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Origin and Types of the Organic Matter Bearing Argillaceous Limestone in the Upper Cenomanian Abu-Roash-F, Beni-Suef Basin, Egypt

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Abstract

Abu-Roash-F member (Mb) represents one of the main carbonate source rocks in different oil basins in Egypt that belong to the Upper Cretaceous (Cenomanian) age. Investigated gas chromatograms of five extracted (OM) organic matter samples belonging to the Abu-Roash-F Mb from drilled WON-C-3X borehole, of the Beni-Suef basin, reveal the OM (organic matter) mainly comprising an admixture of the algae and microorganisms of short-chain n-alkanes (average; 37.64%) with sphagnum moss and macrophytes of a mid-chain n-alkanes (average; 24.3%). The investigated Abu-Roash-F Mb in the present study preferred to nominate based on their OM constituents as an algal limestone source rock. The CPI (carbon performance index) of values between 0.88 and 0.92 (average; 0.92) indicates a mature stage of the studied Mb. The average value of the NAR (natural n-alkane) that is close to zero of (0.04) is attributed to petroleum sources. The low values of TAR (terrigenous/aquatic ratio) of average (0.13) and Paq (aquatic macrophyte proxy) of average (0.69) are an indication of the dominance of submerged and floating plants. The n-C_{27}/n-C_{17} ratio has a value range of 0.31 and 0.34 (average; 0.33) demonstrating the OM affiliation to marine origin. Redox potential was suggested based on Pr/Ph ratios that range from 1.14 to 1.26 (average; 1.22) demonstrating the dysoxic and suboxic of the aqueous depositional medium. The Pr/n-C_{17} versus Ph/n-C_{18} diagram illustrates that the kerogen types of the studied samples were a mixture of type II and II/III. It also referred to the deposition that took place within a transitional marine environment of an aquatic coastal setting. A combination of the ACL proxy (average; 27.94) of a moderate value with a low percentage of very-long-chains (average; 3.12%) may suggest the dominance of the grass plants under temperate to cooler paleoclimate synchronizes the deposition environments of the studied Abu-Roash-F Mb.

Keywords: *Gas chromatograms; Abu-Roash-F member; Beni-Suef basin; NAR, Degree of waxiness; CPI, Pr/Ph, TAR, Paq and ACL proxies.*

1. Introduction

Nile Concession of the Beni-Suef basin is located within area bounded by the latitudes of 28° 00″ N and 29° 00″ N and longitudes 31° 00″ E and 33°00″ E in the NWD (northwestern Desert) of Egypt (Fig. 1). Beni-Suef basin is a type of extensional intra-continental sag basin that is bounded by NW-SE to WNW-ESE normal faults on both sides [1]. The basin was formed by an Early Cretaceous extensional movement associated with the opening of the South Atlantic, leading to the activation of the preexisting Cambrian faults. All commercial and non-commercial hydrocarbon accumulations in this basin mainly came from the Cretaceous deposits within the basin which are characterized by their wide area of distribution, great thickness, and the richness of OM. The entrapment style in the basin generally has a structure of double plunging anticline folds with an NNE-WSW plunge trend [2].

The Cretaceous deposits within the Beni-Suef basin can easily lithologically differentiate into two rock units. The Lower Cretaceous unit is made up primarily of clastic deposits represented by the Kharita Formation, whereas the Upper Cretaceous units are mainly composed of argillaceous and carbonates units involving the Bahariya, Abu Roash, and Khoman formations (Fms) [3].

Hydrocarbon source rock exists in different parts of the sedimentary basins of the Northern Western Desert. They commonly occur within the Upper Cretaceous sedimentary sequence, which are consist of the Cenomanian- Turonian sediments of the Abu Roash formation that divided into seven members nominate from the top to base into Abu-Roash from A to G (Fig. 2)

The Abu-Roash-F Mb (Member) is considered one of the most important sources rock found in almost of the Western Desert basins of the Abu Gharadig Basin, Gindi Basin , and Beni-Suef Basin [4-5]. It consists of argillaceous carbonate rock units deposited within open marine environments. The limestone is brown to coffee brown, and some off-white, moderately hard, and of cryptocrystalline texture [6]. In the investigated area, the Abu-Roash-F Mb ranges in thickness from 24m to 27.3m as recorded in many of the drilled boreholes in the Beni-Seuf basin [7].

