

Petroleum System evaluation of Jurassic and Paleozoic sections in Faghur Basin, North Western Desert, Egypt.

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ABSTRACT

The present study aimed to determine the hydrocarbon potential of the main source rock in the study area and analyze the petroleum systems and guide future hydrocarbon exploration and development in Faghur Basin, Western Desert, Egypt. The methods used encompass Petro-mode 1D soft-ware which used for construction and prediction of geological and geochemical models. The lithostratigraphic cross sections of Safa and paleozoic reservoirs are discussed to distinguish thickness variations, and lithofacies of Safa and Paleozoic sections. Analysis of the source rock potential used to identify the Faghur Basin petroleum system. There are three source rocks in the studied section (Safa SR1, Paleozoic Dhiffah SR1 and Paleozoic Zeitoun SR1). The geochemical results showed that the Safa and Paleozoic source rocks in Faghur Basin vary from Very good to fair organic carbon richness with kerogen of type II & III and characterized by mature level of source rocks. As well as, the petrophysical study indicate that the studied section in Faghur Basin have three reservoir units (Safa RR1, Paleozoic Desouqy RR1 and Paleozoic Basure RR1). The lithology of this reservoir is predominantly fine-grained sandstone which considered as a good reservoir in the northern Western Desert of Egypt. Top seal for the Jurassic Safa Sands is provided by intra-formational shales (Zahra Member) and tight carbonates of the overlying Masajid Formation, and for Paleozoic Desouqy Formation Sands by shales of the Carboniferous Dhiffah Formation.

Keywords: Petroleum System; Geological Elements; Geological Processes; Faghur Basin, Western Desert, Egypt.

Introduction

Faghur Basin lies in the northern part of the Western Desert. The Western Desert has numerous oil potentialities and may soon jump as a great oil province. The area under study deals with Faghur Basin is a part of Khalda concession, in the northern part of the Western Desert of Egypt. It lies between latitudes 30° 16' 48'' - 30° 38' 24'' N and longitudes 25° 42' - 26° 12' E as shown in Fig. (1). The general structural and stratigraphical aspects of the Western Desert have been the subject of many studies, such as; **Amin (1961), Said (1962 and 1990), Norton (1967), Parker (1982), Meshref (1982), El- Khadragey and Sharaf (1994), Shalaby et al. (2000), Zein El-Din et al. (2001), El-Khadragey et al. (2010)** and others.

The generalized stratigraphic column of the northern Western Desert includes most of the sedimentary succession from Pre-Cambrian basement complex to Recent (fig.2), generally the total thickness increases progressively to the north and northeast directions and ranges from about 6000 ft in the south to about 25,000 ft in the coastal area.

The Safa and Paleozoic formations becomes one of the most producer formations in the Western Desert especially in Khalda concession. It overlay by Zahra shale and Masajid Limestone. Throughout the Western Desert, the Safa Formations composed of shales, siltstones, and Sandstones with a minor limestones and coals seams. The age of the Safa is

Callovian/Middle Bathonian. The Safa is represented by coastal marine/shelf rocks with thin Tidal sands (EGPC, 1998).

As well as The Paleozoic sequence in the Northern Western Desert consists mainly of clastic sediments resulting from denudation of the Precambrian highs (Abu El- Naga, 1984). Siwa group represents the lower part of the sequence. Faghur group unconformably overlies Siwa group (Strauss and Aultmann, 1992).

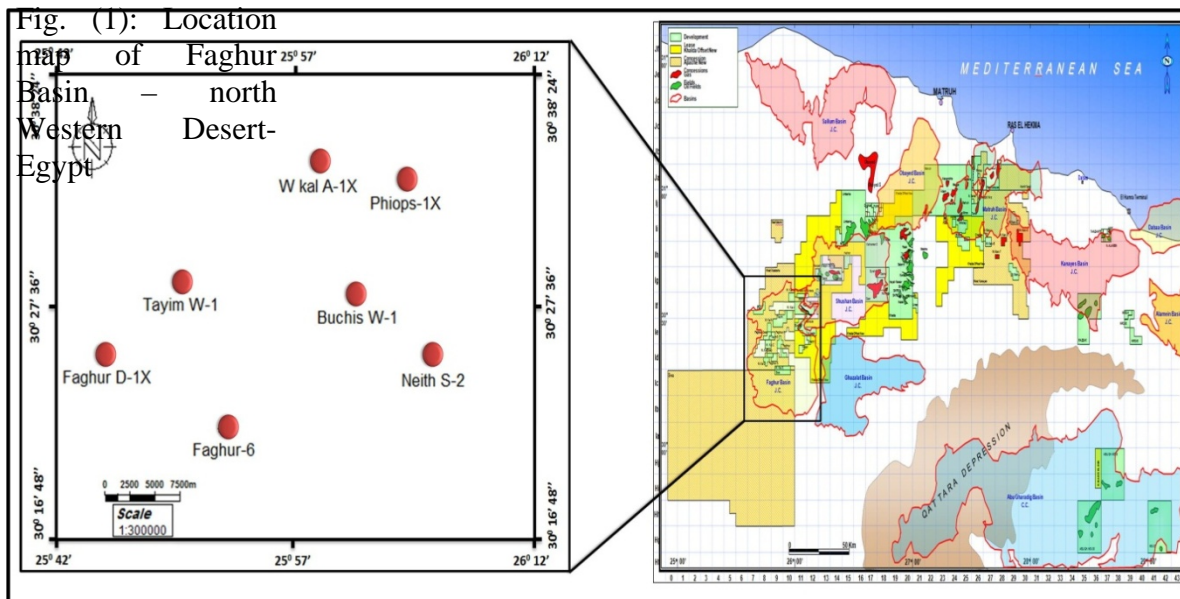




Fig. (2b): Generalized stratigraphic column of the North Western Desert, after (Khaldia, 2001)

Materials and Input

The fundamental materials which applied in this work include composite logs of seven wells (Neith S-2, Phiops-1X, Tayim W-1, Buchis W-1, Faghur D-1X, W Kal A-1X and Faghur – 6, the thicknesses of stratigraphic units in the subsurface, the absolute ages of stratigraphic units, percentages of lithology of the stratigraphic units, thicknesses of eroded sections during the main uplift events in the subsurface, the extrapolated bottom hole temperatures, the surface temperature, Geochemical analyses were done to seventeen samples

that collected from Neith S- 2 well, Measurements were made, the TOC (organic carbon content), and for Ro% value (vitrinite reflectance), Rock-Eval pyrolysis parameters ,the hydrogen index (HI), the oxygen index (OI), and the production index (PI).

Results and Discussions

Lithostratigraphic Cross Sections:

The constructed lithostratigraphic cross sections illustrate the change in lithologic characters or any break in the depositional continuity. These sections show the equivalency of stratigraphic units, and exhibit thickness variation. Borehole data from seven composite logs are used to construct three correlation charts in the SW-NE,SSW-NE and W-E directions (Fig.3).The first correlation chart (A-A') extends along SW-NE directions, and passes through start from Faghur D- 1X well at SW direction and passes through Tayim W1 well and ended by W Kal A-1X well at NE direction (fig. 4), the chart shows five main units, they are Safa SR1, Safa RR1, Paleozoic Dhiffah S1, Paleozoic Zeitoun SR1 and Paleozoic Desouqy RR1 arranged from top to base respectively. The units show variation in thickness and continuity except the Paleozoic Dhiffah S1, Paleozoic Zeitoun SR1 is pinched out at Tayim W-1 well and Faghur D- 1X well respectively. The second correlation chart (B-B') extends along SSW-NE directions, this chart runs through Faghur – 6 , Buchis W- 1 and finally with Phiops- 1X wells, The chart records five main units namely; Safa SR1, Safa RR1, Paleozoic Dhiffah SR1, Paleozoic Desouqy RR1 and Paleozoic Zeitoun SR1 arranged from top to base respectively. The thicknesses of units are variable from well to another, the thickness of Safa SR1 unit in Phiops- 1X well extends more than the other wells. The tops of units in Faghur – 6 and Buchis W- 1wells are uplifted than Phiops- 1X well. Safa RR1 unit not appeared in Buchis W- 1 well, an addition the Paleozoic Dhiffah SR1 and Paleozoic Zeitoun SR1 units not recorded in Faghur – 6 well as illustrated in fig. (5).

The third correlation chart (C-C') extends in W-E directions and passing through Faghur D- 1x, Tayim W-1, Buchis W-1 and Neith S-2 wells fig. (6). The correlation charts shows that the Safa SR1 unit has a great thickness in Tayim W- 1well more than the other wells, the Safa RR1 reservoir is a thin layer has a little thickness and pinched out at Tayim W-1well.The Paleozoic Dhiffah SR1 source rock has a large thickness in Faghur D-1X well reduced and abrupt in Tayim W-1 well. The Paleozoic Desouqy RR1 has continuity through all this section but with a great variety in thickness. The Paleozoic Zeitoun SR1 source rock appeared with a different thickness in (Buchis W-1 and Neith S-2) wells at the east direction and not penetrated in Tayim W-1 and Faghur D- 1X wells.

