Petrophysical characterization of Garia Formation, Lower Eocene, at Bahr Essalam Field, offshore Basin, NW Libya

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Abstract

offshore Basin represents one of the most important basins in Libya, It covers are an area a large part of the Tripoli-Gabes Basin , and a contains main structures as " B " which know Bouri Filed and 'Bahr Essalam' area (NC41) is known as " C "structure and located in the North-western offshore Libya. The Metlaoui group (El-Garia Formation) is main reservoir (Lower Eocene age) in Bahr Essalam Field , consists of Nummulites limestone and tidal dolomites witnessing a regressive pulse in the basin evolution Limestone with average thickness more than 500 feet. The main purpose of this study is to evaluate and investigated the petrophysical characteristics of El-Garia Formation in Field , Bahr Essalam Field through the analysis of well log data available for five wells distributed in Concession NC41.

The well logs signature indicate, the limestone is main lithology. With 16-22% Average porosity and 9.1% average water saturation with 198 ft average net pay . In this study the repeat formation test was used for delineate type of hydrocarbon ,the result indication the gas represent the main type of fluid .

Keywords:*, El-Garia Formation, Metlaoui Group, Lower Eocene, at Bahr Essalam Field, offshore Basin , NW Libya.*

1. Introduction

Petrophysices evaluation is mean the study of the rock properties; porosity, permeability and fluid saturation and distribution, etc. In this study a complete package of porosity and resistivity logs, records including neutron, density and resistivity Logs, have been recorded across the El-Garia Formation reservoirs. Interval of each log was read every 0.5 feet and analyzed in detail for calculation of porosity, volume of shale, water saturation, and net pay thickness by using the Techlog soft ware .

1.2 Location of study

The 'Bahr Essalam' area (NC41) is located in the North-western offshore Libya ,about 110 km from the Libyan coastline. The water depth is about 600 feet, area covers a large part of the Tripoli-Gabes Basin ,figure (1). NC 41 is contains main structures as " B " which know Bouri Filed and 'Bahr Essalam' area (NC41) is known as " C "structure and located in the North-western offshore Libya (Dan Hallett 2002) .The Metlaoui group (El-Garia Formation) is main reservoir(Lower Eocene age) in Bahr Essalam Field , consists of nummulites limestone and tidal dolomites witnessing a regressive pulse in the basin evolution Limestone with average thickness more than 500 feet, the first well discovered in Bahr Essalam the area (C1- NC41) in 1997 was located in the western culmination of structure "C" Bahr Essalam Field 'by Agip Libya the hydrocarbon were found in the Metlaoui group resulted as new gas field discovery(Dan Hallett 2002) , The study area is located in central structure in Bahr Essalam field ("C" Structure) in Concession NC-41 in offshore Basin .