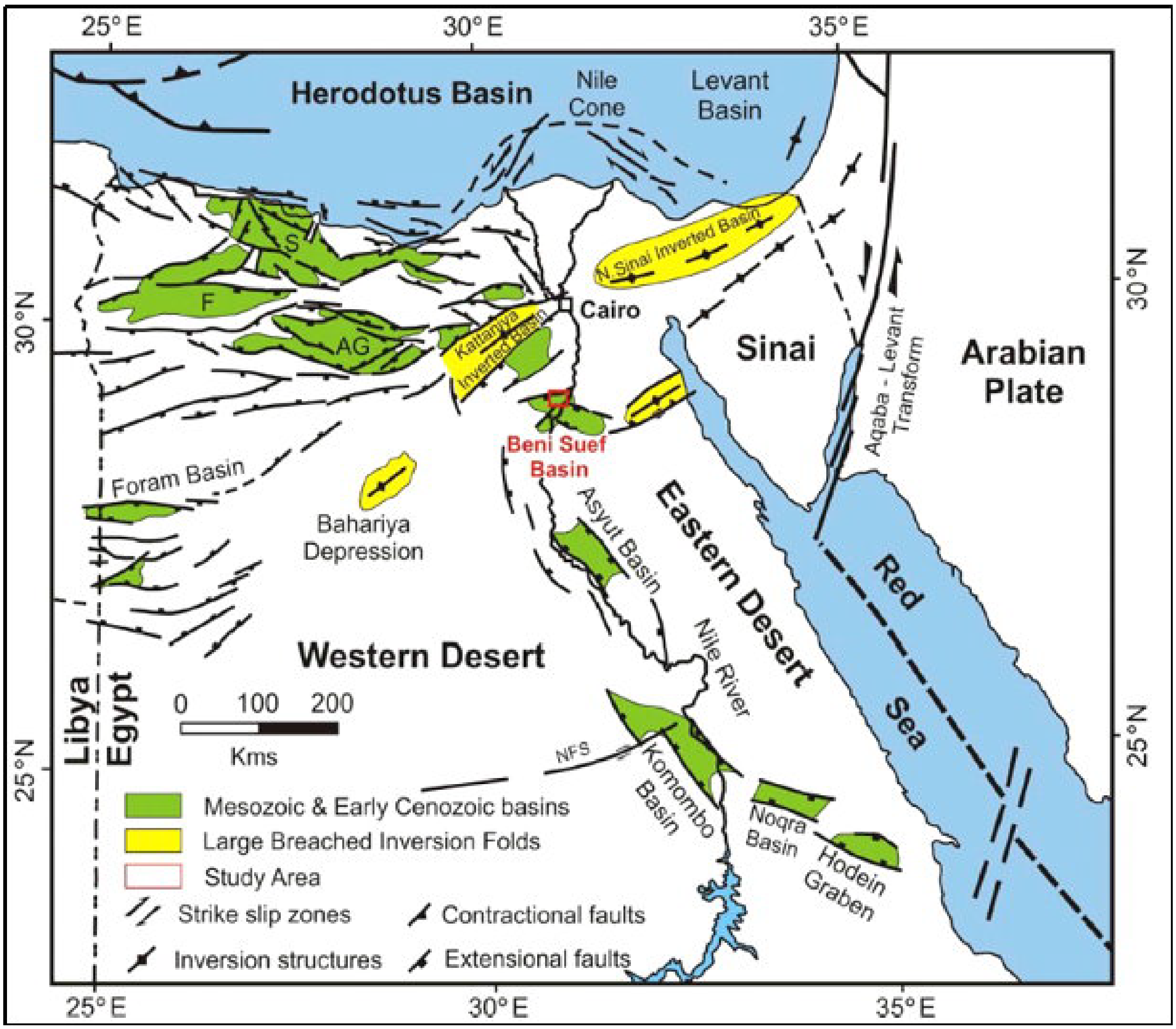

Fig. 1. Mesozoic and Cenozoic basins in the Western Desert and Sinai according to [2,8].

The amount of OM in source rocks commonly corresponds to a moderate and high OM flux which mainly occurs during the preservation in an anoxic condition associated with a minimal rate of sedimentation [9]. The Abu-Roash-F Mb was geochemically recognized by [7] as a very good to excellent oil-prone source rock characterized by a high TOC (≈2wt., %). Rock-eval pyrolysis analysis demonstrates that the Abu-Roash-F composed of kerogen types II and II/III that attained vertical thickness of 27m in the WON-C-3X well [7].

The present study aims to distinguish and identify the n-alkanes and isoprenoid peaks of five extracted cutting samples belonging to the argillaceous limestone of the Abu-Roash-F Mb source rock from a depth interval of 2002.5m and 2017.8m within the WON-C-3X well of the Beni-Suef Basin (Fig. 1 and 2). The obtained integrated peak areas for the five considered samples are measured by applying different important ratios and indices for determining the origin and actual types of the OM and paleoenvironments that prevailed during the deposition of this important source rock member in the Beni-Suef basin.

