Evaluation of Hydrocarbon Source Rock Potential of Well 2A1-59, Western Sirte Basin, Libya

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Abstract

The present work is aimed to evaluate the source rock potential of the Turonian-Campanian rocks (i.e. Etal, Rachmat and Sirt formations) in the well 2A1-59, Sirte Basin, NE Libya. Based on the Total Organic

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Carbon values (TOC), the Etal Formation is fair source rock, the Rachmat Formation is characterized by good to excellent quality, and the Sirt Formation has quality ranging from good to excellent. The Etal Formation contains kerogens of type II/III and type IV, whereas the Rachmat and Sirte formations are characterized by types II and II-III. Based on the T_{max} values, the source rocks are classified as thermally immature and mature.

Keywords: *Organic Geochemistry, Source Rock, Etal Formation, Rachmat Formation, Sirt Formation, Sirte Basin, Libya.*

1. Introduction

Sirte Basin contains 82% of all the oil and 32% of all the gas found in Libya, and consequently has received far more attention than any other region. More wells have been drilled in the basin than in the rest of Libya put together. The reasons for this are that the Sirte Basin, unlike the Kufrah, Murzuq and Ghadamis basins, is principally a Mesozoic and Tertiary basin. It contains excellent Cretaceous source rocks which reached maturity in the Tertiary, a multitude of good quality reservoirs, effective regional seals and structures which for the most part were formed before the principal phase of oil migration (1). The troughs in this basin are Zallah trough, Al - Kotlah Graben, Maradah trough, Ajdabiya trough and Hameimat trough. In addition, there are many small grabens and lows which in different places in Sirte Basin possibly containing local source rocks of Sirt Shale (1). The current study aims to evaluate the source rock potential of the Turonian-Campanian rocks (i.e. Etal, Rachmat and Sirt formations) in the well 2A1-59, Sirte Basin, NE Libya (Fig.1). Etal Formation is represented by evaporites, shale and minor carbonates deposited, while Sirt and Rachmat formations are represented by shale sequence and some of carbonate rocks (Tagrift limestone

(Fig.2)). However other studies recognize other Upper Cretaceous source rocks contributors within Sirte Basin (e.g., 2; 1; 3; 4; 5, 6).