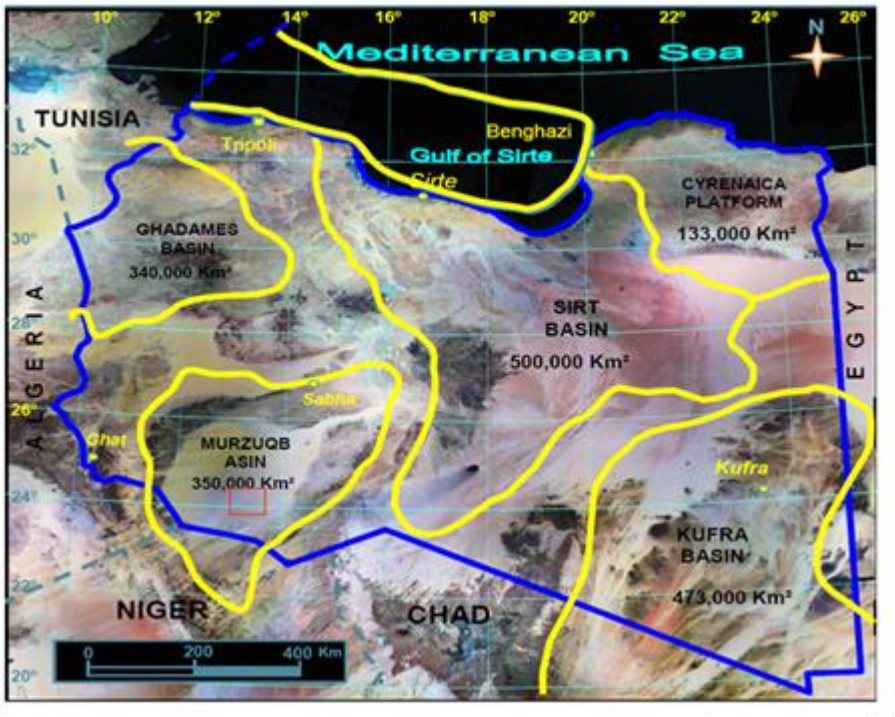

Fig (1) Location of major Sedimentary basins of Libya

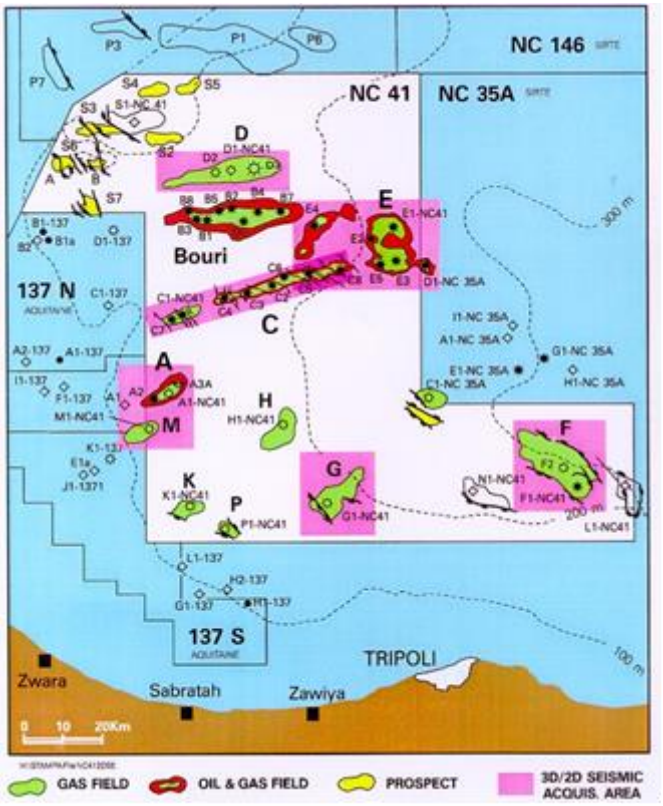

Fig (2) location map of the NC41 in offshore basin (Mellitah ,2015).

1.3 The objective of Study

The objective of study is investigating the petrophysical characteristics of the Metlaoui Group main reservoir El-Garia Formation in Bahr Essalam Field NC41 , general geology and stratigraphy of the study area and define type of hydrocarbon fluid in reservoir by use RFT data.

1.4 Methodology

Methods of study are using all the data available for five wells includes:- e,g. Well logs, RFT Data , Techlog 2015 software in petrophysical analysis .

2-Geological Setting of the Study Area

The petroleum system in the offshores Basin is relatively complex and is controlled by many of different factors such as present of source rock , quality of the source rock ,distribution of the source rock ,Reservoir facies change , Seal facies change and continuity ,Trap size and age and development of migration pathways . Bou-Dabbous Formation is source rock of the

hydrocarbons generated in the basin , The trap type is faulted anticlines, horsts and tilted fault blocks, drape anticlines over carbonate build-ups or faulted relief, and up dip lithology or permeability pinch outs. the hydraulic seal of the reservoir is ensured by the shale argillaceous limestone(mudstone wackestone) formation Cherahil ”A” (Middle Eocene), the ”C” structure consists of a narrow and elongated anticline, asymmetrical with the northern flank being steeper than the southern one, with the major WSW-ENE oriented axis and a overall extension is about 5x45 km. The structural analysis made on the Top El-Garia Formation map identified several faults trends that can be generally grouped in a NW-SE and WSW-ENE trends, reflecting the superimposition of several stress cycle, in Study area The structure contour map and cross section on of the El-Garia Formation by using well formation tops in this study area figures (3&4) .The map represents the top structure South western part of the area is highest around wells CC13-41, and structure change to lower toward the east part ,and could be present fault between well CC11 and well CC13 in central area and other one between well CC12 and well CC1-41 in the east part . the structure cross section was constructed show the area could be affect by tectonic.

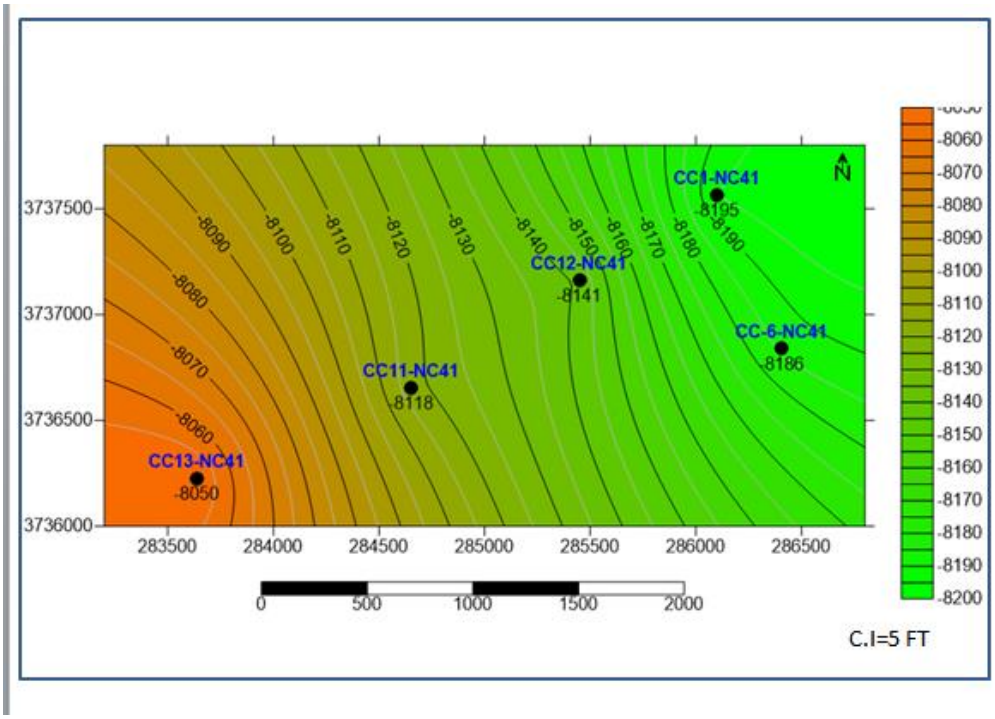

Fig (3): Contour Map of Top El-Garia Formation(by surfer software)

