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Evaluation of Neocomian Shale source rock In Komombo Basin, Upper Egypt

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Abstract

Komombo Basin is one of many other basins located in the southern Western Desert of Egypt that is characterized by its high oil potentialities. Rock-Eval pyrolysis, stable carbon isotopes of crude oils and related source rocks revealed extracts Organic-rich rocks with excellent potential to generate mainly oil. This oil is present in the Early Cretaceous Neocomian shale that reached the early mature stage of oil generation window at vitrinite reflectance measurements between 1.2-1.3% Ro%. Rock-Eval payrolosis TOC % of the samples indicate good source rock since the values ranges from 2.00 to 5.79 TOC wt. % and an average values of 1.80 TOC wt., % at the interval depth 7970-8446 of Komombo-2 well. The pyrolysis yield S2 of 1.50 - 13.89 mg/g HC (av. 4.24 mg/g HC) and associated hydrogen index (HI) values (131-338). The oil is generated at a high thermal maturity (about 0.95% Ro equivalent) from lacustrine shales containing mixed terrigenous and marine organic matter deposited in a moderately oxidizing sedimentary environment. Al Baraka wells produced oils which probably suffered light-end loss by water washing, in variable proportions. The carbon isotop δ13 C values for all oils are lighter than those of the marine Gulf of Suez oils and also significally distinct from the North Western Desert oils, which might be related to the nature of the source rocks that generated these oils.

Keywords: *Structure, Stratigraphy, Depositional, Environment, Source Rock, Basin Modeling, Cretaceous, Komombo, Nile Valley, Upper Egypt, Egypt.*

1. Introduction

Historically in Egypt, petroleum exploration focus has moved from the Gulf of Suez, to the Western Desert, to the Nile Delta onshore, the Nile Delta offshore and back to the Western Desert. Southern Egypt has only attracted sporadic interest since the 1990's with success finally arriving by drilling within komombo concession (Fig. 1a).

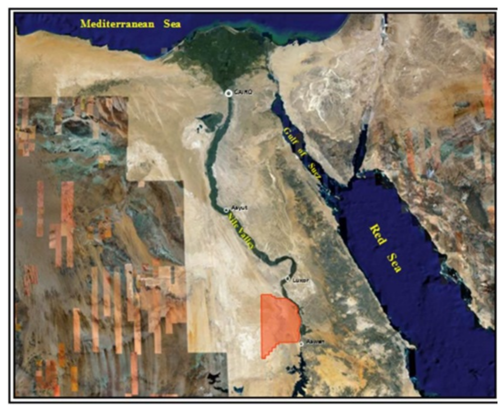

Fig. 1a: Komombo concession index map in Upper Egypt

In 2007 drilling of the Al Baraka-1 well was success and the establishment of the Al Baraka Field (Fig. 1b). However, without a solid subsurface database, the geology of this southern remote basin of Egypt remained little known.

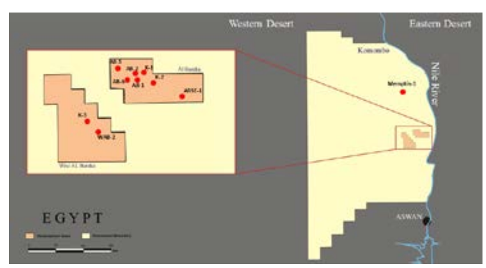

Fig. 1b: Al Baraka field location in Komombo concession

2. GEOLOGICAL SETTING

The Komombo basin in Upper Egypt is a half-graben system and contains thick non-marine sediments deposited during Early Cretaceous Hauterivian, Neocomian to Barremian followed by marine deposition during

Cenomanian/Albian (argillaceous sandstones and shales) and later shales and marine limestones during Late Cretaceous and early Tertiary (Dolson et al., 2001).