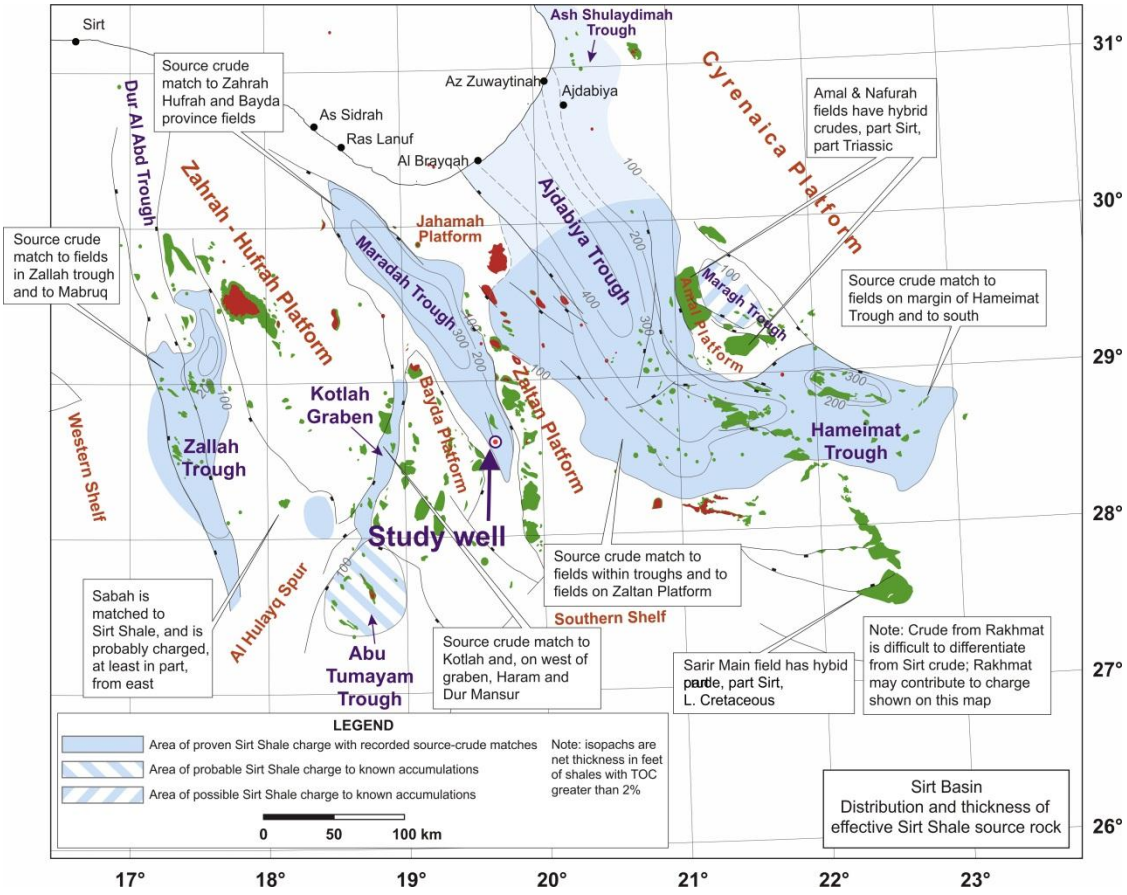

Fig.1 Geological map of Sirte Basin showing the location of the study well 2A1-59 (7).

2. Objective of the Work

The main objective of the present work is to determine the following**:**

- Organic matter richness**.**
- Kerogen type.
- Thermal maturity.

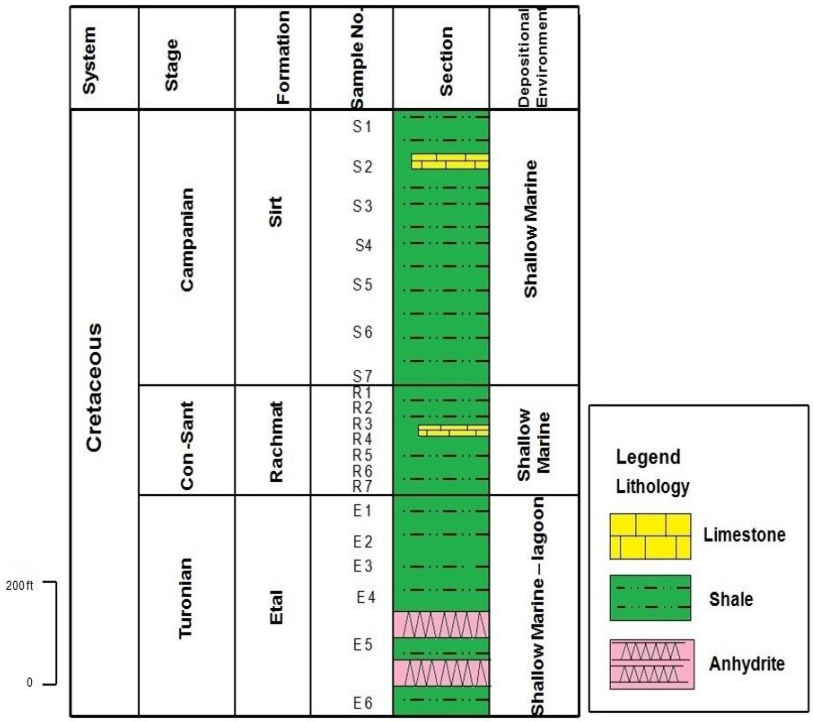

Fig.2 Columnar section of the study well 2A1-59.

3. Petroleum System Overview

The reservoirs in Sirte Basin are represented by clastic and carbonates rocks. The clastic reservoirs are occurred in Cambro-Ordovician, while the carbonate reservoirs are occurred in the Upper. The Sirte Basin is dominantly vertically migrated petroleum system. Upper Cretaceous oil charges multiple reservoirs along the fault zones adjacent to horsts and grabens. Sirt shale of Upper Cretaceous is the dominant mature source rock in the Sirte Basin petroleum system, this shale is thick and preserved in the lows and trough areas scattered in different part of west and east of Sirte Basin Several other potential source rocks have been considered. Sealing petroleum system is provided by the Upper Cretaceous (shale - argillaceous limestone), Eocene (evaporites) and

some other impermeable rocks of other formations. The dominant trap style in Sirte Basin is structural type with some of stratigraphic trap or a combination of the two types (6).