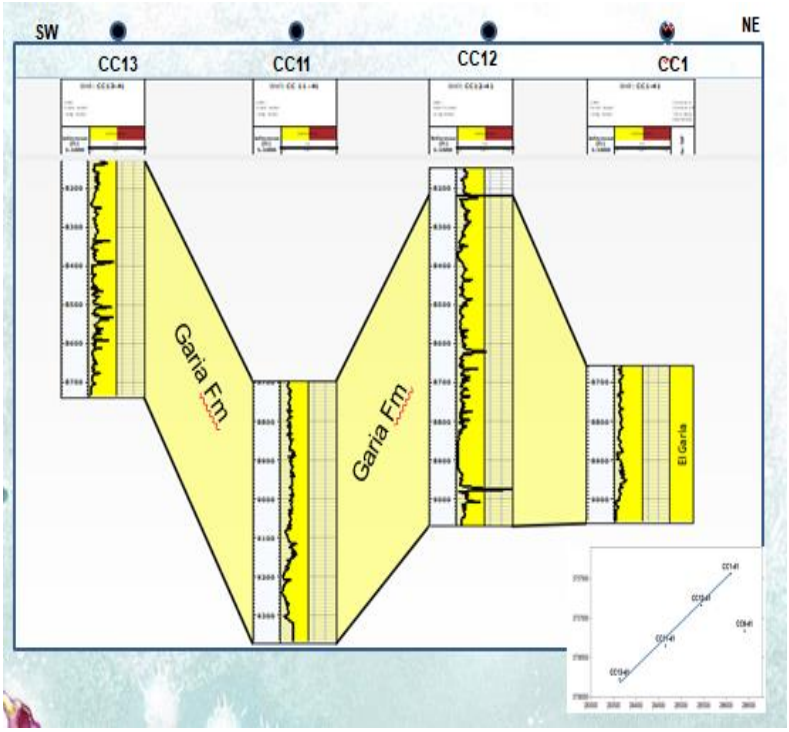

Fig (4) Cross section shows a correlation for the studies wells (by Techlog software)

3- Stratigraphic Sequence:

The lithostratigraphic column in area study starting from Pliocene to Miocene rock in Concession NC41 area of Bahr Essalam field (NC-41block).this information base on all the available data obtained during drilling of wells (Mellitah company report)

❖ 3.1. Raf-Raf Formation

❖ 3.2 Oued Bel –Khedim Formation

❖ 3.3 Melqart formation (Age :Upper Miocene(Tortonian).

Limestone, where gradually passing to more argillaceous rocks, mainly marl with interbed of clay stone. The lower part of this formation consists mainly of Marl with interbed of clay stone.

❖ 3.4 Mahmoud (Age :M-Lower Miocene)

The Mahmoud formation consist mainly of clay stone grading to shale, in the middle part to bottom of Mahmoud , We notice the presence of thin layer of Sandstone, locally abundant. In the middle and lower part generally thin interbed of marl, Sometimes thick and abundant layer.

❖ 3.5 Salambo Formation (Age :Lower Miocene-Oligocene)

This formation starts mainly with Shale interbed of Marl , the Marl gradually became prevalent On the bottom part, starts interbed of Shale that gradually increasing to top of Cherahil .

❖ 3.6 Cherahil "B" Formation (Age : Upper-Middle Eocene)

Cherahil Formation lithology is mainly shale with interlayers of marl, on top presence of thick beds of Limestone in the middle and on the lower part presence of thin layers of Marl. *shale: light grey-grey, greenish-grey, brownish-grey, occ. light green, firm-moderately indurated, fissile, sub fissile-blocky, sub platy, locally splintery, pyritic, locally glauconitic, fossiliferous, locally slightly fossiliferous, slightly -highly calcareous , sandy ,silty in part we can separate the marl in this formation to:

❖ 3.7 Reineche Member (Age : Middle Eocene.)

Reineche member mainly limestone white, off white, tan, cream, very light brown, reddish-brown, soft -medium hard, chalky in part, argillaceous, free calcite crystals,

