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رئيس المعمل رئيس القسم

ISSN: 1091-6466 (Print) 1532-2459 (Online) Journal homepage: <http://www.tandfonline.com/loi/lpet20>

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To cite this article: Abedel Aziz Elfadly, Omayma E. Ahmed & Mohamed M. El Nady (2016) Applications of biological markers in assessing the organic richness of the surface sediments of Suez Gulf, Egypt, Petroleum Science and Technology, 34:15, 1387-1396

To link to this article: <http://dx.doi.org/10.1080/10916466.2016.1200083>



Published online: 09 Sep 2016.



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Applications of biological markers in assessing the organic richness of the surface sediments of Suez Gulf, Egypt

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ABSTRACT

The semienclosed Suez Gulf records various signals of high anthropic pressures from surrounding regions and the industrialized Suez countries. The sedimentary hydrocarbons have been studied in six coastal stations located in the Gulf of Suez. Nonaromatic hydrocarbons were analyzed by GC/FID and GC/MS to assess organic content in surface sediments of Suez Gulf, Egypt, depending on alkane, terpane, and sterane biological marker indicators. The results showed that the hydrocarbons are originated from multiple terrestrial inputs, biogenic and pyrolytic. Several ratios hydrocarbons indicated the predominance of petrogenic in combination with biogenic hydrocarbons.

KEYWORDS

Egypt; *n*-alkanes; sediment; steranes; Suez Gulf; triterpenes

1. Introduction

The Suez Canal is located in northeast Egypt at the entrance of the Red Sea and extends from Port Said in the north and Port Tawfiq in the South, with overall length about 162 km. Its 22.5 m water depth is limited by latitudes 29° 54' and 29° 57' N and longitudes 32° 28' and 32° 34' E. The area of study comprises the important parts of Suez Canal, which includes Inlet of Suez Oil Petroleum Company (SOPC), AL-Kabanon, AL-Atka Harbor (Figure 1), and AL-Nasr Petroleum Company (NPC). The Suez is home to a major oil refinery and many other manufacturing industries and sediment contamination in this area is thus a sensible model site for high entropic pressures by the commercial harbors, development of the city of Suez, and presence of a maritime route North Western of Suez Gulf coasts with an intense traffic. Hydrocarbons come from various origins: ship traffic, fisheries activities, revering inputs, and inputs associated with municipal and industrial sewage waters, especially from storage of crude oil and phosphogypsum at the coast. The objectives of the present study are to (a) determine the occurrence, distribution and source of *n*-alkanes, steranes, and terpanes in surface sediments in some parts of the Gulf; (b) examine the distribution, composition, and relative maturity levels of hydrocarbons in the sediments; (c) identify possible sources contamination in the nonaromatic hydrocarbon; and (d) provide data on hydrocarbon contamination of sediments collected in the Suez Gulf. This is achieved throughout the analysis of nonaromatic hydrocarbons by gas chromatography (GC) and gas chromatography–mass spectrometry (GC/MS). This fraction constitutes the predominant part of crude oils. It contains various hydrocarbons such as *n*-alkanes, isoprenoids, terpanes, and steranes, for which their distribution permits assessment of the various origins of hydrocarbons.

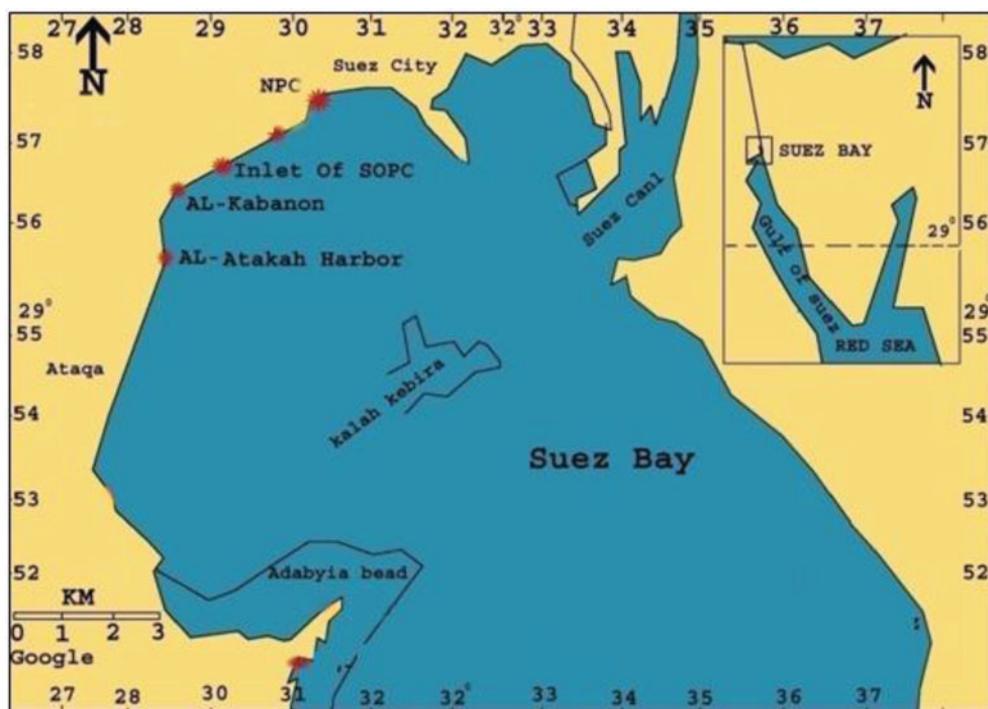


Figure .1 Map showing the area of study along Suez Gulf shoreline, Egypt.