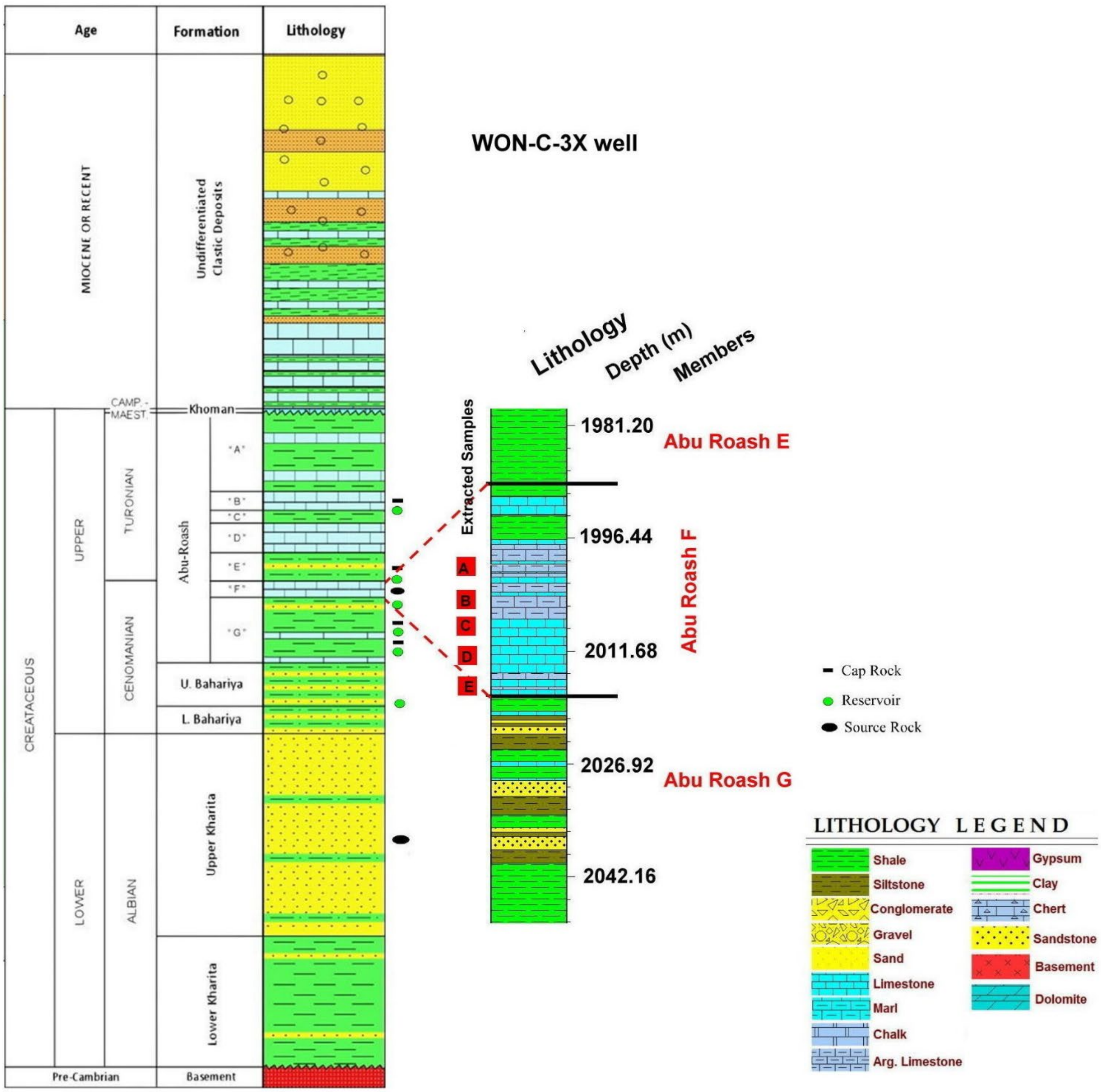

Fig. 2. Generalized litho stratigraphic column of the WON-C-3X well (after [7]).

2. Regional geology

2.1. Stratigraphy

The sedimentary section of the Beni-Suef basin is characterized by shallow marine shelf deposits during the Lower Cretaceous age. From the Upper Cretaceous (Cenomanian-Santonian) the depositional environment initiated with fluvial and estuarine conditions followed again by a marine transgression phase. During the Campanian-Maastrichtian a sedimentary chalk was deposited in a deep marine Environment. From Maastrichtian to Eocene the depositional sediments recorded within different fields indicate the same transgression phase, which was completely absent in the study area by erosion [6,10-11].

Within the investigated area, most of the study wells drilled in the west Beni-Suef basin revealed a similar stratigraphic column with a few exceptions either as variations in thicknesses and/or absence of some rock units. The stratigraphic sequence in the present studied well exhibited a rock unit ranged in age from the Albian (Kharita Formation), which unconformably overlain the Pre-Cambrian Basement complex, to Cenomanian of the Baharaya and the Abu Roash G and F, then Tornian that comprises the Abu-Roash A-E then the Maastrichtian-Campanian (Khoman Formation) (Fig.2).

2.2. Structure and tectonic setting

The North Western Desert structure is generally dominated by faults, which are step-normal faults systems of NE-SW, E-W, and NW-SE trends [4]. The Beni-Suef basin regionally has the same structures and tectonic setting which affected the northern Western Desert which is controlled mainly by the Aptian tectonism. Detailed subsurface mapping and structural analysis that affected the Beni-Suef basin indicates that the Beni-Suef basin was subjected to multiple phases of rifting and structural deformation during its period which led to the development of the basin in both structures and filling strata [12]. These phases are a) Early Cretaceous rifting phase**;** In this phase, the clastic of the Lower Cretaceous rock unit, generally shows thickening in the basinward and is controlled by faults which supported the idea of the initiation of the Beni-Suef basin in this age. Also, this indicates that the growth and the extension of the faults were in the Early Cretaceous; b) Cenomanian- Santonian inactive or passive phase; This phase is the rest of the rifting in which there was a slight effect of tectonism where the thickness of the strata is almost the same throughout the area; c) Late Cretaceous (Campanian-Maastrichtian) phase; In this phase, most of the faults that affected the area were formed this time, and the right-lateral strike-slip movement happened because of the dextral shear during the Late Cretaceous time which led to the rejuvenation of the EWE-oriented deep-seated faults with the Albian NE-SW extension movement.

3. Material and methods

Five selected ditch samples are collected from OM-rich intervals with a TOC range between 1.16 and 2.78wt.% within the depth starts from 2002.5m until 2017.77m. The samples belonging to the limestone rock units of the Abu-Roash-F Mb in the WON-C-3X well, Beni-Suef basin (Fig. 2). A collected ditch samples were divided into two parts to measure the TOC and to extract the OM by solvent to calculate the integrated peak areas from the chromatograms using by the GC instrument. The first sample parts were pulverized to (100-mesh) and removed carbonate by dilute HCl then dry and then heated for 60 minutes at 700^{o}C for further complete carbonate removal like the present study case of limestone. After that samples were washed with distilled water and then dried in the oven. One gram of samples after treatment was combusted (1200^{o}C) by instruments of the Leco-crucible. The system of Leco C230 was used by the infrared detector to calibrate and measure the converted carbon generated by the combusted processes and expressed as TOC expressed by wt., %.

Other pulverized parts of samples were extracted by di-dichloromethane solvent with Soxhlet apparatus for one day. After evaporation of the solvent, the residue was further examined by a gas chromatography instrument (model 3400 GC) with a specification of 50m Quadrex capillary of a fused column of silica. The Nelson data analysis data deals with data system (3000 chromatography). All the above-mentioned analyses were carried out under a standard condition within the Strato-Chem-Services, Cairo, Egypt.

4. Results

4.1. Chromatograms pattern

The chromatograms of the investigated five extracted samples recorded the n-alkane peaks from n-C_{10} to n-C_{41} in all studied samples (samples A to E) except samples D and E which their chromatograms start with a peak of n-C_{11} (Fig. 3). Generally, a unimodal chromatograms pattern with a maxima peak at an odd number of n-C_{17} prevailed in all the extracted samples (Fig. 4). The acyclic isoprenoid alkanes peaks of the pristane (C19) and phytane (C20) were recorded in all samples with Pr/Ph ratio ranges between 1.14 and 1.26 (average; 1.22) showing a slight increase of Pr/Ph ratio by increasing depth. A maximum peak of acyclic isoprenoid pristane (C19) was recorded in two samples of A and E instead of the n-C_{17} peak (Fig. 3).