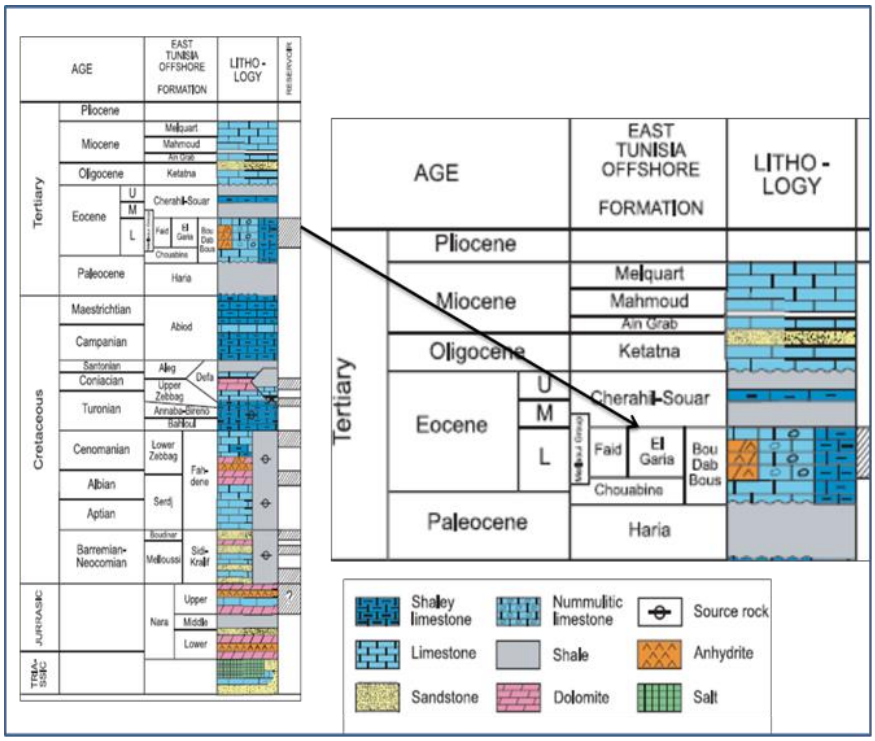

Fig (5) Subsurface stratigraphic chart for the off shore Basin (after Rusk 2002)

❖ 3.8 Cherahil "A" (Souar) Formation (Age: Middle Eocene).

Souar formation is mainly shale with intercalation of marl and thin layers of limestone shale: light to medium grey, light brown, brownish, firm, moderately indurated, sub-fissile to fissile,. with intercalation of marl: buff, light brownish, tan, brownish, soft, sticky, washable,

❖ 3.9 Metlaoui Group (El-Garia Fm.) Age : Lower Eocene

Limestone ,white, milky, occasionally off white to cream, medium hard, occasionally soft, crypto crystalline, occasionally micro crystalline, free calcite crystals, traces of nummulitic.

❖ 3.10 Geologic Features of El-Garia Formation

The El-Garia Formation is main reservoir was found in the Metlaoui Group of Lower Eocene age, consists of nummulites limestone and tidal dolomites witnessing a regressive pulse in the basin evolution, fig (6) show the gross thickness of El-Garia Formation in study area about more than 500 feet with average porosity reached to more than 20%. The facies distribution inside the Metlaoui Group should be controlled by two distinct trends:

A regional NE-SW trend from shallow to deeper open platform environment. This trend affects in fact the whole Eocene section including the Reineche Member which passes from Cherail to Souar Formation;

A local one, with better development of bank facies along the crest of the structure, as suggested in the Bouri model. Thickness map of El-Garia Formation in study area fig (6) shows thickness is increasing in the central part of the area reached to 479 feet and the thickness decrease toward the north east part of the area around well CC1 reached to 150 feet also in the east part reached to 136 feet , and increase in the southwest part reached to 452 feet around well CC13-NC41 .

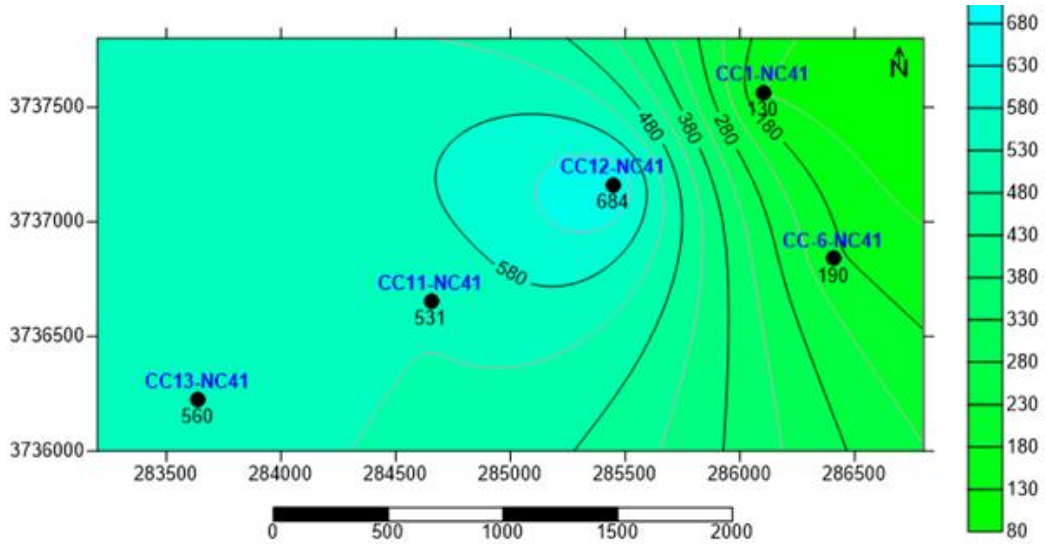

Fig (6) Isopach map of top the El-Garia Formation(surfer software 13)

4 -Results and Discussion

A complete package of porosity and resistivity logs, records including neutron, density and resistivity Logs, have been recorded across the reservoirs. Interval of each log was read every 0.5 feet and analyzed in detail for calculation of porosity, volume of shale, water saturation, and net pay thickness, to determine volume of shale requesting several types of the logs, such as Gamma ray logs, SP , nneutron and density cross plot, calculations to estimate volume of shale in the main reservoir El Garia Formation was depended on Gamma Ray log only.

