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# Reservoir characterization of the Upper Cretaceous Abu Roash "G" Member, using wire line logs and 3D seismic data in West of Nile-X Field, Beni-Suef Basin, Western Desert, Egypt.

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## Abstract

The current work focuses on integration of seismic and well log data for evaluating the Upper Abu Roash "G" Sand Member, in West of Nile-X oil field. A comprehensive petrophysical evaluation was performed for Abu Roash G reservoir. The estimated petrophysical parameters of the reservoir in the study area for the Upper Abu Roash"G" Sand Member range between about 17 % and 22 % for the effective porosity, and range between about 5 % and 15 % for shale volume, and range between about 18 % and 79 % for Water saturation. All of These results show that the Upper Abu Roash "G" Sand Member in this field deem as a good reservoir with high potential for oil production and the cumulative stock tank of original oil in place estimate for the study area is 27 Million Stock Tank Barrel. Depth structure map shows an elongated asymmetrical double plunging anticlinal has an axis of NNE-SSW trend with a steep dip value in the eastern part and a gentle dip in the western part of the study area, which formed petroleum traps in the crest of the study area. The study results show that the Upper Abu Roash "G" Sand Member has a promosing reservoir characterization.

## Introduction

The occurrence of hydrocarbons in Western Desert is closely related to the tectonic activities and stratigraphic history, which has created a series of reservoirs and seals. Most fields in the northern Western Desert are associated to Late Cretaceous-Eocene structures and are located in or at the edge of early depo-centers that later became kitchen regions (Abu El Naga, 1984). Mainly of sedimentary basins in Egypt are located in the northern Western Desert e.g. Matruh- Shushan basin, North Meleiha basin, Alamein basin, Abu Gharadig basin, Gindi basin, Beni Suef basin (of our focus), and Paleozoic Basins (Fig.1). Beni Suef basin is located in the northeast part of the African plate. It is an Early Cretaceous rift basin with NW-SE geometric orientation that has recently been suggested as a frontier basin for future hydrocarbon exploration in Egypt's Eastern and Western Desert. It is located 150 km south of Cairo, Egypt, along both sides of the Nile Valley (Fig.2). There are several oil fields in the Beni Suef basin including, Beni Suef field, Azhar field, Yusif field, Lahun field, Gharibone field, East of Nile field, and West of Nile development lease in which West of Nile-X oil field exist.

The benefit of study is integrate between well log interpretation analysis for evaluating the Upper Abu Roash "G" sand Member in Abu Roash Formation in West of Nile – X oil field, Western Desert, Egypt. Which reservoir characterization is supreme steps in exploration and development phase of any prospect. It gather the results of the different analyses to optimize production, reduce risk, uncertainties and enhance understanding of the reservoir. So the benefit of the study to calculate the qualitative and quantitative well-logging data interpretation. Formation evaluation is enhanced by gathering the available electrical logs for the studied wells and calibrating them for different environmental effects, then then performing various calculation processes for different reservoir parameters, and finally presenting the resulting data through crossplots, and aerial distribution maps.

## Materials and Methodology

Three-dimensional seismic lines and electrical well logs from four wells in the West of Nile-X field were interpreted. A 3D seismic survey was used to construct the current study, which encompassed the western section of the Beni Suef basin (West of Nile area). The area is surrounded by twenty seismic lines which cover an area of nearly 25 km2. Due to the enhanced quality of 3D seismic survey which allow to observe the seismic units relevant to Cretaceous tectonics, especially the Abu Roash "C, F and G" Members and Upper Bahariya Formation. Seismic interpretation is done on depth domain seismic lines by identifying, picking, and correlating reflectors that represent distinct strata of cretaceous sediments. Based on the interpretation of the twenty seismic lines of the 3D seismic depth cube, a structural analysis was performed (Fig.2) were used to

