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Late Cenozoic stress state distributions at the intersection of the Hellenic and Cyprus Arcs, SW Turkey

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ABSTRACT

The history of the Late Cenozoic stress regime was determined for an area between the gulfs of Fethiye and Antalya. Fault kinematic analysis and inversion of focal mechanisms of shallow earthquakes reveal significant evolution of the regional stress regime in SW Anatolia, i.e., the area of interaction between the Hellenic and Cyprus arcs, from the Mio-Pliocene to the present time. Fault kinematic analysis yields two different normal faulting stress regimes along the southwestern part of Fethiye-Burdur Fault zone, e.g., in and around Çameli Basin (Zone A1) and two different strike-slip to normal faulting stress regimes characterized by a roughly orthogonal set of extensional axes between Fethiye and Demre (Zone B) with an older NW–SE $\sigma3$ axis for Mio-Pliocene and a younger NE–SW $\sigma3$ axis for Plio-Quaternary time. Inversion of focal mechanisms of the earthquakes occurring in Zone A1 provides an extensional stress state with approximately N-S $\sigma3$ axis. Inversion of those occurring in Zone B, south of Zone A1, yields a dominantly strike-slip stress state with a NE-SW $\sigma3$ axis and a NW-SE $\sigma1$ axis respectively. The inversion slip vectors from fault planes yield a consistent normal faulting stress regime in Burdur Basin and its surroundings (i.e., along the northeastern part of Fethiye-Burdur Fault Zone, (Zone A2)) during Plio-Quaternary, continuing into recent time as indicated by earthquake focal mechanism inversions. Both states have a consistent NW–SE $\sigma3$ axis. Fault kinematic analysis indicates NW-SE extension acting in Zone C (subarea between Demre and Antalya), south of Zone A2, during Mio-Pliocene time. The inversion of focal mechanisms yields normal faulting also characterized by a consistent NW-SE $\sigma3$ axis. The nearly orthogonal extensional stress regimes (NW-SE and NE-SW) obtained by inversion of both measured and seismic faults seem to have been acting contemporaneously with each other at different intensities from the Mio-Pliocene onwards in SW Turkey. This may be attributed to the geodynamic effects related to the subduction of the African plate beneath Anatolia diffusing along the Hellenic and Cyprus arcs and in the west-southwestward extrusion of Anatolia. The cause of the early NW–SE extension is the slab-pull force due to the subduction process along the Cyprus arc, considered to be dominant until the Plio-Quaternary in the western part of the study area in zones A1 and B. The dominant status of the Cyprus arc continues today in the eastern part of study area in zones A2 and C. The later NE–SW to present day approximately N–S extension, dominant since the Plio-Quaternary, is related to the combined forces of the Anatolian extrusion and the subduction process along the Hellenic arc.

1. Introduction

The field of study, covering an area between the gulfs of Fethiye and Antalya (i.e., SW Turkey), is located at the intersection of the Hellenic (Aegean) and Cyprus arcs (Fig. 1). This area is characterized by essentially Miocene to Quaternary extensional basins on basement units (e.g., Çameli, Burdur and Eşençay basins) for which we previously published microtectonic data and their results (Över et al., 2010, 2013a, 2013b). In this paper we also add new data from the central and SE of the study area to the published data, in order to assess all information together to obtain the actual Mio-Pliocene stress regime evolution in SW Anatolia on a regional scale.

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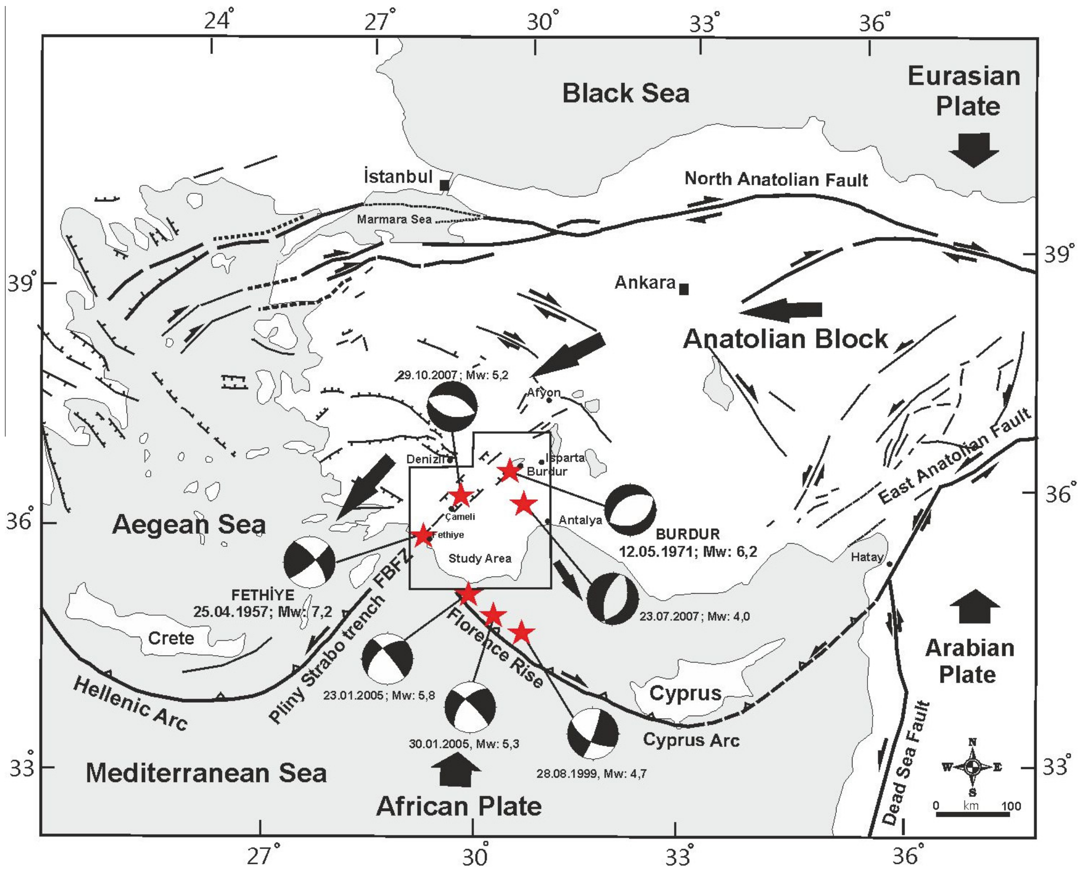

