**MANSOURA JOURNAL OF Geology**

Official Journal of Faculty of Science, Mansoura University, Egypt

E-mail: scimag@mans.edu.eg ISSN:

# Petrophysical Properties of the Paleocene Zelten Formation in block NC59, Sirt Basin, Libya, using well logging data

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**Received:10/4/2022**
**Accepted: 21/4/2022**

**Abstract:** Zelten limestone represents the main reservoir in the Sirte Basin, Libya, concession NC59, Gailo field., The primary objectives of the present work are to evaluate the estimated the petrophysical parameters of the Zelten Formation using well log analysis. from one well (E92-59) were provided for evaluation. Several cross plots were used to evaluate the lithologic components and the saturating fluids in the form of litho-saturation cross plots, as an output parameters from the used Interactive Petrophysics (IP) program, according to the output results, Zelten Formation is mainly composed of limestone successions with few shales divided into a number of different rock types. with few shales. Based on well log analysis data, it is indicated that the thickness of the oil-bearing sequence of the Zelten Formation in the Gialo field is 131.2 feet. It can be divided into six reservoir zones with a net thickness of 2.56 ft for the first zone, 96.06 ft for the fifth zone and the sixth zone being unproductive. This indicates indicating that the Zelten Formation is a good reservoir.

**Keywords :** Petrophysics program - litho-saturation - cross-plot - Zelten - NC59 concession - Sirt Basin Libya.

## 1. Introduction

Sirt Basin is one of the giant basins in Libya. It extends from the Gulf of Sirt in the south to the central parts of Libya. It is covered with a vast area of sandy seas and gravel and cliffs of creaking gravel plains with the presence of seas and sand cliffs from time to time. It was discovered and outlined in the late 1950s using gravity and magnetic surveys during geophysical drilling projects for oil exploration (Fig. 1). Based on the bore hole data of the of the Gialo highs, Sirt Basin is formed due to subsidence of the Tibesti-Sirt arch

during the Cenomanian age. It is dissected extensively by a highly complicated set of deep situated sand channels that extends northward to the Gulf of Sirt (Selley, 1997). The Ajdabiya Trough is the largest and deepest trough in the Sirt Basin cover an area of 22500 km2,, containing about 8000 m (26247 ft) thickness of accumulated sediments.

## 2. Location of the Study Area

The study area is located in the Ajdabiya Basin in the eastern region of the Sirt Basin near the Cyrenaica platform in the north-central part of Libya. The study area represents the northern part of Concession 59 between latitudes 28° 40´ and 29° 20´ N and longitudes 20° 30´ and 21° 10´ E. (Fig. 1). The Ajdabiya Basin, also known as the Maragh Basin, covers an area of about 22,500 $Km^2$.

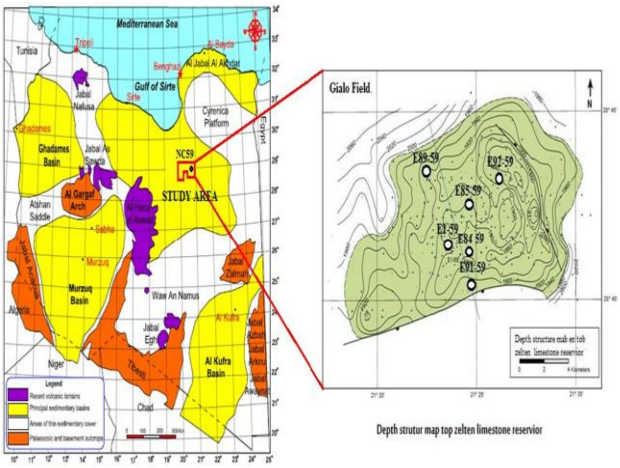


**Fig .1:** Location map of the study area Gialo Field in Sirt basin.

## 3. Geological Setting of Sirt Basin

The Sirt Basin is considered one of the largest oil-producing basins in Africa. It is a major fault structural pattern within the strata and is located in the central north parts of African Plate (Figure 2). This complex structure develops as a colliding fault in the northern African plate on its northern margins. The developed tectonics of the Sirt Basin include thermal curvature and advanced stages of faults that were active in the Late Paleocene and the Cretaceous periods and extended to the Early Eocene, and from the Late Eocene time onwards, followed by a thermal subsidence. The sedimentary sequence in the Sirt Basin reflects the tectonic and structural development of it which is linked closely with the convergence of the Tethys and the opening of the Atlantic Ocean in the Tertiary and the middle ages (Gras and Thusu, 1998). The Sirt Basin was first discovered by the Italian geologists during the thirties and the twenties of the last century. There are more than 6,500 drilled wells and huge number of seismic lines in countless kilometers which enabled constructing a detailed image of the subsurface. Although the coverage of the seismic survey is not uniform, there are some areas, especially the deep basins, are still completely unknown.

