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A bulk kinetic, burial history and thermal modeling study of the Albian Kazhdumi and the Eocene-Oligocene Pabdeh formations in the Ahvaz anticline, Dezful Embayment, Iran

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ABSTRACT

The Ahvaz anticline which is located in the middle region of the Dezful Embayment is certainly one of the most important oilfields in Iran. Burial history reconstruction and one-dimensional thermal maturity modeling of the Late Jurassic to Present-day successions have been conducted in the Ahvaz anticline. The petroleum generation bulk kinetic parameters of the Kazhdumi and Pabdeh formations were computed by a non-isothermal open system pyrolysis at different heating rates. Bulk kinetic experiments reveal that a relatively narrow distribution of activation energies, range from 40 to 52 kcal/mol for the Kazhdumi samples and from 42 to 54 kcal/mol for Pabdeh shales, are directly related to the homogeneity in the organic matter. The principal activation energies of 46 kcal/mol and 48 kcal/mol, frequency factors of $4.36 \times 10^{+11}\ s^{-1}$ and $1.91 \times 10^{+12}\ s^{-1}$ and hydrogen indexes (HI) of 123 and 351 mg/g TOC have been computed for the Kazhdumi and Pabdeh formations, respectively. The lithology composition (percentages of shale, marl, gypsum, limestone and sandstone) of the Late Jurassic-Present formations in the selected wells was determined by using cutting samples and wireline well log data. The computed kinetic parameters and derived lithology composition of strata were applied to thermal maturity modeling. Thermal maturity modeling and burial history reconstruction which is calibrated by vitrinite reflectance data and formation temperature indicate that the palaeo-heat flow ranges from 37 mW/m^2 to 41 mW/m^2.

The Kazhdumi Formation entered the main stage of oil generation during the Late Miocene (6.5 Ma) and the Pabdeh Formation reached early stage of oil window from the Early Pliocene (3.5 Ma). Our results provide the bulk petroleum generation kinetic parameters description of the Kazhdumi and Pabdeh formations and demonstrate the thermal maturation state of source rocks, especially the Albian shales, that has been recognized as most important source rock in the Dezful Embayment.

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1. Introduction

The Ahvaz anticline is one of the most important supergiant oilfield located in the Dezful Embayment in the southwestern region of Iran (Fig. 1). The oil and gas reserves are accumulated in two main carbonate reservoirs in the Ahvaz oilfield: the Oligocene-Early Miocene Asmari Formation and the Upper Cretaceous Sarvak Formation (Bordenave and Hegre, 2005; Rabbani and Bagheri Tirtashi, 2010; Opera et al., 2013). Two excellent source rocks, the Albian Kazhdumi Formation and the upper part of the Pabdeh Formation (Middle Eocene to Early Oligocene), supplied the reservoirs (Bordenave and Hegre, 2005; Rabbani and Bagheri Tirtashi, 2010; Alizadeh et al., 2012; Opera et al., 2013; Aldega et al., 2014; Mashhadi et al., 2015).

During the long geological history, source rocks may undergo complex thermal history in response to regional thermal regime. Thermal modeling of petroleum generation processes encompasses related maturation factors, such as burial history, lithology composition of strata and kinetic parameters of source rocks (Hantschel and Kauerauf, 2009).

Thermal modeling and reconstruction of burial history of the source rocks in the southern part of the Dezful embayment have been investigated through several studies (e.g., Kamali and Rezaee, 2003; Kamali et al., 2005; Rabbani and Bagheri Tirtashi, 2010; Alizadeh et al., 2012; Opera et al., 2013). In the western sides of the Persian Gulf, the Kazhdumi and Padeh formations have poor to fair hydrocarbon generation potential. The petroleum generation from the Kazhdumi Formation began during the Eocene and the high

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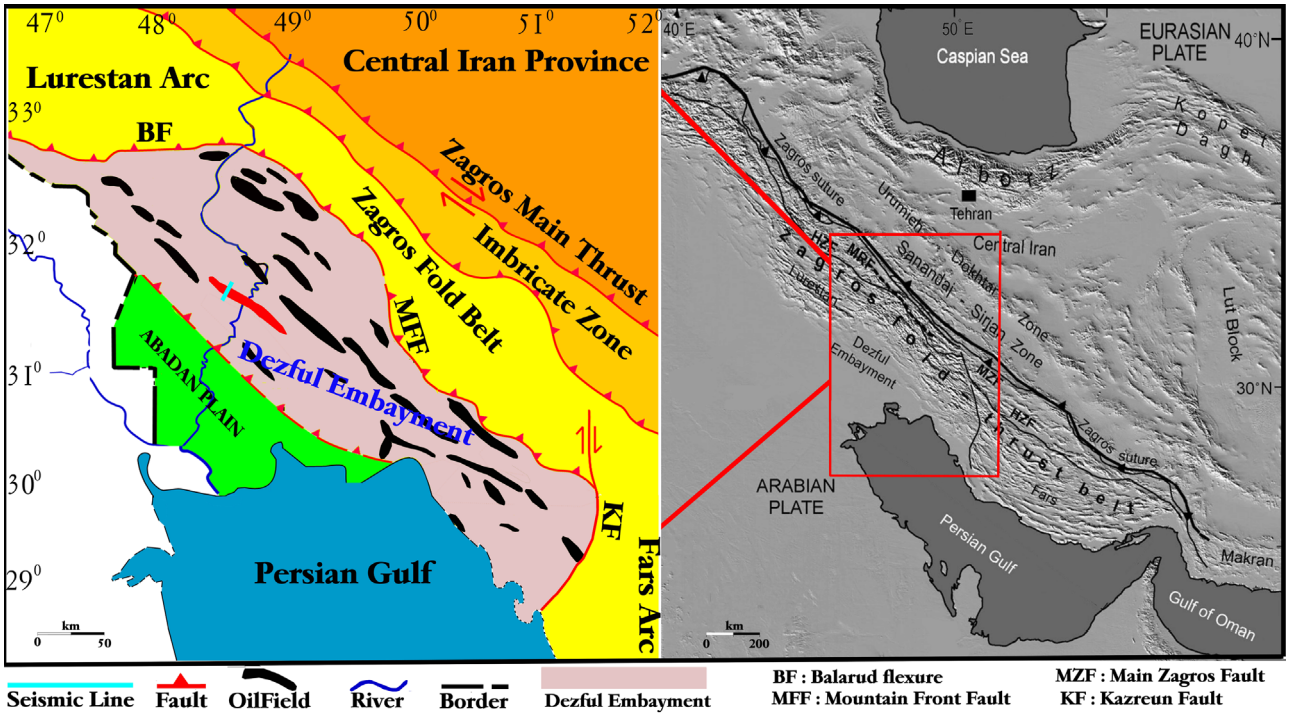