Fig. 1. Study area within the tectonic framework of the eastern Mediterranean region (modified from Barka, 1992; Över et al., 2010).

Both new (unpublished) and previously published data were collected during a TUBİTAK Project (Över et al., 2011). All data were analyzed together, though some of the data have been previously published (Över et al., 2010, 2013a, 2013b). The new data (i.e., unpublished data) were added to those previously published (see text) to obtain reliable results for the whole study area.

The Late Cenozoic stress regimes were obtained by inversion of slip-vectors measured on minor and major fault planes affecting Miocene to Plio-Quaternary deposits, as well as pre-Miocene units. The present-day stress regime was obtained by inversion of focal mechanisms of shallow earthquakes occurring in the study area and its surroundings between 2001 and 2015 and great earthquakes in the last century.

2. Geodynamic setting

The geodynamics of the eastern Mediterranean region are dominated by the relative motions of the Arabian, African and Eurasian plates. This region displays a large variety of tectonic processes: continental collision (in east Anatolia), subduction of oceanic lithosphere and associated back arc spreading along the Hellenic and Cyprus arcs, continental escape (i.e., western motion of Anatolian block), major continental strike–slip faults (North, East Anatolian, and Dead Sea faults) and continental extension (i.e., in the overriding Anatolian Block). The interaction of several different boundary forces which are related to the geodynamic process active in the Eastern Mediterranean region are all superimposed in SW Anatolia producing complex deformation patterns. The northwards motion of the African Plate results in subduction along both the Hellenic and Cyprus arcs (McKenzie, 1972; Le Pichon and Angelier, 1979; De Mets et al., 1990; Barka and Reilinger, 1997; McClusky et al., 2000, 2003; Faccenna et al., 2006; Jolivet and Brun, 2010; Biryol et al., 2011). Global positioning system (GPS) and geodetic studies show that western Turkey is currently undergoing continental lithospheric extension (e.g. McClusky et al., 2000, 2003; Kreemer et al., 2004; Agostini et al., 2010; Brun and Sokoutis, 2010; Özeren and Holt, 2010; Biryol et al., 2011). Similarly, crustal extension observed in SE Turkey, e.g. Hatay region (Boulton and Robertson, 2008), is attributed to subduction along the Cyprus arc (Över et al., 2002). In the literature there are different models to explain the Late Cenozoic crustal extension responsible for the deformation in western Turkey. The basic models proposed to explain the cause of the extension acting in western Anatolia are as follows: (A) the post-orogenic collapse model (Dewey, 1988; Seyitoğlu and Scott, 1991) suggests that the cause of the crustal extension is over-thickened crust due to the closure of the Neotethyan ocean along the Izmir–Ankara–Erzincan suture during latest Oligocene–Early Miocene. (B) The tectonic escape model of Sengor (1979) proposed that the extension is caused by westward extrusion of Anatolia since the Late Serravalian. (C) According to the model proposed by Le Pichon and Angelier (1979) the crustal extension in Anatolia and Aegean regions is related to back-arc spreading accompanied by roll-back of the Mediterranean subducted slab along the Hellenic arc since the late Serravalian (Mercier et al., 1989; Jackson and McKenzie, 1988) and along the Cyprus arc (Robertson et al., 1991; Över et al., 2002, 2010).

A model incorporating geological and seismological data with GPS data shows that the propagation of the North Anatolian Fault into the Aegean and large scale deformation could be related to interaction with the Aegean extension and the Hellenic arc-pull (Armijo et al., 2003; Flerit et al., 2004). Tomographic studies

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