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Research paper

Thermal evolution of the Kuh-e-Asmari and Sim anticlines in the Zagros fold-and-thrust belt: Implications for hydrocarbon generation

Luca Aldega [a,*], Sveva Corrado [b], Eugenio Carminati [a], Ali Shaban [c], Shahram Sherkati [d]

[a] Dipartimento di Scienze della Terra, Sapienza Università di Roma, P.le Aldo Moro, 5, 00185 Roma, Italy
[b] Dipartimento di Scienze, Sezione di Geologia, Università degli Studi Roma Tre, L.go S. Leonardo Murialdo 1, 00146 Roma, Italy
[c] National Iranian Oil Company, Tehran, Iran
[d] Exploration Technical Geoscience, Petronas Carigali Sdn Bhd, Kuala Lumpur, Malaysia

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ABSTRACT

Mixed layer clay minerals, vitrinite reflectance and geochemical data from Rock-Eval pyrolysis were used to constrain the burial evolution of the Mesozoic–Cenozoic successions exposed at the Kuh-e-Asmari (Dezful Embayment) and Sim anticlines (Fars province) in the Zagros fold-and-thrust belt. In both areas, Late Cretaceous to Pliocene rocks, show low levels of thermal maturity in the immature stages of hydrocarbon generation and early diagenetic conditions (R0 I–S and R_o% values < 0.5). At depths of 2–4 km, T_{max} values (435–450 °C) from organic-rich layers of the Sargelu, Garau and Kazhdumi source rocks in the Kuh-e-Asmari anticline indicate mid to late mature stages of hydrocarbon generation. One dimensional thermal models allowed us to define the onset of oil generation for the Middle Jurassic to Eocene source rocks and pointed out that sedimentary burial is the main factor responsible for measured levels of thermal maturity. Specifically, the Sargelu and Garau Formations entered the oil window prior to Zagros folding in Late Cretaceous times, the Kazhdumi Formation during middle Miocene (syn-folding stage), and the Pabdeh Formation in the Late Miocene–Pliocene after the Zagros folding. In the end, the present-day distribution of oil fields in the Dezful Embayment and gas fields in the Fars region is primarily controlled by lithofacies changes and organic matter preservation at the time of source rock sedimentation. Burial conditions during Zagros folding had minor to negligible influence.

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1. Introduction

Organic matter optical analysis and X-ray diffraction of clay minerals are complementary techniques that provide information on the thermal evolution of sedimentary successions in fold-and-thrust belts and allow quantifying the maximum burial the rocks underwent (e.g., Pollastro, 1990; Mählmann, 2001; Di Paolo et al., 2012). These kinds of information are of primary importance for oil exploration studies because they provide insights on source-rock thermal maturity. In addition, some of the thermal parameters derived from these techniques such as vitrinite reflectance and illite content in mixed layer illite-smectite (I–S) are also useful to reconstruct the thickness of eroded sedimentary or tectonic overburden (Aldega et al., 2007a,b, 2011). In addition, Rock-Eval pyrolysis is a complementary technique which allow quantifying the type and amount of hydrocarbons generated from a specific source rock and to assess its potential (Espitalie et al., 1985; Dembicki, 2009).

About 8% of the global oil reserves are accumulated in two carbonate reservoirs in the Zagros fold-and-thrust belt: the Oligocene–early Miocene Asmari Formation and the Upper Cretaceous Bangestan Group (Sarvak and Ilam Formations) which are supplied by excellent source-rocks: the Albian Kazhdumi Formation and the upper part of the Pabdeh Formation (Upper Eocene to Early Oligocene; Bordenave and Hegre, 2005). The oil and associated gas are trapped in NW–SE trending anticlines which formed during the Neogene Zagros orogeny. Current distribution of oil and gas fields in the Zagros fold-and-thrust belt shows that almost all the oil fields are located in the Dezful Embayment whereas most of the gas fields are concentrated in the Fars region (Bordenave and Hegre, 2010).

We investigated two anticlines, namely the Kuh-e-Asmari and Sim anticlines, located in the Dezful Embayment and in the Fars region, respectively, in order to (1) compare the burial history of the Mesozoic–Tertiary succession of key areas in the two regions of the Zagros fold-and-thrust belt, (2) determine timing of hydrocarbon generation of the main source rocks and (3) define the main causes

* Corresponding author. Tel.: +39 06 49914547.
E-mail address: luca.aldega@uniroma1.it (L. Aldega).

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responsible for the present-day distribution of oil and gas fields in the two regions (e.g., different burial of the Mesozoic–Cenozoic succession or thermal regime). To constrain burial models, we used for the first time in the Zagros, a multi-method approach coupling organic matter optical analysis, X-ray diffraction of clay-size fraction of sediments and Rock-Eval pyrolysis. Illite content in mixed layer illite-smectite determinations and vitrinite reflectance measurements were performed for both anticlines on samples collected in the field, whereas Rock-Eval pyrolysis analyses were carried out on subsurface samples from the Asmari-1 well intercepting the Kazhdumi, Garau and Sargelu Formations, three source rocks which define different petroleum systems in the Dezful Embayment (Bordenave and Hegre, 2010). This study shows how inorganic thermal parameters derived from clay minerals can be used as indicators of thermal maturity of sediments and as tool for hydrocarbon exploration in frontier areas where organic matter is lacking or scarcely preserved (e.g., continental deposits or shallow water oxic conditions).

