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Geochemical Characterization of Source Rocks in Block 1A Muglad Basin, Wizeen Oil Field, South Sudan

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Abstract

This study applies Rock-Eval 6 pyrolysis to cuttings from wells WZNW-1 and WZW-1 to assess organic richness, kerogen type, and thermal maturity in Baraka and Abu Gabra formations. Baraka contains mainly type III organic matter, while Abu Gabra contains type II to type II/III organic matter, and proposes Baraka as an additional source rock interval. Several reported Rock-Eval values and their interpretations require reconciliations before the source rock conclusions can be supported.

Keywords

Geochemistry, Rock-Eval Pyrolysis, Source Rocks, Petroleum Potential, Muglad Basin, South Sudan

1. Introduction

Block 1A is located within the Muglad Basin. Muglad Basin in Central Africa is located in the middle of the African Plate and is a Mesozoic and Cenozoic rift basin formed by strike-slip extension of the Central African shear zone. Muglad Basin is filled with a Cretaceous—Cenozoic non-marine sedimentary succession which is more than 13,000 m thick in the deepest parts of the Kaiking Trough. Three major episodes of extensional tectonics are recognized: Early Cretaceous (140 - 95 Ma), Late Cretaceous (95 - 65 Ma), and Paleogene (65 - 30 Ma) [1]. Each episode started as a rifting phase and ended with a sag phase (**Figure 1**).

The Stratigraphic succession of each rift-related depositional cycle begins near the rift margins with basal sand, followed upwards by a shale-dominated interval, reflecting the deepening of the basin. Shale-dominated sediments accumulated during periods of active rifting when subsidence was maximum. Sand-dominated sediments accumulated when the rates of subsidence were relatively low, especially during the thermal sag phases. Syn-rift deposits of the first cycle (Abu Gabra Formation) are dominated by extensive lacustrine shales [2]. The lake water depth was apparently sufficient for the accumulation and preservation of organic-rich shales, that is the main source rocks for the oils found in this basin.

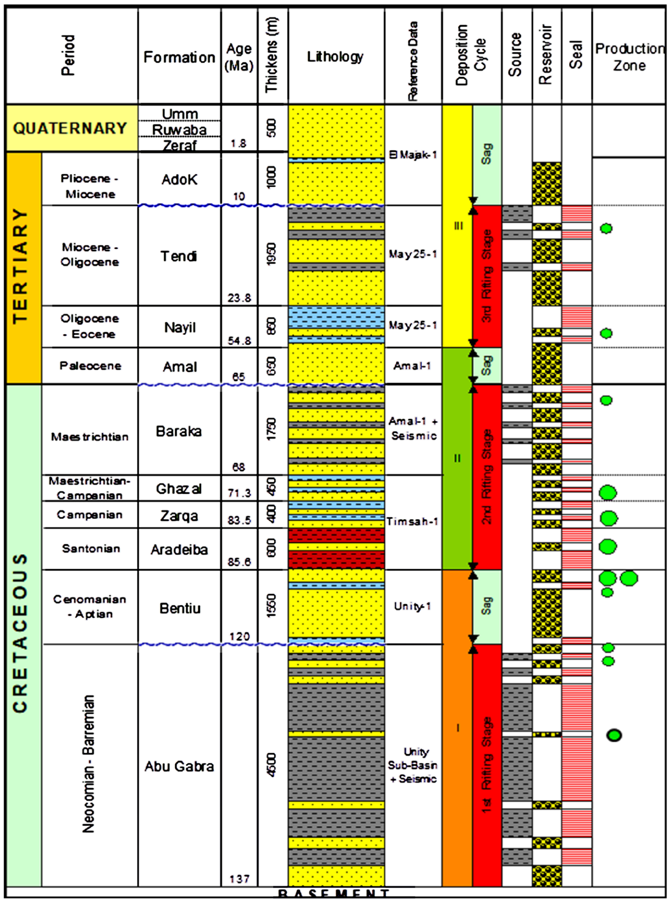

Figure 1. Generalized stratigraphy of Muglad Basin [3].

Later in this period, the structural framework of the Cretaceous formations was basically formed and entered the sag sedimentation period, in which the Bentiu Formation was dominated by a large package of blocky sandstone. The syn-rift deposits of the second episode (Aradeiba, Zarqa, and Ghazal Formations) and the third episode (Nayil and Tendi Formations) consist mainly of lacustrine to fluvial overbank shales in lower parts, while upper parts are dominated by fluvial sands [4]. In early stages, Aradeiba-Ghazal had relatively intensive faulting activities with high-quality mudstone. At sagging sedimentation stages, the Amal Formation was characterized by massive blocky sandstones. The activities of the Central-Africa Shearing Belt stopped in the Paleogene, but the Muglad basin, due to the effect of the Red Sea separation and the East African Rift Valley, entered a new rift development period, as shown in the Generalized Stratigraphy of Muglad Basin in Figure 1.

Wizeen oil field is one of the newly discovered fields which is located in NE of Toma South oil field in Muglad Basin. Currently, the wells that have been drilled in Wizeen oil field are seven. These include WZNW-1, WZW-1, WZN-3, WZN-2, WZN-1, WZ-2 and WZ-1. The WZNW-1 was drilled in 2024 as a study well and correlated with WZW-1. Because there is potential for hydrocarbon reserves in the northwest of Wizeen. However, there is little understanding of source rock within the Wizeen oil field. Abu Gabra is the only source rock known in the Muglad Basin with good and critical petroleum systems, as in Figure 2 and Figure 3. During the drilling of these wells, there are some formations which indicate good potential for source rocks. Therefore, there is a need to evaluate the source rocks within the Muglad Basin, whether the hydrocarbons originate only from Abu Gabra or whether there is another source rock within the Wizeen oil field.

This study aims to characterize the source rocks of the Barak and Abu Gabra interval from wells WZNW-1 and WZW-1. It will: 1) evaluate the oil potential; 2) characterize the organic matter; 3) identify zones conducive to hydrocarbon generation, all coupled with their level of maturity, based on geochemical analysis results obtained from Rock-Eval 6 analysis.

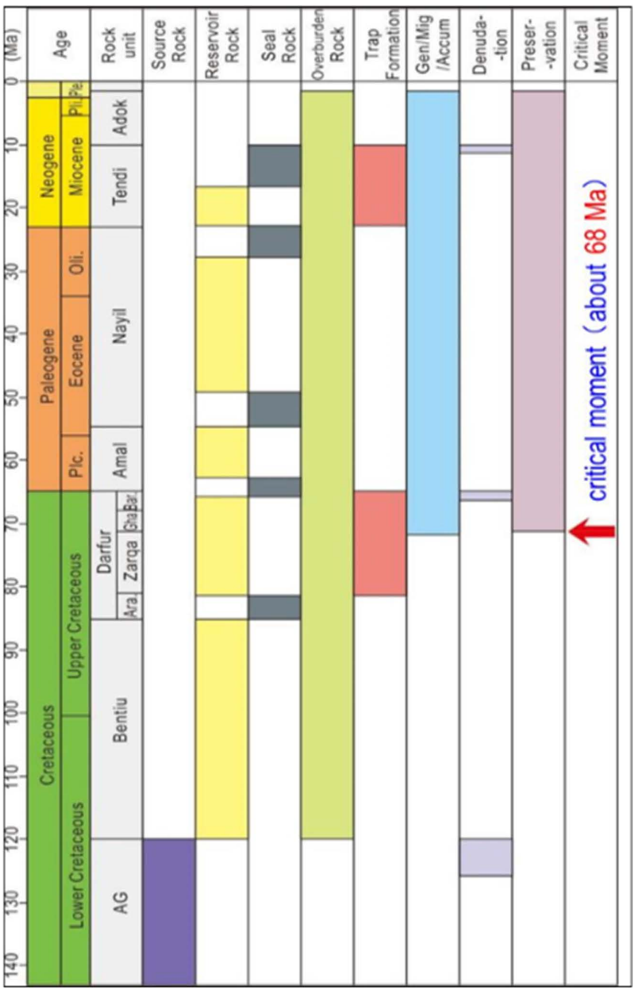

Figure 2. Generalized petroleum system [3].

