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INTEGRATION OF SEISMIC AND WELL LOG DATA FOR CHARACTERIZATION OF THE RUDIES FORMATION AT ZEIT BAY OIL FIELD, GULF OF SUEZ, EGYPT

BY

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ABSTRACT

This work focuses on the characterization of Rudies Formation at Zeit Bay oil field through integrating the well logging and seismic data. The seismic data was processed and interpreted. Depth structure contour map was constructed for Top Rudies using Petrel (2017.4) Software, the map shows a NW-SE elongated dome intersected by semi-vertical normal clysmic faults, this elongated dome represents the structural trap in the field. Petrophysical evaluation was done for Rudies Formation and the petrophysical parameters were estimated using Techlog (2015.3) Software.

According to the petrophysical analysis Rudies Formation is subdivided into two main zones; the first has low GR value (Rudies 1), the second has high GR value (Rudies 2). Rudies1 has an effective porosity ranging from 15.9% to 20.3%, content of shale ranging from 2.5% to 8.1, water saturation ranging from 4.1% to 15.6% and net to gross value ranging from 73.9% to 97.4% where Rudies2 has an effective porosity ranging from17.7% to 21.4%, content of shale ranging from 2.8% to 8.8, water saturation ranging from 7.3% to 19.6% and net to gross value ranging from 68.9% to 87.8%, that means Rudies1 and Rudies2 are very good reservoirs. Rudies Formation seems to be a homogenous reservoir but it is a heterogeneous reservoir that differs both laterally and vertically at its petrophysical characteristics and lithology.

Keywords: Seismic data interpretation, Well log analysis, Rudies Formation, Gulf of Suez, Egypt.

INTRODUCTION

The Gulf of Suez is the largest part of Egypt's distinct oil provinces at oil production and reserves. The Gulf of Suez-Red Sea basin is an excellent example of continental breakup and opening of new oceans. Both of the Gulf of Suez and Red Sea started as continental rifts at the initial phases of separation of Arabia from Africa. After a certain period of continental extension, they were separated from each other by the Dead Sea Transform that allowed continued extension in the Red Sea and abortion of the Suez Rift. Four mega-half grabens of opposite tilt directions are recognized in the Suez Rift and the northwestern part of the Red Sea. Pre-rift structures controlled the locations and orientations of the accommodation zones between these mega-half grabens (Fig. 1 and 2). Rift opening in the Gulf of Suez-Red Sea area started at Late Oligocene-Early Miocene (Robson 1971; Garfunkel and Bartov 1977; Moustafa 1993; Patton et al. 1994; Bosworth and McClay 2001; Cochran 2005).

Many geologists subdivided the Suez Gulf into three tectonic provinces. Each of these provinces exhibits a particular geological characteristic giving rise to specific gravity anomaly trends, seismic results and the coastal configuration. (SUCO, 2010).

a. The northern most province situated north of a line through Ras Zafarana on the west coast and Gebel Zenema (in Sinai) is formed by single fault scarps on each side of the graben. The western edge is formed by the blocks of Ataqa and north Galala and the eastern edge by the Gebel Raha and Gebel Somar.

b. The North Central Province has its suggested southern limit given by a line extending from shukeir on the west coast to Wadi Baba on the east coast. Here, most of the structures are buried under Miocene and Pliocene formations. Fault movements have led to doming. The fault pattern appears to be complicated with movements coming from several directions and down- drops often following alternating step faults. It may be an indication of slight transform movements.

c. The South-Central Province appears to have undergone less faulting and the main features are the Esh-Mellaha, the Gebel Zeit and the Gebel Araba with their foundered flanks. The conjugate couple of faults of the Eritrean and Aqaba trends are predominant.

Fig (1): Location map of Zeit Bay Oil Field.

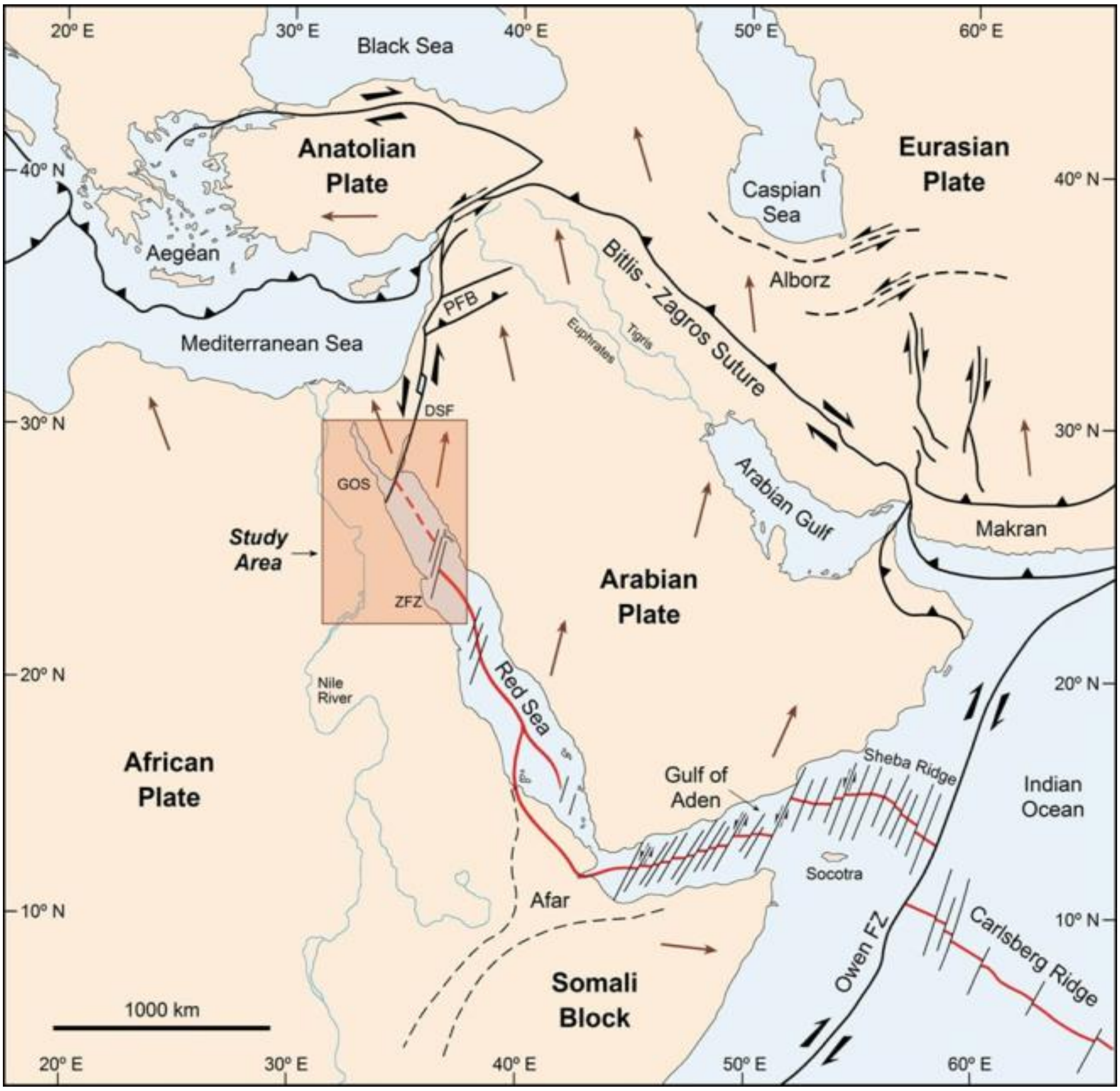

Fig. (2) Plate tectonic setting of the Gulf of Suez, Gulf of Aqaba, and Red Sea areas modified after Hempton (1987), Khalil and McClay (2002) and Bosworth et al. (2005). ZFZ is Zabargad Fracture Zone, DSF is Dead Sea Fault, and PFB is Palmyra Fold Belt. Thin arrows represent the plate movement directions after ArRajehi et al. (2010) and movement direction of Sinai is after Mahmoud et al. (2005).