The obtained results of the measured proxies and ratios from the gas chromatograms of the extracted samples of the Abu-Roash-F Mb were summarized in Table 1.

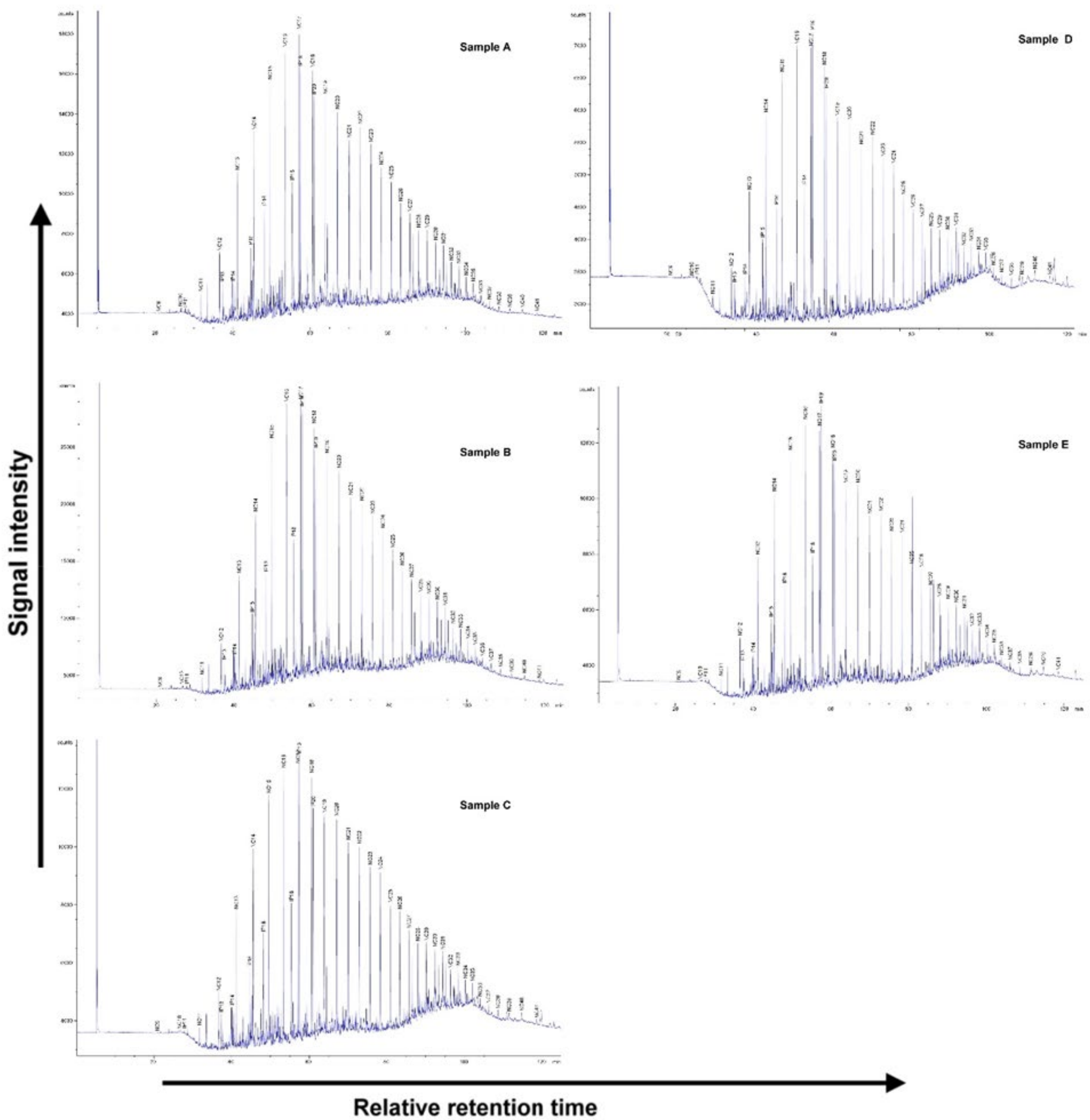

Fig 3. Chromatograms of (NC) normal and isoprenoid (IP) alkanes of the studied five extracted samples (A, B, C, D, and E) from the Abu-Roash-F source rock, Beni-Suef basin.

5. Discussions

5.1. Chain length signature to OM sources

The short chain n-alkanes measured by the summation of n-C_{15} to n-C_{20} is an indication of the source of OM-bearing rocks coming from algae and microorganisms of photosynthetic bacteria [13-14]. Chevalier *et al.* [15] found that algal types of microorganisms of the Chlorophyta and Rhodophyta are the main sources of both the n-C_{15} and n-C_{17}. As well as, Zhao *et al.* [16] found that the distribution of short-chain n-alkanes was directly derived from a biological input composed of microbial degradation and/or petroleum hydrocarbon source. In the present study, the short-chain n-alkanes of the extracted samples show the maximum dominant percentages ranging from 33.27% to 40.15% (average; 37.64%) (Table 1). That contributes to the domination of OM derived from algae and microorganisms in the Abu-Roash F calcareous source rock.

Table. 1. The results of the GC parameters, indices, and proxy used in the present study to predict the types and origin of the OM bearing the Abu-Roash-F member, Beni Suef Basin according to different authors.

