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Formation Evaluation and Lithology Determination for Selected Wells at Aghar Field, Western Desert, Egypt

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Abstract:
The aim of the present work is the evaluation of the petrophysical parameters of The Lower Bahariya Formation using well logging data for seven wells scattered in the study. Petrophysical parameters for Lower Bahariya Formation were calculated using a software program in order to better development and understanding of hydrocarbon potentialities of Lower Bahariya Formation at Aghar Field, Western Desert , Egypt .
Also a lithology identification with cross plots (Neutron-Density), (Sonic-Density) and (Sonic-Neutron) show that the main lithology is sandstone ,limestone, dolomite and shale. It was found that, the porosity of Bahariya Formation in AG-2x well varies from 4.8% to 32.4 % . Also, hydrocarbon Saturation in the studied area exhibit increase in middle and decreases in all direction where maximum value in AG-1X 0.75 % at the studied area.

Keywords: *Formation Evaluation, Lithology, Porosity, reservoir, Shale content.*

1. Introduction

The Western Desert of Egypt covers an area of about 700,000 km2 and comprises almost two thirds of the whole area of Egypt. It extends 1000 km from the Mediterranean shoreline in the North to the
Sudanese border in the South and from 600-800 km from the Nile valley in the East to the Libyan border in the West the Aghar field is located in west Razzak lease area 60 km south west of EL-Hamra terminal on the Mediterranean coast, Figure.1**.** The studied rock unit (Bahariya Formation) is penetrated by seven drill holes distributed in the area of study (Figure.2): (AG-1X , AG-2X , AG-3 , AG4 ,AG-6,AG-7, AG-8) These wells located between latitude 30° 29' 22" and 30° 29' 18" N and longitudes 28° 20' and 28° 21' E**.** The stratigraphy of the northern Western Desert is thick and includes most of the sedimentary succession from Pre-Cambrian basement complex to Recent. The total thickness, despite some anomalies, increases progressively to the north and northeast from about 6000 ft in the southern reaches to about 25,000 ft along the coastal area. The stratigraphic section consists of alternating depositional cycles of elastics and carbonates [1].
The type locality of Bahariya Formation is situated in Gebel El- Dist, Bahariya Oasis, where the base of the formation is not exposed [2]. Norton et al [3], [4] designated the lower part in the nearby Bahariya –1 well. The section is characterized by fine to very fine-grained sandstone with shale. Pyrite and glauconite are common. Thin limestone beds are common in the northwest that occur irregularly and are not easily creatable from well to other. Throughout the Western Desert, the Bahariya Formation conformably rests on the Kharita Formation. The Bahariya Formation is thick (more than1000 ft), the thickest section is in El Ramis -1 well (1580 ft) and it is Early Cenomanian at the type locality. Lithological and paleontological evidences suggest that most of the formation were deposited on a wide extensive shallow marine shelf.

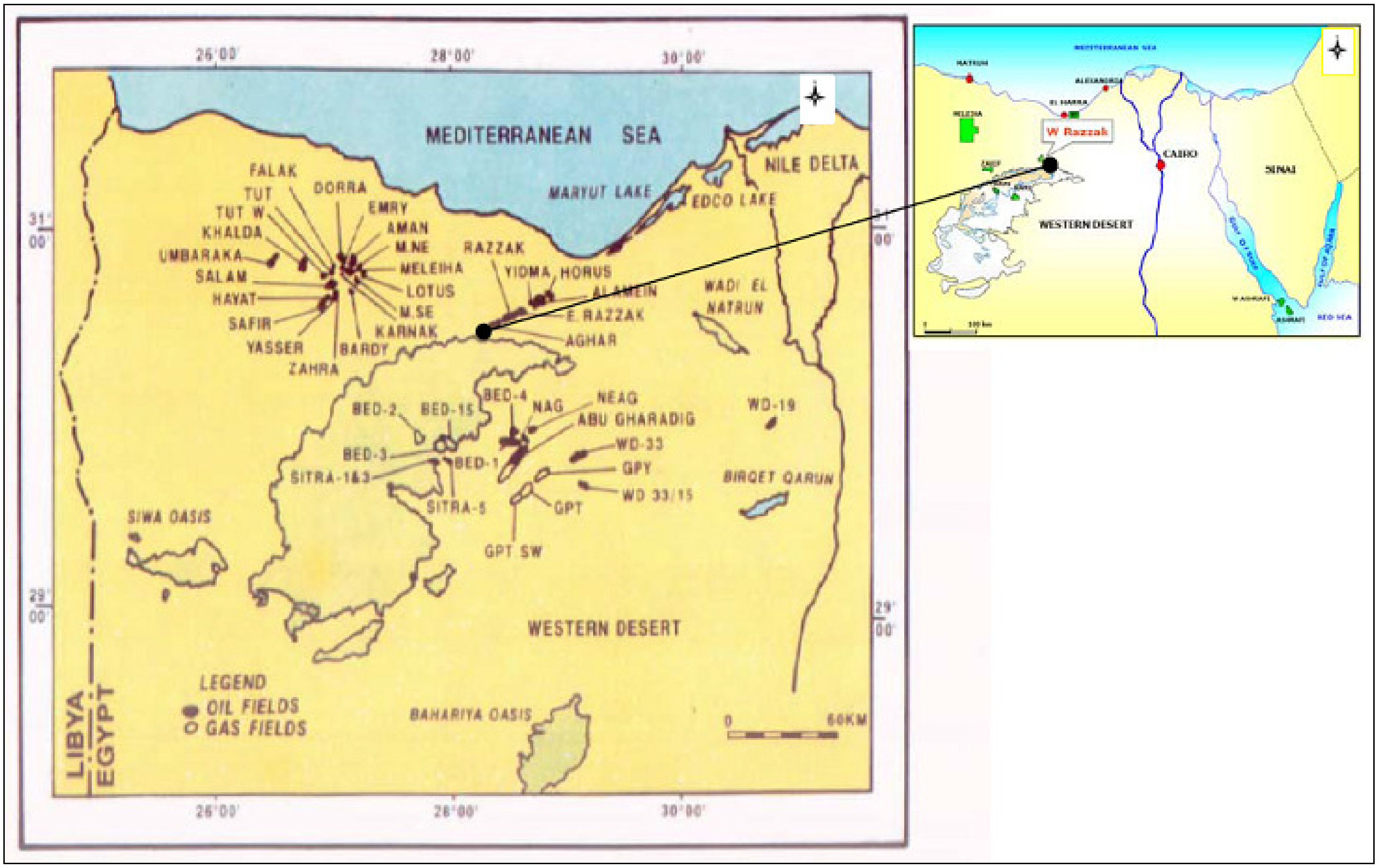

Figure 1: Location map of Aghar Field, Northern Western Desert, Egypt.