Zeit Bay field is located at south western margin of the Gulf of Suez. It is located between longitudes 33° 32` and 33° 36`E and latitudes 27° 42` and 27° 47`N. It is mainly situated in shallow water of depth up to 65ft and apart of the field extends on land at Ras-El-Bahar. The structural feature of Zeit Bay as for all oil fields in the Gulf of Suez suffered several tectonic activities during its development through the geological history. Zeit Bay field as most of the structural features in the Gulf of Suez is represented as an elongated NW tilted fault block. It differs from these major structures in that it has 4-way dip anticline closure feature in the central major part of the structure on the level of Belayim till basement. It has two major basins to the west (western basin) and to the east (eastern basin) with long axis for the regional structure, trending NW- SE, which is bounded by faults from all directions.

MATERIALS AND TECHNIQUES

The available data include seismic and well logging data of six wells distributed in the area (Fig. 3). Twenty seismic 2D lines and four wells (ZB-C3, ZB-A7, ZB-D1, ZB-B2) have been used for seismic interpretation by Petrel (2017.3) Software. The interpretation concentrate on the area contains wells as detected in the following figure. The main target of seismic section data involves determination of the geologic significances from seismic data (Sheriff and Geldart, 1995). Depth structure contour maps are constructed to show the different structural features present in the area. The well-logs have been processed by the Techlog (2015.3) technique named (ZB-A1, ZB-A7, ZB-B7, ZB-C3, ZB-L1, and ZB-D1).

These logged data have been recorded, tabulated and prepared in (LAS) fill formats to be ready for the petrophysical analysis. The logged data in these wells include various types of well logs as Caliper log (CAL), Gamma ray log (GR), Resistivity, Porosity logs (RHOB, NPHI, DT), Natural Gamma ray Spectrometry (NGS) and the photoelectric factor log (PEF). The Techlog (2015.3) Software was used to figure out the precise reservoir rock petrophysical parameters, which subsequently used for carbonate reservoir evaluation.

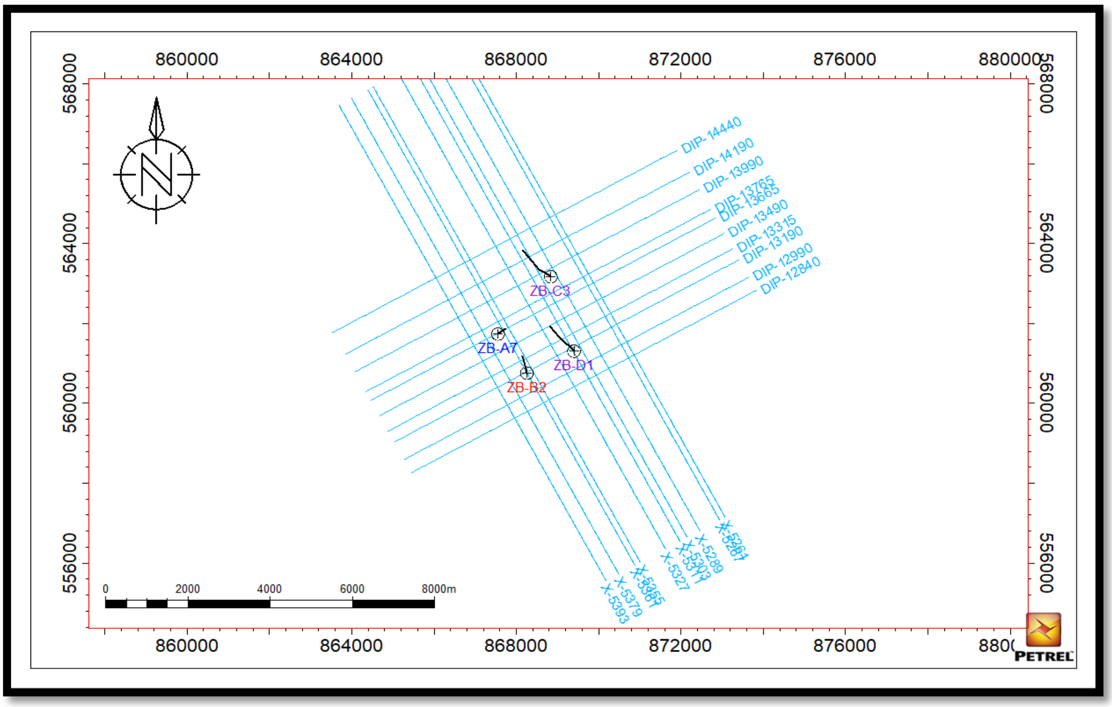

Fig. (3): Map showing the location of the studied 2D lines and wells covers the Zeit Bay field area.

LITHOSTRATIGRAPHIC UNITS

The stratigraphic section of the Gulf of Suez includes three tectono-stratigraphic sequences. These are pre-rift, syn-rift, and post-rift. The stratigraphic succession of Zeit bay field is similar to the sequences presented elsewhere in the southern part of Gulf of Suez basin (Fig. 4 and 5). Zeit Bay stratigraphic column is ranging in age from Pre-Cambrian basement to Recent, where reservoir units are ranging in age from Pre-Cambrian basement to Hammam Faraun. The Kareem/Rudeis carbonate reservoir overlies the Basal Miocene sand. It attains a maximum