Sample no.	Depth (m)	Short-chain (%) Σn-C_{15-19}	Mid-chain (%) Σn-C_{21-25}	Long-chain (%) Σn-C_{27}-n-C_{31}	Very long-chain (%) ≥ n-C_{33}	NAR	Degree of waxiness	CPI
A	2002.5	33.28	25.57	11.44	2.74	0.06	1.01	0.92
B	2008.63	39.66	23.83	10.73	2.61	0.06	0.82	0.95
C	2011.68	37.63	24.36	10.86	3.12	0.04	0.88	0.90
D	2014.7	40.15	24.49	11.02	3.87	0.04	0.83	0.89
E	2017.77	37.51	23.26	11.05	3.29	0.03	0.86	0.94
	Average	37.64	24.30	11.019	3.13	0.04	0.88	0.92

Sample no.	Depth (m)	n-C_{27}/n-C_{17}	TAR	Paq	ACL_{25-33}	Pr/Ph	Pr/n-C_{17}	Ph/n-C_{18}
A	2002.5	0.31	0.13	0.69	27.89	1.14	0.87	0.89
B	2008.63	0.32	0.13	0.69	27.88	1.19	0.97	0.90
C	2011.68	0.34	0.13	0.69	27.94	1.24	1.03	0.87
D	2014.7	0.31	0.14	0.68	28.01	1.25	1.05	0.90
E	2017.77	0.34	0.14	0.68	27.98	1.26	1.08	0.94
	Average	0.33	0.13	0.69	27.94	1.22	1.00	0.90

NAR (natural n-alkanes ratio) = (Σn-C_{19-33})-(2*Σn-C_{20-32}/Σn-C_{19-33}); CPI (carbon preference index) = ((n-C_{25}+n-C-$_{27}$+n-C_{29}+n-C_{31}+n-C_{33})/(n-C_{24}+n-C_{26}+n-C_{28}+n-C_{30}+n-C_{32})/(n-C_{25}+n-C_{27}+n-C_{29}+n-C31+n-C_{31})/(n-C_{26}+n-C_{28}+n-C_{30}+n-C_{32}+n-C_{34}))/2; TAR (terrigeous / aquatic ratio) = (n-C_{27}+n-C_{29}+n-C_{31})/(n-C_{15}+n-C_{17}+n-C_{19}); Paq (aquatic non-emergent macrophytes/ aquatic mergent and terrestrial macrophytes ratio) = (n-C_{23}+n-C_{25})/(n-C_{23}+n-C_{25}+n-C_{29}+n-C_{31}); Degree of Waxiness = (Σn-C_{21-31})/Σn-C_{15-20}); ACL_{25-33} (proxy ratio) = (25*n-C_{25}+27*n-C_{27}+29*n-C_{29}+31*n-C_{31}+33*n-C_{33}/(n-C_{25}+n-C_{27}+n-C_{29}+n-C_{31}+n-C_{33}).

The mid-chain n-alkanes are measured by summation of n-C_{21} to n-C_{25} [17]. The mid-chain n-alkanes represent the precursor origin of the OM that is derived from sphagnum moss and aquatic macrophytes (seagrass) [15-16]. Most of the modern sphagnum moss is mainly characterized by the dominance of n-C_{23}. [18] assumed that especially the odd mid-chain n-alkanes (n-C_{21}, n-C_{23}, and n-C_{25}) assess the deposition of OM (macrophytes) in an aquatic coastal freshwater-marine origin. The measured percentages of the mid-chain of the extracted samples have corresponding values ranges between 23.25% and 25.57% (average; 24.3%) which represents the second dominance of the seagrass as another source component of the studied OM bearing Abu-Roash F member,

The long chain n-alkanes measured by the summation of n-C_{27} to n-C_{31} are mainly related to the source origin of terrigenous vascular higher plants [18]. The prevailing of odd n-alkanes ≥ 27 is mainly a sign of vascular higher plants [17,19]. The measured long chain percentages of the studied samples are 10.7-11.4% (average; 11%) which refers to the depositional setting occurring within the site of slightly proximal to land-plant origin.

Plotting of the short- mid- and long-chain n-alkanes percentage of the presented samples on the ternary diagram of [18] and [20] diagram (Fig. 4) shows the composition of the OM bearing Abu-Roash member is composed of an admixture of the algae, sphagnum moss micro- and macro- phytates which mainly occur at a coastal depositional environment.

