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Plio–Quaternary tectonic regime changes in the transition zone between Alborz and Kopeh Dagh mountain ranges (NE Iran)

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ABSTRACT

This paper is concerned with the changes in the Plio–Quaternary stress states in NE Iran and provides evidence for regional active deformation across a wide transition zone between the Alborz and Kopeh Dagh mountains. The Arabia–Eurasia convergence is involved in the strike–slip faulting along NE-trending left-lateral faults in the eastern Alborz as well as NW-trending right-lateral faults in the western Kopeh Dagh. The inversion result of fault kinematic data (slip-vector measurement of fault plane and focal mechanisms) strongly indicates an active transpressional tectonic regime in the study area.

We provide evidence for drastic temporal changes in the stress state during the Plio–Quaternary based on the inversions of fault kinematic data. A regional transpressional tectonic regime with a mean N036 ± 20°E trending horizontal σ_1 is representative for the modern stress state. The older state reveals compressional to transpressional tectonic regimes comprising a N135 ± 20°E trending horizontal σ_1. The modern transpressional tectonic regime characterized by a regional NE-trending σ_1 is consistent with the inversion of earthquake focal mechanisms that yield a N47°E trending σ_1 for the present day stress state. The kinematic results are significantly homogeneous and mechanically compatible with the active geological structures, in the way that reverse and strike–slip faulting are coherent with a single σ_1 direction.

1. Introduction

The N-trending convergence between the Arabian plate and Eurasia since Eocene times has led to the current geologic and tectonic settings of Iran. The present day Arabia–Eurasia convergence rate is measured to be ~22 ± 2 mm yr^{-1} at the longitude of Bahrain (McClusky et al., 2003; Reilinger et al., 2006; Sella et al., 2002; Vernant et al., 2004). The boundaries of deformation zones are well characterized by the distribution of seismicity and changes of topography concentrating in the mountain belts of Zagros, Alborz and Kopeh Dagh (Jackson and Mckenzie, 1984). Tectonic studies provide evidence for clear active faulting distributed within the Iranian blocks such as Central Iran (Meyer and Le Dortz, 2007; Le Dortz et al., 2009; Walker and Jackson, 2004).

The GPS data confirmed the ongoing N–S convergence in NE Iran which is oblique to the NW-trending Kopeh Dagh mountain range. The present day tectonics of NE Iran are characterized by instantaneous motion rates for different tectonic domains with respect to Eurasia (Masson et al., 2007; Tavakoli, 2007; Vernant et al., 2004).

The overall motion between the South Caspian Basin (SCB) and Central Iran is accommodated by the Alborz range. The range has been focused by several geologists from different points of views (e.g., Abbassi and Farbod, 2009; Allen et al., 2003a; 2003b; Axen et al., 2001; Guest et al., 2006; 2007; Jackson et al., 2002; Landgraf et al., 2009; Moinabadi and Yassaghi, 2007; Ritz et al., 2006; Yassaghi and Madanipour, 2008; Zanchi et al., 2006). Similarly, the late Cenozoic tectonics of NE Iran have been studied by several authors (e.g., Afshar Harb, 1979; Hollingsworth et al., 2006; 2008; Lyberis and Manby, 1999; Shabanian et al., 2009a; 2009b; 2010; Siame et al., 2009; Tchalenko, 1975). Our study area comprises a transition zone between the Alborz and Kopeh Dagh (Fig. 1A). This tectonic domain is made up of four major fault zones. The Shahrud, Abr and Jajarm fault zones in the eastern Alborz, and the Ashkhaneh and Showqan fault zones in the western Kopeh Dagh (Fig. 1B). The kinematics of present day deformation and its relationship with the seismicity have not been studied in detail in this connection domain. Thus, the deduction of the Plio–Quaternary states of stress in this area, which plays a key role in the active transfer of plate boundary forces, is significant enough to be investigated. The current investigation focuses on three specific issues: 1 — the characterization of changes in the Plio–Quaternary state of stress using inversions of slip vectors measured on fault planes with a broad range of displacement values; 2 — the identification of present day stress field by inversion of seismically determined fault