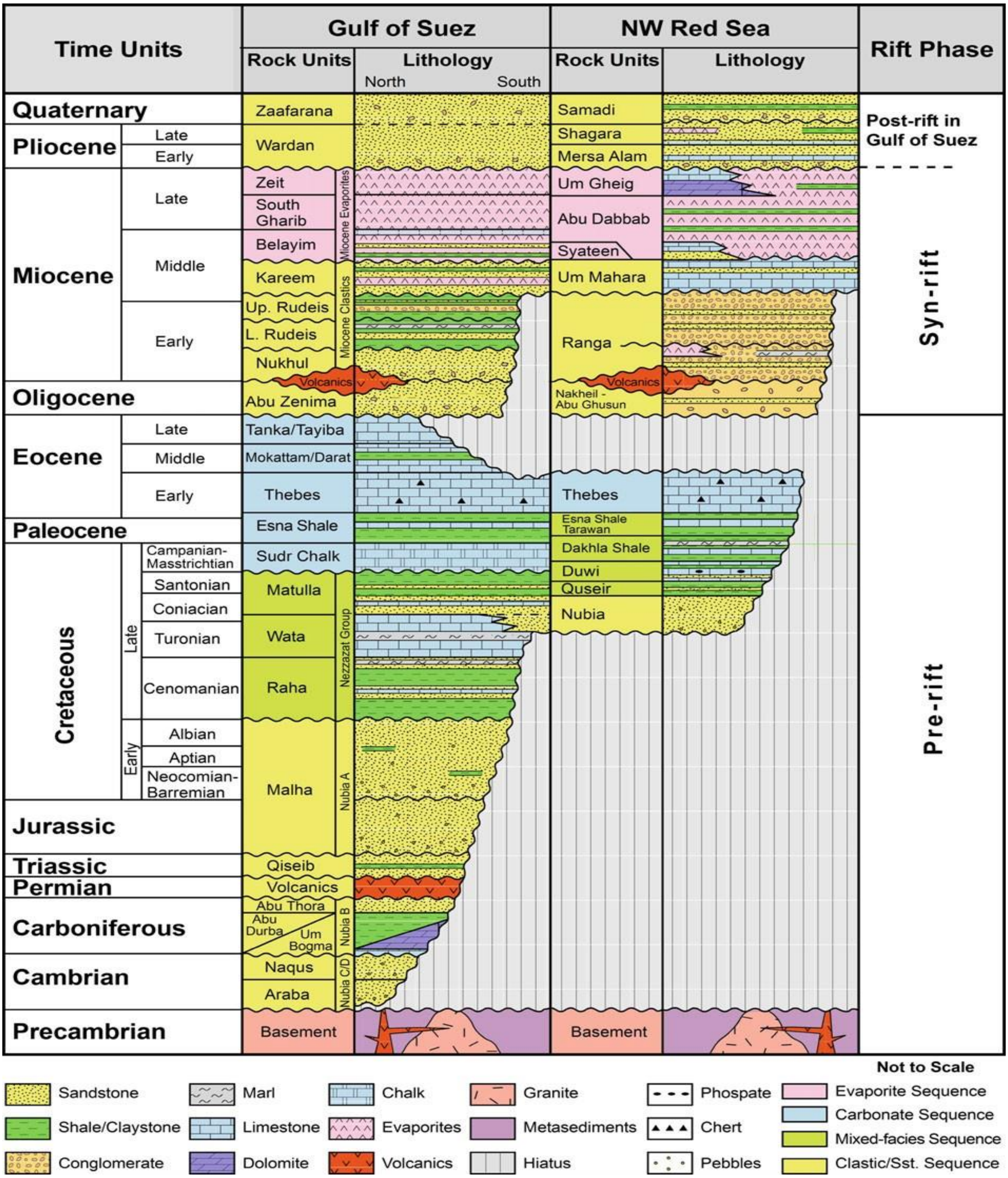

Fig. (4): Stratigraphic sections of the Gulf of Suez (after Moustafa and Khalil, 2017) and NW Red Sea rifts (after Khalil and McClay 2016, 2018).

thickness of 600 ft. and pinches out laterally on the crestal part of the structure. The Belayim evaporites form the vertical seal of the carbonates. The Kareem/Rudeis strata show deep water shales on the flanks and carbonate on the crest. Mohamed Darwish, (2016) made a detailed chronostratigraphic, sedimentologic facies analysis and wireline log calibration to study the evolution of the Miocene oil-bearing syn-rift sequences. In the Zeit Bay Field

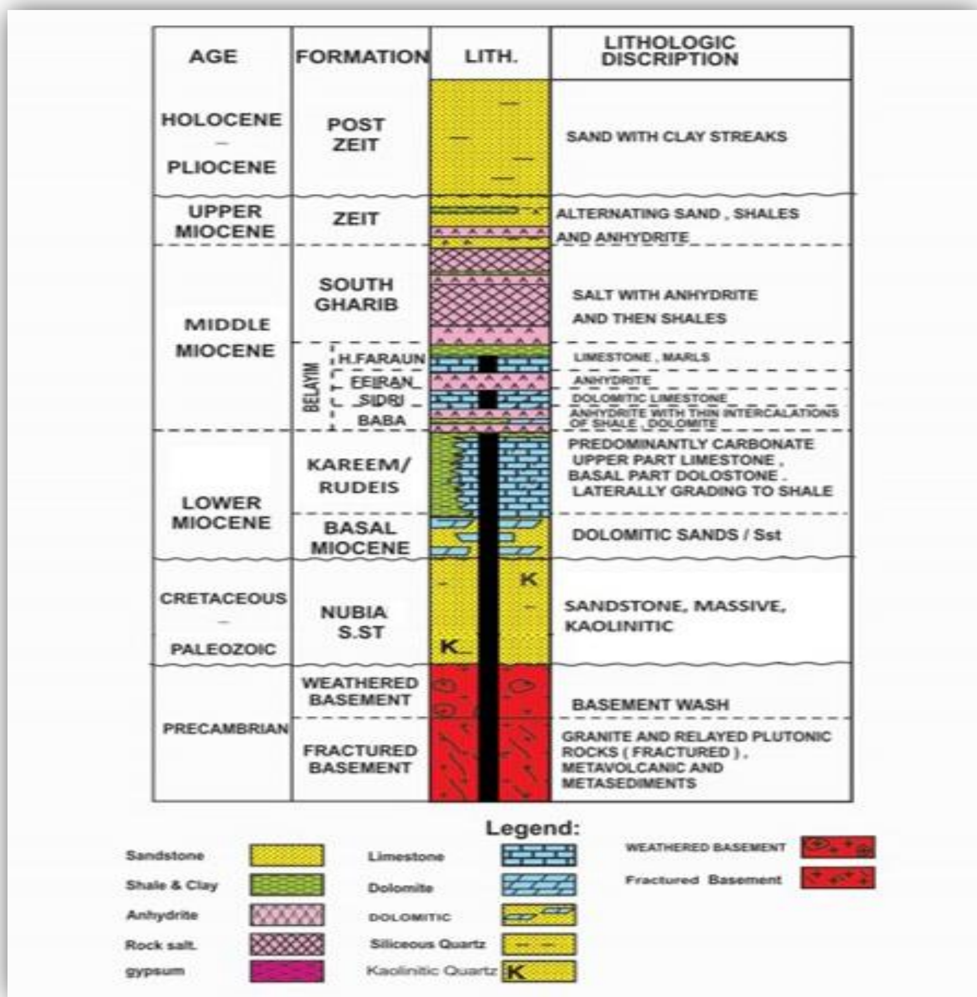

Fig. (5): Generalized stratigraphic column of Zeit Bay field (after SUCO,1988)

RESULTS AND DISCUSSION

1 - Seismic data interpretation

The structural interpretation is the primary purpose for detecting the unconformities, faults and folds (Abu El Ata et al., 1999). To make a seismic interpretation, you have to tie the geologic horizons to the seismic reflectors initially. Here the well tops are very helpful and accurate. Then, pick the seismic horizons and detect the structural elements. Within the seismic horizon picking, the two seismic lines are intersected at a point that avail the picking of this horizon at the other seismic section and so on to tie a loop and check the interpretation. Finally, after horizon picking and fault picking, depth structure contour maps could be made.