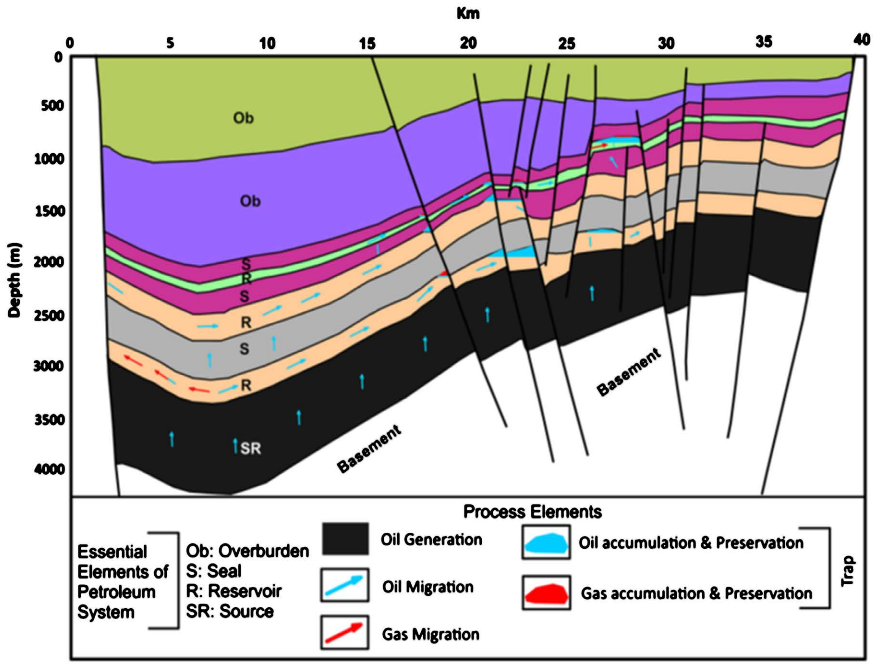

Figure 3. Petroleum system elements and processes of the Muglad Basin with significant accumulation of oil and gas [2].

2. Materials and Methods

2.1. Materials

A total of 480 cuttings samples from two oil wells (WZNW-1, WZW-1) were used in this study. 120 samples from WZNW-1 were collected from shale lithology at a depth of (2000 - 3000 m), interval of Baraka formation. Also, 120 samples of shale lithology at a depth of (4000 - 5500m), interval of Abu Gabra formation, were collected for this study. In WZW-1, 120 samples of shale lithology were collected at a depth of (1000 - 1600 m), in the Baraka formation interval. In the Abu Gabra interval, 120 samples were also collected between the depths of (2000 - 5000 m). These samples were put into clean boxes and transported to the laboratory for analysis using Rock-Eval 6 Pyrolysis. These samples were collected from these two wells in the sedimentary basin of the Muglad Basin (South Sudan) in the Wizeen oil field (**Figures 4-6**). It is important to note that the stratigraphic stages were delineated through biostratigraphic studies. The samples were analyzed using Rock-Eval 6 at the laboratory of the Egyptian Petroleum Research Institute Center.

2.2. Methods

2.2.1. Sample Processing

The method builds upon the work of [5], which determined the organic matter accumulation rate and kerogen type in the rock using parameters such as TOC, HI, S2, and T_{max}.

Samples consist of 20 g of already ground rock cuttings screened from shale lithology and placed in a beaker. Liquid soap and water are added, and the mixture is allowed to settle for half an hour. The samples were then processed with water through a column composed of two sieves (800 and 100 μm), followed by drying in an oven at a temperature between 30˚C and 50˚C to remove the contaminants from the samples. The dried samples were crushed and homogenized in an agate mortar. Subsequently, 65 to 100 mg of each sample is weighed using a precision balance. These samples are then placed in crucibles and loaded into the carousel of the Rock-Eval 6 apparatus for analysis.

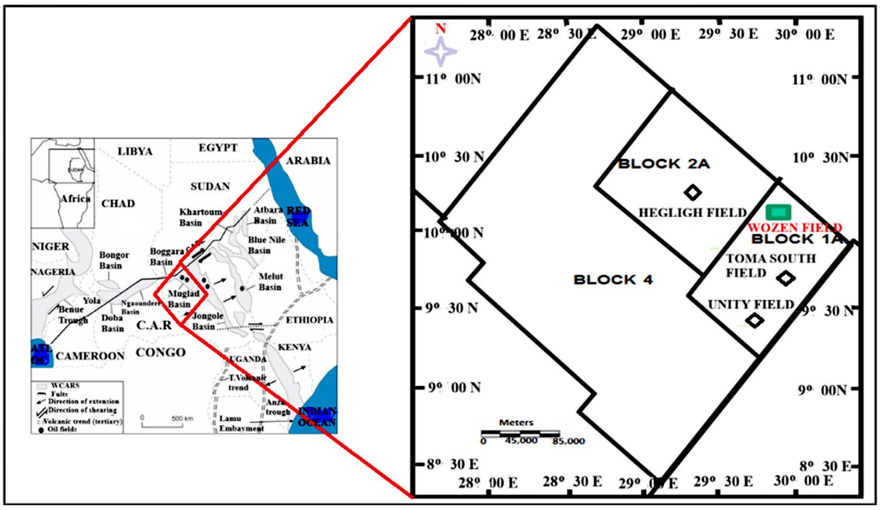

Figure 4. Geological map of the study area in Muglad Basin, South Sudan [3].

