and the mean value is 35%. The hydrocarbon saturation reaches up to 65%.

Figure (18) represents the litho-saturation log of Bahariya formation at Yomna-19 well which indicates that there are three productive zones with in the Upper Bahariya, the most productive zone is zone one and two as the sand increase and it is characterized by the presence of good hydrocarbon saturation as the pay zone is 35ft for zone one and 25ft for zone two and zone three is less productivity than the others as the net pay reaches to 5.5ft, The effective porosity ranges between 10% to 40% but the mean value is 18%, the water saturation ranges between 0% to 100% and the mean value is 35%. The hydrocarbon saturation reaches up to 65%. And the shale content ranging from 20-70% but the mean value is 35%.
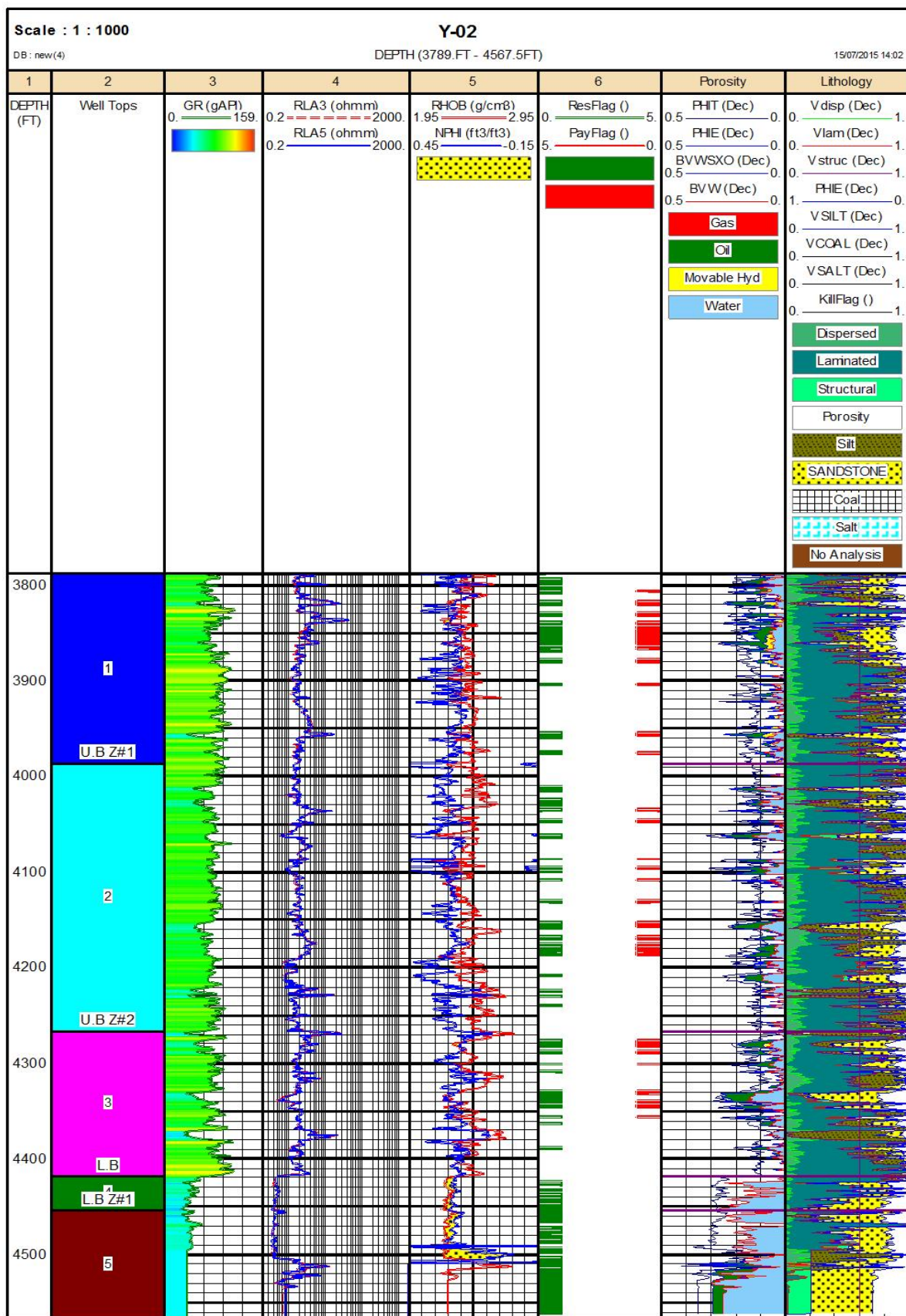
Figure (17) Litho-Saturation Cross-plot of Bahariya reservior at Yomna-2

