



Hydrocarbon Potential Assessment for Dokan and Gulneri Formations (Upper Cretaceous) in K-130 Well Kirkuk Oil Field, Kurdistan, North of Iraq

Razawa H. Sarraj¹

1Faculty of Science, Department of Geology, University of Sulaimani, Sulaimaniyah-Iraq

E-mail: razawa.abdulrahman@univsul.edu.iq

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Abstract

Eight rock samples from the Dokan and Gulneri formations in one subsurface section of Kirkuk-130 Well in Northern Iraq were chosen to be studied optically and analytically to determine the source- rock properties of the both rock units. The studied samples showed richness in amorphous organic matter with generally low percentages for other organic matter components. Three palynofacies were distinguished representing proximal suboxic-anoxic shelf and shelf- to – basin transition for the Dokan Formation, whereas a distal suboxic-anoxic basin appeared to be the paleodepositional environment for the Gulneri Formation. The Dokan Formation appears to be poor to fair, whereas the Gulneri Formation showed very good to excellent richness in organic matter as measured from total organic carbon (TOC) contents. The Rock- Eval Pyrolysis data for the studied formations showed that the quality of organic matter in the Dokan Formation is mostly type II/III kerogen, whereas in the Gulneri Formation it is mostly type I kerogen. Thermal maturity indicators, as observed from pyrolysis parameters, indicate an immature state for both studied formations. Accordingly, it is concluded that the Dokan and Gulneri formations did not contribute to generating the accumulated oil in the Kirkuk Field.

Introduction

The supergiant Kirkukoil Field comprises three domes that NW-SE, they are about 100 km in length and three to four km in width. The structure generally comprises a longitudinal asymmetrical anticline consisting of three domes, namely, Baba, Avahah and Khurmala. These three domes are separated by two saddles of Amsha and Dibaga. The two main domes (Baba and Avahah) are located in Kirkuk while the third one (Khurmala) is located in Arbil.

The oil produced by the field is 37° API, 2 wt% Sulpher crude, from a main limestone reservoir of the upper Eocene- Oligocene age and the Shiranish-Qamchuqa reservoir from the Cretaceous age. (NOC, 1994) It is well known that the effective source rock in the region belongs to the middle and upper Jurassic Sequence (Sargelu, Naokelekan, Barsarine and Chia Gara formations). Different authors have proved that during their evaluations of the aforementioned formations, either in the Kirkuk area or areas near Kirkuk (Al-Beyati, 1998; Najaf, 2001; Abdula, 2010; Mustafa, 2009; Mohialdeen et al., 2013; Saeed, 2014, Fatah, 2014, Abdula, 2015, Mohialdeen and Hakimi, 2015, Fatah and Mohialdin , 2016).

In this work, an attempt is made to evaluate the Dokan and Gulneri formations in Well K-130 in the Kirkuk Oil Field, from a hydrocarbons potential point of view, to confirm their contribution to generating oil accumulated in the Cretaceous and Tertiary reservoirs in the field.

Materials and Methodology:

Eight core samples totalling 20m in thickness from the Dokan and Gulneri formations in well K-130 were selected to be studied optically and analytically.

The method of Brass and Williams, 1973 followed with some modification for preparing palynological slides using 10% HCl for 24 hours then washing by distilled water then adding concentrate HCL for about 24 hours and then washing 5 times by distilled water then adding concentrate HF acid for 48 hours then washing 5 times by distilled water then sieving(screening) by nylon mesh 10 μ and finally staining and making slides in geochemical laboratory in in geology department .The prepared palynological slides were examined using transmitted light microscopy to identify different organic matter components and determine palynofacies.

Five samples from the aforementioned eight samples were sent to *Robertson Geo lab Nor As* in Norway to be analyzed by means of Rock- Eval pyrolysis to determine the TOC% and different parameters related to potentiality and maturity of organic matter in the studied samples.

Location of the study area:

The selected section for this study is located between depths of 1,191 and 1,171 m within well K-130 in the Kirkuk Oil Field (Figure: 1). The UTM coordinates of the well are 442 686.22 E and 3929 449.78 N in the southern part of the Kirkuk structure on the Baba dome.