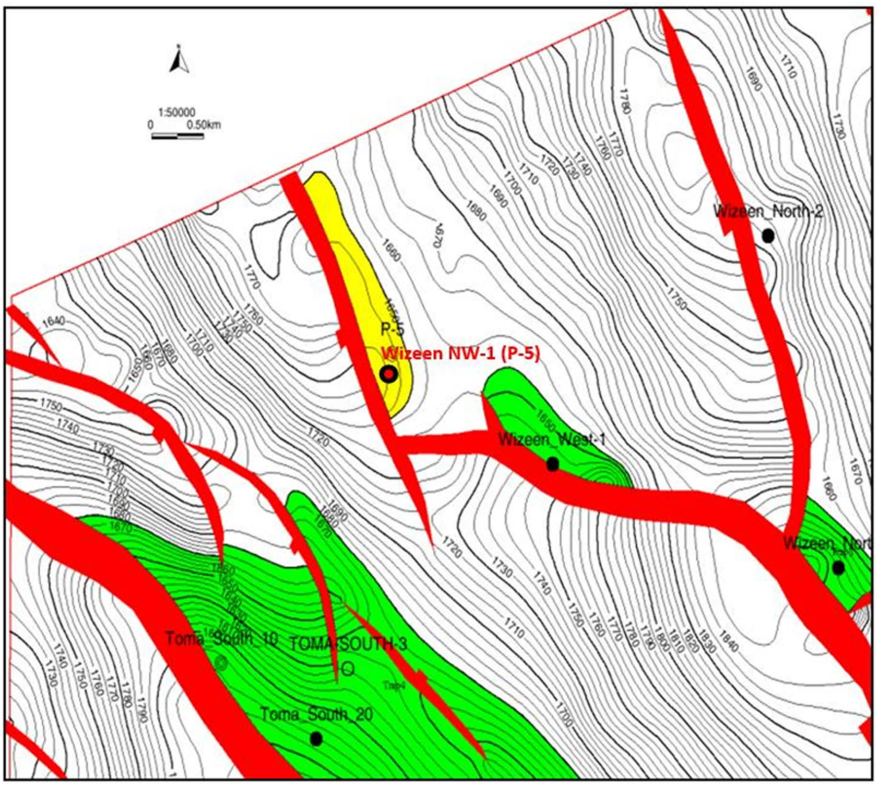

Figure 5. Time structure map of study wells [3].

2.2.2. Analysis Principle of Sample or Programmed Pyrolysis Method

Rock-Eval pyrolysis is a physicochemical method that involves heating a quantity of 65 to 100 mg of ground rock at a progressive temperature increase of 25˚C/min up to 650˚C under an inert atmosphere (helium). This process determines the quantity and quality of hydrocarbon and oxygenated compounds (CO_2) released during pyrolysis (Figure 7). The essential data is acquired through a single analysis lasting one hour per sample. The effluents emitted during the temperature

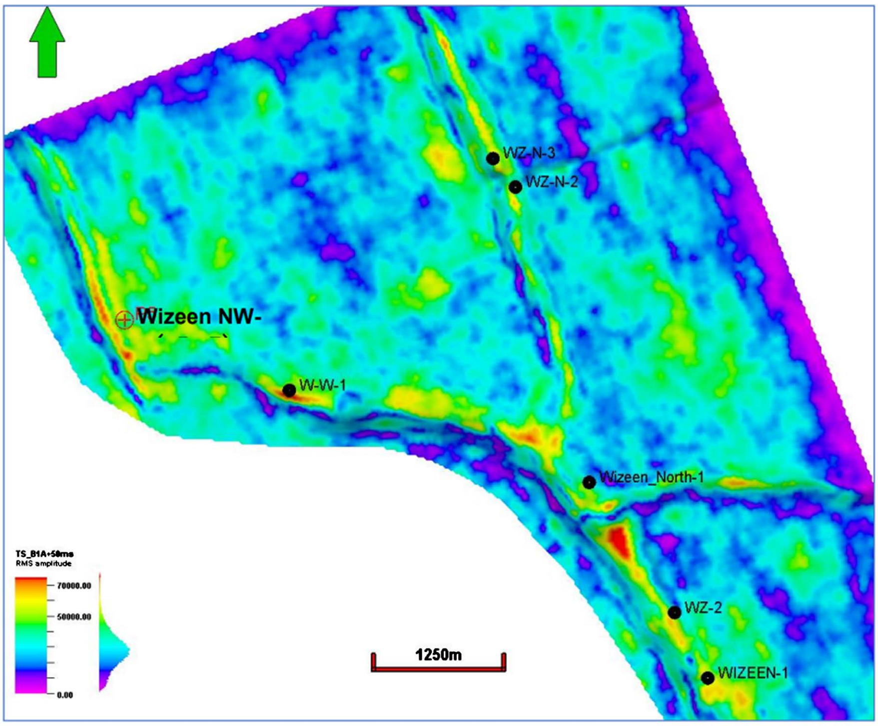

Figure 6. RMS Amp attribute of the study wells with other Wizeen wells [3].

Figure 7. Photo of the Rock-Eval 6 apparatus.

ramp-up are collected and quantified. The parameters measured or calculated in this study are:

- S2: This represents the oil potential or hydrocarbons derived from pyrolysis. It corresponds to the quantity of hydrocarbon compounds generated by the cracking of kerogen when the rock is heated up to 600˚C. It is expressed in mg HC/g of rock (**Table 1**).
- **TOC (Total Organic Carbon):** This gives the weight proportion of total organic matter in one gram of sample (% weight). It helps determine the petroleum potential of source rocks. While essential for classifying source rocks, TOC is less relevant than S2 in estimating oil potential because it includes inert carbons incapable of generating hydrocarbons (**Table 1**).

Table 1. Petroleum potential of source rocks [6].

Organic Matter (OM)		
Rock Eval Parameters		
TOC (% Poids)	S2 (mg HC/g Roche)	Petroleum Potential
0 < TOC < 0.5	0 < S2 < 2.5	Poor
0.5 < TOC < 1	2.5 < S2 < 5	Fair
1 < TOC < 2	5 < S2 < 10	Good
2 < TOC < 4	10 < S2 < 20	Very good
TOC > 4	S2 > 20	Excellent

- **T_{max} (˚C):** This is the pyrolysis temperature and a key parameter of Rock Eval. It quantifies the thermal maturity of a rock and represents the temperature of maximum hydrocarbon generation. T_{max} values are less reliable when S2 < 0.2 mg HC/g rock [7]. T_{max} allows a coarse evaluation of the degree of organic matter maturation (**Table 2**). This maturity level depends on other factors, including the type of organic matter.

Table 2. Thermal maturity [8].

Rock-Eval Parameters	
T_{max} (˚C)	Thermal maturity
T_{max} < 435	Immature
435 < T_{max} < 445	Early maturity
445 < T_{max} < 450	Peak Maturity
450 < T_{max} < 470	Advanced maturity
T_{max} > 470	Over mature

- **HI (Hydrogen Index):** This is the proportion of hydrocarbon effluents emitted during pyrolysis relative to TOC. Its formula is: HI = (100 × [S2/TOC]), expressed in mg HC/g TOC. It is important to note that the hydrogen content of organic matter is one of the most significant factors controlling the generation of oil and gas. [9] demonstrated that the hydrogen in kerogen is proportional to the hydrocarbons S2 released during pyrolysis, and that the hydrogen index correlates with the H/C ratio of kerogen. Therefore, marine organisms and algae have higher HI values compared to terrestrial organisms. HI is used to assess the type and origin of organic matter in sedimentary rocks (**Table 3**).

Table 3. Type of kerogen and expelled products.

HI (mg HC/g TOC)	Type of kerogen	Hydrocarbon formed
<50	IV	-
50 - 200	III	Gas
200 - 300	III/II	Oil and Gas
300 - 600	II	Oil
>600	I	Oil

The results obtained were interpreted using petrographic software.

2.2.3. Quality Control

1) Calibration and Reference Materials

Standard Reference Materials: calibration and routine quality control of the Rock-Eval 6 device are classically performed using the certified standard reference material IFPEN-160000. This standard is run to validate hydrocarbon (HC), carbon monoxide (CO), and carbon dioxide (CO_2) infrared and FID responses.