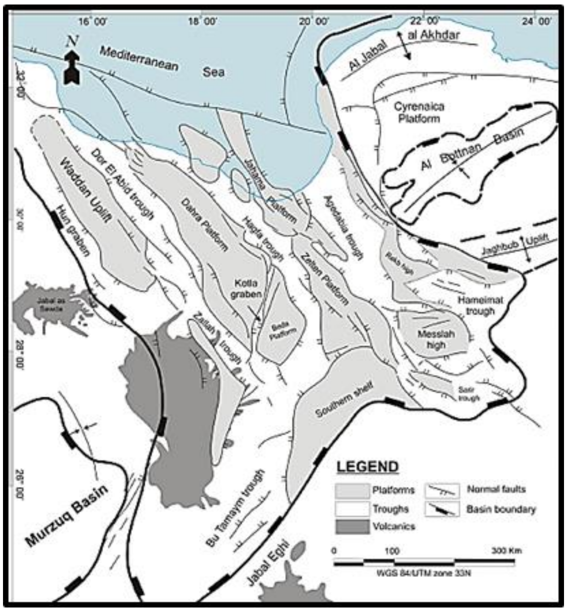


**Figure 2**: The tectonic framework of the Sirte Basin (Mouzughi and Taleb, 1981).

### 3.1 Stratigraphy of Sirt Basin

Thickness of the sedimentary sequences in the Sirt Basin is highly variable with many troughs and platforms, ranging from 1500 to 7000 m thick. (Goudarzi, 1980) representing Cambrian to Tertiary deposits (Tawadros, 2001). The basement rocks are represented by weathered and fractured granitic rock masses while the metamorphic rocks are assigned to the Late Pre-Cambrian and the Early Cambrian age sequence. The Paleozoic sedimentary sequence is represented only by the Cambro-Ordovician Hufrah sediments which are widely distributed in the basin. The Jurassic and Triassic sediments are characterized by a thin succession of the Nubia sandstone that is found in the northeastern part of the basin. The Lower Cretaceous period is thicker and is located in the southeastern part of the basin. It is represented also by the Nubia sandstone sequence (Triassic-Lower Cretaceous). The Upper Cretaceous sediments represent the thickest sequence in the Sirt Basin, ranging from Cenomanian to Maastrichtian ages. These thicknesses depend on their location in the basin with the thickest sediments around in the center of basin (Hallett, 2002). (Figure 3) shows the dominant stratigraphic cross-section, which reaches down basement.

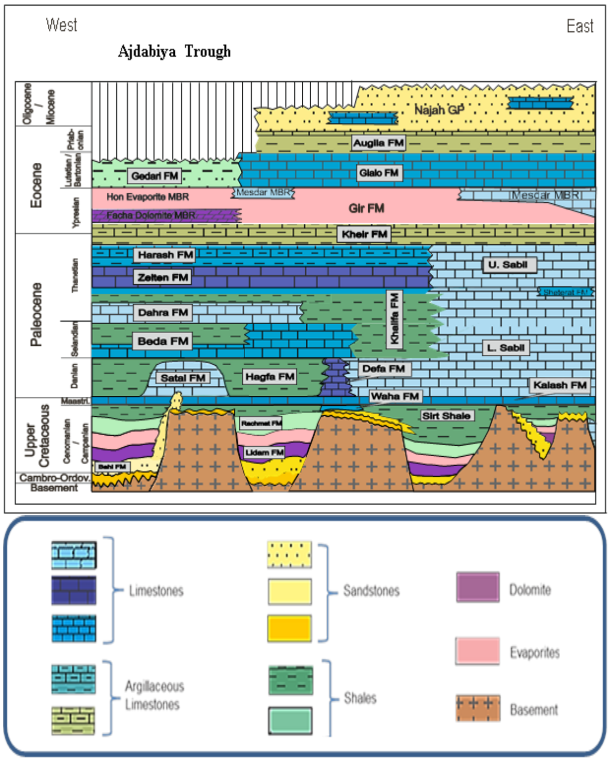


**Figure 3:** Generalized stratigraphic and lithologic chart of the northern Sirt Basin (Barr and Weegar, 1972).

## 4. Well Logging Technique

Wireline logging tools are important for characterizing the petrophysical properties of the subsurface formations, providing detailed information about the hydrocarbon-bearing reservoirs, determining the lithologies that are penetrated by bore holes, and testing the fluids connection between wells. The borehole wireline assessment is the best geological and geophysical method for determining the characteristics of reservoir rocks, and determining the location of the hydrocarbon-bearing zones (Schlumberger, 1974).

