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Research paper

Organic geochemistry and petroleum potential of Early Cretaceous Garau Formation in central part of Lurestan zone, northwest of Zagros, Iran

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ABSTRACT

Deposition of organic rich black shales and dark gray limestones in the Berriasian-Turonian interval has been documented in many parts of the world. The Early Cretaceous Garau Formation is well exposed in Lurestan zone in Iran and is composed of organic-rich shales and argillaceous limestones. The present study focuses on organic matter characterization and source rock potential of the Garau Formations in central part of Lurestan zone. A total of 81 core samples from 12 exploratory wells were subjected to detailed geochemical analyses. These samples have been investigated to determine the type and origin of the organic matter as well as their petroleum-generation potential by using Rock-Eval/TOC pyrolysis, GC and GCMS techniques. The results showed that TOC content ranges from 0.5 to 4.95 percent, PI and Tmax values are in the range of 0.2 and 0.6, and 437 and 502 °C. Most organic matter is marine in origin with sub ordinary amounts of terrestrial input suggesting kerogen types II-III and III. Measured vitrinite reflectance (Rrandom%) values varying between 0.78 and 1.21% indicating that the Garau sediments are thermally mature and represent peak to late stage of hydrocarbon generation window. Hydrocarbon potentiality of this formation is assessed fair to very good capable of generating chiefly gas and some oil. Biomarker characteristics are used to provide information about source and maturity of organic matter input and depositional environment. The relevant data include normal alkane and acyclic isoprenoids, distribution of the terpane and sterane aliphatic biomarkers. The Garau Formation is characterized by low Pr/Ph ratio (<1.0), high concentrations of C27 regular steranes and the presence of tricyclic terpanes. These data indicated a carbonate/shale source rock containing a mixture of aquatic (algal and bacterial) organic matter with a minor terrigenous organic matter contribution that was deposited in a marine environment under reducing conditions. The results obtained from biomarker characteristics also suggest that the Garau Formation is thermally mature which is in agreement with the results of Rock-Eval pyrolysis.

1. Introduction

The Berriasian-Turonian Garau Formation is considered the major source rock for petroleum in southern Iran. The geochemistry of oils and the source potential of this formation in Iran have been the subject of numerous prior studies (e.g., Bordenave and Burwood, 1990; Bordenave and Huc, 1995; Bordenave, 2002; Kamali and Rezaee, 2003; Kamali et al., 2006; Ezampanah, 2012; Bordenave et al., 1993). Most of the studies have been carried out in the Dezful Embayment, Fars and the Persian Gulf. In contrast, little work has been conducted in Lurestan basin. The Garau Formation in Lurestan zone (northwestern Zagros, Iran) (Fig. 1 A) is composed of black shales and dark gray argillaceous limestones containing bitumen. From Lurestan zone toward Dezful Embayment and Fars basin this formation gradually passes into carbonate platform strata of the upper Khami Group (Beydoun et al., 1992; Motiei, 1993) (Fig. 2).

The early to middle Cretaceous sequence, characterized by deposition of black shale intervals rich in organic matter in deep marine environments, is recognized in most oceanic deposits of