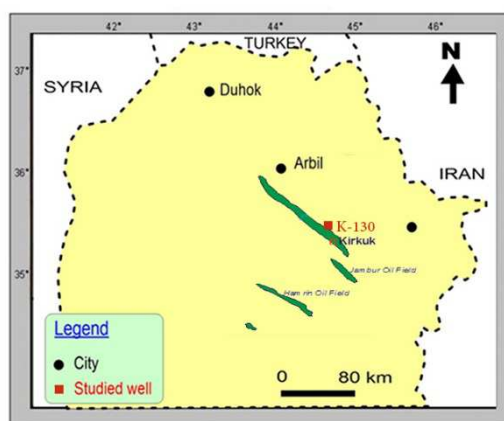


Figure-1: Map of well k-130 within the Kirkuk Oil Field Kurdistan Region , Northern Iraq.

Dokan Formation:

The Dokan Limestone Formation was first described by Lancaster and Jones in 1957 (Bellen et al., 1959). The type locality is at the site of the Dokan dam in the High Folded Zone of NE Iraq. It comprises 4 m of light grey and white oligosteginal limestone, locally rubble, with glauconitic coatings of pebble-like masses (ibid.). Fracture systems in the Dokan Formation produced oil in the Baba dome (Kirkuk) and Bai Hassan and gas from the Jambour Field (Dunnington, 1967a as cited in Aqrawi et al., 2010). In the subsurface the limestone it is dark grey and often argillaceous. The formation thickens to the southwest, reaching 150m in the Chemchemical wells. Further west it is 5–30 m thick in the Kirkuk, Bai Hassan, Demir Dagh and Qara Chugh areas (Jassim and Buday, 2006). The Dokan Formation in the studied well is 10.5 m thick pale grey Limestone (Figure:2).

Jassim and Buday (2006) stated that the base of this formation is glauconitic at Dokan but conglomeratic at Bai Hassan. The Dokan Formation runs eastwards into the upper part of the Pelagic Balambo Formation (Figure: 3)

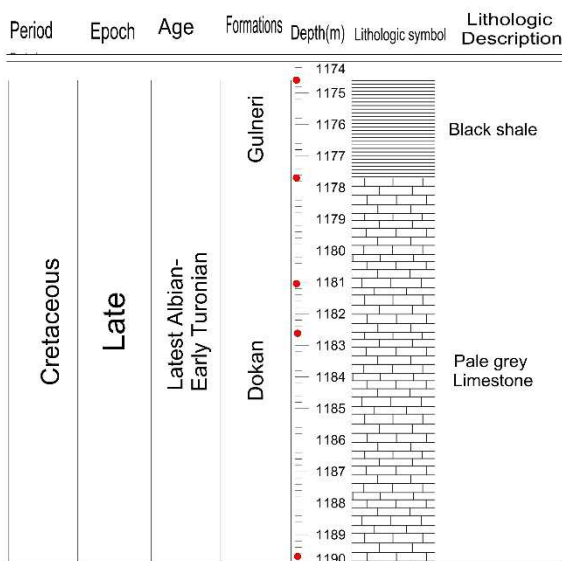


Figure-2: Lithostratigraphic column of Dokan and Gulneri formations in K-130 well
 Note: ● selected samples for pyrolysis and TOC analysis