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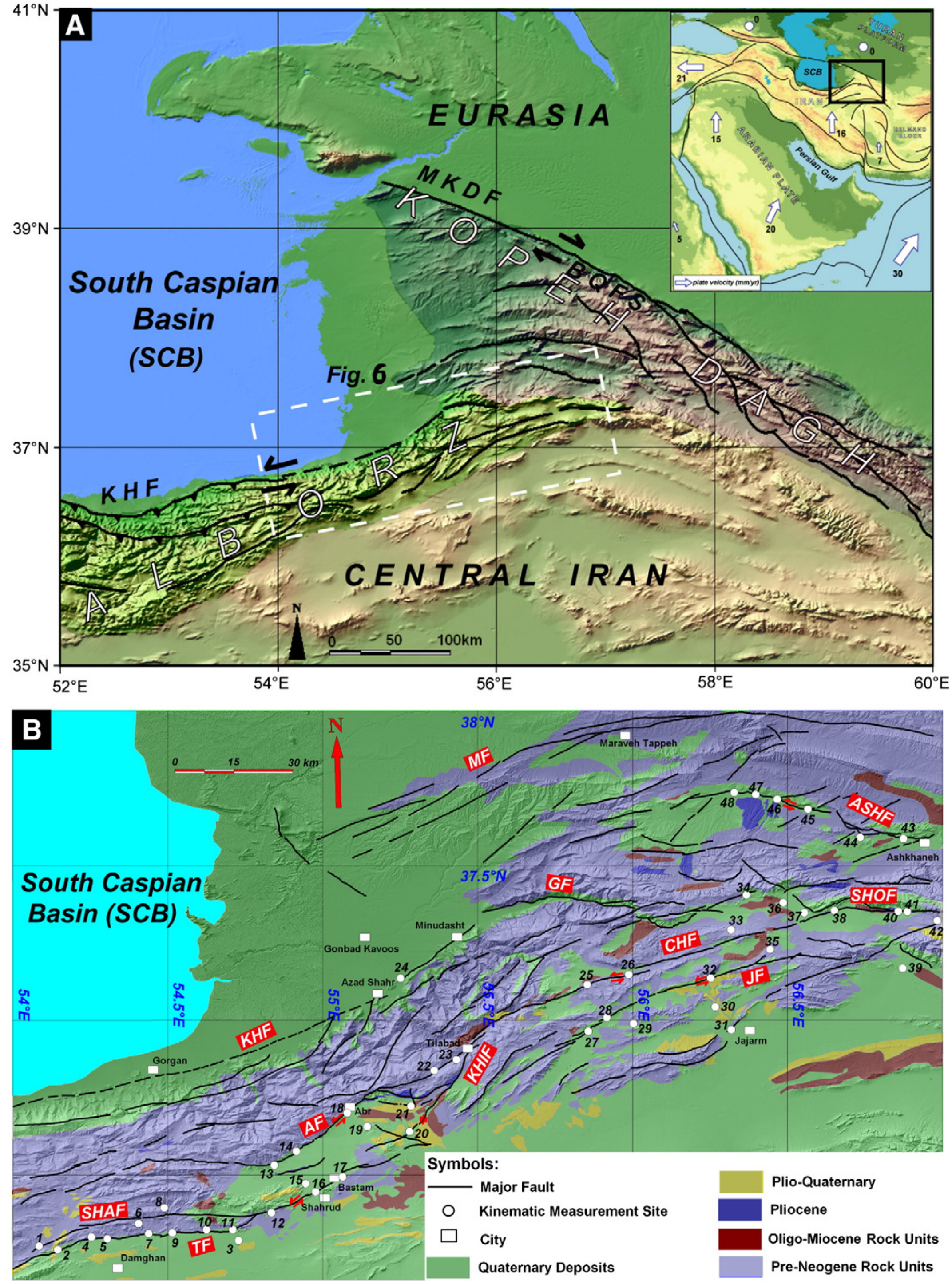

Fig. 1. A. Simplified fault map of northeast Iran superimposed on GTOPO 30 topographic image. The Khazar Fault (KHF) exists in the boundary zone between the South Caspian Basin (SCB) and Alborz mountains. The Main Kopeh Dagh Fault (MKDF) forms a topographic boundary between Eurasia and Kopeh Dagh mountains. The black rectangle in the inset box indicates the location of Fig. 1A in the Middle East Alpine collision belt. White arrows and their associated numbers represent the plate motion in mm yr^{-1} with respect to Eurasia (Reilinger et al., 2006). B. Geologic map of the studied region showing kinematic measurement sites. The map is redrawn and simplified based on the geological map of NIOC (Huber and Eftekhar-nezhad, 1977) and GSI (Nazer et al., 1992; Shahrabi et al., 1990; Soheili et al., 1990; Saidi et al., 1993). The abbreviations are as follows: Bakharden-Quchan Fault System (BQFS), Abr Fault (AF), Ashkhaneh Fault (ASHF), Cheshmeh-Nik Fault (CHF), Golestan Fault (GF), Jajarm Fault (JF), Khazar Fault (KHF), Khij Fault (KHIF), Shahrud Fault (SHAF), Showqan Fault (SHOF), Tazareh Fault (TF) and Maraveh Tappeh Fault (MF).

slip vectors (focal mechanism of earthquakes); and 3 — the verification of the coherence and mechanical compatibility of the inversion results with the geological and structural characteristics of the region illustrating the kinematic significance of each fault system.

In the following sections, we first provide a brief review of seismicity and active tectonics of NE Iran, accompanied by a description of the applied methodology. Then, we present the results deduced from inversion of fault kinematic data throughout the region. Additionally, we describe indicators of active faulting complemented by structural and geomorphic observations confirming the reliability of the identified Plio–Quaternary stress states. In particular, we analyze the slip vectors obtained from earthquake focal mechanisms to verify its consistency