2. Experimental

2.1. Materials

A total of four surface sediment samples were selected to cover about 18.7 km from the Suez Gulf coast (Figure 1). Sediments were collected utilizing a stainless-steel grab. About 8–100 g of each sample was taken and weighted in an aluminum dish and oven-dried at 105°C to a constant weight to obtain percentage water content for each sample. The studied sites and their locations, activities, and distances from NPC 700 at depth, outlet of SOPC are inlet of SOPC at a depth of 1.067 km, AL-Kabanon at a depth of 2300 m, and AL-Atka Harbor at a depth of 3500 m

2.2. Methods

Hydrocarbons were extracted by direct saponification via alkaline hydrolysis. All the EOM were separated by microglass columns 10 cm length and 0.8 mm diameter, filled with activated silica using a three-step scheme providing three fractions: saturates, elution with hexane; aromatics, elution with benzene; and polar compounds, elution with methylene chloride. Saturated hydrocarbon fractions were subjected to capillary GC. The instrument used was Agilent Technologies 7890 gas chromatograph system, equipped with flame ionization detector (FID). Oven temperature was programmed from 100°C to 300°C at fixed rate of 3°C min⁻¹ and HP-1 fused silica capillary column (60 m × 0.53 mm × 0.5 μm) (Renee et al., 2016). The biomarker traces using Perkin Elmer Claruss 500 GC-MS apparatus. Samples were injected onto a fused silica capillary column (30 m in length, 0.32 mm diameter, film thickness 0.25 μm) coated with HP-5 MS. Helium was the carrier gas with flow rate of 1.5 ml/min. and temperature was programmed from 80 to 310°C at rate of 3°C/min. The identification of biomarker is obtained through the relative triterpenes and steranes abundance was calculated using the integrated peak areas for the relevant ion *m/z* 191 and *m/z* 217 chromatograms.

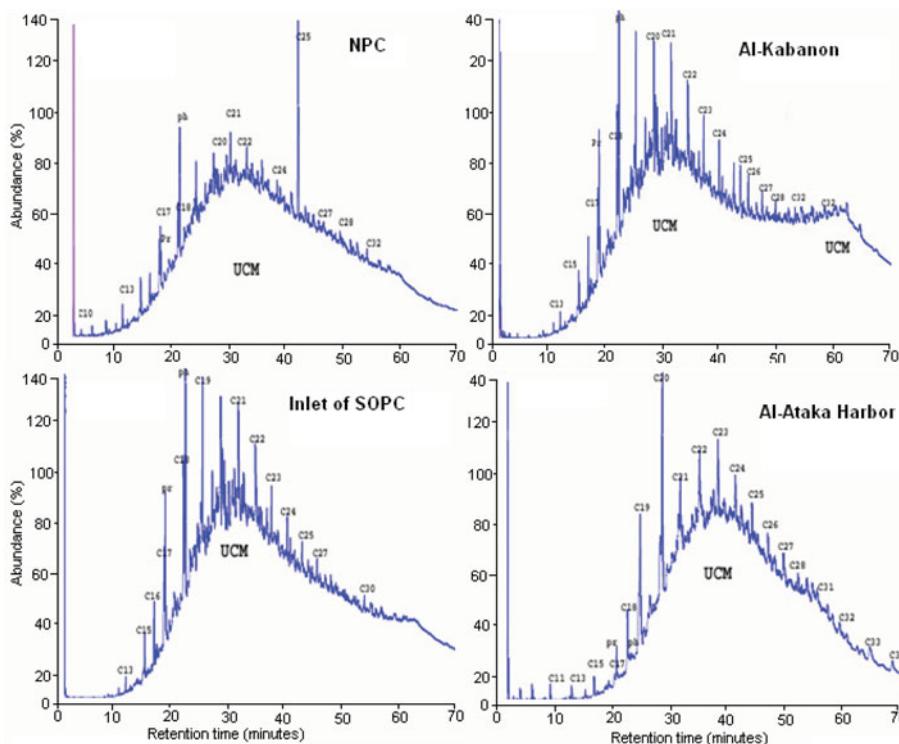


Figure 2. Gas chromatograms of saturated hydrocarbon fractions for different representative stations. The numbers indicate the carbon chain length of *n*-alkanes.

3. Results and discussion

3.1. *n*-Alkanes

Chromatographic profiles of saturated hydrocarbon fractions showed generally the presence of nC_{10} to nC_{40} *n*-alkanes (Figure 2). For surface sediments of Suez Gulf, the dominant peaks occur at C_{17} or C_{18} and C_{29} or C_{31} for the short chain (C_{15} – C_{20}) and long chain (C_{21} – C_{35}) *n*-alkanes, respectively (Figure 2). The most abundant alkanes found in all sediments were nC_{27} , nC_{29} , nC_{31} , and nC_{33} , which are representative of the terrestrial plant-related higher *n*-alkanes with odd carbon predominance. The odd–even carbon number preference (OEP) values in the sediment samples ranged from 1.28 to 1.99 (Table 1). The low OEP values suggest petroleum input, strong bacterial activities or low flux of terrestrial vascular plant debris (Meyers and Ishiwatari, 1993). These indicate that surface sediments in different regions along the Suez Gulf have different sources of dominant *n*-alkanes. We also observed the presence of two isoprenoid alkanes' pristane and phytane.

