The role of tear faults on morphology of Ashkhaneh fault zone

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ABSTRACT

NE Iran is dominated by active strike-slip and thrust faults that accommodate a part of convergence between Arabian and Eurasian Plates. One of the main accommodative structures in this region is the Ashkhaneh thrust fault zone. This fault zone has been dissected by a number of strike-slip tear faults. In this paper, we describe general characteristics of the tear faults and their role on the tectonics of Ashkhaneh fault zone to highlight how morphology features influence by active tectonics. The tear faults and Ashkhaneh fault probably have interactions, so that the likely movement along one of these faults may cause reactivation of the other faults.

Keywords: Active tectonics, Strike slip fault, Tear fault, Ashkhaneh fault, NE Iran

INTRODUCTION

The northeastern Iran (Kopeh Dagh) region is located at the eastern corner of the Arabian-Eurasia collision zone (Jackson, 1995). The region is experiencing N-S crustal shortening between the Lut and Central Iranian Blocks and the Eurasian Plate (Figure 1).

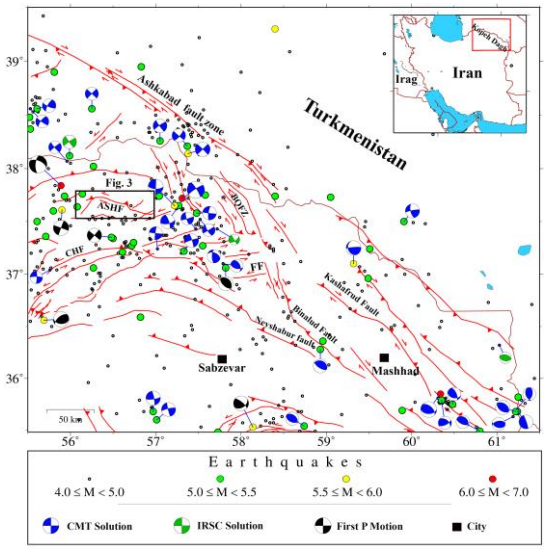

Figure 1. Active faulting in northeastern Iran. Black focal mechanism solutions are from Basic Parameters of Earthquakes in Iran (Mirzaei et al., 2002). ASHF: Ashkhaneh fault, BQFZ: Bakharden–Quchan fault zone, FF: Farhadan fault, CHF: Cheshmeh-Nik fault.

Based on geodetic GPS measurements (Vernant et al. 2004), the accommodation of Arabia-Eurasia plate convergence within the longitude of the Kopeh Dagh occurs with a present-day shortening rate of about 23 mm yr^{-1}.

Faulting in this region includes strike-slip, thrust-slip and oblique-slip motion (Figure 1). The existing focal mechanism solutions confirm these motions in region (Figure 1).

In this paper, we describe strike slip tear faults in the active Ashkhaneh fault zone, which is situated in the western Kopeh Dagh. We discuss the significance of the tear faulting in this zone for descriptions of the local tectonics and for interaction between faults.

TEAR FAULTS

Tear faults are relatively small scale local strike-slip faults, commonly subsidiary to other structures such as folds and thrust faults and plays an important role in the separation of structural units (Twiss and Mores, 2007; Qingfen et al., 2008; Yong et al., 2010, 2014).

Thrust sheets are not structurally continuous features; instead, they are divided (or segmented) by tear faults, which accommodate differential displacement of different parts of the sheet, or connect parts of the active thrust that are not coplanar (Figure 2) (Twiss and Mores, 2007). They likely connect en echelon thrusts at depth (Lin et al., 2011). A part of the thrust sheet may shorten by folding, and an adjacent part may shorten by faulting. The discontinuity in displacement is then taken up by a tear fault (Figure 2).