TOC and Mineral Carbon: Certified reference standards to ensure correct splitting of total organic carbon (TOC) and mineral carbon (Min C) across temperature ramps.

2) Blank Procedures

Baseline Checks: Empty crucible (blank) runs are scheduled between sample sequences to monitor system cleanliness, memory effects, and baseline stability in both the pyrolysis and oxidation oven.

Contamination Tracking: Blanks verify that no residual hydrocarbons or carbon gases bleed over from high-concentration source rock or organic-rich shale samples.

Then the results are interpreted using a petrographic software model 10.1029/2005GC000932.

3. Results and Discussion

The purpose of geochemical (Rock-Eval Pyrolysis) analysis is to identify and measure important parameters and constraints relating to source rock quality, quantity, and kerogen type. These parameters also help to resolve the composition and origin of the organic matter to evaluate the source rock effectively. What follows is a discussion of the results obtained from detailed geochemical analysis of the targeted source interval.

3.1. Quantity of Organic Matter (TOC wt%)

3.1.1. Baraka Formation

From Table 4, pyrolysis results of WZNW-1, the TOC% ranges between 1.1 and 1.4 weight percent. This means the studied source rock from these samples can be classified as fair to good generative potential.

From WZW-1 in the Baraka formation, the TOC% also ranges between 1.1 and 1.4 weight percent. These studied source rocks can be classified as fair to good generative potential (Table 5). Generally, Baraka source rocks can be classified as fair to good source rocks [6] (Figure 8).

3.1.2. Abu Gabra Formation

The TOC% in WZNW-1 from the Abu Gabra formation ranges between 1.1 and 2.1 weight percent. These studied source rocks can be classified as fair to very good generative potential (Table 6) and Figure 9. In WZW-1, the TOC% ranges between 0.9 and 1.4 weight percent. These source rocks can be classified as fair to good generative potential [6] (Table 7) and Figure 9. Although the TOC% shows fair to very good generative potential in two wells (WZW-1 and WZNW-1), most of S2 falls between 0.5 and 1.7. That implies that it is poor.

Table 4. Summarized pyrolysis results of WZNW-1 for defined source rock interval for Baraka formation.

Baraka Formation								
Well	Depth (m)	Lithology	S1 (mg HC/g Sediment)	S2 (mg HC/g Sediment)	TOC (wt%)	HI (mg HC/g TOC)	OI (mg HC/g TOC)	T_{max} (˚C)
WZNW-1	2000 - 2200	shale	0.2	0.9	1.1	90	55	419
		shale	0.2	0.9	1.1	90	56	419
		shale	0.2	0.9	1.1	90	55	417
		shale	0.4	0.8	1.2	50	58	418
		shale	0.4	0.8	1.3	50	59	420
		shale	0.3	1.0	1.3	100	100	429
		shale	0.2	1.0	1.2	100	150	439
		shale	0.2	1.1	1.3	100	150	439
		shale	0.1	1.2	1.3	110	100	439
		shale	0.2	1.2	1.4	110	100	440
	2200 - 2400	shale	0.1	1.3	1.4	100	100	440
		shale	0.1	1.3	1.4	190	130	440
		shale	0.3	1.1	1.3	190	130	440
		shale	0.2	1.1	1.3	190	130	440
		shale	0.1	1.2	1.4	180	140	445
		shale	0.2	1.2	1.4	170	140	445
		shale	0.3	1.1	1.4	170	140	445

Continued

WZNW-1	2200 - 2400	shale	0.2	1.2	1.3	170	140	444
		shale	0.3	1.0	1.3	160	130	444
		shale	0.3	1.0	1.3	160	130	443
	2400 - 3000	shale	0.3	1.0	1.4	160	130	443
		shale	0.3	1.0	1.4	150	130	440
		shale	0.3	1.0	1.3	150	140	440
		shale	0.2	1.1	1.3	160	140	440
		shale	0.4	1.0	1.4	170	140	440
		shale	0.3	1.1	1.4	180	130	440
		shale	0.2	1.1	1.3	180	130	440
		shale	0.3	1.1	1.4	170	130	441
		shale	0.2	1.2	1.4	180	130	441
		shale	0.2	1.2	1.4	180	130	440

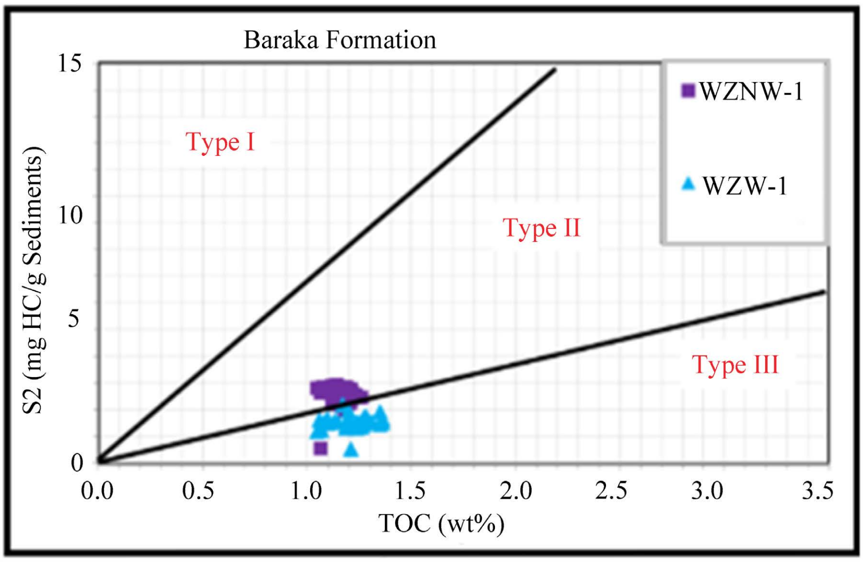

Figure 8. Plot TOC% versus S2 for the Baraka formation samples.

Table 5. Summarized pyrolysis results of WZW-1 for defined source rock interval for Baraka formation.

Baraka formation								
Well	Depth (m)	Lithology	S1 (mg HC/g sediment)	S2 (mg HC/g sediment)	TOC (wt%)	HI (mg HC/g TOC)	OI (mg HC/g TOC)	T_{max} (˚C)
WZW-1	1000 - 1200	shale	0.6	0.5	1.1	92	49	420
		shale	0.5	0.6	1.1	92	49	420
		shale	0.1	1.1	1.2	99	50	429

Continued

WZW-1	1000 - 1200	shale	0.1	1.1	1.2	99	50	432
		shale	0.4	1.0	1.4	100	50	439
		shale	0.2	1.2	1.4	99	60	439
		shale	0.1	1.3	1.4	100	60	438
		shale	0.1	1.2	1.3	100	50	438
		shale	0.2	1.2	1.4	190	60	440
		shale	0.2	1.1	1.3	190	60	440
	1200 - 1400	shale	0.2	1.1	1.3	190	70	442
		shale	0.2	1.1	1.3	190	60	442
		shale	0.2	1.0	1.2	200	60	440
		shale	0.3	1.1	1.4	200	70	440
		shale	0.1	1.1	1.2	200	70	440
		shale	0.2	1.1	1.4	200	60	442
		shale	0.2	1.2	1.4	200	60	442
		shale	0.2	1.2	1.4	190	60	441
		shale	0.2	1.2	1.2	190	70	441
		shale	0.2	1.0	1.3	200	60	441
	1400 - 1600	shale	0.1	1.1	1.3	200	60	441
		shale	0.2	1.2	1.2	200	60	440
		shale	0.3	1.0	1.3	200	60	440
		shale	0.3	1.0	1.3	199	60	440
		shale	0.2	1.1	1.3	199	60	441
		shale	0.2	1.1	1.3	190	60	440
		shale	0.2	1.0	1.2	200	60	440
		shale	0.3	1.0	1.3	200	70	440
		shale	0.3	1.1	1.4	200	60	441
		shale	0.3	1.1	1.4	200	60	442

Table 6. Summarized pyrolysis results of WZNW-1 for defined source rock interval for Abu Gabra formation.