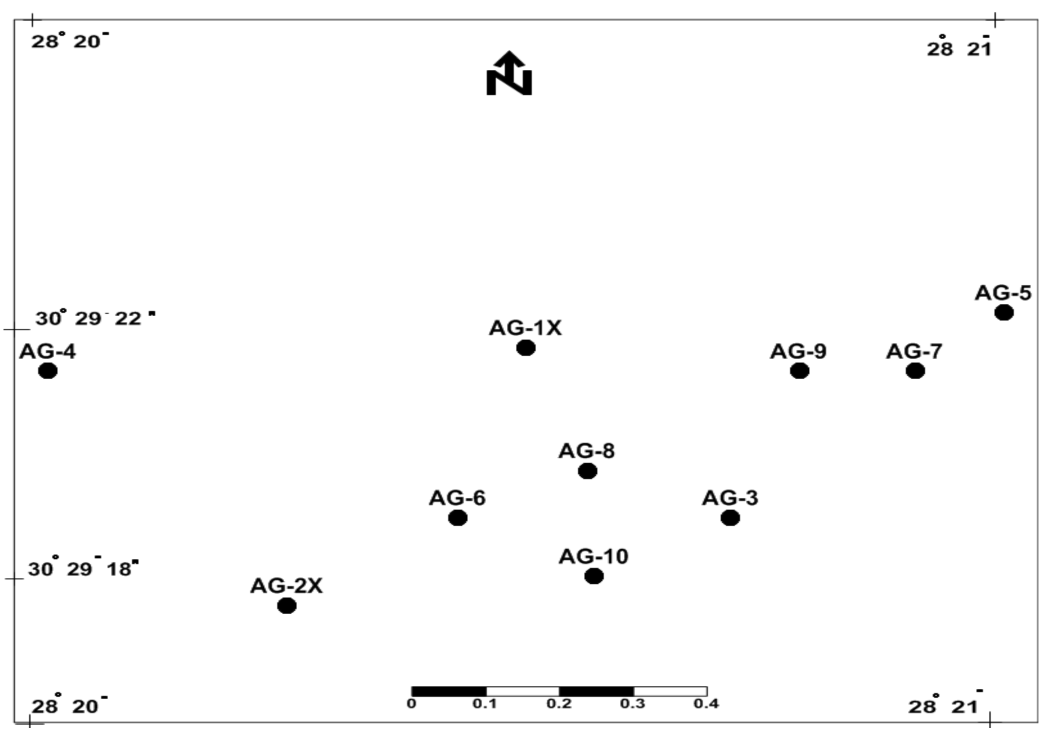

Figure 2: Base Map for Aghar Field., Western desert, Egypt.

2. Formation Evaluation

2.1. Well Logging Data analysis

The present work deals with the computerized well logging analysis by using Interactive Petrophysics^{TM} (IP) [5], where The studied rock unit (Bahariya Formation) is penetrated by seven drill holes distributed in the area of study (AG-1x , AG-2x , AG-3 , AG4 ,AG-6, AG-7, AG-8) .

Well logging data in this work measured from logging tool which can be summarized in the table below where all the log data are in digitized format and could presented in Figure.3.

Well name	Formation	GR	Resistivity			Density	Neutron	Sonic
Aghar-1X	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC
Aghar-2X	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC
Aghar-3	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC
Aghar-4	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC
Aghar-6	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC
Aghar-7	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC
Aghar-8	Bahariya	GR	MSFL	LLS	LLD	FDC	CNL	BHC

Table 1: Available well logging Data

<u>2.1.1. Data Calculations and Corrections</u>

The calculation and correction modules can be achieved by Data base editing .these involve the basic and environmental corrections such as:

1) Depth aligning of logs by verify the obtained digitized values with its points on the log curve.
2) Applying environmental corrections of resistivity tools for borehole size, mud resistivity, temperature of mud resistivity, mud cake and temperature of cake.
3) Applying neutron, density, Gamma logs environmental corrections for temperature, pressure effects, mud weight and salinity. all the corrected values could be presented in analog format at figure.4 which showing the Corrected Log data For Bahariya Formation for (AG.2X) Well.

Formation evaluation is the main task of well log analysis. Before beginning, the data editing and correction must be completed. The objective of formation evaluation task is to estimate the volume of shale,total porosity, effective porosity, water saturation and hydrocarbon saturation and lithology identification.

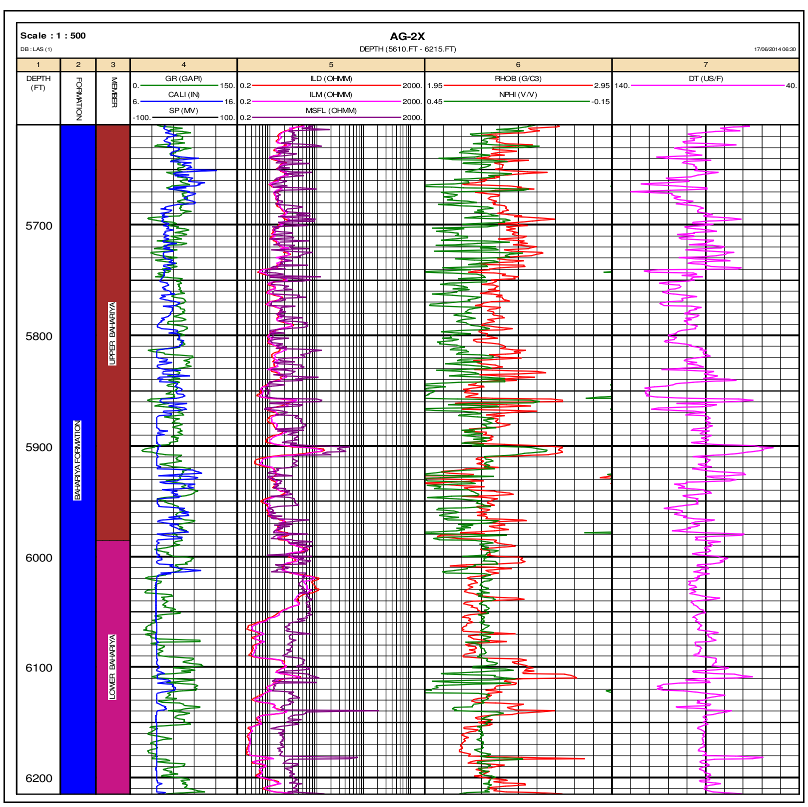

Figure 3: Raw Data For Bahariya Formation for(AG-2X) well.