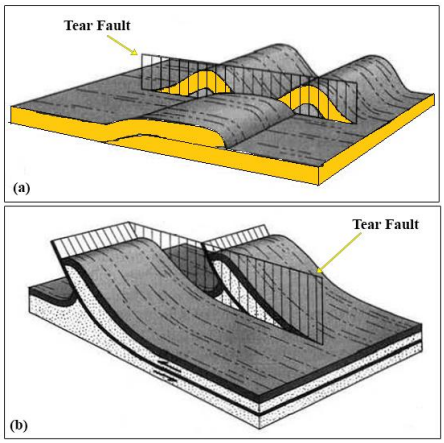

Figure 2. Thrust sheets segmented by strike-slip tear faults. (a) Shortening is accommodated by folding on one side of a strike-slip tear fault and by thrusting on the other. (b) Two non-coplanar imbricate thrusts are connected by a strike-slip tear fault (after Twiss and Mores, 2007).

In terms of geometry and motion, tear faults are steeply dipping (or near-vertical shear zones) and oriented subparallel to the regional direction of displacement and accommodate different amounts of crustal lengthening or shortening in adjacent regions (Twiss and Mores, 2007; Lin et al., 2011) (Figure 2).

INTERACTIONS BETWEEN THRUSTS AND TEAR FAULTS

Interactions between thrusts and tear faults have been observed in many earthquakes; for example, the 2003 Mw 6.9 Zemmouri earthquake in northern Algeria (Lin et al., 2011) and the 2011 Mw 7.1 Van earthquake in Turkey (Akoğlu et al., 2017). Other well-known examples of tear fault ruptures are the 1988 Spitak, 1994 Northridge, 2005 Kashmir and 2008 Wenchuan earthquakes (Philip et al., 1992; Akoğlu et al., 2017).

Magistrale and Day (1999) indicated that the presence of a tear fault favors the jump of dynamic rupture from the source earthquake thrust fault to its adjacent thrust fault segments. According to Akoğlu et al. (2017), tear faults either act as a barrier to impede the rupture or instead help it to jump to adjacent thrust segments. Li et al. (2011) calculated Coulomb stress changes caused by the thrust earthquake fault (2003 Mw 6.9 Zemmouri, Algeria) on tear faults that are orthogonal to the strike of the source fault. They found that slip on tear faults is strongly promoted by an adjacent thrust earthquake.

ASHKHANEH FAULT ZONE

The E-W trending Ashkhaneh (or Takal-Kuh) fault zone, with ~ 80 km length, is located in the western Kopeh Dagh (Figures 1 and 3). Bretis et al. (2012) suggested that part of the Miocene to recent N-S shortening between Iran and Eurasia has been accommodated along Ashkhaneh fault

zone. This fault zone consists of an oblique thrust with a number of sinistral strike-slip and tears faults (e.g. Bretis et al., 2012) (Figure 4).

Based on the geomorphic and the topographic difference on either side of the Ashkhaneh fault, this fault can be divided into two main segments: the western segment with about 35 km long and the eastern one with about 45 km (Figure 3). Strike-slip tear faults cut the Ashkhaneh fault along its length (Figure 4). These tear faults are mainly seen in two locations of eastern segment, where the strike of Ashkhaneh fault changes from W-E to NW-SE (6 and 5 in Figure 3) and where the strike of Ashkhaneh fault changes from NW-SE to E-W (1-4 in Figure 3). These tear faults have left lateral movements (Figure 3). The westernmost part of the western segment of Ashkhaneh fault zone has been dissected by a sinistral strike-slip fault (hereafter we call it west Ashkhaneh fault) (Figure 4a). Difference in GPS velocity field between Northern and southern area of Ashkhaneh fault (Figure 5a) and different strain-rate along Ashkhaneh fault (Figure 5b) may lead to formation of transverse faults (Figure 5c).