Abu Gabra formation								
Well	Depth (m)	Lithology	S1 (mg HC/g sediment)	S2 (mg HC/g sediment)	TOC (wt%)	HI (mg HC/g TOC)	OI (mg HC/g TOC)	T_{max} (˚C)
WZNW-1	4000 - 4500	shale	0.5	0.6	1.1	54.5	55	410
		shale	0.6	0.5	1.1	50	56	440
		shale	0.4	0.6	1.0	200	56	440
		shale	0.5	0.7	1.2	200	56	440
		shale	0.4	0.8	1.2	200	56	440
		shale	0.4	0.8	1.2	220	55	442

Continued

WZNW-1	4000 - 4500	shale	0.5	0.7	1.3	220	58	442
		shale	0.4	1.0	1.4	210	58	442
		shale	0.5	1.0	1.5	210	58	445
		shale	0.5	1.0	1.5	250	100	439
	4500 - 5000	shale	0.4	1.1	1.5	260	100	439
		shale	0.3	1.1	1.4	260	90	443
		shale	0.3	1.1	1.4	250	90	443
		shale	0.5	1.1	1.6	250	80	442
		shale	0.5	1.2	1.7	250	100	443
		shale	0.4	1.2	1.6	260	110	443
		shale	0.4	1.2	1.6	260	110	442
		shale	0.4	1.2	1.6	260	120	444
		shale	0.7	1.1	1.8	270	120	444
		shale	0.8	1.1	1.9	280	140	444
	5000 - 5500	shale	0.4	1.5	1.9	280	146	443
		shale	0.6	1.5	2.1	270	148	443
		shale	0.5	1.5	2.0	270	149	442
		shale	0.5	1.5	2.0	280	150	442
		shale	0.4	1.6	2.0	280	150	444
		shale	0.3	1.6	1.9	270	149	443
		shale	0.2	1.7	1.9	270	149	443
		shale	0.4	1.7	2.1	270	148	444
		shale	0.3	1.7	2.0	280	146	444
		shale	0.4	1.6	2.0	280	148	444

Table 7. Summarized pyrolysis results of WZW-1 for defined source rock interval for Abu Gabra formation.

Abu Gabra formation								
Well	Depth (m)	Lithology	S1 (mgHC/g sediment)	S2 (mgHC/g sediment)	TOC (wt%)	HI (mgHC/g TOC)	OI (mgHC/g TOC)	T_{max} (˚C)
WZW-1	2000 - 3000	shale	0.1	0.9	1.0	90	50	420
		shale	0.2	0.8	1.0	300	50	440
		shale	0.1	0.9	1.0	300	49	440
		shale	0.1	1.0	1.1	290	49	440
		shale	0.2	1.0	1.2	290	48	440
		shale	0.1	1.1	1.2	290	48	441
		shale	0.2	1.0	1.2	280	47	441
		shale	0.1	1.1	1.2	280	50	440

Continued

	2000 - 3000	shale	0.2	1.0	1.2	280	50	429
		shale	0.2	1.0	1.3	270	50	429
	3000 - 4000	shale	0.2	1.0	1.3	270	50	431
		shale	0.3	1.1	1.3	270	50	431
		shale	0.3	1.0	1.4	280	49	440
		shale	0.2	1.1	1.3	290	49	440
		shale	0.4	1.0	1.4	280	52	440
		shale	0.3	1.1	1.4	300	52	442
		shale	0.3	1.1	1.4	300	52	442
		shale	0.1	1.2	1.4	280	51	441
		shale	0.1	1.2	1.3	300	51	442
WZW-1		shale	0.2	1.2	1.3	290	51	441
	4000 - 5000	shale	0.2	1.2	1.4	290	52	442
		shale	0.3	1.0	1.4	290	50	440
		shale	0.3	1.0	1.3	390	50	440
		shale	0.3	1.0	1.3	300	49	440
		shale	0.2	1.1	1.3	300	49	441
		shale	0.3	1.0	1.3	300	50	441
		shale	0.3	1.0	1.3	300	50	440
		shale	0.3	1.1	1.4	290	49	440
		shale	0.3	1.1	1.4	290	49	440
		shale	0.3	1.1	1.4	290	49	440

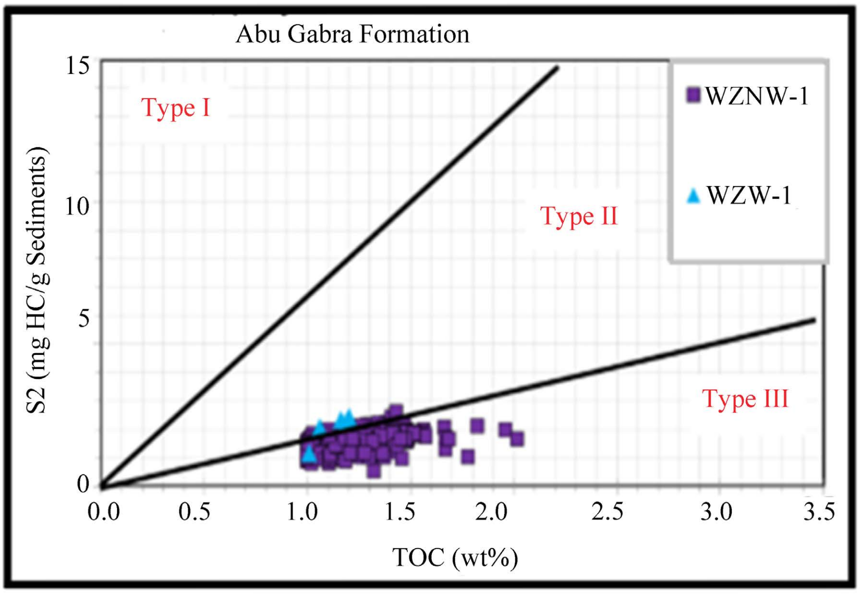

Figure 9. Plot TOC% versus S2 for the Abu Gabra formation samples.

3.2. Genetic Type and Classification of Organic Matter

The determination of the genetic type of organic matter is essential in predicting the oil and gas potential and also in typifying the kerogen. To differentiate between genetic types of organic matter, hydrogen index (HI) can be used [8] [10] [11]. Accordingly, a HI between 50 - 200 mg HC/g TOC indicates a gas-generating potential (kerogen type III). When HI ranges between 200 - 300 mg HC/g TOC, then its kerogen type is II - III, which can produce mixed hydrocarbons (gas and oil but mostly gas). On the other hand, HI ranging from 300 - 600 mg HC/g TOC indicates mainly type II kerogen (oil and gas-prone). Furthermore, HI > 600 mg HC/g TOC classifies the kerogen as type I (oil-prone) [8].