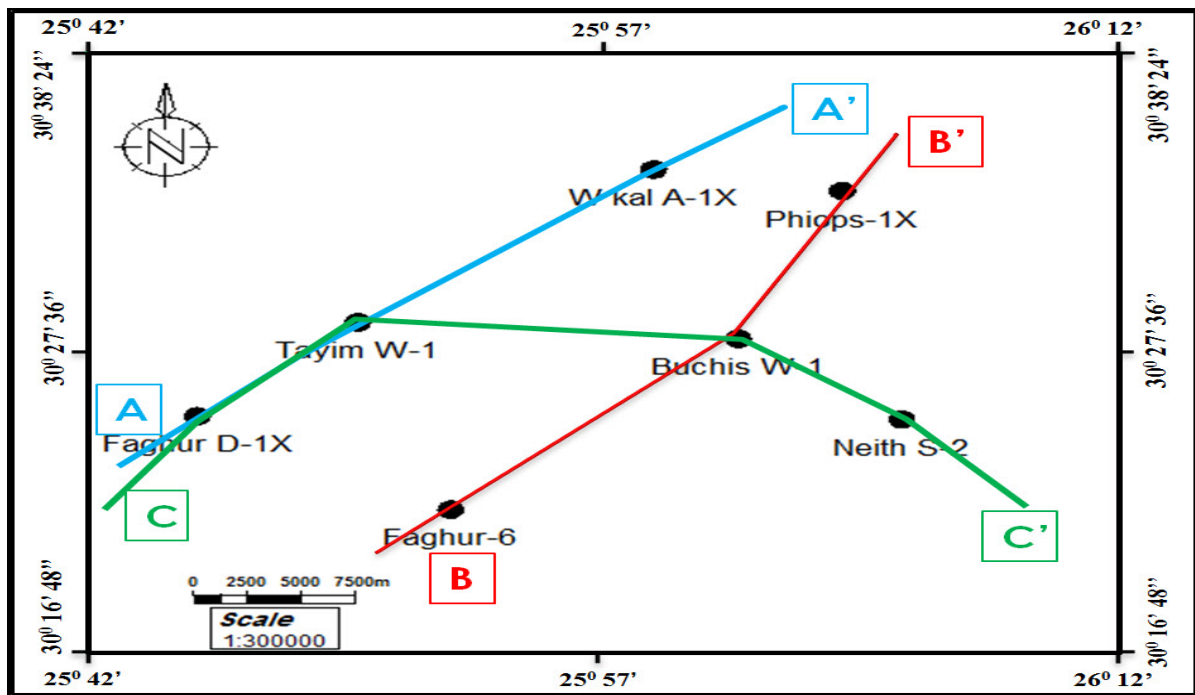


Fig. (3): Base map showing the drilled wells and correlation charts profiles.

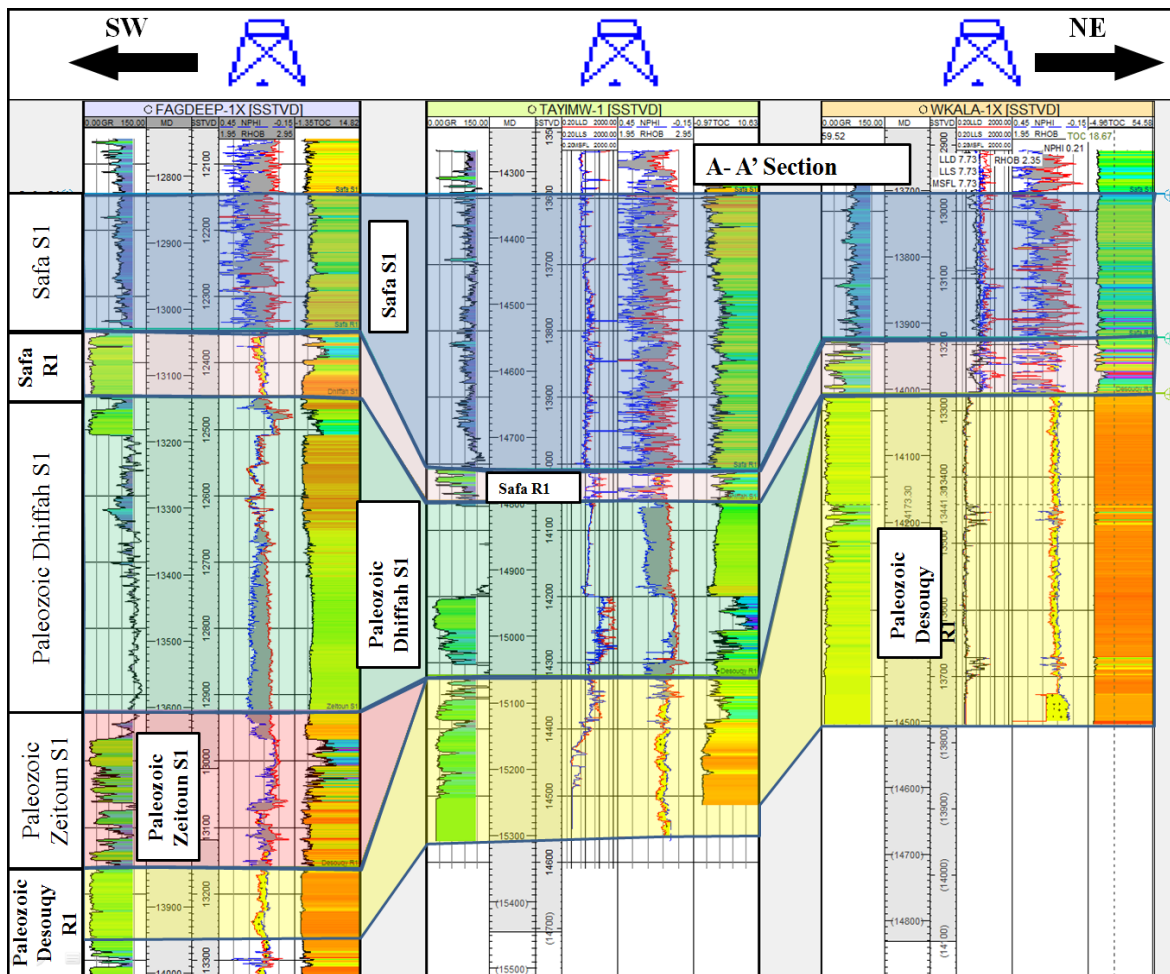


Fig. (4): Correlation chart along the profile (A-A').

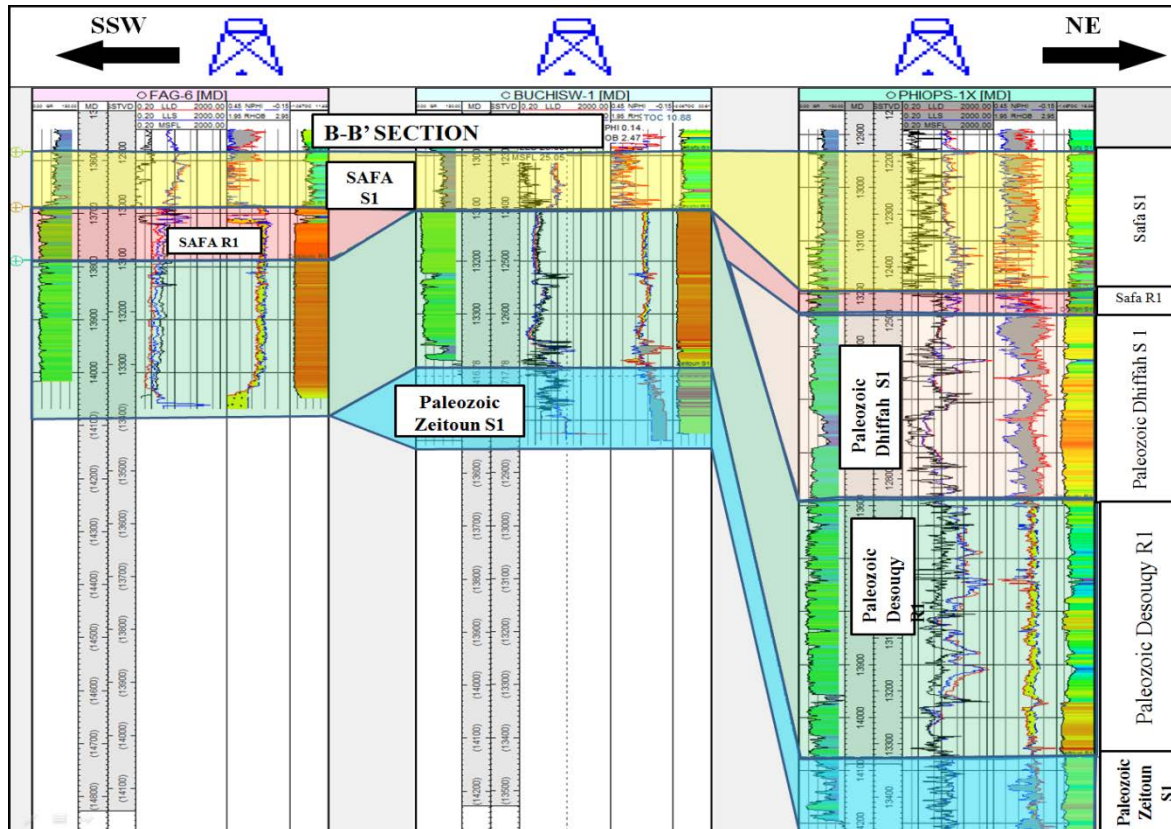


Fig. (5): Correlation chart along the profile (B-B').