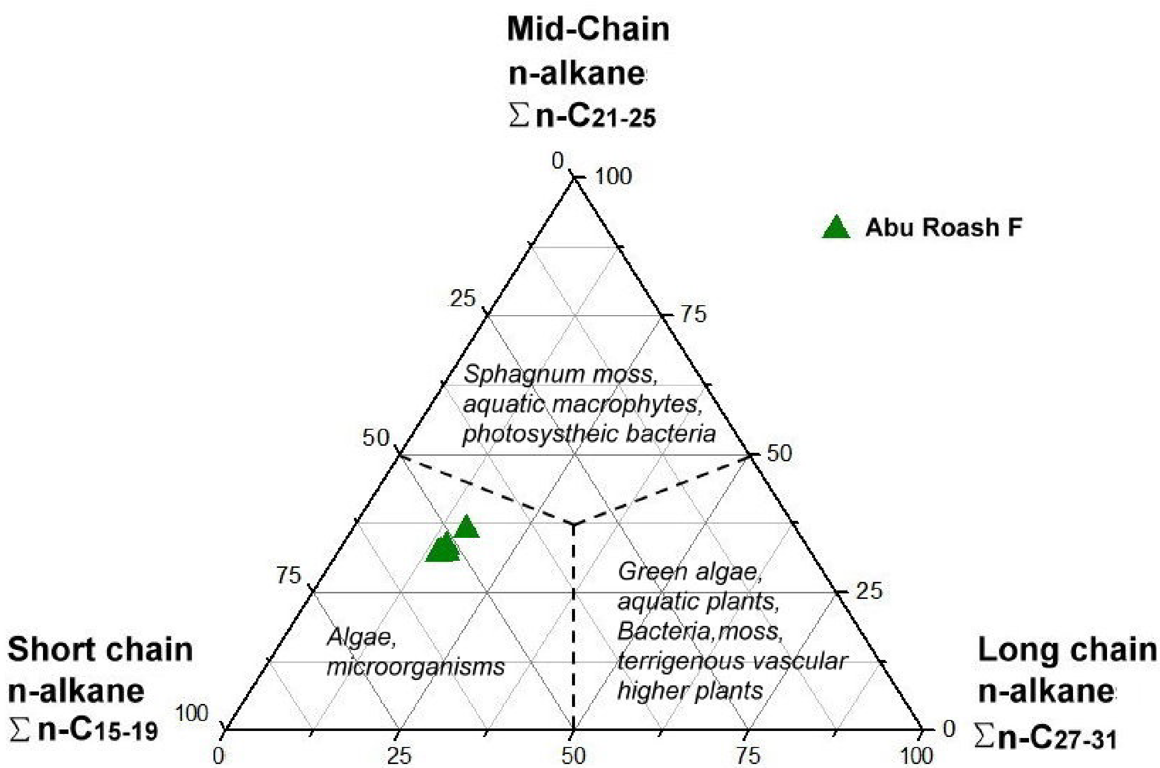

Fig. 4. Plotted of short- mid- and long-chain n-alkane percentages of five extracted samples belonging to Abu-Rosh F Member on trigonal OM origin diagram according to [16].

The very long chain ≥ n-C_{33} is documented according to [21] for a sign of plants belonging to warmer and hot arid climatic zones. In the present study, the percentages of the very long chain in the investigated samples range between 2.6% and 3.8% (average; 3.12%) promote the presence of a vascular plant with a considerately small amount promote a temperate paleoclimate condition during the deposition of the investigated member.

The maxima of isoprenoid pristane in the chromatograph in the upper part (sample A and B) and lower part (sample F) of the Abu-Roash-F Mb instead of the predominant of the odd n-alkane C17, as shown in Figure 3 (samples C, D and E) may be attributed to OM altered by biodegradation. The relatively complex structure of the isoprenoid persists in the biodegradation process than the n-alkanes which was easily biodegradable [22].

5.2. Biomarker indices and ratios

5.2.1. Natural n-alkanes ratio

NAR (natural n-alkanes ratio) were used to differentiate the proportions of n-alkanes which may belong to either petroleum hydrocarbon sources from n-alkanes produced from natural intact living terrestrial and/or marine plant sources [23-25]. Where the NAR ratio is close to zero value, it gives evidence of petroleum hydrocarbon sources. If the ratio is close to one value it gives evidence of natural intact living plant sources of either terrestrial or aquatic [23,26]. The present study shows that the calculated ratio for the present samples of Abu-Roash F is within the values close to zero in-between 0.03 and 0.06 (average; 0.04) which promotes the petroleum origin source n-alkanes.

5.2.2. Degree of waxiness

The waxiness proxy established by [27] to distinguish low waxiness n-alkanes which are mainly related to marine sources from those of high waxiness n-alkanes related to the terrigenous source of a high-molecular-weight n-alkanes.

El Diasty *et al.* [28] compared the GC of many oil samples from the Western Desert of Egypt and concluded that high waxy oil (waxiness >1) is mainly associated with the terrigenous type sources of Bahariya formation. Whereas the moderate waxiness of black oil (waxiness < 1) concern to nonclastic carbonate rock of the Alamein Dolomites Formation (i.e. the waxiness degree increase by increasing the clastic source where decrease by increasing the nonclastic carbonates source rocks in the Western Desert)

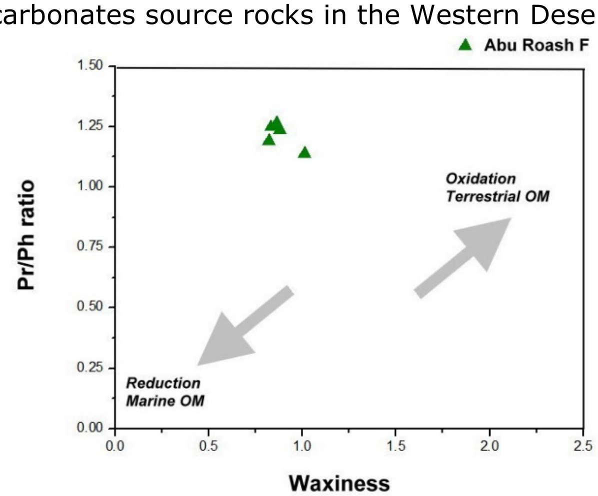

Fig. 5. Cross plot of the investigated samples on the Pr/Ph ratio versus degree of waxiness according to [28] diagram.

The present study reveals the degree of waxiness of the nonclastic source rock of Abu-Roash F exhibits a moderate degree of waxiness with values ranging between 0.82 to 1.01 (average; 0.88) which is the same as the nonclastic source rock of the Alamein dolomites formation. Furthermore, plotting the degree of waxiness versus the Pr/Ph ratios of the studied samples on the diagram of [28] shows that the samples lay in position between the terrigenous and marine depositional and I between the oxidation and reduction conditions (Figure 5).

5.2.3. CPI (carbon performance index)

CPI is used to differentiate the predominance of the n-alkanes odd numbers over n-alkanes even numbers within a range between n-C_{25} and n-C_{33} according to [29] and [30]. The CPI has two implications; the first is used as an indicator of the maturity level of the OM-bearing source rock. The second is an additional referee to distinguish the source input of OM [16,31-32]. Generally, CPI values higher than 1 are an indication of immature OM. Whereas a CPI value is less than 1 is a referee for mature OM [16]. The very high value of CPI attains 5 to 10 is evidence of n-alkane of vascular higher land plants while low values are evidence of the source of n-alkanes originating from bacteria, algal, and /or microorganisms [24,33].

The CPI values of the studied samples show a limited predominance of low values between 0.88 to 0.95 (average; 0.92) which is attributed to both the mature stage of the OM bearing Abu-Roash-F Mb beside the dominated of the alga, bacterial and microorganism dominated input.

Furthermore, plotting of the Abu-Roash F samples on the CPI versus Pr/Ph ratio diagram of [34] as shown in Figure 6 shows that all the samples lay within the area concerned with marine hypersaline carbonate and/or evaporites site.