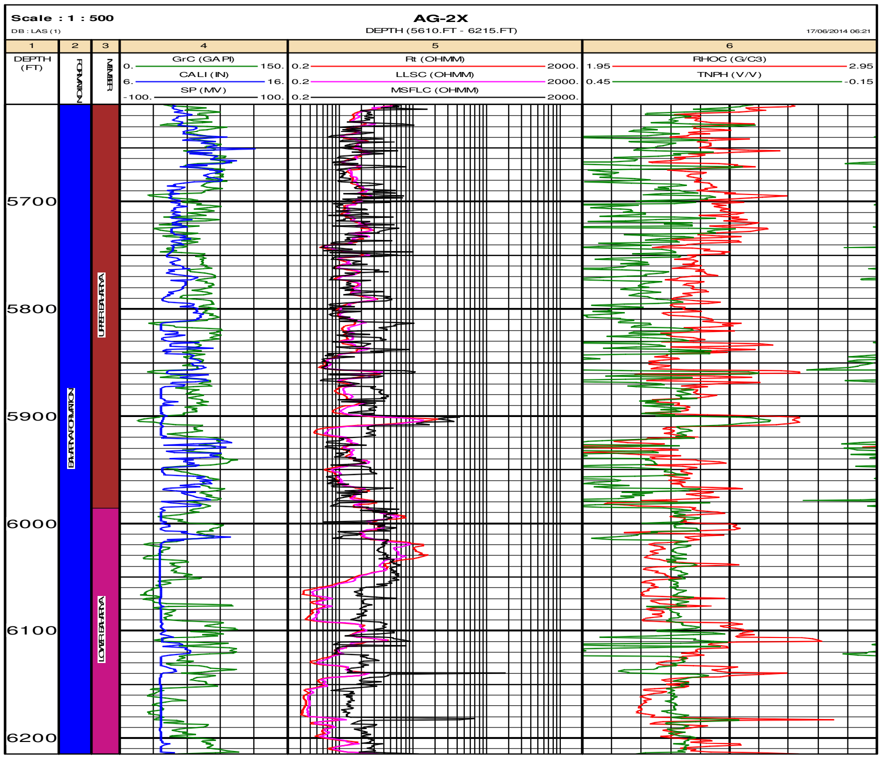

Figure 4: The Corrected Log data For Bahariya Formation for (AG.2X) Well.

2.2. Determination of Shale Volume

The presence of shale in any formations considered as one of the serious problems in the determination of the formation porosities and the contained fluid saturations **[6].** It causes erroneous determinations for the different rock matrices. By applying Interactive Petrophysics (IP) Software to calculated the volume of shale of the studied reservoir in the area. According to schlumberger teqniques to depended on the minimum value of volume of shale. It was found that volume of shale calculated from Gamma Ray log is the minimum value one the all used tool to determine the volume of shale. The volume of shale for the selected wells was calculated and presented. As examples for well (AG-2x) at Figure.5.

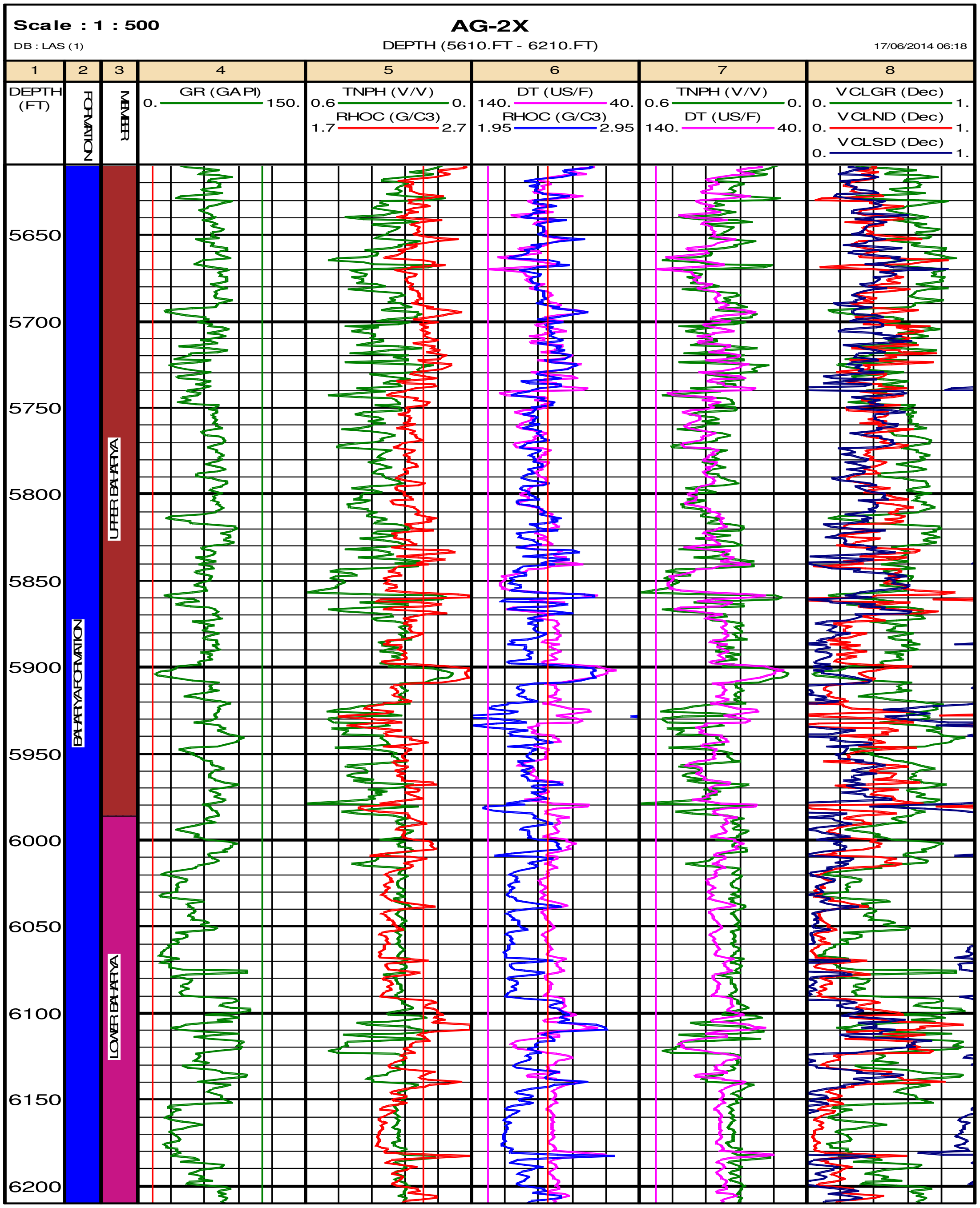

Figure 5: Presentation of calculated Volume of the shale in (AG-2x) well.

2.3. Determination of Porosities

Porosity is the volume of the non-solid portion of the rock that is filled with fluid divided by the total volume of the rock. Primary porosity is the porosity developed by original sedimentation process, by which the rock was created. It is often referred to in terms of percentages. Porosity values can be determined from porosity tools which include density, neutron and sonic.