Schull (1988) and Taha (1992) documented production from similar nonmarine rifts in South Sudan, which have an analogous tectono-stratigraphic history, possibly related to Mesozoic rifting of the African/Arabian Plate. Recent modelling and re-interpretation of magnetic and gravity data confirmed the presence of about 3.8 kms (12,500 ft) thick sediments within the basin (Meshref, 1990).

Wood et al., (2012) stated that two major sedimentary sequences, separated by an angular unconformity, can be distinguished. A basal Early Cretaceous sand/shale sequence is lying directly on the metamorphic basement, overlain by an Early Cretaceous to Late Cretaceous sand/shale sequence. Sedimentation effectively terminated in the Santonian/Campanian coincident with the earliest development of the Red Sea which bounds the eastern side of the Western Desert basin. Massive erosion and back filling by the proto Nile River has completed the sedimentary history of the western desert area (Fig. 1c)

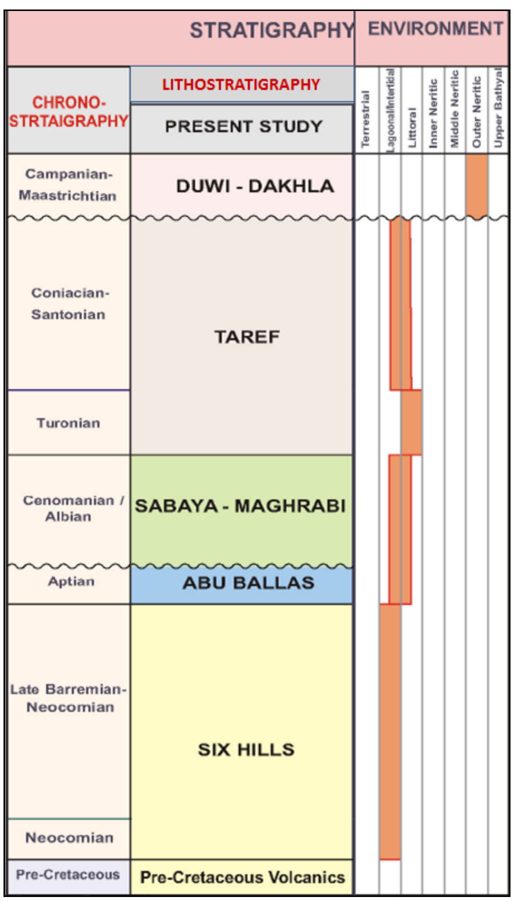

Fig. 1c: Komombo Concession Generalized Stratigraphic Column

The basal sequence consists of non-marine sands and shales deposited in a restricted marine environment, while the overlying sequence consists of a basal non-marine section grading upward into marginal and coastal marine environment deposits. Both sequences have oil potential. Structurally, field reservoirs are controlled by two main extensional fault sets, a dominant northwest southeast set, parallel to the main bounding fault system and a second subsidiary set trending effectively north-south. A third east-west set is present but tends to be more controlling in the deeper sections.

3. Evaluation of Neocomian Shale source rock

The Neocomian Shale source rock deposited in Komombo basin area is evaluated as adequate potential source rock which can generate hydrocarbons in Komombo basin. Hence, this part will discuss the Early Cretaceous (Neocomian) shale from selected wells to evaluate its source rock properties in the study area by applying the geochemical techniques. The sedimentary section in Komombo area includes several shale intervals. These shales are within; Neocomian, Aptian, Cenomanian and Campanian sequences. Among these shale intervals the Neocomian Shale is considered the promising source rock since it is the oldest thick unit deposited during the Early Cretaceous time in the entire area of the Komombo basin. It is buried in deep depths (>8000ft) in the troughs and had been affected by many tectonic phases. The Neocomian shale is indicating presence of possible source rocks in the basinal area. Meanwhile, the shale thicknesses decrease markedly away from the basin. Hence, it is expected to find a source rock facies along the central northwest-southeast trending belt where most of the discoveries are found (Fig. 1b).