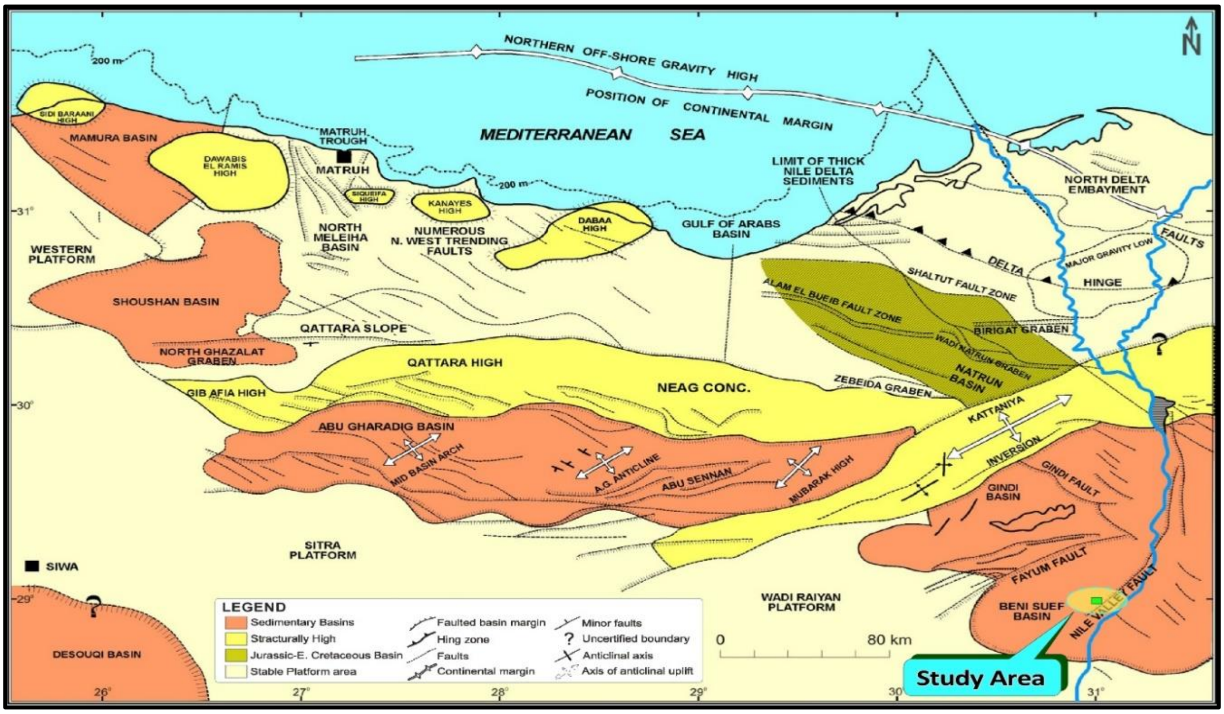


**Figure 1:** The tectonic framework in the Western Desert of Egypt (Modified after Bayoumi 1996).

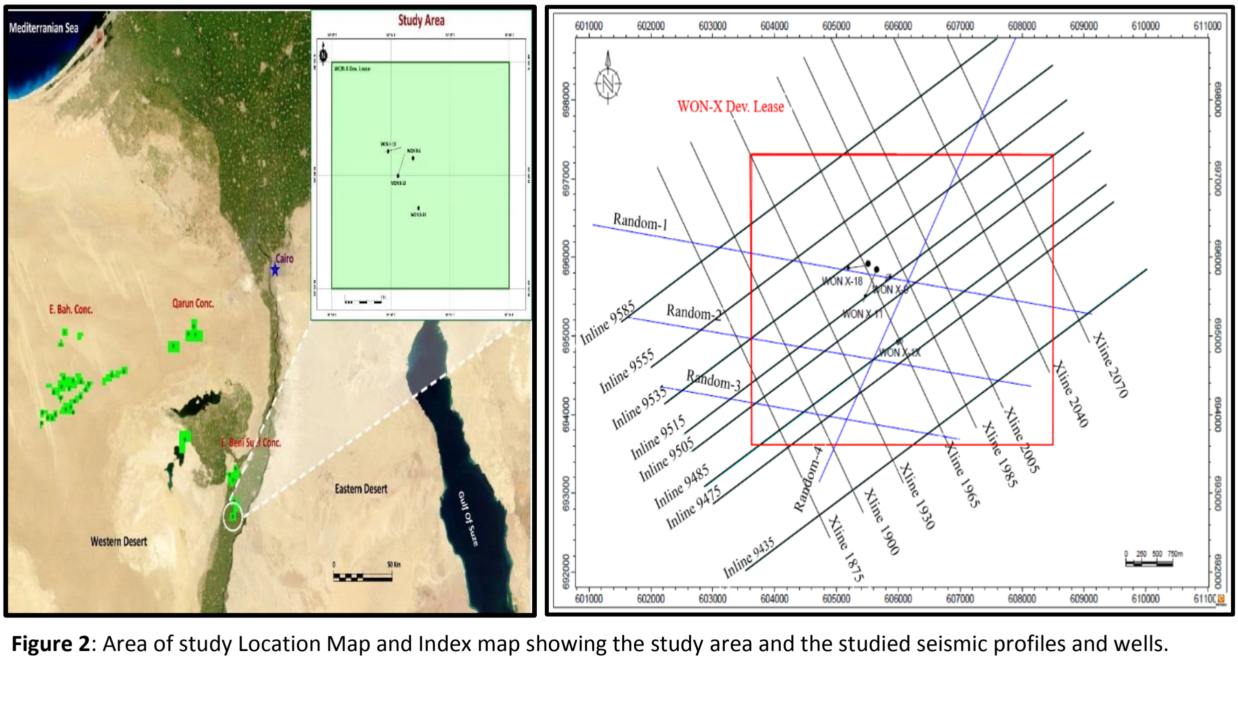


**Figure 2**: Area of study Location Map and Index map showing the study area and the studied seismic profiles and wells.

depict and identify the structural features which the area was subjected.

The depth structure map for top of Abu Roash "G" Member (Base Turonian - Upper Cenomanian) have been constructed in order to determine the structural architecture of the area. After that; Evaluation of the petrophysical properties through the petrophysical analysis of the sandstone petroleum reservoir in the top part of the Abu Roash "G" Member.

The aim of current study can be achieved by integrating multidiscipline such as the interpretation of seismic data as well as the analysis of petrophysical data.

## Geological Setting

### ➢ Stratigraphy Setting

The stratigraphic succession of the Northern Western Desert is thick and includes most of the sedimentary deposits from Pre-Cambrian basement complex to recent (Schlumberger, 1995), and consist of alternating depositional cycles of clastics and carbonates, five cycles have been recognized by Abdine (1974) (Fig.3). In Beni Suef Basin (the study area), Beni Suef basin can be deemed as a rift basin conversely, it is, by far, quiet similar to that of the northern territories of the Western Desert, with the exception that the basin is controlled by the Aptian/Albian NE-SW extension movement (Zahran et al., 2011). This movement was the reason to erode the pre-Albian succession, where the Kharita Formation (Albian) overly directly on the crystalline rocks of the Egyptian Pre-Cambrian Basement complex. May be the absence of pre-Albian succession is related to high Pre-Cambrian basement relief in this basin. In West of Nile Fields, the Paleocene-Middle Eocene Apollonia Formation, Campanian-Maastrichtian Khoman Formation and sometimes the top part of Abo Roash Formation are missed in these area which represented by the old ancestral Nile. It's a large erosional feature that consists Tertiary Clastic sediments. In the study area (Fig.4).

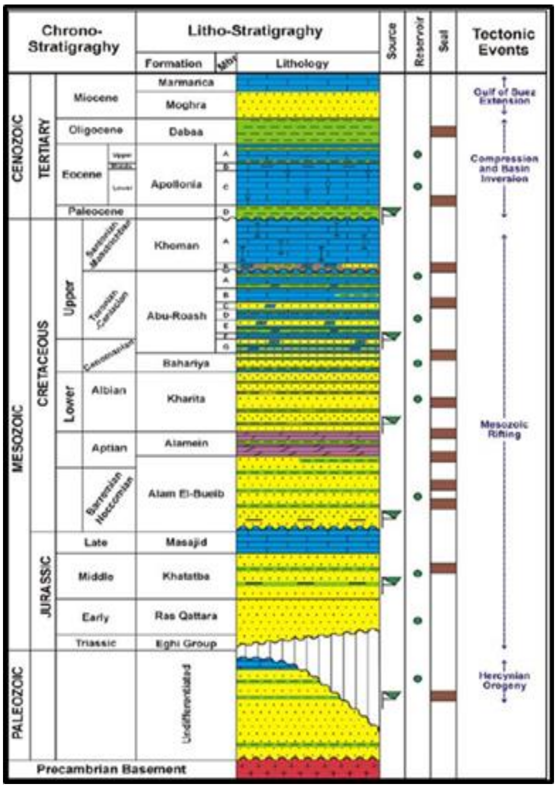


**Figure 3:** Generalized stratigraphic column of the north Western Desert of Egypt. (After, Moustafa, et al., 2003).

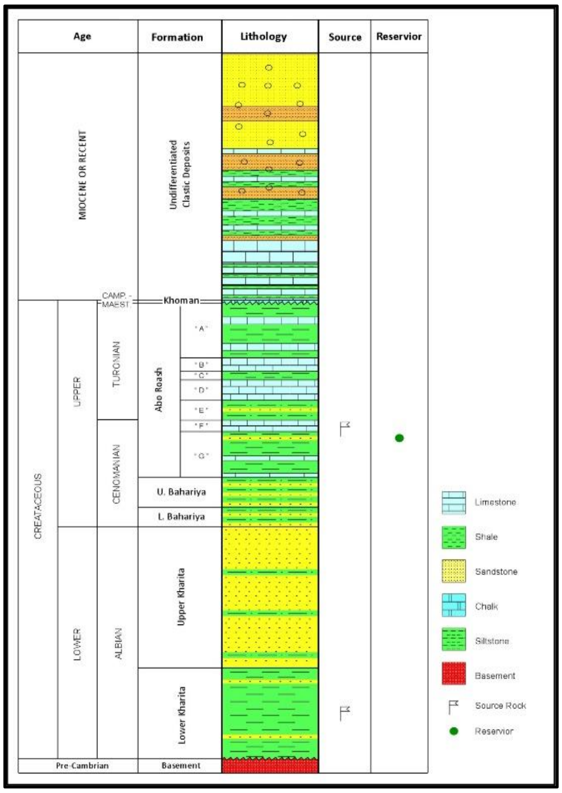


**Figure 4:** Local stratigraphic column of the study area. (Qarum Petroleum Company report).

### ➢ Tectonic setting

Two main tectonic forces related to Tethyan plate tectonics, that affected the Late Jurassic to Early Tertiary succession, are resulted in the structural patterns in the northern western desert of Egypt. These forces are: (1) the sinistral shear that occurred in the Late Jurassic to Early Cretaceous and (2) the dextral shear during the Late Cretaceous to Paleocene time (Meshref et al, 1990) (Said, 1962). The Beni Suef basin is bifurcated by the River Nile from to two main parts in the Western and the Eastern Desert of Egypt at the northwestern part of a series of NW–SE oriented Cretaceous basin system. This basins are, from northwest to southeast these include: Beni Suef basin, Asyut basin, Komombo basin, and the Hodein graben (Bosworth et al., 2015) (Fig.1). The main structural pattern of East Beni Suef Basin is a wide major graben, between two structural high areas in the north east and south west sides of the graben. Also, the all faults in the Basin as a normal faults with dominated NW-SE and WNW-ESE (Aboul-Magd, 2015; Salem and Sehim, 2017). The interpretation of The Beni Suef Basin revealed that it is a rift basin in form of a half graben and this basin is thought to be developed as a result of its presence in a regime of an extensional stress contemporaneous to the opening of South Atlantic that affected the North and Central Africa which occurred on the Early Cretaceous. This extensional regime also resulted in reactivation of the pre-existing Jurassic basins

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that trending east-west, such as Faghur and Abu Gharadig basins in Egypt as well as the Sarir Troughs in Libya (Bosworth et al. 2008).