2.3.1. Average Porosity

The average porosity value was calculated by averaging φs, φD, and φN

$$\phi_{AV} = \frac{\phi_s + \phi_D + \phi_N}{3} \quad \textbf{[7]}$$

2.3.2. Effective porosities (ϕe)

This type of porosities depends largely on the degree of connection between the rock pores with each other forming channels, to facilitate the path of fluids through the lithologic contents, there are two ways to calculate the effective porosities the former is the general equation.

$\phi e1 = \phi t * (1-Vsh)$

→ The latter is the empirical formula:

$$\varphi_{e2} = \frac{2\varphi_{NC} + 7\varphi_{DC}}{9}$$

Where: ϕNC is the neutron porosity corrected for shaliness effect.
ϕDc is the density porosity corrected for shaliness effect.

The corrected neutron and density porosities are calculated **[8]** from the equations.

$$\varphi_{NC} = \varphi_N - \left[\frac{\varphi_{Nsh}}{0.45}\right] * 0.30 * V_{sh}$$

$$\varphi_{DC} = \varphi_D - \left[\frac{\varphi_{Dsh}}{0.45}\right] * 0.13 * V_{sh}$$

Where: ϕNsh is the neutron porosity of a shale zone,
ϕDsh is the density porosity of a shale zone.

Figure. 6 showing the calculated porosity for well (AG-2x).

2.4. Determination of Saturation

The fraction of pore space containing water is termed water saturation (Sw). The remaining fraction containing oil or gas is termed hydrocarbon saturation (Sh) which equals (1-Sw). the general assumption is that the reservoir was initially filled with water and that over geological time, oil or gas that formed elsewhere migrated into the porous spaces. However, the migration hydrocarbons never displace all the interstitial water.

In this part, there are interpretation techniques for determining the water saturation in shaly sandstone, where during the past years, Archie's equation [9] has been modified to account for the presence of shale in the formation and its effect on the resistivity measurements. This part will outline some of techniques followed in the determination of the water saturation, under the subsurface geologic conditions prevailing in the study area.

Determining the fluid saturation requires the availability of corrected values of the fluid resistivities (RW and Rmf) and the rock resistivities (Rxo and Rt), the resistivity of shale (Rsh), the volume fraction of shale (Vsh) and the corrected effective porosity (ϕe) (using Indonesian equation).

Archie :

$$\frac{1}{R\tau} - \frac{\phi^m \; S_W^n}{\square \; R_w}$$

Indonesian [10]**.**

The water saturation (Sw) determined by INDONESIA equation:

$$S_w^{n/2} = \left[\frac{\sqrt{\frac{1}{R_t}}}{\frac{V_{sh}^{(1-Vsh\ /2)}}{\sqrt{R_{sh}}} + \frac{\sqrt{\varphi_e^m}}{\sqrt{a^x R_w}}}\right]$$

Where:

Sw	water saturation
Vsh	the volume fraction of shale
Rsh	the resistivity of shale
Rw	formation water resistivity
ϕe	corrected effective porosity
a	for clean formation, usually equals to 1.0 in sands.

The calculated average porosity was 0.23 %, while the average hydrocarbon saturation values was 0.37% which presented at figure.6

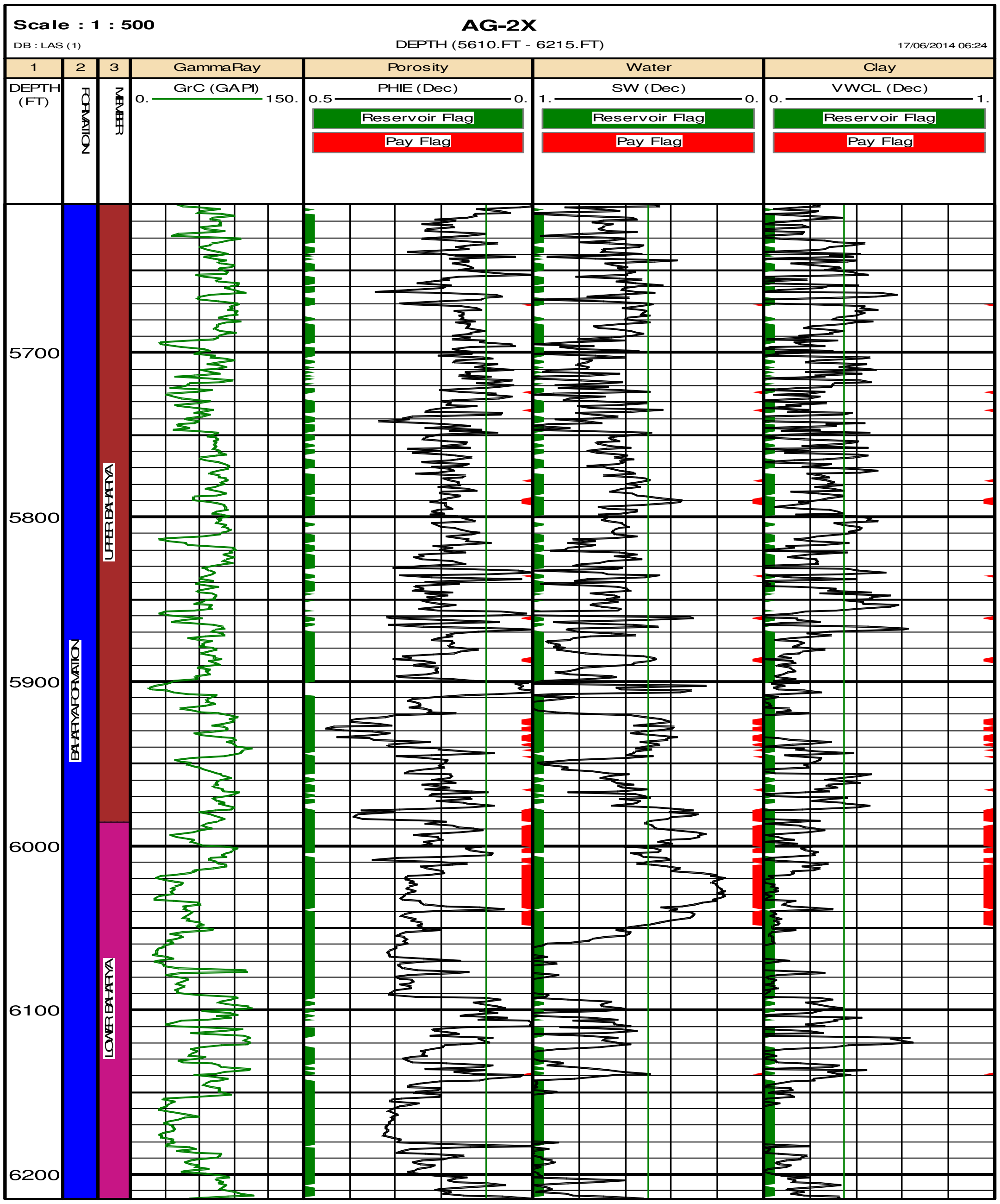

Figure 6: Presentation of calculated Porosity and Fluid Saturation in (AG-2x) well

3. Lithology Identification

Well logging data provide continuous information about the physical in situ properties of the borehole wall and therefore it has become a standard method in hydrocarbon industry for the investigation of subsurface geology. So the fundamental of any interpretation is the determination or the evaluation of formation lithology where this application is particularly important where it gives view about lithology distribution in the formation. In the present study the determination of lithology and the mineral identification will be defined by cross plots .