In the end, burial and thermal models were compared with existing burial histories from other oil fields in the Zagros fold-and-thrust belt and the evolution of temperature during Zagros folding and at maximum burial conditions was traced.

2. Geological setting

The Zagros fold-and-thrust belt is the result of Cenozoic convergence and Alpine-type orogenic continental collision between the Central Iran Domain and the Arabia plates (e.g., Mouthereau et al., 2012; Navabpour and Barrier, 2012). The Zagros fold-and-thrust belt is constituted by two main zones, the High Zagros Imbricated Zone to the north and the Zagros Simply Folded Belt to the south, bounded by the High Zagros Fault (HZF in Fig. 1A).

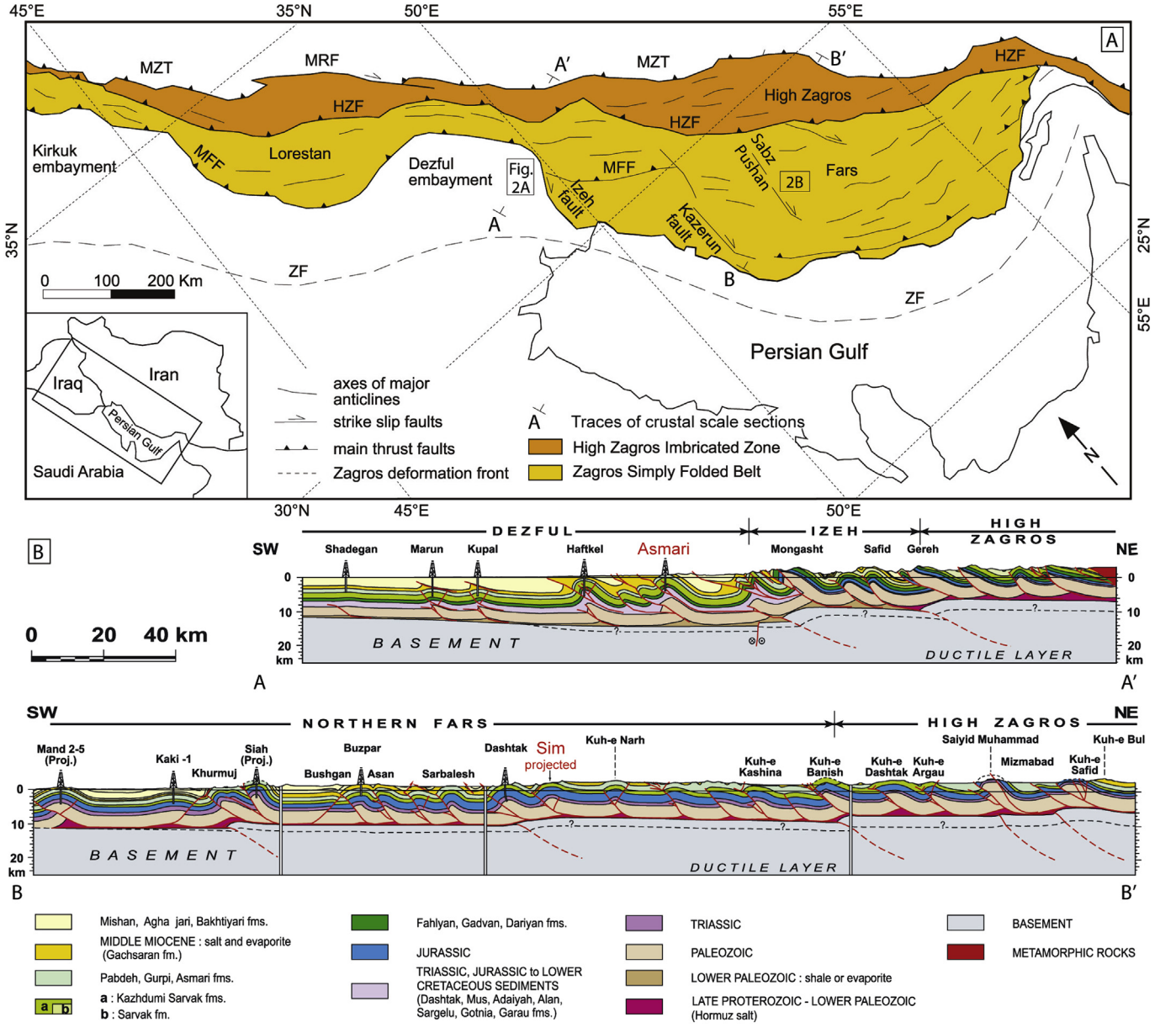

Figure 1. A) Structural setting of the Zagros fold-and-thrust belt showing the major fault zones, the geological provinces and the fieldwork areas (modified after Pirouz et al., 2011). HZF: High Zagros Fault, MFF: Zagros Mountain Frontal Fault, ZF: Zagros Front. B) Crustal scale cross-sections across the Dezful Embayment and the Fars province (modified after Sherkati et al., 2006).

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