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Research paper

Petroleum source rock characterisation and hydrocarbon generation modeling of the Cretaceous sediments in the Jiza sub-basin, eastern Yemen

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ABSTRACT

Cretaceous sedimentary rocks of the Mukalla, Harshiyat and Qishn formations from three wells in the Jiza sub-basin were studied to describe source rock characteristics, providing information on organic matter type, paleoenvironment of deposition and hydrocarbon generation potential. This study is based on organic geochemical and petrographic analyses performed on cuttings samples. The results were then incorporated into basin models in order to understand the burial and thermal histories and timing of hydrocarbon generation and expulsion.

The bulk geochemical results show that the Cretaceous rocks are highly variable with respect to their genetic petroleum generation potential. The total organic carbon (TOC) contents and petroleum potential yield ($S_1 + S_2$) of the Cretaceous source rocks range from 0.43 to 6.11% and 0.58–31.14 mg HC/g rock, respectively indicating non-source to very good source rock potential. Hydrogen index values for the Early to Late Cretaceous Harshiyat and Qishn formations vary between 77 and 695 mg HC/g TOC, consistent with Type I/II, II-III and III kerogens, indicating oil and gas generation potential. In contrast, the Late Cretaceous Mukalla Formation is dominated by Type III kerogen (HI < 200 mg HC/g TOC), and is thus considered to be gas-prone. The analysed Cretaceous source rock samples have vitrinite reflectance values in the range of 0.37–0.95 Ro% (immature to peak-maturity for oil generation).

A variety of biomarkers including *n*-alkanes, regular isoprenoids, terpanes and steranes suggest that the Cretaceous source rocks were deposited in marine to deltaic environments. The biomarkers also indicate that the Cretaceous source rocks contain a mixture of aquatic organic matter (planktonic/bacterial) and terrigenous organic matter, with increasing terrigenous influence in the Late Cretaceous (Mukalla Formation).

The burial and thermal history models indicate that the Mukalla and Harshiyat formations are immature to early mature. The models also indicate that the onset of oil-generation in the Qishn source rock began during the Late Cretaceous at 83 Ma and peak-oil generation was reached during the Late Cretaceous to Miocene (65–21 Ma). The modeled hydrocarbon expulsion evolution suggests that the timing of oil expulsion from the Qishn source rock began during the Miocene (>21 Ma) and persisted to present-day. Therefore, the Qishn Formation can act as an effective oil-source but only limited quantities of oil can be expected to have been generated and expelled in the Jiza sub-basin.

1. Introduction

The area of interest of this study is the Jiza sub-basin, forming the western part of the Jiza-Qamar Basin (Fig. 1). The Jiza-Qamar Basin is a Mesozoic sedimentary basin across the eastern Yemen (Fig. 1) that was formed as a result of rifting linked to the Mesozoic breakup of Gondwanaland (Redfern and Jones, 1995). The Jiza-Qamar Basin has attracted the interest of numerous researchers and oil companies (e.g., Bott et al., 1994; Brannan et al., 1997; Alaug, 2011a,b; Al-Wosabi and Alaug, 2013; Hakimi and Abdullah, 2014a; Hakimi et al., 2014a; Hakimi et al., 2015). All these publications have been done in the eastern part of the Jiza-Qamar Basin (i.e., the Qamar sub-basin). However, the Jiza sub-basin in the western Jiza-Qamar Basin (Fig. 1) is one of the hydrocarbon exploration frontier regions in eastern Yemen where very few data are available for the adequate assessment of the hydrocarbon generation potential.