3.1. The Neutron-Density Cross plots

The measurements of the neutron, density, and sonic logs depend not only on porosity, but also on the formation lithology, on the fluid in the pores, and in some instances, on the geometry of the pore structure. [11]. Figure.7 show the Neutron-Density Cross plots for Aghar 2X and Aghar 7 wells. which shows that the main lithology is sandstone ,limestone, dolomite and shale .

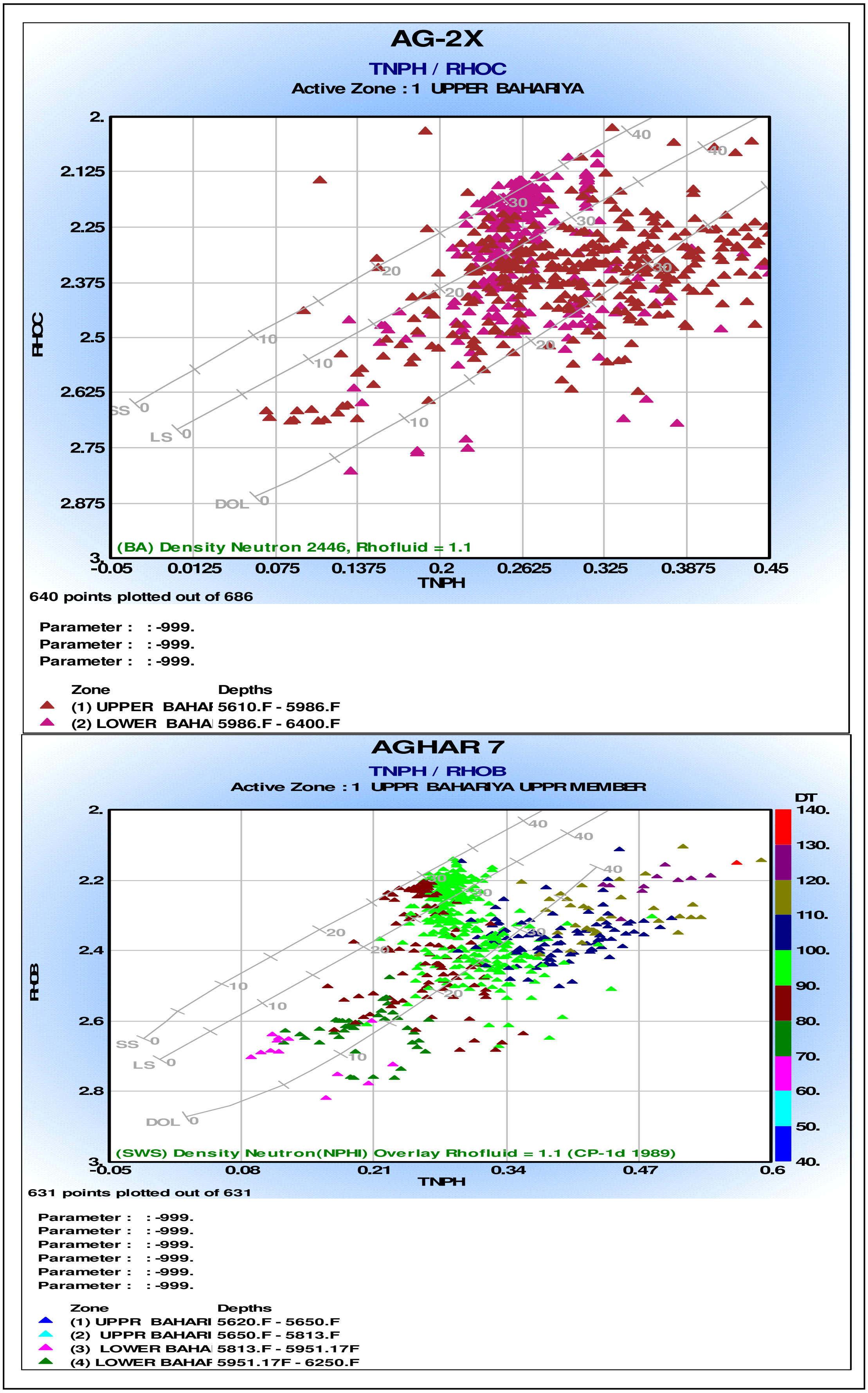

Figure 7: The Neutron – Density Cross plots of the Bahariya Formation in Aghar 2X and Aghar 7

3.2. The Sonic-Density Cross Plot

Cross plots of sonic (ΔT) versus density(ρb) have poor porosity and reservoir rock(sandstone, limestone, dolomite) resolution, but they are quite useful for determining some evaporate minerals**.** Figure.8 show the Sonic –-Density Cross plots for Aghar 7 well. From which shows that the main lithology is sandstone, with intercalations of limestone, dolomite and shale.

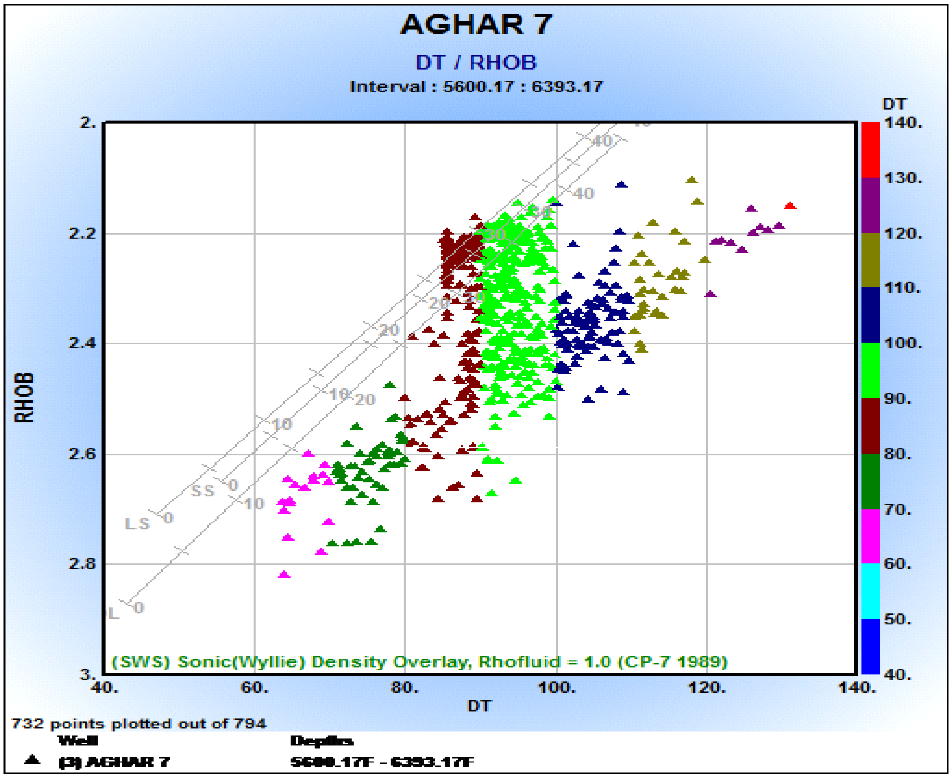

Figure 8: The Sonic – Density Crossplots of the Bahariya Formation in (Aghar 7) well.

