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Source Rock Evaluation of the Lower and the Upper Silurian Tanazefet Shale

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الملخص

لقد تم تجميع عينات لبية من بئران من منطقة حوض مرزق لغرض عمل تحاليل جيوكيميائية وذلك لتقييم الصخور المصدرية للنفط في هذه المنطقة باستخدام جهاز الحرق الاهوائي للعينات. هده التقييمات اشتملت تقييمي الكمية والجودة حيت تم استعمال مجموع الكربون العضوي لتقييم الكمية وتم استخدام نوعية الكيروجين لتقييم نوعية المادة العضوية المخزنة والتي بينتها العلاقة مابين نسبتي الأوكسجين والهيدروجين المتحصلة من التحاليل. النتائج أوضحت بأن الطبقة السفلي من تكوين تانازفت تعتبر صخر مصدري ممتاز للنفط وفي المقابل النتائج أظهرت بأن الطبقة العلوية للتكوين تعتبر صخر ردئي لتوليد النفط. وكذالك النتائج أوضحت أن الكيروجين من الفئة الثانية التي ولدت النفط.

Abstract

Core samples of Tanazeft Shale from two wells at Murzuq Basin were collected and analyzed in the Pyrolysis Rock Eval instrument for source rock evaluation includes source rock quality and quantity. The studied samples were collected from NC 115 and NC 174 blocks. The analysis results of total organic carbon (TOC) are the parameter that was used to determine organic matter (OM) richness of shale samples understudy and source rock type was identified as Kerogen type II .This was done by using the cross plot between both Hydrogen and Oxygen Indexes (HI & OI) of the sample results. All indications from sample results shoes that the lower part of Tanazefet Formation (Hot Shale Member) is a very good source rock while the upper part is a poor source rock. These analyses shoes also the kerogen type of the Hot Shale Member is type II which indicate oil prone stage.

Keywords: *source rock, kerogen, hot shale*

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Introduction

Murzuq Basin is considered as a large intracratonic basin covering over 350 000 km2, consists nearly 3500 m thick of sedimentary sequences (Figure,1). However, the stratigraphy of the basin is comprised mostly Palaeozoic and Mesozoic sediments, the principal hydrocarbon play in the basin consists of preglacil sandstone reservoir of Ordovician age sourced and sealed by overlying Silurian shale [1, 2].

The northern part of the Murzuq Basin represents the most important part for the hydrocarbon discoveries in the basin [3, 4]. The distribution and the depositional conditions of the lower Silurian source rock as well as its maturity and the time of oil generation in this part of the basin need farther investigation. To date the geochemical studies remain rather few, with just a limited number of publications largely based on total organic carbon TOC, pyrolysis and uranium contents. A combination of organic geochemistry and organic petrology analyses is therefore necessary for a more complete potential assessment of the basin.

In this study, the lower and the upper parts of the Tanazeft Shale will be geochemically evaluated based on organic geochemistry analysis. Two consitions were choseing to select samples from the lower and the upper parts of Tanazefet shale which is called Hot Shale Member. These consitions are NC 115 and NC 174 (Figure 1)