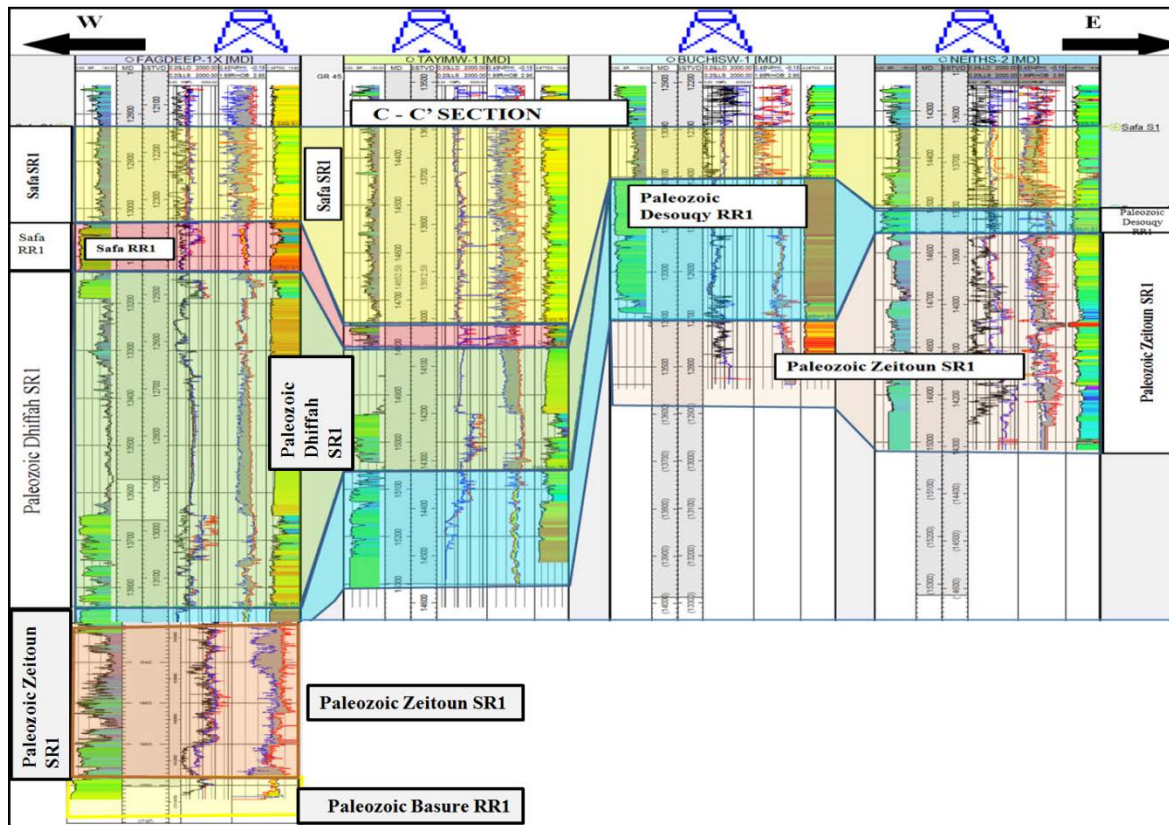


Fig. (6): Correlation chart along the profile (C-C').

Elements of petroleum system

A petroleum system is defined as a natural hydrocarbon system that includes (active source rocks, the generated hydrocarbons, essential elements and processes that lead to hydrocarbon accumulations) **Magoon and Dow (1994a and 2000)**. On the other hand, Petroleum System is the basic geologic unit used to assess oil and gas reserves and resources and includes all genetically related petroleum that occurs in shows and accumulations.

3. Source rock evaluation

The Early - Middle Jurassic of Khatatba and Devonian formations is the main source rocks for hydrocarbon generation and expulsion in the Faghur Basin, There are three source rock formations, the Safa SR1 and Paleozoic Zeitoun SR1 are the main source rocks that studied geochemically through seventeen samples taken from Neith S- 2 well, the average TOC values of Safa and Paleozoic source rock are 11.24 wt. %, and 1.956 wt.%, respectively this results indicated that the Safa source rock is a very good for hydrocarbon generation fig.(7 and 9), and the Paleozoic source rock ranging from fair to good for hydrocarbon generation figs.(8 and 9). Figure (10) showed that the kerogen type of Safa and Paleozoic source rocks are of Type II and III. The source rocks are identified as a mature source rock based on RO % values (fig.11), as well as the T-Max values pointed to that the source rock can be able to generate oil (fig.12). The main Safa SR1 are believed to be deltaic and

lagoonal coals and organic-rich shales within the Jurassic Khatatba Formation, although deeper Paleozoic source rocks of similar organic facies may also contribute to oil generation in some sub-basins. The third source rock is the Paleozoic Dhiffah SR1 formation is a good to very good organic carbon richness.

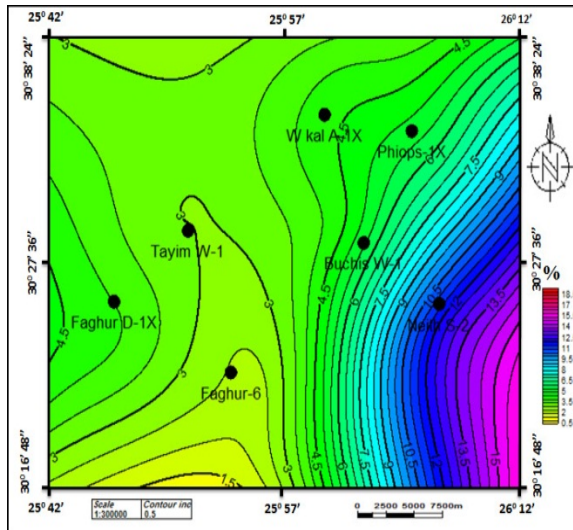


Fig. (7): Total Organic carbon content of Safa SR1 formation.

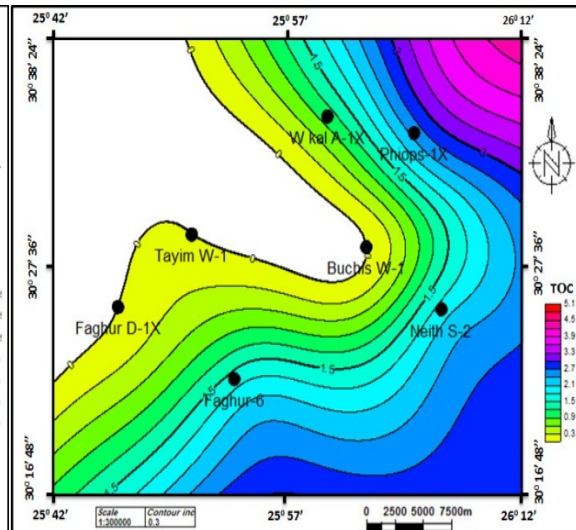


Fig. (8): Total Organic carbon content of Paleozoic Zeitoun SR1 formation.

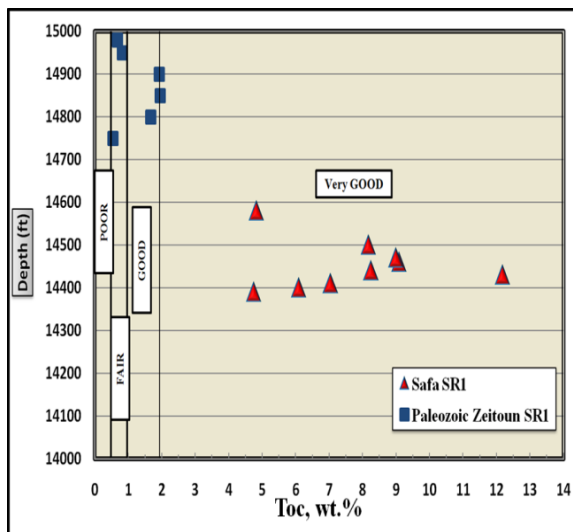


Fig. (9): Organic carbon richness of measured (TOC) of Safa SR1 and Paleozoic Zeitoun SR1 formations in Neith S-2 well

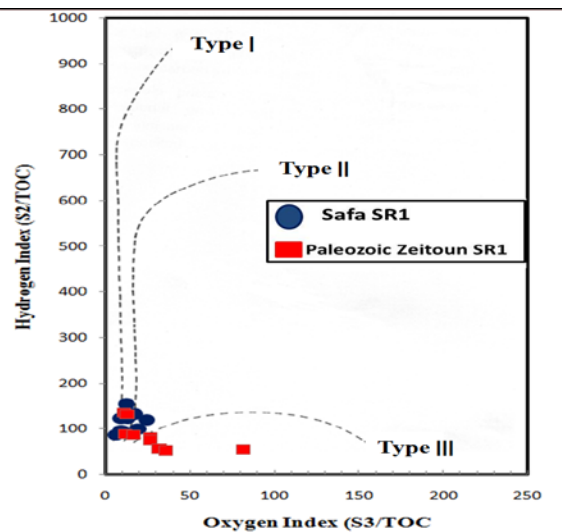


Fig. (10): Modified Van Krevelen type diagram showing kerogen types of Safa SR1 and Paleozoic Zeitoun SR1 formations in Neith S-2 Well.

