FULL LENGTH ARTICLE

Biomarker characteristics of crude oils from Ashrafi and GH oilfields in the Gulf of Suez, Egypt: An implication to source input and paleoenvironmental assessments

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KEYWORDS
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Abstract The present work aims to evaluate the organic geochemistry of the crude oils recovered from Ashrafi and GH oilfields within the Gulf of Suez to assess and investigate oil characterization, maturation, source depositional environments and oil families. The saturated hydrocarbons were determined by gas chromatography and gas chromatography/mass spectrometry. Pristane/phytane, isoprenoids/n-alkanes, CPI, homohopane, diasteranes, gammacerane index, C29 20S/20S+20R, C29/C30 hopane and Ts/Tm are determined. The results suggest that the studied crude oils belong to marine oil and are characterized by high level of maturation and sourced mainly from organic matters of marine origin with few terrestrial inputs.

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1. Introduction

The Gulf of Suez Province is highly faulted and corresponds to a continental rift, which started in evolution at the beginning of the Miocene times [1]. It is represented by an elongated graben about 300 km long and 30 km wide between the Sinai Peninsula and the Eastern Desert of Egypt (Fig. 1). The biological marker patterns of crude oils are commonly used for oil/oil and oil/source rock correlations and to assess such source rock attributes as lithology, depositional environment, kerogen type, maturity and to distinction of ancient marine and non marine petroleum source rocks [1].

The organic geochemical characteristics of crude oils discussed by [2–4]. More recently [5] divided the oils of the southern part of the Gulf of Suez into three types: “Type I” is sourced from carbonate rocks of marine origin, type II appears to be originated from Tertiary source rocks with contribution from high land plants, and “Type III” is a mixture of type I and type II. Sharaf [6] recognized two oil groups from October and Abu Rudies fields. “Group I” heavy oil, derived mainly from hypersaline reducing environment. “Group 2”
moderate to light oils, formed under low salinity environment with minor contribution from terrigenous organic matter. Hammad and Barakat [7] concluded that the oils from some oil fields in the Gulf of Suez were generated from mixed and algal organic matter deposited in transitional and reducing environments. El Nady [8] recognized that the crude oils of the Gulf of Suez are sourced mainly from marine organic matters. Barakat et al. [9] stated that there is a close genetic relation between the oils in the southern part of Gulf of Suez. El Nady and Harb [10] recognized that the crude oils in the north Gulf of Suez are mature and derived mainly from mixed organic sources (mainly terrestrial with marine input) under transitional environments. El Nady [11] reported that the crude oils in the south Gulf of Suez are mature, originated mainly from marine sources and show good correlation with the Lower Miocene source rocks in the southern part of Gulf of Suez. El Nady et al. [12] divided the crude oils in the central part of Gulf of Suez into moderately mature oil generated from marine and mature oils generated from source rocks deposited in lacustrine environment. Harb and El Nady [13] divided crude oils in the Gulf of Suez into heavy oil originated mainly from terrestrial organic sources and light oils of high maturity level originated mainly from marine organic sources. Faramawy et al. [14] classified the crudes in the central Gulf of Suez, as aromatic intermediate oils characterized by high maturity level and derived from organic matter of marine origin with few terrestrial.

The present work attempts to evaluate the organic geochemical characteristics of the crude oils recovered from some oil fields within the Gulf of Suez to assess and investigate oil characterization, maturation, source depositional environments. This target was achieved through analytical results of gas chromatography and gas chromatography-mass spectrometry analysis (GC–MS) for two crude oil samples collected from Ashrafi and GH oilfields distributed within the South Gulf of Suez (Fig. 1). These samples are represent for the producing horizon zones (Belayim, and Rudies formations) of Late-Early Miocene age and characterized by limestone facies with depths ranging from 2267 and 5285 ft, respectively. The oil samples were kindly supplied by (EGPC) from Gulf of Suez and Belayim petroleum company.

2. Experimental techniques

(1) The crude oil samples were fractionated by medium pressure liquid chromatography into saturated hydrocarbons, aromatic hydrocarbons and polar compounds.

(2) Gas chromatographic analysis of the saturated hydrocarbon fractions was achieved by Perkin Elmer Instrument Model 8700 (Agilent Technologies, Inc., Wilmington, DE), provided with a flame ionization detector (FID). Oven temperature programmed for 100 to 320°C at 3°C/min. and final time 20 min. SPB-1 capillary column of 60 m. in length and 0.53 i.d. Nitrogen was used as carrier gas, the optimum flow rate was 6 ml min.