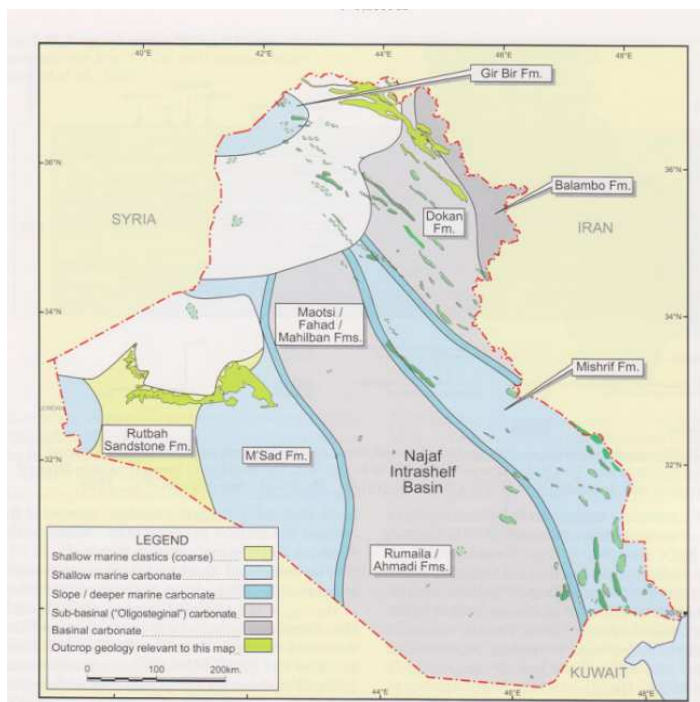


Figure-3: Latest Albian-Early Turonain paleogeography of Iraq (after Aqrawi et al. , 2010).

Gulneri Formation:

The Gulneri Formation was first recognized and described by Lancaster and Jones in 1957 in the same type locality of the previously mentioned Dokan Formation (site of the Dokan Dam), as mentioned by Bellen et al. (1959). The formation in its type locality consists of about 2 m of black, bituminous, finely laminated, calcareous, shale with some glauconite and collophane in the lower part. The high bitumen content and dwarfed fossils indicate that the formation was deposited in an euxinic environment (Jassim and Buday, 2006). The lithology of the formation in the studied section is dark grey to black shale with a thickness of about 9.5 m. (Figure:2).

Results and Discussion

Optical study:

An optical examination using transmitted light microscopy revealed the richness of the samples and their amorphous organic matter (AOM) with smaller quantities of palynomorphs and phytoclasts (equidimensional and blade shapes). The identified palynomorphs mostly consisted of spores. (Figure: 4 A) Depending on the percentages of the aforementioned organic matter components, the following palynofacies were recognized (Table 1). (Figure: 4 B, C, and D) and (Figure: 5)

Palynofacies 1 (P.F.1)

This palynofacies comprises the lowermost part of the Dokan Formation between approximate depths of 1,189.9 and 1,189 m (Figures: 4 B and 5), and also in the upper part of the formation between approximate depths of 1,184.9 and 1,180.5 m. This palynofacies is characterized by smaller amounts of palynomorph and some phytoclasts and more AOM and is lithologically composed of pale grey limestone.

Table- 1: Percentages of organic- matter components in the studied area

Formation	Depth (m)	Phytoclasts %		Palynomorph %	A.O.M. %
		Equidimentional	Blade		
Gulneri	1174.6	9	1	0	90
Gulneri	1177.7	3	1	1	95

Dokan	1181.1	5	6	1	88
Dokan	1182.6	5	2	5	88
Dokan	1184.4	5	6	2	87
Dokan	1185.9	25	20	3	52
Dokan	1188.1	25	20	9	46
Dokan	1189.9	0	15	5	80

Palynofacies 2 (P.F. 2)

This palynofacies has been observed within the middle part of the Dokan Formation between depths of 1,189 and 1,184.9 m (Figures: 4 C and 5). This palynofacies is characterized by decreasing AOM with an obvious increase in phytoclasts. Relatively high percentages of palynomorphs were observed in this palynofacies within the whole studied section. The nearly 45% of phytoclasts appeared to consist of equal quantities of both equidimensional and blade shapes. Lithologically, this palynofacies is composed mainly of pale grey Limestone.

Palynofacies 3 (P.F.3)

This palynofacies can be seen in the Gulneri Formation between depths of 1,180.5 and 1,171 m. Although this palynofacies is very similar to P.F.1 regarding its organic matter component percentages, they differ in their lithologies (Figures: 4D and 5). The lithology of this palynofacies is composed mainly of dark shale.