In general, the drilled Neocomian section is dominated by a shale, sandy mudstone alternating with thin sandstone interbeds. It is widely distributed in the troughs of the Komombo basin and the studied area as well (Abdelhady, 2012). Two wells in Komombo basin were selected for the study as they have conventional cores and ditch cutting shale samples being available at Komombo-2 and Al Baraka-1 wells. These shale samples represent the Neocomian source rocks.

The Neocomian shale is usually present in Komombo basinal area at depths between 8160 ft – 8250 ft in Komombo-2 well and 8190 ft – 8400 ft in Al Baraka-1 well. The samples for source rock analysis for organic richness (TOC%), hydrocarbon potential and kerogen types (Rock-Eval) were collected. Pyrolysis results of shale samples and microscopic maceral and palynomprphs analysis of some samples were considered. Composition of organic matter, palynofacics, paleo-environment and preservation of source rocks were obtained from examination of kerogen samples under transmitted light microscope.

3.1 Organic matter richness

According to Tissot (1984) the TOC values within the limit of 0–0.5% are considered to be poor source rocks, whereas sediments with 0.5–1% TOC values are classified as marginal source rocks. Sediments certain more than 2% TOC are considered to be good source.

Neocomian shale sections from Komombo-2 and Al Baraka-1 wells in the basinal area were geochemically investigated. (Tables 1 and 2) Illustrate the Rock-Eval payrolosis TOC % of the samples (Fig. 2 and 3). The results of Komombo-2 well indicate presence of good source rock since the rocks certain values ranges from 2.00 to 5.79 TOC wt. % and the average values is 1.80 TOC wt., % at the interval depth 7970-8446 in Komombo-2 well. The pyrolysis yield S2 of 1.50 -13.89 mg/g HC (av. 4.24 mg/g HC) and associated hydrogen index (HI) values (131-338).

