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Geological and geomorphological evidence for the southwestern extension of the East Anatolian Fault Zone, Turkey

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ABSTRACT

The left lateral strike slip East Anatolian Fault Zone (EAFZ) is the main structural link between the North Anatolian Fault Zone (NAFZ) in north and subduction in the Mediterranean Sea and the transform Dead Sea Fault Zone (DSFZ) in south. We studied the southwestern continuation of the EAFZ using combined field investigations including geomorphology, geology and paleoseismology. Mapping of offset drainages, lineaments, shutter ridges and fault planes in young geological units suggests existence of active faults between the Mediterranean coast and Türkoğlu where it intersects with the DSFZ. Yumurtalık and Toprakkale faults are the main tectonic structures and detailed examination of geological and geomorphological evidences suggest their Quaternary activity. Paleoseismic trenching on these faults provided evidence for at least two surface rupturing events in the last 9,000 yr. Detailed examination of paleo-valleys of the Ceyhan River suggests that the course of the river migrated due to the activity of the Toprakkale Fault. Obtained geological and geomorphological data indicates that the EAFZ continues across the Amanos Mountains and the slip transfer is mainly accommodated by the Toprakkale and Yumurtalık faults.

1. Introduction

The left lateral strike-slip East Anatolian Fault Zone (EAFZ) is one of the major active tectonic structures of the Eastern Mediterranean (Fig. 1a). The EAFZ constitutes the southeastern boundary of the westward escaping Anatolian Block, and accommodates the relative motion between the Anatolian Block and the Arabian Block (Şengör et al., 1985; Dewey et al., 1986; Barka and Kadinsky-Cade, 1988; Şaroğlu et al., 1992; Taymaz et al., 2004; Westaway, 2003; Barka and Reilinger, 1997; Bozkurt, 2001). The EAFZ is about 550 km in length, running from Karlıova in the NE to the Mediterranean Sea in the SW (Fig. 1a). The northeast extension of the EAFZ terminates in the Karlıova junction, where it intersects with the North Anatolian Fault Zone (NAFZ). Although there is agreement regarding the main trace of the fault zone between Karlıova in the northeast and Türkoğlu in the southwest, the junction location with the Dead Sea Fault Zone (DSFZ) is under debate. For example, some researchers (e.g.; Şengör, 1980; Jackson and McKenzie, 1984; Lovelock, 1984; Gülen et al., 1987; Hempton, 1987; Muehlberger and Gordon, 1987; Barka and Kadinsky-Cade, 1988; Karig and Kozlu, 1990; Perinçek and Çemen, 1990; Kempler and Garfunkel, 1991; McKenzie, 1972; Chorowicz et al., 1994; Westaway, 2003; Westaway and Arger, 1996; Arger et al., 2000; Yürür and Chorowicz, 1998; Koçyiğit and Erol, 2001; Yurtmen et al., 2000; Robertson et al., 2004; Meghraoui et al., 2011) claim that the EAFZ meets with the DSFZ around Türkoğlu but some others (e.g. Allen, 1969; Arpat and Şaroğlu, 1975; Büyükaşikoğlu, 1980; Kelling et al., 1987; Kiratzi, 1993; Rotstein, 1984; Şaroğlu et al., 1992; Şengör et al., 1985; Över et al., 2004; Duman and Emre, 2013) suggest that the junction is in the Amik Basin (Fig. 1b).

Similarly, the southwestern continuation of the EAFZ past Türkoğlu is also still under debate. Opinions of previous researchers about the southwestern continuation of the EAFZ past Türkoğlu can be compiled into three groups, described below.

First, the EAFZ intersects with the DSFZ around Türkoğlu and the fault zone crosses the Amanos Mountains and extends up to the Iskenderun Bay (Fig. 1b), and consequently to the Cyprus Arc (Barka and Kadinsky-Cade, 1988; Dewey et al., 1973; Şengör, 1980; Gülen et al., 1987; Hempton, 1987; Jackson and McKenzie, 1984; Karig and Kozlu, 1990; Kempler and Garfunkel, 1991; McKenzie, 1970, 1972, 1976; Westaway, 2003; Westaway and Arger, 1996; Arger et al., 2000; Koçyiğit and Erol, 2001; Yurtmen et al., 2000; Robertson et al., 2004; Meghraoui et al., 2011; Karabacak and Altunel, 2013; Mahmoud et al., 2013). Of particular note, Karabacak and Altunel (2013) provided geological and geomorphological evi-

