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SOURCE ROCK EVALUATION AND 1D MODELING FOR EAST BAHARIYA CONCESSION, YOMNA FIELD, WESTERN DESERT, EGYPT

BY

Dahman, A[a], Nooh, A. Z[b], Kamh, G. M.[c]

[a] Khalda Petroleum Company, Cairo, Egypt.

[b] Egyptian Petroleum Research Institute (EPRI), Cairo, Egypt.

[c] Geology Department, Faculty of Science, Menoufiya University, Menoufiya, Egypt

ABSTRACT

This study focuses on the source rock evaluation and the hydrocarbon generation in the East Bahariya concession, the eastern trough of Abu Gharadig basin, Western Desert, Egypt. By using the available data from Yomna field a subsurface evaluation of the encountered stratigraphic rock unit was carried out. Geochemical analysis of source rock and oil to source correlation to support the hydrocarbon origin in reservoir in the study area. These analysis were executed to determine the organic and the effect of both structural & stratigraphic implications on the source rock, in order to conduct more activities in the study area. The main objective of this study is to evaluate the prospectively, hydrocarbon potentialities and petroleum system elements of the study area, deals mainly with the source rock evaluation and the hydrocarbon generation. Also present the petroleum system in the area such as reservoir, source rock with its maturation stages and the proposed migration path to enhance the productivity of the field and add more rooms or prospects. Detecting the efficiency of hydrocarbon expulsion from source areas to Reservoir in the study areas will open new rooms of prospect new locations of shallow reservoir.

It was concluded that the ARF Member, Khatatba and Alam El Bueib (AEB) formations are rich in organic matter with TOC mostly >2.00 % and both could be considered as an effective source rock for the oil presented in Yomna7a & 22 wells. Accordingly we have a good opportunity to drill more development wells to enhancement the productivity of the study area.

Keywords

Yomna Field, 1D modeling, Source Rock Evaluation, Migration Pathway

INTRODUCTION

Yomna oil field (the study area) located in East Bahariya concession, south of the Northeast Abu Gharadig Concession and West of Qarun Oil Field, Western Desert of Egypt (Fig. 1). Exploration Campaign have been conducted through 4 Phases of Drilling activities confirms oil provinces on levels of Abu Roash, Bahariya and Jurassic Formations

The northern part of the Western Desert of Egypt forms a featureless plain with some exceptions of small folds and faults of Abu Roash complex that reflects its geological history (Said, 1990). Most of the surface is covered with Neogene strata of lithological uniformity. Deep drilling in the Western Desert has shown that the sedimentary column is thick, which made up larges wells and basins and is ranged in age from Paleozoic to Recent (EGPC, 1992).The Mesozoic-Cenozoic deformation of Egypt is a result of the movement of the African Plate and the surrounding (Eurasian, Arabian, and South American) Plates. Surface and subsurface geological data have helped recognition of several phases of deformation including extensional deformation leading to opening of rift basins and compressional deformation leading to closure of some of these basins. Up to present, all commercial and non-commercial hydrocarbon accumulations have been found in the Cretaceous

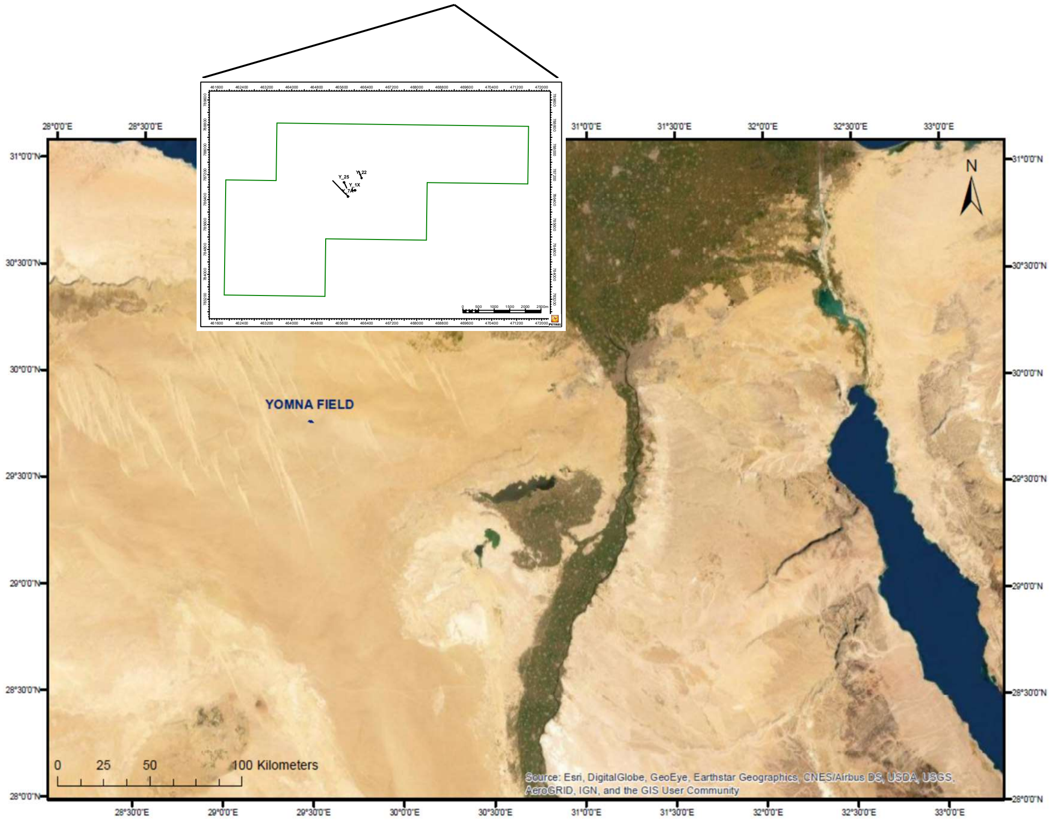


Fig. 1: **Location map of the Yomna oil field in the Western Desert, Egypt.**

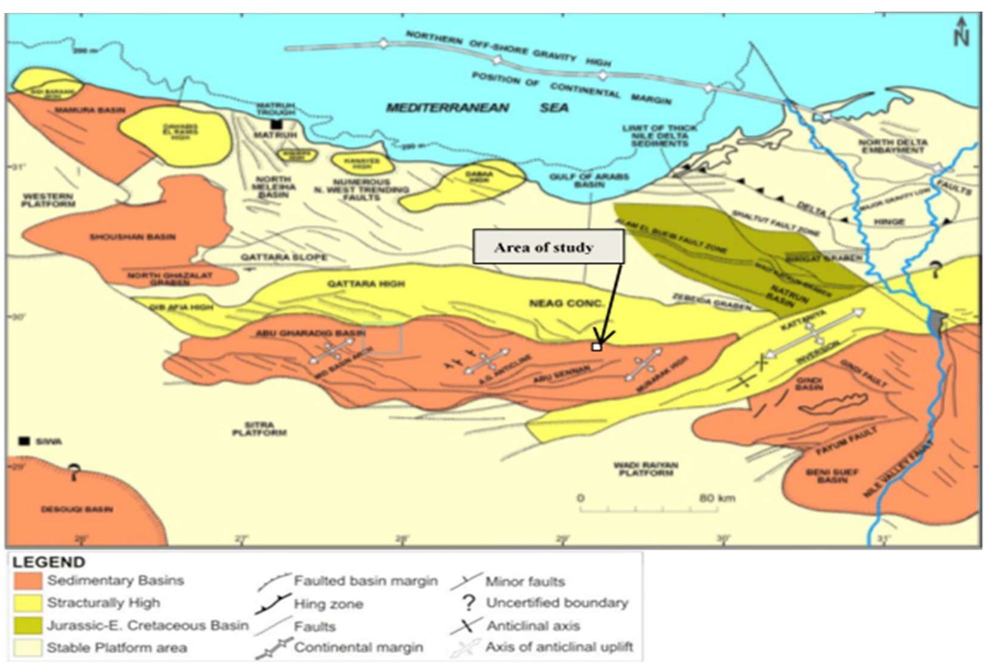


Fig. 2: **Simplified tectonic map showing the main basins in the north Western De sert (Bayoumi, 1996).**

ormations. Thick organic rich sediments were deposited under favorable conditions for oil generation at the depo-center of the Jurassic and Cretaceous basins. Source rock identification and quantification using geochemical analysis. Geochemical evaluation was carried out to evaluate the potential source rock intervals in terms of organic carbon content, kerogen type, depth of maturity and the possible time of hydrocarbon expulsion. Hydrocarbon source rocks exist in different parts of the sedimentary section of the Northern Western Desert. Jurassic sediments of the Khatatba Formation and Lower Cretaceous sediments of the Alam El Bueib Formation where carbonaceous shales and coals are predominant (Sultan and Halim, 1988) and include terrestrial plant material (type III) (Parker, 1982).