The carbon preference index (CPI), obtained from the *n*-alkane distributions, is used as source indicator of *n*-alkanes in marine sediments. CPI values of *n*-alkanes derived from land plant epicuticular waxes range from 4 to 10, while those from petroleum and other anthropogenic activities such as combustion of fossil fuel, wood and agricultural debris have values close to 1 (Wakeham, 1996). The CPI value, defined in Table 1, was calculated from *n*-alkane distributions in the studied samples ranged from 0.62 to 1.95 values, suggesting *n*-alkanes of mixed origin. However, values >4 suggested that the *n*-alkanes were derived from terrigenous plant (Qiu and Saliot, 1991).

Pristane and phytane are common isoprenoid alkanes that are usually derived from phytanyl side-chains in chlorophyll. The ratios obtained for samples sediments ranging from 1.69 to 4.00 and 6.32 to 10.98, respectively (Table 1) indicates mainly a biogenic source. In uncontaminated sediments, the

Table 1. Indices featuring diagnostic biomarkers in sediment samples from Suez Gulf, Egypt.

| Data | Sample | | | |
|---|--------|---------------|------------|-----------------|
| | NPC | Inlet of SOPC | aL-Kabanon | Al-Ataka Harbor |
| OEP | 1.99 | 1.74 | 1.31 | 1.28 |
| CPI | 1.95 | 0.87 | 0.62 | 0.73 |
| Pr | 2.38 | 3.82 | 4.00 | 1.69 |
| Ph | 7.43 | 10.32 | 10.98 | 6.32 |
| Pr/Ph | 0.32 | 0.37 | 0.36 | 0.27 |
| Pr/nC17 | 1.23 | 1.55 | 1.98 | 2.8 |
| Ph/nC18 | 2.90 | 2.60 | 2.79 | 1.02 |
| nC29/C17 | 0.42 | 0.53 | 0.74 | 1.09 |
| C35/C34 homohopanes | 0.60 | 0.60 | 0.75 | 0.80 |
| Homohopane index | 0.57 | 0.76 | 0.59 | 0.62 |
| Ts/Tm | 0.76 | 0.40 | 0.61 | 0.53 |
| Ts/(Ts+Tm) | 0.63 | 0.29 | 0.58 | 0.35 |
| C24/C23 Tricyclic terpanes | 0.63 | 0.58 | 0.52 | 0.54 |
| C26/C25 Tricyclic terpanes | 0.86 | 0.61 | 0.71 | 0.66 |
| C29 Norhopane/C30hopane | 0.78 | 0.58 | 0.42 | 0.54 |
| Moretane/hopane | 0.07 | 0.09 | 0.08 | 0.08 |
| Gammacerane index | 0.16 | 0.17 | 0.24 | 0.06 |
| C27 Steranes (%) | 28.16 | 30.0 | 27.08 | 0.0 |
| C28 Steranes (%) | 37.27 | 31.80 | 42.14 | 48.60 |
| C29 Steranes (%) | 34.58 | 38.20 | 30.00 | 51.40 |
| C28/C29 R.Steranes | 0.44 | 0.41 | 0.35 | 0.38 |
| Diasteranes/Steranes | 0.48 | 0.74 | 0.16 | 0.97 |
| Steranes/hopanes | 0.38 | 0.60 | 0.45 | 0.56 |
| Tricyclic terpanes/Steranes | 0.31 | 0.18 | 0.28 | 0.19 |
| 20S/20S+20R/C29 Steranes | 0.48 | 0.51 | 0.49 | 0.52 |
| $\beta\beta$ ($\beta\beta+\alpha\alpha$) C29 Steranes | 0.53 | 0.53 | 0.50 | 0.50 |

CPI: Σ odd (C15–C34)/ Σ even (C15–C34); CPI2: C27+C29+C31+C33/ C28+C30+C32+C34; Pr/Ph: pristane (Pr) over phytane (Ph) ratio; Pr/nC17: pristane to carbon number nC17; Ph/nC18: phytane to carbon number nC18; OEP: C21+6C23+C25/4(C22+C24); UCM: Unresolved complex mixture; TAR: C27+C29+C31/C15+C17+C19; ACL: average chain length: $(25(nC25)+27(nC27)+29(nC29)+31(nC31)+33(nC33))/(nC25+nC27+nC29+nC31+nC33)$; C35/C34 Homohopanes; Homohopane index = $(C35 \text{ homohopane } S+R)/(C31+C32+C33+C34+C35 \text{ homohopanes } S+R)$; Ts/Tm: Trisnorneohopanes ratios; Ts/(Ts+Tm); Trisnorhopanes/ Trisnorhopanes+ Trisnorneohopanes; C24/C23 = C24/C23 tricyclic terpanes; C25/C26 = C25/C26 tricyclic terpanes; Norhopane/Hopane = C29norhopane/C30hopane; Gammaceraneindexgammacerane/(gammacerane+C30hopane); %C27Steranes(S+R) = $100 \times C27/(C27+C28+C29)$; %C28Steranes(S+R) = $100 \times C28/(C27+C28+C29)$; %C29Steranes(S+R) = $100 \times C29/(C27+C28+C29)$; Diasteranes/Steranes = $C27+C28+C29(R+S)$ diasteranes/C27+C28+C29(R+S) steranes; Steranes/hopanes = $C27+C28+C29(R+S)$ steranes/C30 hopane; Tricyclic terpanes/Steranes = $(C23+C24+C25+C26)$ tricyclic terpanes/C27+C28+C29(R+S) steranes.

pristane/phytane ratio ranging from 0.27 to 0.37, whereas a value lower than 1 suggests petroleum contamination with both fresh and degraded petroleum hydrocarbons (Le Dreau et al., 1997). The studied samples have pristane/n-C₁₇ and phytane/n-C₁₈ ratios range from 1.23 to 2.8 and from 1.02 to 2.9, respectively (Table 1). These ratios indicate that these samples were derived mainly from mixed organic matter deposited under reducing and oxidizing environments (Peters et al., 2005). The nC₂₉/nC₁₇ ratio is a widely used parameter that reflects the relative contribution of terrestrial and marine lipids (Le Dreau et al., 1997). The nC₂₉/nC₁₇ ratio of studied samples ranged from 0.42 to 1.09 (Table 1) reflecting a prevailing terrestrial source in the upstream sediments.