Fig. 1. (A) Location map and main structural features related to the Dezful Embayment (B) Locality map of Ahvaz oilfield (red) in the Dezful Embayment (modified from Fakhari et al., 2008).

sulfur content oil were probable sourced from the Kazhdumi Formation in these sectors of the Persian Gulf (Rabbani et al., 2014; Mashhadi and Rabbani, 2015). In these studies, the default kinetics parameters implemented in the modeling software were used; the kinetic parameters of the source rocks were not derived from lab analysis results. Due to effects of the kinetics parameters of source rocks in the petroleum generation processes, determining of these parameters are a key element in thermal modeling.

The bulk kinetic parameters of the Kazhdumi and Pabdeh formations, obtained by Rock-Eval pyrolysis, are approximated by the linear combination of a number of first-order kinetic equations, each of these being characterized by a pre-exponential factor and the activation energy value of Arrhenius equation:

$$K = A\, e^{-E/RT} \tag{1}$$

where K is reaction rate, A the frequency (amplitude or pre-exponential) factor (s^{-1}), E the activation energy ($J\,mol^{-1}$), R (8.31441 $J\,mol^{-1}\,K^{-1}$) the universal gas constant and T the absolute temperature (K) (Hunt, 1996).

This study aims to determine the bulk kinetic parameters of the Kazhdumi and Pabdeh source rocks, and reconstruct in one-dimensional the burial history of the Late Jurassic to present-day strata in two wells in the Ahvaz oilfield. In addition, provide additional information on analyses of the source rock characteristics and hydrocarbon generation of the Kazhdumi and Pabdeh formations in the Ahvaz oilfield (Fig. 1).

2. Geological setting

The Zagros fold-and-thrust is the result of the Arabia/Eurasia collision initiated at Eocene (35 Ma) as the rifted Arabian lithosphere was underthrusted beneath the Iranian plate (Mouthereau et al., 2012; Opera et al., 2013). The Zagros fold-and-thrust belt is constituted by two main zones, the High Zagros (Imbricated Zone) to the north and the Zagros Folded Belt to the south (Fig. 1). The Zagros folded belt has been divided laterally into the Lurestan, Dezful Embayment and Fars regions from northwest to southeast (Fig. 1).

The Dezful Embayment, a 60,000 km^2 (Bordenave and Hegre, 2005) depressed area, is situated southwest of the Mountain Front Fault, between Lurestan and Fars Arcs (Fig. 1). The Dezful Embayment is structurally bounded by the Mountain Front Fault (MFF) to the north, the Kazerun Fault to the east and the Balarud flexure to the west (Mouthereau et al., 2012). It encompasses an impressive gathering of about 60 oilfields (Fig. 1) some of which are giant and super giant oilfields. The super-giant Ahvaz oilfield in the middle of the Dezful Embayment (Fig. 1) is the anticline with thrust faults (Sherkati et al., 2005; Fakhari et al., 2008) cutting through the folded strata (Fig. 2), in which fold axis is a smooth curve line (Figs. 3 and 4). The Ahvaz oilfield is NW-SE trending (Fakhari et al., 2008) long symmetrical anticline (Figs. 3 and 4). This structure contains 18 billion barrels (18×10^9 bbls) of proven oil reserve (Speight, 2014). The Oligo-Early Miocene Asmari Formation which is situated at depths of 2300–2900 m (true vertical depth) (Fig. 3) is the main petroleum reservoir rock, followed by the Cenomanian to Turonian (Fig. 5) limestones of Sarvak Formation (Bordenave and Hegre, 2005; Mouthereau et al., 2012), situated at depths of 3200–4100 m (true vertical depth) (Fig. 4).

Although the reservoir quality of the high-energy limestones of Asmari Formation varies due to deposition under different conditions and subsequent diagenetic modifications (Honarmand and Amini, 2012), its quality is generally enhanced by a prominent system of fractures which occur near the tops of the high-relief anticlines (Bordenave and Hegre, 2005).

The Sarvak Formation deposited in an intrashelf basin with the sedimentation of the thin-bedded oligostegina limestone and in shelf margin (around the intrashelf basin) conditions with rudist debris. The rudist debris enhances reservoir quality of the Sarvak Formation (Ghabeishavi et al., 2010). The Ahvaz-Asmari is the largest producing oilfield-reservoir system in Iran (Speight, 2014). The organic-rich calcareous shales (Ghasemi-Nejad et al., 2009) pertaining to the Kazhdumi Formation, which were deposited in a

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