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Petroleum generation modeling of the Late Cretaceous coals from the Jiza-Qamar Basin as infer by kerogen pyrolysis and bulk kinetics

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HIGHLIGHTS

- Late Cretaceous coals are representing good oil-source rock potential in the Jiza-Qamar Basin.
- One major organic facies Type II–III is identified with HI up to 300 mg HC/g TOC.
- Organic facies of coals could have mainly paraffinic and P–N–A oils with high wax contents.
- Bulk kinetic analysis indicate that the organic facies are fairly heterogonous organic matter.
- The onset of oil-generation began at 40 My, whereas the peak oil-generation occurred at 20–15 My.

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ABSTRACT

The petroleum generating potential of the Late Cretaceous coal within the Mukalla Formation is evaluated. Bulk and quantitative pyrolysis techniques and organic petrology were used to characterize the kerogen composition, generative potential and kinetic models to determine the variability of the organic matter and their effect on the timing of petroleum generation. These measurements identified one major organic facies containing an oil-prone Type II/III kerogen, with HI values >300 mg HC/g TOC that produces mainly paraffinic and paraffinic–naphthenic–aromatic (P–N–A) oils with high wax contents.

Bulk kinetic analysis on Late Cretaceous coal samples reveal a relatively broad distribution of activation energies (42–69 kcal/mol). Using a generic heating rate of 3.3 °C/My, the onset temperature for oil generation (TR 10%) is ~139 °C and the peak generation temperature (geologic T_{max}) range from 150 to 167 °C. A 1D model predicts that the Mukalla coals in the Jiza-Qamar Basin began oil generation at ~40 My and reached peak generation ~20–15 My ago. Therefore, the Mukalla coals could have be generated mature oils in the Jiza-Qamar Basin.

1. Introduction

The Jiza-Qamar Basin is a Mesozoic sedimentary basin across the eastern Yemen (Fig. 1) that was formed as a rifting depositional site linked to the Mesozoic breakup of Gondwanaland [1]. The basin is undergoing active hydrocarbon exploration and research and its potential is still being discovered. The Late Cretacouse Mukalla Formation is widely distributed throughout the Jiza-Qamar Basin and among the most studied source rocks with respect to petroleum generation in the region [2–4]. Late Cretaceous Mukalla shales have been interpreted to be mainly gas-prone [2–4], whereas Mukalla coal and coaly shale sediments are known to have higher potential for liquid hydrocarbon generation [4]. Mukalla coals specifically from Jiza-Qamar Basin have not been investigated yet. In this paper the hydrocarbon generative potential of these Late Cretaceous coals are characterized using bulk kinetic and quantitative pyrolysis techniques. The main objective of the study is to determine the organofacies and petroleum type that might be generated from Late Cretacouse Mukalla coals in the Jiza-Qamar Basin. These data are then used as input for kinetic modeling to predict temperatures and timing for the onset (TR 10%) and peak of petroleum generation.

2. Samples and experimental methods

Forty-three core and cutting samples were collected from coal intervals within the Mukalla Formation in three exploration wells