(3) Gas chromatography–mass spectrometry used a 50 m × 0.25 mm fused silica capillary column of bonded SE 54 installed with a finnigan MAT TSQ-70 combined gas chromatography/quadrupole mass spectrometer. The column oven was programmed from 100 to 310°C at 4°C/min. These analyses are carried out in the Egyptian Petroleum Research Institute.

3. Results and discussion

3.1. Normal-alkanes

The distribution of n-alkanes in crude oils can be used to indicate the organic matter source [15]. Fig. 2 shows the finger-
prints of gas chromatography for the saturated hydrocarbons of the studied crude oil samples. These figures show that the oils appear to be mature, based on the abundance of n-alkanes in the range n-C15 to n-C20, slightly even carbon preference and moderately to low concentration of heavy normal alkanes. The increase in the n-C15 to n-C20, suggests marine organic matters with a biomass contribution to the from algae and plankton [1]. The striking molecular feature of oils are characterized by uniformity in distribution patterns, suggesting that oils are related and have undergone similar histories, with no signs of water washing or biodegradation [15]. The carbon preference index (CPI) of the studied oils range from 1.01 and 1.12, respectively (Table 1) and laying within the range that generally shows no even or odd carbon preference, which in turn indicates mature samples [16].

3.2. Pristane/phytane

The pristane/phytane (Pr/Ph) ratio is one of the most commonly used geochemical parameters and has been used as an indicator of depositional environment with low specificity due to the interferences by thermal maturity and source inputs [15]. Ten Haven et al. [17] stressed that high pr/Ph (>3.0) indicates terrigenous input under oxic conditions and low pr/Ph (<0.8) indicates anoxic/hypersaline or carbonate environments. The oil samples of Ashrafi and GH oilfields are characterized by pristane/phytane ratios of 0.16 and 0.38, respectively (Table 1) and waxiness values are 0.68 and 0.94 (Table 1). This confirms that the studied oils have been originated from marine organic source deposited under suboxic conditions [17]. Moreover, the carbon preference indexes (CPI) are 1.01 and 1.12 (Table 1) which indicates that the oils fall in the field of more reducing zone of thermal maturation level.

3.3. Isoprenoids/n-alkanes

In crude oil studies, the ratios of isoprenoids to n-alkanes are widely used since they provide information on maturation and biodegradation as well as source [18]. A combination of the isoprenoids and n-alkanes distributions provides valuable information about the source of organic matter, the organic facies, biodegradation and the maturation level [18]. The isoprenoids/n-alkanes ratios (pr/n-C17 and ph/n-C18) are 0.29 and 0.35 (Table 1). These ratios suggest marine organic matters source (mainly algae) deposited under reducing environment. They also indicate a genetic close relation between the studied oils [15].

3.4. Steranes

The distribution of steranes is best studied on GC/MS by monitoring the ion m/z = 217 which is a characteristic fragment in the sterane series. The resulting mass chromatograms for samples are shown in Fig. 3A. The compounds were identified in their key fragmentograms based on the relative retention times and by comparison of their mass spectra with the published data. It is agreed that the relative amounts of C27–C29 steranes can be used to give indication of source differences [18].

Table 1 Geochemical parameters derived from GC and GC–MS analyses of the Belayim and Rudies oils from Ashrafi and GH oilfields, Gulf of Suez, Egypt.

<table>
<thead>
<tr>
<th>Geochemical data</th>
<th>Belayim oil</th>
<th>Rudies oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristane/phytane</td>
<td>0.16</td>
<td>0.38</td>
</tr>
<tr>
<td>Pristane/n-C17</td>
<td>0.26</td>
<td>0.32</td>
</tr>
<tr>
<td>Phytane/n-C18</td>
<td>0.43</td>
<td>0.42</td>
</tr>
<tr>
<td>CPI</td>
<td>1.01</td>
<td>1.12</td>
</tr>
<tr>
<td>C27 Steranes (%)</td>
<td>24.04</td>
<td>32.24</td>
</tr>
<tr>
<td>C28 Steranes (%)</td>
<td>35.24</td>
<td>27.03</td>
</tr>
<tr>
<td>C29 Steranes (%)</td>
<td>0.1</td>
<td>0.11</td>
</tr>
<tr>
<td>C29 20S/20S + 20R</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>Diasteranes index</td>
<td>40.72</td>
<td>40.74</td>
</tr>
<tr>
<td>Homohopane index</td>
<td>0.74</td>
<td>0.56</td>
</tr>
<tr>
<td>C29/C30 hopane</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Steranes/hopanes</td>
<td>1.28</td>
<td>1.25</td>
</tr>
<tr>
<td>Ts/Tm</td>
<td>0.53</td>
<td>0.54</td>
</tr>
</tbody>
</table>

