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Active faulting, earthquakes, and restraining bend development near Kerman city in southeastern Iran

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ABSTRACT

We provide descriptions of strike-slip and reverse faulting, active within the late Quaternary, in the vicinity of Kerman city in southeastern Iran. The faults accommodate north-south, right-lateral, shear between central Iran and the Dasht-e-Lut depression. The regions that we describe have been subject to numerous earthquakes in the historical and instrumental periods, and many of the faults that are documented in this paper constitute hazards for local populations, including the city of Kerman itself (population ∼200,000). Faults to the north and east of Kerman are associated with the transfer of slip from the Gowk to the Kuh Banan right-lateral faults across a 40 km-wide restraining bend. Faults south and west of the city are associated with oblique slip on the Mahan and Jorjafk systems. The patterns of faulting observed along the Mahan-Jorjafk system, the Gowk-Kuh Banan system, and also the Rafsanjan-Rayen system further to the south, appear to preserve different stages in the development of these oblique-slip fault systems. We suggest that the faulting evolves through time. Topography is initially generated on oblique slip faults (as is seen on the Jorjafk fault). The shortening component then migrates to reverse faults situated away from the high topography whereas strike-slip continues to be accommodated in the high, mountainous, regions (as is seen, for example, on the Rafsanjan fault). The reverse faults may then link together and eventually evolve into new, through-going, strike-slip faults in a process that appears to be occurring, at present, in the bend between the Gowk and Kuh Banan faults.

1. Introduction

We investigate the distribution of active faults around the city of Kerman in eastern Iran and the role that these active faults play in accommodating tectonic strain in the region. The faults occur in restraining bends along major strike-slip faults and are extremely well exposed due to the arid and sparsely vegetated environment of southeastern Iran. We are, therefore, able to describe the faults with a level of detail that is not possible in most actively deforming parts of the world: allowing us to investigate the general processes involved in the development of structures within restraining bends along major strike-slip fault systems.

The region around Kerman city (population ∼200,000) has a long record of destructive earthquakes, with historical accounts stretching back to ∼1850, and with numerous instrumentally-recorded events over the past ∼30 years including the 1981 Sirch and Golbaf earthquake sequence (e.g. Berberian et al., 1984), the 2003 Bam earthquake (e.g. Talebian et al., 2004; Jackson et al., 2006), and, most recently, the 2005 Zarand earthquake (Talebian et al., 2006). The city of Kerman, although shaken by many of the recent events, has not been subjected to heavy damage in the instrumental period. One of our aims in writing this paper is to aid future detailed studies of seismic hazard to Kerman city and its surroundings.

In addition to informing estimates of seismic hazard in Iran, our results also have general application in describing well-exposed examples of restraining bend development along major active strike-slip faults. Strike-slip faults are an important component of many active regions of continental shortening (e.g. Tapponnier and Molnar, 1979; Jackson and McKenzie, 1984; Baljinnyam et al., 1993).

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They accommodate this shortening either by translation (or expulsion) of material, by spatial separation (partitioning) of dip-slip and strike-slip components, or through a combination of strike-slip faulting and vertical axis rotation (e.g. Allen et al., 2006). Restraining bends, where a localised component of shortening is introduced due to changes in fault strike, are a common feature of strike-slip faults in regions of tectonic shortening. The faulting within these restraining bends is often very diffuse and may evolve rapidly (e.g. Cunningham and Mann, 2007; Mann, 2007).

In the following sections, we first briefly describe the tectonic and geological background of the study area. We then catalogue the many destructive earthquakes that have affected the Kerman region both historically and recently. In Section 4 we provide brief descriptions, made from both field and remote-sensing studies, of the active faults in the vicinity of Kerman city. Then, in Section 5, we describe how the population of active faults accommodate right-lateral strike-slip across eastern Iran and how they may have changed through time.

2. Geological and tectonic background

2.1. Active tectonics

The active tectonics of Iran are controlled by the northward motion of Arabia relative to Eurasia, which is at a rate of ~25 mm/yr at longitude 56°E (Fig. 1a; Vernant et al., 2004). The GPS velocities relative to Eurasia decrease to zero at both the northern and eastern borders of Iran. This indicates that the major part of the continental shortening is confined within the political borders of the country, with the majority of the deformation concentrated in the Zagros mountains of southern Iran (*Z* in Fig. 1b), and in the Alborz and Kopeh Dagh mountains in the north (A and K in Fig. 1b).