3.2. Tricyclic terpanes

The concentration of tricyclic terpanes in organic matters is more sensitive to the specific paleo environments and used as a qualitative indicator of maturity (Van Grass, 1990). In high mature organic matters, the tricyclic terpanes is dominated more than in low mature organic matters (Hunt, 1996). Our study reveals that the concentration of C₂₂ tricyclic terpanes peak A in the studied samples is low in Inlet of SOPC (Figure 3; see peak identifications in Table 2) indicate that the organic matter of this sample is low mature. However, the other samples from NPC, the C₂₂ tricyclic terpanes peak A is higher, which may support the idea that the organic matters are more mature and sourced mainly from carbonate source rocks. On the other hand, C₂₃ to C₂₉ tricyclic terpane peaks B to J (Figure 3; see peak identifications in

Table 2. Identification of peaks in triterpanes (m/z 191) and steranes (m/z 217) mass fragmentograms.

| Triterpanes (m/z 191) | | Steranes (m/z 217) | |
|--------------------------|--------------------------------------|-----------------------|---|
| Peaks | Compounds Name | Peaks | Compounds Name |
| A | C22 Tricyclic Terpane | A | C ₂₇ $\alpha\beta$ diasterane (20S) |
| B | C23 Tricyclic Terpane | B | C ₂₈ $\beta\alpha$ diasterane (20S) |
| C | C24 Tricyclic Terpane | C | C ₂₈ $\beta\alpha$ diasterane (20R) |
| D | C25 Tricyclic Terpane (22R) | D | C ₂₇ $\alpha\alpha\alpha$ sterane (20S) |
| E | C26 Tricyclic Terpane (22S) | E | C ₂₇ $\alpha\beta\beta$ sterane (20S) |
| F | C26 Tricyclic Terpane (22S) | F | C ₂₇ $\alpha\alpha\alpha$ sterane (20R) |
| G | C28 Extended Tricyclic Terpane (22S) | G | C ₂₉ $\beta\alpha$ diasterane (20R) |
| H | C28 Extended Tricyclic Terpane (22R) | H | C ₂₉ $\beta\alpha$ diasterane (20S) |
| I | C29 Extended Tricyclic Terpane (22S) | I | C ₂₈ $\alpha\alpha\alpha$ sterane (20S) |
| J | C29 Extended Tricyclic Terpane (22R) | J | C ₂₈ $\alpha\beta\beta$ sterane (20R) |
| K | C27 Trisnorhopane (Ts) | K | C ₂₈ $\alpha\beta\beta$ sterane (20S) |
| L | C27 Trisnorhopane (Tm) | L | C ₂₈ $\alpha\alpha\alpha$ sterane (20R) |
| M | C28 Bisonorhopanes | M | C ₂₉ $\alpha\alpha\alpha$ sterane (20S) |
| N | C29 Norhopanes | N | C ₂₉ $\alpha\beta\beta$ sterane (20R) |
| O | C29 Normoretane | O | C ₂₉ $\alpha\beta\beta$ sterane (20S) |
| P | C30 Hopane | P | C ₂₉ $\alpha\alpha\alpha$ sterane (20R) |
| Q | C29 Moretane | Q | C ₃₀ $\alpha\beta\beta$ steranes (20R) |
| R1 | C31 Homohopane (22S) | R | C ₃₀ $\alpha\beta\beta$ steranes (20S) |
| R | C31 Homohopane (22R) | S | C ₃₀ $\alpha\alpha\alpha$ steranes (20R) |
| S | C30 Gammacerane | | |
| T | C32 Homohopane (22S) | | |
| U | C32 Homohopane (22R) | | |
| V | C33 Homohopane (22S) | | |
| W | C33 Homohopane (22R) | | |
| X | C34 Homohopane (22S) | | |
| Y | C34 Homohopane (22R) | | |
| Z | C35 Homohopane (22S) | | |
| a | C35 Homohopane (22R) | | |

Table 2) are generally of high detection levels in the studied organic matters, indicating that these organic matters have inputs derived from marine organic material with input from terrestrial origin, except for SOPC, which was characterized by low concentration of C₂₃ to C₂₉ tricyclic terpanes revealing inputs derived from terrestrial organic material (Hunt, 1996). Triterpane distributions (m/z 191) contain high concentrations of the C₃₀ hopanes (peak P; Figure 3; see peak identifications in Table 2). These characteristics in the studied organic matters indicate input of their derivation from organic-rich marine carbonates or evaporites deposited under anoxic conditions (Riediger et al., 1990). The presence of low normoretanes (peak O) and moretanes (peak Q; Figure 3) indicates an organic matters comprising of marine origin. Furthermore, the high abundance of C₂₉ norhopane (peak N) and low C₂₈ bisnorhopane (peak M; Figure 3, Table 2), which is considered to be slightly marine indicator with input from terrestrial origin (Waples and Machihara, 1991). The presence of gammacerane (peak S; Figure 3; see peak identifications in Table 2) suggest a marine, lacustrine, near-shore, or deltaic depositional environments. Also, the distribution of the homohopanes with a regular decrease in peak height from the C₃₁ to C₃₅ (Figure 3; see peak identifications in Table 2) indicates a clastic facies for the studied organic matters (Waples and Machihara, 1991).