CPI: Σodd/Σeven carbon numbers.

a C29 20S/20S + 20R: steranes maturity level.

b Homohopane index: (C35 homohopane S + R)/(C31 + C32 + C33 + C34 + C35 homohopanes S + R).

c Diasteranes index: (C27 diasteranes S + R)/[(C27 diasteranes + R) + C29 steranes S + R].

d C29/C30 hopane.

e Steranes/17a (H)-hopanes ratio.

f Ts/Tm: Trisnorhopanes/Trisnorhopanes ratios.
The studied crude oils are characterized by predominance of C28, C29 and C30 steranes (20S and 20R, Fig. 3A) which indicate oils derived mainly from mixed terrestrial and marine organic sources [18].

The amount of C27 diasteranes, diasteranes index and concentration of 20S and 20R isomers are important to detect the maturity level of crude oils. Andrew et al. [19] recognized that the maturity level of oils increase with the increase of these parameters (high concentration of C27 diasteranes, diasteranes index, and C29 20S/(20S + 20R > 0.1). It is obvious that the studied oils have slightly high concentration of C27 diasteranes 20S and 20R (Fig. 3A) with diasteranes index range from 0.11 and 0.12, C29 20S/(20S + 20R) from 0.13 and 0.15 (Table 1). These data reveal that the studied oils are characterized by high maturity level.

3.5. Triterpanes

The triterpanes are the more important petroleum hydrocarbons that retain the characteristic structure of the original biological compounds. Tricyclic, tetracyclics, hopanes, and other compounds contribute to the terpane fingerprint mass chromatogram (m/z = 191) are commonly used to relate oils and source rocks [18]. Mass fragmentogram at m/z = 191 was used to detect the presence of triterpanes in the saturate hydrocarbon fraction of the studied oils (Fig. 3B). The most distinct features are tricyclic terpanes, Ts/Tm and C29/C30 hopane ratios (Table 1).

3.5.1. Tricyclic terpanes

The concentration of tricyclic terpanes in crude oils is more sensitive to the specific paleoenvironments [20]. In addition it has been used as a qualitative indicator of maturity [21]. In high mature oils, the tricyclic terpanes is dominated more than in low mature oils. Our study reveals that the concentration of C22 tricyclic terpanes in the studied oil samples (Fig. 3B) is relatively high which may support the idea that the oils are more mature and sourced mainly from carbonate source rocks [20,21]. On the other hand, C21, C23 to C28 tricyclic terpanes (Fig. 3B) are generally of low detection levels in the studied oils indicating that these oils have some inputs derived from terrestrial organic material [15]. This confirms with our conclusion for steranes biomarkers.

3.5.2. Homohopanes

The homohopanes (C31 to C34) are believed to be derived from bacteriopolyholanol of prokaryotic cell membrane, abundant C35 homohopane may be related to extensive bacterial activity in the depositional environment [15]. The distribution of homohopanes 22R+22S C35/(C31–C35) (homohopane index) in crude oils 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 and immediately after deposition of the source sediments [1]. Low C35 homohopanes is an indicator of highly reducing marine conditions during deposition, whereas high C35 homohopane concentrations are generally observed in oxidizing conditions during deposition [1]. The studied crude oils have

![Figure 3](image-url)

**Figure 3** Gas chromatograms–mass spectrometry of steranes (A) and triterpanes (B) of saturated hydrocarbons fraction of Belayim and Rudies oils from Ashrafi oilfield, Gulf of Suez, Egypt.
The studied crude oils could be classified into one type of oil namely marine oil.

The gas chromatography and gas chromatography–mass spectrometric analyses revealing the studied oils are mature and sources derived mainly from mixed organic sources from terrestrial and marine inputs a biomass contribution from algae and plankton in different saline environments.

References