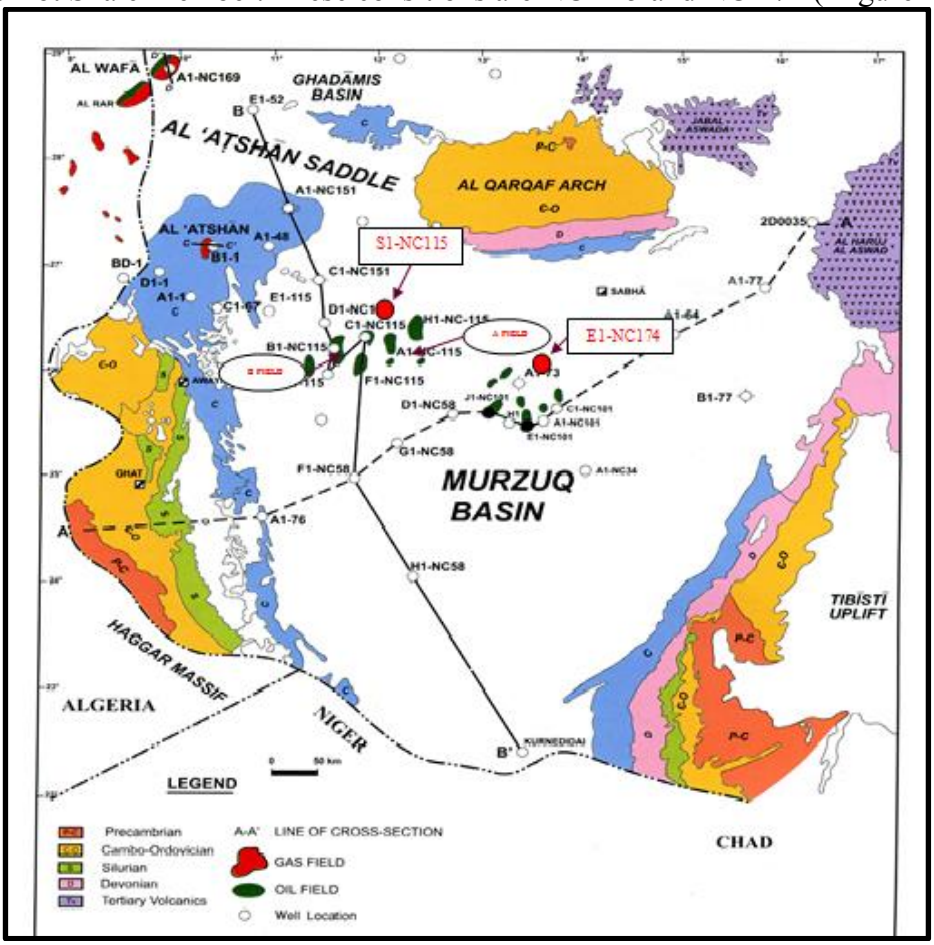

Figure (1): Location map of the NC 115 and NC 174 consitions at Murzuq Basin after [4].

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Stratigraphy and geology of study area.

The stratigraphic column of the Murzuq Basin is showing in Figure (2). The rock unites are reneging from the Precambrian to the Quaternary in age, with missing formations from Late Cretaceous and Cenozoic ages[4].

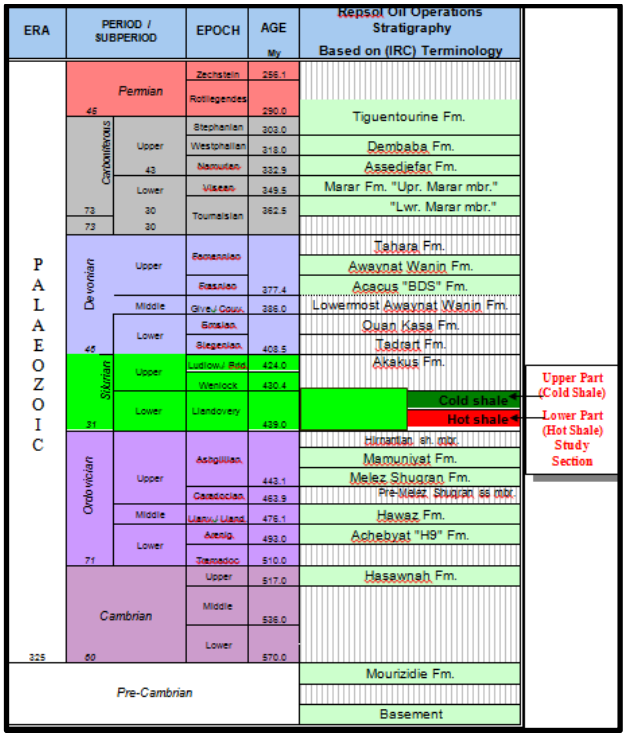

Figure (2): Stratigraphic column of Murzuq Basin [5]

The Silurian began with major transgression which spread from the north, across much of North Africa margin by melting of the ice led to eustatic sea level rise, culminating in highstand with deposition of the Tanezzuft Formation shales. An unconformity separates the Mamuniyat Formation from the overlying shale of the Silurian Tanezzuft Formation [6].

The Tanezzuft Formation consists of dark gray claystone usually with shaly lamination, very compact, frequently micaceous and pyretic, sometimes with silty and sandy interlaminae and beds, which become increasingly common upward[3]. The formation is very rich in graptolites and there are indicate an Early to Middle Llandovery age. The Tanezzuft Formation is up to 475 m thick in outcrop in the southwestern Murzuq Basin, while subsurface thickness in concession NC115 wells varies between 117 and 368 m [3]. The thickness distribution of this formation is showing in (Figure 3). The Tanezzuft shale is generally regarded as the main source in the Murzuq Basin. Tanezzuft hot shale most attractive source potential, the net thickness of the lower highly radioactive shale of the Tanezzuft Formation illustrated in (Figure 3). The geochemical results indicate that the hot shale in the Murzuq Basin has generated huge quantities of hydrocarbon, with in NC-115 alone the hot shale interval may have generated approximately 8.3 to 19.4 mmbb1/km2, giving the potential for