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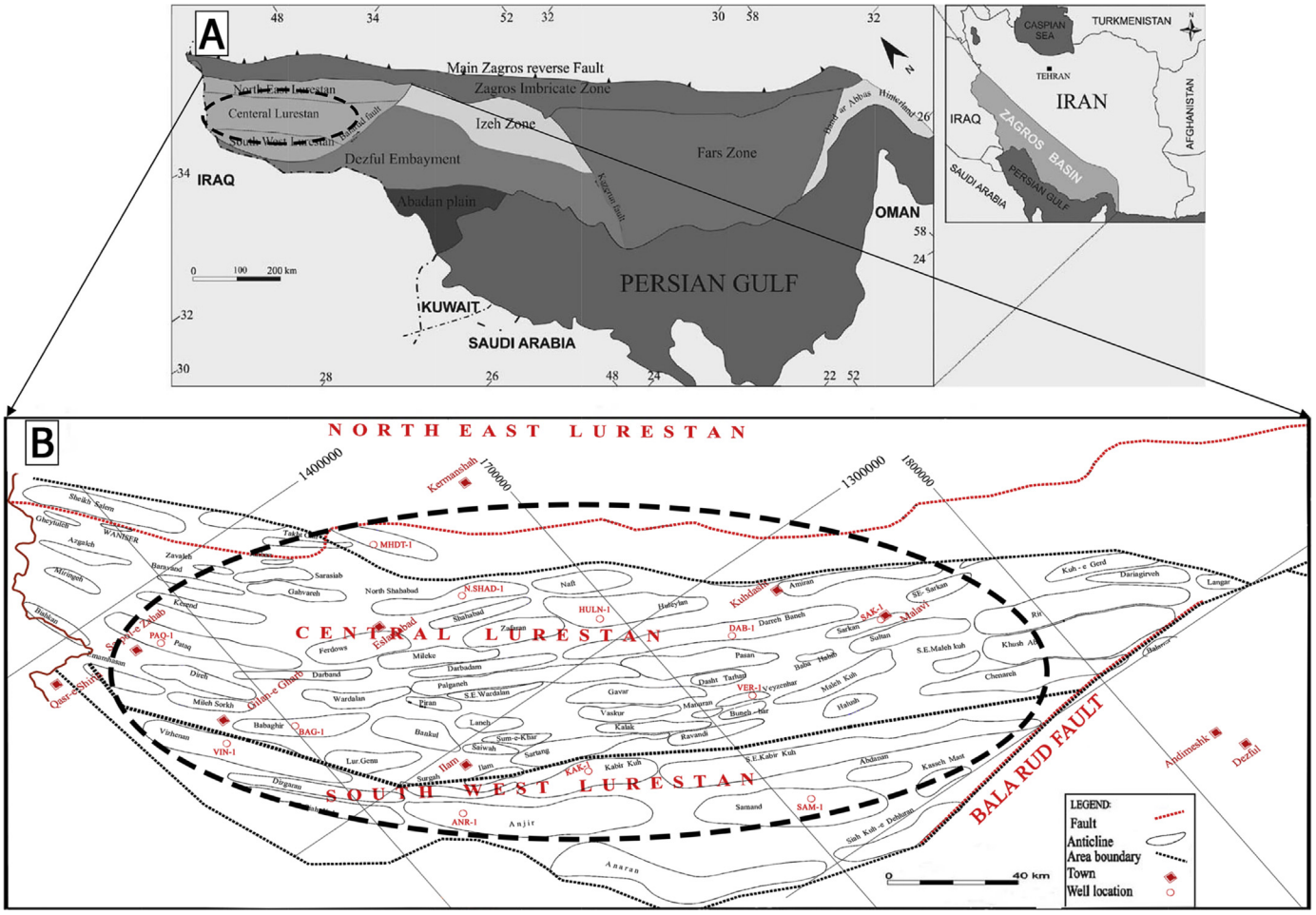

Fig. 1. (A) Location map of the Zagros Basin (modified after Farzipour-Saein et al., 2009). (B) The study area is located in central part of Lurestan zone the northwestern of the Zagros Basin.

that time-interval, especially in Tethys (Arthur et al., 1990; Leckie et al., 2002; Baudin, 2005). The concentration of CO_2 in atmosphere reached the high levels during early to middle Cretaceous, leading to the greenhouse climate and significant changes in marine ecosystems (Arthur et al., 1985). According to Larson (1991), these conditions were triggered by increasing sea floor spreading, oceanic crustal production and submarine volcanism (Fig. 3). The sea level also rose universally coincident with these warm and humid conditions (Haq et al., 1987) and persisted across the Aptian-Turonian interval (Wilson et al., 2002). It has been supposed that deposition of black shale layers rich in organic matter took place during these conditions which are evidence of oceanic anoxic events (OAEs) (Schlanger and Jenkyns, 1976; Coccioni et al., 2006).

The objective of this study is to characterize the source rock potential of the Garau Formation in Lurestan zone (northwestern Zagros). Conventional geochemical methods for assessing source rock potential, Rock-Eval pyrolysis (Espitalié et al., 1977), GC, GC-MS and burial history modeling techniques are appropriate methods to assess petroleum potential of source rocks and rapid geochemical characterization of sedimentary organic matter.

2. Geological background

2.1. Geological setting

The Zagros fold–thrust belt is the deformed state of the Zagros sedimentary basin. This basin extends over the northeastern (present coordinates) Afro-Arabian continental margin and was affected by Early Cretaceous to present Zagros orogeny (Alavi, 2007). This belt is one of the important tectonic units of Iran and has a length of more than 1500 km, and width between 100 and 300 km (Motiei, 1993; Alavi, 2004) (Fig. 1A). During the Palaeozoic, Iran, Turkey and the Arabian plate (which now has the Zagros belt situated along its NE border), together with Afghanistan and India, made up the long, very wide and stable passive margin of Gondwana land bordering the Palaeo-Tethys Ocean to the north (Berberian and King, 1981). The final closure of Palaeo-Tethys in the Tethyan domain took place during the Triassic to Jurassic (Stampfli and Borel, 2002; Golonka, 2004). The Neo-Tethys opened from the Late Carboniferous to the late Early Permian, beginning in the east of Australia and progressing to the eastern Mediterranean area (Stampfli and Borel, 2002). The Zagros orogeny is a product of the closure of the Neo-Tethys that involved three major sequential geotectonic events (Alavi, 1994, 2004, 2007): (1) subduction of the Neo-Tethyan oceanic crust beneath the Iranian plates, (2) emplacement of slivers of oceanic crust over the Afro-Arabian continental margin, and (3) collision of the Afro-Arabian continental margin with the Iranian plates.

The sedimentary column in the Zagros is estimated to be 7–12 km. This is classified into four groups of rocks accumulated in different tectonosedimentary environments through Latest Neoproterozoic to Phanerozoic (Alavi, 2004, 2007). The Lowermost