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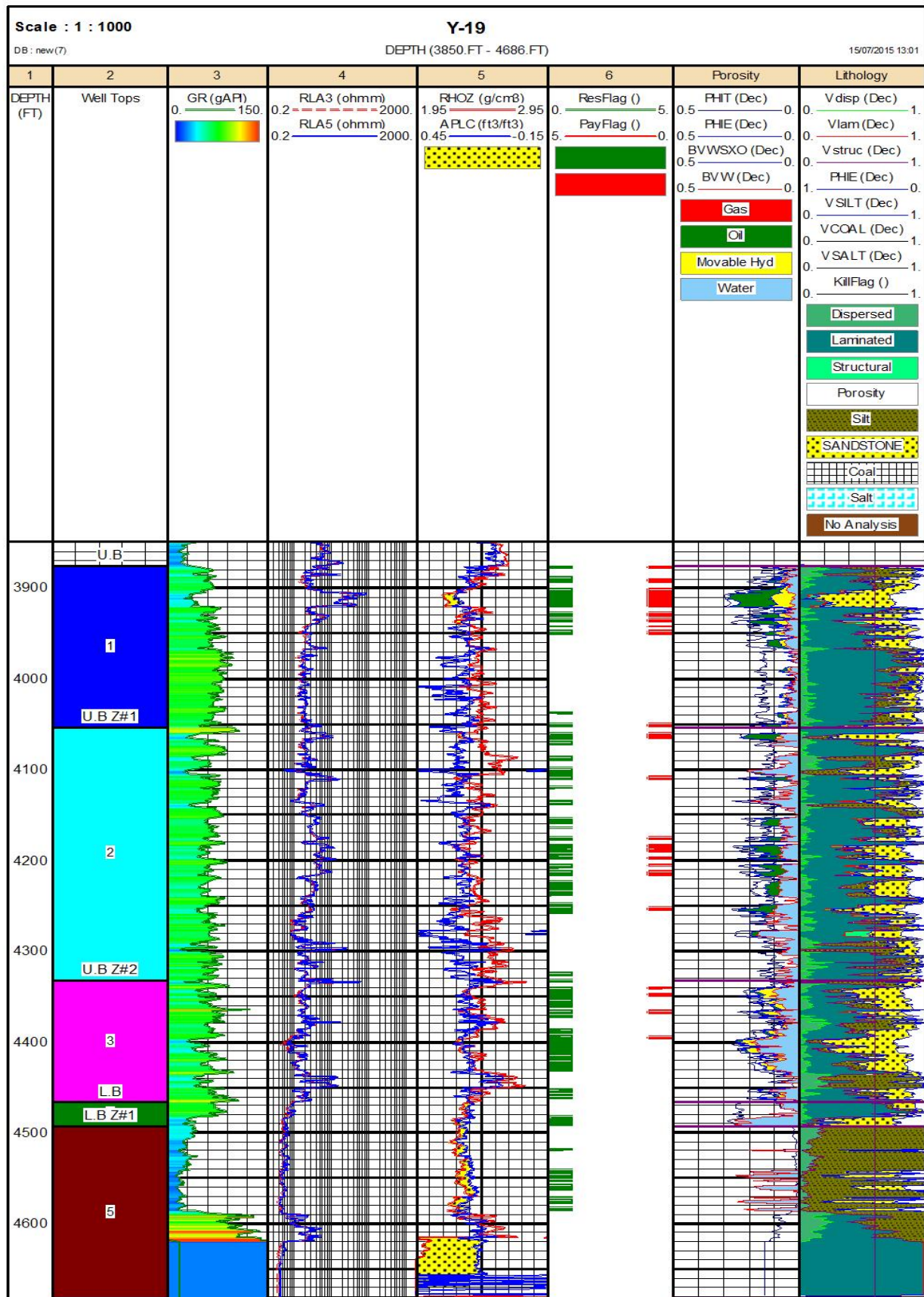*ISSN: 2395-3470*
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Figure (18) Litho-Saturation Cross-plot of Bahariya reservior at Yomna-19