3.3. The Sonic-Neutron Cross Plots

Cross plots of sonic versus neutron can be used to determine lithology for Aghar -7 well (Figure.9) from which we can see that it containing mainly a sandstone with intercalations of Shale and limestone

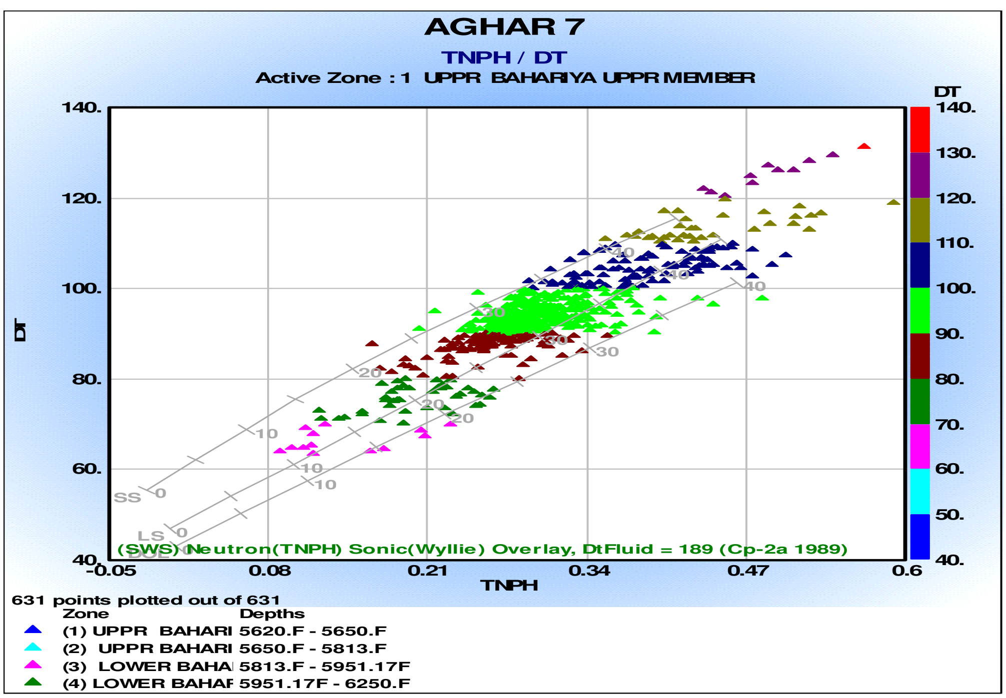

Figure 9: The Sonic –Neutron Crossplots of the Bahariya Formation in (Aghar 7) well.

3.4. Litho- Saturation Cross Plots

Litho–saturation cross plot is a representation, zone wise, for the contents of rocks and fluids with depth of the well. The materials content includes the shale and matrix (limestone and sandstone), while the fluids content involves the water (reducible and irreducible) and hydrocarbons. However, the following is a brief about these rock lithologies and fluid saturations in the studied wells.

<u>3.4.1. Litho-Saturation Cross plot of AG-7 Well</u>

The litho-saturation cross plot of Bahariya Formation in AG-7 well (Figure.10) shows that, the rock unit is composed of shale and limestone with thin layer of sand stone in the upper part . Sandstone begin to increase in the lower part. The oil increase in the middle part of sequence (L.Bahariya Formation). From litho saturation cross plots of the studied wells we noticed that the oil appear in upper Bahariya and show gradual increasing in lower Bahariya especially in AG-7 at depth (5650-6200 ft).

