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Tectonic and climatic controls on fan systems: The Kohrud mountain belt, Central Iran

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ABSTRACT

Late Pleistocene to Holocene fans of the Kohrud mountain belt (Central Iran) illustrate the problems of differentiating tectonic and climatic drivers for the sedimentary signatures of alluvial fan successions. It is widely recognised that tectonic processes create the topography that causes fan development. The existence and position of fans along the Kohrud mountain belt, NE of Esfahan, are controlled by faulting along the Qom-Zefreh fault system and associated fault zones. These faults display moderate amounts of historical and instrumental seismicity, and so may be considered to be tectonically active. However, fluvial systems on the fans are currently incising in response to low Gavkhoni playa lake levels since the mid-Holocene, producing incised gullies on the fans up to 30 m deep. These gullies expose an interdigitation of lake deposits (dominated by fine-grained silts and clays with evaporites) and coarse gravels that characterise the alluvial fan sediments. The boundaries of each facies are mostly sharp, with fan sediments superimposed on lake sediments with little to no evidence of reworking. In turn, anhydrite–glauberite, mirabilite and halite crusts drape over the gravels, recording a rapid return to still water, shallow ephemeral saline lake sedimentation. Neither transition can be explained by adjustment of the hinterland drainage system after tectonic uplift. The potential influence in Central Iran of enhanced monsoons, the northward drift of the Intertopical Convergence Zone (ITCZ) and Mediterranean climates for the early Holocene (~6–10 ka) point to episodic rainfall (during winter months) associated with discrete high magnitude floods on the fan surfaces. The fan sediments were deposited under the general influence of a highstand playa lake whose level was fluctuating in response to climate. This study demonstrates that although tectonism can induce fan development, it is the sensitive balance between aridity and humidity resulting from changes in the climate regime of Central Iran that influences the nature of fan sequences and how they interrelate to associated facies.

1. Introduction

The association between active faults and alluvial fans is well established in the research literature (e.g., Allen and Hovius, 1998; Jones, 2004; Harvey, 2012; Bahrami, 2013). Moreover, fluvial-fans (megafans), alluvial fans and fan deltas have been widely documented from the margins of many ancient and recent depositional basins in extensional (Gawthorpe and Leeder, 2000; Leeder and Mack, 2001), transtensional (Dorsey, 2002; Le Dortz et al., 2011; Sözbilir et al., 2011) and compressional tectonic settings (Jones, 2004; Leleu et al., 2009; Waters et al., 2010). In many modern structurally active areas it is very tempting to interpret any cyclical or episodic sedimentation as tectonically controlled. In such settings an important question is whether or not the character of the alluvial fan sediments and sequences can be used to assess the degree and rate of fault activity (e.g., Ford et al., 1997; Quigley et al., 2007).

It is clear that tectonism provides the opportunity for alluvial fan development through creation of topography, increasing gradients of river systems supplying sediments, and creating accommodation space for storage of sediment. Tectonic activity has a fundamental control on fan development, of any size (Blair and McPherson, 1994; Allen and Hovius, 1998; Jones, 2004). However, the influx of coarse clastic sediment alone cannot be taken as direct evidence of fault activity and rejuvenation of a drainage basin.

Our hypothesis is that climatically controlled events can produce sedimentary signatures similar to those created by tectonism and individual fault activity (Pope and Wilkinson, 2005; Waters et al., 2010). In fact it is well known in arid zones that small changes in rainfall can have pronounced and even devastating effects on river discharge, and therefore sediment supply and lake levels within intermontane basins (Vázquez-Urbez et al., 2013). In addition there are low frequency/high magnitude flood events associated with enhanced monsoon and seasonal winter rainfall due to ITCZ migration that lead to substantial runoff (e.g., Frostick and Jones, 2002). All of these affect the development and character of sediments on alluvial fans (e.g. Walker and Fattahi, 2011; Arzani, 2012).

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This paper will firstly summarise the general geology and geomorphology of the study area based on satellite imagery, digital topography, geology maps and our own detailed fieldwork observations. We then describe the alluvial fan sedimentology, proximal fan hot-spring intercalated travertines and distal intercalated playa lake sediments which are all part of the distal alluvial fan system. Finally, we use a variety of published age constraints from periods of Late Pleistocene and early Holocene fan abandonment from central and eastern Iran, to contrain the timing and controls on the alluvial fans draining the southwestern side of the Kohrud Mountain belt of Central Iran, an area never previously studied in detail.

2. Geological setting

The Iranian Plateau is a relatively flat area whose morphology strongly contrasts with that of the mountains to the south (Zagros) and to the north (Alborz and Kopet Dagh). Mean elevations in the plateau region are typically 1500–2000 m asl, in contrast with the desert lowlands of the Dasht-e Kavir and Dasht-e Lut to the east (Fig. 1), which are <1000 m asl. The plateau includes regions with more pronounced topography such as the NW–SE trending Urumieh–Dokhtar Zone, which is largely formed by an Eocene magmatic arc. The Iranian Plateau is a sector of the larger Turkish–Iranian Plateau, that covers ~1.5 million km^2 in area (Fig. 1).