- **Source rock and Entrapment**

The oil Potentiality of Abu Roash-F member in Beni Suef and Azhar oil fields and proved that the Abu Roash-F member is an effective source rock in the area (El-Sherbiny, 2017). And West of Nile-X block shows a suitable petroleum trap of structural type developed as asymmetrical double plunging anticline.

## Results and Discussion

### Structural interpretation

The primary purpose for detecting the unconformities, faults and folds is structural interpretation (Abu El Ata et al., 1999), Generally, three structural features can be distinguished; faults, folds, and unconformities. In order to recognize these three elements seismic expressions should be established, which would facilitate the given seismic data interpretation (Abedi and El-Toukhy, 1990). The interpretation of 3D seismic data leads to imaging the subsurface structural elements using five picked reflectors on the pre-stack time migrated (PSTM) seismic volume. The seismic reflectors were picked are Upper Bahariya Formation, Abu Roash "G", Abu Roash "F" and Abu Roash "C" Members in addition to Base Channel of old ancestral Nile. The interpreted fold, related deFormation and associated features are discussed in the following, using seismic sections and mapped intervals.

- **WNW-ESE seismic section (Random-1):**

This seismic section oriented to the WNW-ESE direction of the study area (Fig.5), which passing through WON X-18 and WON X-9 wells. It's about 6.7 Km long which shows seismic reflectors were picked; Upper Bahariya Formation, Abu Roash "G", Abu Roash "F" and Abu Roash "C" Members in addition to Base Channel of old ancestral Nile. Seismic reflectors seem to be parallel to semi parallel to each other which reflect a quite depositional regime. And gradually dipping toward the WNW-ESE direction.

The seismic section shows that the Late Cretaceous sequence from the Bahariya Formation to Abu Roash Formation was affected by Compressional force in a WNW-ESE direction that resulted from a strong folding phase took place along the northern territories of the Western Desert which resulted in an elongated asymmetrical anticlinal structure, having one limp dip gently toward the WNW direction and the other limp dip steep toward the ESE direction.

A severe folding phase occurs along the northern territories of the Western Desert during the late Cretaceous-Early Tertiary. Therefore; a noticeable crustal-shortening happened due to the development of NE-SW double plunging anticlinal folds which affected the older Jurassic and Cretaceous rocks. (Moustafa, 2008).

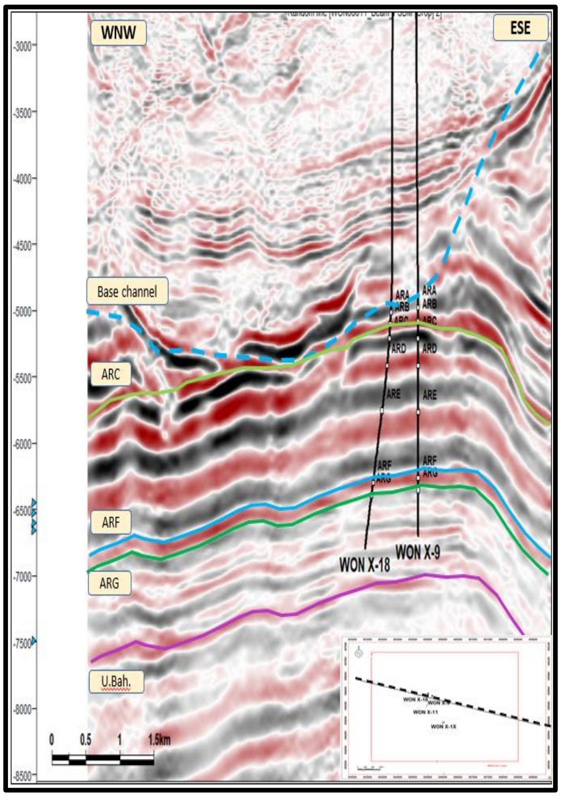


**Figure 5:** The WNW-ESE interpreted seismic section (Random line-1).

- **Subsurface Structure contour maps:**

Structure contour maps are a prevalent method of representing the elevations for a certain surface and its geometry. The contours are shown at regular intervals across the map, it is important that all the depths are referenced to the mean sea level (True Vertical Depth Sub Sea). Structure contour map constructed on the horizon was selected in the study is Abu Roash "G". It's considered as the prime reservoir in the area of study. The map shows a structurally high area in the central part of the study area, in the form of elongated an asymmetrical double plunging anticlinal structure, has an axis of NNE-SSW trend, with a steep dip value in the eastern part and a gentle dip in the western part of the study area, recording the maximum elevation in depth value about - 6325 ft., on the other hand, the deeper point of Abu Roash "G" Member was seen in the area in the eastern and western parts of the study area (structurally low) recording depth value about - 6825 ft. (Fig.6).

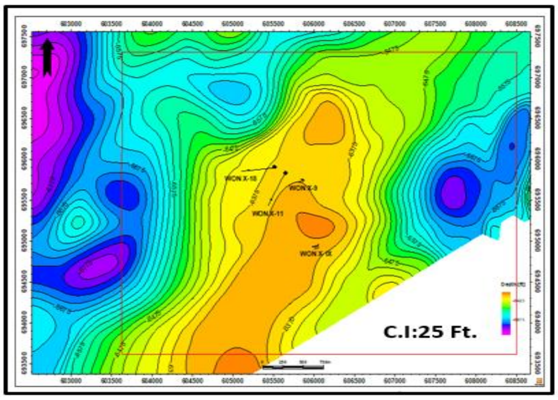


**Figure 6**: Depth structure map on top of Abu Roash "G" Member for WON-X dev. Lease.

## Well Log Analysis

### ➢ Neutron Density cross plot

The prediction of lithology based on data point locations in graphical X-Y plots regards to pure lithology reference data and the points may also contain data in the Z- axis is known as cross plot (Krygowski, 2003), Abu Roash "G-5" zone represent the Upper clastic reservoir zone of Abu Roash "G" Member. Which divided to four cycles which is Zone -4, Zone -3, Zone -2 and Zone -1 from bottom to top. Lithological components extracted from Neutron-Density Cross plot for Upper Abu Roash G reservoir in the study wells as follow:

**<u>WON X -1X well</u>**

**Zone-1:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-1) sandstone reservoir) (Fig.7), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.28 gm/cc to 2.43 gm/cc and total porosity ranging from 18% to 24%. This indicates that the zone is mainly reservoir very fine sandstone sometime grading to into silty facies.

**Zone-2:** due to facies change of sandstone to laminated sandy. It's not a reservoir in WON X -1X well.

**Zone-3:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-3) sandstone reservoir(Fig.8), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.28 gm/cc to 2.43 gm/cc and total porosity ranging from 15% to 27%. This indicates that the zone is mainly reservoir sandstone and sometime grading into silty facies.

**Zone-4:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-1) sandstone reservoir (Fig.9), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.28 gm/cc to 2.46 gm/cc and total porosity ranging from 14% to 24%.

