Fuel 232 (2018) 530–542

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Late Jurassic bituminous shales from Marib oilfields in the Sabatayn Basin (NW Yemen): Geochemical and petrological analyses reveal oil-shale resource

Mohammed Hail Hakimi[a,*], Adel M. Al-Matary[b], Osman Salad Hersi[c]

[a] Geology Department, Faculty of Applied Science, Taiz University, 6803 Taiz, Yemen
[b] Department of Earth and Environmental Sciences, Sana'a University, Sana'a, Yemen
[c] University of Regina, Department of Geology, 3737 Wascana Parkway, Regina, SK S4S 0A2, Canada

ARTICLE INFO

Keywords:
Late Jurassic
Oil-shale
Pyrolysis
Types I/II and II-S
Marib oilfields
Sabatayn Basin
Yemen

ABSTRACT

In this study, bituminous shale samples were collected from Late Jurassic sedimentary section in the Marib oilfields to study their petrologic and organic geochemical properties. The results of this study indicate that the Late Jurassic bituminous shales can be considered as an oil-source rocks in the Sabatayn Basin (NW Yemen). The analyzed Late Jurassic shales have high organic matter (TOC up to 10%) content of kerogen Types I/II. These kerogen types in the analyzed samples are consistent with the high dominance of alginite and amorphous organic matter. Open pyrolysis–gas chromatography results are generally consistent with the Rock-Eval results and further indicate that the analyzed shale samples contain Types I/II and II-S kerogen and generally can produce paraffinic oils with low to high wax content. Type II-S kerogen can produce oil with high sulphur content at low maturity level. The maturity data reflect immature and very early maturity stages of petroleum formation of the Late Jurassic bituminous shales. Therefore, the kerogen types in the Late Jurassic bituminous shales has not been altered by thermal maturity for oil generation, thus, artificial heating is required of kerogen cracking generate significant oil.

1. Introduction

Yemen country has number of petroleum-bearing sedimentary basins, which are associated with coal, carbonaceous shale, and shale source rocks [1–10]. Commercial hydrocarbons production primarily takes in the onshore sedimentary basins of Yemen (Fig. 1A), which include the Sabatayn and Masila basins [11–13]. The mature organic-rich shale facies are commonly known to act as source rock of conventional petroleum resources in the onshore basins of Yemen [2,5,6].

In the last 20 years, the exploration and development activities for commercial petroleum in the onshore basins of Yemen have been concentrated on the petroleum-bearing formations of the Late Jurassic and Cretaceous units [1–10]. The origin of the conventional petroleum resources in the onshore basins of Yemen is a marine-derived organic matter within the Late Jurassic Madbi source rock [1–3,5,14]. Recently, research on unconventional oil resources has increased significantly due to the decline of production from conventional reserves [15,16]. Very early mature bituminous shale intervals within the onshore basins of Yemen can be considered as unconventional petroleum source rocks. The study of the source rock characteristics of those immature to very early mature bituminous shales will significantly increases the conventional petroleum source rocks and development the petroleum exploration in the basins of Yemen.

Marib oilfields are the largest oil fields in Yemen, located in the north-western part of the Sabatayn Basin (Fig. 1B). The Marib oilfields have been studied by numerous researchers and their publications are performed on the petroleum source rocks [1–4,17]. The mature organic-rich shale intervals in the Late Jurassic Madbi Formation are common source rocks of conventional petroleum resources in the Sabatayn Basin [3,4,6]. These mature organic-rich shale intervals were collected from the flanks of the structural high of the Sabatayn Basin (Fig. 2). At this location, the shales are deeper, and therefore are fully mature. Up-dip migration from those shales was readily yielded oil and/or gas, in the kitchen area illustrated in Fig. 2.

In this study, we focus on the Late Jurassic bituminous shale intervals (i.e., Sabatayn and Madbi formations) from wells near a structural high that are, where the Sabatayn and Madbi formations are relatively shallow, and therefore are, at most, immature to very early mature. We intend to document the characteristics of the kerogen type in these bituminous shales and their oil generation potential. Therefore,

* Corresponding author.
E-mail address: ibnalhakimi@yahoo.com (M.H. Hakimi).

https://doi.org/10.1016/j.fuel.2018.05.138
Received 27 March 2018; Received in revised form 9 May 2018; Accepted 27 May 2018

