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ORIGINAL ARTICLE

Biomarker characteristics of the Turonian–Eocene succession, Belayim oilfields, central Gulf of Suez, Egypt

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Abstract This study assesses the hydrocarbon source rocks of the Belayim oilfields, central Gulf of Suez, Egypt. Detailed geochemical methods, including liquid chromatography, gas chromatography and gas chromatography–mass spectrometry, are used to characterize organic-rich facies of the Turonian–Eocene deposits. Crude oil samples are analyzed using C_7 and stable carbon isotopes, in addition to analysis of the extracts, in order to throw light on the organic matter source, composition, and thermal maturity. The source rocks are mainly derived from algae and bacteria deposited under normal saline and reducing palaeoenvironmental conditions, with a minimal contribution from terrestrial organic and mainly clay-poor source rocks. This is evidenced by the *n*-alkane distribution, the pristane/phytane, homohopane, gammacerane index, the high concentration of cholestane, the presence of the C_{30} *n*-propylcholestanes and low diasteranes ratios. The source rock extracts range from immature to marginally mature, based on biomarker maturity-related parameters. A similar scenario is envisaged from the crude oil samples which showed a partial positive correlation with the source rocks of the Eocene Thebes Formation, and the Upper Cretaceous Brown Limestone. Our data suggest that Turonian–Santonian Matulla Formation samples may signify the presence of some oil in the study area.

1. Introduction

The first oil discovery on the Gemsa Peninsula, Gulf of Suez, Egypt was in 1886. This was followed by intensive exploration which eventually resulted in the discovery of more than 120 oilfields providing more than 50% of the overall daily oil production of the country (Egypt Country Analysis Briefs, 2009). The Belayim development leases (about 260 square km) in which the two oilfields of Belayim Marine and Belayim Land are located, represent one of the largest oil accumulations in the Gulf of Suez (Fig. 1).

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Geological and geochemical evidence has shown that carbonate rocks are the source of the Gulf of Suez oils. Identification of possible source rock facies in the crude oils using routine geological criteria and bulk geological data, proved inconclusive in this supposition. More recently, the use of biological fossils (or biomarkers) in conjunction with bulk parameters was effective in the evaluation of the source rocks and the genetic classification of oils in the Gulf of Suez.

Biomarkers such as hopanes and steranes have received much attention because of their usefulness as indicators of organic matter type and quality, depositional conditions (e.g. salinity, oxicity, anoxicity, etc.), assessment of maturity level, extent of biodegradation and lithology. Such features make biomarkers potentially applicable to oil–oil correlations. With the increased need to improve the success of petroleum exploration and to reduce risk, the characterization of oils using biomarkers and isotope geochemistry has provided a new impetus to the evaluation of petroleum systems, plays, and prospects. Molecular geochemistry can assist in ascertaining the depositional environment of petroleum source rocks via the types of contributing organisms in their related oils (e.g. Moldowan et al., 1985; Mello et al., 1988; Peters et al., 2005; Roushdy et al., 2010; El Diasty and Peters, 2014). The central Gulf of Suez and adjacent areas have been subjected to extensive geochemical studies in order to evaluate the oils and their related source rocks (Rohrback, 1983; Mostafa, 1993; Barakat et al., 1997; El Diasty and Peters, 2014). Very few, if any, of these studies have dealt with the study of source rock generating potential and its correlation with the oil being recovered from reservoirs. The richness assessment of the source rock is not estimated in the current study as this will be discussed in a forthcoming paper. Our analyses showed that the source rocks encountered are rich enough to generate hydrocarbons at optimum maturity. This paper focuses on the use of detailed biomarker data in a trial to: (1) evaluate the hydrocarbon potential and thermal maturity of the Upper Cretaceous-Eocene subsurface deposits in the Belayim oilfields; (2) envisage organic matter source, depositional environment and redox conditions; and (3) elucidate the geochemical characteristics of the local oil, in addition to correlating them with the source rock parameters.