3.3. Homohopanes

The distribution of homohopanes 22R+22S in the organic matter can be used as an indicator of the associated organic matter type, as it can also be used to evaluate the oxic/anoxic conditions of source during deposition of the source sediments. Low C₃₅ homohopanes are an indicator of highly reducing marine conditions during deposition, whereas high C₃₅ homohopane concentrations are generally observed in oxidizing water conditions during deposition (Peters et al., 2005). The studied organic matters have low concentrations of C₃₁-C₃₅ homohopanes (20S and 20R; peak R1; Figure 3; see peak identifications in Table 2), which are more significant to abundance of anoxic environment. The homohopane index is the

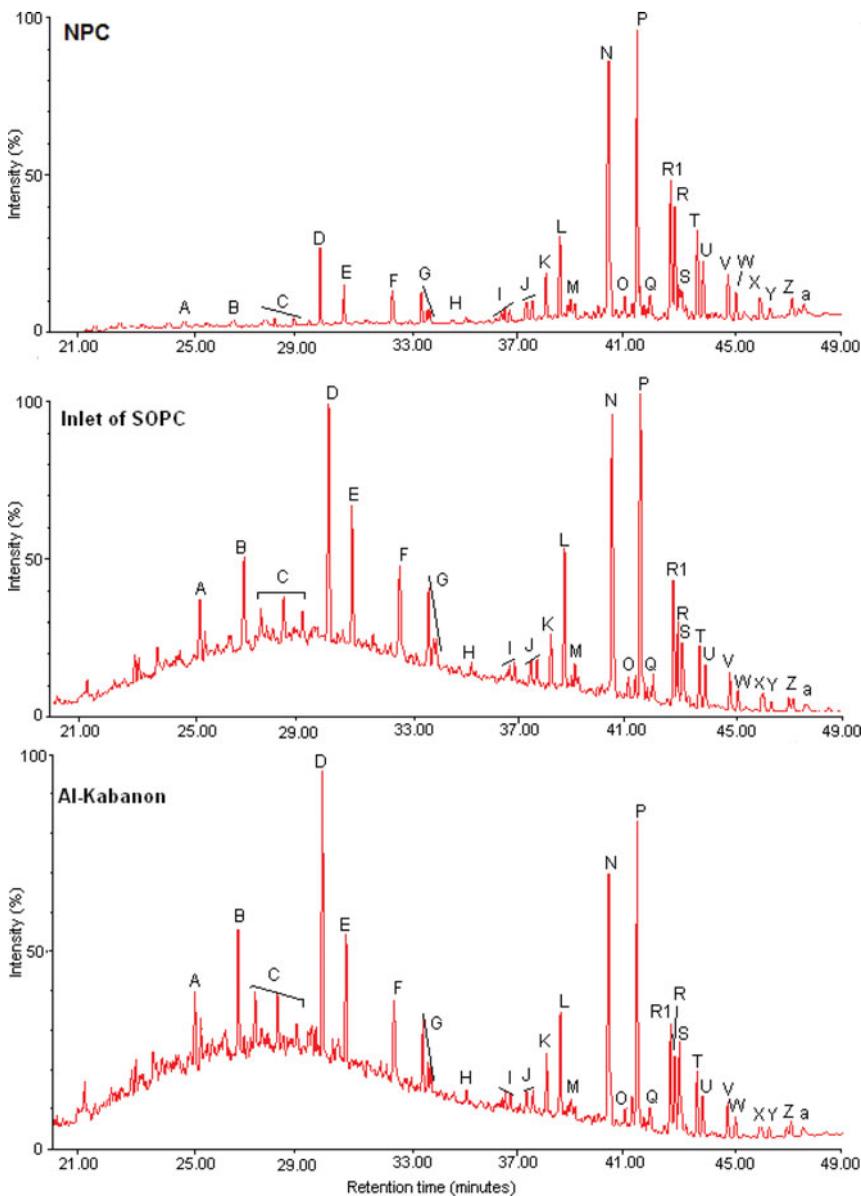


Figure 3. Triterpanes (m/z , 191) of saturated hydrocarbons fractions of surface sediments from different representative stations of Suez Gulf, Egypt.

ratio $C_{35}/(C_{31}-C_{35})$ homohopanes, usually expressed as a percentage are calculated and listed in [Table 2](#). The homohopane indices of the studied samples values are 0.57 to 0.76 ([Table 2](#)) and are more significant to hypersaline marine origin under anoxic conditions (Peters et al., 2005).

3.4. *Trisnorneohopane/trisnorhopane (Ts/Tm)*

The Ts/Tm ratio increases as the portion of shale in calcareous facies increases (Hunt, 1996). Also, this ratio was proved to be useful as paleofacies indicator, though not as decisive as mature parameters. Van Grass (1990) proved that during the late maturation, Ts/Tm ratios begin to decrease. El Nady (2008) reported that Ts/Tm ratio does not appear to be appropriate for quantitative estimation of maturity. We can conclude that the Ts/Tm ratios for extract samples ranged from 0.40 to 0.76. It indicates more

mature and/or clay-rich source rock. Furthermore, the $T_s/(T_s+T_m)$ ratios show different thermal maturity magnitudes among the analyzed samples (Waples and Machihara, 1991). The extract samples ranged from 0.29 to 0.63 (Table 1). This result confirms the previous conclusions.