The relation between OI and HI can be plotted on a modified van Krevelen diagram (**Figure 10** and **Figure 11**), which is used to determine the origin and type of the kerogen [12]. Also, the plots of TOC% versus S2 (mg HC/g Rock) (**Figure 12**) as well as the T_{max} versus hydrogen index (**Figure 13**) cross plots help in determining the kerogen type and thermal maturity level. The 2 plots indicate that.

3.2.1. Baraka Formation

From the Baraka formation, HI (Hydrogen Index) from two wells (WZNW-1, WZW-1) ranges between 50 and 200 mg HC/g TOC. This indicates a gas-generating potential. It implies that kerogen type III is present in most of the samples, as in **Table 4**, **Table 5**, and **Figure 10**.

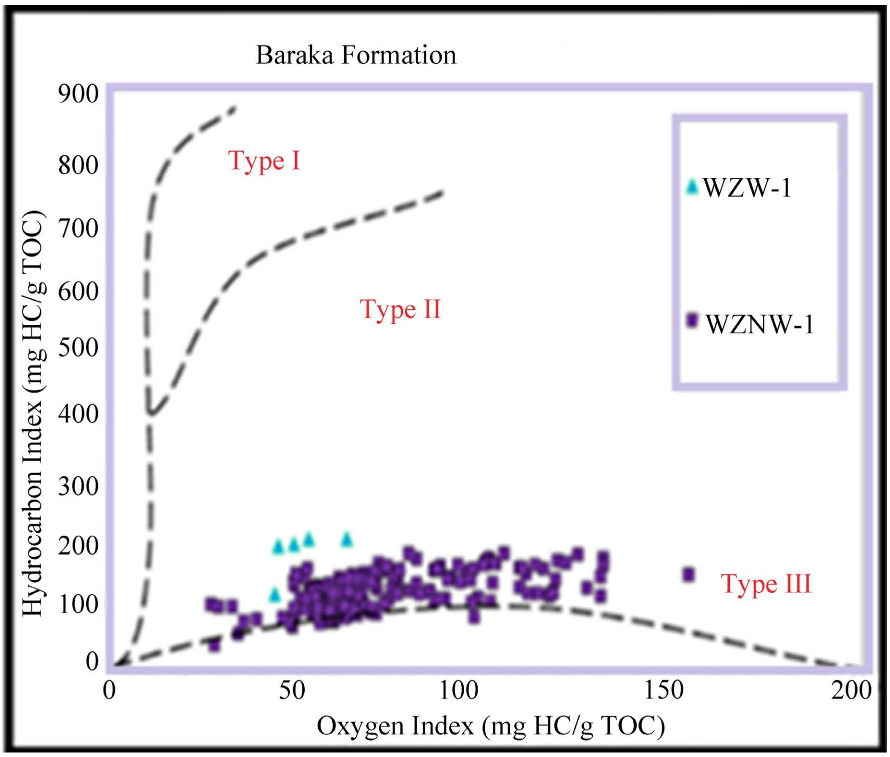

Figure 10. Plot of the studied Baraka formation samples on a modified van Krevelen diagram.

3.2.2. Abu Gabra Formation

In the Abu Gabra formation, HI (Hydrogen Index) from two wells (WZNW-1, WZW-1) ranges between 200 and 300 mg HC/g TOC. This indicates an oil-generating potential. It implies that kerogen type II and type II - III are present in most of the samples. Type II produces oil, and type II - III produces mixed hydrocarbons (oil & gas, mostly gas) (**Table 6**, **Table 7** and **Figure 11**).

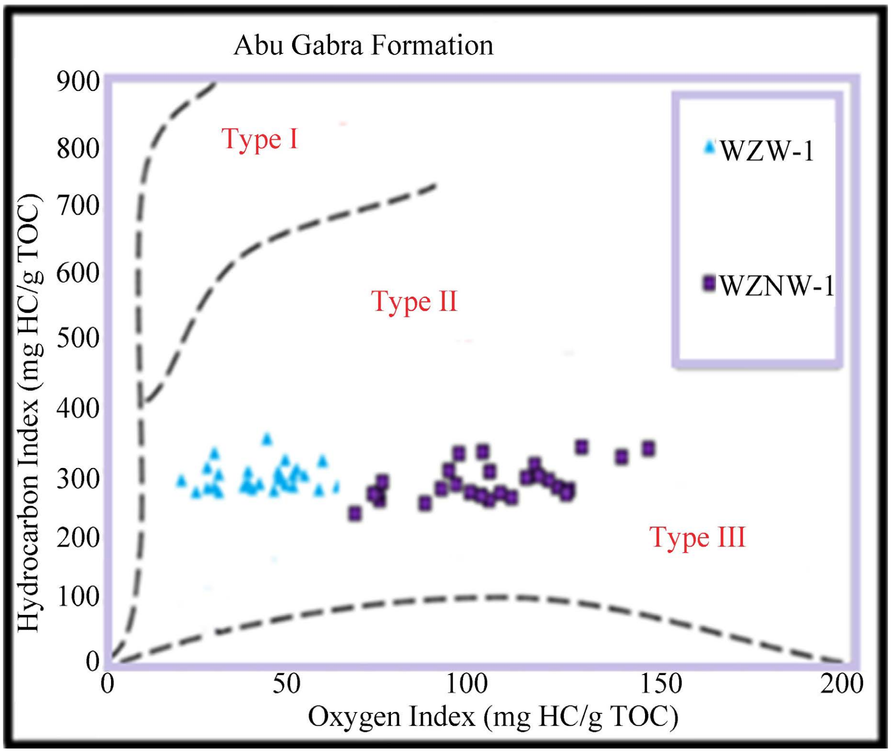

Figure 11. Plot of the studied Abu Gabra samples on a modified van Krevelen diagram.

3.3. Thermal Maturation

Many physical and chemical properties of organic matter are changeable during the thermal evolution of a source rock, during the diagenesis, catagenesis, and metagenesis stages. These changes can be indications for thermal maturity [13]. Assessment of thermal maturity of organic matter in the studied wells was carried out using pyrolysis T_{max} values (**Figures 12-15** and **Table 1**, **Tables 4-7**).

Pyrolysis T_{max} is the most widely used method in evaluating thermal maturity of a source rock, which differs significantly according to the kerogen type [7] [13] [14]. The oil generation window lies between T_{max} values of 435˚C and 465˚C [6].

3.3.1. Baraka Formation

The T_{max} values of the Baraka formation samples from WZW-1, range between 435˚C and 450˚C. This means they are all mature. Then, the T_{max} values for the samples from WZNW-1 range between 415˚C and 450˚C. The T_{max} values for other samples from WZNW-1 range between 415˚C and 430˚C. This means they are immature. Other samples from WZNW-1 range between 430˚C and 450˚C. They are mature and within the oil window Figure 12 and Figure 14.