PROSPECT GENERATION AND LEADS

According to **Gluyas and Swarbrick (2004),** exploration wells are drilled into

Prospect. Prospects are volumes of rock in the earth crust that are believed, but not proven to contain the four key components: a valid trap, an effective seal, a reservoir and petroleum source rock that has generated and expelled petroleum into the trap. Once an exploration well penetrates a prospect, it ceases to be a prospect. It became a proven petroleum field or more likely a dry hole, which means that it lacks petroleum. A lead is nothing more than an ill-defined prospect. The boundary between what is lead and what is prospect is open to individual interpretation. As a result of the present study, using the subsurface and petrophysical evaluation, a new location is proposed to be a prospect as in figure (19). The intersections of the NW-SE and NE-SW trending faults gave rise to varying structural closures at Yomna field. These closures formed good traps for trapping hydrocarbons in main reservoirs (Bahariya Formation). The structural closures formed in this field mainly three-way closure type. So, from through interpretation of the seismic sections trends (NW-SE and NE-SW), depth structural contour maps and petrophysical characteristics of Yomna field, i arrived to prospect areas for new drilling wells. I classified Yomna field to into two closures "A" and "B", the closure "A" area located in the northeastern part, whereas the closure "B" area sited in the Southwestern part of this field.

The new prospect area was selected based on structurally closure high, located along the northwest– southeast trending Major normal fault #2 and good Petrophysical characteristics.
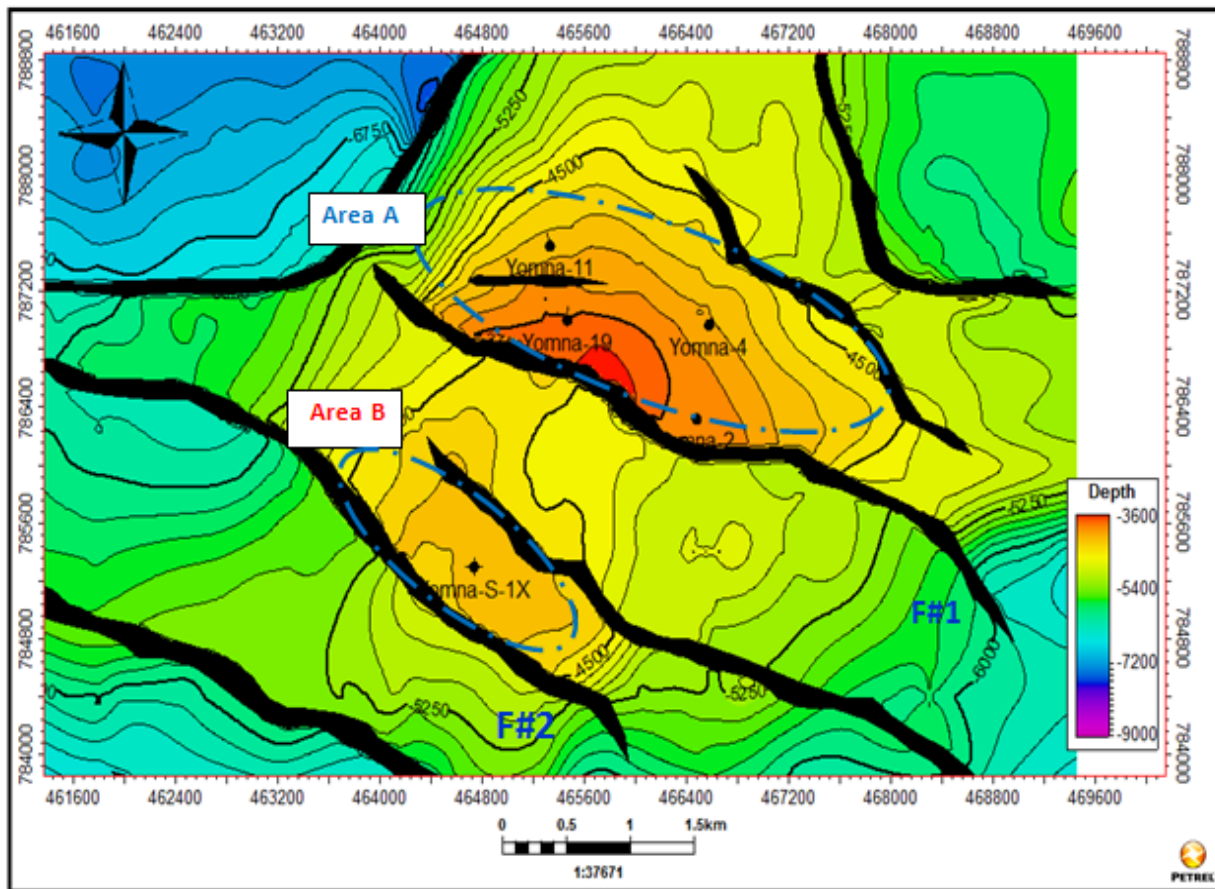
Figure (19) Structure Contour Map on the top of Upper Bahariya formation showing the new prospect area B