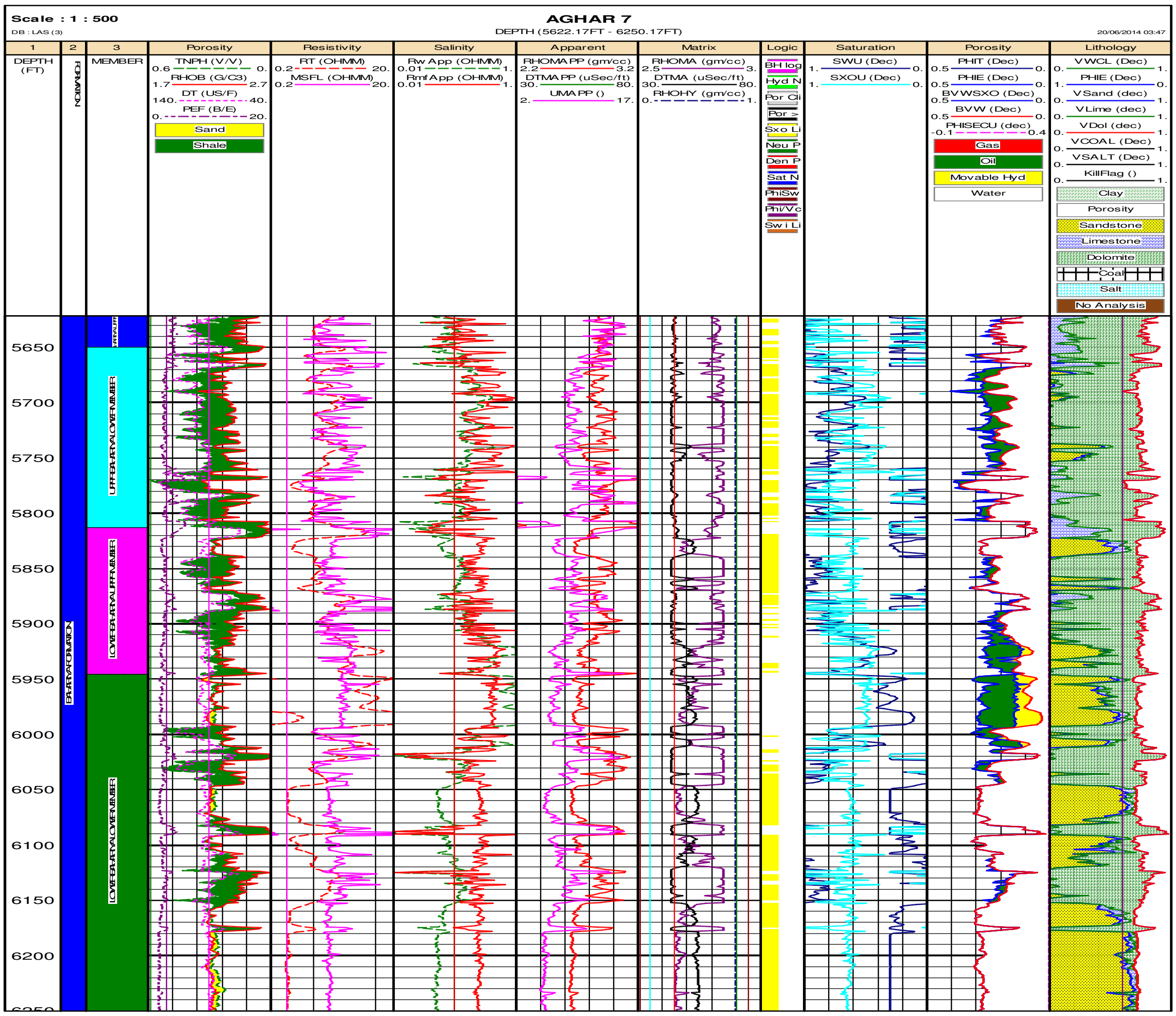

Figure 10: The Litho-Saturation Cross Plot of the Bahariya Formation in (AG-7) Well

3.5. Horizontal Distribution of Petrophysical Parameters

Horizontal Distribution of petrophysical parameters for the selected wells at the studied area could be presented in the form of Iso-parametric maps as Shale, porosity and saturation maps.

The results of well log analysis for the Lower Bahariya Member of Aghar wells are listed in Table (2).

WELL	Effective porosity phie	Volume of shale vsh(GR)	Volume of shale vsh(ND)	Water saturations swu	Hydrocarbon saturation SH
AGHAR-2X	0.222	0.43	0.23	0.76	0.24
AGHAR-3	0.221	0.36	0.21	0.64	0.36
AGHAR-7	0.25	0.35	0.27	0.61	0.39
AGHAR-8	0.20	0.34	0.34	0.68	0.32

Table 2: Reservoir petrophysical parameters (Phie, Vsh, Sw and Sh) for the selected wells .

3.5.1. Shale Distribution Map

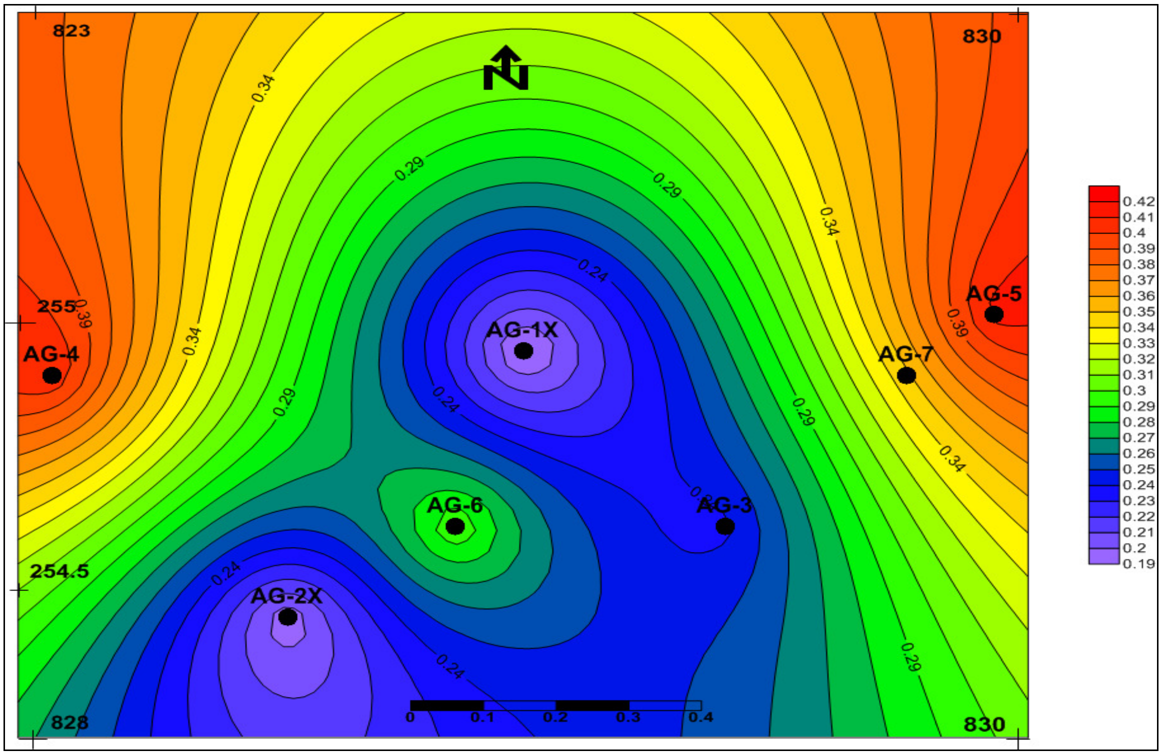

Figure 11: Shale Distribution Map of Aghar Field.

The shale distribution map illustrate the horizontal distribution of shale in the study area it show that, the shale has minimum value at central area of the map where maximum value is represented in east and west directions Figure.11.