## 5. Results and discussion

The data available for this study is in digital Las file form, and due to the scarcity of available data, a complete data set was provided for only one well in the Gialo Field, south of the city of Ajdabiya,. These data sets include gamma-ray (GR), self-potential (SP), density (RHOB), neutron (NPHI), PEF curve, and shallow and deep resistivity logs (RS & RD). For the petrophysical data of the available well, the numerical data was reviewed before being entered into to the used IP program to determine the state of the database and to identify missing or disconnected numbers, and know how to work properly to correct such errors.

The qualitative and quantitative interpretation of the log data derived from one well (E92-59) were identified. After careful application of the cutoff values including 10 % porosity, 35 % shale content, and 50 % water saturation, the studied reservoir was discriminated into six zones the net-pay zones were then determined. Out of these zones, only five zones were assigned as two hydrocarbon-bearing zones which are easily identified and located within the depth reservoir interval (6175-6412.5ft).

From the litho-saturation cross-plot (CPI), the vertical distribution of the hydrocarbon content can be presented and explained. Based on this CPI, the average porosity values vary between 15.7 and 19.7%, the average water saturation varies between

2.56 and 96.06 feet and total net-pay thickness equals 131.24 feet. The relatively low bulk volume of water (BVW = Phi*Sw = 0.004-0.01, Table 1, Fig 4) indicates that the reservoir will produce hydrocarbons with few water content.

**Table 1:** The average petrophysical parameters of the pay zones of the studied six Zelten zones assigned from the petrophysical processing

| Zone No. | Top (ft) | Bottom (ft) | Gross (ft) | Net-pay (ft) | N/G | Av PHI | Av Sw | Av VSh | PHI*H | PHI*Sw | PHI*H*So |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Zone 1** | 6175 | 6196.5 | 21.5 | 2.56 | 0.119 | 0.157 | 0.599 | 0.196 | 0.402 | 0.094 | 0.161 |
| **Zone 2** | 6196.5 | 6218 | 21.5 | 21.0 | 0.977 | 0.197 | 0.487 | 0.234 | 4.137 | 0.096 | 2.122 |
| **Zone 3** | 6218 | 6252 | 34.0 | 9.06 | 0.266 | 0.164 | 0.601 | 0.267 | 1.486 | 0.098 | 0.594 |
| **Zone 4** | 6252.5 | 6286 | 33.5 | 2.56 | 0.076 | 0.169 | 0.528 | 0.279 | 0.433 | 0.089 | 0.204 |
| **Zone 5** | 6286 | 6400 | 114.0 | 96.06 | 0.843 | 0.187 | 0.483 | 0.398 | 17.96 | 0.090 | 9.285 |
| **Zone 6** | 6400 | 6412.5 | 12.5 | ---- | ---- | 0.185 | 0.051 | 0.367 | ---- | 0.042 | ---- |
| **All Zones** | 6175 | 6412.5 | 237.5 | 131.24 | 0.553 | 0.186 | 0.493 | 0.263 | 24.41 | 0.092 | 12.38 |

**Note:** N/G is the net to gross ratio, av. PHI is the average effective porosity, Av Sw is the average water saturation, Av Vsh is the average shale volume percentage, and H is the net-pay thickness.

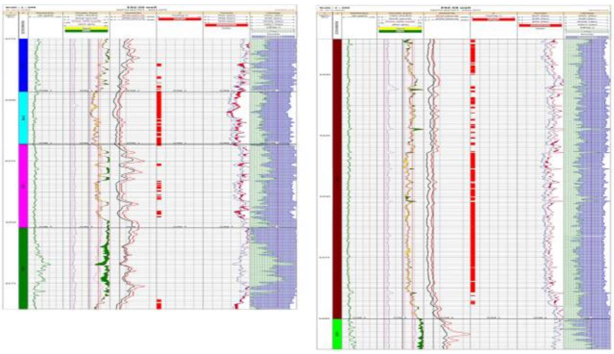

**Figure 4**: Litho-saturation plot of the six zones of the Zelten Formation in E92-59 well.

In the density-neutron cross plot, the measured points are clustered round the limestone line, i.e., it is indicated that main composition of the studied Zelten Formation is limestone with some shift to the dolostone composition which is attributed to the present shale content (Fig 5).