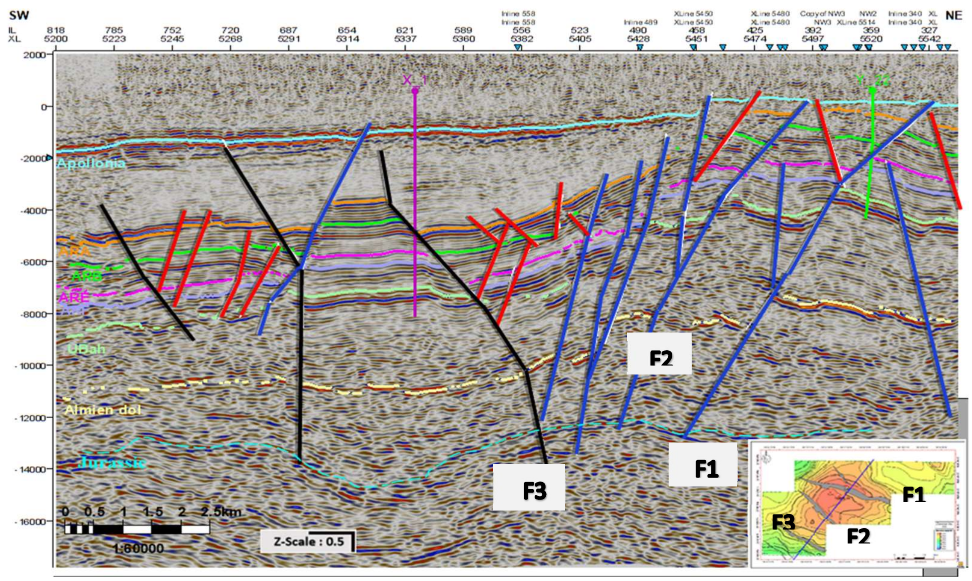


Fig. 3 : Shows the mainly structure trends on study area the blue and black colors are oldest and red colors are late Cretaceous.

METHODOLOGY

Complete set of 20 Seismic lines, Wireline Well logs, geochemical reports. Using the wireline logs of four wireline logs for Petrophysical evaluation by IP software to confirm the presence of hydrocarbon for the selected wells. Geochemical analysis used to confirm the presence and efficiency of source rock in the study area and to create 1D Basin Model by petro-mod software for petroleum generation potential of a basin using regional geology, identifying the source rock, assessment of type, quantity and maturity of the organic matter, the heat flow with its variation through time, generation, migration and accumulation of petroleum, thermo-dynamics and hydrodynamics.

RESULTS AND DISCUSSION

Seismic interpretation technique by Petrel software used to pick horizons (Jurassic, Alamien Dolomite, Bahariya, Abu Roash, Khoman, and Apollonia), Fault interpretation and Surface Griddling & Merge contour grids with fault polygon. Seismic profile (Fig.3) indicate the main deformation took place after the deposition of Abu-Roash formation which show some erosion of Abu-Roash members at the crest of anticline. Khoman and Apollonia are very thin at the crest of the anticline syn-deposition. Also show Khoman growth thickness criterion, because the sediments thickness of Khoman Formation on the hanging-Wall side of the fault are greater than those of the foot wall. This criterion is indicating to the presence of an active tectonic movement during the sedimentation time of Khoman Formation at the Late Cretaceous (from Campanian to Maastrichtian time). ARE Structure map (Fig.4) shows that the structurally high values occur in the Central part of the Field and structurally low in the South western part of the Field that related to dextral shear during the Late Cretaceous time that making trend NW- SE However, during the Late Cretaceous the right motion between Africa and Laurasia, due to the opening of the North Atlantic Ocean.

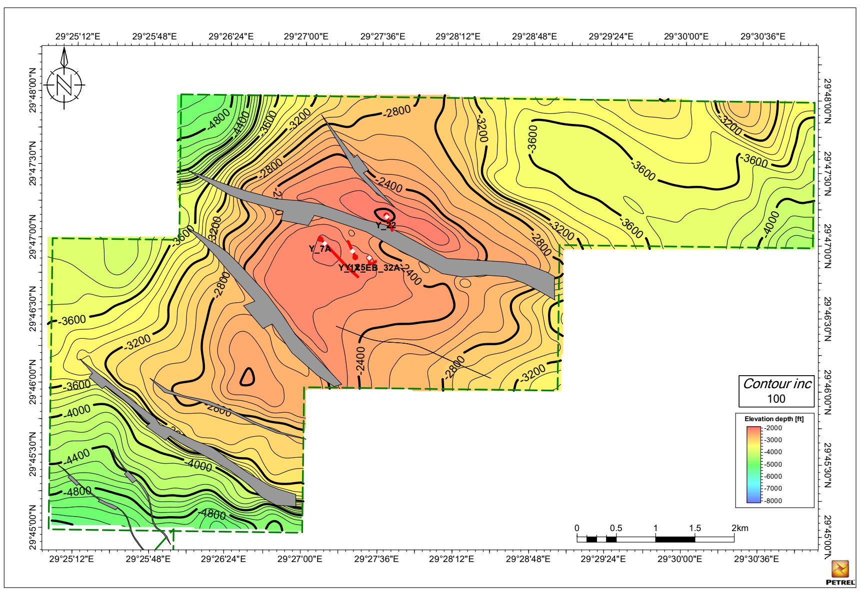


Fig. 4: **Shows ARE Depth Structure map**

A comprehensive petrophysical analysis using the wireline logs for four wells in the study area was carried out by IP software to confirm the presence of hydrocarbon for the selected wells, (Vcl, Φeff, and Sw) cut-off parameters for Abu Roash "E" reservoir units have been determined from actual production data. After applying this cut-off the pay zones for the studied reservoirs had been identified in the studied wells; Yomna – 07a and Yomna – 22 (Fig. 5). The petrophysical properties of Abu Roash "E" reservoir units are represented, for the net sand and the net pay, in Table-1.

SOURCE ROCK EVALUATION

Geochemical analysis for samples obtained from Pseudo-well shows that, the organic matter of Abu Roash "F" Member consists of (unstructured lipids 85-100% and some structured and terrestrial materials).

Table 1 Well Log parameters of Abu Roash "E" reservoir.

