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Geochemical characteristics of some crude oils from Alif Field in the Marib-Shabowah Basin, and source-related types

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ABSTRACT

The Marib-Shabowah Basin is an important hydrocarbon province in western Yemen, but the origin of hydrocarbons is not fully understood. In this regard, geochemical characteristics are used to provide information on source organic matter input, depositional environment and the correlation between crude oils from different pay zones. Two oil families are present within the study area and classified based on biomarker and non-biomarker parameters. The family I oils are characterized by low API gravity, high sulfur and trace metal (Ni, V) contents and low Ph/Ph ratio <1.0. These oils were derived from an alga organic matter that was deposited in a highly anoxic, hypersaline marine depositional environment and generated at low maturity.

Family II oils have medium to high API gravity, low sulfur and trace metal contents and relatively high Pr/Ph ratios (1.09–1.59). The family II oils were derived from mixed marine and terrigenous organic matter and deposited under sub-oxic conditions. These oils were generated from source rocks with a wide range of thermal maturity ranging from early to peak oil window. The oil characteristics suggest that family I oils may be derived from the Tithonian age Safer calcareous shales and family II oils from the deeper Kimmeridgian Madbi shales.

1. Introduction

Sedimentary organic matter and crude oils contain complex assemblages of biological marker compounds (biomarkers) that preserve the molecular structure of various compounds that constitute the organisms. Biomarkers are widely used in the petroleum industry to identify groups of genetically related oils, to correlate oils with source rocks and to describe the probable source rock depositional environments for migrated oil of uncertain origin and the degree of biodegradation (Moldowan et al., 1985; Peters and Moldowan, 1993; Peters et al., 2005).

Many oilfields have been discovered in the Marib-Shabowah Basin, an important hydrocarbon province in the western part of Yemen (Fig. 1), since oil was first discovered in the late 1980s. The Alif Field, located in the central portion of the Marib-Shabowah Basin (Fig. 1), is one of the most prolific oilfields. The Marib-Shabowah Basin has attracted the interest of numerous researchers, authors and oil companies for the exploration of hydrocarbons. The Marib-Shabowah Basin developed during the Jurassic and is related to rifting of the Arabian plate from the Gondwana supercontinent (Redfern and Jones, 1995; Beydoun et al., 1996). The stratigraphic section in the Marib-Shabowah Basin is dominated by a thick Mesozoic succession and ranges in age from Jurassic to Cretaceous (Fig. 2). The organic-rich shales of Madbi Formation (Kimmeridgian) and Safer Member (Tithonian) are the prolific oil prone source rocks in the Marib-Shabowah Basin (Brannin et al., 1999; Csato et al., 2001; Hakimi and Abdullah, 2013). The Alif Member is considered the main reservoir in the Marib-Shabowah Basin (Fig. 2) and comprises over 90% of recoverable oil in the basin (JNOC, 2000 "personal communication"). Previous geochemical studies on the Marib-Shabowah Basin oils are unpublished. Within this perspective, we report the results of an organic geochemical investigation on crude oils from the Alif Field. The objective is to use biomarker distributions together with the bulk geochemical parameters to characterize the oil types and to assess the respective depositional environment and thermal maturity of their potential source rocks.

2. Samples and methods

The materials used in this study include 10 crude oil samples representing different petroleum reservoirs in the Alif Field, Marib-

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Shabowah Basin (Table 1). The geographic locations of the wells chosen are shown in Figure 1.

The ratios of transition metals (vanadium and nickel) in crude oil are useful in the determination of source rock type, depositional environment and maturation because they remain unchanged irrespective of diagenetic and in-reservoir alteration effects (Barwise, 1990; Udo et al., 1992). Absolute concentrations of vanadium and nickel can be used to classify and correlate oils. These metals are the major metals in petroleum (Boduszynski, 1987). The metals analysis was conducted at Geochem Laboratories Limited (USA).

Asphaltenes were precipitated from the crude oils by adding a 40 fold excess of *n*-hexane. The precipitated asphaltenes were filtered. The fractions of the hexane soluble organic matter were separated into saturated hydrocarbons, aromatic hydrocarbons and NSO compounds using liquid column chromatography. A chromatographic column (30×0.72 cm) was packed with equal volumes of alumina and silica (both activated for 2 h at 200 °C).

The saturated hydrocarbon fractions were then analyzed by gas chromatography (GC) and gas chromatography–mass spectrometry (GC–MS). A FID GC with HP-5MS column and helium carrier gas was used. A temperature program from 40 to 300 °C at a rate of 4 °C/min and then held for 30 min at 300 °C was used for GC analysis. GC–MS experiments were performed on a V 5975B inert MSD mass spectrometer with a GC attached directly to the ion source (70 eV ionization voltages, 100 mA filament emission current, 230 °C interface temperature with full scan).

