



Research paper

Geochemical characteristics of crude oils, their asphaltene and related organic matter source inputs from Fula oilfields in the Muglad Basin, Sudan



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ARTICLE INFO

Article history:

Received 22 September 2014

Received in revised form

8 June 2015

Accepted 1 July 2015

Available online 6 July 2015

Keywords:

Crude oil

Biomarker

Precipitated asphaltene

Fula oilfields

Muglad Basin

Sudan

ABSTRACT

Bulk geochemical characteristics of crude oils, coupled with geochemical analyses of reservoir oil asphaltenes from Fula oilfields in the Muglad Basin, have provided information on source organic matter input, depositional environment and the correlation between these crude oils and their potential source rocks in the basin. Only one oil family is present within the Fula oilfields as indicated by biomarker and non-biomarker parameters. The Fula oils are characterized by moderate API gravity, low sulphur and moderate trace metal (Ni, V) contents, and high wax contents. This suggested that the oils were generated from source rock that was deposited in a principally lacustrine environment. This is supported by bulk geochemical characteristics and biomarker compositions. A variety of biomarker-specific parameters obtained from *n*-alkanes, regular isoprenoids, terpanes and steranes indicate that the Fula oils were generated predominantly from algae-derived organic matter that was deposited in a lacustrine environment which then experienced a slight seawater influence under suboxic to relatively anoxic conditions. These oils were generated from source rock with a wide range of thermal maturity ranging from early to peak oil window. The biomarker characteristics of these oils are consistent with those of the early Cretaceous Abu Gabra shales. The oil-source rock relationship is also demonstrated by similarities in the structural moieties of the Fula oil asphaltene and the Abu Gabra shale kerogens. The Pyrolysis GC of the analyzed Fula oil asphaltene indicates that the oils were derived from Type I-algal organic matter, consistent with paraffinic high wax oils.

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1. Introduction

The Muglad Basin is an important hydrocarbon province in Sudan (Fig. 1), but the origin of the oils and their source rocks potential is still poorly known. The area that forms the scope of this study lies in the Fula sub-basin, in the north-eastern part of the Muglad Basin (Fig. 1). Many oilfields have been discovered in the Muglad Basin including the Keyi and Moga oilfields analyzed in this study (Fig. 1). There were reports on the presence of possible source rocks in the Muglad Basin that occur within the Early Cretaceous rock units (Mohamed et al., 2000; Zhang and Qin, 2011; Lirong et al., 2013). The Early Cretaceous Abu Gabra Formation is the

most important source rock present in the basin (Mohamed et al., 2000; Zhang and Qin, 2011; Lirong et al., 2013). Abu Gabra organic-rich shales have been interpreted to be mainly oil-prone (Mohamed et al., 2000; Zhang and Qin, 2011; Lirong et al., 2013; Makeen et al., 2015a, b and c). Several studies had been undertaken on the basin concerning petroleum geology, stratigraphy, palynomorph assemblages, 1D basin modelling, the tectonic history and structural geology of the basin (e.g. Fairhead, 1988; Kaska, 1989; Wycisk et al., 1990; Guiraud and Maurin, 1992; McHargue et al., 1992; Wilson and Guiraud, 1992; Genik, 1993; Mohamed et al., 1999, 2000; Dou et al., 2002; Tong et al., 2004; Eisawi et al., 2012; Lirong et al., 2013; Makeen et al., 2015b, c), yet detailed bulk geochemical and biomarker investigations on the produced crude oils and to correlate between oils and the potential source rocks in the Muglad Basin are lacking. In this regard, 15 crude oils and their asphaltenes from different petroleum reservoir sections