Well	Res. Unit	Net pay (ft)	Porosity %	Shale volume %	Water Saturation %
Yomna-7a	Ch1	9	27	9	53
Yomna-22	Ch1	15	30	1.7	32
	Ch2	4.5	30	5	30

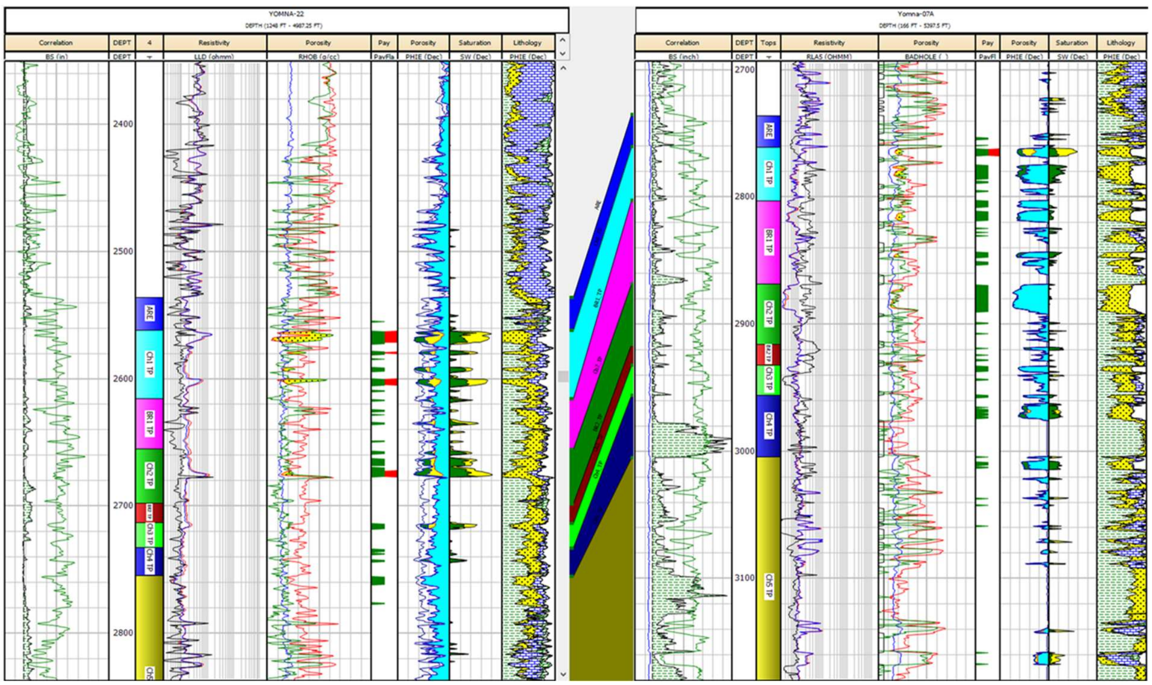


Fig. 5: **Well section between the 2 wells in the study area showing petrophysical analysis of Abu Roash "E" unit.**

The samples 1400`-1450`, 6500`-6550` and 7910`-7920 (from Dabaa, ARE, Bahariya, Respectively) contain about 40-50% terrestrial material mixed with unstructured lipids. Structured lipids are in the form of liptodetrinite in all samples.The samples obtained from Yomna-1X revealed that, most samples contain organic matter composed of a mixture of unstructured lipids and humic organic matter in different proportions with the latter generally increasing with depth. Sporinite (up to 5%) with traces of cutinite and resinite were noted in many samples from the Kharita and older section. The modified Van Krevelen diagram (Fig.6) which showing the kerogen type through relationship between the HI and the OI of the samples indicating that, Pseudo-well & Yomna -1X wells are characterized by type (I – II) kerogen. Concerning to the hydrogen index (HI) values indicated that Abu Roash "F" Member in Pseudo-Well well has excellent potential for liquid generation (kerogen type I) in addition to, mixed source (kerogen type II), where the HI values are ranging from 415 to 960 mg/g TOC with average of 727 mg/g TOC and suggested that the kerogen contained is capable of generating oil. (Fig.6). Concerning to Yomna-1X well the first source rock in the intervals 640`-680`, 3690`- 3700` and 12920`-12930` within the Apollonia, Abu Roash "G" and Upper Safa sections, respectively.is characterized by fair potential for mainly oil generation (pyrolysis S2 yields 3.46-4.70 mg HC/g rock & HI 385-510). The second source rock is countered Khatatba (U.Safa member) in the intervals 11960`-12140`, ARG 3730`-`3740`, Bahariya 3840`-3850`, Dahab

7390`-7400`, Alam El-Bueib (10020`-10030`, 10120`-10130`, 10350`-10360` & 10530`-10540`). Most of these rocks have very high organic content (TOC mostly >2.00 %) and fair to excellent potential to generate oil and gas (pyrolysis S2 yields 2.03-70.73 mg/g, mostly >5.00 mg/g, and HI mostly 220-350.

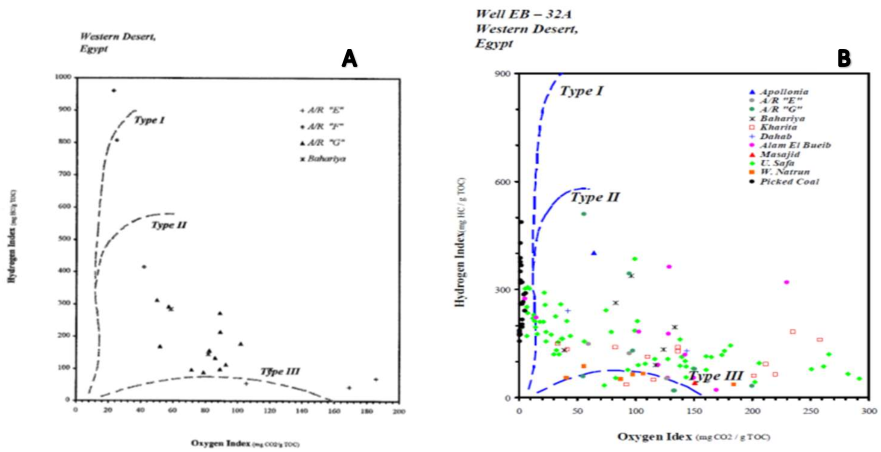


Fig. 6: Modified Van Krevelen diagram for (A) X-1X & (B) Y-1X Wells.

Finally the rest of data results show third source rock type is gas-prone, as indicated by the relatively low Hydrogen Indices (HI mostly <200), and is common within the analyzed Khatatba (U.Safa member) especially below 12390`, and is encountered in the ARE 2840`-2850`, Bahariya 4410`-4420`, Kharita 6600`-6710` and Alam El Bueib 10360`-10370`. Most of these rocks generally have very high organic contents and fair to very good potential for mainly gas generation (TOC mostly >2.00% & pyrolysis S2 yields 2.10-14.40). (Fig.7).

The maturity level of organic matter basically determine by vitrinite reflectance (Ro) values which measured for kerogen vitrinite, but it can also determine from Tmax data which obtained from Rock Eval pyrolysis. The maturity profile constructed from Ro% measurements for PSEUDO-WELL Well showed that, the values are generally increase with increasing burial depth and suggest that the analyzed section is thermally immature to marginally mature and the top of the oil window (defined by 0.6 %Ro) appeared to be encountered close to the top of the Abu Roash "F" Member at approximately ≈ 7040`. Also, the projection of the maturity profile at ~0.29% Ro close to the surface suggests the removal of several 2500 feet since maximum burial. Moreover, the unstructured lipids TAI values appear to be changes from amorphous to massive with increasing maturity and generally supports the Ro% values.

The relationship between the Tmax (°C) and depth indicated that, Abu Roash (F) Member in Pseudo-well well is thermally immature to marginally mature (Fig. 8). Most of the analyzed samples have abundant good quality vitrinite. The data quality is very good in most samples, despite that reflectance suppression was noted in many samples below 7000` due to lipid rich vitrinite and/or rough texture. The calculated Ro value of the deepest sample at 14020` is based on limited number of measurements and is therefore questionable. There is a general increase of vitrinite reflectance and TAI maturity with depth ranging from immature for oil generation at 640` to the upper wet-gas zone at 13290`. However, there is abundant scatter of reflectance values that may be caused by suppressed reflectance, rough texture, and possible caving below 6000`. True maturity of the organic matter may be slightly higher than that indicated by vitrinite reflectance. TAI on sporinite in samples from 13290 to 14030` indicate that maturity ranges from the lower oil generation zone to the upper dry-gas zone in that section. However, the Ro maturity profile constructed from the best quality Ro maturity data, with the suppressed values excluded, places the top oil window (defined by 0.6 %Ro) at about 6600`, and the bottom oil window (defined by ~1.35 %Ro) at ~14700`. This maturity profile appears in line with maturities derived from the TAI on sporinite and the unstructured lipids texture and further indicates that the lower part of Khatatba (below ~13000`) is close to the gas window. The projection of the Ro maturity profile close to the surface at ~0.3 %Ro suggests the removal of about 3000` since maximum burial.