The south west- north east trending seismic section (Dip line 13315)

This seismic section is SW-NE direction of the study area (Fig. 6). The seismic section shows the picked stratigraphic horizons, the first (purple) represents top Belayim, the second (black) represents top Rudies, and the last (blue) represents top wash_ basement.it also shows the faults affecting the study area (F1, F2, F3, F4 and F5). All faults are normal faults and seems to be semi-vertical. The faults and horizons present in the structure high area in the field (elongated dome).

Depth structure contour map on top Rudies in Zeit Bay field

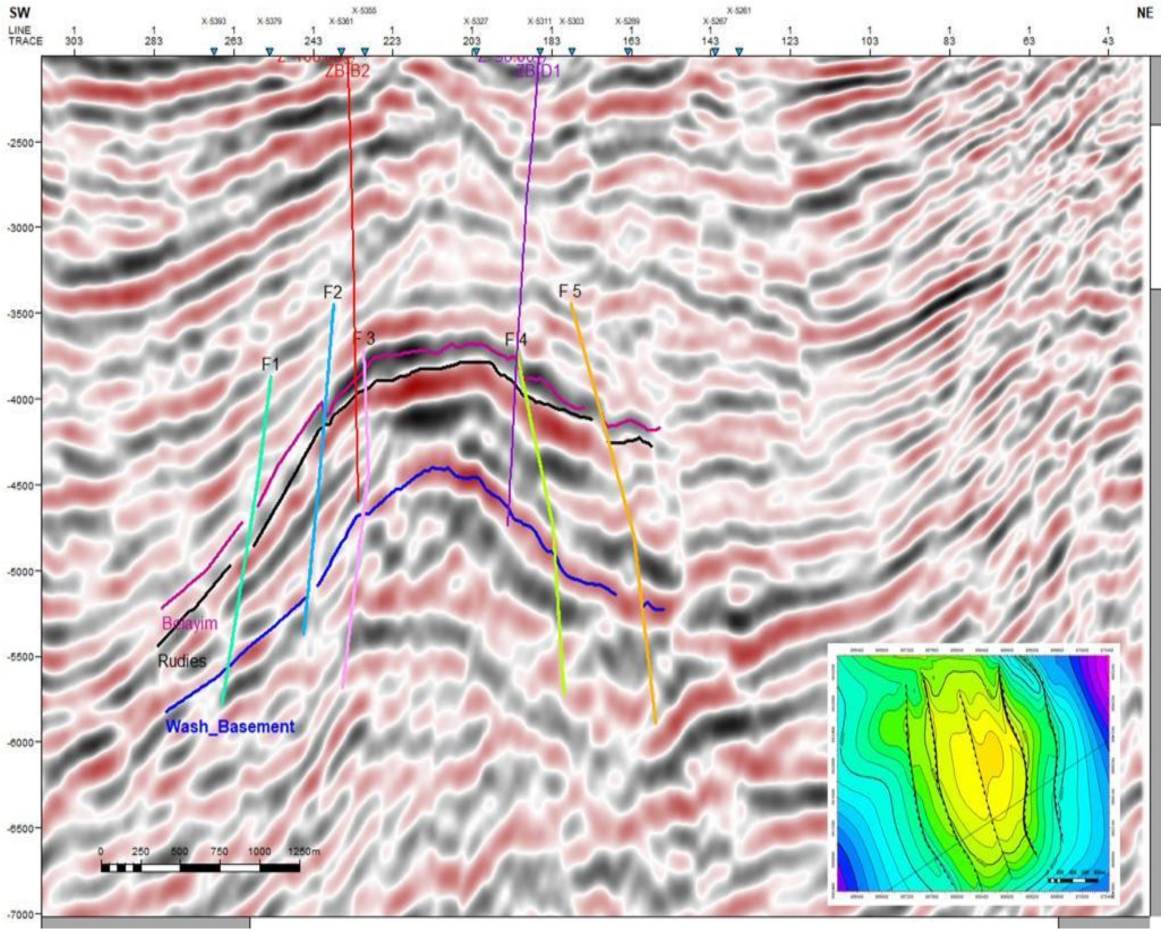

Fig. (6): SW-NE trending seismic section (Dip Line- 13315) showing the picked stratigraphic horizons and the picked faults.

The map shows NW-SE elongated dome on the level of Rudies that is intersected by five faults from west to east as follow:- F1, F2 are normal faults trending NNW-SSE and dipping to the west with fault throw about 100ft for each fault. F3 is almost N-S normal fault, semi vertical in shape with some strike movement (oblique) , the fault cut is about 50ft. F4 is a N-S normal fault dipping to the east direction with about 200ft throw.F5 is a marginal normal fault trending N-S and dipping to the east with fault cut 100ft (Fig. 7).

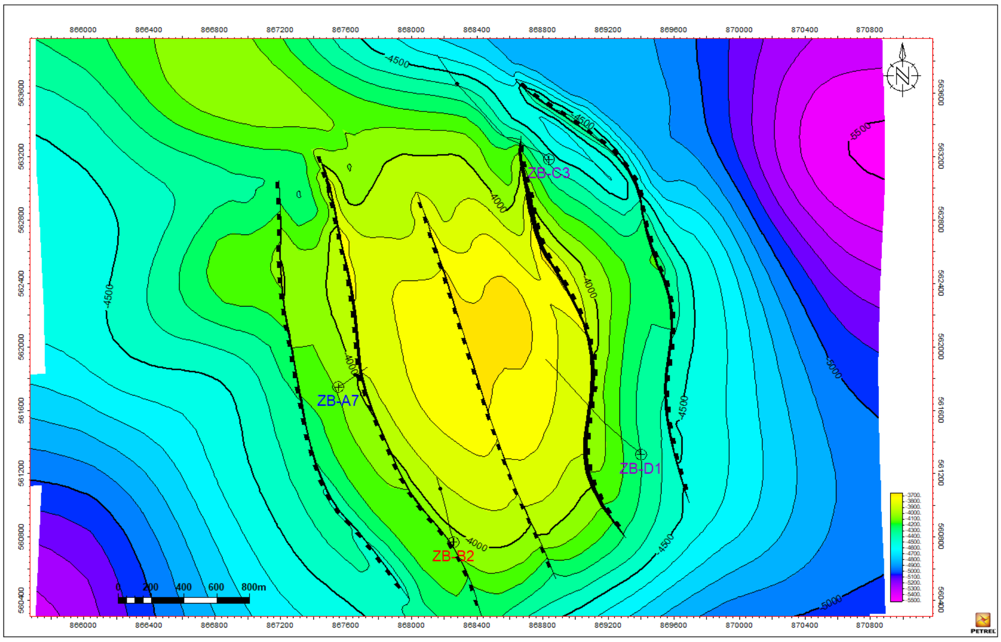

Fig. (7): Depth structure contour map on top Rudies in Zeit Bay field.

1.1. Well Log Analysis

Well-log is a continuous record of measurement made in borehole respond to variation in some physical properties of rocks through which the bore hole is drilled (Asquith and Krygowski 2004). The following figure shows a schematic workflow for well log interpretation using techlog program (Fig. 8).

