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Source rock characterization of the Albian Kazhdumi formation by integrating well logs and geochemical data in the Azadegan oilfield, Abadan plain, SW Iran

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ABSTRACT

There are several source rock units in the Zagros Basin. Nevertheless, the Cretaceous Kazhdumi formation has presumably produced the majority of the commercial hydrocarbons in this area. The presence of organic matter rich and thermally mature rock units containing oil or gas prone kerogen is the key factor controlling the hydrocarbon generation potential. Owing to the lack of organic geochemical studies such a potential is poorly investigated in the Azadegan oilfield. In this study, firstly we investigate the lower Cretaceous Kazhdumi formation potential source rock based on geochemical parameters including type and amount of kerogen and thermal maturity, obtained from analyzing 45 cutting samples from 9 wells by using Rock-Eval 6 apparatus. Moreover, vitrinite reflectance measurements were carried out on 11 samples utilizing Zeiss Axioplan II microscope for further examination of the thermal maturation. Burial history analysis and thermal maturity modeling suggests that Kazdumi formation is marginally mature (vitrinite reflectance in the range of 0.5–0.7%) with hydrocarbon expulsion beginning since about 14 Ma. The results indicate increasing maturity from south to the north as a result of burial deepening of the Kazhdumi Formation. It contains type II and mixed types II/III kerogen with TOC (Total Organic Carbon) values up to 4.88 wt% and Source Potential Index (SPI) value of 3.72 t HC/m^2 providing a moderate source for the hydrocarbons encountered in the reservoir rocks.

In the second part of this research, we attempt to characterize the Kazhdumi source rock by using intelligent systems. In this regard, a three-layered back-propagation Artificial Neural Network (ANN) with Levenberg–Marquardt (LM) training algorithm was designed to predict TOC values from well log data (RHOB, THOR, SGR, NPHI, DT). This network is capable of predicting TOC with correlation coefficient of 98.63% and 82.62% and MSE of 0.0067 and 0.1772 for training and testing steps, respectively. According to the ANN modeling and TOC distribution map, organic richness of the Kazhdumi formation increases from south to the north over the study area.

1. Introduction

Source rocks are fundamental to any petroleum system: no source rock, no hydrocarbons (Hunt, 1996). Therefore, a critical step is to determine whether a source rock is present in an area of interest or not. Thus, adequate quantities of organic material must be present for a geologic unit to be characterized as a potential source rock. The quantity of the organic matter within rocks is usually expressed as total organic carbon (TOC) and the relative ability of a source rock to generate petroleum is defined by its kerogen quantity and quality (Hunt, 1996). Unfortunately, these data are usually sparse since exploration wells intentionally penetrating into the source rock horizons are limited, so few samples can be used for laboratory analysis. This places a great emphasis on employing methods for source rock prediction by using common data such as well log data, which is available almost in all wells. Conventional methods are based on the physical properties of the organic matter such as low density and low sonic velocity, influencing well log responses. So, to date various well log data have been used to detect and quantify organic matter in the sediments (Carpentier et al., 1989; Fertle and Rieke, 1980; Fertle,

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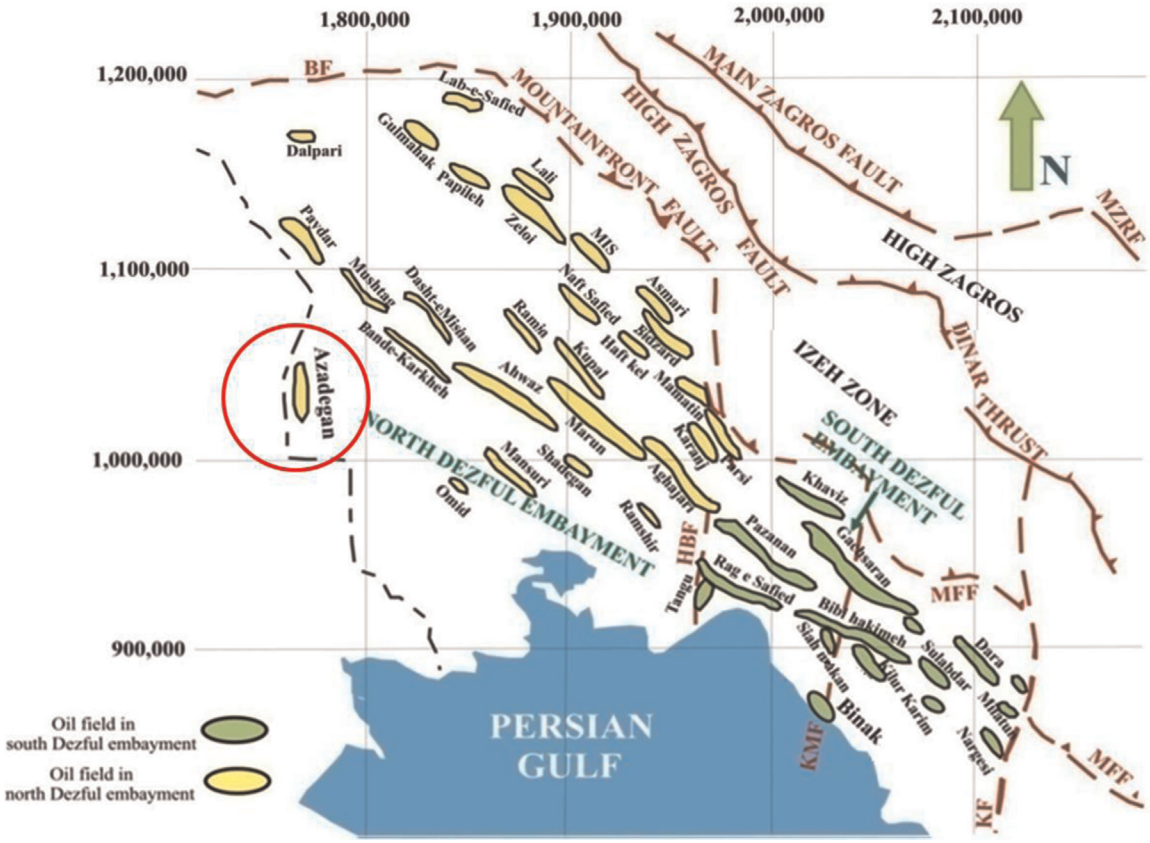