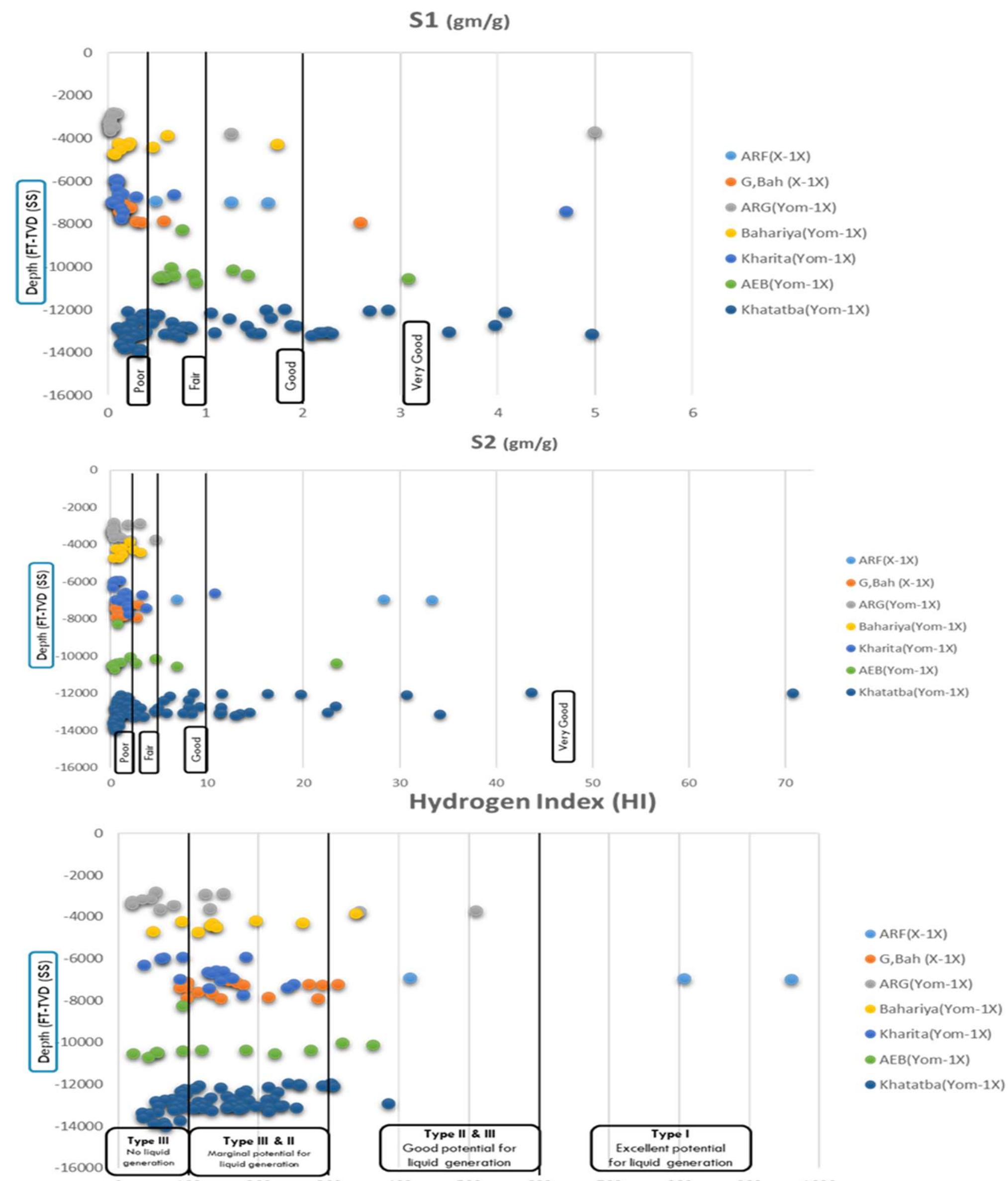


Fig. 7: **S1, S2 & HI values of X-1X & Y-1X Wells**

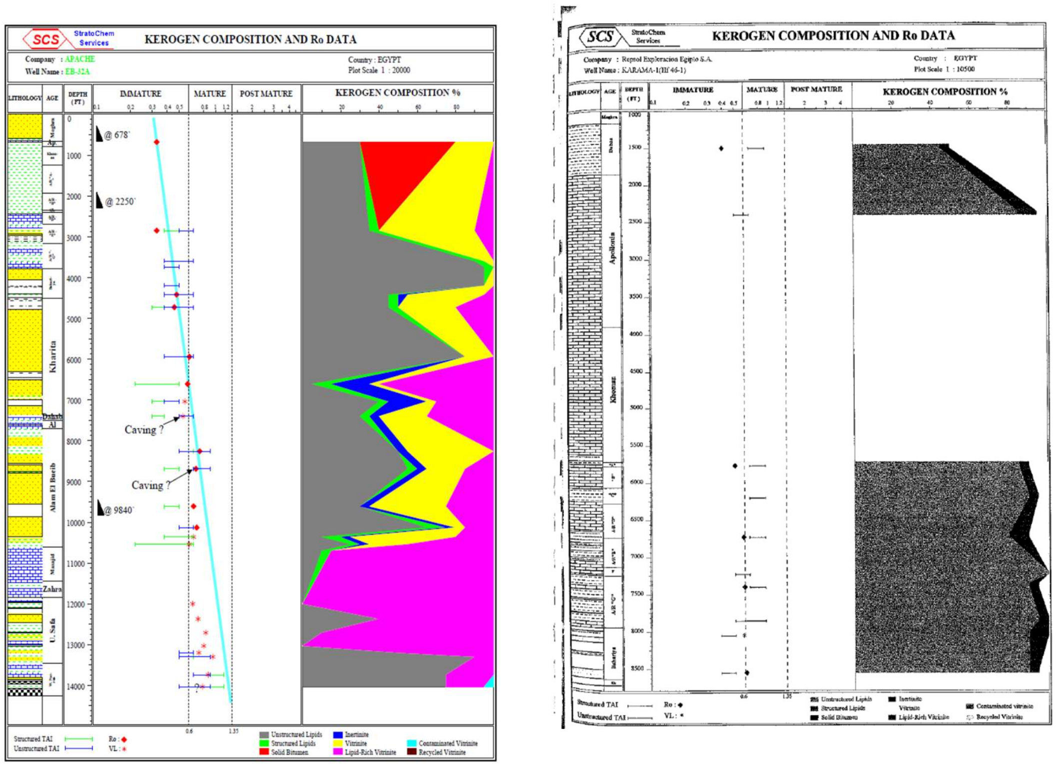


Fig. 8: **Maturity profile and Kerogen composition in Y-1X & X-1X well respectively**

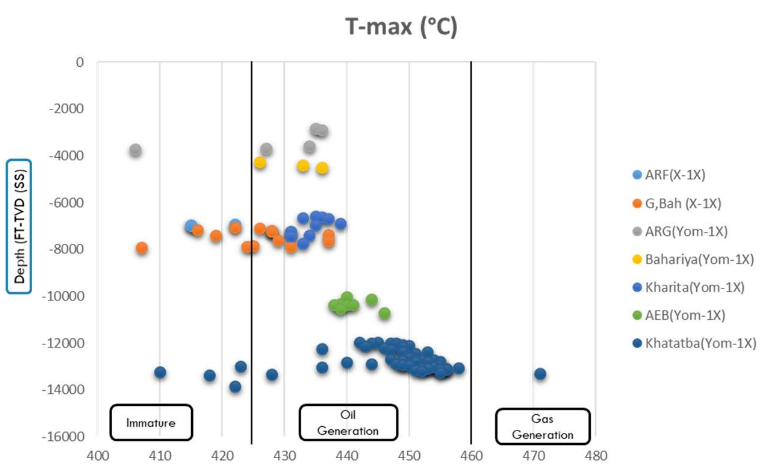


Fig. 9: **The relation between Tmax (°C) and depth for (X-1X & Y-1X Wells).**

Considering the present thermal maturity level of the Khatatba source rocks, they would have had higher organic contents and better hydrocarbon generating potential prior to maturation (Fig. 9).