Summary and Conclusion

The study area Yomna field is located in the north western part of East Bahariya concession which is located at the North Western Desert of Egypt.The main purpose of this study is delineating the subsurface geological and petrophysical analysis of the area under study by reviewing the general stratigraphy and structural relationships, using subsurface geological and geophysical data and different well-logs to study the geologic setting of the study area and petrophysical parameters of the Bahariya Formation. To achieve this goal the current study started with the description of the geology of the area including a detailed discussion of stratigraphic rock units, structure and tectonic evaluation of the North Western desert where Yomna field located is.

Seismic data interpretation has been carried out to clarify the structural elements of the study area using Petrel 3D seismic interpretation software in order to construct the depth structure contour map on the top of Khoman, Abu Roash "A", Abu Roash "E", Upper Bahariya and Lower Bahariya to figure out the general geological setting and the features affecting the study area and also 3D structural

model have been applied to imagine the discontinuities and following faults dissecting the studied formation tops.

Petrophysical analysis have been applied for the wells within the study area by applying qualitative correlation passing though the available wells trending northeast-southwest to obtain comprehensive information and set up a good background about the various encountered formations. A comprehensive analytical formation evaluation have been established to interpret the basic logging data for the deduction of the Petrophysical parameters of main reservior (Bahariya formation) such as the porosity, shale content, water saturation and hydrocarbon based on a number of equations and empirical formula. This was done by the interactive Petrophysics (IP) software.

Neutron-Density cross plots have been applied in this study to obtain the lithological components of Upper and Lower Bahariya formation, as well as the shale type and clay minerals cross plots have been applied to differentiate between the shale types and to see the affect of clay minerals on the effective porosity.

Quantitative interpretation had been done by choosing the best model from the given data so we can obtain results, which are as closed as possible to the reality, the choice of the interpretation model must take into account all the geological information given by the closed analysis of logs are porosity, water saturation, and permeability, as well as sums and averages of these values. As the clay volume was determined by using the gamma ray, the neutron and density logs, and then the effective porosity was calculated by the using weighted average neutron-density with clay correction and also the water saturation was derived using Indonesia equation then the best cutoff of porosity, clay volume and water saturation (Φeff, Vcl and SW) for Bahariya reservior.

The obtained results from the petrophysical analysis reveal that Upper Bahariya zone one are of interest for the presence of hydrocarbon potentiality while the zone two and three member has less interest even though clastic zone.

As a result of the present study, using the subsurface and petrophysical evaluation, a new location is proposed to be a prospect area that is located on such a three-way dip closure that is very suitable place for hydrocarbon accumulations.

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