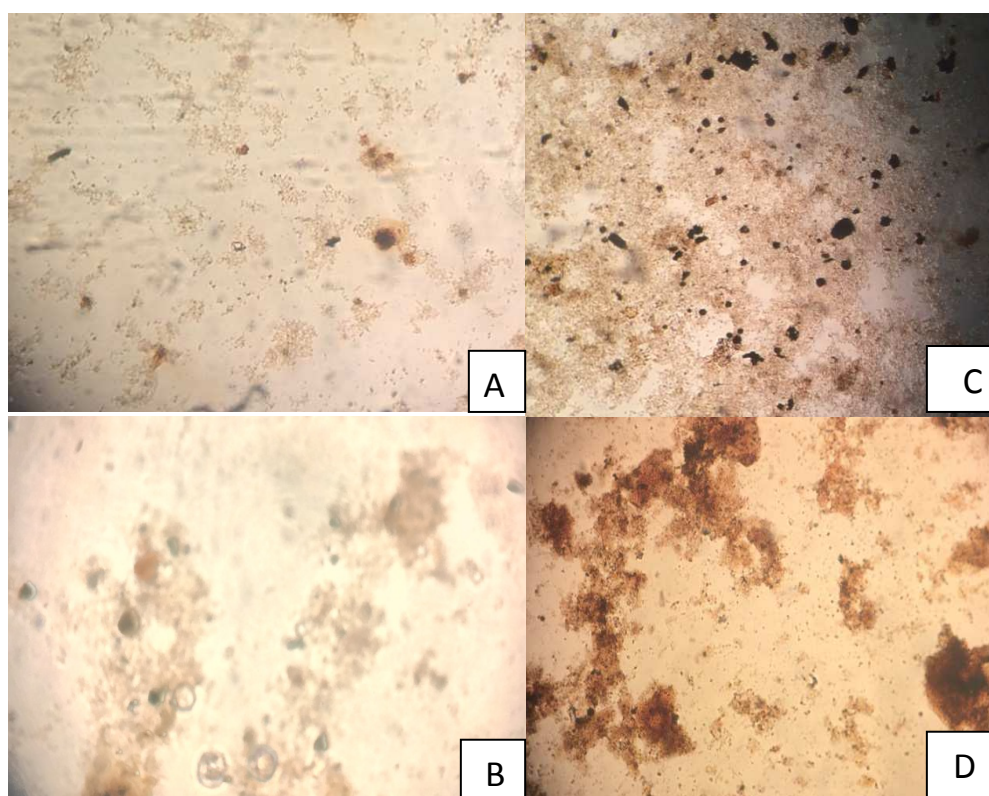


Figure-4: Photomicrograph of Sedimentary organic matter constituent , magnification: 100x .(A) spore present in in the organic matter, depth 1181.1m, Dokan formation ,(B) P.F.1 , depth 1181.1m, Dokan Formation, (C) P.F.2 , depth 1188.1m, Dokan Formation and(D) P.F.3, depth 1177.7m, Gulneri Formation.

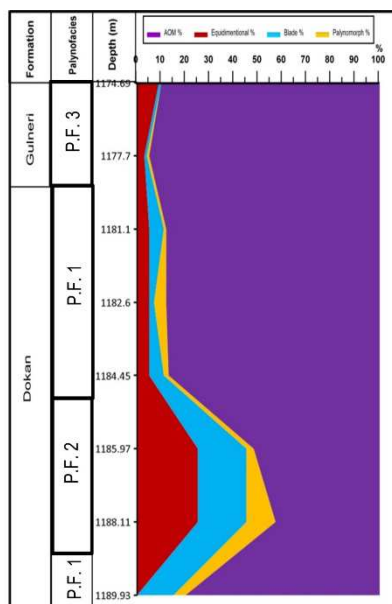


Figure-5: Distribution of different types of organic matter within the studied samples ,well k-130 ,Kirkuk Oil Field, Kirkuk, Kurdistan , N Iraq.

The locations of the three recognized palynofacies on the ternary diagram of phytoclasts, palynomorphs and AOM, as proposed by Tyson (1995), are shown in (Figure-6). As can be observed from the ternary diagram, P.F.1 and P.F.3 are both located in field **IX**, which is known to be a **distal suboxic-anoxic basin**. According to Tyson (1995), this field is characterized by AOM: dominated by assemblages, a low abundance of palynomorphs, partly due to masking; frequently alginate, with a rich, deep basin or stratified shelf sea deposits, especially a sediment-starved basin. The field is also characterized by kerogen type II > I and highly oil-prone organic matter.