The arid interior of Iran (Dasht-e-Kavir, Fig. 1a) is virtually aseismic and appears to not be deforming as rapidly as its surroundings. Central Iran is moving northwards relative to western Afghanistan at a rate of 16 ± 2 mm/yr at the present-day (Vernant et al., 2004). This northward motion introduces north-south, right-lateral, shear

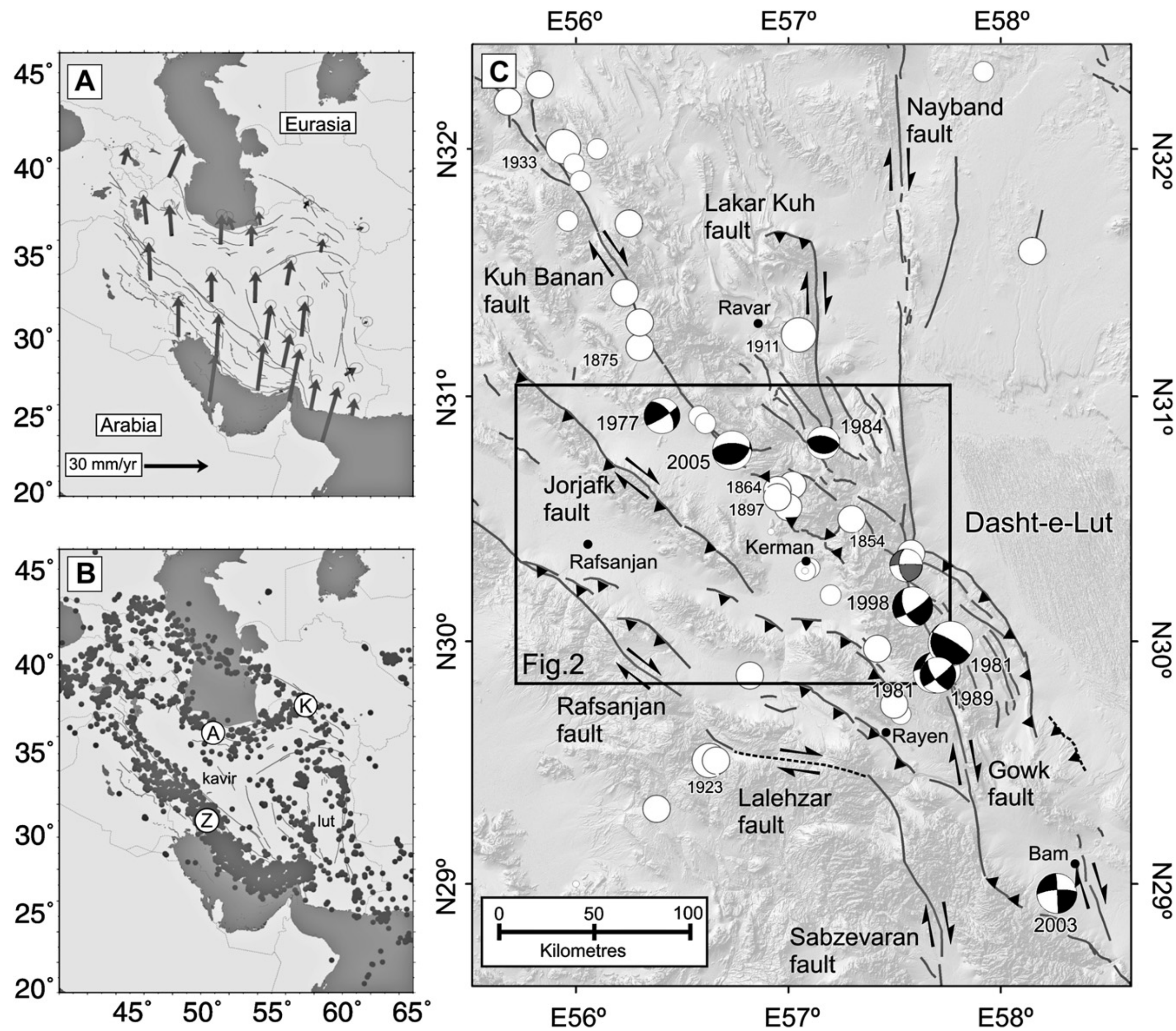

Fig. 1. (a) Map of Iran with GPS velocities of points relative to Eurasia from Vernant et al. (2004). (b) Map of Iran showing epicentres of earthquakes from the catalogue of Engdahl et al. (1998). Z = Zagros; A = Alborz; K = Kopeh Dagh. (c) Shaded-relief topographic map of the Kerman region (SRTM topography; Farr and Kobrick, 2000). Fault-plane solutions of major earthquakes are from waveform modelling (Jackson, 2001; Talebian et al., 2004; Talebian et al., 2006) and the Harvard CMT catalogue (http://www.globalcmt.org/). Epicentres of historical earthquakes are from the catalogue of Ambraseys and Melville (1982). The maps are in a Mercator projection.