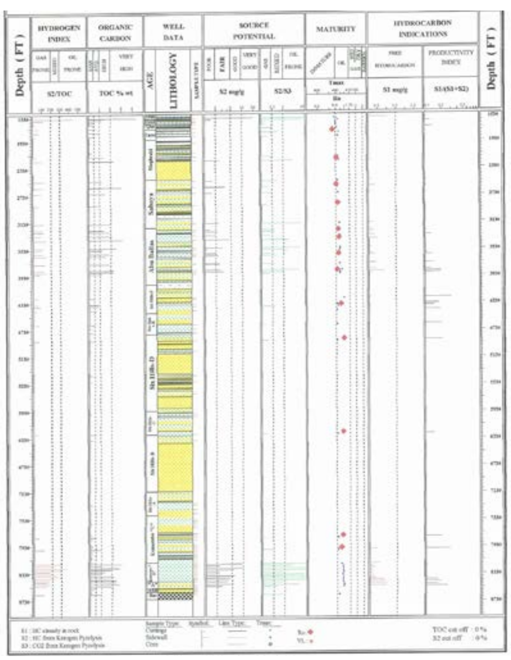

Fig. 2: Al Baraka-1 well geochemical log

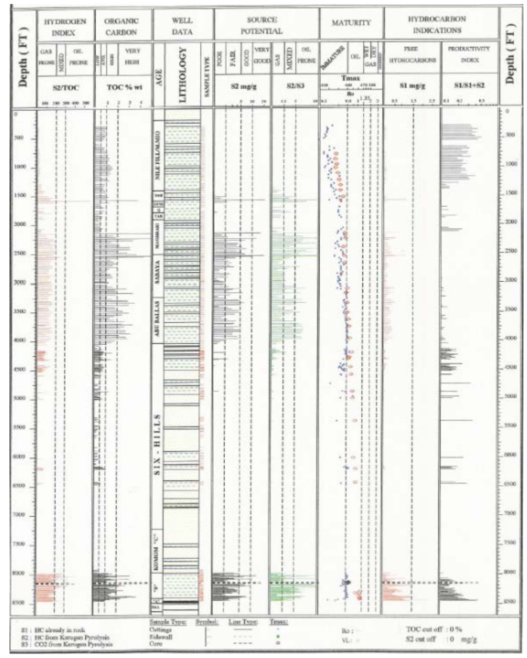

Fig. 3: Al Baraka-1 well geochemical log

Table 1:RockEval pyrolsis and TOC % data values of komombo-2

Depth (ft)		S1	S2	S3	PI	S2/S3	TOC	Tmax	HI	OI
7970	7980	0.47	3.61	1.01	0.12	3.57	1.31	440	276	77
7980	7990	0.48	4.75	1.85	0.09	2.57	1.64	441	290	113
7990	8000	0.21	2.04	1.27	0.09	1.61	0.97	441	210	131
8000	8010	0.15	1.52	1.03	0.09	1.48	0.80	441	190	129
8010	8020	0.35	3.56	0.78	0.09	4.56	1.30	442	274	60
8020	8030	0.77	13.89	0.89	0.05	15.61	3.22	443	431	28
8030	8040	0.26	6.63	0.81	0.04	8.19	2.00	444	332	41
8040	8050	0.18	2.66	0.83	0.06	3.20	1.18	443	225	70
8050	8060	0.24	1.46	0.77	0.14	1.90	0.97	442	151	79
8060	8070	0.26	3.70	0.79	0.07	4.68	1.52	443	243	52
8070	8080	1.27	10.97	0.74	0.10	14.82	3.12	441	352	24
8080	8090	0.70	3.81	1.26	0.16	3.02	1.85	440	206	68
8090	8100	0.50	2.46	1.22	0.17	2.02	1.22	437	202	100
8100	8110	0.33	1.88	1.09	0.15	1.72	1.08	438	174	101
8110	8120	0.51	2.23	0.70	0.19	3.19	1.21	440	184	58
8120	8160	0.48	2.80	0.60	0.15	4.67	1.26	442	222	48
8160	8170	1.35	7.25	0.81	0.16	8.95	2.44	439	297	33
8170	8180	0.83	4.96	0.55	0.14	9.02	2.01	441	247	27
8180	8190	1.66	9.41	0.57	0.15	16.51	2.78	437	338	21
8190	8200	1.17	7.08	0.58	0.14	12.21	2.19	435	323	26
8200	8220	0.65	4.60	0.34	0.12	13.53	1.79	442	257	19
8220	8230	0.33	2.42	0.47	0.12	5.15	1.26	440	192	37
8230	8240	0.35	2.58	0.48	0.12	5.38	1.43	441	180	34
8240	8250	0.83	3.72	0.62	0.18	6.00	1.88	442	198	33
8250	8260	0.82	4.11	0.65	0.17	6.32	2.01	441	204	32
8260	8270	1.09	5.23	0.69	0.17	7.58	2.61	440	200	26
8270	8280	1.06	4.34	1.00	0.20	4.34	1.92	442	226	52
8280	8290	0.69	4.31	0.76	0.14	5.67	2.04	439	211	37
8290	8300	1.07	4.72	0.69	0.18	6.84	2.07	440	228	33
8300	8310	0.69	3.01	0.46	0.19	6.54	1.56	443	193	29
8310	8320	0.68	3.31	0.68	0.17	4.87	1.60	441	207	43
8320	8330	0.56	2.09	0.46	0.21	4.54	1.25	442	167	37
8330	8340	0.56	1.72	1.14	0.25	1.51	1.31	442	131	87
8340	8350	0.56	1.83	1.28	0.23	1.43	1.36	444	135	94
8350	8360	0.81	2.24	2.03	0.27	1.10	1.50	441	149	135
8360	8370	1.58	7.08	1.02	0.18	6.94	3.38	441	209	30
8370	8380	1.83	7.92	1.05	0.19	7.54	3.74	442	212	28