Fig. (8): schematic workflow for well log interpretation using techlog program.

Vertical distribution of hydrocarbon occurrences represented by (CPI) Computer processed interpretation.

In ZB-B7 well, Rudies1 consists mainly of dolomitic limestone and dolomite where Rudies2 is mainly dolomite and Kareem is calcareous shale. Kareem/Rudies formation is overlain by Belayim Formation only Feiran and Hammam faraun members are present. feiran consists of anhydrite with streaks of dolomite and hammam faraun consists of carbonate (dolomite) overlain by shale layer. The gross thickness of Rudies1 is 490 ft and the effective porosity is about 20.6% with 90.2% hydrocarbon saturation and 3% content of shale and very high net to gross value so that Rudies1 is considered a very good reservoir. The gross thickness of Rudies2 is 76.7 ft and the effective porosity is 18.8% with 89.9% of hydrocarbon saturation and 2.8% content of shale (Fig. 9).

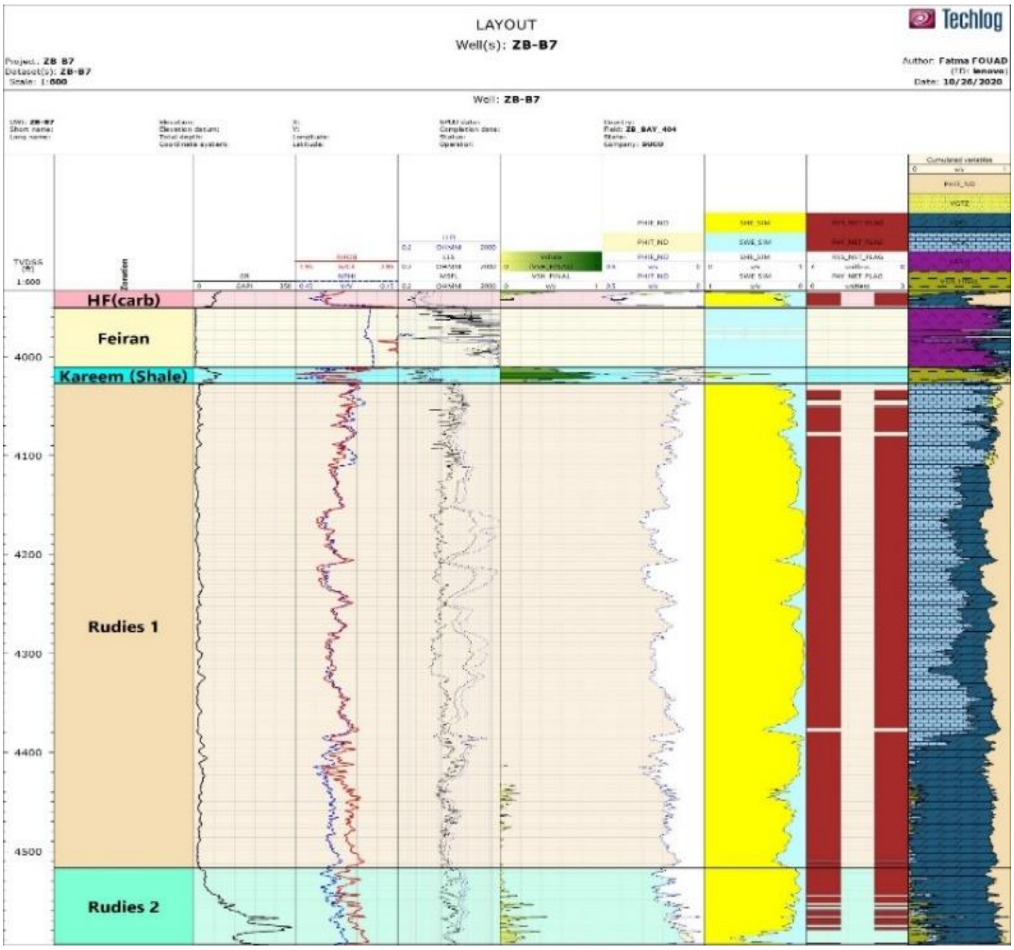

Fig. (9): Computer processed interpretation (CPI) of ZB-B7 well by using Techlog program software.

Table (1): Reservoir Summary of ZB-B7 well.

Zone Name	Gross Thickness (ft)	Net Thickness (ft)	Av Phi	Av sw	Av Vcl
Rudies 1	489.994	467.048	20.6	9.8	3
Rudies 2	76.715	52.489	18.8	10.1	2.8

In ZB-C3 well, Rudies1 consists of dolomitic limestone and sandy dolomite. The gross thickness of Rudies1 is 170.7 ft with effective porosity about 16.1% and hydrocarbon saturation 94.4%. the shale content is low (2.7%). Rudies 2 is not found at ZB-C3 well where Kareem is subdivided into two units the first is Kareem argillaceous dolomite and Kareem sandy dolomite. It is notable that in block C of Zeit Bay field the carbonate rocks decrease and the clastic rocks increase (Fig. 10).