5.2.4. Lacustrine-marine ratio (n-C_{27}/n-C_{17})

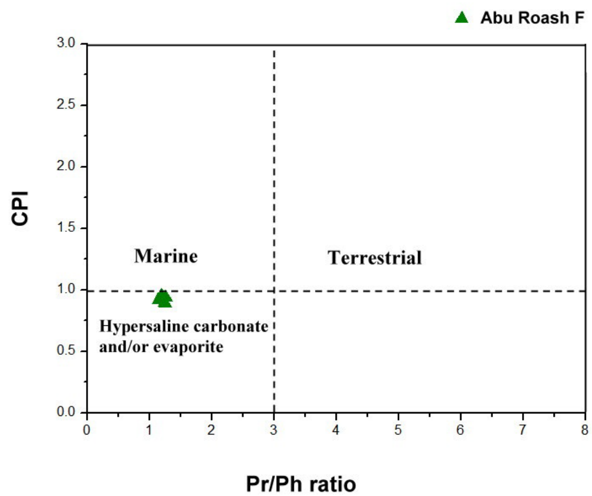

Fig. 6. Cross plot of the investigated samples on the CPI versus Pr/Ph ratio according to [34] diagram.

Katz *et al.* [35] used the ratio of n-C_{27}/n-C_{17} to differentiate the OM of lacustrine origin from the OM of marine origin. The lacustrine OM generally has a high value of n-C_{27}/n-C_{17} proceeding the value of 1 and may reach a value of 2. Whereas the n-C_{27}/n-C_{17} of low ratio <1 mainly reconstructs the OM of the marine origin. Accordingly, by calculate the above-mentioned ratio for the presently studied samples shows that the n-C_{27}/n-C_{17} ratio ranges within the values of 0.31-0.34 (average; 0.33) which illustrates the OM bearing the studied members has affinities to marine origin.

5.2.5. TAR (terrigenous/aquatic ratio) and Paq (aquatic macrophytes proxy)

Mille *et al.* [23] used the terrigenous/aquatic ratio as a function of terrestrial over aquatic plants by determining the concentration relationship of long-chain n-alkanes over short-chain n-alkanes. The high values of the TAR ratio > 25 reflect the dominance of the terrigenous OM over aquatic OM input [16,32]. The calculated ratio for the present samples has a very low TAR ratio ranging from 0.12 to 0.14 (average; 0.13) The TAR of the Abu-Roash-F samples gives evidence of the predominance of aquatic OM over the terrestrial one. The above-mentioned conclusion agreed with a depositional setting of a shallow marine depositional set that formed the carbonates source rock of the Abu-Roash-F Mb in the Beni-Suef basin.

The Paq proxy measures the abundance of aquatic non-emergent macrophytes to aquatic emergent and terrestrial macrophytes [34,36]. Li *et al.* [37] examined the Paq proxy for three categories of submerged and floating plants (SF), terrestrial higher plants (TE), and emergent plants (EM) and concluded that the high Paq proxy of values between 0.64 and ≥0.86 is generally attributed to the first category of submerged and floating plants. Whereas the terrestrial higher plants have a Paq proxy of values between 0.2 and 0.24 and emergent plants have a Paq proxy of values between 0.16 and 0.4.

From the above-mentioned three plant categories, the calculated Paq proxy of the studied members has a value range between 0.67 and 0.69 (average; 0.69) which is an indicator of the OM source from submerged and floating plants are the main constituents in the present studied Abu-Roash F member.

5.2.6. ACL (average chain length) proxy

The ACL proxy was established by Poynter *et al.* [38] to suggest a paleoclimate indicator. The ACL is used since in warmer regions the biosynthesize of the land plant produced a longer chain compound with a higher melting point of wax. Whereas in the cooler and temperate region, biosynthesis produces a shorter chain instead [39]. Li *et al.* [37] compared the ACL with the temperature of many recent lands vegetation and found that a relatively high ACL > 30 mainly correspond to an increase in temperature whereas the ACL of Low value <29 is generally related to a low mean average temperature. Moreover, another interpretation concept for the ACL proxy suggested by Wei *et al.* [40] is that the value of the ACL decreases as the grassland over woody plants increases and vice versa. The ACL measured proxy of the present study Abu-Roash-F Mb shows a value range from 27.89 to 28.01 (average 27.94). Based on the above-mentioned hypothesis, these values may indicate the temperate to cooler climate region during the deposition of the studied member and/or the predominance of the grassland and floating moss over higher plants that are more accepted vegetation concluded during the present study.

5.2.7. Pr/Ph, Pr/n-C_{17}, and Ph/n-C_{18} ratios

Isoprenoids Pr (Pristane) and Ph (phytane) originated from chlorophyll [30]. The Pr/Ph ratio is used generally as redox potential to elucidate the oxygenated–reducing condition during the OM preservation. Zhao *et al.* [41] distinguished dysoxic-suboxic environments of mainly possess a Pr/Ph ratio >1, whereas the anoxic environments mainly have a Pr/Ph ratio <1.

The Pr/Ph of the studied samples has a Pr/Ph ratio ranging between 1.14 and 1.26 (average; 1.22). the Pr/Ph ratio shows a slightly gradual increase toward the bottom of the Abu-Roash F member indicating a predominance of dysoxic of minimal oxygen in water medium to suboxic of slightly oxidized circumstances.

Pr/Ph ratio also may be used as an indication of the depositional paleoenvironments. Peters *et al.* [42] recorded a high Pr/Ph ratio of 2.56 for source rock possessing marine kerogen of types II and III where the Pr/Ph ratio of 1.75 was mostly related to coastal swamp and mixed fluvial-marine environments. As the Pr/Ph ratio reaches 2-4 the coastal swamp setting was the most favourable depositional environment.

Plotting the Abu-Roash F samples on the Pr/Ph versus the Pr/n-C_{17} diagram according to [43] show that the studied member possesses an intermediate position revealing a mixture of terrigenous, marine, and lacustrine organic matters (Fig. 7).