Table 2:RocEval pyrolsis and TOC % data values of Al Baraka-1

Depth (ft)		S1	S2	S3	PI	S2/S3	TOC	TMAX	HI	OI
7770	7800	0.09	0.37	0.60	0.20	0.62	0.57	442	65	105
7800	7890	NA	0.00	NA	NA	NA	0.27	NA	NA	0
7890	7920	NA	0.00	NA	NA	NA	0.24	NA	NA	0
7920	7950	NA	0.00	NA	NA	NA	0.23	NA	NA	0
7950	7980	0.42	1.12	0.44	0.27	2.55	0.96	442	117	46
7980	8010	NA	0.00	NA	NA	NA	0.26	NA	NA	0
8010	8040	NA	0.00	NA	NA	NA	0.20	NA	NA	0
8040	8070	NA	0.00	NA	NA	NA	0.17	NA	NA	0
8070	8100	NA	0.00	NA	NA	NA	0.22	NA	NA	0
8100	8130	NA	0.00	NA	NA	NA	0.15	NA	NA	0
8130	8160	NA	0.00	NA	NA	NA	0.30	NA	NA	0
8160	8190	0.58	9.22	0.31	0.06	29.75	2.90	449	318	11
8190	8220	0.14	2.38	0.37	0.06	6.44	1.05	453	227	35
8220	8250	0.29	9.86	0.31	0.03	31.79	2.70	453	365	11
8250	8280	0.14	5.74	0.49	0.02	11.72	1.92	453	299	26
8280	8310	0.19	2.28	0.50	0.08	4.57	1.32	454	173	38
8310	8340	0.12	2.32	0.25	0.05	9.28	1.00	451	232	25
8340	8370	0.24	5.86	0.26	0.04	22.53	2.21	453	265	12
8370	8400	0.34	4.45	0.25	0.07	17.81	1.97	453	226	13
8400	8430	0.80	3.99	0.26	0.17	15.34	2.36	452	169	11
8430	8460	0.87	3.69	0.74	0.19	4.99	2.35	453	157	31
8460	8490	0.95	4.81	0.58	0.17	8.29	2.70	456	178	21
8490	8520	0.90	2.74	0.81	0.25	3.39	1.96	454	140	41
8520	8550	NA	0.00	NA	NA	NA	0.44	NA	NA	0
8550	8580	NA	0.00	NA	NA	NA	0.18	NA	NA	0
8580	8610	NA	0.00	NA	NA	NA	0.18	NA	NA	0
8610	8640	0.12	1.03	0.22	0.10	4.68	0.98	444	105	22

3.2 Organic matter type

Type of organic matter in Neocomian shale is determined using the microscopic examination of the isolated Kerogen residue and maceral analysis of the different organic constituents. The kerogen type was identified from the relation between OI and HI to be mixed type I and type II (Fig. 4 and 5). In Komombo-2 well the organic matter changes to consist primaly of unstructured lipids with some structured and terrestrial material. The structure lipids are in the form of alginite. In Al Baraka-1 well the organic matter changes to consist primarily of micrinized unstructured lipids continues to depth 8640 ft.