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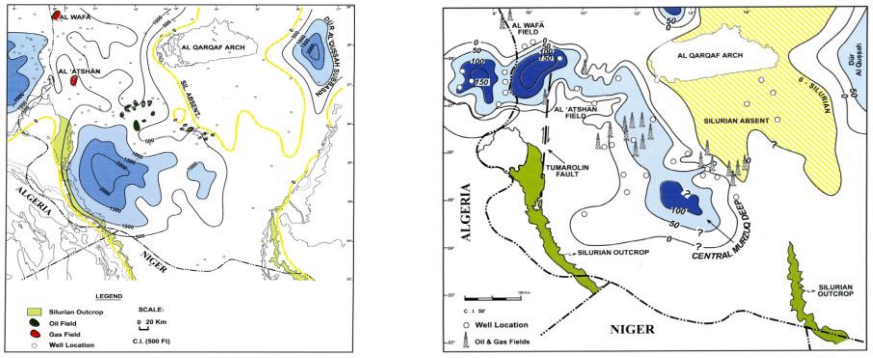
approximate amounts of entraped hydrocarbons in the Murzuq Basin of around 40 billion barrels [3]. The anoxic conditions of deposition of the hot shales probably developed as a result of restricted marine circulation in shallow seas broken by numerous islands and peninsulas, the natural result of a low energy marine transgression over an irregular post-glacial topography. The Early Silurian bottom waters were dense and very anoxic which, coupled withvery low sedimentation rates, allowed the preservation of very high concentration of organic matter [1].



A B

Figure (3):Isopach map of Tanezzuft Formation (A) and the Hot Shale Member (B) [4].

Methodology

The Geochemical routine work started from washing, drying, lithological description, picking and crushing was done of all selected samples to be ready for further geochemical analyses. All samples cleaned from drilling mud and any contamination by normal water for many times and sieved by using very fine sieve (mesh No. 325 and Aperture 45 MIC) until all contaminated material is clearly removed. The samples kept in an oven under temperature about 40 ^{o}C for period time (24 hours) to be surely all water evaporated. The picking means pick-up the grains which believe are represented the specific interval of source rock. To be in safe, the big and strange grains which might be reworked or caved have been ignored. By using crushing machine all picked grains of the rock samples were crushed to become powder for further analysis. The normal water and organic solvent (Methanol) were importantly used for clean crushing machine container after each sample to avoid the contamination which may be caused between the samples. The pyrolysis technique (Rock Eval 6/TOC) is now widely used to evaluate the source rock richness and potentiality.

Result and Discussion

Obtained results from analyzed rock samples (cutting and core) from S1-NC115 and E1-NC174 wells that have been run in Rock Eval 6/TOC instrument are shown in table (1, 2).

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Table (1):showing the Rock-Eval results of the samples from wellS1-NC115.

S.No	Formation	Depth (ft)	S1	S2	S3	Tmax	OI	HI	TPI	TOC
1	Awaynat-Wanin	3260.00	0.14	2.50	0.20	441	13	165	0.05	1.52
2	Awaynat-Wanin	3410.00	0.17	3.71	0.29	445	23	299	0.04	1.24
3	Tanazzuft	4670.00	0.17	0.95	0.06	448	16	242	0.15	0.39
4	Tanazzuft	4675.00	0.20	0.95	0.07	442	18	232	0.17	0.41
5	Tanazzuft	4700.00	0.56	1.98	0.09	446	8	187	0.22	1.06

Table (2): showing the Rock-Eval results of the samples from wellE1-NC174.

S-NO	Formation	Depth (ft)	S1	S2	S3	Tmax	HI	OI	TPI	TOC
1	Tanazzuft	6350.00	0.03	0.44	0.80	439	83	152	0.06	0.52
2	Tanazzuft	6900.00	0.03	0.65	0.71	443	157	172	0.04	0.41
3	Tanazzuft	7242.00	2.58	16.47	0.18	442	278	3	0.14	5.92
4	Tanazzuft	7254	4.46	33.81	0.14	440	298	1	0.12	11.35
5	Tanazzuft	7268.00	3.00	23.68	0.14	446	320	2	0.11	7.40
6	Tanazzuft	7284.00	3.04	16.71	0.14	443	302	2	0.15	5.54