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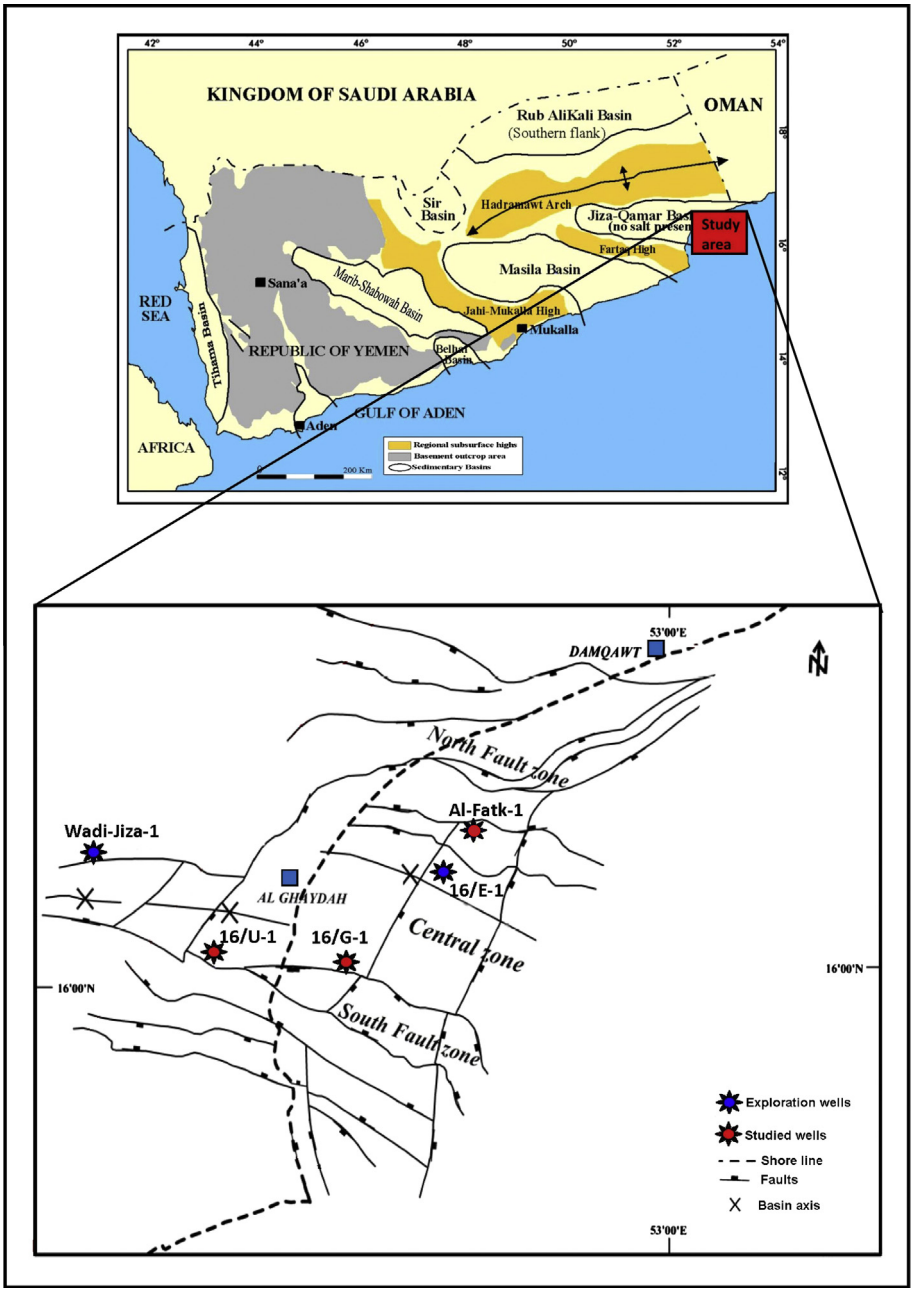

Fig. 1. Main sedimentary basins in Republic of Yemen (modified after Beydoun et al., 1998) showing location map of the Jiza-Qamar Basin and the studied wells.

at Qamar sector, Jiza-Qamar Basin (Fig. 2 and Table 1). Most of organic petrographic and geochemical analytical were carried out at the Organic Petrology and Geochemistry Laboratories of the Geology Department in the University of Malaya.

The geochemical analytical included total organic carbon (TOC), pyrolysis (SRA), open pyrolysis–gas chromatography (Py-GC) and kinetic analyses (Tables 1–4).

The collected samples were crushed to less than 200 mesh and analyzed using a Weatherford Source Rock Analyzer TM TOC/TPH instrument (equivalent to Rock–Eval equipment) to identify the source kerogen type and maturity for the preserved organic matter. Parameters measured include: total organic carbon (TOC), free hydrocarbons (S_1) in the rock, remaining hydrocarbon generative potential, mg HC/g rock (S_2), carbon dioxide yield, mg CO_2/g rock (S_3), and temperature of maximum pyrolysis yield (T_{max}) (Table 1). Hydrogen (HI), Oxygen (OI), production yield (PY), and production (PI) indexes were calculated (Table 1), as described by Espitalié et al. [5] and Peters and Cassa [6].

Following the pyrolysis analysis, several coal samples were selected for further geochemical and coal petrographic analyses. The selected coal samples were analyzed on a pyrolysis gas chromatography (Py-GC) to provide compositional and structural characteristics of kerogen. The pyrolysis gas chromatography (Py-GC) is based on quickly heating of rock samples whereby the total evolved hydrocarbons can be monitored as a function of temperature. This Pyrolysis analysis is carried out using a Frontier Lab Pyrolyser System which can perform thermal desorption (from 40 to 300 °C) and pyrolysis (at 600 °C). The system is coupled to an inert (quartz and Ultra ALLOY-5), 30 m, 0.25 mm internal diameter column (0.52 lm film thickness) fitted to an Agilent GC chromatograph equipped with a flame ionization detector. The pyrolysis products were released over the range 300–600 °C