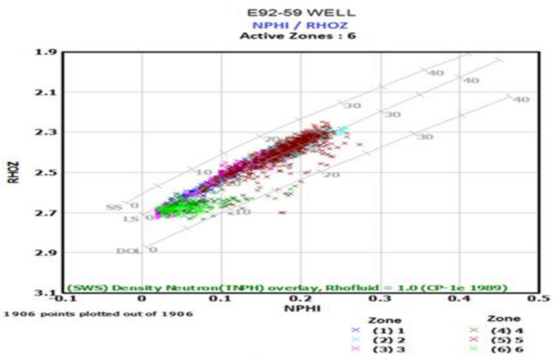


**Figure 5:** Plotting the density (RHOB) as a function of the neutron porosity (NPHI) of Zelten Formation.

Also, plotting the thorium content versus the potassium, indicates dominance of the chlorite as a main composition of the present clay content which is characterized by relatively low potassium and thorium content (mostly less than 1.2 %, and 3.0 ppm, respectively(Fig 6).

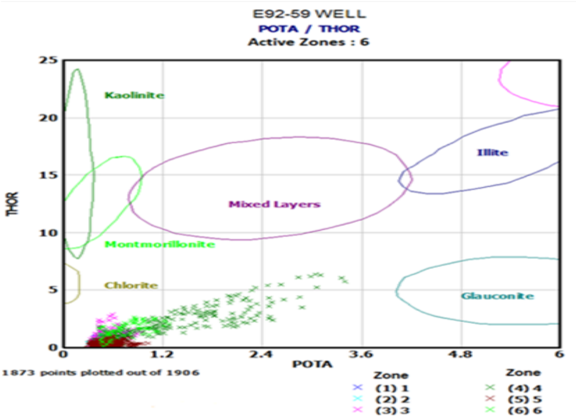


**Figure 6:** Plotting the Thorium (THOR) versus the potassium content (POTA) of Zelten Formation Plotting the porosity versus the water saturation (Sw) is a useful technique which can help in revealing the dominant water saturation and the waster cutoff value. It is indicated that the measured points of most zones are clustered around the line of the 30 % BVW, while samples of zone4 are mostly shifted to higher BVW values especially for samples of zones 4 and few samples from the other zones which are characterized by high water saturation (Sw 50 %). This may be attributed to their higher shale volume as indicated from (Figure 7). Based on this plot, it is indicated that samples of zone 4 is the best zone with the lowest water saturation, i.e., the lowest probability for producing water cut.

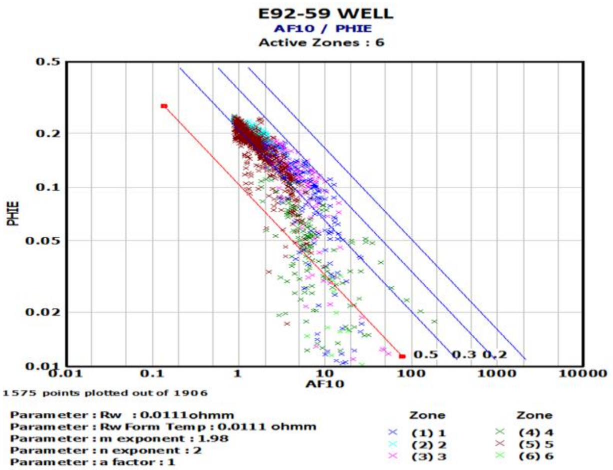


**Figure 7:** Estimating the water saturation of Zelten Formation in E92-59 well divided into six zones.

## 6. Conclusions

The raw well log data and the obtained parameters were presented vertically against depth in a litho-saturation plot for the different wells, where it is indicated that Zelten Formation is well presented in well E92-59 indicating the best thickness, and the vertical variation of lithology, porosity, density, electrical resistivity, and water saturation as output parameters inferred from the raw data that represented by gamma rays, density, photoelectric factor, neutron, sonic, and resistivity data which was implemented using the IP3.6 software;It is indicated that Zelten Formation consists mainly of limestone sequences intercalated with few shale streaks.Based on the well log data, it is indicated that the gross thickness of Zelten Formation in the Gialo Field reaches to 237.5 feet as a total with net pay thickness equals to131.2 feet. It may be subdivided into six reservoir zones with a net pay thickness ranging between 2.56 feet for zone 1 to 96.06 feet for zone 1 with no pay assigned for zone 6. The relatively low bulk volume of water 'BVW' (0.042-0.098) indicates that the reservoir will produce hydrocarbons with fairly low water content. The reservoir zone 5 is considered the most prospective zone in Zelten Formation in E92-59 well (at depth interval 6286-6400 feet) due to its relatively high thickness (96.06 feet), good average porosity (0.187), low average saturation (0.483), and the relatively low shale volume (0.398). It is also indicated that zone 2 at depth interval 6196.5-6218 feet is considered a secondary prospective zone with good net pay thickness (21.0 feet), good average porosity (0.197), relatively low average water saturation (0.487), and low average shale volume (0.234

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