4.1 -Determination Volume of Shale:

$$Vsh = (GR\ log - GRclean) / (GRsh - GRclean) \ldots\ldots\ldots\ldots\ldots \text{Equation.(1)}$$

Where: ***Vsh***: is the volume of shale (**API**). ***GR log*****:** the Gamma ray reading on the log.

GR clean: the minimum reading on the log. ***GR sh*** : the maximum reading on the log.

Table (1): the average volume of shale in the El Garia reservoir in the studied well

WELL Name	Average Volume of Shale (%)
CC1-NC41	6
CC6-NC41	12
CC11-NC41	13
CC12-NC41	11
CC13-NC41	11

4.2- Porosity Determination:

Effective porosity is the total porosity after the shale correction is applied. Rock porosity can be obtained from sonic log, density log or neutron log. All porosity logs neutron and density logs are used to determine the total porosity (**ØN-D**) of the El Garia reservoir. The density porosity (**ØD**) was determined based on type of reservoir rock from Equation , while the Total Porosity (**Øt** or **ØN-D)** from Equation (2).

4.3 Density Porosity:

$$ØD = = (\rho bma - \rho blog)/(\rho bma - \rho f) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: ***ρb*** =bulk Density, gm/cc (**log**). ***ρfl*** =Fluid Density, (**equal 1 gm/cc**). ***ρb ma*** =Matrix Density, **equal 2.71** gm/cc (for Limestone)**.** ***ØD*** =Density Porosity**.**

4.3- Neutron Porosity:

The neutron porosity has been directly read from the neutron logs .The average porosity for Garia reservoir in the studied wells are presented in Table (2)

Table(2): Shows the average porosity of the El Garia reservoir of studied wells

Well Name	Average Porosity
CC1-NC41	21
CC6-NC41	16
CC11-NC41	21
CC12-NC41	16
CC13-NC41	16

The porosity in the study area is ranging from 16% to 21 %. Porosity map Fig (7) was constructed to show the porosity distribution in the El Garia reservoir

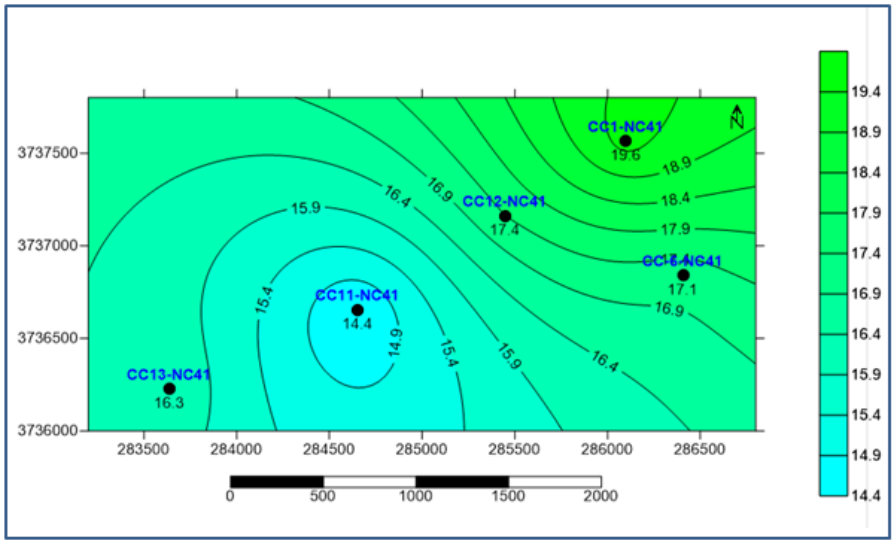

Fig (7) Average porosity map of main reservoir (by surfer software)

4.4 -Formation Evaluation Of Well CC-NC41

A quantities log analysis has been carried out covering the reservoir section

The water saturation is calculated using Archie Equation (3) .

$$S_w = [(a \times R_W)/(Ø^m \times R_t)]^{1/n} \dots\dots\dots (3) \quad .$$

Where: **a** = Tortuosity factor = **(1). Ø** = Total porosity **($Ø_{N-D}$)% m** = Cementation factor = **(2). Rt** = Formation resistivity **(Ω.m). n** = Saturation exponent = **(2). Rw** =Water Resistivity = **(0.029 Ω.m).** The water saturation was show on table below to show the water saturation and/or hydrocarbon distribution in the El Garia reservoir

Table (3) gives the water saturation and/or hydrocarbon distribution in the El Garia reservoir

Table (3) Average water saturation of the El Garia reservoir in studied wells

Well name	Average water saturation (%)
CC1-NC41	**4**
CC6-NC41	**6.9**
CC11-NC41	**7**
CC12-NC41	**17**
CC13-NC41	**10.7**

The value of water saturation ranges from 4% to 17%. In increases toward the central area where values reached 17% in well CC12-NC41and lowest value was found in well CC1-NC41 in the Northeast part area, based on the result of the water saturation increasing toward the central area between values 17% water saturation in wells CC12& and decreasing toward the North east part also in the east area and toward southwest part around well CC13-NC41 reached 10.7 %.

