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Research paper

Folding style of the Dezful Embayment of Zagros Belt: Signatures of detachment horizons, deep-rooted faulting and syn-deformation deposition

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ABSTRACT

Defining the governing factors on the geometry of the Dezful Embayment folds, a major oil province in the Zagros Fold-Thrust Belt in SW Iran, reduces the risks inherent in hydrocarbon exploration. The goal of the current study is to find a reasonable relationship between folding and faulting in the northern part of the Dezful Embayment. The role of major and minor detachment horizons and deep-rooted faults on structural style is also a matter of investigations. To achieve these goals, geological surface information and the available well and 2D and 3D seismic data were used to construct a balanced structural cross-section. The area is subdivided into NE and SW sectors based on dissimilar physiographic features of the surface and structural and stratigraphic characteristics. In the both sectors, the Miocene Gachsaran Formation acted as the upper detachment horizon. In the NE sector, the role of the Gachsaran Formation as major detachment horizon in decoupled folding styles of overlying and underlying units is prominent. The Gachsaran Formation becomes less effective as a detachment horizon towards the SW as its thickness decreases and its facies change. The Triassic Dashtak Formation is most probably a major detachment horizon in the study area and evidence of another deeper detachment horizon (such as the pre-Cambrian-Cambrian Hormuz Series) is not apparent based on available data. The Lower Cretaceous Garau, Upper Cretaceous Gurpi and Paleocene-Eocene Pabdeh formations and the Oligocene Kalhur Member are subordinate detachment horizons. The role of major faults in the area, such as the Mountain Front Fault in driving thick-skinned deformation is taken into account along with the dominant thin-skinned deformation in the study area. The Kuh-e Asmari Anticline is the only emergent anticline exposing the Paleocene strata due to the activity of the deep-rooted Lahbari Thrust. This study reveals the commanding role of the upper detachment Gachsaran Formation and the overlying syn-deformation fluvial clastics of the Aghajari (Miocene) and Bakhtyari (Pliocene) formations on disharmonic folding styles.

1. Introduction

The Zagros Fold-Thrust Belt (ZFTB) is a well-known natural laboratory of folding in southwest Iran. Because of its economic importance, this belt has long been of interest to geologists, especially structural geologists. The ZFTB hosts about 9% oil and 15% gas of worldwide reservoirs (Sherkati, 2005). A significant part of these reservoirs (45 oil fields) are located in the Dezful Embayment (Vergés et al., 2011). In this embayment, most of the hydrocarbon traps are anticlines (Bordenave and Hegre, 2005, 2010); therefore, identification of factors which affect the geometry of the anticlines is essential to exploration.

Despite the existence of seismic profiles and well data, prediction of the structural style in the deeper areas for which seismic imaging is usually of poor quality is often difficult to unravel. Since an accurate prediction of the deep structure is a key to understand the evolution of the different structures while enhancing their restoration to the pre-folding state, the characterization of the deformation style at different structural levels is of crucial interest. Therefore, the current study examined the geological structures of the northern part of the Dezful Embayment at the regional scale with the following aims: 1. describing the relationship between the folds and faults, 2. discovering the influence of the detachment horizons and syn-deformation deposits on the geometry of the folds and 3. determining the role of the deep-rooted faults in the structural style of the northern part of the Dezful Embayment and the southwest part of the Izeh zone (Fig. 1).

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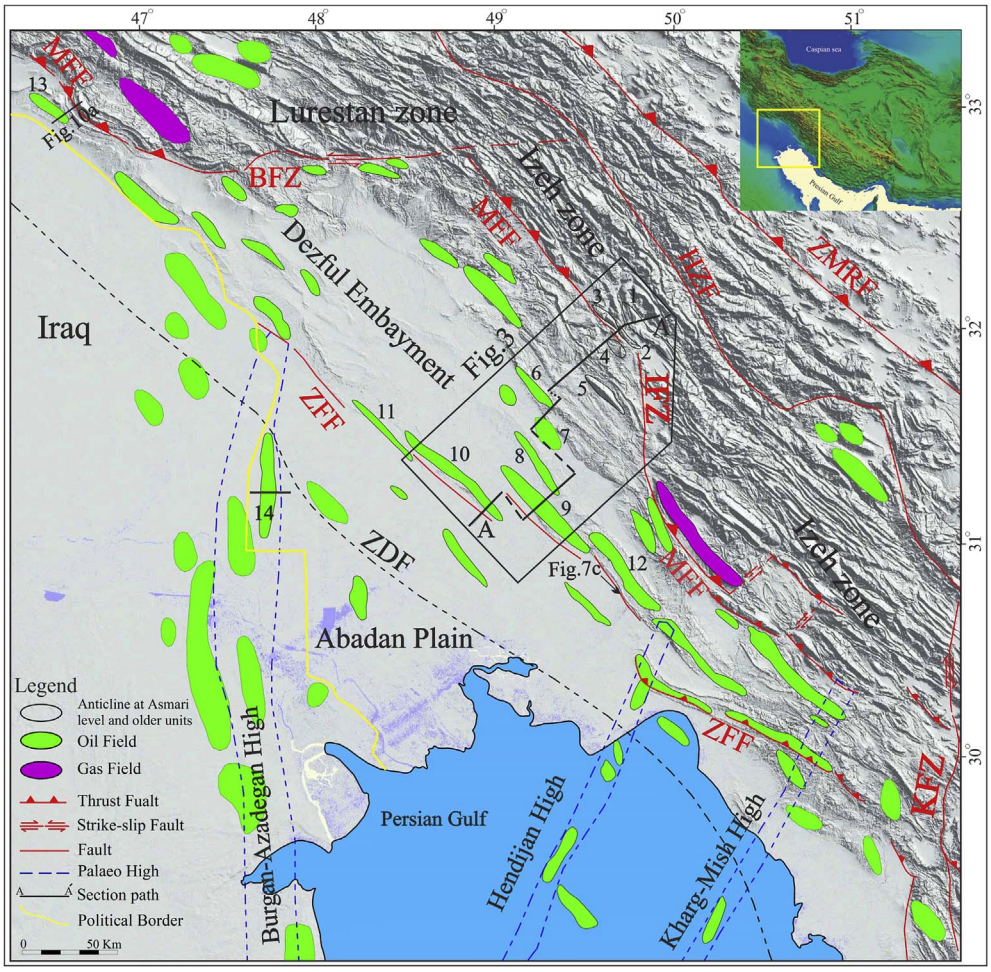