3.5. Norhopane/hopane

The C_{29} norhopane rivals C_{30} hopane on m/z 191 mass chromatograms (norhopane/hopane ratio > 1.0) of saturated fractions extracts from organic-rich carbonate-evaporite rocks (e.g., calcite, halite, gypsum, anhydrite) generally show larger peaks on the m/z 191 chromatogram for the C_{29} norhopane compared with the C_{30} hopane. C_{29} norhopane/ C_{30} hopane ratios are generally high in organic matters generated from organic rich carbonates and evaporate (Peters et al., 2005). The studied samples have high concentration of C_{29} norhopane than C_{30} hopane (Figure 3; peaks N and P, Table 2), with high C_{29} norhopane/ C_{30} hopane ratios range from 0.42 to 0.78 (Table 1). These data illustrate that the samples might be sourced from source rocks rich in carbonaceous organic matters (Waples and Machihara, 1991). This assumption is confirmed by low abundance of C_{29} moretane (peak Q), gammacerane (peak S), and slightly low concentration of C_{28} bisnorhopanes (peak M).

3.6. Moretane/hopane

Moretanes and hopanes compounds occur in most rocks and crude oils in varying quantities, depending on their source, different stereo isomers, and the extent of maturation, in contrast to hopanes, which indicate a major bacterial input to the sediment and rare in organic materials of marine origin (Hunt, 1996). The abundance of C_{29} moretane (peak Q) lower than C_{30} hopane (peak P; Figure 3; see peak identifications in Table 2) with C_{29} moretane/ C_{30} hopane ratios ranging from 0.07 to 0.09 (Table 1) revealing that the extracts sample originated mainly from mixed organic origin rich in terrestrial organic matters (Peters et al., 2005).

3.7. Tricyclic terpane ratios (C_{24}/C_{23} and C_{26}/C_{25})

Tricyclic terpanes are used to correlate organic matters and source-rock extracts, predict source rock characteristics, and evaluate the extent of thermal maturity and biodegradation. The different ratios of tricyclic terpanes by carbon number confirm their derivation from marine carbonate/evaporite with minor terrigenous input (Peters et al., 2005). The various values of C_{24}/C_{23} and C_{26}/C_{25} tricyclic terpane of the studied samples ranging from 0.52 to 0.63 and 0.61 to 0.86, respectively (Table 1), showing that the extracts are deposited in dominant marine environment with abundant carbonate source rocks that contain type-II kerogen, and deposited under marine conditions with input of predominantly algal-derived organic matter.

3.8. Gammacerane

Gammacerane is highly specific for water-column stratification (commonly due to hypersalinity) during source-rock deposition (Peters et al., 2005). This index is usually measured using m/z 191 fragments and expressed as gammacerane/(gammacerane + C_{30} hopane). Sediments that were deposited in hypersaline lakes under often contain high relative concentrations of gammacerane, which is a biomarker generally associated with water column stratification (Brocks et al., 2003). Gammacerane is also often profused in fresh water sediments and probably increases when the depositional environment is more saline, exhibiting both marine and lacustrine environments (Peters et al., 2005). Gammacerane (peak S) occurs in slightly high amounts all studied samples than S. No. 4 (Figure 3; see peak identifications in Table 2) indicating slightly low mature sample than the others. On the other hand, a high gammacerane index (gammacerane/hopane) is interpreted to indicate highly reducing and hypersaline conditions during deposition. Sinninghe Damsté et al. (1995) showed that the gammacerane index is an indicator for water column stratification as it varies from 0.06 to 0.24 (Table 1). This suggests a carbonate-rich source