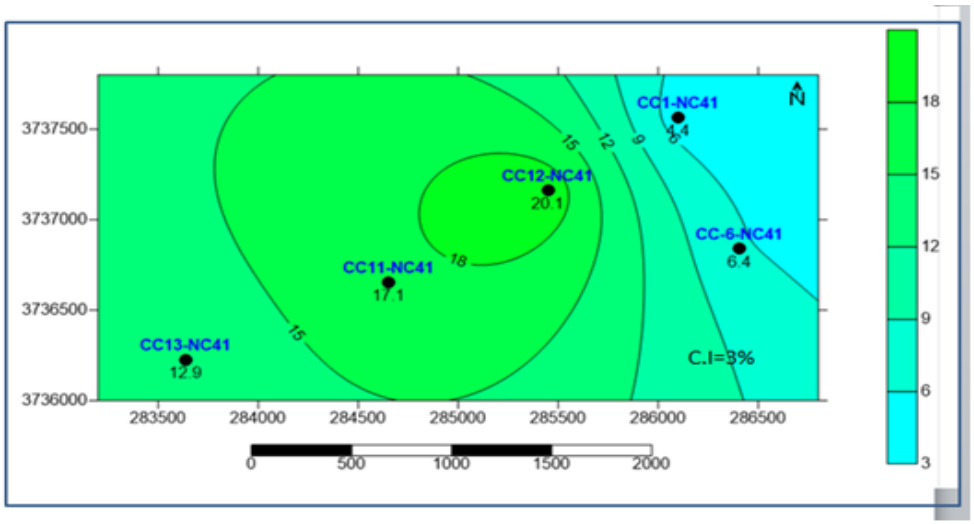

Fig (8) shows the water saturation map (surfer software)

4.5 - Net Pay thickens

The net pay thickens of the reservoir represents intervals having porosity greater than or equal to the porosity cut-off of (9 %), water saturation is less than cut-off of (50%), and volume of shale of less than of (30%).The net pay thickness of each well is summarized in Table (4).Map was constructed Figure (9) shows the net pay distributions of the El Garia Reservoir

Table (4) includes the net pay thickness of the El Garia Formation .

Well name	V.SH %	Por %	SW%	Net pay thickness(ft)
CC1-NC41	6	21	4	133
CC6-NC41	12	16	6.9	173
CC11-NC41	13	21	7	214
CC12-NC41	11	16	17	180
CC13-NC41	11	16	10.7	233

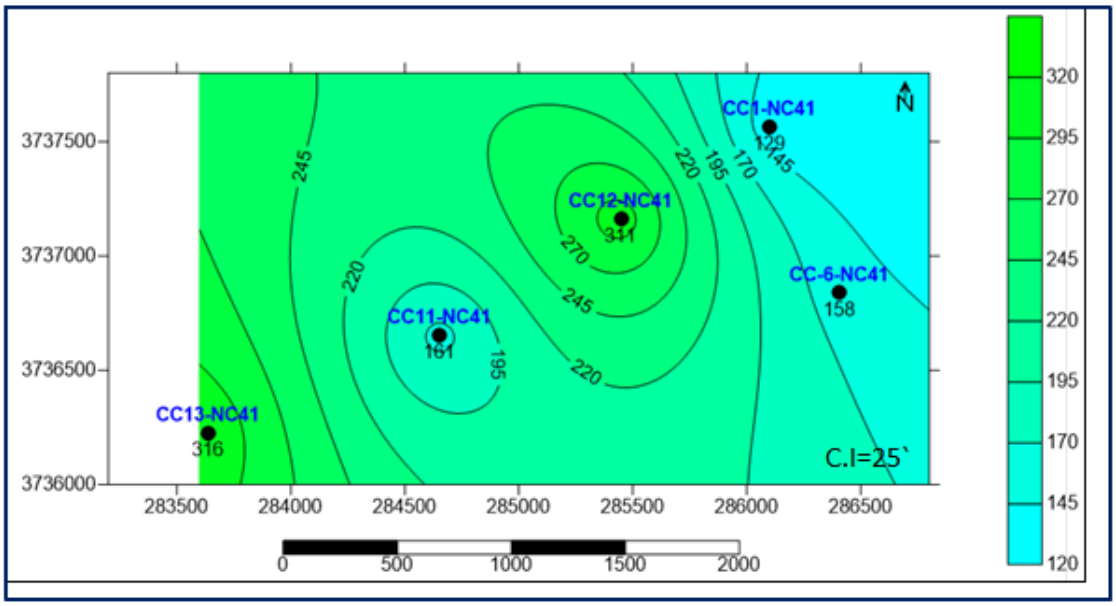

Fig (9): Net pay map of El Garia Formation (surfer software)

5- El Garia Reservoir Characteristics

El Garia Reservoir in study area consists of main of Limestone with thin beds of dolomite rock , the reservoir is recognized by nummulitic , the gross thickness of El-Garia Formation in study area about more than 500 feet. The petrophysics parameters of the reservoir in studied wells show good reservoir quality with good porosity and good permeability with low volume of shale . Figure(10) shows type of reservoir in study area well CC6-NC41 . Figure (11) shows all points located on line limestone is indicated the lithology is limestone and the porosity is affect by light hydrocarbon (red point) and presents of the hydrocarbon .