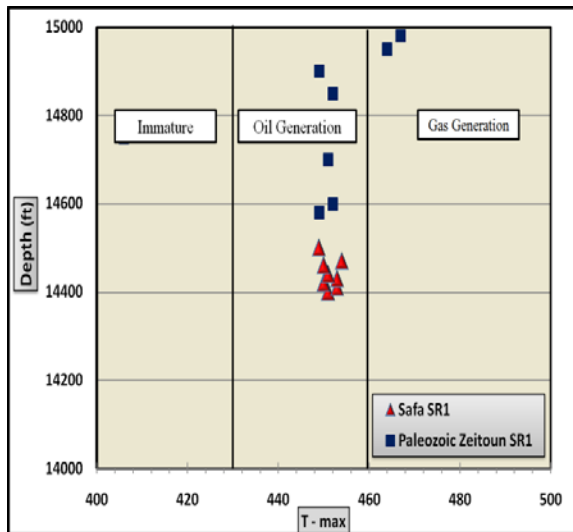


Fig.(11): The maturation of source rock (Ro %) of Safa SR1 and Paleozoic Zeitoun SR1 members in Neith S- 2 well

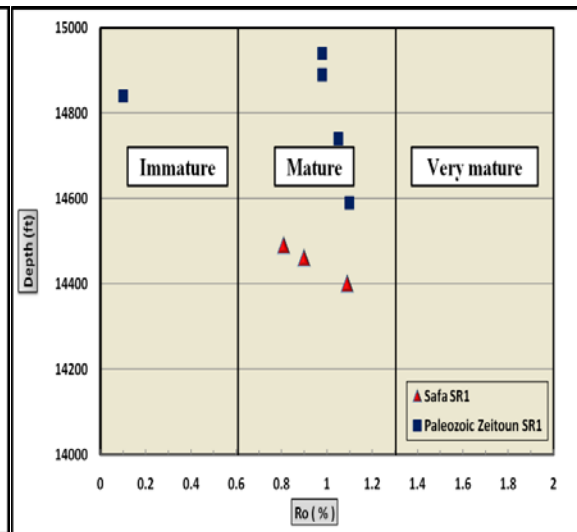


Fig. (12): The Tmax plot of Safa SR1 and Paleozoic Zeitoun SR1 members in Neith S- 2

Reservoir Rocks:

In Faghur Basin there are three reservoir rocks (Safa RR1, Paleozoic Desouqy RR1 and Paleozoic Basure RR1), they are mainly located in the Early –middle Jurassic and the Carboniferous part. The lithology of the reservoir is predominantly fine-grained sandstone. The well logging data derived petrophysical parameters of the main reservoir intervals.

The Safa RR1 net pay are distributed along the section ranged from 12 ft to 46 ft, with average effective porosity 6.5 % – 12.5 %, the volume of shale content start from 1.8 % to 37 %, and water saturation (SW) values ranged from (12 %) to (92%) fig. (13), (14), (15) and (16).Where as the Paleozoic Desouqy RR1 reservoir has a variety in pay thickness ranged from 34 ft to 77 ft, with average effective porosity 3.7 %, where the shale content reached 13.9 %.And SW values vary from (98 %) to (27.2 %). figs. (17), (18), (19) and (20).

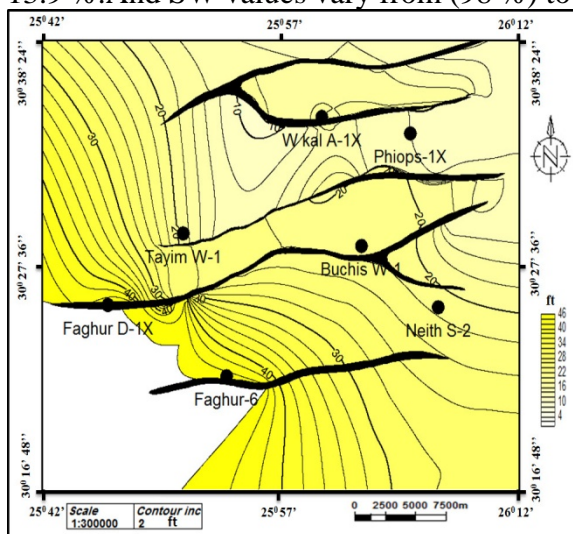


Fig. (13): Net pay map of Safa RR1 formation

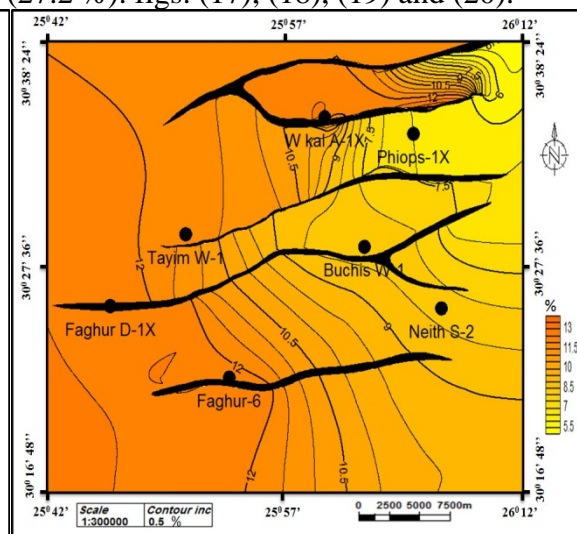


Fig. (14): Effective porosity map of Safa RR1 reservoir

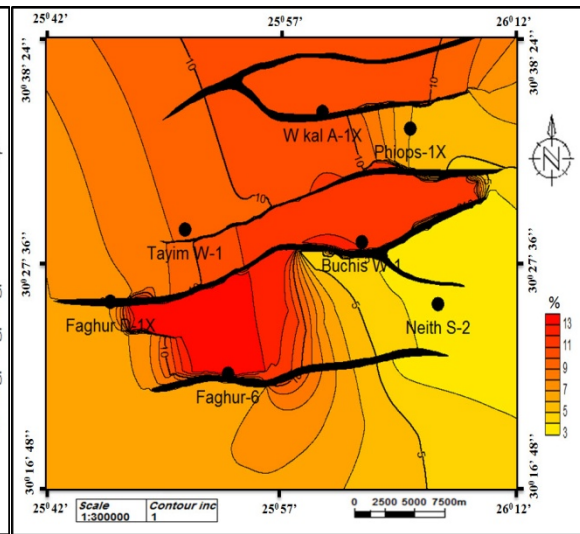
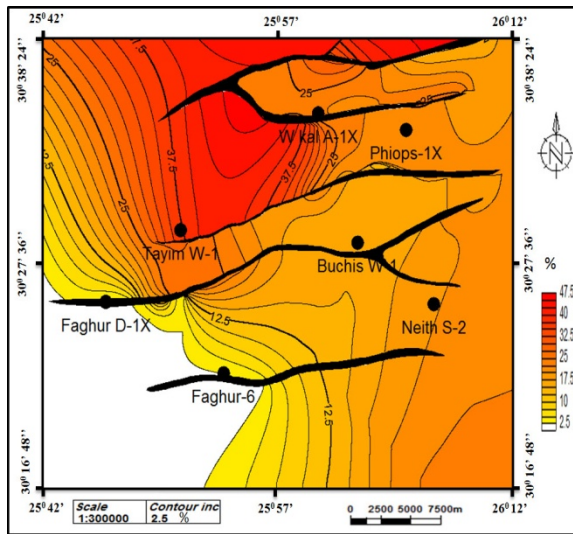


Fig. (15): Shale Volume Map of Safa RR1 Reservoir. **Fig. (16):** Water saturation of Safa RR1 reservoir.

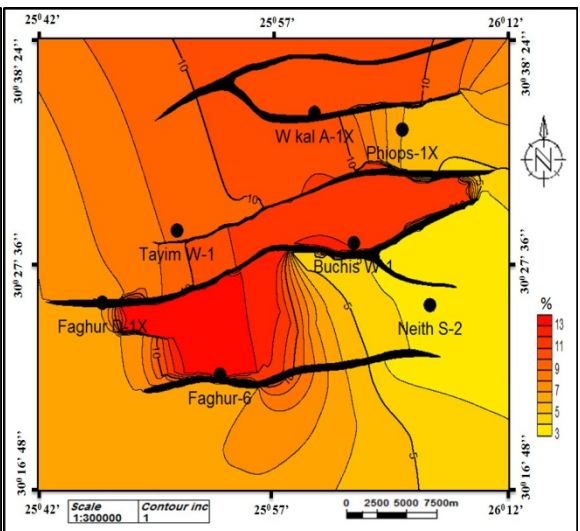
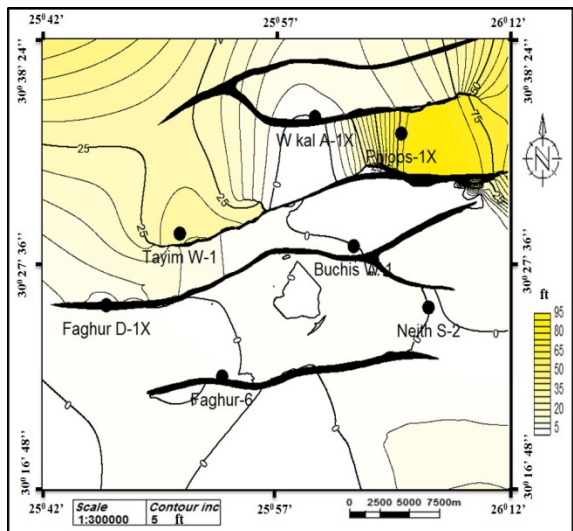


Fig. (17): Net pay map of Paleozoic Desouqy RR1 Reservoir

Fig. (18): Effective Porosity Map of Paleozoic Desouqy RR1 Reservoir.