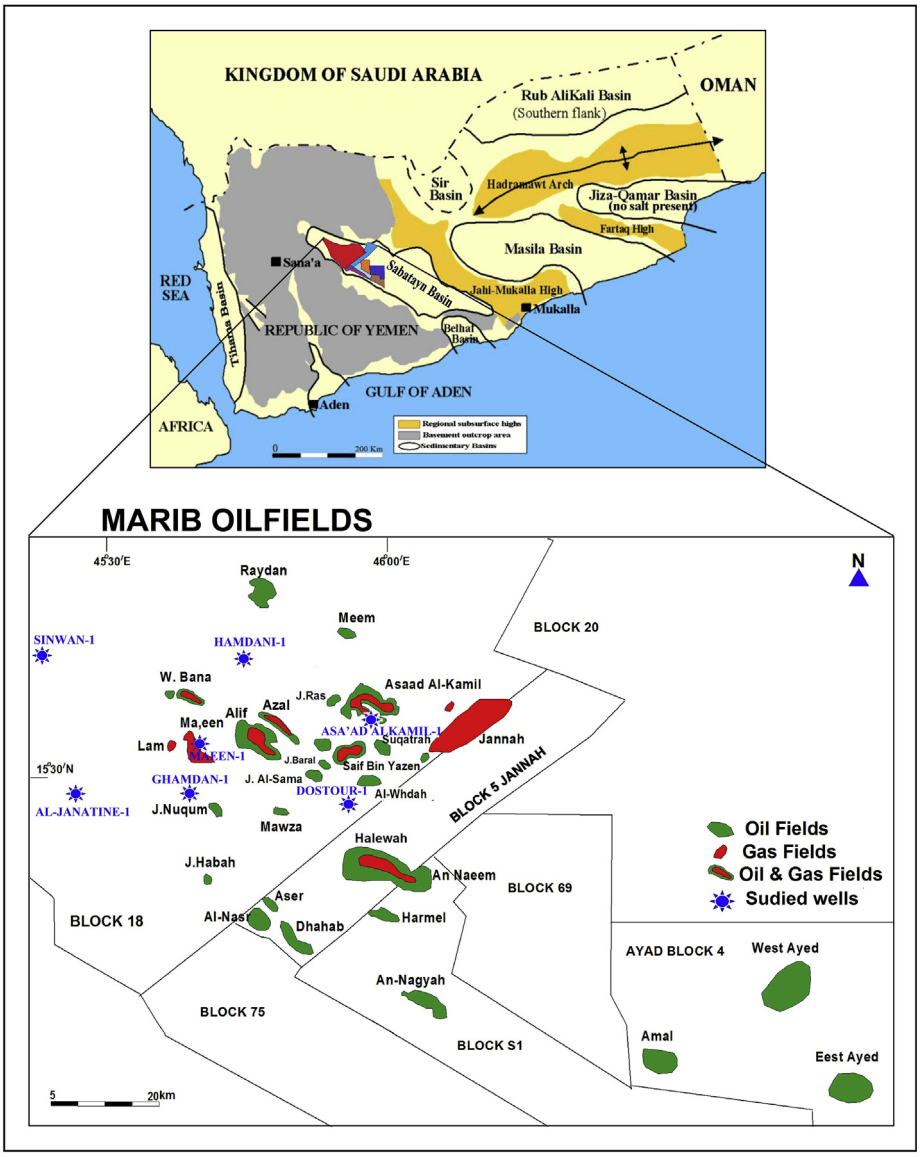

Fig. 1. (A) Main onshore and offshore sedimentary basins in Yemen (modified after Beydoun et al. [21]; (B) location map shows oil and gas fields in the Marib including seven studied wells.

we apply the pyrolysis (i.e., Rock-Eval and Py-GC) analyses and organic petrology to characterize the organo-facies of the studied rocks. The primary objectives of this study are to quantify the organic matter, characterize kerogen type and quality, including petroleum generation potential of the Late Jurassic bituminous shale intervals, estimate conventional and unconventional petroleum resources that can be associated to these bituminous shales and assess the viability of future field development plans (FDP).

2. Geological setting

The Afro-Arabian plate was part of a larger continental block of Gondowana. Disintegration of Gondwana and the opening of the Indian Ocean in early Mesozoic time resulted in northwest – southeast oriented extensional downwarps across the Somalia-Arabia block, including the Berbera–Sabatayn, Al Mado–Say'un-Masila and Jeza-Qamar basins [18–22].

Inception of the Sabatayn Basin started in late Jurassic and accelerated in early Cretaceous time [19]. The rifting activity that generated the Sabatayn Basin was constrained by several normal faults that resulted in horst-graben structures and tilted blocks (Fig. 2). The structural framework of the Sabatayn Basin has played a considerable role in the structural trapping system for the hydrocarbon accumulations in the oilfields in the basin (Fig. 2). Initiation of the Sabatayn rifting occurred in early Kimmeridgian, and continued until early Berriasian (basal Early Cretaceous) ages (Fig. 3).

The stratigraphic column of the Sabatayn Basin includes a thick Mesozoic succession followed by lower to middle Paleogene (Paleocene to Eocene) strata (Figs. 2 and 3). Paleozoic and Triassic systems are not represented in the basin and Precambrian crystalline basement rocks are non-conformably overlain by Early Jurassic rocks of the Kuhlan Formation (Fig. 3). The Kuhlan Formation is represented by mostly continental deposits which consist of fluviatile and arkosic red beds [23]. The upper part of the Kuhlan Fm becomes shallow marine/marginal marine sediments that grade to the carbonates of the Middle Jurassic Shuqra Fm [23]. Thus, the Shuqra Formation lies conformably over the Kuhlan Formation (Fig. 3). The Madbi Formation was deposited during the Late Jurassic, commencing in the Kimmeridgian and continuing through the Tithonian [23]. The Madbi Formation lies on the Shuqra Formation with a conformable contact. The Madbi Formation consists of organic-rich calcareous shale and subordinate sandy units. The formation consists of a mixed organic matter which indicates