On the other hand, P.F.2, located in field VI of the ternary diagram (Figure: 6), which is known to be a **proximal suboxic-anoxic shelf**, characterized by high AOM preservation due to reducing basin conditions, has an absolute phytoclast content which may be moderate to high due to turbiditic input and/or its general proximity to source. This field is also characterized by kerogen type II oil-prone organic matter (Tyson, 1995).

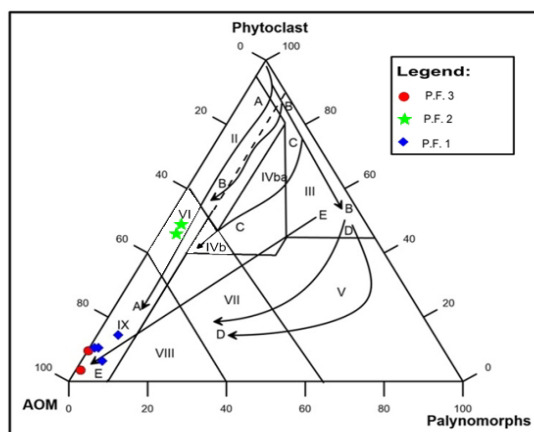


Figure-6: APP Ternary diagram after (Tyson, 1995) and the location of studied samples.

TOC and Rock-Eval Pyrolysis data:

The results of the Rock-Eval analysis for the five samples from the two formations are listed in Table 2. It has been noticed that Dokan Formation has a generally lower TOC content than the Gulneri Formation. The highest TOC content was 4.14%, which was recorded at a depth of 1,177.7m in the Gulneri Formation, whereas the lowest TOC content was about 0.27% which was recorded at a depth of 1,182.6m in the Dokan Formation (Table 2). Generally, the average TOC content of the Dokan Formation appeared to be about

0.45%, and for the Gulneri Formation it was about 3.74%. Accordingly, the TOC in the Dokan Formation can be considered poor according to the classification of Leckie et al. (1988), whereas the TOC content in the Gulneri Formation can be considered very good for generating hydrocarbons.

Table-2: Rock – Eval data for the pyrolyzed samples from the Dokan and Gulneri formations in K-130 well

<i>Formation</i>	<i>Depth</i> (<i>m</i>)	<i>TOC</i> <i>wt %</i>	<i>S1</i> <i>mg/g</i>	<i>S2</i> <i>mg/g</i>	<i>S3</i> <i>mg/g</i>	<i>Tmax</i> <i>C°</i>	<i>HI</i> <i>HC/TOC</i>	<i>OI</i> <i>HC/TOC</i>	<i>PI</i> <i>(S1/S1+S2)</i>	<i>GP</i> <i>(S1+S2)</i>	<i>BI</i> <i>(S1/TOC)</i>
<i>Gulneri</i>	1174.6	3.34	1.89	26.39	0.66	427	790	20	0.07	28.86	0.56
<i>Gulneri</i>	1177.7	4.14	2.59	33.77	0.85	428	816	21	0.07	36.36	0.62
<i>Dokan</i>	1181.1	0.50	0.67	2.44	0.52	422	488	104	0.22	3.11	1.34
<i>Dokan</i>	1182.6	0.27	0.18	0.88	0.38	426	326	141	0.17	1.06	0.66
<i>Dokan</i>	1189.9	0.59	0.40	2.36	0.44	426	400	75	0.14	2.76	0.67

TOC% = Total Organic Carbon Percentage

S1= is milligram of hydrocarbon that distilled thermally from one gram of the rock (mg HC/ g rock)

S2= is milligram of residual hydrocarbons per one gram of rock (mg HC/ g rock)

S3= is milligram of CO₂ per one gram of rock (mg CO₂/g rock)

Tmax = is the oven temperature that corresponds to the maximum rate of S2 peak

PI: Also known as a transformation ratio, is represented the amount of free hydrocarbon fractions S1 over the genetic potential (S1+S2).