4. Materials and Methods

4.1. Samples

Twenty ditch cutting samples consisting of shale and calcareous shale was collected by the Waha Company from the depth interval 6890 to 8370 ft. of the well. The samples were analyzed to determine their Total Organic Carbon (TOC), and to identify thermal maturity of organic matters. The cover samples included Sirt Formation (Campanian), Rachmat Formation (Coniacian-Santonian) and Etel Formation (Turonian (Fig.2)).

4.1.1. Preparation of Cutting Samples

The cutting samples were washed with doubly distilled water and dried at room temperature prior to analysis. These samples were ground to a fine powder (particle size of <150 μm) using a ring-mill. The TOC content was determined on 100mg powered sample using a LECO carbon analyzer (CR-412). Rock-Eval pyrolysis was determined on 100mg powered sample using an OGE-II rock pyrolyzer. The initial temperature of Rock-Eval pyrolysis was set at 300°C for 3min, then increase to 600°C at a rate of 25°C/min. The Rock-Eval parameters including volatile hydrocarbon content (S_1), remaining hydrocarbon generative potential (S_2), and temperature at maximum generation (T_{max}) values of all samples were determined. All analyses used in this work were conducted in Arabian Gulf Oil Company (AGOCO) Laboratory.

5. Rustles and Discussions

Table (1). Illustrates the values of total organic carbon and Rock–Eval pyrolysis for the studied samples of the Etal, Rachmat and Sirt formations. The obtained data shows the Etel Formation contents low TOC (< 1) reflecting fair quality of source rock, Rachmat Formation contains high TOC (<1% - >2%) indicating fair to excellent source rock, whereas the Sirt Formation has high TOC content (>2%) is characterized by good to excellent source rock.

Table: 1. Rock- Eval and TOC data for the Etal, Rachmat and Sirt formations in the study well 2A1-59.

Sample No	Sample type	Depth	Fm.	Tmax	TOC	HI	OI	PI	S1	S2	S1+S2	S3
1	Cutting	6890	Sirt Formation	438	1.08	245	71	0.1	0.28	2.65	2.93	0.77
2	//	7220		433	1.72	406	49	0.1	0.75	7	7.75	0.85
3	//	7270		434	2.28	475	38	0.09	1.05	10.8	11.85	0.87
4	//	7310		436	1.65	375	51	0.09	0.61	6.18	6.79	0.85
5	//	7350		436	1.93	455	37	0.09	0.9	8.8	9.7	0.73
6	//	7380		435	2.85	484	37	1	1.52	13.8	15.32	1.08
7	//	7410		433	2.67	474	44	1	1.43	12.67	14.1	1.19
1	//	7530	Rachmat Formation	432	4.22	511	33	0.12	2.93	21.57	24.5	1.43
2	//	7610		434	2.91	502	34	1	1.69	14.61	16.3	1
3	//	7650		437	1.38	310	50	0.12	0.56	4.29	4.85	0.7
4	//	7680		436	0.76	426	76	0.1	0.38	3.24	3.62	0.58
5	//	7710		438	0.71	405	92	0.11	0.35	2.88	3.23	0.66
6	//	7750		435	1.08	244	0	0.11	0.32	2.64	2.96	0
7	//	7800		436	1.15	271	0	0.1	0.36	3.12	3.48	0
1	//	7890	Etal Formation	434	0.91	221	0	0.1	0.26	2.02	2.28	0
2	//	7930		434	0.55	138	0	0.17	0.16	0.76	0.92	0
3	//	7990		431	0.56	164	0	0.19	0.22	0.92	1.14	0
4	//	8080		436	0.86	201	113	0.17	0.34	1.73	2.07	0.9
5	//	8200		437	0.67	150	0	0.15	0.18	1.01	1.19	0
6	//	8370		434	0.55	0	0	0.16	0.16	0.85	1.01	0

In additional Sirt and Rachmat formations become the most promising source rock for hydrocarbon generation as reflected by high pyrolysis yield (S_2) and total organic carbon (TOC wt %) content. This assumption is also supported by the plot of TOC versus S_2 (Fig. 3). Overall, the relation between genetic petroleum potential (S_1 + S_2) and TOC of the studied samples in well 2A1 59 (Fig.4) confirms the above results, indicating the majority samples from the Sirt and Rachmat formations locates in the zone of the potential source rocks for hydrocarbon generation, while the Etal Formation locates in the zone of non -potential source rock .