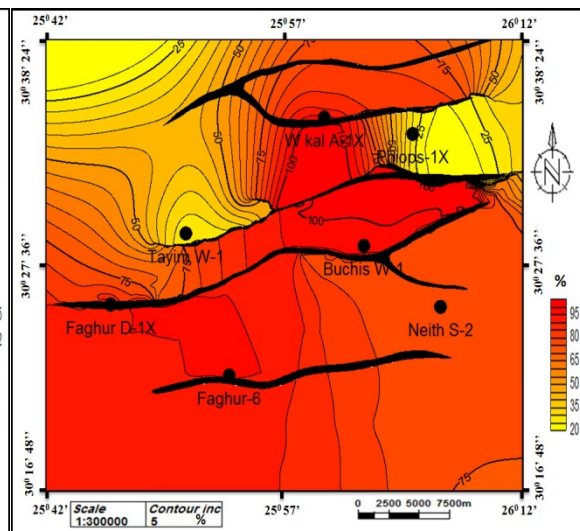
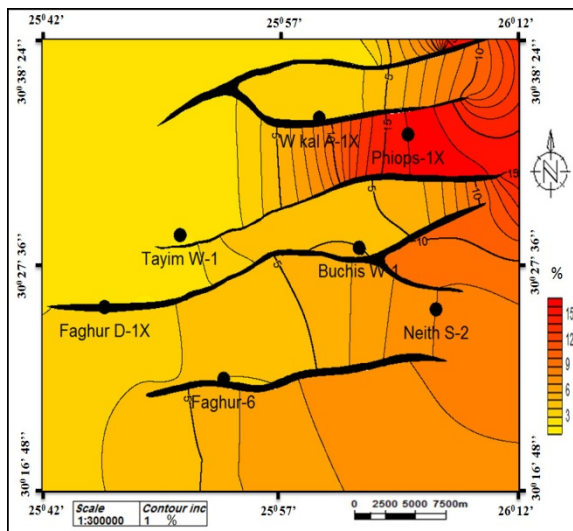


Fig. (19): Shale Volume map of Paleozoic Desouqy RR1 Reservoir.

Figure (20): Water Saturation Map of Paleozoic Desouqy RR1 Reservoir.

Seal Rocks

Seal rock is an essential element of the Petroleum System, which capable for preventing the hydrocarbons from escaping out of the petroleum system. Top seal for the Jurassic Safa Sands is provided by intra-formational shales (Zahra Member) and tight carbonates of the overlying Masajid Formation, and for Paleozoic Desouqy Formation Sands sealed by shale of the Carboniferous Dhiffah Formation. The seal rocks has thickness ranges from 4 ft to 30 ft, fig. (21 and 22).

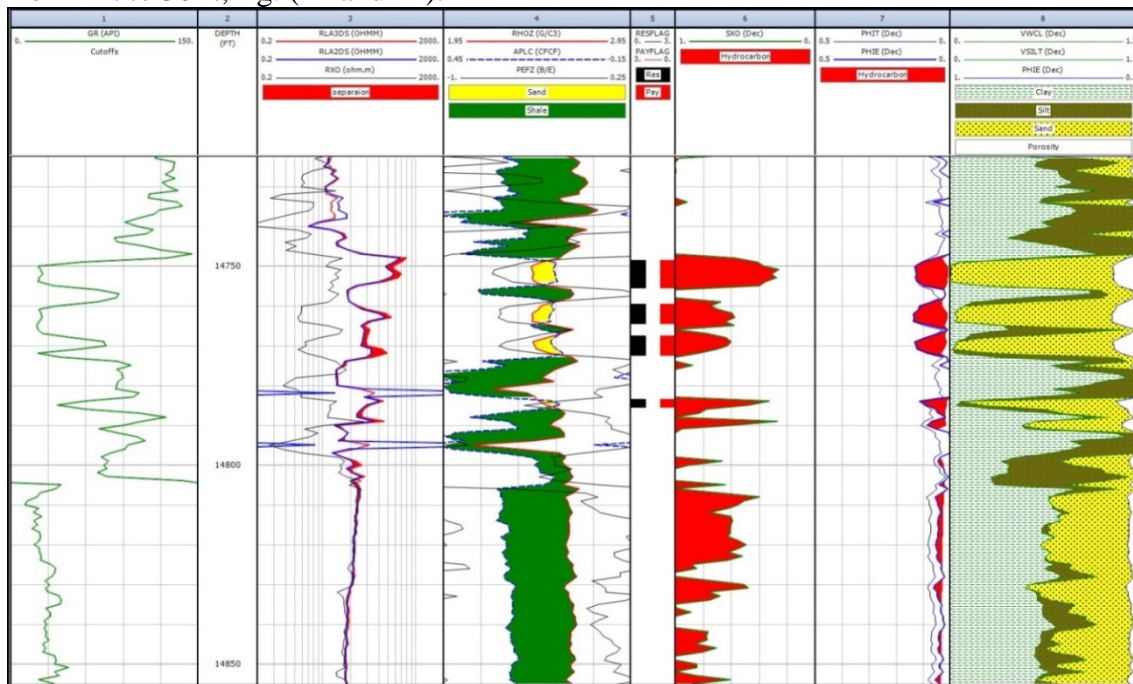


Fig. (21): Cross plot of Safa RR1 reservoir in Tayim W- 1 well.

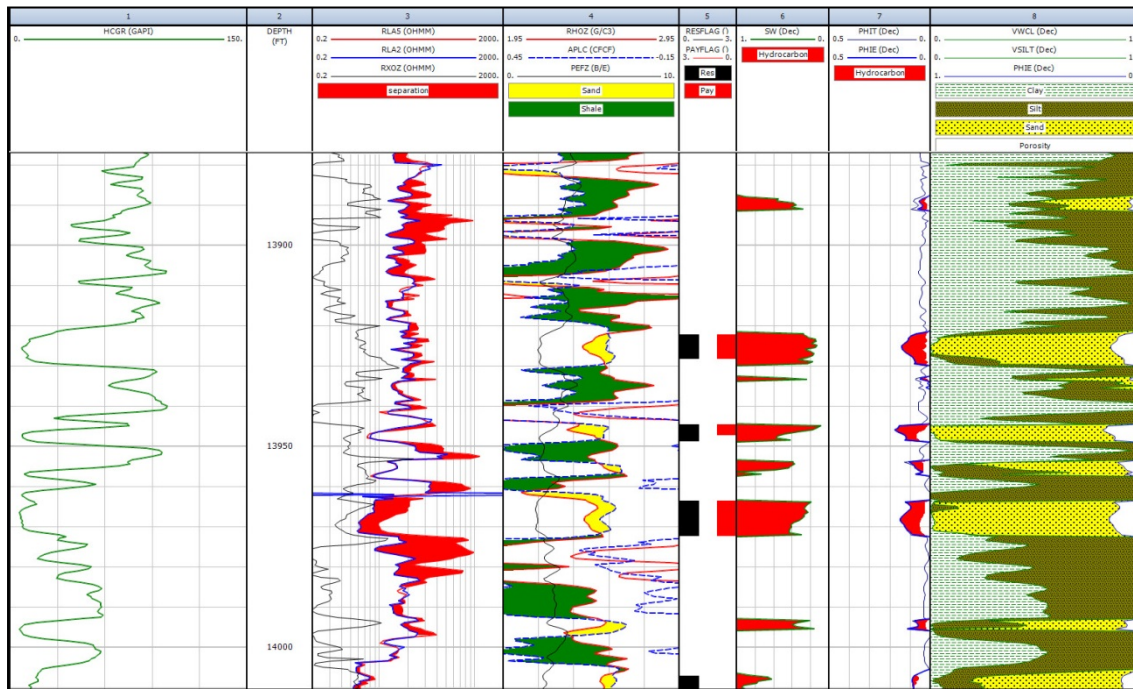


Fig. (22): Cross plot of Safa RR1 reservoir rock in W Kal A- 1X well.

The overburden rock

The overburden rock in the Faghur Basin comprises all the formations above the Safa and Paleozoic source rocks, i.e., Zahra, Masajid, Alam El- Bueib, Alamein, Dahab, Kharita, Bahariya, Abu Roash, Khoman, Apollonia, Dabaa, Moghra and Marmarica formations with a total thickness varies from 12722 ft to 14282 ft, The lithology of the overburden rocks in Faghur Basin wells is variable, include mix of thinly bedded claystone and limestone with occasional thin sandstones layers. Based on corrected bottom hole temperature (BHT) and the surface temperature, the average geothermal gradient of the overburden rock is around 1.3^of/100ft in Faghur Basin wells, these gradient provide favorable conditions for the source rock maturation and petroleum generation in the study area.

Petroleum System Processes

The petroleum system processes include trap formation and generation-migration, and accumulation of petroleum. A proper evaluation of any petroleum system should also include the processes that are crucial for accumulation of oil and gas, including the timing of trap formation and the timing of hydrocarbon generation and migration (Magoon, 1992; Magoon and Dow, 1998).