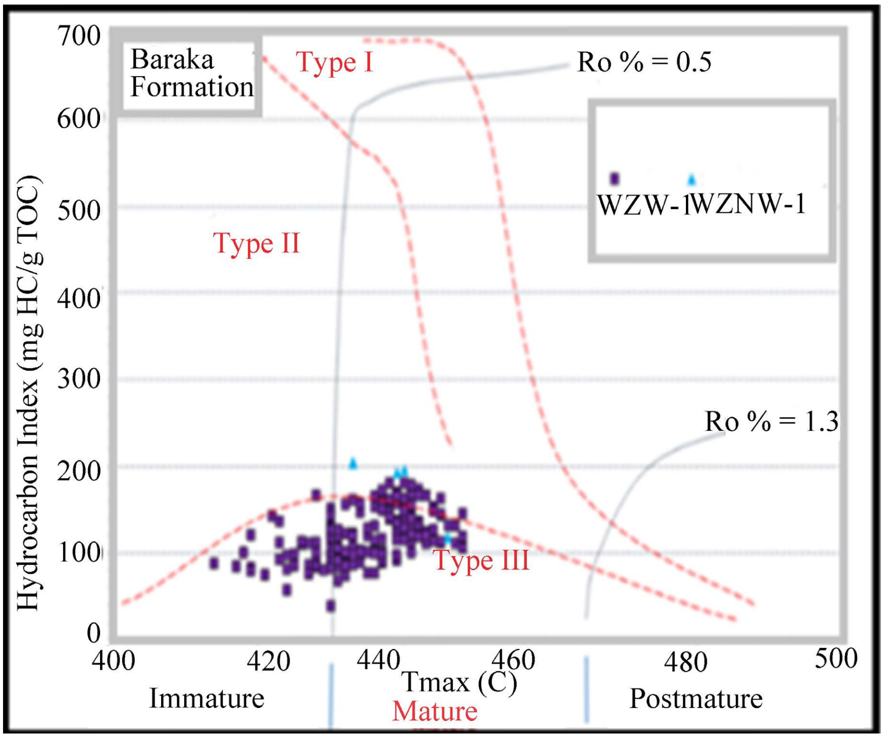

Figure 12. Plot of the study Baraka formation samples on a T_{max} versus hydrogen index diagram.

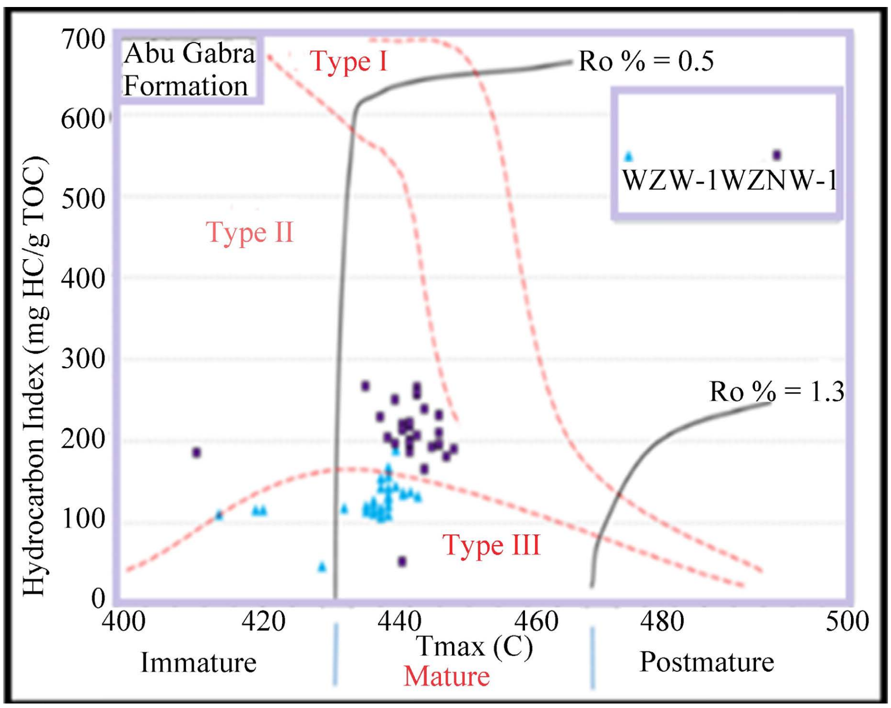

Figure 13. Plot of the study Abu Gabra formation samples on a T_{max} versus hydrogen index diagram.

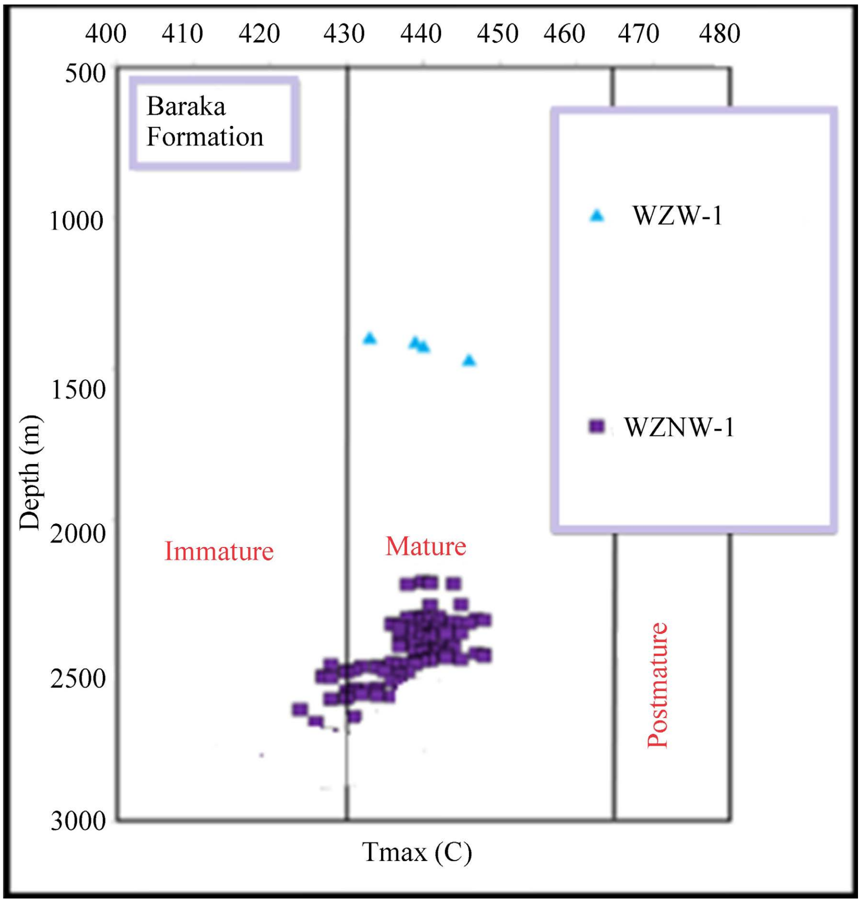

Figure 14. Plot of Baraka formation T_{max} versus Depth for the studied wells (solid lines are based on [6].

3.3.2. Abu Gabra Formation

For Abu-Gabra formation, the T_{max} values for most of the samples range between 430˚C and 450˚C for both WZW-1 and WZNW-1. This implies that most of the samples are mature, and they are within the oil window (**Figure 13** and **Figure 15**).