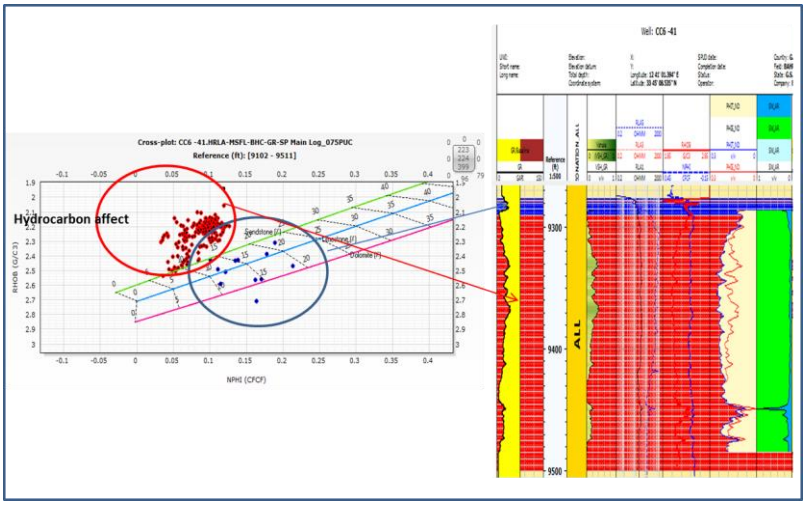

Fig (10): cross plot between neutron and density log in El Garia Reservoir(CC6-41 done by Techlog software)

Other cross plot between thorium/potassium ratio, (Th/K) , Photoelectric factor Figure (11), for to define type of clay mineral in the reservoir , the clay minerals are mainly chlorite and some glauconitic present in well CC13-NC41

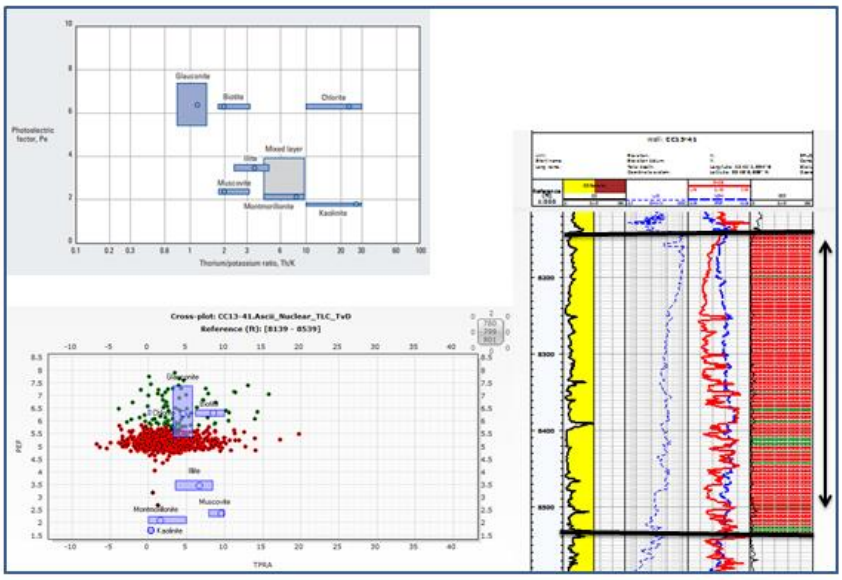

Fig (11) Cross plot between thorium/potassium ratio, (Th/K) and Photoelectric factor(Tech log software)

5.1- **integrate Repeat Formation Tester With Petrophysics Result**

To definite the type of hydrocarbon in well we using the RFT data to recognize the type of hydrocarbon also the contact between fluid in reservoir. the Repeat Formation Tester (RFT)

data and well logs used for interpreting the reservoir fluid type and contacts between fluids . The Figure(12)shows the result of petrophysics analysis for CC12-NC41, the contact between hydrocarbon water contact at depth 8619 feet ,this contact between hydrocarbon and water but what type of hydrocarbon is main target in this study , used RFT for dissimilar between hydrocarbon type .

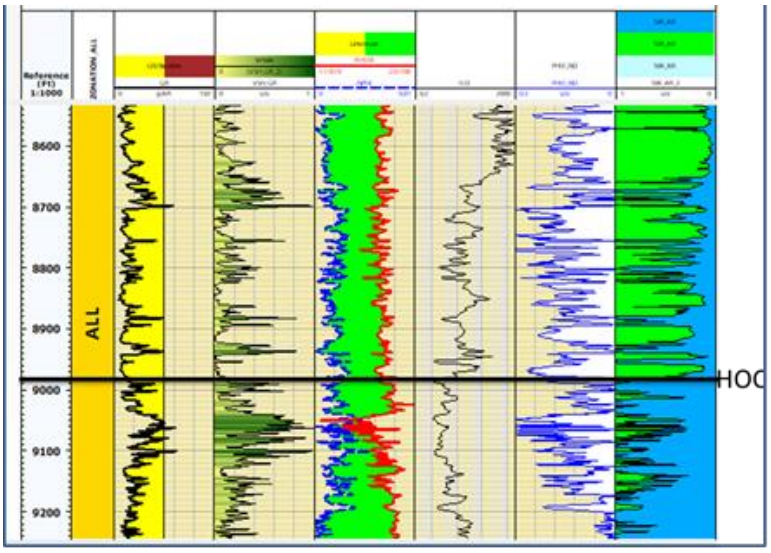

Fig (12) show the contact between hydrocarbon zone and free water(Techlog software)

Table 5.5 show Repeat Formation Test data in wellCC12-NC41(Melittah,2013)