GP: Is a semi-quantitative index that corresponds to the total amount of free hydrocarbon S1 and pyrolysis hydrocarbon S2.

BI: sometimes called Migration Index (S1/TOC %), is to determine the depth at which a source rock begins to expel oil. A cross-plot of hydrogen index (HI) versus oxygen index (OI) (Figure: 7) shows the dominance of kerogen type II/III for the Dokan Formation and mostly type I for the Gulneri Formation. This difference in kerogen type between the two formations is an indication of the variation in their environments (the depositional environment of the Gulneri Formation appears to be deeper than that of the Dokan Formation). Baban and Sarraj, (2007) studied the paleodepositional environment of the Dokan and Gulneri formations in Kz-12, Ja-50 and Tq-1 wells and they also used the ternary diagram of Tyson (1995) and concluded that the paleodepositional environment of Dokan Formation was distal suboxic –anoxic basin in (Kz-12 and Tq-1) wells, distal dysoxic- anoxic shelf and partly distal dysoxic- oxic shelf in (Ja-50) well , while the paleodepositional environment of the Gulneri Formation was mainly distal suboxic –anoxic basin in (Kz-12 and Ja-50) well while Tq-1 well was proximal suboxic- anoxic shelf) Accordingly, the difference in TOC richness between the two formations can be interpreted as better preservation conditions for the organic matter within the deeper depositional environment of the Gulneri Formation. A cross-plot of HI versus Tmax (Figure: 8) clearly shows the thermally immature condition of all the analyzed samples from either their Tmax records or their equivalent vitrinite reflectance (% Ro). It is well known that organic matter of less than 435 C° Tmax or less than 0.3% Ro is generally considered to be immature organic matter. (Ibrahimbas and Reidiger, 2004; Mohialdeen et al, 2013)

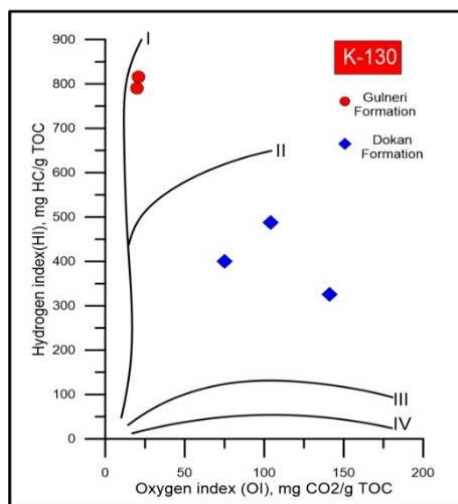


Figure-7: OI versus HI cross-plot shows different types of kerogen and location of the studied samples from Dokan and Gulneri formations, well k-130, Kurdistan, N Iraq.

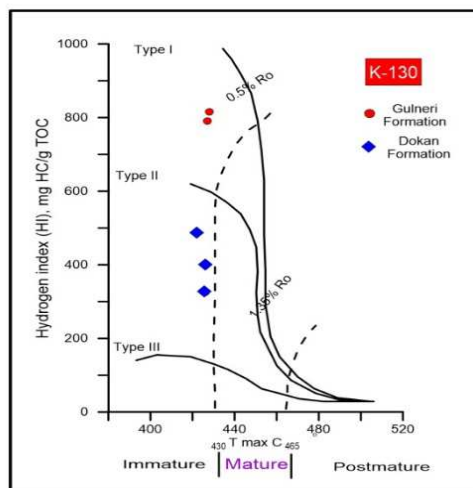


Figure-8: HI and Tmax Cross-plot (Espitalie et al., 1986) and location of the studied samples.

A plot of the transformation ratio or production index (TR or PI, which is the ratio of the petroleum, oil plus gas, actually formed by kerogen to the genetic potential) versus T_{max} (Figure: 9) also supports the immaturity of the samples as mature organic matter should show a TR higher than 0.2 (Espitalie et al., 1977). The sample from a depth of 1181.1m from the Dokan Formation whose TR was equal to 0.22 was not considered to be a mature sample as it failed within a stained or contaminated field of the cross-plot, and that was mostly due to its low T_{max} .