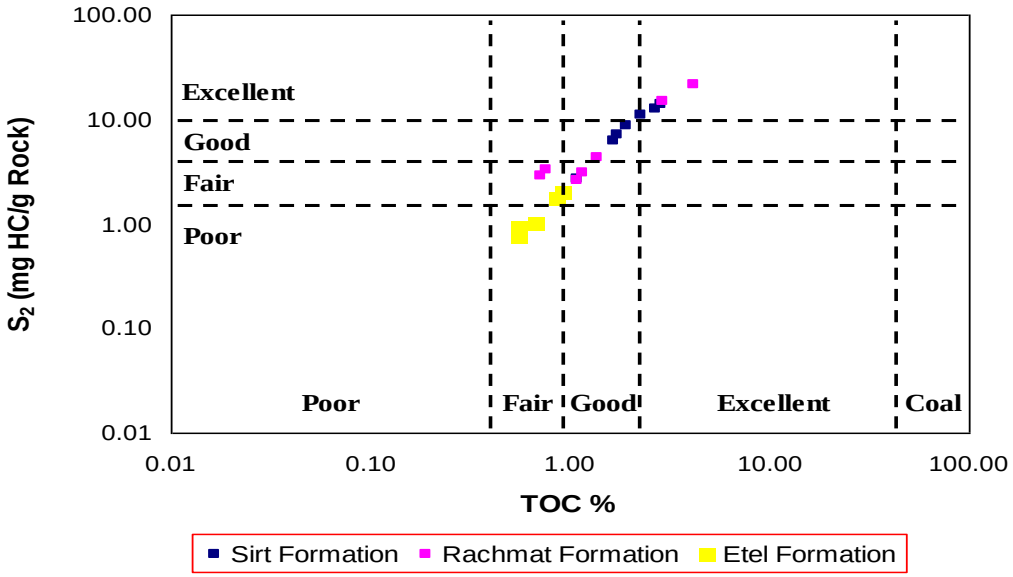

Fig.3 Plot of TOC vs. S_2 showing the hydrocarbon potentialities for the Etal, Rachmat and Sirt formations (fields after 8).

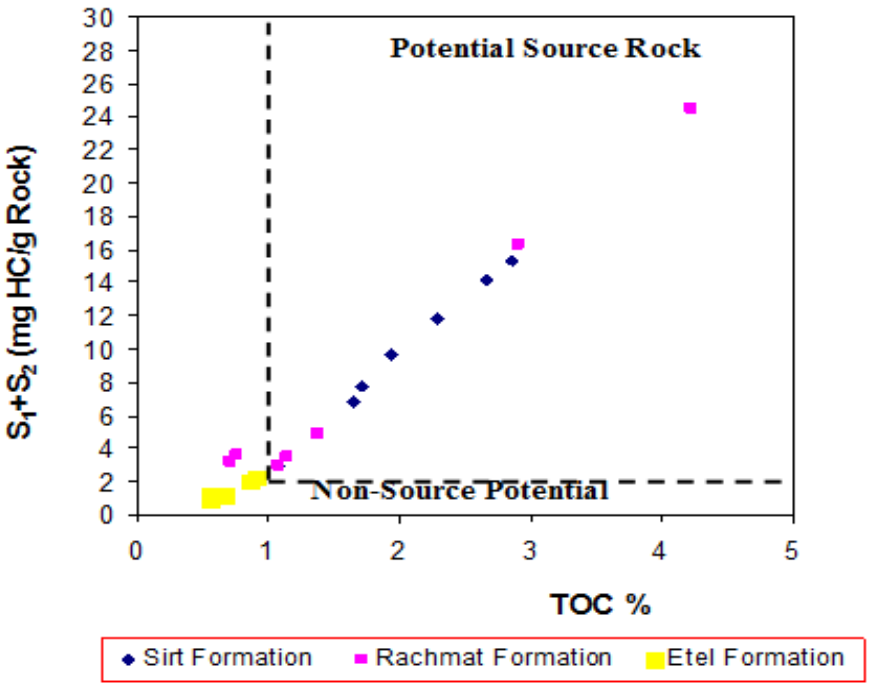

Fig.4 Plot of TOC vs. S_1+S_2 showing the hydrocarbon potentialities the Etal, Rachmat and Sirt formations (fields after 9).