3. Results and discussion

Biomarker distributions and bulk oil parameters were used to assess the genetic relationship between hydrocarbon generation and their source rock depositional environments. Based on bulk geochemical properties and fingerprints (GC and GC–MS), the investigated oils were classified into two genetic families. A description of the geochemical characteristics of the oil families follows.

3.1. Non-biomarker characteristics

3.1.1. Bulk properties of crude oils

The bulk crude oil properties and compositions for the studied oils are presented in Table 1. The crude oils from the Alif Field have a variety of API gravity values in the range of 15.0–58.7° (Table 1). Low API gravity is generally associated with either biodegraded oils or with immature sulfur-rich oils (Baskin and Peters, 1992).

Biodegradation may occur in an oil reservoir, and the process dramatically affects the fluid properties of the hydrocarbons (e.g., Miiller et al., 1987). The early stages of oil biodegradation are characterized by the loss of *n*-alkanes or normal alkanes followed by loss of acyclic isoprenoids (e.g., pristane and phytane). Compared with those compound groups, other compound classes (e.g., highly branched and cyclic saturated hydrocarbons as well as aromatic compounds) are more resistant to biodegradation (Larter et al., 2005). In this respect, the analyzed oil samples contain a complete suite of *n*-alkanes in the low-molecular weight region and acyclic isoprenoids (e.g., pristane and phytane; Fig. 3). Therefore, there is no sign of biodegradation among the oil samples. This is also indicated by the oil samples generally containing more saturated hydrocarbons than aromatic hydrocarbons with saturate/aromatic hydrocarbons ratios >1 (Table 1). On the other hand, the relationship between API gravity and sulfur content reflects that the low API gravity is associated with sulfur-rich oils (Fig. 4). A wide range of bulk property values of the crude oils analyzed indicates that two oil families are represented (Table 1). Family I represent four crude oils, which have low API gravities, corresponding to high sulfur content of 3.03–6.00 wt% (Fig. 4), suggesting that these oils were generated from clay-poor marine source rocks deposited under highly reducing conditions (Gransch and Posthuma, 1973; Moldowan et al., 1985). In contrast, family II represents six crude oil

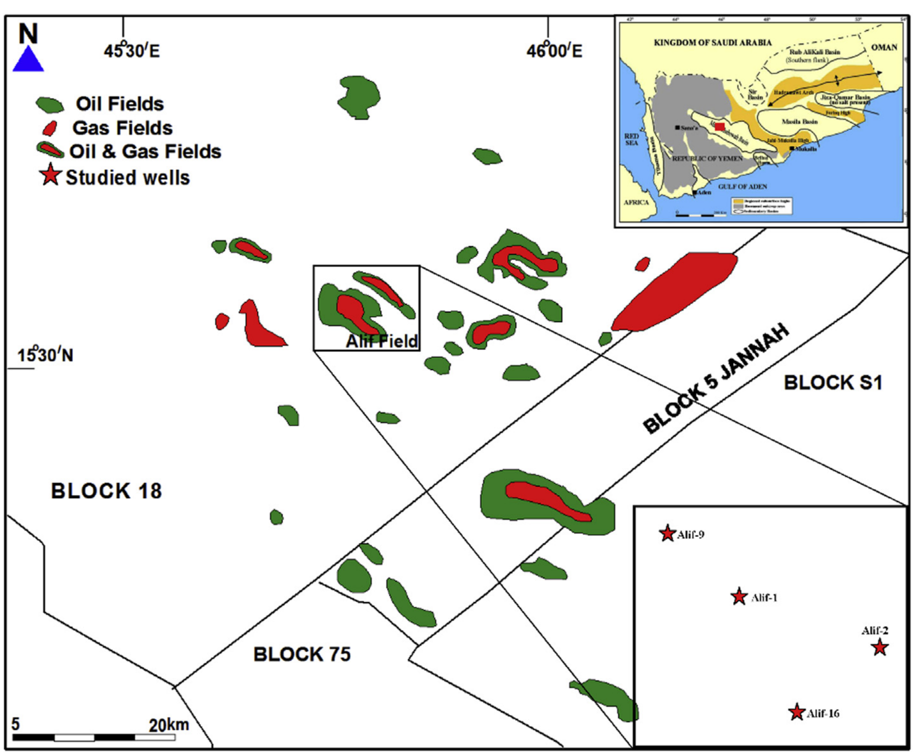

Figure 1. Location map of the fields in the Marib-Shabowah Basin including Alif Field and studied wells.