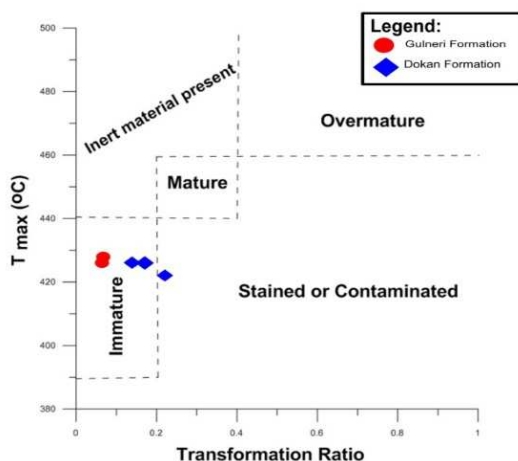


Figure-9: TR versus T_{max} (Espitalie et al., 1977) and locations of the studied sample.

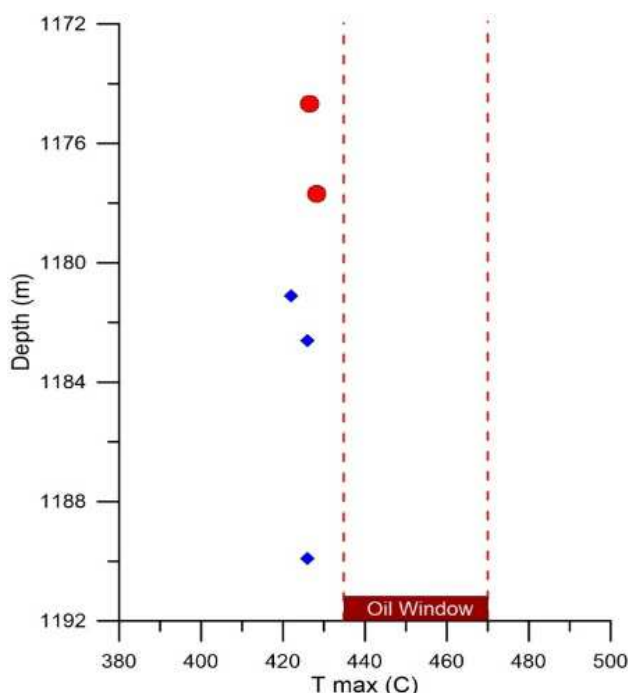


Figure-10: Depth versus Tmax cross-plot (English et al, 2004) and location of studied samples.

As the studied section has no great thickness, there is no great difference in their depths; therefore, no obvious difference was observed in their maturity (Figure: 10)

A diagram of TOC versus Genetic Potential (GP), which represents the amount of petroleum (oil and gas) that the kerogen is able to generate) (Figure: 11) shows a very clear difference between the Dokan and Gulneri Formations regarding their future ability to generate hydrocarbons. The GP is a factor which depends mainly on the organic matter richness of the rock, the Gulneri Formation rich in organic matter shows very good to excellent potential for hydrocarbons generation (in a future maturity condition), whereas the Dokan Formation, due to its poor organic matter content, shows poor potential for generating hydrocarbons at the present time, and even after maturation.