The essential elements and processes must be correctly placed in time and space so that organic matter included in a source rock can be converted to a petroleum accumulation at the appropriate time (Magoon and Dow, 1994). In our study, we analyze trap formation, generation and expulsion processes to identify the petroleum system of Faghur Basin

Hydrocarbon Generation in Faghur Basin

The burial and thermal history models of the studied wells were constructing using PetroMod-1D. The data needed to construct the models are formation tops or true stratigraphic thickness, geologic age of the time-rock unit, geothermal gradient, erosion and the non-deposition periods or hiatus. Accordingly, seven burial history and hydrocarbon generation were constructing for (Neith S-2, Phiops-1X, Tayim W-1, Buchis W-1, Faghur D-1X, W Kal A-1X and Faghur – 6), this burial history curves are plotted from the geological data of the studied wells.

The timing of hydrocarbon generation and expulsion of the source rock is assessed by reconstruction of 1D model of burial history of studied wells. Table (1) showed that the depth of the peak and end generation oil window for each well (figs.23, 24, 25, 26, 27, 28 and 29). The timing of hydrocarbon generation ranging from 87.84 at 9972 ft to 130.77 MY at 9016 ft in the Buchis W- 1 and Faghur D- 1X wells respectively.

The depth of the end generation was not penetrated by all of the boreholes studied. Where the total drilled depths of the (Neith S-2, Phiops-1X, Tayim W-1, Buchis W-1, Faghur D-1X, W Kal A-1X and Faghur – 6) wells are 14940 ft, 14300ft, 15350 ft, 13500 ft, 16963ft, 14231 ft and 14070 ft respectively.

In Faghur Basin, the source rock entered the oil window during Early to Middle Cretaceous. So our source rock has been able to generate oil during Early Late Cretaceous to Neogene for most of the studied wells.

Table (1): Depth and time of the hydrocarbon generation in Faghur basin

Well Name	Peak of Hydrocarbon Generation (ft)	Age of Start Generation MYBP	End of Hydrocarbon Generation (ft)	Age of End Generation MYBP
NEITH S-2	9329	101.37	Not reached	-----
PHIOPS-1X	9305	101.89	Not reached	-----
TAYIM W-1	9132	108.70	Not reached	-----
BUCHIS W-1	9972	87.84	Not reached	-----
Faghur D -1X	9016	130.77	Not reached	-----
W Kal A - 1x	9111	97.13	Not reached	-----
Faghur - 6	9593	94.44	Not reached	-----

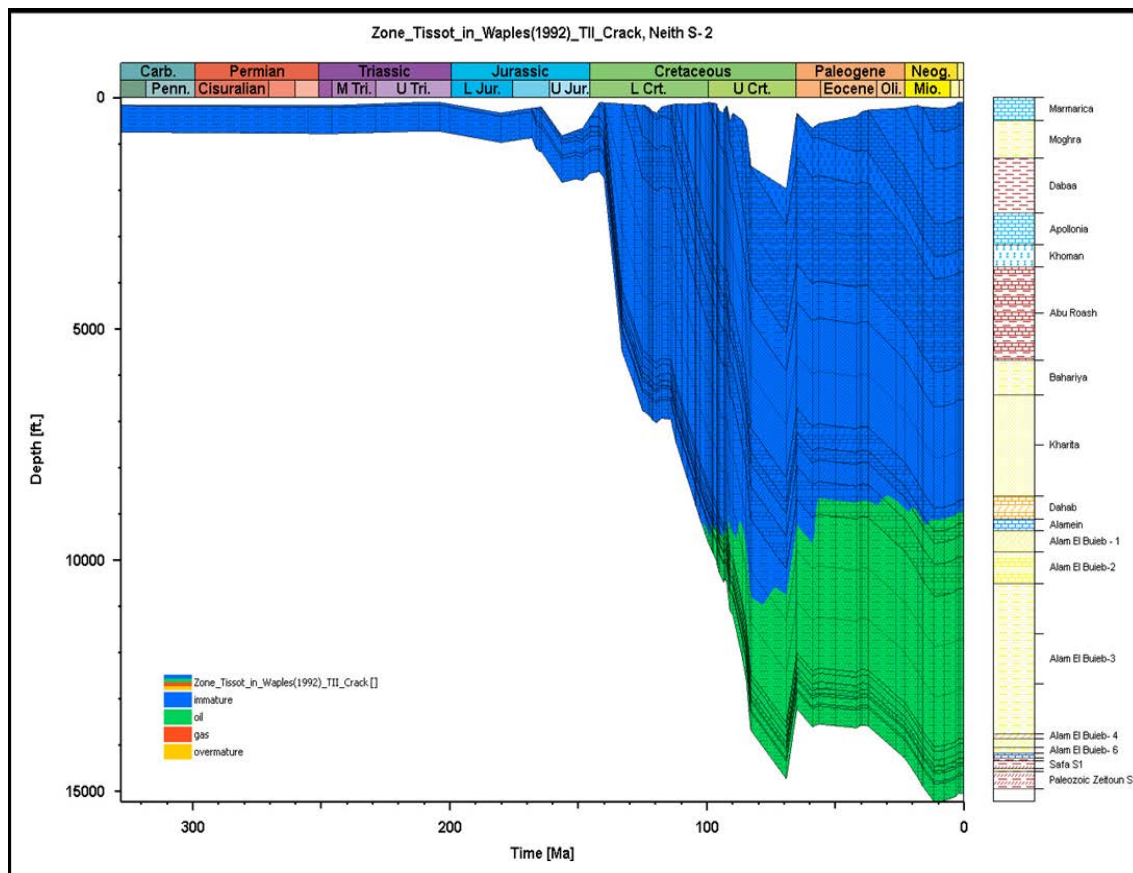


Fig. (23): The Burial history and hydrocarbon zones in Neith S-2 well..

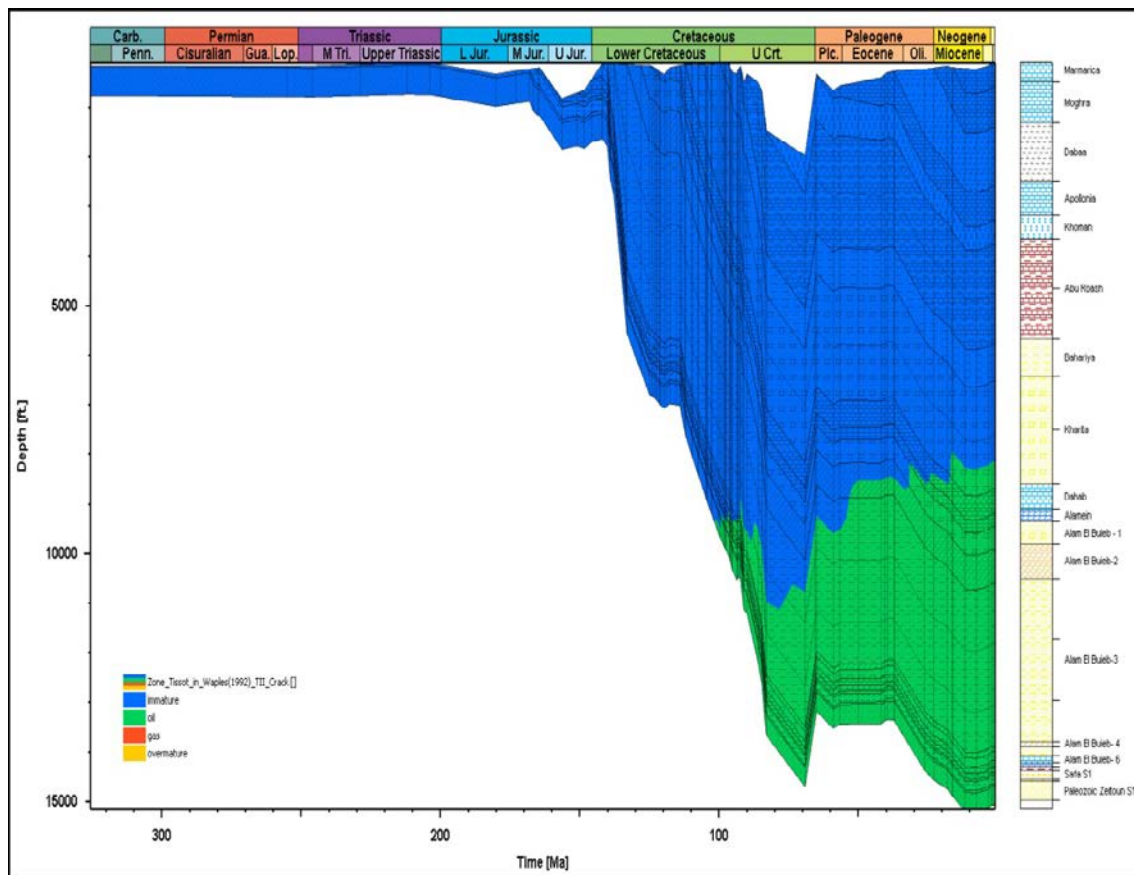


Fig. (24): The Burial history and hydrocarbon zones in Phiops- 1X well.