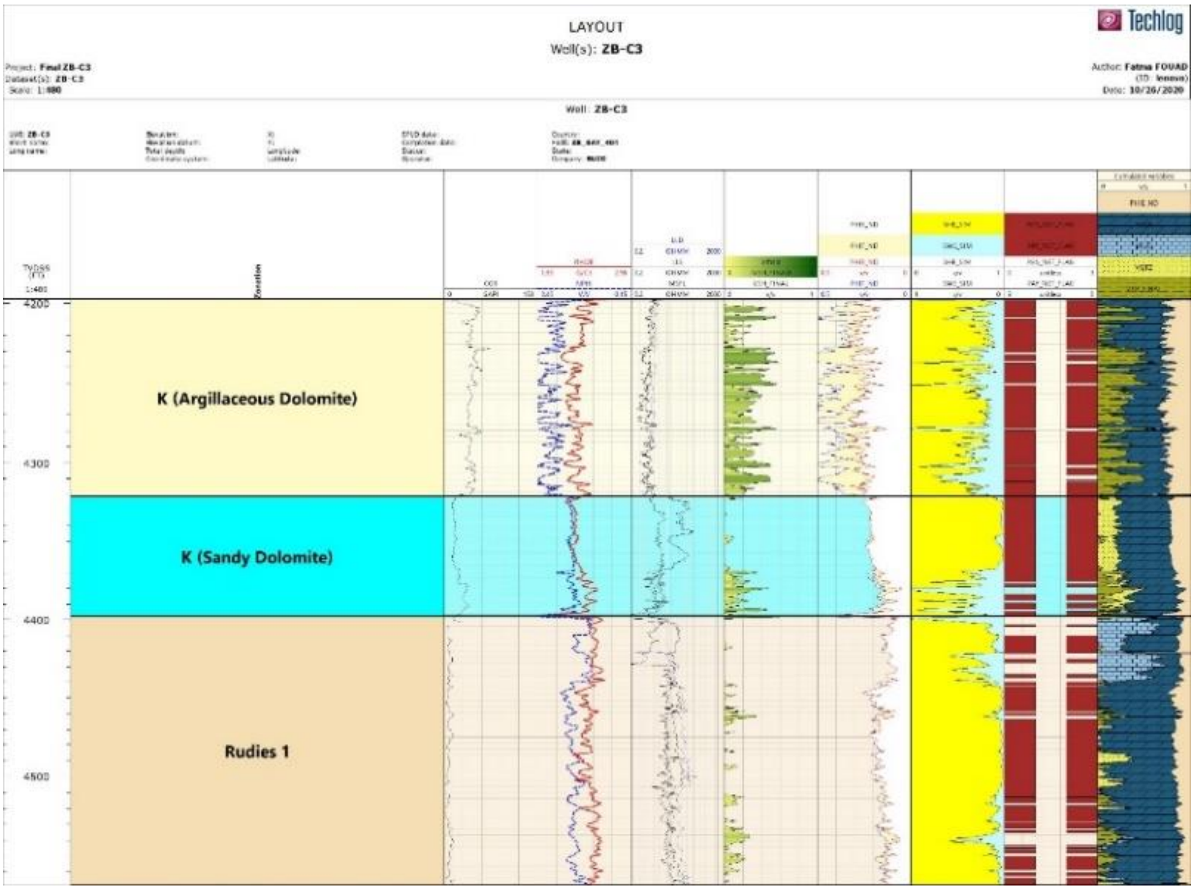

Fig (10): Computer processed interpretation (CPI) of ZB-C3 well
by using Techlog program.

Table (2): Reservoir Summary of ZB-C3 well.

Zone Name	Gross Thickness (ft)	Net Thickness (ft)	Av Phi	Av sw	Av Vcl
Rudies 1	170.722	125.843	16.1	5.6	2.7

In ZB-L1 well, Rudies1 consists of dolomitic limestone and Rudies2 composed mainly of dolomite. The shale content increases on land in Rudies2 to reach about 8.8%. the gross thickness of Rudies2 is 119 ft and the effective porosity is 19.3% with hydrocarbon saturation 92.7%. the gross thickness of Rudies1 is 220 ft and effective porosity is 20.1% with hydrocarbon saturation 95.9%. The shale content is 2.5%. Kareem is mainly shale overlain by Belayim evaporites that consists mainly of anhydrite (Fig. 11).

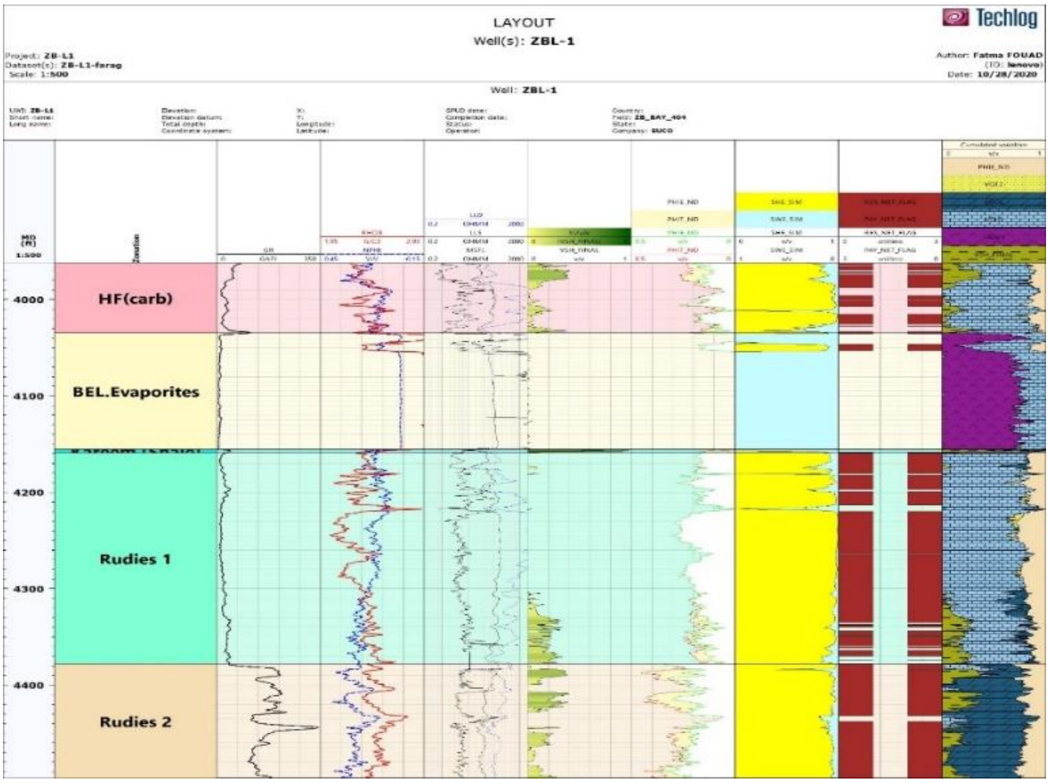

Fig. (11): Computer processed interpretation (CPI) of ZB-L1 well by Techlog program software.

Table (3): Reservoir Summary of ZB-L1 well.

Zone Name	Gross Thickness (ft)	Net Thickness (ft)	Av Phi	Av sw	Av Vcl
Rudies 1	**220**	**206.5**	**20.1**	**4.1**	**2.5**
Rudies 2	**119**	**104.5**	**19.3**	**7.3**	**8.8**

Neutron Density Cross Plot

According to (Krygowski, 2003) the cross plot means 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.

At ZB-A1 well both Rudies 1 and Rudies 2 composed mainly of dolomite only few points are scattered between limestone and dolomite showing grain density ranging from 2.5 gm/cc to 2.7 gm/cc and total porosity ranging from 17% to 33% at Rudies 1 where it is ranging from 15% to 25% at Rudies 2 (Fig. 12).