3.5.2. Effective Porosity Distribution Map

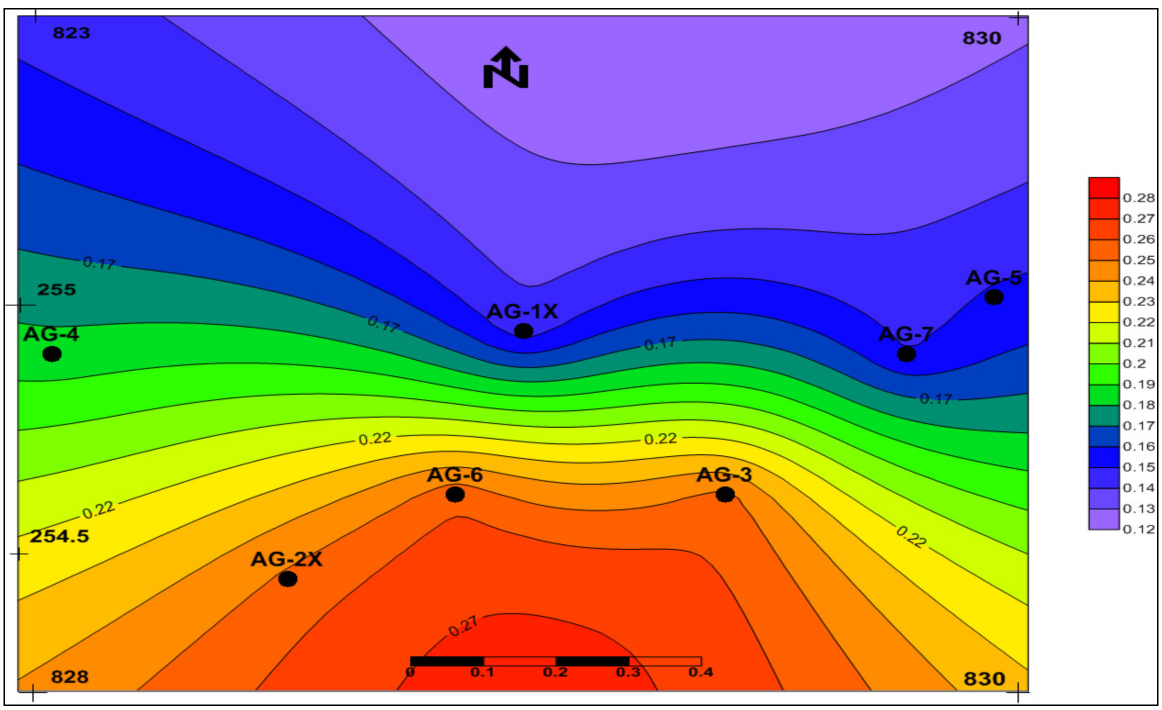

Figure 12: Effective Porosity Distribution Map for Aghar Field.

The effective porosity distribution map reflects a gradual increase to the southeast and southwest directions, where decreases towards the north Figure.12

3.5.3. Hydrocarbon Saturation Distribution Map

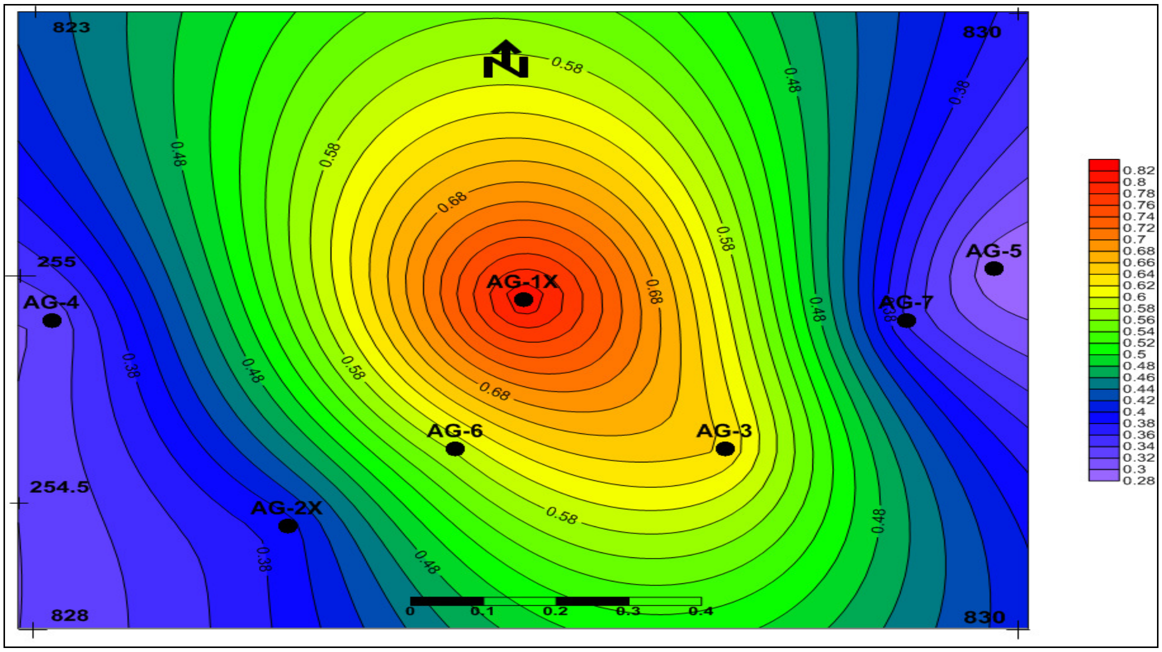

Figure 13: Hydrocarbon Saturation Distribution Map for Aghar Field

This map exhibit increase in middle and decreases in all direction where maximum value in AG-1X which is the reverse direction of water saturation distribution map Figure.13.

4. Summary and Conclusion

The aim of this work is to evaluate the petrophysical parameters of Lower Bahariya Formation utilizing well logging data.

The logging data of seven wells (AG-1X ,AG-2X, AG-3, AG-4, AG-6, AG-7and AG-8) results of Bahariya Formation were used for evaluating the petrophysical parameters and hydrocarbon potentialities of Bahariya Formation. as well as lithology identification.

In the area under investigation, the shale has minimum value at central area of the map where maximum value is represented in east and west directions

Also, the formation porosities (total and effective) are determined through the porosity tools (density, sonic and neutron). These porosities are corrected for the effect of shaliness. The total porosity distribution map shows a gradual increase toward the southeast and southwest directions. While it decreases to the northeast The effective porosity distribution map reflects a gradual increase to the southeast and southwest directions, where decreases towards the north. Also hydrocarbon saturation is determined where hydrocarbon saturation map exhibit increase in middle and decreases in all direction where maximum value in (AG-1X) which is the reverse direction of water saturation distribution map.

Also a lithology identification with cross plots (Neutron-Density),(Sonic-Density)and (Sonic-Neutron) show that the main lithology is sandstone ,limestone, dolomite and shale .

In the present study ,the produced petrophysical results were represented, zone-wise, in the form of litho-saturation crossplots for four wells to show the vertical variations of these parameters with depth.

Bahariya Formation is the main producing horizon in Aghar oil field. It is represented by fine to very fine-grained sandstone, well sorted, sub-angular to sub-rounded, straight to concave-convex contact alternated with shale and limestone. It is divided into two zones, Upper and Lower, each zone is subdivided into two sub-zones. Bahariya Formation was deposited on a wide extensive shallow marine shelf from litho saturation cross plots we noticed that the oil appear in upper Bahariya and show gradual increasing in Lower Bahariya especially in AG-3 at depth (5820-5950 ft) and AG-8 at depth (5900-6900 ft) from this study it is interpreted why the Lower Bahariya is the main pay zone at Bahariya Formation, Aghar Field, Western Desert Egypt.

The porosity of Bahariya Formation in AG-2x well varies from 4.8% to 32.4% for Boyle's law porosity and varies from 5.1% to 35.2% for residual fluid porosity. Porosity can be used to determine storage capacity and to assess the quality of the reservoir. The obtained high values of porosity indicate that the Bahariya Formation is represented by high quality reservoir . Hydrocarbon Saturation in the studied area exhibit increase in middle and decreases in all direction where maximum value in AG-1X 0.75 % which is the reverse direction of water saturation distribution map .

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