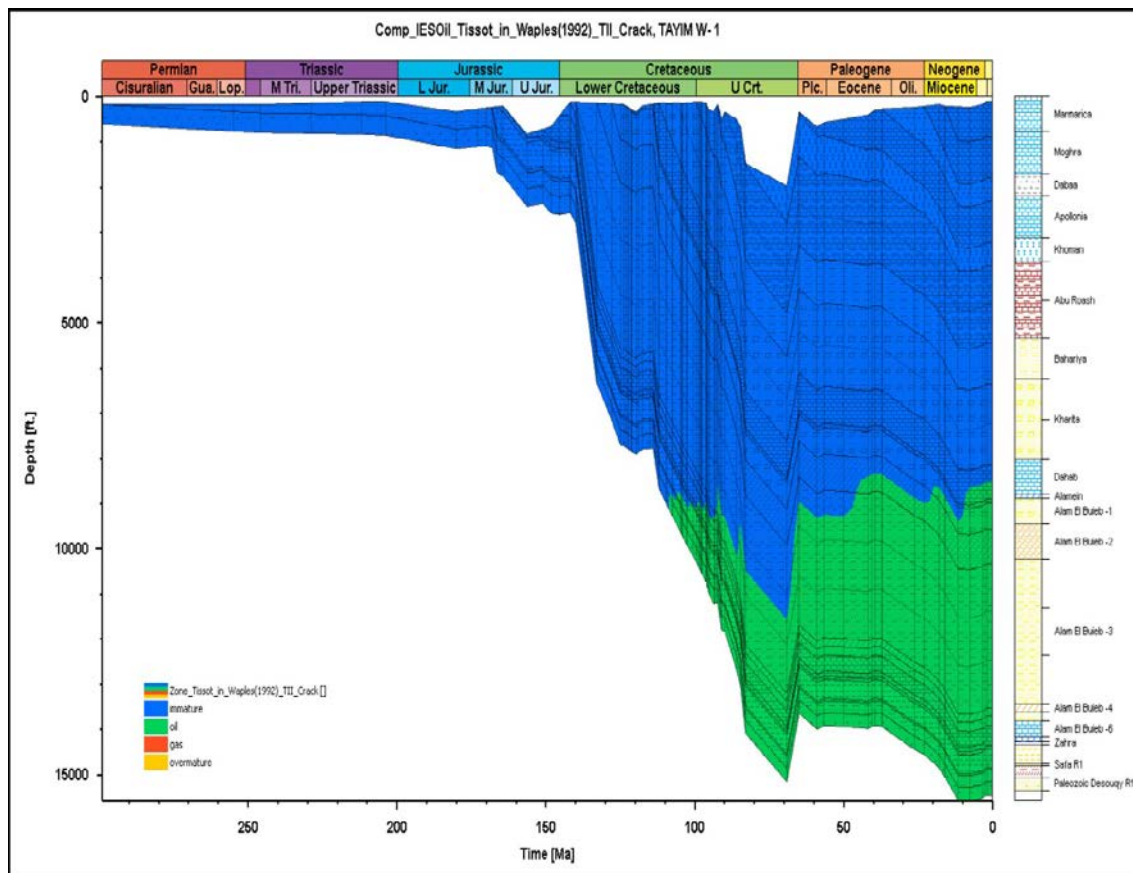


Fig. (25): The Burial history and hydrocarbon zones in Tayim W- 1 well.

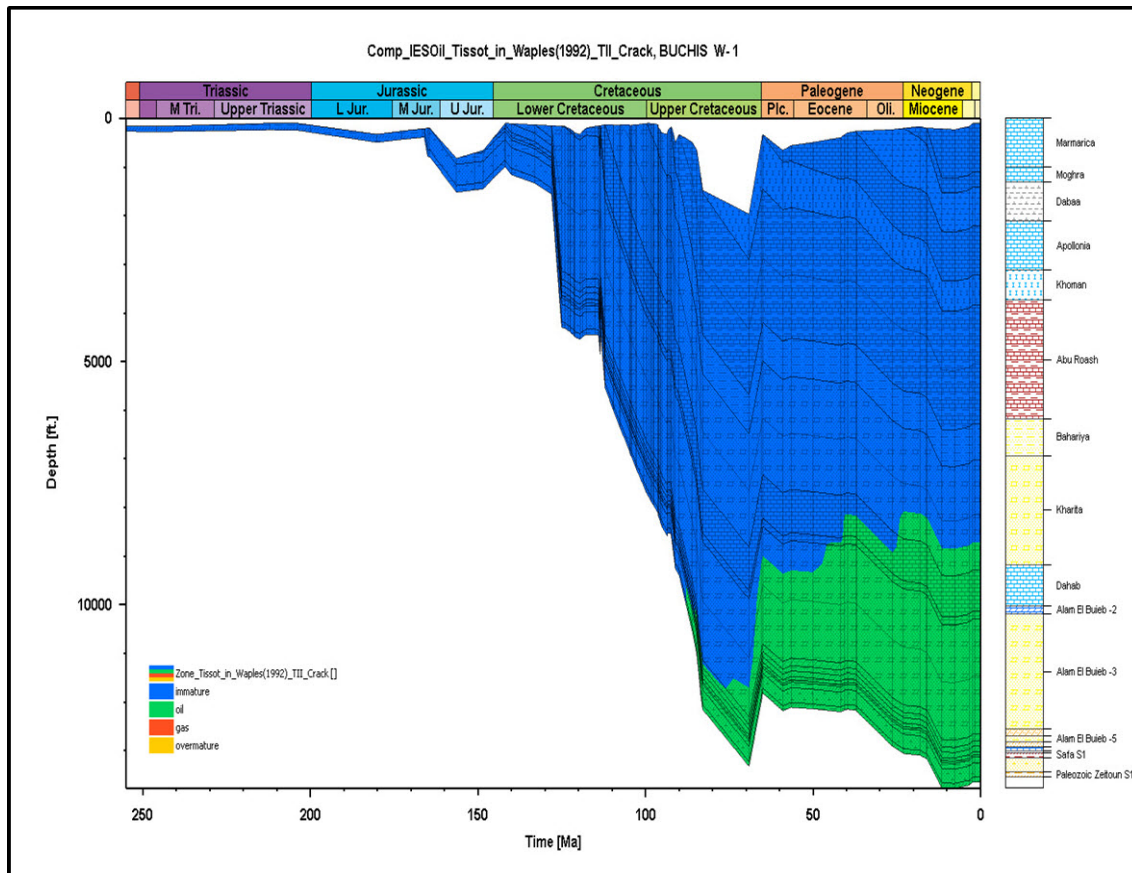


Fig. (26): The Burial history and hydrocarbon zones in Buchis W- 1 well.