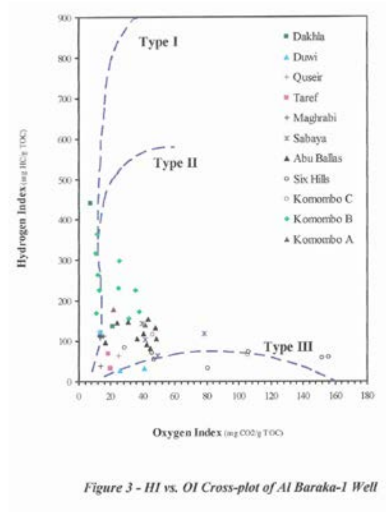

Fig. 4: Al Baraka-1 well HI vs. OI cross-plot

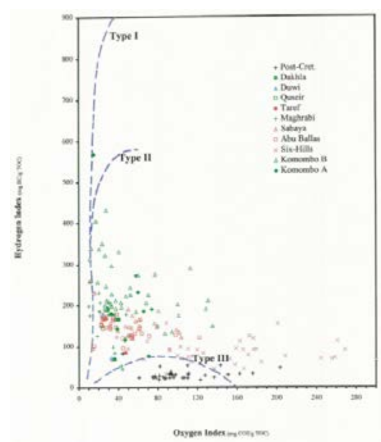

Fig. 5: Komombo-2 well HI vs. OI cross-plot

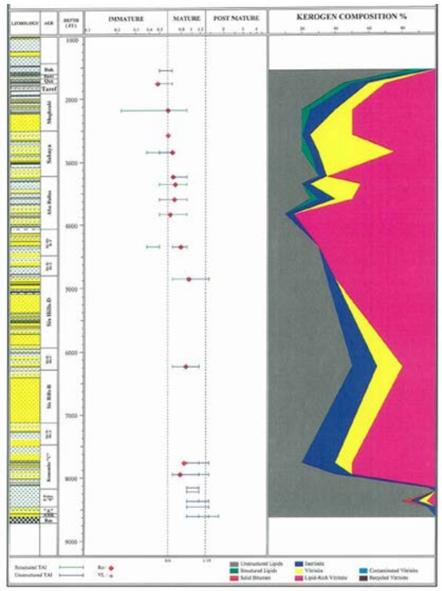

Fig. 6: Al Baraka-1 well kerogen log

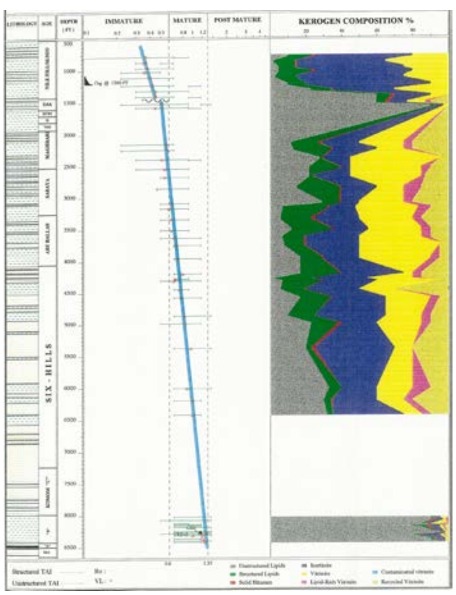

Fig. 7: Komombo-2 well kerogen log

3.3 Source Potential

The source generating (capability) potential of the Neocomian source rock in wells; Komombo-2 and Al Baraka-1 is indicated by the pyrolysis-derived S2 peak (hydrocarbon cracked from kerogen, mg HC/g rock) results (Tables 1 and 2). The average S2 values of the analysed samples in the two wells measures 3.23 mg HC/g rock reflecting good generating potential source rocks.

The total genetic potential (GP=S1+S2) of these samples is ranging from 2.00 to 15.00 (average 5.00) mg HC/g rock in well Komombo-2 and from 0.46 to 10.15 (average 4.40) mg HC/g rock in well Al Baraka-1, indicating a good source rock. The production index (PI= S1/S1+S2), or transformation ratio (TR), ranges from 0.12 to 1.00 (average 0.23) in well Komombo-2 and from 0.02 to 0.25 (average 0.12) in well Al Baraka-1 (Tables 1 and 2). These values (average 0.18) indicate occurrence of mature kerogen in the oil-window zone. The hydrocarbon type index (S2/S3) were ranged from 2.85 to 16.51 (average 6.15) in well Komombo-2 and from 0.62 to 17.81 (average 11.58) in well Al Baraka-1 mg HC/g rock (Tables 1 and 2).

4 Maturation of organic matter (Kerogen)

The maturation of organic matter was evaluated using the following procedures: 1) Thermal Alteration Index (TAI) and Vitrinte Reflectances (Ro %) of kerogen. 2) Hydrogen Index (HI) and Tmax.