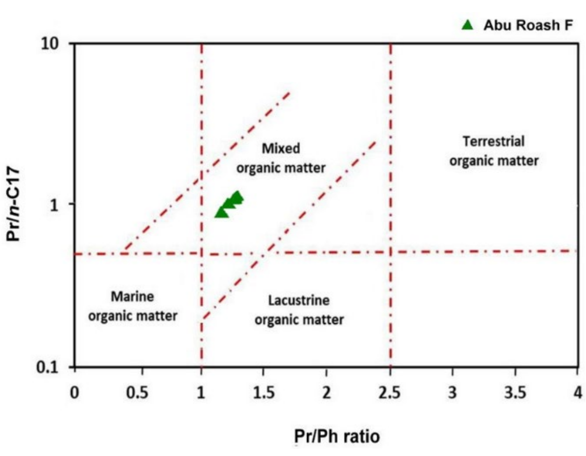

Fig. 7. Cross plot of the Abu-Roash-F member on the Pr/n-C_{17} versus Pr/Ph ratios according to [43] diagram.

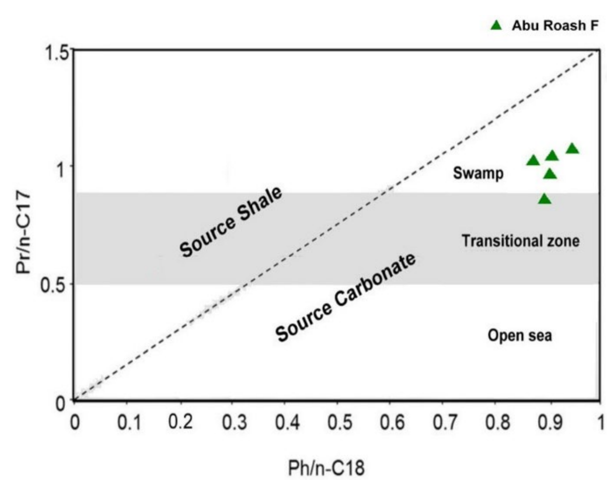

Fig. 8. Cross plot of the studied Abu-Roash-F member on the Pr/n-C_{17} and Ph/n-C_{18} according to [44] diagram.

The biomarker of the Pr/n-C_{17} ratio is used by [44] to differentiate the origin of OM either from the aquatic swamp of the Pr/n-C_{17} >1 or from open marine water of the Pr/n-C_{17} <0.5. The previous author used the relationship between the ratios of Pr/n-C_{17} versus Ph/n-C18 to differentiate the clastic terrigenous source from the non-clastic carbonates source rocks (Fig. 8). From Figure eight, the position of the studied samples lay within the area of carbonate source rock with transitional and swampy depositional sets. The Pr/n-C_{17} for the studied members shows a value range between 0.86 and 1.08 (average; 1) which may be attributed to depositional settings belonging to transitional marine and coastal paralic swamps (Fig. 8).

Furthermore, plotting of the investigated samples on the [45] Pr/n-C_{17} versus Ph/n-C_{18} diagram (Fig. 9), elucidates that the types and depositional sets of the studied samples confirm that the redox potential was of intermediate suboxic-dysoxic environments. The OM are mainly of the mature mixed types II and III kerogen belonging to transitional marine environments (Fig. 9).

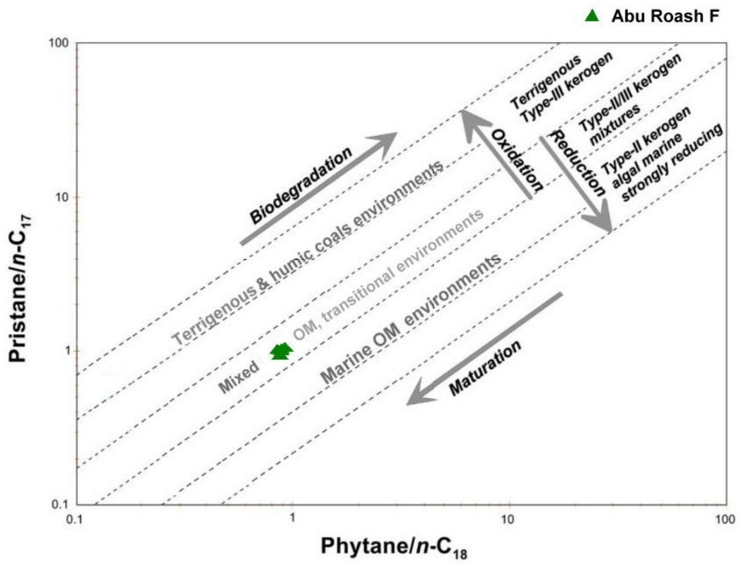

Fig. 9. Cross plot of the studied Abu-Roash-F member on the Pr/n-C_{17} and Ph/n-C_{18} according to [45] diagram.

6. Conclusions

Geochemical investigation of the organic matter-rich interval involved the calcareous source rock of the Abu-Roash F Mb in the well WON C-3X between the depths of 2002.5m and 2017.8m (Beni Suef- Basin) demonstrates that the algae and aquatic microphytes of the low and mid- chain n-alkanes were the main constituents of the OM bearing Mb. The intermediate value of the waxiness degree prefers the relatively considerable amounts of macrophyte input. The marine setting was promoted by determining the n-C_{27}/n-C_{17} ratio of a very low average value (0.33; less than one). The maturity of the studied Abu-Roash F member is distinguished by calculating the CPI of average values (0.92; less than one) which promotes the mature source rock stage. Measurements of the TAR and the Paq proxies for the five representative samples reveal the dominance of submerged and floating plants as a main constituent plant input. The redox potential was suggested based on the measurements of the Pr/Ph ratios which show a gradual increase with depth from dysoxic toward a suboxic environment. A grassland over woody plants under temperate to cooler conditions was suggested based on the lower measuring values of both very-long-chain percentages (3.13%) and the ACL proxy (27.94).

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