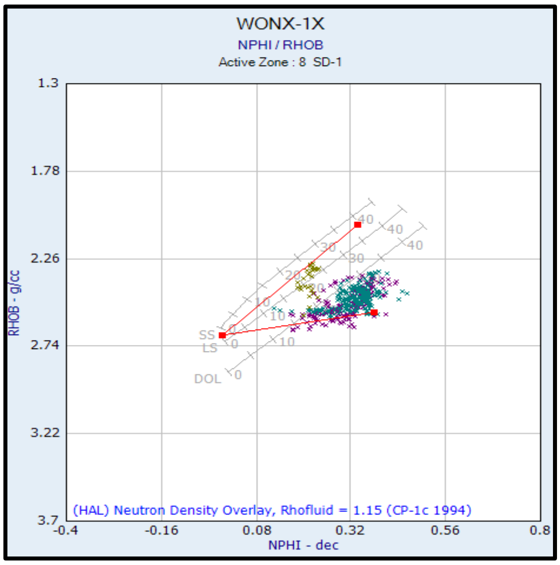


**Figure 7:** WON X-1X Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-1.

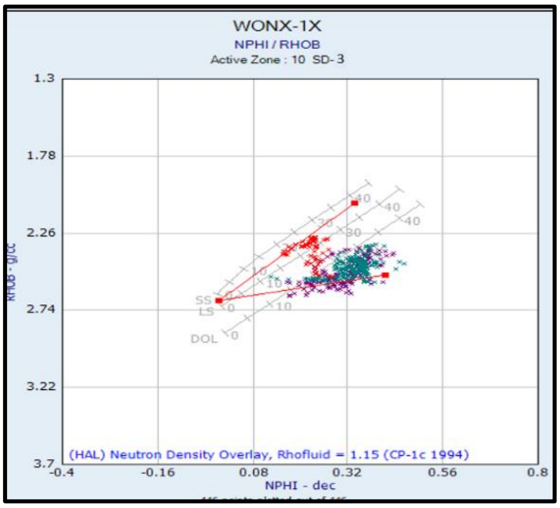


**Figure 8:** WON X-1X Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-3.

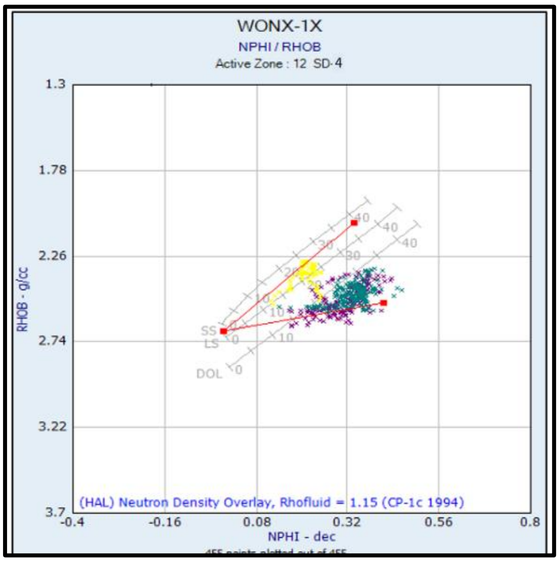


**Figure 9:** WON X-1X Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-4.

**<u>WON X -9 well</u>**

**Zone-1:** due to facies change of sandstone to laminated sandy. It's not a reservoir in WON X -9 well.

**Zone-2:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-2) sandstone reservoir (Fig.10), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.28 gm/cc to 2.43 gm/cc and total porosity ranging from 18% to 24%. This indicates that the zone is mainly reservoir very fine sandstone sometime grading to into silty facies.

**Zone-3:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-3) sandstone reservoir) (Fig.11), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.28 gm/cc to 2.47 gm/cc and total porosity ranging from 14% to 25%. gm/cc. This indicates that the zone is mainly reservoir sandstone and sometime grading into silty facies.

**Zone-4:** Neutron/density cross plots of Upper Abu Roash “G” subdivision (Zone-4) sandstone reservoir (Fig.12), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.30 gm/cc to 2.42 gm/cc and total porosity ranging from 22% to 28%.

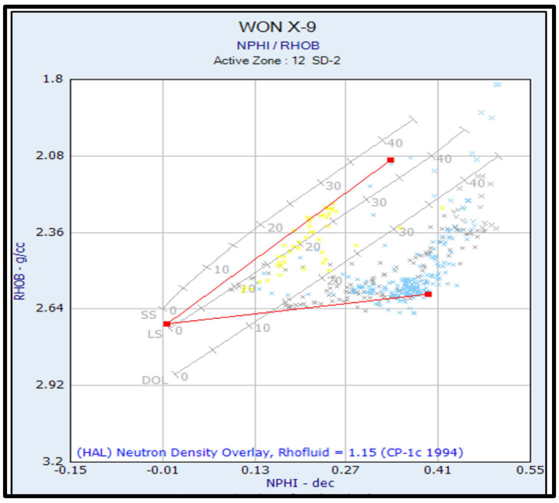


**Figure 10:** WON X-9 Neutron density cross-plot showing the lithological components of the U. Abu Roash “G” Zone-2.

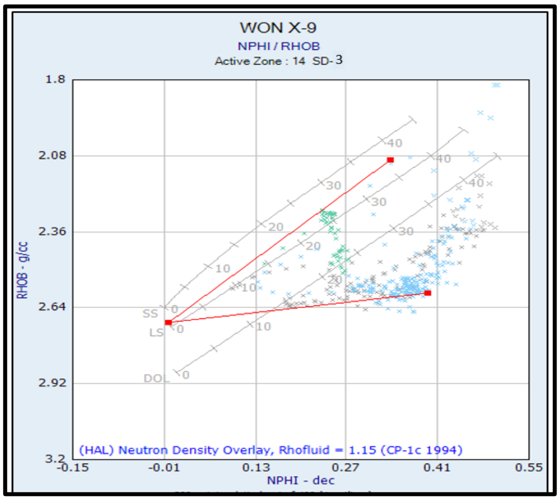


**Figure 11:** WON X-9 Neutron density cross-plot showing the lithological components of the U. Abu Roash “G” Zone-3.

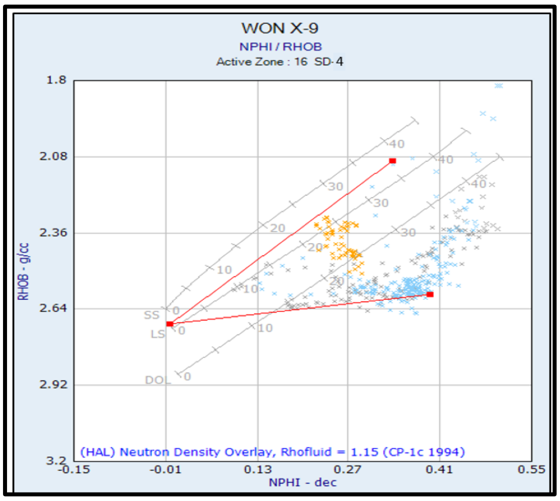


**Figure 12:** WON X-9 Neutron density cross-plot showing the lithological components of the U. Abu Roash “G” Zone-4.

**WON X -11 well**

**Zone-1:** Neutron/density cross plots of Upper Abu Roash “G” subdivision (Zone-1) sandstone reservoir) (Fig.13), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.35 gm/cc to 2.42 gm/cc and total porosity ranging from 16% to 23%.

**Zone-2:** Neutron/density cross plots of Upper Abu Roash “G” subdivision (Zone-2) sandstone reservoir) (Fig.14), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.22 gm/cc to 2.37 gm/cc and total porosity ranging from 20% to 27%. This indicates that the zone is mainly reservoir very fine sandstone sometime grading to into silty facies.