Iran has a complex tectonic history that involves closure of minor ocean basins (Berberian, 1981), which originally separated microcontinental blocks. Precambrian to Carboniferous strata of these microcontinents are very similar, indicating that they once formed part of a broad platform on the eastern margin of Gondwana (Scotese and McKerrow, 1990; Heydari et al., 2003). Permian rifting was responsible for the separation and northward motion of the Iranian microcontinents away from Arabia. Collision with Eurasia took place during Middle–Late Triassic time (Berberian, 1981; Stampfli et al., 1991; Davoudzadeh, 1997). By the Jurassic a subduction zone developed along the western edge of the Sanandaj–Sirjan Zone (Fig. 1), and the Urumieh–Dokhtar magmatic arc began to form (Berberian, 1981; Alavi, 1994). The initial collision of Arabia and Eurasia took place at ~35 Ma, in the late Eocene (Allen and Armstrong, 2008), and convergence has continued to the present (Agard et al., 2005).

A major tectonic re-organisation at ~5 Ma led to the end of or reduction in slip on many faults within the Turkish–Iranian Plateau, and the onset of the present configuration of deformation across a vast area from western Turkey to eastern Iran (Allen et al., 2004). The precise reason for this re-organisation is not clear, but crustal thickening and shortening across an orogenic plateau tends to cease once a critical elevation threshold is reached (M.B. Allen et al., 2013). Seismogenic thrusts within the Zagros are very rare above elevations of 1250 m (Nissen et al., 2011), although the rise in elevations above this level indicates that another process must operate to produce the plateau.

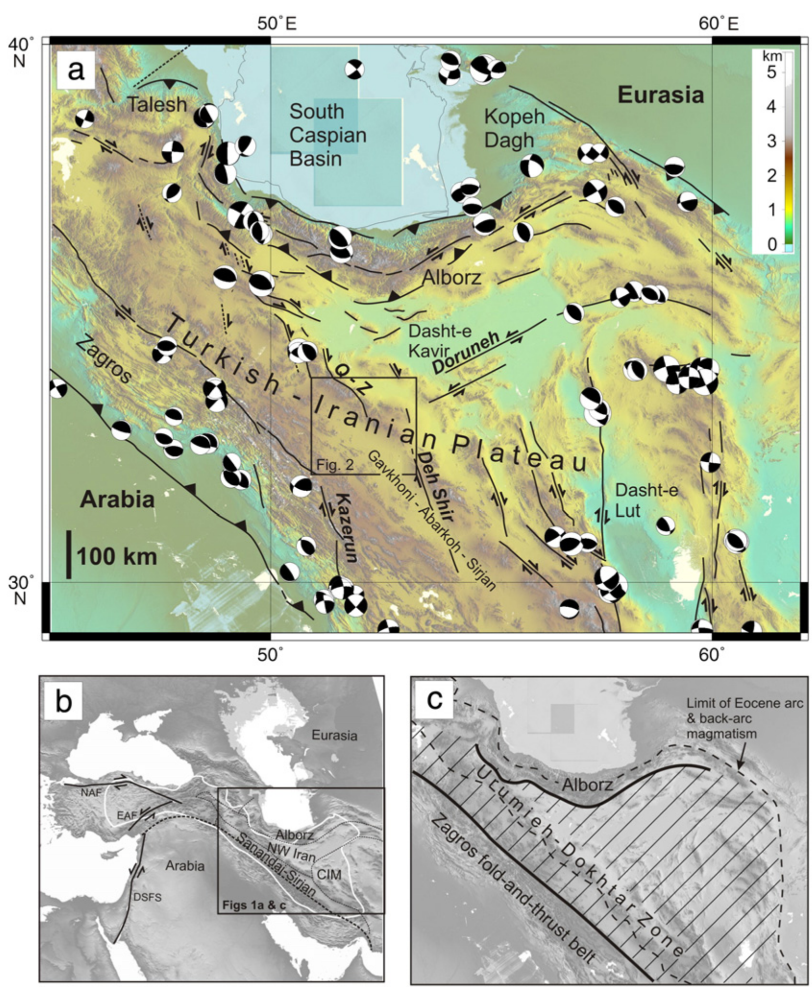

Fig. 1. (a) Neotectonic map of Iran, after Allen et al. (2011). Q-Z = Qom-Zefreh Fault. (b) Location map for (a). Thick white line is the approximate boundary of the Turkish–Iranian plateau. Dashed lines mark basement block boundaries within Iran. CIM — Central Iranian Microcontinent; DSFS — Dead Sea Fault System; EAF — East Anatolian Fault; NAF — North Anatolian Fault. (c) Cenozoic tectonic units of Iran. The extent of Central Iran is shown by hatching between the Zagros suture and the southern side of the Alborz (solid lines).