Table (3) summarizes the results from Rock-Eval and bulk geochemical analyses that were carried out on eleven samples from S1-NC115 (this project) and E1-NC174 (analyzed previously from MSc. dissertation) [5].At the S1-NC115 and E1-NC174 wells the whole of the Tanezzuft Formation was geochemically analyzed, there is a vertical variation in the total organic carbon (TOC) content. The highest value of TOC (11.35 %) was recorded in well E1-NC174 at a depth of 7254 feet within the Lower Tanezzuft Formation, while the lowest value (0.39 %) occurred in S1-NC115 well at a depth of 4670 feet within the Upper Tanezzuft Formation. The TOC and hydrogen index (HI) profiles (Figure 4) peak at four points, within the Lower Tanezzuft Formation (7242' – 7284') with an average of 7.5% TOC and 300 HI (mg HC/gTOC).
No systematic increase in the T_{max} (Table 3) was observed through the wells S1-NC115 and E1-NC174. But the PI increases from less than 0.1 to more than 0.1 in both wells (Figure 5).

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Table (3):Summary of bulk geochemical analyses data, shown the meanaverage.

Location	Formation	Depth (ft)	T_{max}	S_1	S_2	TOC %	PI	HI
S1-NC115	Upper Tanezzuft	4670	448	0.17	0.95	0.39	0.15	242
	Lower Tanezzuft	4700	446	0.56	1.98	1.06	0.22	187
E1-NC-174	Upper Tanezzuft	6350	439	0.03	0.44	0.52	0.06	83
	Lower Tanezzuft	7254	440	4.46	33.81	11.35	0.12	320

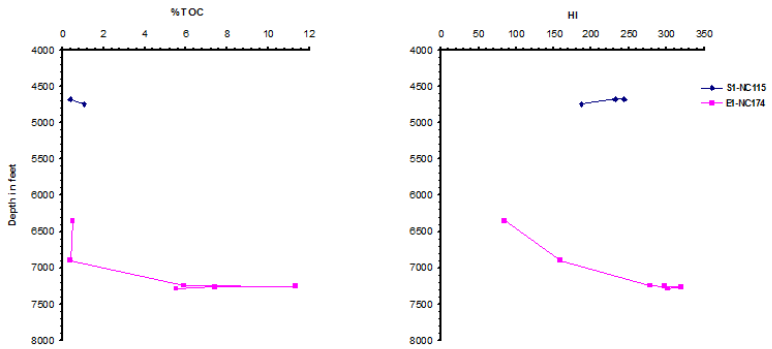

Figure (4):The variation of Total Organic Carbon (TOC wt %) and the Hydrogen Index (HI) with depth.

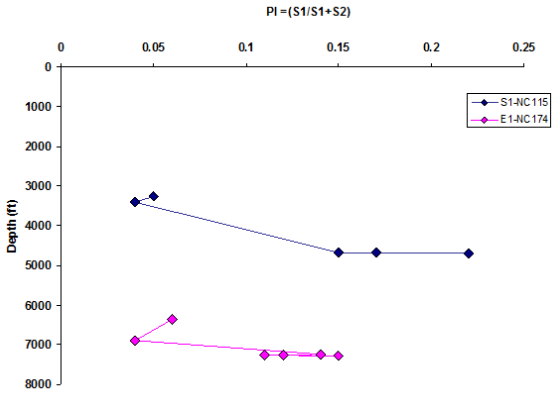

Figure (5): Productivity Index versus Depth.

The petroleum potential of source rock is defined by its geochemical parameters which represent the amount and quality of organic matter contained in the sediments along with its thermal maturity. The samples results can be discussed in this chapter into four points: Source Potential, Maturity, Source to oil correlation and Burial history and Timing of Oil Generation of the study wells. Generally, the Lower Tanezzuft Formation hot-shale are characterised by graptolitic laminated dark grey to black shale. The intervals of dark shale with high organic carbon content (TOC >1%) give initial indicators of a potential source rock; greater source potential is usually associated with

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the darker-coloured lithologies. However, the colour and organic carbon content are not enough to characterise source rock potential, other geochemical characters of the organic matter (e.g. Hydrogen Index, Total yield and kerogen Type) are required to ensure the hydrocarbon potential.