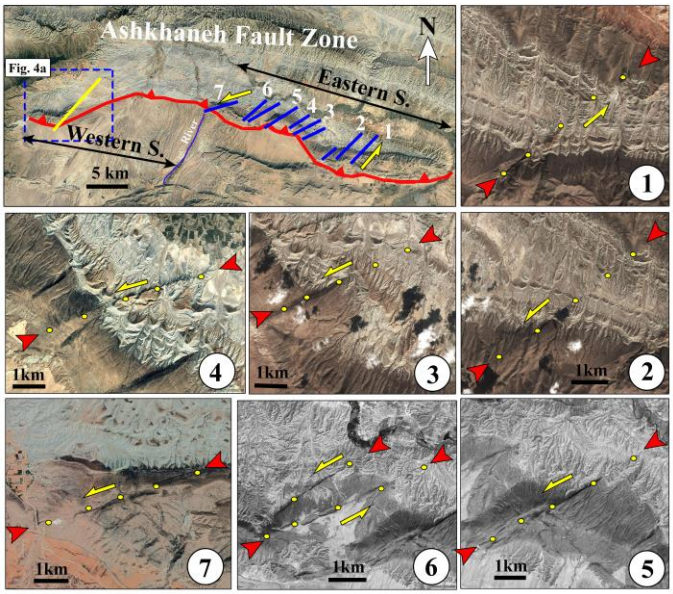

Figure 3. Google Earth satellite imagery of the Ashkhaneh fault zone. See also Fig. 1 for the location. The blue and yellow lines depict the strike-slip and tear faults (1-7), respectively. Yellow circles and red arrows represent the tear fault traces.

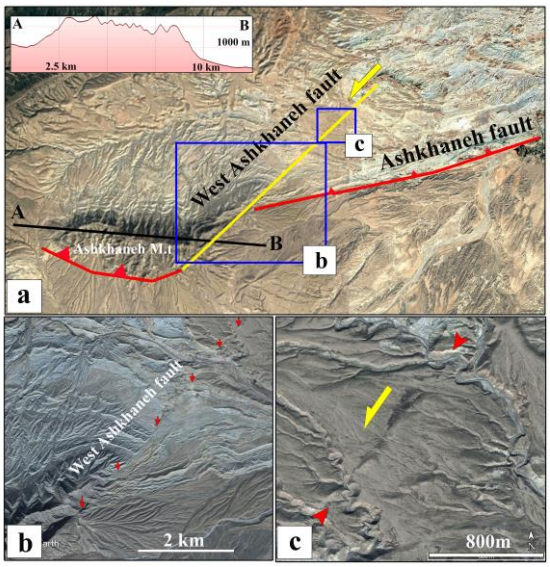

Figure 4. (a) Google Earth satellite imagery of the westernmost part of the western segment of Ashkhaneh fault zone. See also Fig. 3 for the location. (b and c) Google Earth satellite imagery of the west Ashkhaneh

fault. Red pointers and red arrows represent the west Ashkhaneh fault trace.

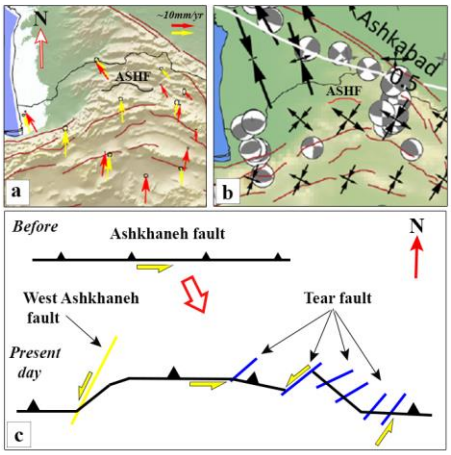

Figure 5. The yellow and red arrows represents GPS estimated movement of the Arabian plate relative to the Eurasian plate (a) and strain-rate tensor using the velocity field (b) are taken from Khorrami et al. (2019). (c) Schematic cartoon of the Ashkhaneh fault zone evolution.

Geometry of strike-slip tear faults and Ashkhaneh thrust fault may indicate faults interaction, so that the likely movement along one of these faults may cause reactivation of the other faults. Interactions between thrusts and tear faults have been observed in many earthquakes; for example, the 2003 Mw 6.9 Zemmouri earthquake in the northern Algeria (Lin et al., 2011); the 2019 Weiyuan Earthquake Sequences in Sichuan, China (Wang et al., 2020).

CONCLUSION

The Ashkhaneh Fault zone is an active oblique thrust fault system in NE Iran, linked with a number of ENE striking sinistral strike slip tear faults with marked displacements. The tear faults have influenced morphology of Ashkhaneh Fault zone. The Ashkhaneh fault and tear faults seems to have interactions, so that the likely movement in one of these faults will lead to movement in other faults.

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