The relationship between the Hydrogen Index (HI) and Oxygen Index (OI) reflects that, Etal Formation contains mixed type II, II/III and type IV of kerogen where Rachmat and Sirt formations contain type II and type II/III kerogen (Figs.5-6). Generally, the majority samples of Sirt and Rachmat formations are thermally mature whereas the Etal Formation is thermally immature to mature (Fig.7).

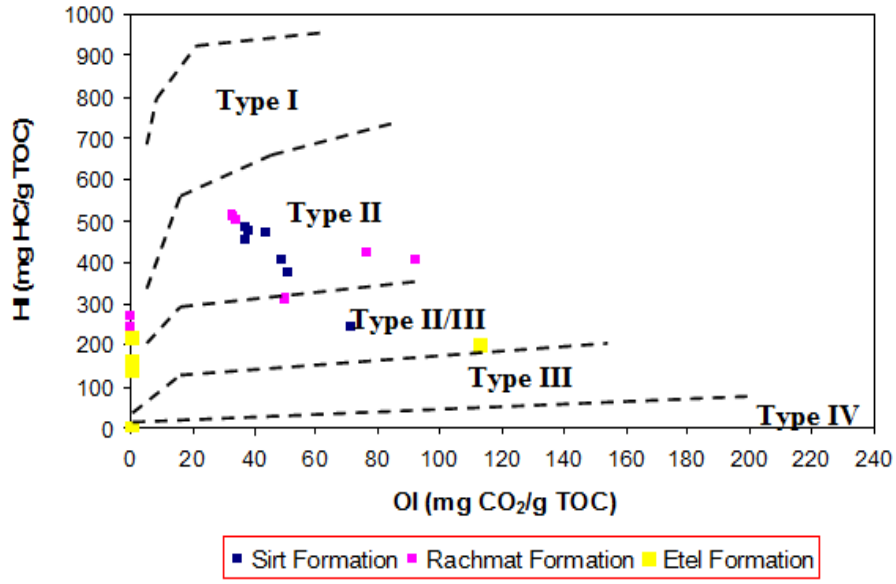

Fig.5 Plot of OI vs. HI showing the kerogen type for the Etal, Rachmat and Sirt formations (fields after 10).

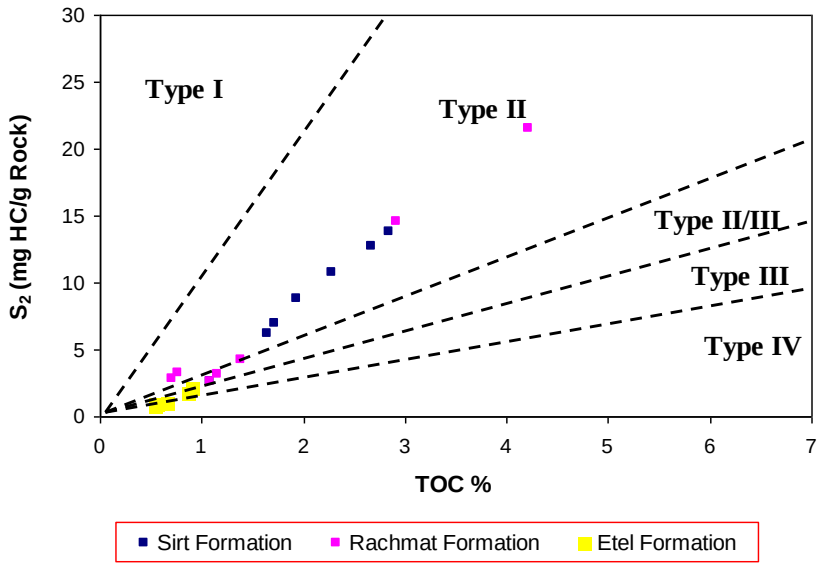

Fig.6 Plot of TOC vs. S_2 showing the kerogen type for the Etal, Rachmat and Sirt formations (fields after 11).