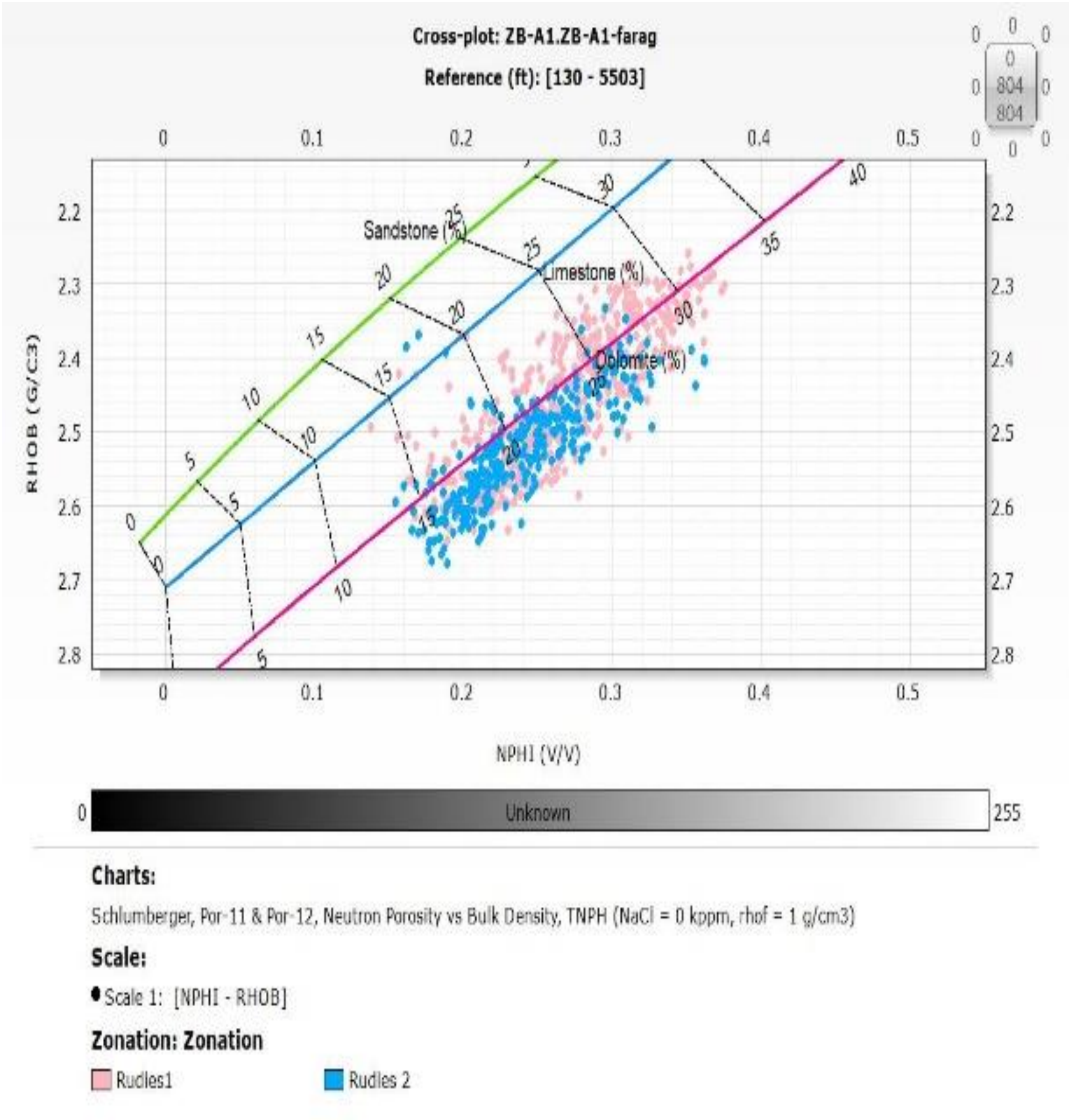

Fig. (12): The Neutron density cross plot showing the lithological components at ZB-A1 Well.

At ZB-A7 well, Rudies 1 is mainly limestone with few points scattered around dolomite showing grain density ranging from 2.35 gm/cc to 2.6 gm/cc. Rudies 2 is mainly dolomite showing grain density ranging from 2.6 gm/cc to 2.75 gm/cc. Rudies 1 show total porosity ranging from 10% to 25% and Rudies 2 show total porosity ranging from 15% to 30% (Fig. 13).

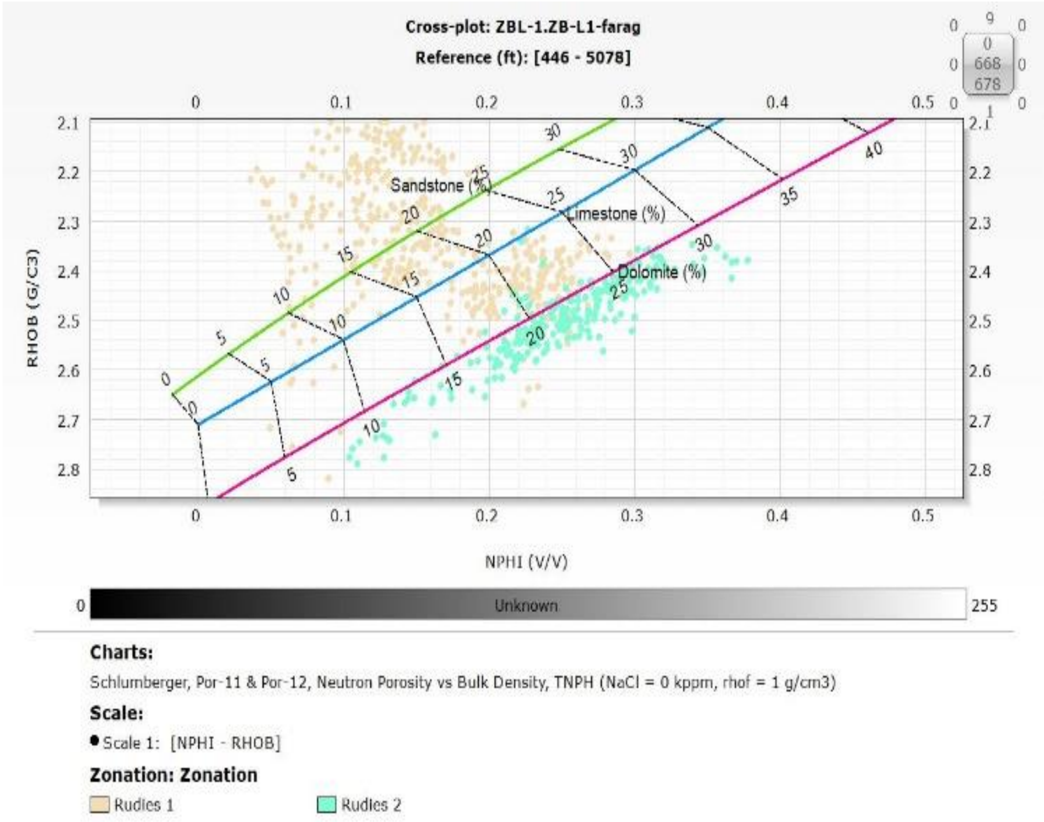

Fig. (13): The Neutron density cross plot showing the lithological components at ZB-A7 Well.

Only Rudies 1 is found at ZB-C3 well which consists mainly of dolomite with some points scattered around limestone. Rudies 1 has total porosity ranging from 15% to 20% showing grain density ranging from 2.5 gm/cc to 2.7 gm/cc Where Kareem consists of two zones, the first is Kareem argillaceous dolomite and the other is sandy dolomite (Fig. 14).