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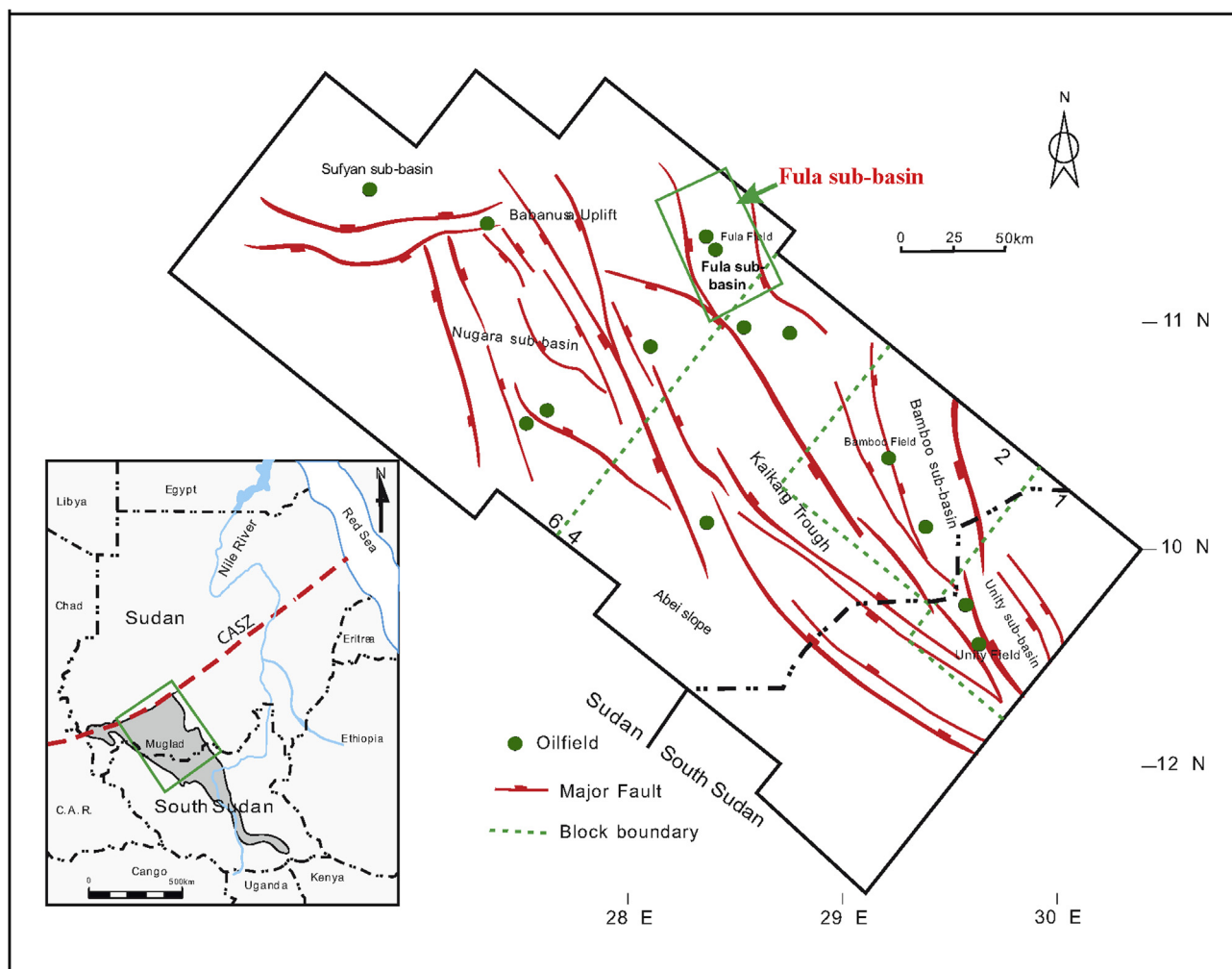


Fig. 1. Location map of the Fula-sub Basin including Moga and Keyi oilfields in the Muglad Basin (Lirong et al., 2013; Makeen et al., 2015a and b).

in the Fula oilfields were characterized by a variety of biomarker and non-biomarker parameters using different techniques. The main objectives of the current study are to: (1) characterize the oil types and compositions; (2) assess biomarker characteristics indicative of source, palaeo-depositional conditions, and thermal maturity, and (3) establish the genetic relationship between the studied crude oils and the potential Abu Gabra shale source rock previous work by Makeen et al. (2015a,b,c,d).

2. Geological setting

The Muglad basin is recognized as the chief rift basin in Sudan's interior, trending northwest-southeast, and covers an area of about 120,000 km². The basin is approximately 800 km long and 200 km wide (Fig. 1). The Fula sub-basin lies in the northeastern part of the Muglad Basin, Sudan, covers an area of about 3600 km², and is a Cretaceous and Tertiary sedimentary basin. Abdelhakam and Ali (2008) postulated that the Muglad Basin is part of a trend of Cretaceous sedimentary basins of apparent rift origin, and which cut across north central Africa from the Benue Trough in Nigeria, through Chad and the Central African Republic, into Sudan. Three rifting episodes occurred during the Early Cretaceous, Late Cretaceous, and early–middle Tertiary, respectively (McHargue et al., 1992). A 13 km-thick sedimentary section was deposited in the

deep troughs due to these episodes of rifting (Schull, 1988) consisting of three depositional cycles. Generally, the synrift sediments are fine-grained and the later thermal subsidence (sag) phase sediments are coarser grained. Fig. 2 modified from Schull (1988) and Kaska (1989), demonstrates a generalized stratigraphic framework of the Muglad basin, including the Fula sub-basin, and defines usage of the stratigraphic terms used in this paper. Abdalla et al. (2001) and Abdelhakam and Ali (2008) divided the stratigraphic column of the Muglad basin into three cycles of deposition. The first depositional cycle (Early Cretaceous) consists mainly of Barremian–Aptian Abu Gabra Formation comprising the main lacustrine source beds and can be divided into three main intervals. The lower interval is dominated by medium- to coarse-grained fluvial sandstones which are interbedded with thin claystones, whereas the middle interval is dominated by thick organic rich laminated shales, and the upper interval is dominated by interbedded sandstones and dark shales (Lirong et al., 2013). The shales and claystone in the middle interval are considered to be the main source rocks in the Fula sub-basin and throughout the Muglad Basin (Schull, 1988; Mohamed et al., 2000; Dou et al., 2002; Tong et al., 2004). Mohamed et al. (2000) reported that the Abu Gabra sediments contain oil-prone Type I and Type II kerogen with average HI of 270 mg HC/g TOC and TOC of 1.3% wt. The Abu Gabra Formation is overlying by a regional unconformity and the post-rift

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