**Zone-3:** Neutron/density cross plots of Upper Abu Roash “G” subdivision (Zone-3) sandstone reservoir) (Fig.15), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.29 gm/cc to 2.45 gm/cc and total porosity ranging from 19% to 27%. gm/cc. This indicates that the zone is mainly reservoir sandstone and sometime grading into silty facies.

**Zone-4:** Neutron/density cross plots of Upper Abu Roash “G” subdivision (Zone-4) sandstone reservoir) (Fig.16), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.30 gm/cc to 2.42 gm/cc and total porosity ranging from 22% to 28%.

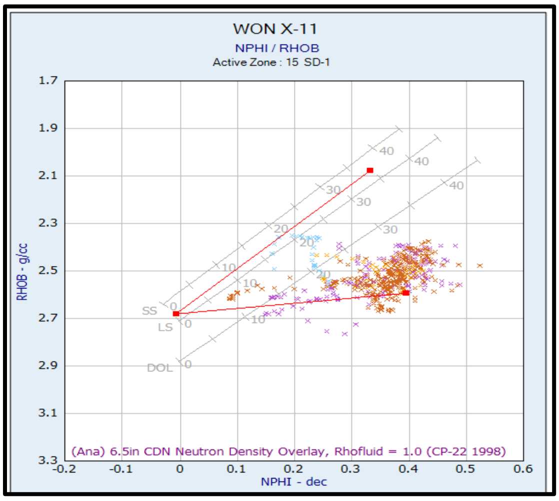


**Figure 13:** WON X-11 Neutron density cross-plot showing the lithological components of the U. Abu Roash “G” Zone-1.

**WONX -18 well**

**Zone-1:** due to facies change of sandstone to laminated sandy. It’s not a reservoir in WON X -18 well.

**Zone-2:** Neutron/density cross plots of Upper Abu Roash “G” subdivision (Zone-2) sandstone reservoir) (Fig.17), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.30 gm/cc to 2.45 gm/cc and total porosity ranging from 17% to 23%. gm/cc. This

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indicates that the zone is mainly reservoir sandstone and sometime grading into silty facies.

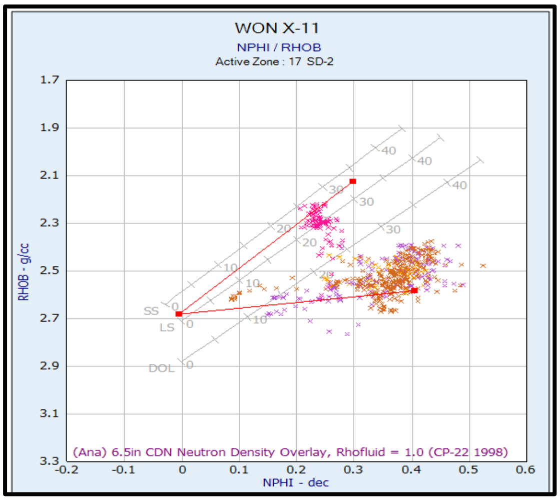


**Figure 14:** WON X-11 Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-2.

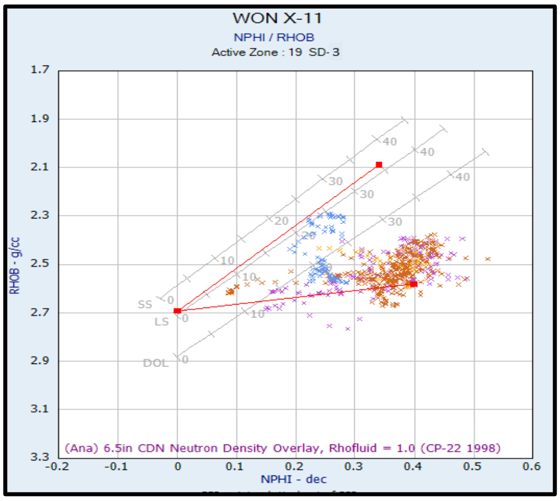


**Figure 15:** WON X-11 Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-3.

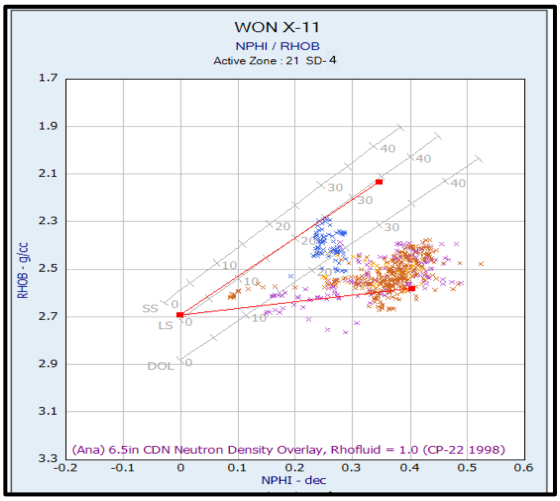


**Figure 16**: WON X-11 Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-4.

**Zone-3:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-3) sandstone reservoir) (Fig.18), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.27 gm/cc to 2.44 gm/cc and total porosity ranging from 23% to 28%. gm/cc. This indicates that the zone is mainly reservoir sandstone and sometime grading into silty facies.

**Zone-4:** Neutron/density cross plots of Upper Abu Roash "G" subdivision (Zone-4) sandstone reservoir) (Fig.19), display that the plotted points are scattered and lie between sandstone and limestone lines with grain density (ρmat) ranging from 2.30 gm/cc to 2.44 gm/cc and total porosity ranging from 9% to 26%. gm/cc.

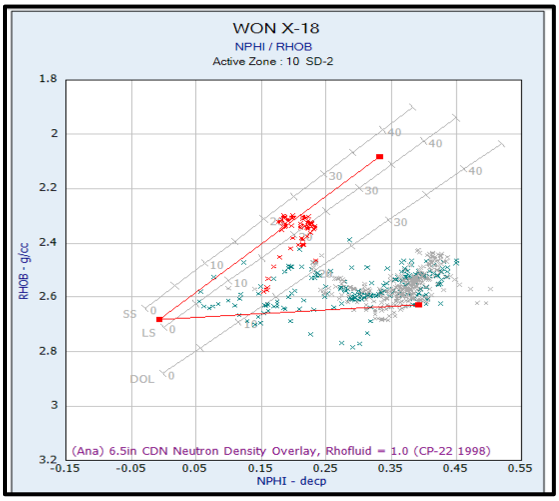


**Figure 17:** WON X-18 Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-2.

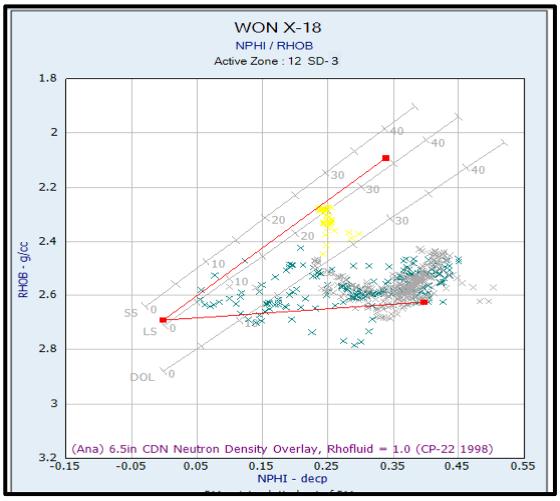


**Figure 18:** WON X-18 Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-3.

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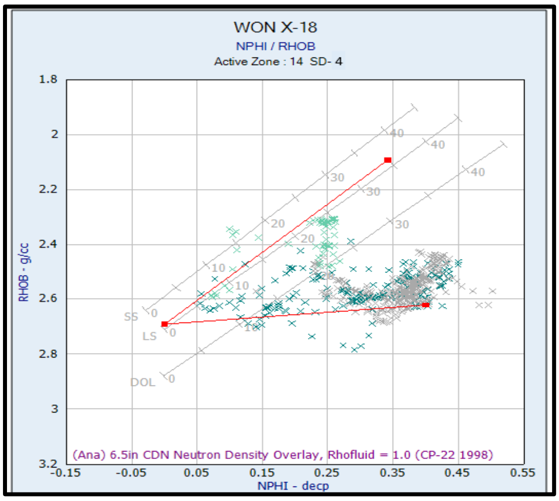