Based on modified cross-plot of Mango, (1987) (Fig. 10) for light hydrocarbon parameters. This plot used to estimate the temperature of hydrocarbon expulsion and assess maturity of the light hydrocarbon charge. The analyzed oil has value of 6.4 which indicates an expulsion temperature of ~119^o C for the study oil and suggested a thermal maturity close to 0.82% Ro.

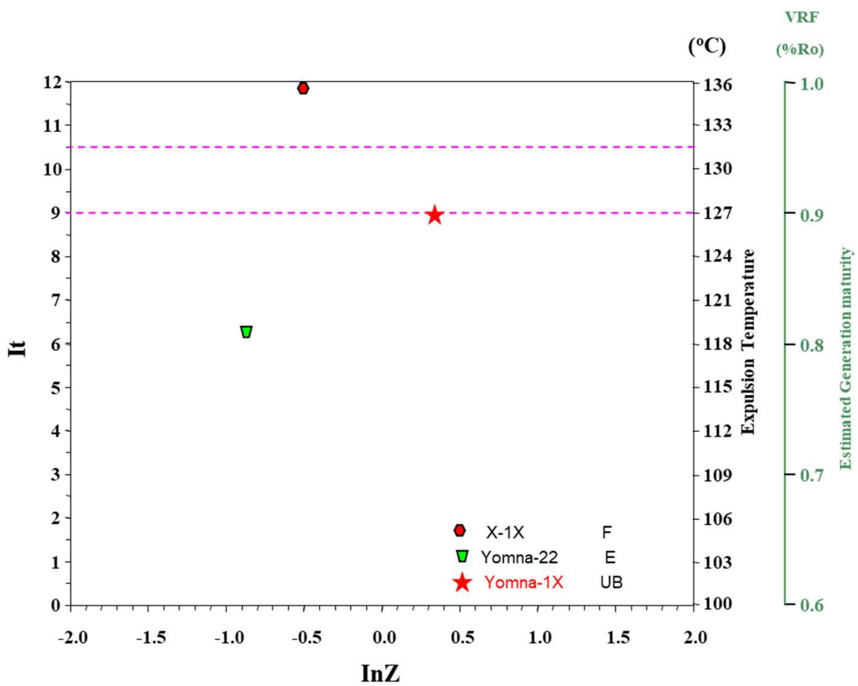
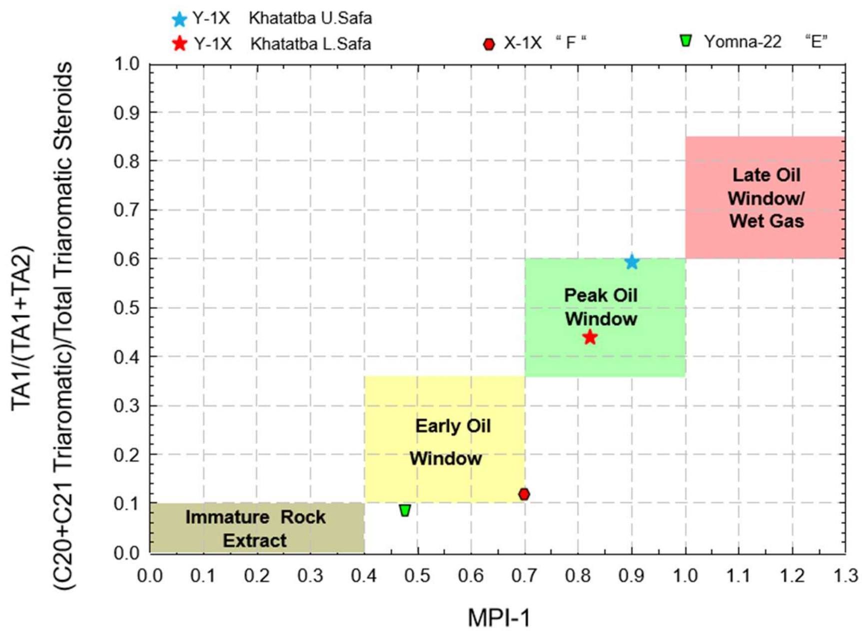


Fig. 10: **Expulsion temperature of oil as derived from C7 compounds**

On the other hand, Methylphenanthrene index (MPI-1) and C20+C21 Triaromatic/Total Triaromatic Steroid data, the oil sample has a narrow range of thermal maturities and reflected that, the oil had generated at the early oil window thermal maturity for X-1X (pseudo well) and oil window for Y-1X Khatatba. (Fig. 11).



Fig, 12: **Cross-Plot of MPI versus C20 + C21 Triaromatic/Total Triaromatic Steroids.**

For this concern, Isoprenoid/n-alkane ratios plot was used which depend on the relative abundances of Pristane/n-C17 and Phytane/n-C18 as indicators of biodegradation, maturity and organic facies (Fig. 12). The oil sample appeared to be generated from a predominantly mixed to marine organic source matter at moderate thermal maturity.

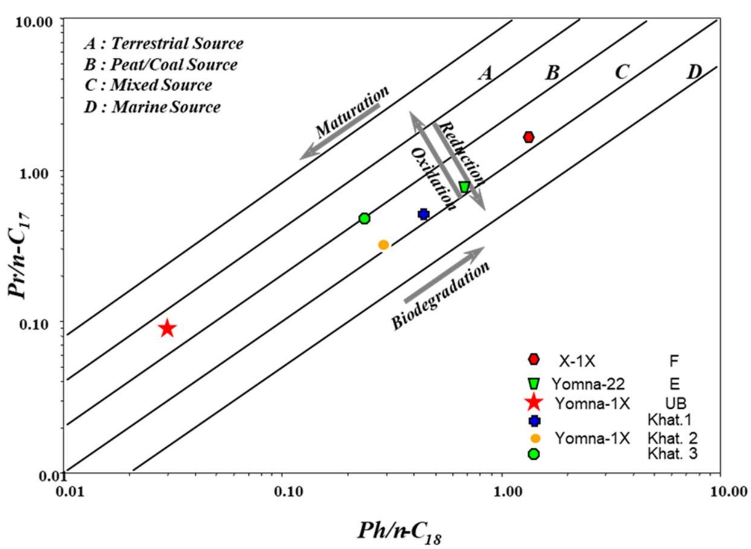


Fig. 13: **Cross-Plot of Pr/n-C17 versus Ph/n-C18 for Yomna-22 ARE oil & ARF, Khatatba source extract**