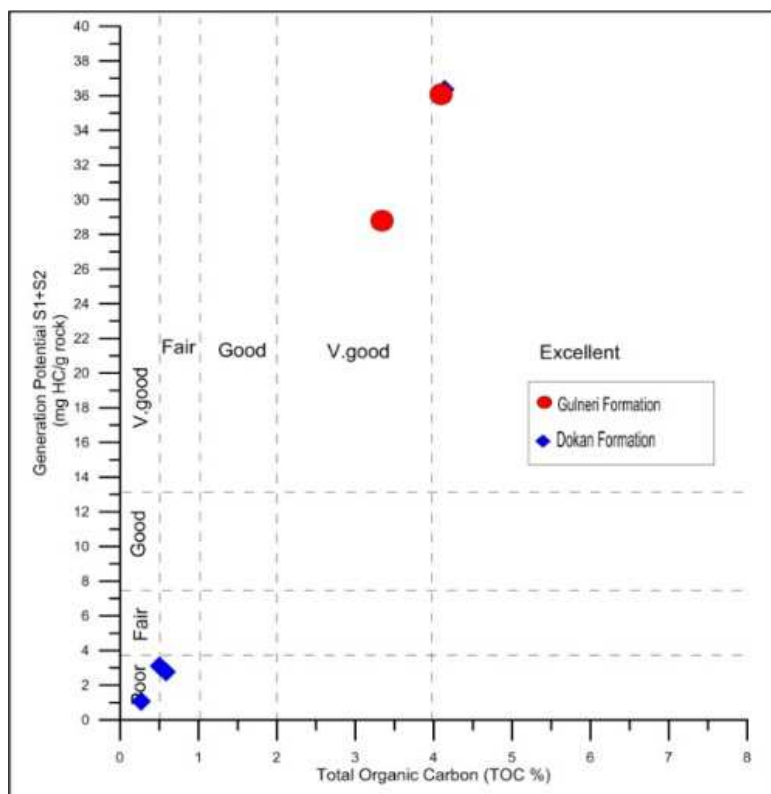


Figure-11: GP (S1+S2) versus TOC wt. % (Ghori, 2002) and location of studied samples.

The relationship between TOC and S₂ (Figure: 12), also shows very good to excellent potential for the Gulneri Formation in comparison to the poor to fair potential of the Dokan Formation.

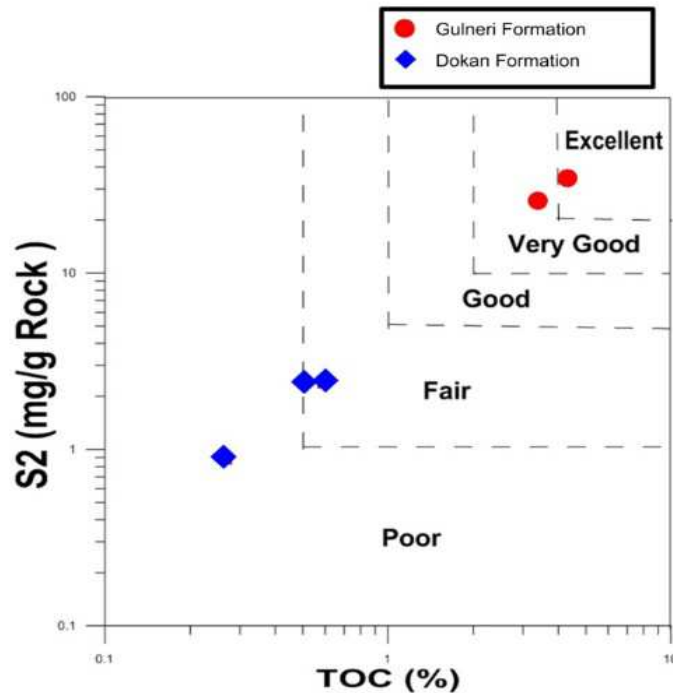


Figure-12: TOC% and S₂ cross-plot after (Ghori, 2000) and location of the studied samples.

Conclusions:

The main conclusions of this study can be summarized as follows:

- Depending on the percentages of organic matter components, the Dokan Formation can be subdivided into two palynofacies, but the Gulneri Formation only has one.
- Both P.F.1 and P.F.3 represent a distal suboxic-anoxic basin, whereas P.F.2 represents a proximal suboxic-anoxic shelf.
- From a richness of organic matter point of view, the Dokan Formation can be considered as poor-to-fair source rock, whereas the Gulneri Formation can be considered as very good to excellent source rock.
- As for the kerogen type, the Dokan Formation appears to contain kerogen type II/III (oil and gas prone), whereas the Gulneri Formation appears to be mostly type I kerogen (oil prone).
- Both the Dokan and Gulneri formations in the studied area are thermally immature, so they did not contribute the accumulated oil in nearby reservoirs.
- The Gulneri Formation in the studied area can be considered to be potential source rock, as it contains an acceptable quantity of organic matter as source rock but has low thermal maturity.

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