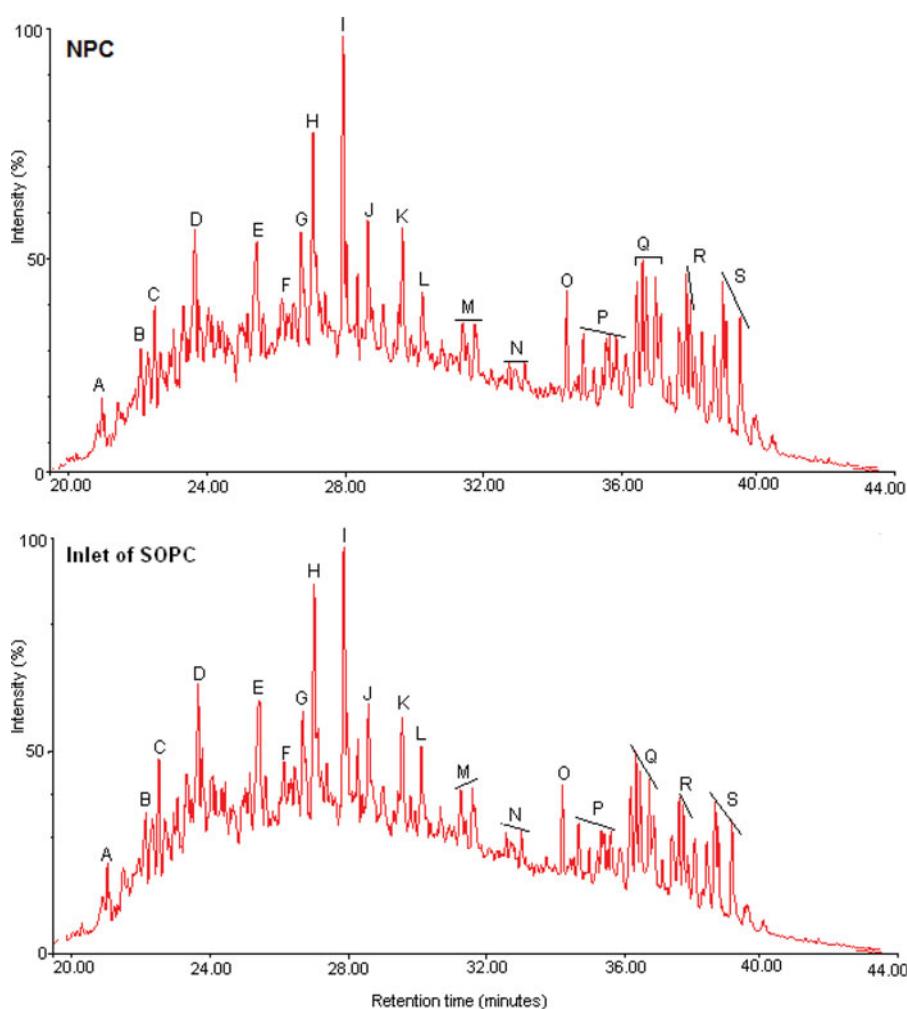


Figure 4. Steranes (m/z , 217) of saturated hydrocarbons fractions of surface sediments from different representative stations of Suez Gulf, Egypt.

rock, deposited in a strictly anoxic environment with a stratified water column for the studied extracts samples.

3.9. Steranes

Figure 4 shows that the distribution of steranes and diasteranes of studied samples of saturated hydrocarbons fractions of surface sediments of Suez Gulf, Egypt, and peak identification is listed in Table 2.

3.10. C_{27} , C_{28} , C_{29} , and C_{30} steranes

The C_{27} , C_{28} , and C_{29} sterane is an effective tool used to differentiate depositional settings using GC-MS m/z 217. The main sources of C_{27} steranes are of marine origin, and that of C_{29} steranes are mostly from advanced plants. C_{28} steranes consist of a mix of advanced plants and algae (Peters et al., 2005). The high C_{29} sterane abundances are usually associated with source rocks containing primarily higher plant organic matter (Bacon et al., 2000). The C_{27} - C_{28} - C_{29} steranes distributions of the studied samples from the Gulf of Suez are shown in Figure 4. This figure showed that the steranes distribution is characterized by slightly high predominance of C_{28} sterane peaks I to L than C_{27} steranes (peaks, D to F), and C_{29}

steranes peaks M to P, except S. No. 4 has decay for the C_{27} steranes (Figure 4; see peak identifications in Table 2) also the relatively low concentration C_{27} diasteranes peak A (Figure 4; see peak identifications in Table 2), as well as there is high abundance from C_{30} sterans peaks Q-S (Figure 4; Table 1) indicates that the studied organic matters are derived from a mixed to abundant marine depositional environment of a mix of advanced plants and algae (Peters et al., 2005). Also, the presence of C_{30} steranes (Figure 4, peaks R and S; see peaks identifications in Table 2) indicates a marine depositional influence. The C_{28}/C_{29} regular steranes value <0.5 is an indication that the organic matters were derived from carbonate-rich source rocks that contain type-II kerogen, deposited under marine conditions with input of predominantly algal-derived organic matter (Peters et al., 2005). In the present study, the C_{28}/C_{29} regular steranes values ranging from 0.35 to 0.44 (Table 1) indicating that the organic matters under investigated were derived from carbonate-rich source rocks that contain type-II kerogen, deposited under marine conditions with input of predominantly algal-derived organic matter. Moreover, the steranes/hopane ratios (Table 1) of the studied samples ranging from 0.38 to 0.60 reflect organic matters derived from source rock rich in terrestrial organic origin and slightly high mature level. These results are confirmed by the ratios of tricyclic terpanes/steranes (Table 1), where it is ranging from 0.18 to 0.31 (Peters et al., 2005).

3.10. Diasterane/steranes

The diasterane/sterane ratio indicates a clay-rich environment and characterizes carbonate from clay-rich source rocks (Fildani et al., 2005). The diasterane/sterane ratios can be used to classify mature from highly mature source and then depict the source of petroleum whether from carbonate or clastic source rocks (Brincat et al., 2001). In this study the ratios of diasterane/sterane for the studied samples ranging from 0.16 to 0.97 (Table 1) indicating their derivation from a varied clay content, with abundant anoxic clay-poor carbonate source rock.

3.11. $20S/(20S+20R)$ and $\beta\beta/(\beta\beta+\alpha\alpha)$ C_{29} sterane

With increasing thermal maturity, $20S/(20S+20R)$ rise from 0 to 0.5, and cause an increase in $\beta\beta/(\beta\beta+\alpha\alpha)$ values to ~ 0.7 (Seifert and Moldowan, 1986). This ratio appears to be independent of source organic matter input and thus making it effective at higher levels of maturity (Peters et al., 2005). All of the investigated samples have $20S/(20S+20R)$ and $\beta\beta/(\beta\beta+\alpha\alpha)$ C_{29} sterane ratios ranging from 0.48 to 0.52 and 0.50 to 0.53, respectively (Table 1), indicating a maturity and being dominated by marine algal/bacterial organic matter, with a variable terrigenous input.