4. Conclusions

The following can be concluded.

1) The quantity of the organic carbon of the studied Bara formation rock is classified as fair to good Generative potential. They correspond mainly to kerogen type III. Then, the Abu Gabra formation is classified as fair to very good generative potential. They correspond to maily kerogen type II and type II - III.

2) For evaluating the thermal maturity, pyrolytic T_{max} was used. It shows that most of WZW-1 and WZNW-1 samples are located in the immature and mature stages in the Baraka formation, whereas Abu Gabra samples are also located between the immature and mature stages.

3) The Baraka formation seems to be one of the sour rocks in the Muglad Basin, in addition to the known Abu Gabra source rock.

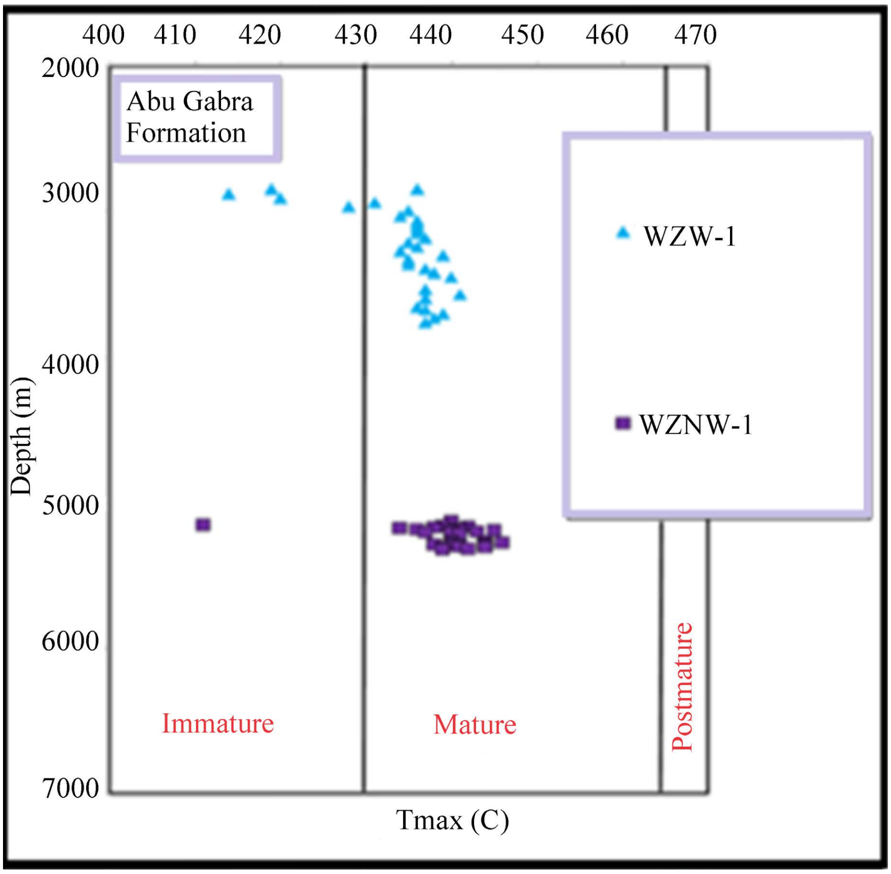

Figure 15. Plot of Abu Gabra formation T_{max} versus Depth for the studied wells (solid lines are based on [6].

5. Recommendations

Although this study presents a relatively comprehensive organic geochemical analysis, the following studies are suggested here.

- Organic petrography should be undertaken to directly determine vitrinite reflectance values. These should then be compared with pyrolysis and biomarker-derived vitrinite reflectance values presented here for accurate thermal maturity estimation.
- Organic stable isotope analyses can be used to continue to refine the origins and environments of deposition of the various source-rock lithofacies.
- If oil samples are recovered from the formation, "oil to source correlation" could be informative in some more wells in the Wizeen oil field.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper. It is for educational purposes.

References

[1] Lirong, D., Dingsheng, C., Zhi, L., Zhiwei, Z. and Jingchun, W. (2012) Petroleum Geology of the Fula Sub-Basin, Muglad Basin, Sudan. *Journal of Petroleum Geology*,

36, 43-59. https://doi.org/10.1111/jpg.12541

[2] Makeen, Y.M., Abdullah, W.H., Hakimi, M.H. and Mustapha, K.A. (2015) Source Rock Characteristics of the Lower Cretaceous Abu Gabra Formation in the Muglad Basin, Sudan, and Its Relevance to Oil Generation Studies. *Marine and Petroleum Geology*, **59**, 505-516. https://doi.org/10.1016/j.marpetgeo.2014.09.018

[3] GPOC (2023) Petroleum System Modeling of Northern Field of Muglad Basin for New Exploration Prospect.

[4] Makeen, Y.M., Shan, X., Ayinla, H.A., Adepehin, E.J., Ayuk, N.E., Yelwa, N.A., *et al.* (2021) Sedimentology, Petrography, and Reservoir Quality of the Zarga and Ghazal Formations in the Keyi Oilfield, Muglad Basin, Sudan. *Scientific Reports*, **11**, Article No. 743. https://doi.org/10.1038/s41598-020-80831-y

[5] Espitalie, J., Madec, M., Tissot, B., Mennig, J.J. and Leplat, P. (1977) Source Rock Characterization Method for Petroleum Exploration. *Offshore Technology Conference*, Houston, 1-4 May 1977, OTC-2935-MS. https://doi.org/10.4043/2935-ms

[6] Peters, K.E. (1986) Guidelines for Evaluating Petroleum Source Rock Using Programmed Pyrolysis. *AAPG Bulletin*, **70**, 318-329. https://doi.org/10.1306/94885688-1704-11d7-8645000102c1865d

[7] Peters, K.E. and Cassa, M.R. (1994) Applied Source Rock Geochemistry. In: Magoon Leslie, B. and Dow, W.G., Eds., *The Petroleum System*: *From Source to Trap*, American Association of Petroleum Geologists, 93-120. https://doi.org/10.1306/m60585c5

[8] Peters, K.E., Walters, C.C. and Moldowan, J.M. (2005) The Biomarker Guide. 2nd Edition, Cambridge University Press. https://doi.org/10.1017/cbo9780511524868

[9] Demaison, G.J. and Moore, G.T. (1980) Anoxic Environments and Oil Source Bed Genesis. *AAPG Bulletin*, **64**, 1179-1209. https://doi.org/10.1306/2f91945e-16ce-11d7-8645000102c1865d

[10] Waples, D.W. (1985) Geochemistry in Petroleum Exploration. International Human Resources Development Corporation, Boston, 232 p.

[11] Hunt, J.M. (1991) Generation of Gas and Oil from Coal and Other Terrestrial Organic Matter. *Organic Geochemistry*, **17**, 673-680. https://doi.org/10.1016/0146-6380(91)90011-8

[12] Van Krevelen, D.W. (1961) Coal: Typology-Chemistry-Physics-Constitution. Elsevier Science, 170p.

[13] Tissot, B.P. and Welte, D.H. (1984) Petroleum Formation and Occurrence. 2nd Edition, Springer, 699p.

[14] Bordenave, M.L. (1993) Applied Petroleum Geochemistry. Editions Technip, 999 p.