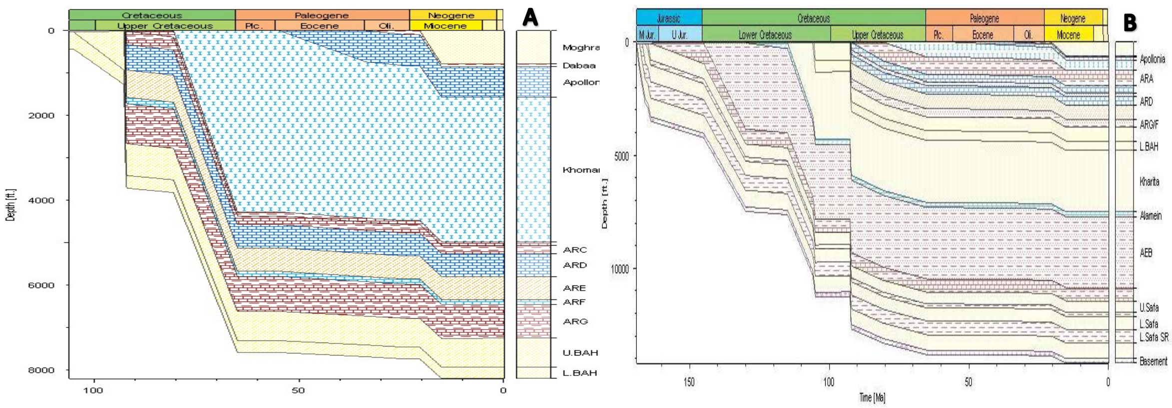


Fig. 14: **Burial History of (A) X-1X & (B) Y-1X Well Wells**

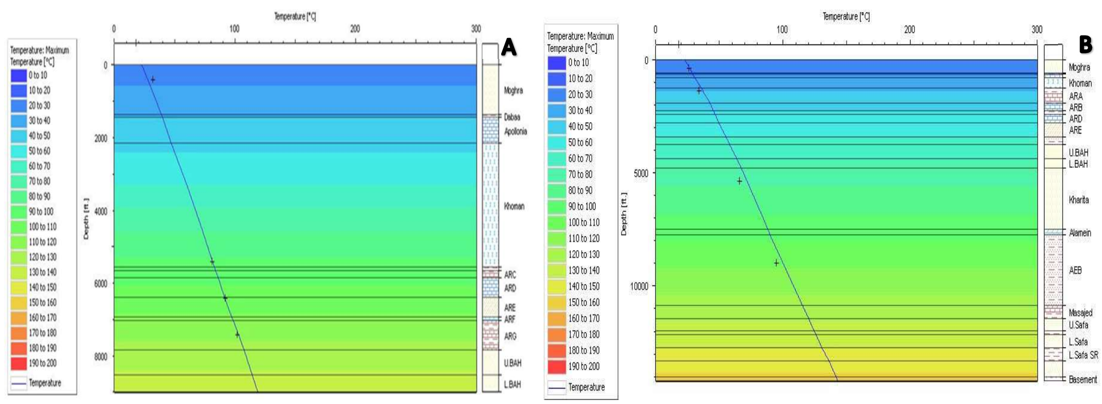


Fig. 15: **The temperature Gradient through Depth in (A) X-1X & (B) Y-1X Wells**

1D BASIN MODELING

1D Basin Model by petromod software for petroleum generation potential of a basin using regional geology, identifying the source rock, assessment of type, quantity and maturity of the organic matter, the heat flow with its variation through time, generation, migration and accumulation of petroleum, thermo-dynamics and hydrodynamics. A geological data enabled us to construct a time-stratigraphy for the location of interested and to specify its temperature history. Time-stratigraphic data are usually available as formation tops and ages obtained by routine biostratigraphic analysis of cuttings. If no well data are available, a time-stratigraphy can sometimes be constructed using seismic data, especially if the seismic reflectors can easy tied to well data.

The Burial histories

The geologic history for each individual modeled formations the geologic history for each individual modeled formations/members can be illustrated by several burial histories for the study wells (Fig. 13).

The burial and thermal histories

One of the important processes required to construct thermal burial history models is to calculate the geothermal gradient in a given sedimentary sequence, the determination of geothermal gradient in the studied wells required the use of bottom-hole temperatures (BHT) and surface temperatures which obtained from every well. The relation between modeled temperature (solid line) and measured temperature (solid points) and its increase with depth are fitted together and is shown in depth plots from (Fig.14). During the burial history of the area the source rock is suffering increasing temperatures. Due to the heat flow and the thermal gradient the source rock reaches the oil window (the zone where petroleum is generated) at a vitrinite reflectance of approximately 0.6% Ro and leaves the oil window and inter the gas window approximately at 1.35 % Ro. The reconstructed burial histories of the studied wells in East Abu Gharadig Basin by the time-depth history plots, after applying the temperature effects, showed a close relationship to the basin tectonic evolution, and the distribution of temperatures through the basin can be notice through (Fig. 15).

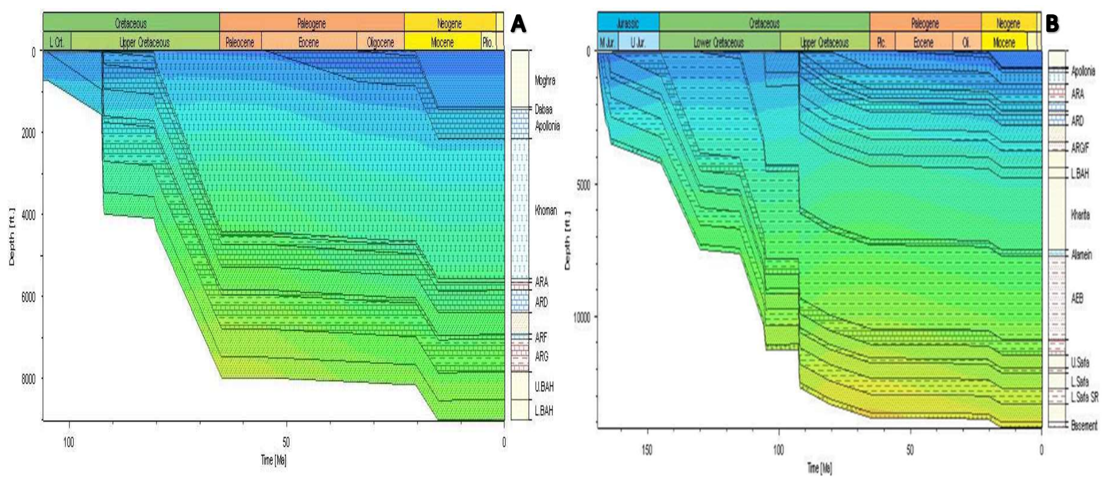


Fig. 16: **Modeled Burial and thermal histories in (A) X-1X & (B) Y-1X Wells.**

The burial history and hydrocarbon zones

The timing of hydrocarbon generation may be determined more directly by determining kinetic parameters. After constructing the burial and thermal history models, and locating the oil window of Abu Roash “F” source rock, by using Sweeny and Brunhum (1990) easy %Ro, we found that, the oil window is extremely variable from a well to another. In Pseudo-Well well, Abu Roash “F” source rock has just enter the early oil window (0.55-0.7) since 70 Ma and still present till now

Fig. 16).On the other hand, Khatatba (U.Safa) & Khatatba (L.Safa) source rock in Yomna-1X well has just enter the early oil window (0.55-0.7) since 110 & 116 Ma and still present till now.

Hydrocarbon generation

The proportion of generated hydrocarbon expelled from the source rock during the main stage of oil formation is strongly dependent upon the type and initial amount of kerogen percent. Nearly all of the oil generated by rich source rocks may be expelled but below a minimum initial concentration of it. According to this, The Abu Roash "F" Member Pseudo-Well generation map reflects that, the generated hydrocarbon from the early mature source rock reached about 0.25 Mtons Kg/m2 and 2.73 & 1.68 Mtons for Yomna-1X Khatatba (U.Safa) & Khatatba (L.Safa) respectively.

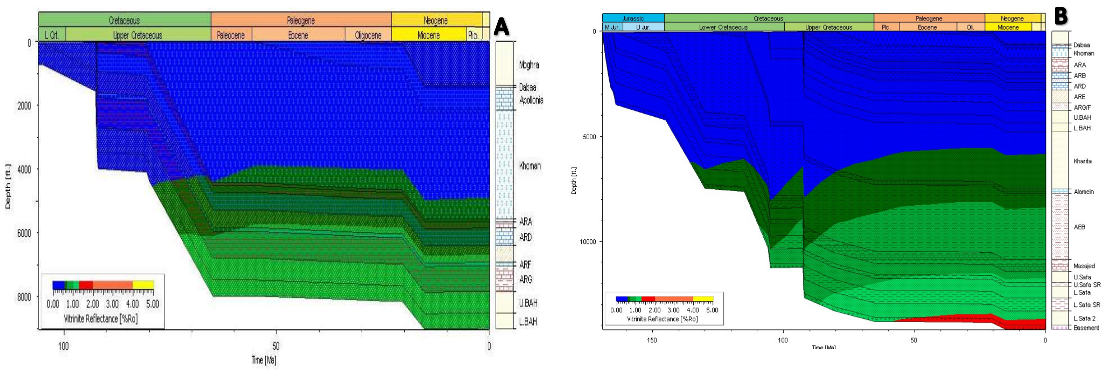


Fig. 17: **The Burial history and hydrocarbon zones in (A) X-1X & (B) Y-1X Wells.**