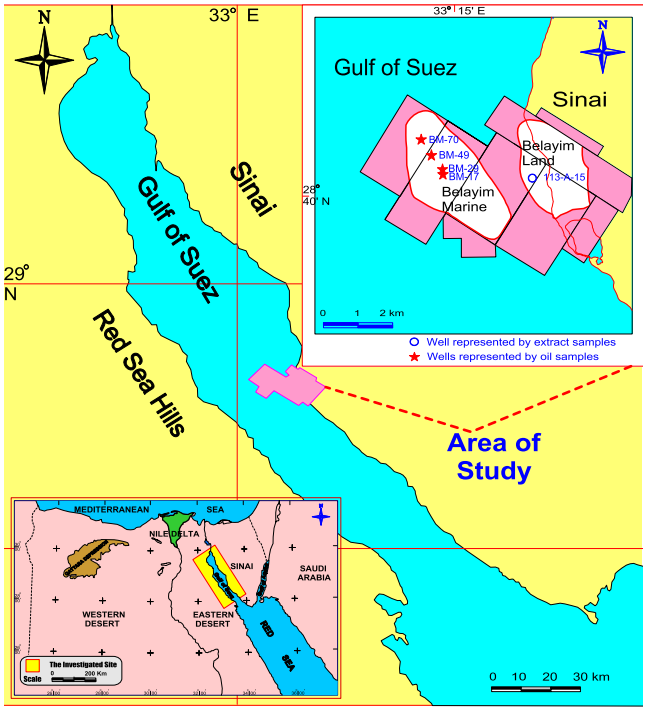

Figure 1 Location map of the studied wells, Belayim oilfields, central Gulf of Suez, Egypt.

2. Geological setting

The Gulf of Suez represents one of the most intensively faulted areas on Earth. It is approximately 300 km long with an average width of 70 km and it forms the northern extension of the Red Sea, covering an area of about 25,000 square km at an average water depth of 55–100 m (Young et al., 2000). It extends NW of 27°30′ N to 30°00′ N, and its width varies from about 50 km at its northern end to about 90 km in the south where it merges with the Red Sea (Bosworth and McClay, 2001). Tectonic subsidence and sedimentation were slow during the initial phase of rifting which was related to the separation of the African and Arabian plates (Meshref, 1990) during the latest Oligocene to the Early Miocene (*ca* 24–15.5 Ma). The Gulf of Suez is the main oil-producing province in Egypt, with oil being produced from Paleozoic, Mesozoic and Cenozoic rocks. The lithostratigraphic units in the Gulf of Suez range in age from Precambrian to Holocene. The succession can be divided into three lithostratigraphic megasequences (Plaziat et al., 1998). The units include: (i) a pre-rift (pre-Miocene or Paleozoic–Eocene, e.g. Schütz, 1994) succession including basement; (ii) a syn-rift (Oligocene–Miocene) interval (Al-Husseini, 2012); and (iii) a post-rift (post-Miocene or Pliocene–Holocene) interval (Alsharhan, 2003). These units vary in thickness, lithology, areal distribution, depositional environment, and hydrocarbon importance (Alsharhan, 2003). The lithostratigraphic successions of the Belayim Land and Belayim Marine are shown in Fig. 2 as reported by Petrobel (2005).

This paper concentrates on the middle and upper parts of the pre-rift interval, which comprises the Nubian Complex (Paleozoic-Lower Cretaceous) at the base, overlain by a Cenomanian–Late Eocene sequence (Alsharhan, 2003). The Nubian (or Nubia) Sandstone describes the Paleozoic–Cretaceous clastic succession which overlies unconformably the basement complex, as in the Belayim Marine oilfield. This is followed by an Upper Cretaceous succession consisting of four formations (Raha, Abu Qada, Wata, and Matulla) arranged from base to top (Fig. 2). This sequence is in general composed of coarse sandstones and shallow-marine dolomitic limestones with interbedded shales. From the Cenomanian through the Turonian, deposition took place largely in a restricted, shallow-marine, inner sub-littoral environment (Schütz, 1994). This is overlain by the Brown Limestone/Sudr Chalk (Campanian–Maastrichtian) deposited in marine sub-littoral contexts with less organic-rich sediments (Schütz, 1994).

The top of the pre-rift succession is terminated by the Eocene Thebes Formation, an argillaceous limestone unit with