**Figure 19:** WON X-18 Neutron density cross-plot showing the lithological components of the U. Abu Roash "G" Zone-4.

### ➢Well log analysis results

The best cut offs in WON-X Field for Upper Abu Roash "G" reservoir were indicated from production history in the area which showed the porosity cut-off is greater than 12 % and clay volume cut off is less than 30 % and the water saturation cut off is less than 65 %. Table-1 shows the reservoir summary for the WON-X wells.

| WELL | Reservoir | Zone | Gross sand (FT.) | | Net pay sand (FT.) | AVG. Ø.eff % | AVG. SW% | AVG. Vsh% |
|---|---|---|---|---|---|---|---|---|
| | | | MD | TVDSS | | | | |
| WON X-1X | Upper Abu Roash " G" | SD-1 | 8 | 8 | 6 | 18 | 35 | 12 |
| | | SD-3 | 13 | 13 | 11 | 19 | 30 | 11 |
| | | SD-4 | 18 | 18 | 12 | 19 | 53 | 8 |
| WON X-9 | | SD-2 | 11 | 11 | 8 | 20 | 20 | 5 |
| | | SD-3 | 14 | 14 | 8 | 21 | 35 | 8 |
| | | SD-4 | 14 | 14 | 8 | 20 | 57 | 15 |
| WON X-11 | | SD-1 | 6 | 4 | 4 | 17 | 36 | 13 |
| | | SD-2 | 23 | 17 | 19 | 22 | 18 | 8 |
| | | SD-3 | 14 | 12 | 9 | 19 | 35 | 14 |
| | | SD-4 | 19 | 17 | 11 | 19 | 54 | 14 |
| WON X-18 | | SD-2 | 17 | 14 | 15 | 20 | 19 | 6 |
| | | SD-3 | 15 | 11 | 0 | 21 | 79 | 11 |
| | | SD-4 | 21 | 17 | 0 | 19 | 76 | 14 |

**Table 1:** The reservoir summary and zones of the four wells

### Reservoir mapping and lateral variation

Upper Abu Roash-G sand may be deposited completely in shallow marine environments, where the sands display as acute linear trends and discontinuous in the study area (Farag, 2016), and the existence of mud drapes indicate to tidal flat and sub tidal marine (Nichols, 2009), this sand are coarse to medium grain mature well sorted; it's contains light grey to grey flaser bedding sandstone with thin lenses of siltstone and heterolithic facies which is composed of lenticular lamination (Osman, 2017), the equal proportion of mud and sand, Also the ripple of sand enclosed by mud wavy lamination formed Lenticular lamination (Reineck and Singh, 1972).

The net reservoir sandstone map of Abu Roash "G" zone-1, 2, 3 and 4 were mapped as follow:

#### ➢ Upper Abu Roash "G" zone-1:

The net reservoir sandstone isopach map of the Upper Abu Roash "G" sand-1" (Fig.20) includes the sand flat that shows an increase to south part of the study area especially, the sandstone body with maximum value in WON X-1X well about 8 feet and minimum value about 1 feet in WON X-18 well. It trending to the north eastern direction to the south west direction.

The water saturation values of Upper Abu Roash "G" Zone-1 ranging between (max. 100% - min. 28%) the higher values of water saturation distributed towards downward of structure closures and the low water saturation values within the main closures; due to facies changes from sandy mudstone to reservoir sand flat facies. Which reflect that water saturation values controlled by structure and facies (Fig.21).

The distribution of effective porosity shows values ranging between (max. 22% - min. 0 %) at reservoir sand flat and sandy mudstone facies. The effective porosity has controlled by facies distribution (Fig.22).

#### ➢ Upper Abu Roash "G" zone-2:

The net reservoir sandstone isopach map of the Upper Abu Roash "G" sand-2" (Fig.23) includes the sand channel stacked on sand flat without obvious down cut, where the channel founded in WONX-11 and WONX-18 wells and these channel with maximum value in WONX-18 well about 14 feet and trending to the north-south direction of the study area. And the sand flat with maximum value in WONX-9 well about 11 feet, also trending to the north east-south west direction of the study area.

The water saturation values of Upper Abu Roash "G" Zone-2 ranging between (max. 100% - min. 18%) the higher values of water saturation distributed towards downward of structure closures and the low water saturation values within the main closures; due to facies changes from sandy mudstone to subtidal channel and reservoir sand flat facies. Which reflect that water saturation values controlled by structure and facies (Fig.24).

The distribution of effective porosity shows values ranging between (max. 23% - min. 0 %) at subtidal channel and reservoir sand flat facies to sandy mudstone facies. The effective porosity has controlled by facies distribution (Fig.25).

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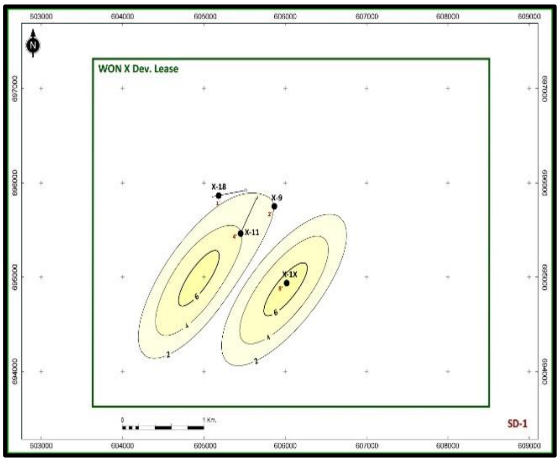