4.1 (TAI) and (Ro %) of kerogen

The TAI values measured for the kerogen sample; from Neocomian shales of wells; Komombo-2 and Al Baraka-1 range from 2+ to 3 indicating early to mature levels, This means that Neocomian Shale have reached the gas window zone.

Also, these TAI values are equivalent to Ro (%) range 1.2-1.3% which arc determined for Neocomian Shale in well Komombo-2 at depth interval 8280-8410 ft. From Al Baraka-1 well the vitrinite reflectance values, which increase with depth, a reliable maturity profile could be constructed this profile projects to =0.43% Ro close to the surface and reaches about 1.50% Ro close to the top of the basement (=8600) (Fig. 8 and 9).

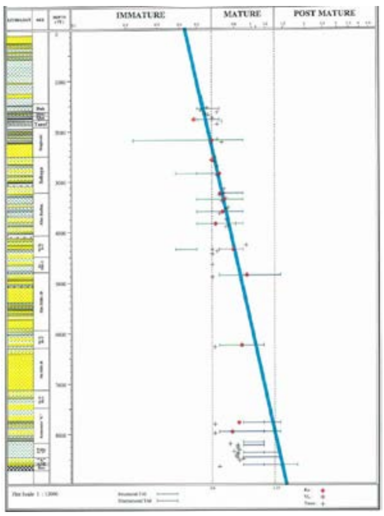

Fig. 8: Al Baraka-1 Vitrinite Reflectance log

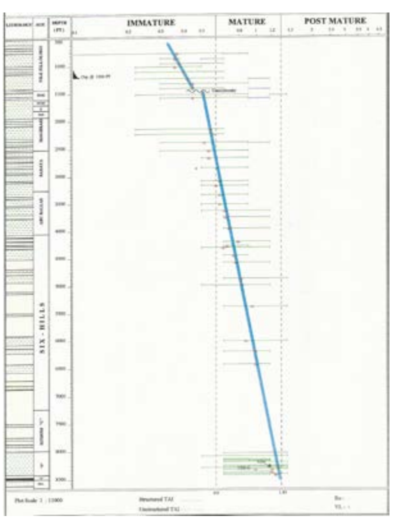

Fig. 9: Komombo-2 Vitrinite Reflectance log

Based on this maturity profile, the top of the oil window (defined by 0.6%ro) should be encountered at approximately 2200 ft and the bottom of the oil window (defined by 1.35% Ro) lies at approximately 8000 ft. the section from the Aptian to Neocomian member have entered the late mature stage of hydrocarbon generation (>1.0% Ro). Also the projection of the Ro maturity profile to about 0.43% close to the surface suggests that some 4000 ft have been eroded from the top of the section since maximum burial.

4.2 (HI) and Tmax

The hydrogen index (HI) corresponds to the quantity of pyroloyzed organic compound or hydrocarbon from S2 relative to total organic carbon (Peters, 1986). The HI values of kerogens of analyzed Neocomian Shale samples from Komombo-2 and Al Baraka-1 wells which are moderately high (226-365) and (314-431) respectively, indicate high capacity to generate mainly oil with some gases. On the other hand, the Tmax values of samples in well Komombo-2 are ranging between 420°C to 447°C suggests a lower thermal maturity than that derived from Ro data. The Tmax values of the analyzed samples from Al Baraka-1 well which mostly range between 437°C to 458°C and show comparable maturity to that derived from the Ro results down to 4380 ft. below 4860 ft the T max profile follows a trend suggests a lower thermal maturity then that derived from Ro data, TAI values, on the other hand, appear to correlate better with the interpreted Ro profile, especially in the deeper part of the penetrated section.

5 Conclusions

The oil of Al Baraka field within Komombo concession in the southern western desert of Egypt is believed to be are generated at a high thermal maturity (about 0.95% Ro equivalent) from lacustrine shales containing mixed terrigenous and marine organic matter deposited in a moderately oxidizing sedimentary environment.

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