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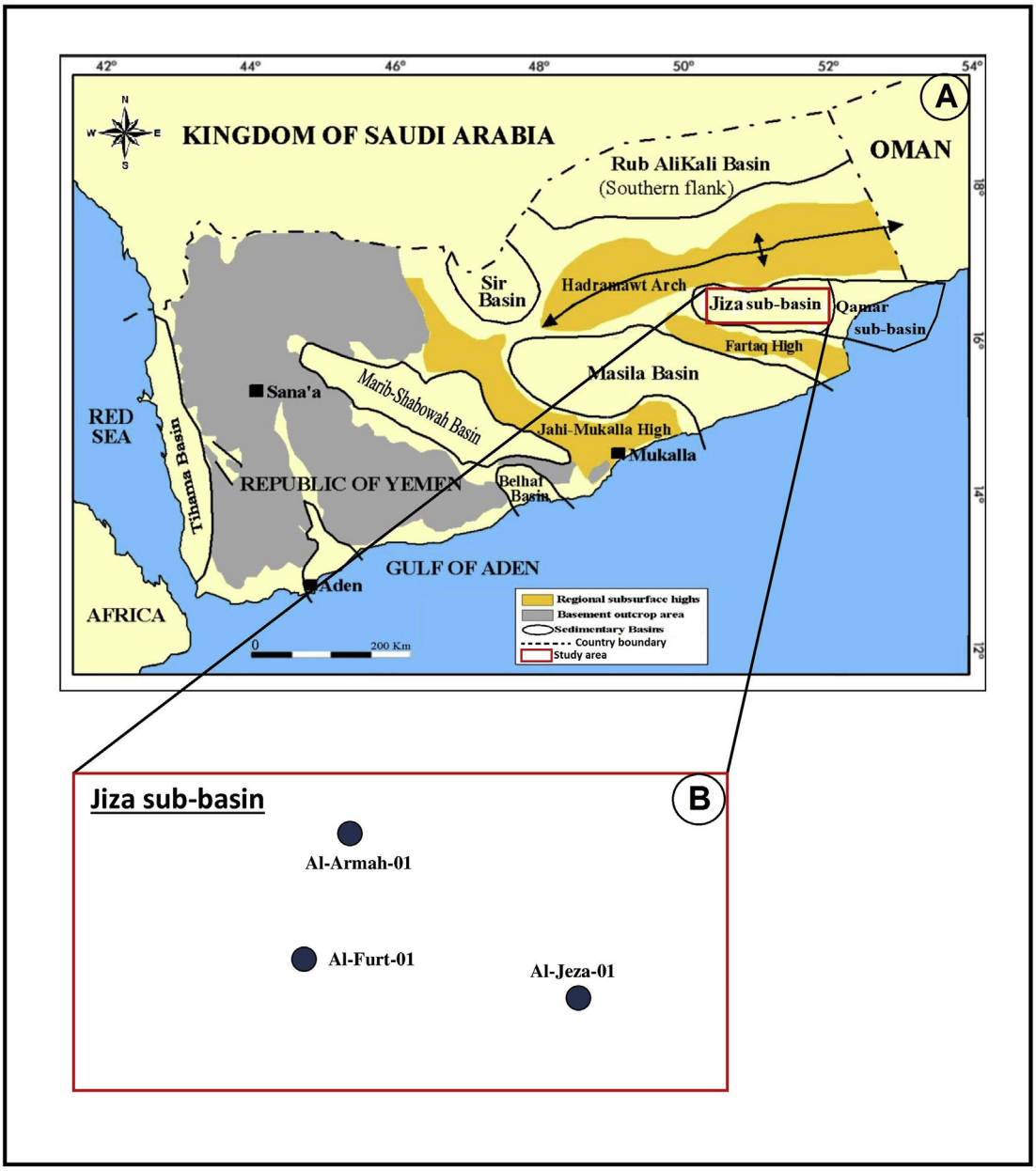

Fig. 1. (A) Main sedimentary basins in the Republic of Yemen (modified after Beydoun et al., 1998) showing location of area of interest and three well locations in the Jiza sub-basin (B).

Therefore, this study focuses on the evaluation of organic matter type, richness, and thermal maturity and hydrocarbon generation potential of the thick Cretaceous sedimentary rocks in this sub-basin. In addition, the results of source rock characterization are incorporated into basin models in order to determine the timing of hydrocarbon generation and expulsion.

2. Geologic setting

The Jiza-Qamar Basin is situated in eastern Yemen, extending into Oman (Fig. 1). The basin developed as a rift-basin during the Late Jurassic–Early Cretaceous as part of the breakup of Gondwanaland and the evolution of the Indian Ocean (Redfern and Jones, 1995). The Jiza-Qamar Basin contains more than 4 km of Jurassic to Tertiary sedimentary section (Fig. 2). On top of the Precambrian basement rests the Kuhlan and Shuqra formations, which were deposited during Mid to Early Jurassic time (Fig. 2). The Kuhlan Formation includes fluviatile and arkosic red beds that grade upward into the shallow-marine facies of the Shuqra Formation, the latter represents the early transgressive sediments of the Late Jurassic (Beydoun et al., 1998).

The sediments of the overlying Madbi Formation were deposited during Kimmeridgian time (Beydoun et al., 1998). These sediments are composed of organic-rich shale and limestones, which reflect a marine setting (Beydoun et al., 1998; Hakimi et al., 2012a, 2014b). Shallow water carbonates of the Naifa Formation lying conformably on the top of the Madbi Formation (Fig. 2). Rifting occurred in the Jiza-Qamar Basin during latest Jurassic to Early Cretaceous followed by thermal subsidence during the Late Cretaceous.

During the Early to Late Cretaceous, post-rift sediments accumulated in the basin forming the Saar, Qishn, Fartaq, Harshiyat,