**Figure 20:** Net reservoir Isopach map for Upper Abu Roash "G" sand-1

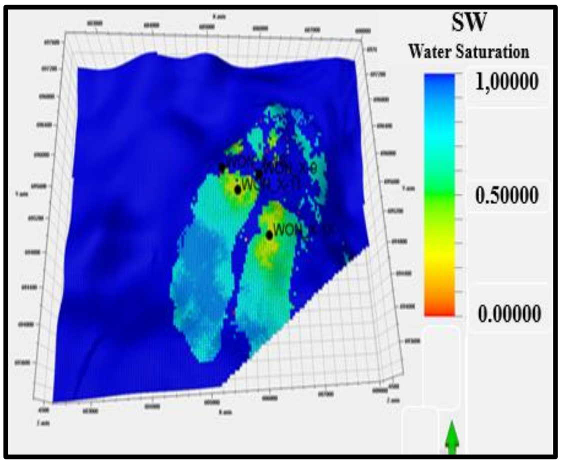


**Figure 21:** Modeled water saturation map for Upper Abu Roash-G zone-1.

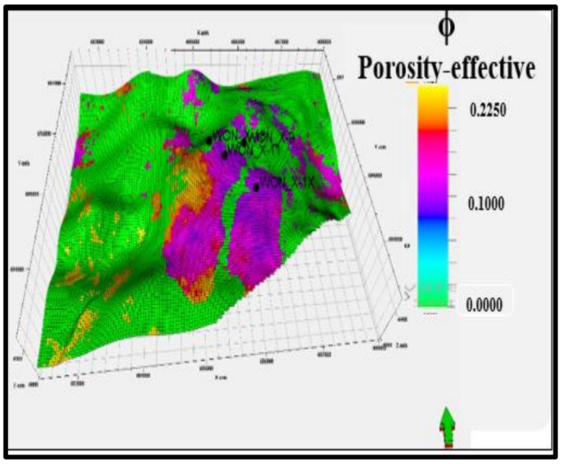


**Figure 22:** Modeled effective porosity map for Upper Abu Roash-G zone-1.

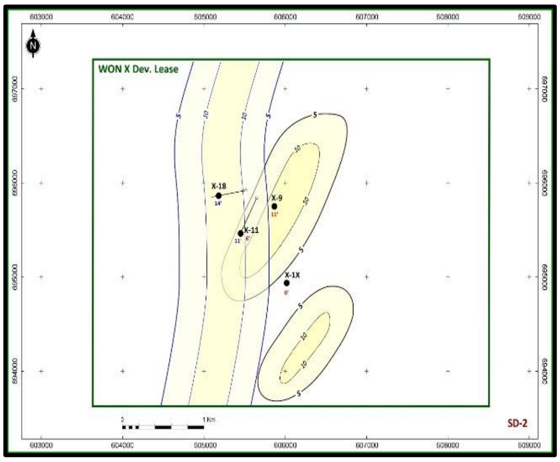


**Figure 23:** Net reservoir Isopach map for Upper Abu Roash "G" sand-2.

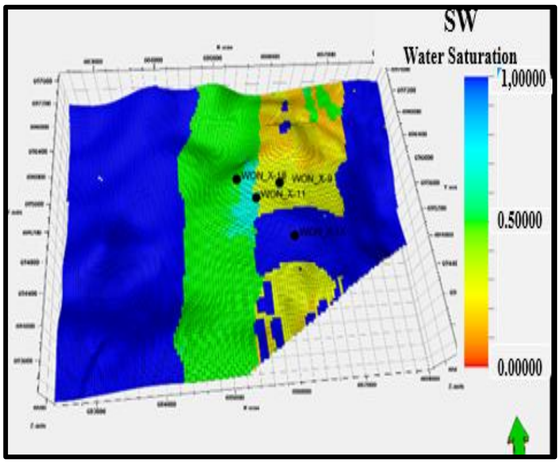


**Figure 24:** Modeled water saturation for map Upper Abu Roash-G zone-2.

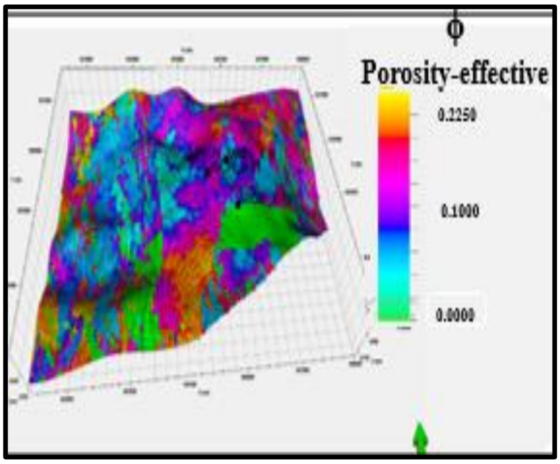


**Figure 25:** Modeled effective porosity map for Upper Abu Roash-G zone-2.

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- **Upper Abu Roash "G" zone-3:**

The net reservoir sandstone isopach map of the Upper Abu Roash "G" sand-3" (Fig.26) includes the sand flat that shows an increase in the middle part of the study area especially, the sandstone body with maximum value in WONX-9 well about 14 feet and minimum value WONX-18 well about 11 feet trending to the north east-south west direction of the study area. These sand is distinguish with a wide spread in all study area.

The water saturation values of Upper Abu Roash "G" Zone-3 ranging between (max. 100% - min. 25%) the higher values of water saturation distributed towards downward of structure closures and the low water saturation values within the main closures; due to facies changes from sand flat silt rich to reservoir sand flat facies. Which reflect that water saturation values controlled by structure and facies (Fig.27).

The distribution of effective porosity shows values ranging between (max. 22% - min. 0 %) at reservoir sand flat and sand flat silt rich facies respectively. The effective porosity has controlled by facies distribution (Fig.28).

- **Upper Abu Roash "G" zone-4:**

The net reservoir sandstone isopach map of the Upper Abu Roash "G" sand-4" (Fig.29) includes the sand flat that shows an increase in the eastern and western part of the study area especially, the sandstone body with maximum value in WONX-1X well about 18 feet and minimum value in WONX-9 well about 14 feet trending to the north east-south west direction of the study area. Also these sand is distinguish with a wide spread in all study area.

The water saturation values of Upper Abu Roash "G" Zone-4 ranging between (max. 100% - min. 44%) the higher values of water saturation distributed towards downward of structure closures and the low water saturation values within the main closures; due to facies changes from sand flat silt rich to reservoir sand flat facies. Which reflect that water saturation values controlled by structure and facies (Fig.30). The distribution of effective porosity shows values ranging between (max. 21% - min. 0 %) at reservoir sand flat and sand flat silt rich facies respectively. The effective porosity has controlled by facies distribution (Fig.31).