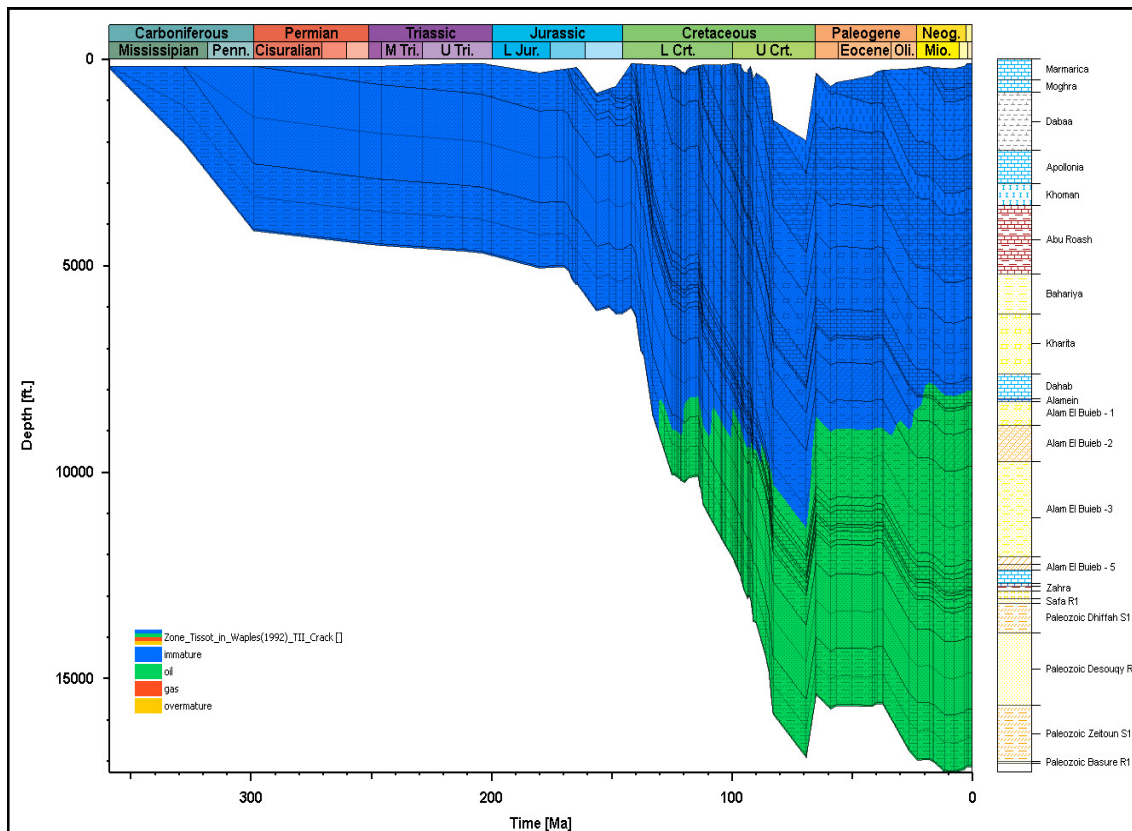


Fig. (27): The Burial history and hydrocarbon zones in Faghur D - 1 X well

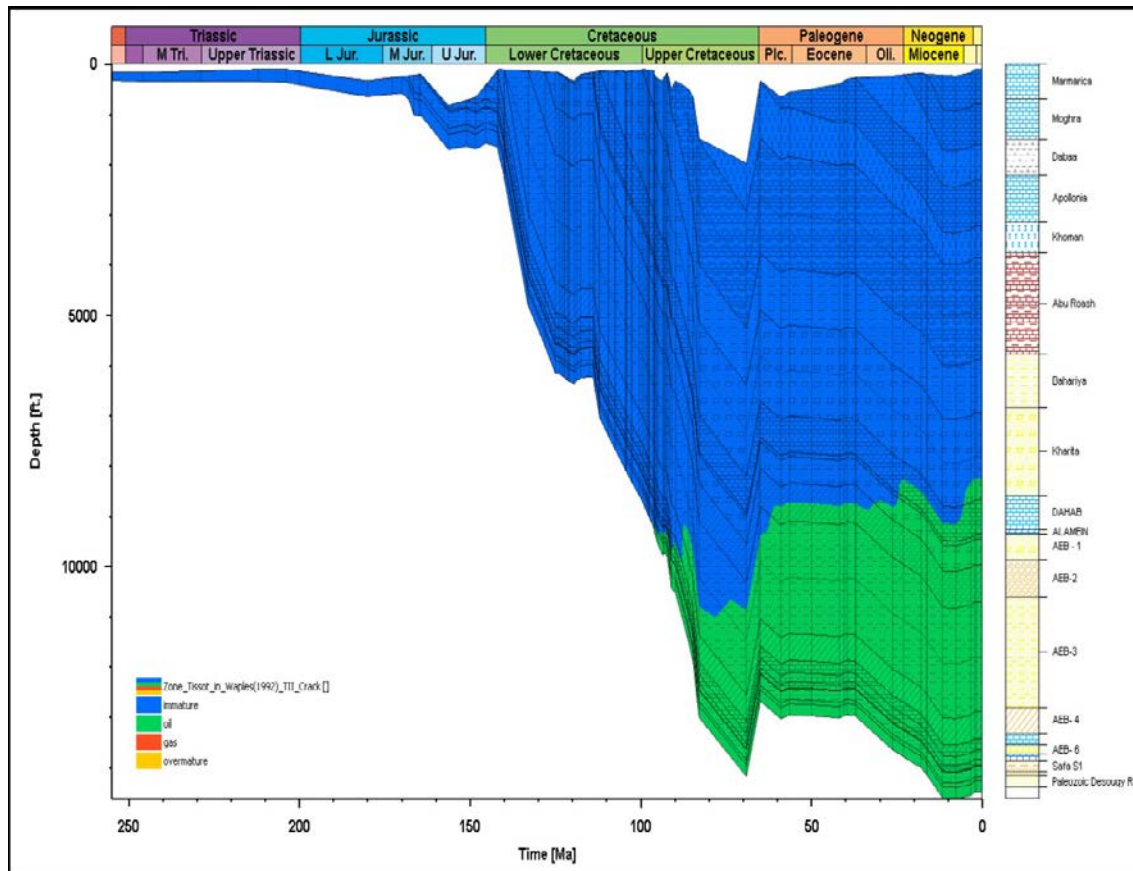


Fig. (28): The Burial history and hydrocarbon zones in W Kal A- 1X well.

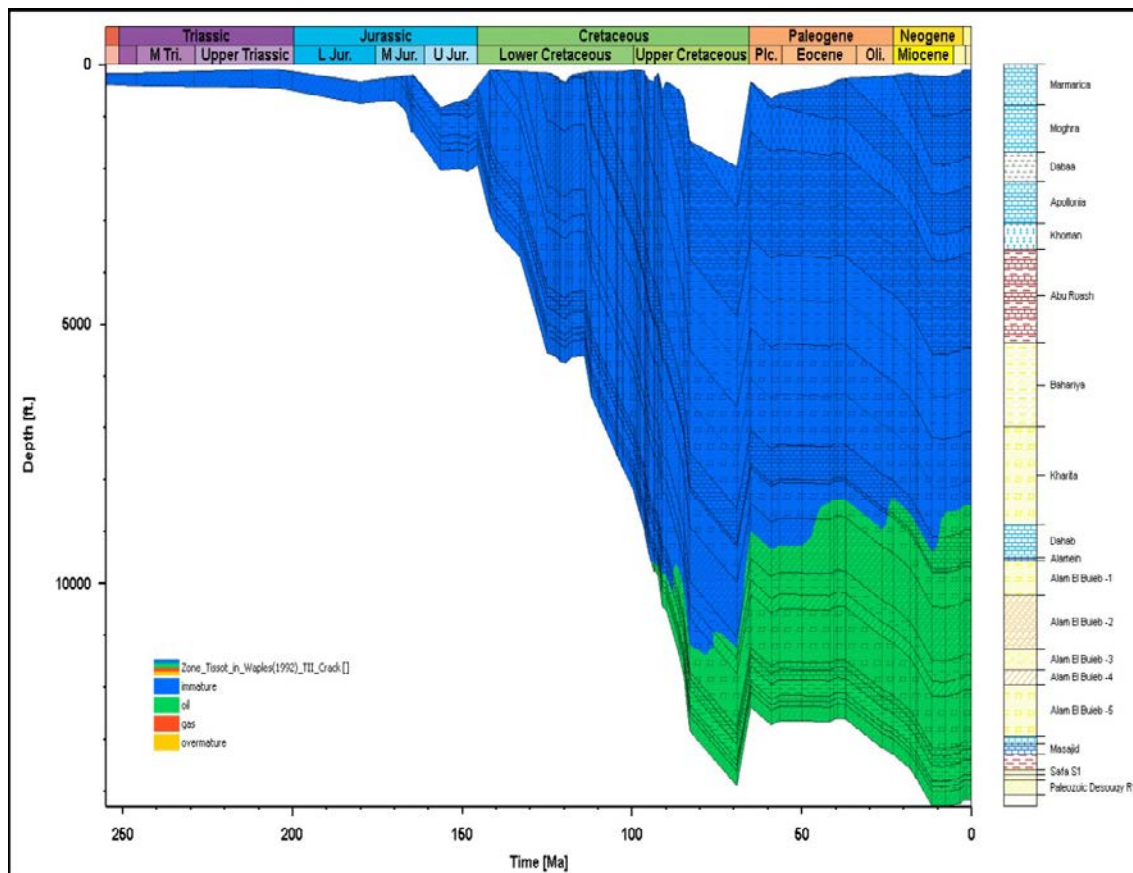


Fig. (29): The Burial history and hydrocarbon zones in Faghur - 6 well.

Hydrocarbon Expulsion in Faghur Basin

Hydrocarbons are expelled from a source rock as discrete phases depending on the hydrocarbon saturation of the source rock, conduits-micro fractures, and overpressure caused by oil and gas generation and fluid expansion on temperature increase and capillary pressure.

The hydrocarbon expulsion in Faghur Basin for Safa and Paleozoic formations started during the lower Cretaceous (from 84 – 101 my). The hydrocarbon generation of Safa and Paleozoic reservoirs in Faghur Basin wells is mainly oil this may be due to the higher percentage of oil-prone kerogen type.

Trap Formation

The hydrocarbon discovered in the western desert have been drilled as a structural prospect, either in the form of three or four closure structures or as a fault block structures. The structure elements were the main factors determining the trapping of oil in almost all the discoveries. Syrian arc-related structural trends form the bulk of the productive traps discovered in the Western Desert, **Dolson et al. (2001)**.

The traps in Faghur Basin are affected with the same structure factors, however, many of the traps described as stratigraphic traps, which are unconformable overlain by impermeable Mesozoic strata and as in Jurassic sandstones and shale (Safa formation).

Conclusion

- The Safa and Paleozoic petroleum System has been identified in Faghur Basin oil fields. The source rock of Safa and Paleozoic Formation entered a mature zone and characterized by a mix of Type II and rarely of Type III kerogen showing oil-prone source rock as a major constituent in the basin.
- The averages TOC values are 10.5 wt. %, 2.5 % wt. and 1.96 % wt. in Safa SR1, Paleozoic Dhiffah SR1 and Paleozoic Zeitoun SR1 respectively.
- The Safa and Paleozoic reservoirs lithology is predominantly fine-grained sandstone. The average porosity of Safa RR1 and Paleozoic Desouqy RR1 are 12.5 % and 13.9 %, respectively.
- The shale of Zahra Member and tight carbonates of the overlying Masajid Formations form the seal of Safa RR1 and for Paleozoic Desouqy RR1 Sands are sealed by shales of the Carboniferous Dhiffah Formation.
- The overburden rock has a thickness varies from 12722 ft to 14282 ft, with a variable lithology Including a mix of thinly claystone and limestone beds, occasional with a thin sandstones layers, the average geothermal gradient of the overburden rock is around 1.3°/100ft that provide a favorable conditions for the source rock maturation and petroleum generation in the study area.
- The structure elements are the main factors determining the trapping of oil in the Faghur Basin. Moreover the stratigraphic traps were represented.
- Hydrocarbon generation started at early to Late Cretaceous about a (from 84 – 101 my), and Continue in generation until the present day.

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