Conclusions

Semienclosed Suez Gulf surficial sediments showed different levels and sources of aliphatic hydrocarbons, and biological biomarkers and related indices may refer to anthropogenic contamination, especially related to petrogenic sources, as well as recent biogenic materials. Near refinery, harbor, and beaches input (terrestrial), discharges, and anthropogenic petrogenic AHC inputs were predominant. This was supported by high Org-C₁-normalized low n-alkane CPI and OEP; and the high degree of maturity of hopane biomarkers. On the contrary, sediments exhibited the high n-alkane CPI and OEP, and a low degree of maturity of hopane biomarkers. These features suggested that these sediments have a dominant biogenic origin. Biomarker parameters for most sediment samples indicate the predominance of petrogenic in combination with biogenic hydrocarbons.

References

- Bacon, C. N., Calver, C. R., Boreham, C. J., Lenman, D. E., Morrison, K. C., Revill, A. T., and Volkman, J. K. (2000). The petroleum potential of onshore Tasmania: A review. *Geol. Surv. Bull.* 71:1–93.

- Brincat, D., and Abbott, G. (2001). Some aspects of the molecular biogeochemistry of laminated and massive rocks from the Naples Beach Section (Santa Barbara-Ventura Basin). In: Isaacs, C. M., Rullkötter, J. (eds.), *The Monterey formation: from rocks to molecules* (pp. 140–149). New York, NY: Columbia University Press.
- Brocks, J. J., and Summons, R. E. (2003). Sedimentary hydrocarbons, biomarkers for early life. *Biogeochemistry* 8:63–115.
- El Nady, M. M. (2008). Biomarkers assessment of crude oils and extracts from Jurassic-Cretaceous rocks, North Qattara Depression, North Western Desert. *Egypt. J. Pet. Sci. Technol.* 26:1063–1080.
- Ficken, K. J., Li, B., Swain, D. L., and Eglinton, G. (2000). An n-alkane proxy for the sedimentary input of submerged/floating freshwater aquatic macrophytes. *Org. Geochem.* 31:745–749.
- Fildani, A., Hanson, A. D., Chen, Z., Moldowan, J. M., Graham, S. A., and Arriola, P. R. (2005). Geochemical characteristics of oil and source rocks and implications for petroleum systems, Talara basin, northwest Peru. *AAPG Bull.* 89:1519–1545.
- Hunt, J. (1996). *Petroleum geochemistry and geology*. New York, NY: Freeman.
- Le Dréau, Y., Jacquot, F., Doumenq, P., Guiliano, M., Bertrand, C., and Mille, G. (1997). Hydrocarbon balance of a site which had been highly and chronically contaminated by petroleum wastes of a refinery (from 1956 to 1992). *Mar. Pollut. Bull.* 34:456–468.
- Meyers, P. A. (2003). Application of organic geochemistry to paleolimnological reconstruction: a summary of examples from the Laurentian Great Lake. *Org. Geochem.* 34:261–289.
- Meyers, P. A., and Ishiwatari, R. (1993). Lacustrine organic geochemistry-an overview of indicators of organic matter sources and diagenesis in lake sediments. *Org. Geochem.* 20:867–900.
- Peters, K. E., Walters, C. C., and Moldowan, J. M. (2005). *The biomarker guide* (2nd ed.). Cambridge, England: Cambridge University Press.
- Qiu, Y. J., and Saliot, A. (1991). Non-aromatic hydrocarbons in 'dissolved phase' ($b 0.7 \mu\text{m}$) and their fractionation between 'dissolved' and particulate phases in the Changjiang (Yangtse River) estuary. *Mar. Envir. Res.* 31:287–308.
- Renee, I. A., Nagla, M. K., and Roushdy, M. I. (2016). Monitoring of pollution in sediments of the coasts in Egyptian Red Sea. *Egyptian Journal of Petroleum* 25:133–151.
- Riediger, C. L., Fowler, M. G., Brooks, P. W., and Snowdon, L. R. (1990). Triassic oils and potential Mesozoic source rocks, Peace River Arch area, Western Canada Basin. *Org. Geochem.* 16:295–305.
- Seifert, W. K., and Moldowan, J. M. (1986). Use of biological markers in petroleum exploration. In: Johns, R. B. (ed.), *Methods in geochemistry and geophysics* (vol. 24, pp. 261–290). Amsterdam, the Netherlands: Elsevier.
- Sikes, E. L., Uhle, M. E., Nodder, S. D., and Howard, M. E. (2009). Sources of organic matter in a coastal marine environment: evidence from n-alkanes and their $\delta^{13}\text{C}$ distributions in the Hauraki Gulf, New Zealand. *Mar. Chem.* 113:149–163.
- Sinninghe Damsté, J. S., Kenig, F., Koopmans, M. P., Köster, J., Schouten, S., Hayes, J. M., and de Leeuw, J. W. (1995). Evidence for gamacerane as an indicator of water column stratification. *Geochim. Cosmochim. Acta* 59:1895–1900.
- Van Graas, G. W. (1990). Biomarker maturity parameters for high maturities: calibration of the working range up to the oil/condensate threshold. *Org. Geochem.* 16:1025–1032.
- Wakeham, S. G. (1996). Aliphatic and polycyclic aromatic hydrocarbons in Black Sea sediments. *Mar. Chem.* 53:187–205.
- Waples, D. W., and Machihara, T. (1991). *Biomarkers for geologists. A practical guide to the application of steranes and triterpenes in petroleum geology. Methods in Exploration Series 9*. Dallas, TX: AAPG.