Fig. 1. Structural map of central part of the ZFTB. The Dezful Embayment is separated from other zones by the Mountain Front Fault (MFF), Balarud Fault Zone (BFZ), Izeh Fault Zone (IFZ), Kazerun Fault Zone (KFZ) and Zagros Front Fault (ZFF). Zagros Main Reverse Fault (ZMRF), High Zagros Fault (HZF), Zagros Deformation Front (ZDF). Payoun (1), Toukak (2), Kamarun (3), Pare Siah (4), Kuh-e Asmari (5), Naft-e Safid (6), Khandagh (7), Kupal (8), Marun (9), Ahwaz (10), Band-e Karkheh (11), Aghajari (12), Changuleh (13) and Azadegan (14) anticlines.

2. Geological setting and mechanical stratigraphy of Dezful Embayment

The Zagros orogenic Belt is a part of the Alpine-Himalayan Belt that is the result of the opening and subsequent closing of the Neo-Tethys Ocean between Central Iranian and Arabian plates (Takin, 1972; Berberian and King, 1981; Dercourt et al., 1986; AlaviM, 1994; Stampfli and Borel, 2002). The convergence started with ophiolite obduction in the Late Cretaceous (Agard et al., 2005; Saura et al., 2011) and continued with a main folding phase in Late Miocene (Homke et al., 2004; Emami, 2008; Fakhari et al., 2008; Khadivi et al., 2010). The ZFTB is divided into several zones based on the along-strike changes in structural styles and position of the deformation front and stratigraphy (Mouthereau et al., 2012). These zones are from NW to SW: the Kirkuk Embayment, the Lurestan zone, the Dezful Embayment, the Izeh zone and the Fars zone (Motiei, 1995; Stocklin, 1968; Falcon, 1974; Sherkati and Letouzey, 2004; Lacombe et al., 2006; Casciello et al., 2009; Mouthereau et al., 2012).

The Izeh zone is situated in the northeast of the Mountain Front Fault (MFF) and southwest of the High Zagros Fault (HZF) (Fig. 1). This zone corresponds to a narrow band between the Fars and Lurestan zones. The Bangestan and Khami Groups crop out in the resistant core of many of the Izeh zone folds (Abdollahie Fard et al., 2006; Sepehr et al., 2006). This zone is also subdivided into two northern and southern subzones (Sepehr et al., 2006). In the northern subzone, the folds are dominantly box and chevron geometries that formed above a relatively shallow detachment horizon within the Albian Kazhdumi Formation (Sherkati and Letouzey, 2004; Sepehr et al., 2006). Eocene marls of the Pabdeh Formation also formed an efficient detachment horizon in this subzone (Sherkati and Letouzey, 2004; Sepehr et al., 2006). In contrast, in the southern subzone, folds are formed above a deeper detachment (Triassic Dashtak Formation) compared to the northern subzone (Sepehr et al., 2006). In this subzone, the Kazhdumi Formation played the role of a subordinate detachment horizon (Sherkati and Letouzey, 2004). As a result, the anticlines in the southern subzone are larger than those in the northern subzone (Sepehr et al., 2006).

In the central part of the ZFTB, the Dezful Embayment is bounded by the Zagros Foredeep Fault (ZFF), Mountain Front Fault (MFF) and its segments, the Kazerun Fault Zone (KFZ), the Balarud Fault Zone (BFZ) and the Izeh Fault Zone (IFZ) (Fig. 1) (AlaviM, 1994; Berberian, 1995; Sepehr and Cosgrove, 2004). Excluding the Kazerun Fault Zone, none of the mentioned faults are outcropping at the surface and they have been identified from sedimentological and morphotectonic evidences and earthquake data (Falcon, 1961; Berberian, 1995; Pattinson and Takin, 1971; Sepehr and Cosgrove, 2004, 2005, 2007). These faults along with the Burgan-Azadegan, Hendijan and Kharg-Mish paleo-highs (Fig. 1) have affected sedimentation and tectonic evolution of the study area (Sepehr and Cosgrove, 2004; Sherkati and Letouzey, 2004; Abdollahie Fard et al., 2006).

The Dezful Embayment was flexed in response to the uplift of the Zagros Belt in the hinterland side (northeast of the MFF) and as a result, the post-Oligocene foredeep basin (Falcon, 1974; Berberian, 1995; Sherkati et al., 2006; Van Buchem et al., 2006; Saura et al., 2015; Pirouz et al., 2017) was formed with the partial accumulation of syn-deformation up to 5000 m siliciclastic the Aghajari and Bakhtyari formations. Therefore, this embayment is known as thickest part of the Mesopotamian foredeep basin (Sepehr and Cosgrove, 2004; Aqrawi