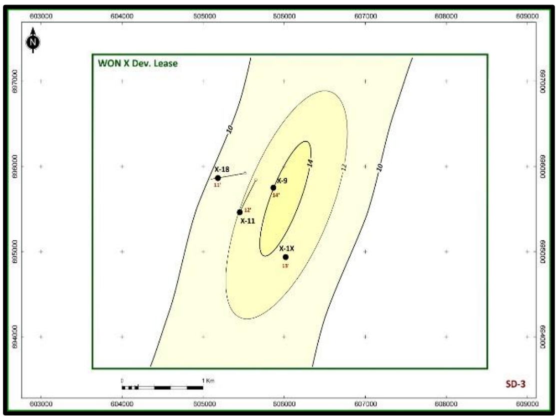

**Figure 26:** Net reservoir Isopach map for Upper Abu Roash "G" sand-3.

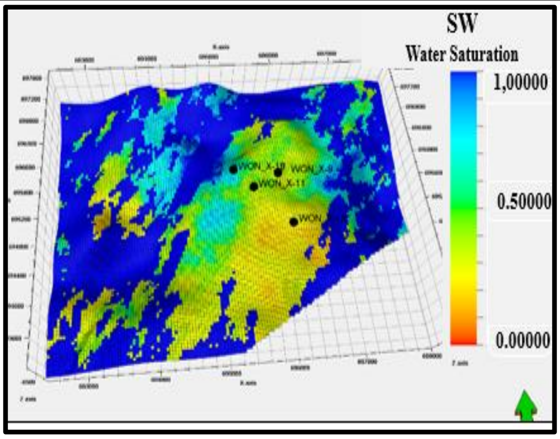

**Figure 27:** Modeled water saturation map for Upper Abu Roash-G zone-3.

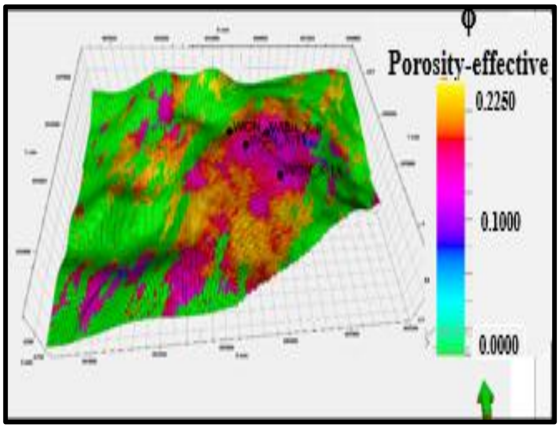

**Figure 28:** Modeled effective porosity map for Upper Abu Roash-G zone-3.

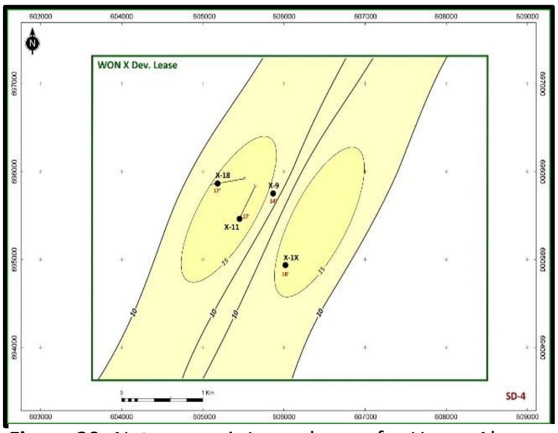

**Figure 29:** Net reservoir Isopach map for Upper Abu Roash "G" sand-4.

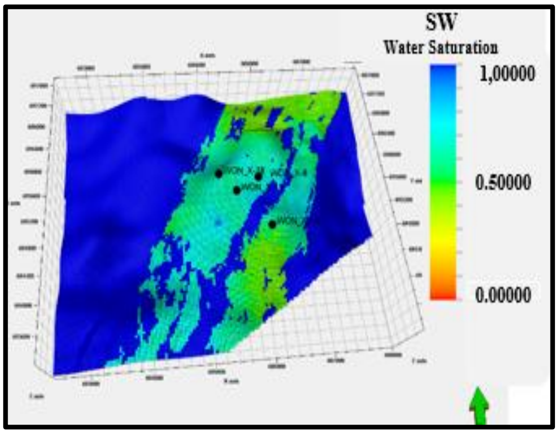

**Figure 30:** Modeled water saturation for map Upper Abu Roash-G zone-4.

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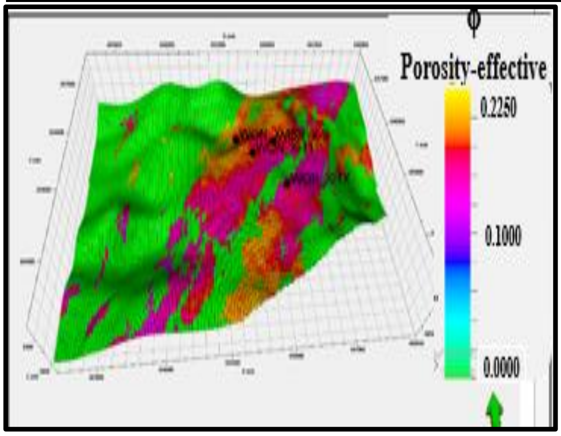


**Figure 31:** Modeled effective porosity map for Upper Abu Roash-G zone-4.

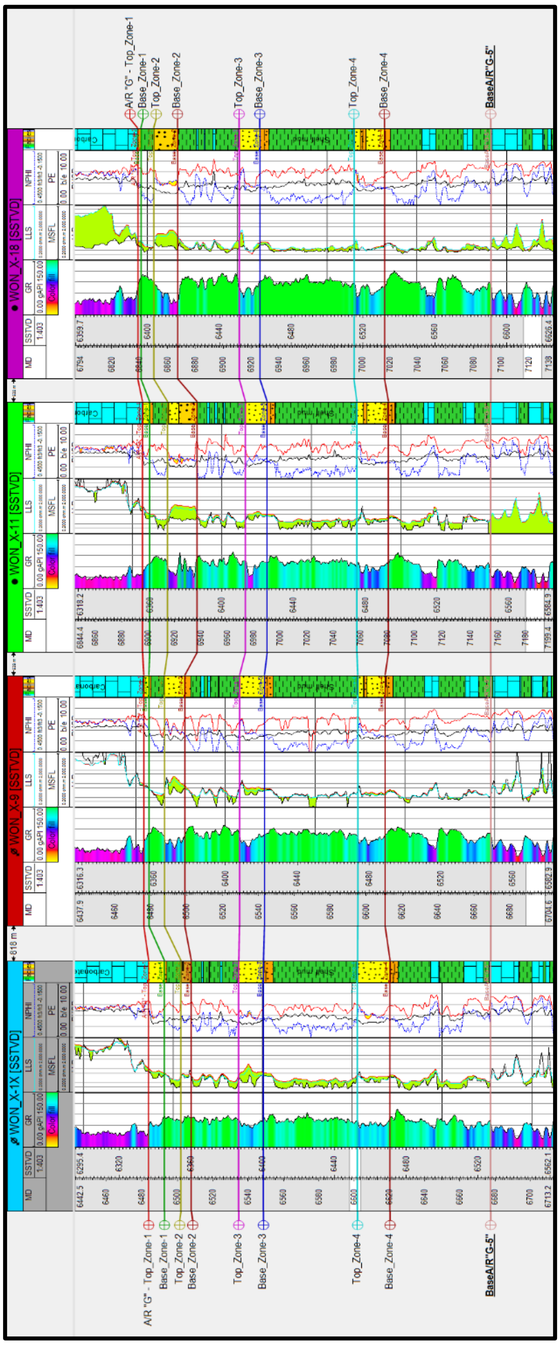


**Figure 32:** Openhole logs responses of Upper Abu Roash"G" subdivision in the study wells.

### Hydrocarbons Volume calculation

Preliminary hydrocarbon volumes have been estimated for Upper Abu Roash 'G' Member ("G-5").The reservoir input parameters were based on the sums and averages from the first four drilled wells penetrating the reservoir section. These estimations were calculated based upon the following formula expressed in terms of stock tank of original oil in place (STOOIP): STOOIP (STB)= 7758 * A * h * Φeff * (1-Sw) * N/G * 1/Bo Where, A= reservoir area in acres, h= net pay thickness in feet, Φeff =effective porosity in fraction, (1-Sw) = hydrocarbon saturation in fraction, N/G = net to gross reservoir ratio, Bo = Formation volume factor and 7758 is an acre foot conversion for oil. The cumulative stock tank of original oil in place STOOIP estimated for zones is 27 Million Stock Tank Barrel separated as table-2.

| Fm. | Zone | STOOIP (MMSTB) |
|---|---|---|
| Upper Abu Roash "G" | Zone-1 | 2 |
| | Zone-2 | 4 |
| | Zone-3 | 9 |
| | Zone-4 | 12 |
| | Cumulative | 27 |

**Table 2:** The stock tank of original oil in place STOOIP estimated for zones.

## Conclusions

The structure responsible for hydrocarbon entrapment in the study area was a structural high which corresponds to the crest of an asymmetrical double plunging anticlinal structure of WON-X oil field. The petrophysical study was conducted to identify the productive zone, distinguish between oil and water in the reservoir, and define the petrophysical parameters to be used later on petrophysical model. The analysis showed pay zones in the Upper Abu Roash "G" Member. After calculating clay volume, water saturation, and average effective porosity and after applying cut-offs, All zones encountered net pays as follows; 29 feet cumulative net pay for WON X-1X well, 24 feet cumulative net pay for WON X-9 well, 43 feet cumulative net pay for WON X-11 well, and 15 feet cumulative net pay for WON X-18 well. After mapping of the petrophysical characteristics for the different reservoirs at Upper Abu Roash "G" Member encountered in the study area was show that the water saturation controlled by a combination of structure and facies elements. Clay volume and effective porosity of all zones is controlled by facies distribution. Based on the cumulative stock tank of original oil in place STOOIP estimated for zones is 27 Million Stock Tank Barrel of oil.

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## Conflicts of interest

There are no conflicts to declare.

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