Oil to source correlation

Oil sample of Yomna-22 & Yomna-1X wells within the study area. Two source rock hydrocarbon extract samples are collected from well Yomna-1X and well Pseudo-Well to represent the Jurassic Khatatba formation and Cretaceous ARF and Alam El Bueib formations, respectively. For the biological marker correlations three source rock hydrocarbon extracts from the Khatatba, Alam El Bueib and ARF formations and two oil samples from UB & ARE reservoirs are recognized. On the other hand, the source rock extracts of the ARF formation show low to moderate saturate content (22.2%), a moderate aromatic content (29.6%) and fairly high NSO+asphaltenes content (46%). Such value suggest the derivation from source with predominant marine organic matter at fairly low maturity level. The δ^{13} C values for the saturate & aromatic fraction of the sample are -25.5%o and -23.6%o respectively. The high sulfur content of 2.20%, the high V content of 161 ppm and the Ni concentration of 57 suggest that the ARF extract probably generated was from a carbonate-rich organic source at low maturity. The whole extract gas chromatogram generally show unimodal n-C_{15+} profile, with a clear peak for the n-C_{14-17} region and fairly regular decrease for the heavier alkanes.

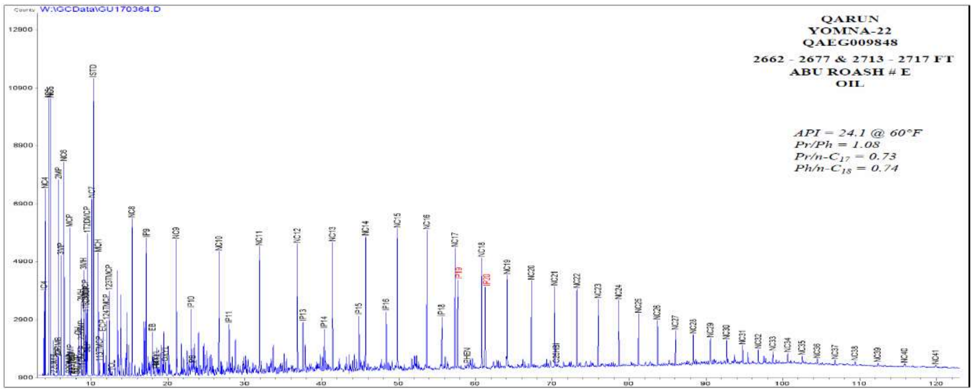


Fig. 18: **Whole oil gas chromatogram for Yomna-22 well oil Sample.**

Crude oils and source rock extracts in the study area show similarities in the gross chemical composition to both of ARF & Khatatba source extract, as both have high percent of saturated hydrocarbon contents, exceeding the aromatic and asphaltenes and resins fractions (Table 2). These show a mixed relation between oils and extracted samples as both are related to normal oils, however the oil samples appear slightly more mature than the extracts. Geochemical analyses were carried out on one crude oil & one Gas Samples obtained from Yomna-22 well within the study area, which recovered from the Abu Roash "E" Member at the depths 2662 -2677 & 2713-2717 feet. The analytical methods utilized included API gravity determination, whole oil/gas Chromatography, liquid chromatography by MPLC, carbon isotope, gas chromatography / mass spectrometry (GC/MS) on the saturate and aromatic fractions and metal content (Fig. 17, 18, 19, 20 and 21).

Table 2 Geochemical characteristics of Crude oil and source rock extract.

Well	Fm.	Interval	Sat %	Aro %	NSO %	ASPH %
Yomna-22	ARE	2622-2677 & 2713-2717	54.84	10.72	27.84	6.60
X-1X	ARF	7200-7230	22.50	31.50	39.30	6.70
Yomna-1X	Khatatba (U.Safa)	12070-12080	41.67	19.44	38.89	--
	Khatatba (L.Safa)	12700-12780	5.31	19.78	10.26	64.65
		13020-13200	8.75	31.77	15.72	43.76

The high pristane/phytane ratios of the ARF (X-1X) compared to n-alkanes, which reflects low maturity. Pr/Ph ratio of 1.15, together with the high Pristane/n-C17 and Phytane/n-C18 ratios of 2.27 and 2.13, respectively suggest generation from a source rock containing predominantly marine organic matter at low thermal maturity. These ratios indicate a reduction depositional environment with more marine input.

On the other hand, the isoprenoid ratios of the (Yomna-1X) pristane/phytane ratios of the AEB, Khatattba 1.64, 1.65 respectively suggest generation from a source rock containing

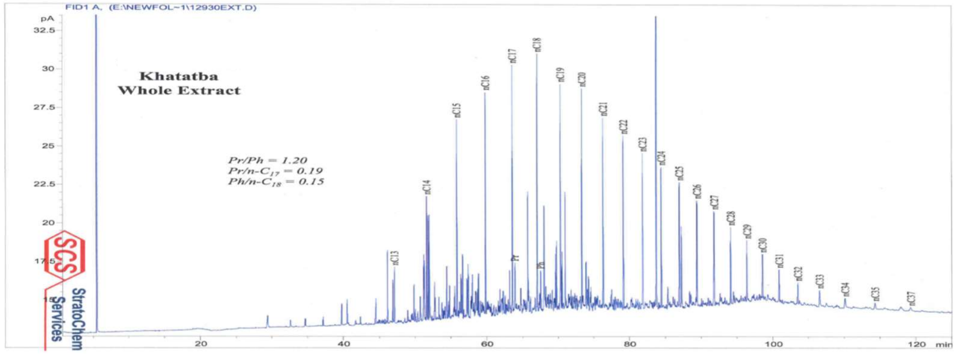


Fig. 19 Whole oil gas chromatogram for Pseudo well ARF Source Sample.

predominantly terrestrial organic matter. Pr/Ph ratio of 1.64-1.65, together with the Low Pristane/n-C17 and Phytane/n-C18 ratios of 0.3 & 0.27 and 0.27 & 0.17 respectively suggest source rocks indicate a slightly oxic depositional environment. This evidence reflects a no genetic relationship between the studied crude oils and source rocks extract from Yomna-1X and match genetic correlation to X-1X.

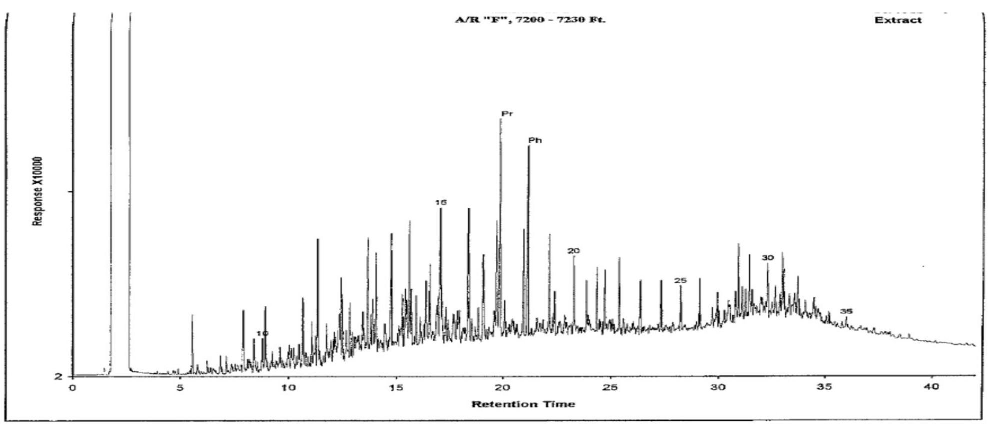


Fig. 20: **Gas chromatograms of saturated hydrocarbon fractions of extract from AEB, Y-1X Well**