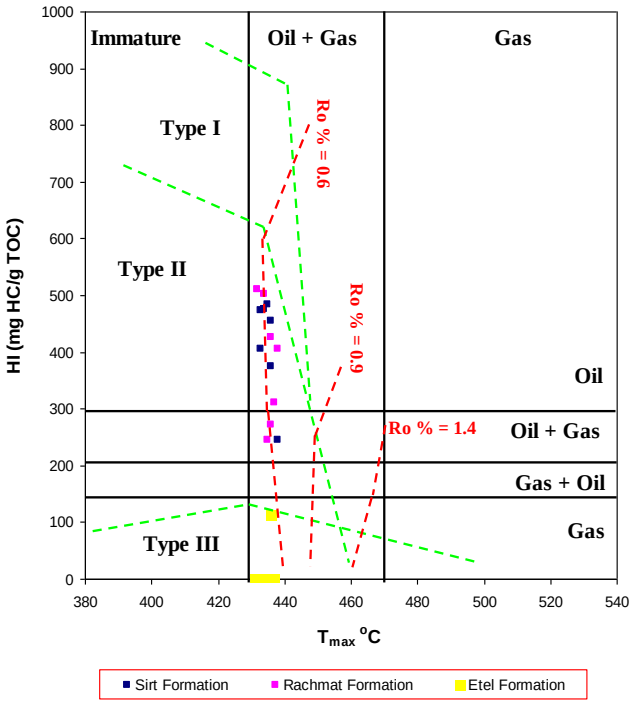

Fig.7 Plot of Tmax vs. HI showing the thermal maturity for the Etal, Rachmat and Sirt formations (fields after 6).

According to (12) the S_1/TOC ratio range of 0.1–0.2 is indicative of source rocks entering the window of oil maturation. Ratios more than 1.5 indicate the contribution of nonindigenous migrated oil. The ranges of 0.25–0.69 for the analyzed samples suggest an indigenous non-migrated nature for the hydrocarbons (Fig.8).

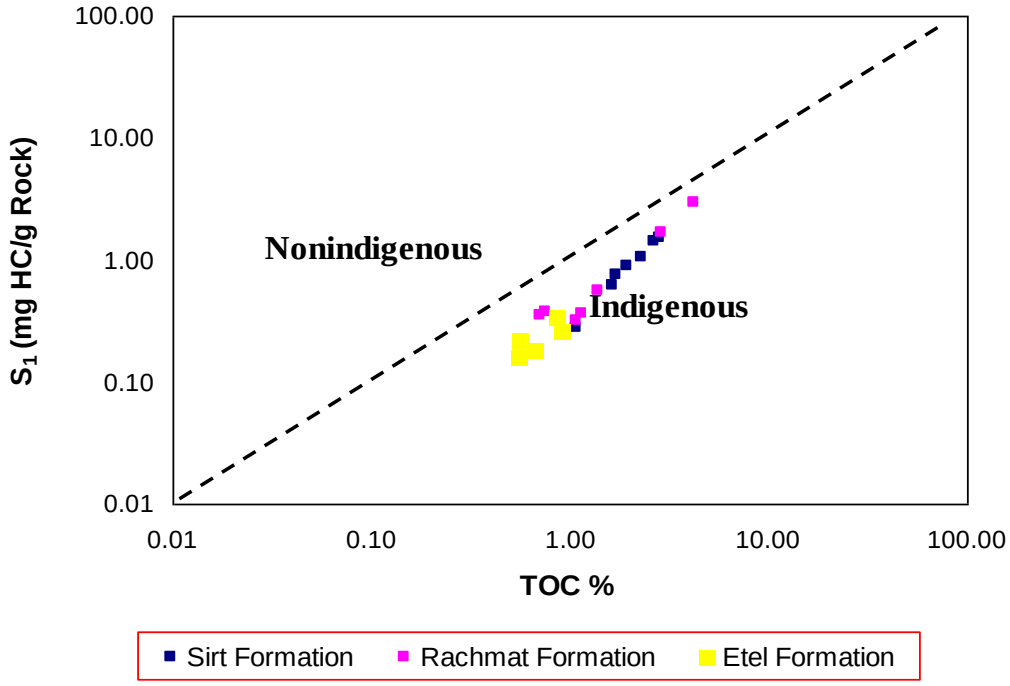

Fig.8 Plot of TOC vs. S_1 showing the hydrocarbon type for the Etal, Rachmat and Sirt formations (fields after 13).