Fig. 1. Location map of the Abadan Plain. The Azadegan oilfield is outlined by red circle. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

1988; Herron, 1988; Mendelson and Toksoz, 1985; Meyer and Nederlof, 1984; Passey et al., 1990; Schmoker, 1981, 1979). More recently intelligent systems are exploited as useful tools for identifying the complex relationship among TOC and well log data even in highly heterogeneous formations, as applied by Alizadeh and Moradi (2006), Alizadeh et al. (2012), Bolandi (2013), Huang and Williamson (1996), Kadkhodaie-Ilkhchi et al. (2009) and Kamali and Allah Mirshady (2004).

Several potential source rock units and reservoir rocks with different geological characteristics were deposited in the Azadegan oilfield making this area a petroleum prolific region in the Dezful embayment (Bolandi, 2013; Sadati, 2012; Tahmorasi, 2013). So far, petroleum potential of Kazdumi formation has not been investigated, adequately. The current study is focused on evaluation of petroleum generation potential of the Kazhdumi Formation in the Azadegan oilfield based on Rock-Eval analysis, vitrinite reflectance measurements, thermal/burial history reconstruction and intelligent modeling of TOC content by means of neural networks (ANN).

2. Geological setting

The study area is located in the northern part of the Dezful Embayment on the Abadan Plain (SW Iran) (Fig. 1), which is part of the Zagros fold-and-thrust belt (Alavi, 1994, 2004; Motiei, 1995). The Abdan Plain is considered as one of the petroliferous areas in the Zagros mountain range containing many super giant oil and gas fields characterized by two types of structural closure: gentle N–S to NE–SW (Arabian type) and open to tight SW–NE trending basement-cored anticlines (Arabian type) in the SE, and open to tight SW–NE trending anticlines (Zagros Fold Thrust Belt) AbdollahieFard et al. (2006). The Azadegan oilfield is a part of the Mesopotamian-Persian Gulf lowland (Berberian and King (1981)) having N–S fold axes trending known as “Arabian plate trend” being in contradiction to the Zagros type structures (NW–SE) caused by the basement faulting and subsequent movements of the Early Cambrian Hormuz Salt (AbdollahieFard et al. (2006)). The Kazhdumi formation as a part of Bangestan group (James and Wynd, 1965) is a proven Early Cretaceous source rock (Bolandi, 2013; Sadati, 2012) and stratigraphically positioned between the Cenomanian–Turonian Sarvak Formation and Aptian Dariyan Formation. It mainly consists of carbonate rocks and is known as one of the richest source rocks throughout the Abadan plain.

3. Theory and methodology

The overall goal of this research is to evaluate the hydrocarbon potential of Kazhdumi formation in the Azadegan oilfield by integration of geochemical and well log data. The specific objectives of this study include (1) geochemical evaluation (quantity, quality and maturity) of Kazhdumi formation in the Azadegan oilfield by using Rock-Eval and vitrinite reflectance measurements, (2) burial/thermal history reconstruction, and (3) investigation of TOC distribution in the Kazhdumi formation by using ANN modeling.

For this study, 45 cutting samples of the possible source rock of Kazhdumi formation were taken from 9 wells in order to assess its geochemical characteristics. For this purpose, each cutting sample was decontaminated (from micas that come from lost circulation material (LCM) and iron filings from the drill bit) and pulverized to a fine powder prior to analysis. All samples were weighed to 60–70 mg and subjected to Rock-Eval 6 pyrolysis, a powerful analytical tool that assesses quantity, type and thermal maturity of rock