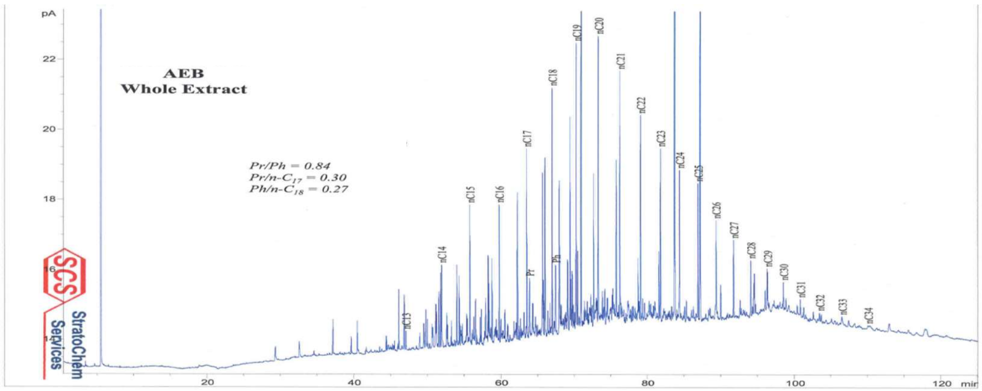


Fig. 21: **Gas chromatograms of saturated hydrocarbon fractions of extract Khatatba (U.Safa), Y-1X Well**

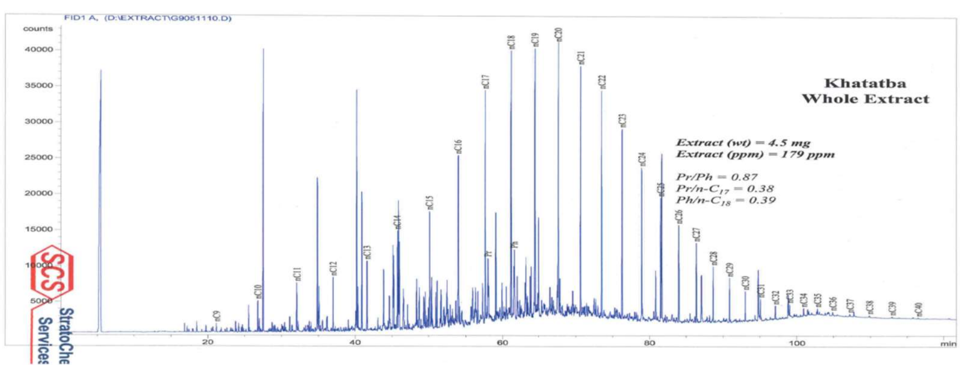


Fig. 22: **Gas chromatograms of saturated hydrocarbon fractions of extract Khatatba (L.Safa), Y-1X Well**

Migration and accumulation efficiency

A consensus is emerging that petroleum migration occurs by movement as a separate phase in a water-wet rock matrix (e.g., Durand, 1983; England W.A.., 1994; Welte, 1988). An alternative theory, that petroleum migrates in aqueous solution, may be rejected on the grounds that (1) the water solubility of the constituents of petroleum are too low to transport the required masses and that (2) a solution mechanism would enrich petroleum reservoir in the more soluble aromatic components, whereas the reverse is observed. Through this study conclude the both horizontal and vertical migration through faults to shallow reservoirs, this migration affected by the tectonic frame work through geological ages discussed in the tectonic section (Fig. 26) Also the main contribution of facies laterally and vertically which help the movement of hydrocarbon to the reservoir.

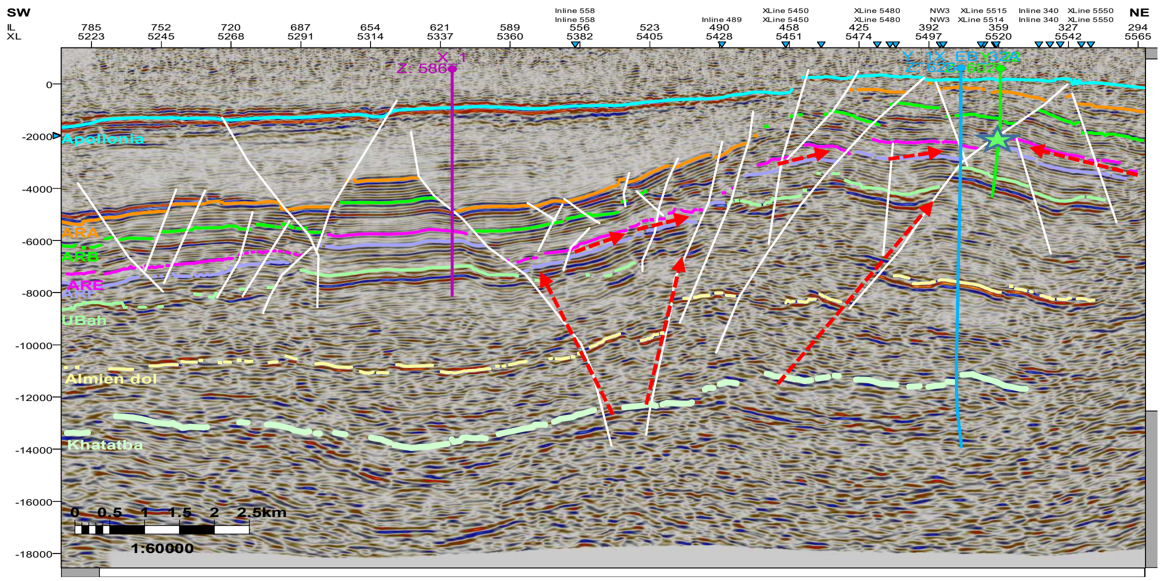


Fig. 23: Oil accumulation and Migration path way through the study area.

CONCLUSIONS

The geochemical results revealed that, The Eastern trough of the Abu Gharadig Basin is located in the Northern part of the concession. This sub-basin comprises a Well-developed Jurassic shale section with excellent source rocks in the Khatatba Formation which deposited in a continental to inner-middle shelf environments. Several intervals within Khatatba have oil and gas prone source rocks (Kerogen type's II& III) also the late cretaceous Abu Roash "F", carbonate on inner-middle neritic environment has outstanding oil source characterization with good to very good potential to generate mainly oil and is considered as a strongly oil-prone source rock (Type I- II Kerogen) for most of the studied area. Moreover, a geochemical analysis was carried out on one crude oil obtained from Yomna-22 well within the study area which recovered from the Upper Cretaceous ARE Member at (2662 – 2677 & 2713 - 2717) ft. The oil sample from Yomna-22 well has 24.1^{o} API. The whole oil gas chromatograms showed a normal crude oil with an n-alkane distribution pattern in the range of iC_4 to n- C_{35+}. In addition to, the oil sample suggested to be generated at moderately thermal maturity close to 0.6% R_o and an expulsion temperature of ~125^{o} C. Besides that, the oil was generated from a predominantly marine organic source rock which deposited under mixed environmental conditions. The time of oil generation from Khatatba sources started most likely during the middle to late santonian (Abu Roash deposition) or about 90 million years ago. However expulsion did not commence until 75 million years ago during Campanian (Base Khoman Deposition) and stopped expelling oil 34 million years ago during the Miocene. Thus timing of oil migration relative to the structure trap formation.

ARE oil sample are slightly more mature than the extracts which deposited in transitional environments with mixed organic source input. Where the sediment sorting is poor or the mudstones are particularly silty, only a very small capillary barrier may need to be overcome before petroleum can migrate from coarse-grained into fine-grained rocks. A small petroleum accumulation may build up in each layer of coarse-grained rock, and then the seal may be breached, allowing further flow.

From the previous discussion it was concluded that petroleum flow is predominantly vertical from the ARF Member, Khatatba and AEB formation which could be considered as an effective source rock for the oil presented in Yomna7a & 22 wells. The possible pathways for hydrocarbon transportation (migration pathways) from the expulsion area (kitchen) to the possible hydrocarbon accumulation areas which located at the shallower depths. Detecting the migration pathway of the hydrocarbon from source areas to Reservoir in the study areas will open new rooms of prospect new locations of shallow reservoir. Accordingly we have a good opportunity to drill more development wells to enhancement the productivity of the study area.

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