6. Conclusions

Geochemical Rock-Eval and organic carbon analysis (LECO) were performed on twenty (20) samples from the Well 2A1-59. The results of the analyses led to the following conclusions.

1- The Etal Formation is poor to fair source rock, Rachmat Formation shows fair to excellent source rock while Sirt Formation is mainly good to excellent source rock.

2- The organic matter type of Etal Formation is characterized by mixed type II, II/III and type IV of kerogen, whereas the Rachmat and Sirt formations are predominant type II and type II/III of kerogen.

3- The Etal Formation is classified as non-potential source with thermally immature to mature, whereas Rachmat and Sirt formations are classified as potential source with thermally mature.

7. References

[1] Hallett, D. (2002): Petroleum geology of Libya. Amsterdam, Elsevier Inc., 503 p.

[2] Rusk, D. C. (2001): Petroleum potential of the underexplored basin centers—A twenty-first-century challenge, in M.W. Downey, J. C. Threet, and W. A. Morgan, eds., Petroleum provinces of the twenty-first century: AAPG Memoir 74, p. 429–452.

[3] Aboglila S., and Elkhalgi A. (2013): Organic Geochemical Evaluation of Cretaceous Potential Source Rocks, East Sirte Basin, Libya. International Journal of Geosciences; 700-710 p.

[4] Khaled K., Darwish M., Abu Khadra A. and Burki M. (2014): Geochemical Evaluation of Campanian Sirte Shale Source Rock, Arshad Area, Sirt Basin, Libya., IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG); Volume 2, Issue 3, 84-101p.

[5] Hassan S. and Christopher C. (2014): Hydrocarbon Provinces of Libya: A Petroleum System Study. AAPG Special Volumes; 101-141 p.

[6] Hallett, D. and Lowes C. D., (2016): Petroleum geology of Libya. 2nd edition, Amsterdam, Elsevier Inc., 404p.

[7] Sikander, A.H., Basu, S., Rasul, S.M. and Wafa, F. (2008): Hydrocarbon potential and volumetric considerations for the Cretaceous source rocks, SE Sirt Basin. Third Symposium on the

Sedimentary Basins of Libya, Geology of East Libya, vol. 2 (eds. M.J. Salem, R.M. Aburawi, A.A. Misallati), Earth Science Society of Libya, Tripoli, p. 151–254.

[8] Dembicki, H.J. (2009): Three common source rock evaluation errors made by geologists during prospect or play appraisals. AAPG Bulletin; 93(3): 341-356.

[9] El Nady, M.M., Hussein, S.A., Sharaf, L.M. and Ghanem, M.F. (2016): Quantity, thermal maturity of organic matter and relation to prospective source rock horizons in Tut-1x well, North Western Desert, Egypt. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects; 38(21): 3187-3194.

[10] Van Krevelen, D.W. (1961): Coal: typology-chemistry physics constitution: Elsevier Science, Amsterdam; 514p.

[11] Longford, F.F. and Blanc-Valleron, M.M. (1990): Interpreting Rock-Eval pyrolysis data using graphs of pyrolyzable hydrocarbons vs. total organic carbon, AAPG Bulletin; 74: 799-804.

[12] Hall, L.S., Boreham, C.J., Edwards, D.S., Palu, T.J., Buckler, T., Hill, A.J. and Troup, A. (2016): Cooper Basin source rock geochemistry: Regional hydrocarbon prospectivity of the Cooper Basin. Geoscience Australia, Part2; 62p.

[12] Smith, T.J., 1994. Petroleum system logic as an exploration tool in a frontier setting. In: Magoon, L.B., Dow, W.G. Eds.), The Petroleum System-From Source to Trap (Vol. American Association of Petroleum Geologists Memoir (60). American Association of Petroleum Geologists, Tulsa, p. 665.

[13] Hunt, J.M. (1996): Petroleum geochemistry and geology, 2nd edition, vol. 743. New York; Freeman and Company. Nnmber of Pages?