The Lower Tanezzuft Formation Hot Shale, in well S1-NC115 and well E1-NC174 all have mean TOC values greater than 6 wt % (Table 3), which indicates very good source potential. Whereas the Upper Tanezzuft Formation cold-shale has mean TOC <1 wt%, which makes it only a fair to poor quality source rock, and represents the lowest potential unit within this section. The hydrogen index values for the whole section range from 83 to 320(mgHC/g TOC) (Table 3) with an average value of more than 210 denoting oil potential. The Lower Tanezzuft hot-shale characterised by hydrogen index values more than 300 suggesting an oil-prone source rock, while the Upper Tanezzuft cool-shale characterised by hydrogen indexes from 80 to 150 suggesting oil to gas prone source rocks [7].

To obtain an idea of the kerogen type and the source rock quality, the TOC values are plotted against the S_2 (the amount of hydrocarbons that still remains within source rock). It can be observed from Figure (6) that the Lower Tanezzuft hot-shale consists predominantly of Type II kerogen with calculated hydrogen index values of 313(HI is calculated from the slope of TOC and S_2). The Lower Tanezzuft Formation hot-shale at S1-NC115 and E1-NC174 has mean S_2 values of 19 mg/g, indicating high residual potential. In contrast, the Upper Tanezzuft cold-shale is characterised by low S_2 (mean S_2 = 0.75 mg/g), indicating they retain very poor potential. However, the Lower Tanezzuft hot-shale is mature (see maturity displaying), and this may suggest that at these localities has already generated hydrocarbons, which causes a reduction in the calculated hydrogen values (calculated HI = the slope of TOC versus S_2). Therefore, the cross plot of TOC and S_2 is restricted to immature to early mature source rock samples [8].

Kerogen type can also be assessed from a plot of Hydrogen Index values against, oxygen index Figure (7). This cross plot was clearly shown that two samples from well E1-NC 174 in kerogen type III area , where all Lower Tanazzufthot-shale samples are classified in kerogen type II area.

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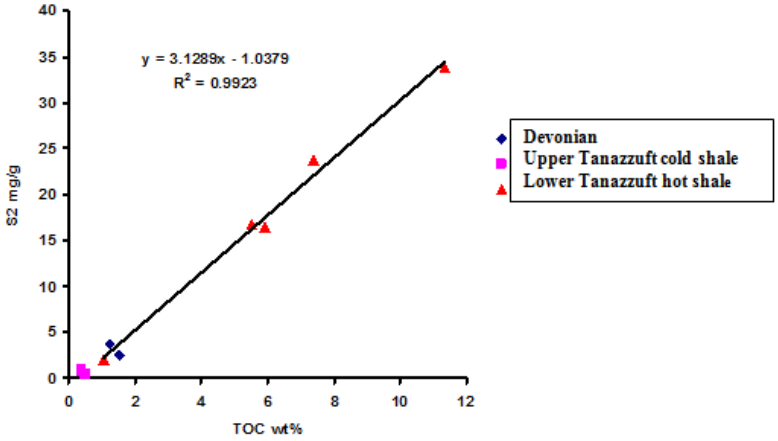

Figure (6):.The relationship between the S_2 and TOC, with calculated values for the hydrogen index. Note; hydrogen index values were calculated from the slope of TOC and $S_2$for S1 NC-115 and E1 NC-174 wells.

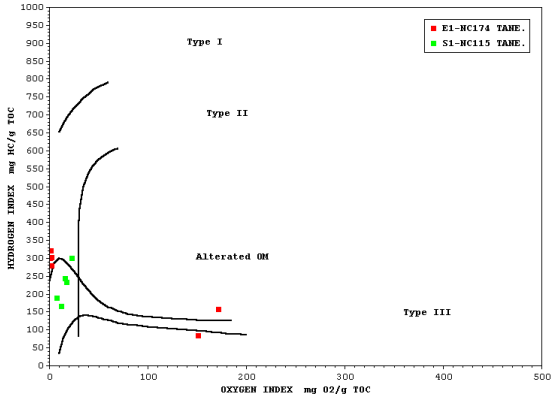

Figure (7): Across plot of the HI versus OI to investigate the kerogen type, all of thedata is plotted in the area that indicates kerogen type II

Conclusion

Interpretation based on the geochemical analysis which were carried out on the studied samples from S1-NC115 and E1-NC174 wells, a number of points can be concluded

The Lower Silurian source rocks (especially the lower part of Tanezzuft Formation hot-shale) are very good source rock potential characterised by graptolitic laminated dark grey to black shale. Consists predominantly of marine Type II oil prone kerogen with calculated hydrogen index values of 313mg HC/gm TOC.

The Lower Silurian Upper Tanezzuft Formation cold shale has mean TOC <1 wt% and low hydrogen index average 120 mg HC/gTOC,which makes it only a fair quality source rock and may produce gas if it is mature enough.

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