Test No.	Run	Depth (ft.TVD)	Depth (ft.ssl)	QG BHP (psia)	SG BHP (psi)	SG BHP (psia)	Gradient (psi/ft)
3	1	8224	8147	35.26			-
4	1	8230	8153	3,704.21	3,682.31	3,696.81	
5	1	8239	8162	3,704.54	3,684.00	3,698.50	0.036
6	1	8246	8169	3,705.61	3,685.35	3,699.85	0.152
7	1	8256	8179				
8	1	8254	8177	3,707.10	3,686.85	3,701.35	
9	1	8275	8198	3,709.17	3,688.41	3,702.91	0.099
10	1	8284	8207	3,714.60	3,694.42	3,708.92	0.603
11	1	8304	8227	3,757.66	3,737.35	3,751.85	2.156
12	1	8314	8237	3,714.17	3,693.81	3,708.31	
13	1	8324	8247	3,713.92	3,693.61	3,708.11	
14	1	8340	8263	3,713.98	3,693.70	3,708.20	0.004
15	1	8354	8277	3,714.95			0.069
16	1	8370	8293	3,716.56	3,696.33	3,710.83	0.101
17	1	8383	8306	3,718.25	3,697.22	3,711.72	0.130
18	1	8400	8323	3,720.84	3,701.16	3,715.66	0.152
19	1	8417	8340	251.63			
20	1	8431	8354	3,722.02	3,698.65	3,713.15	
21	1	8448	8371	2,810.09			

The Repeat Formation test was applied and selected a total of (59 points) RFT pressure measurements have been taken across Garia Reservoir

after estimate pressure gradient use the equation below According to the difference in fluid densities, a difference in the pressure gradient occurs during the measurement. Obtained by inversely slope from plot formation pressure versus depth. The relationship between fluid density and the pressure gradient can be expressed as follow: 1- Gas gradient range from (0.08-0.18) psi/ft. 2- Oil gradient range from (0.23-0.39) psi/ft. 3-Water gradient from (0.433-0.465) psi/ft. 4-Fresh water gradient = 0.433 psi/ft .5-Saline water gradient = 0.465 psi/ft Pressure gradient can be calculated by used this equation (4)

Gradient = (P2-P1)/(MD1-MD2) ……(4)

Where P1= pressure bed number 1 ,P2 = pressure bed below number 2, md1 = depth bed number1 , md2 = depth bed number2, the pressure vs. depth plot shows a gas gradient value of 0.09 psi/ft and oil gradient value of 0.21 psi/ft. The result was 329feet of gas zone and 42 feet oil zone as shown in Figure(13)

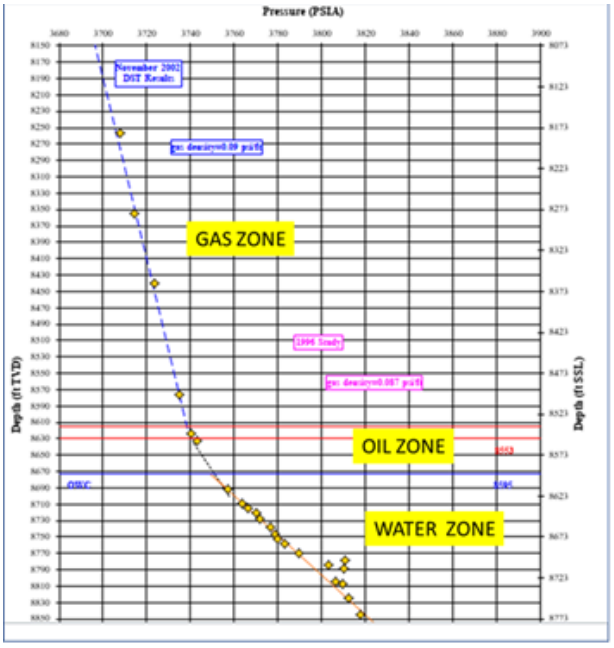

Fig (13) RFT RESULT(Done by Techlog software)

Conclusions

After Evaluate the petrophysical characteristics of the El Garia Reservoir , it can be

concluded that this field is structurally controlled since it is located in the western portion of the offshore Basin Concession NC 41 . Generally, Bahr Essalam Field structure is a fault anticline that trends from northwest to southeast directions. The structure contour map of El Garia reservoir indicates that the area is structurally controlled and is affected by step faults.

reveals lithological facies that consist mainly of the lithological facies consists mainly limestone. The petrophysical parameters indicate that El Garia reservoir is a good reservoir because of the low shale volume and the relatively high porosity. The hydrocarbon water contacts of the reservoir has been be determined by used RFT data and plotting the pressure values versus depths.

the Petrophysics result base on the wire line log data only used the Techlog software on five wells indicated that the average porosity 18%,. The water saturation about9.1% and average of the net pay thickness is varies in net pay thickness 198 feet. This result of petrophysics indicate the El Garia reservoir is good reservoir quality and the variation between wells have been affected by the trend of faults the might be indicates that area structurally controlled .

REFERENCES

- Hallett, D., and A. El-Ghoul, 1996, Oil and gas potential of the deep trough areas in the Sirt Basin, Libya, in M. J. Salem, A. S. El-Hawat, and A. M. Sbeta, eds., Geology of the Sirt Basin: Amsterdam, Elsevier, v. 2, p. 455–484.
- Unpublished reports, (2012,2015, 2017) ,Mellitah reports ,Hot engineering, Degolyer and Macnaughton .
- Schlumberger. (1997&2006), Basic Petroleum Engineering