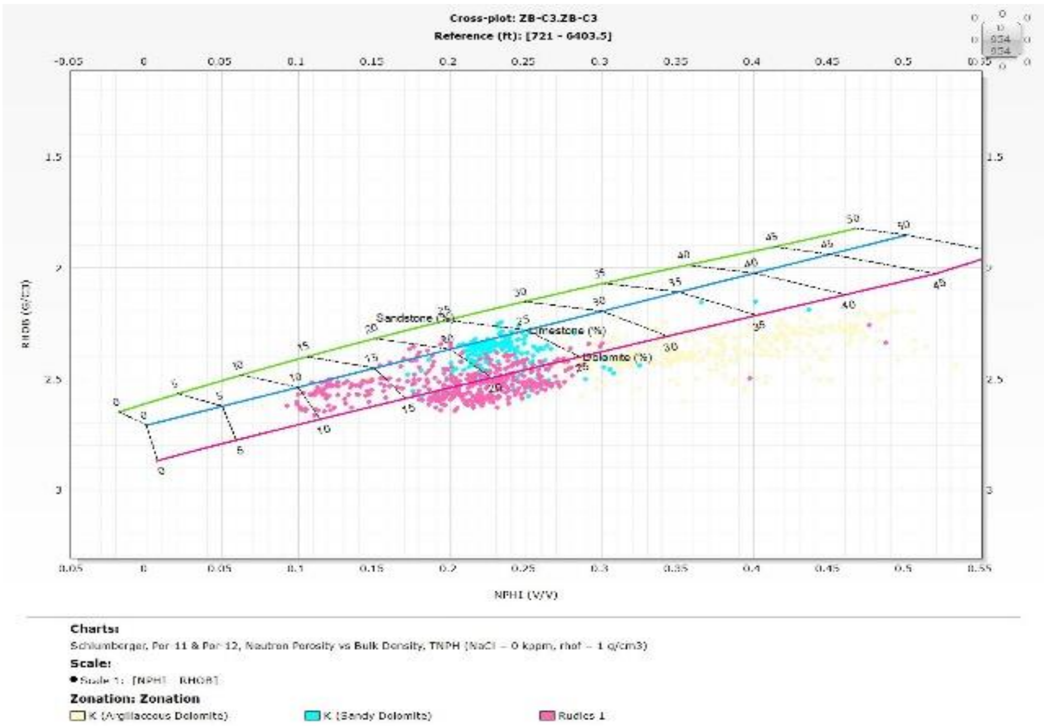

Fig. (14): The Neutron density cross plot showing the lithological components at ZB-C3 Well.

At ZB-L1 well, Rudies 1 is mainly Limestone with a lot of scattered points showing total porosity ranging from 15% to 25% and grain density ranging from 2.2 gm/cc to 2.5 gm/cc where Rudies 2 is mainly dolomite showing total porosity ranging from 15% to 27%and grain density ranging from 2.5 gm/cc to 2.7 gm/cc (Fig. 15).

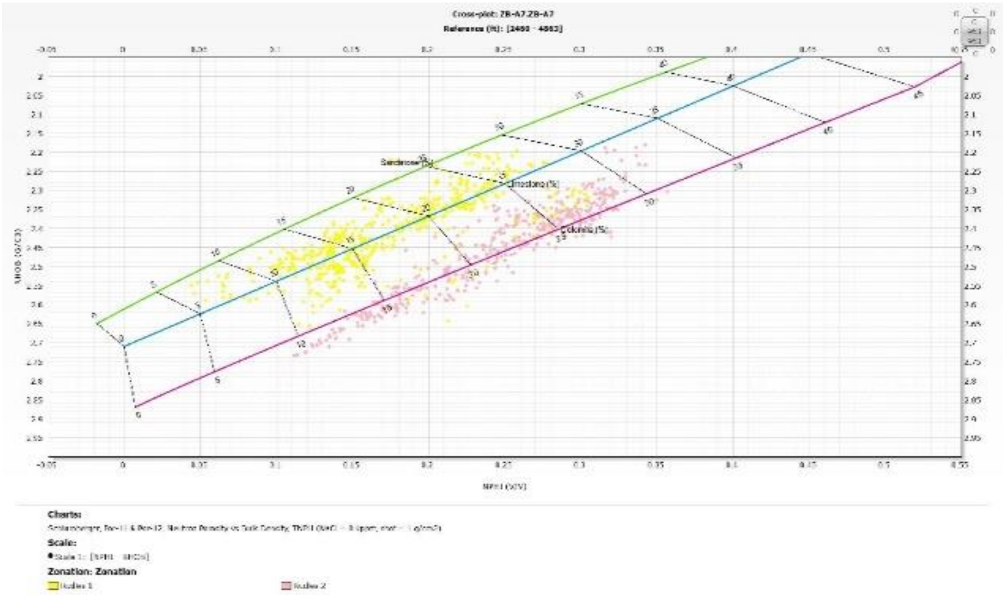

Fig. (15): The Neutron density cross plot showing the lithological components at ZB-L1 Well.

At ZB-B7 well, Rudies 1 is a dolomitic limestone with only few points scattered around sandstone showing total porosity ranging from 15% to 25% and grain density ranging from 2.3 gm/cc to 2.5 gm/cc where Rudies 2 is mainly dolomite showing total porosity ranging from 15% to 27% and grain density ranging from 2.5 gm/cc to 2.7 gm/cc (Fig. 16).

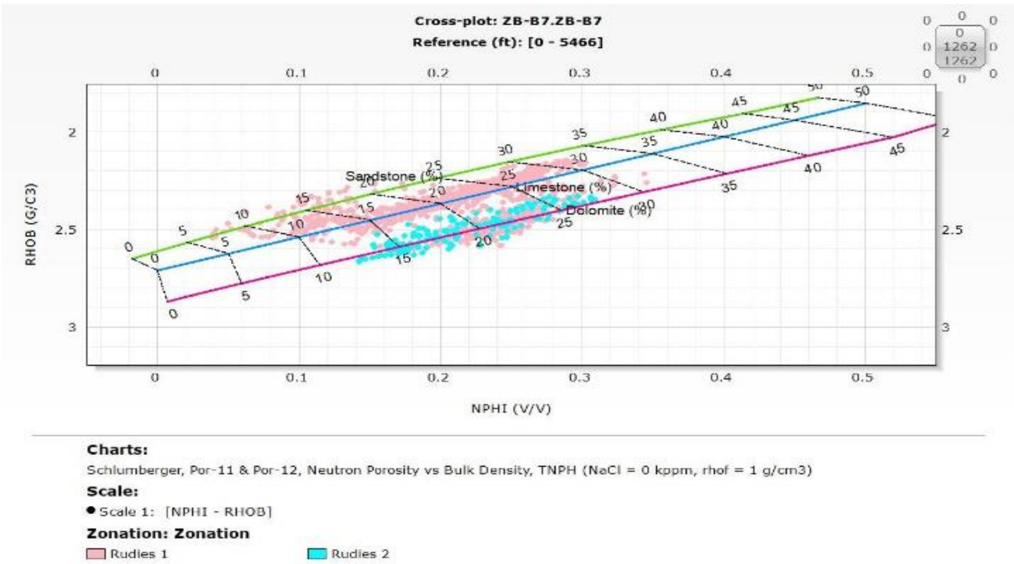

Fig. (16): The Neutron density cross plot showing the lithological components at ZB-B7 Well.

CONCLUSION

The structure responsible for hydrocarbon entrapment in the study area was a structural high which corresponds to the crest of the faulted elongated dome present in the Zeit Bay field. Petrophysical evaluation was done for Rudies Formation and the petrophysical parameters were estimated. Rudies Formation is subdivided into two main zones; the first has low GR value (Rudies 1), the second has high GR value (Rudies 2), both of them is a good reservoir according to its petrophysical characteristics but Rudies 1 seems to be better than Rudies 2 . The study show that Rudies Formation seems to be a homogenous reservoir but it is a heterogeneous reservoir that differs both laterally and vertically at its petrophysical characteristics and lithology. The strong change of facies is due to the strong tectonic activity at this field through the early to late Miocene times.

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