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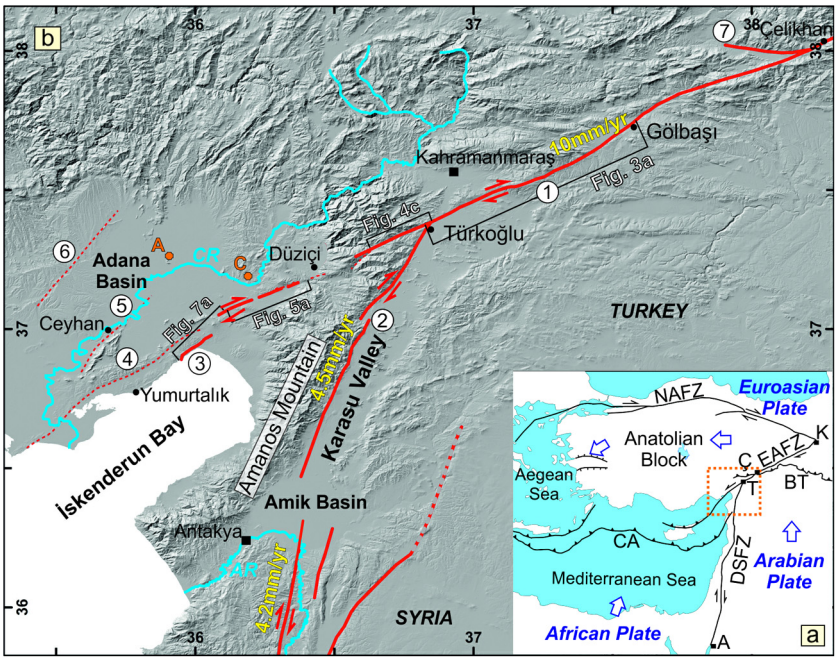

Fig. 1. (a) The seismotectonic framework of the Eastern Mediterranean region with the movement of Arabia (Ar) and Anatolia (An) relative to Eurasia (Eu). (NAFZ: North Anatolian Fault Zone, EAFZ: East Anatolian Fault Zone, BT: Bitlis Thrust, CA: Cyprus Arc, K: Karlıova, Ç: Çelikhan T: Türkoğlu, A: Aqaba). **(b)** Map of the southwestern part of the East Anatolian Fault Zone, showing the active fault segments in red lines (dashed where inferred). Abbreviations cited in the text: 1 – Gölbaşı-Türkoğlu segment, 2 – Karasu Fault, 3 – Yumurtalık Fault, 4 – Osmaniye–Karataş Fault, 5 – Misis–Ceyhan Fault, 6 – Kozan Fault, 7 – Sürgü Fault; AR: Asi River, CR: Ceyhan River; C: Castabala, A: Anazarbus (SRTM data is from Jarvis et al., 2008). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

dence suggesting that the EAFZ-DSFZ junction is not in the Amik Basin and that slip on the DSFZ is transferred to the EAFZ via the Karasu Fault Zone. In addition, geodetic data provided by Mahmoud et al. (2013) indicates significant fault slip occurred near Iskenderun Bay.

Second, the major trace of the EAFZ extends along the Karasu Segment in the Karasu Valley to the south (Fig. 1b) and it meets with the DSFZ in the Amik Basin (Allen, 1969; Arpat and Şaroğlu, 1975; Büyükaşikoğlu, 1980; Kelling et al., 1987; Kiratzi, 1993; Rotstein, 1984; Şaroğlu et al., 1992; Şengör et al., 1985; Över et al., 2004; Duman and Emre, 2013; Emre et al., 2013), however there is no field data about the triple junction in Amik Basin. In addition, subsurface data examined by Karabacak and Altunel (2013) suggest there is no change in fault geometry or a fault intersection in the Amik Basin.

Third, some researchers (e.g. Chorowicz et al., 1994; Lovelock, 1984; Muehlberger and Gordon, 1987; Perinçek and Çemen, 1990; Yürür and Chorowicz, 1998) suggest that the DSFZ connects with the EAFZ through the Karasu Fault around Türkoğlu, but the EAFZ terminates in this area and does not extend further southwest.

This paper presents geological and geomorphological evidence for the southwestern continuation of the EAFZ further southwest of Türkoğlu. Detailed field observations supported by paleoseismological studies show that there is a NE–SW-trending active deformation zone across the Amanos Mountains. The deformation zone is characterized by diverted stream channels including the Ceyhan River, a bend of the watershed line on the Amanos Mountains, an offset drainage system and fault planes observed in Quaternary-aged units. We believe that this paper provides direct field evidence for the southwestern continuation of the EAFZ, which would make a significant contribution to the discussion regarding the southwestern continuation of the EAFZ and the knowledge of Eastern Mediterranean tectonics.

2. Tectonic Setting and Seismicity

The tectonics of the Eastern Mediterranean region are governed by the NAFZ to the north, the EAFZ and the DSFZ to the east, and the Aegean and the Cyprus Arcs to the south where the Arabian, African and Eurasian plates converge (Fig. 1a). The DSFZ extends between the Gulf of Aqaba in the south and the EAFZ in the north. In the south, it trends in a N–S direction and usually has a simple geometry but the fault zone bifurcates into multiple branches towards the north (Fig. 1) (e.g. Brew et al., 2001; Meghraoui et al., 2003; Gomez et al., 2003; Mart et al., 2005; Altunel et al., 2009; Karabacak et al., 2010; Karabacak and Altunel, 2013). The main branch of the DSFZ in southern Turkey extends along the western bank of the Asi River to the south of the Amik Basin (Fig. 1b) (Rojay et al., 2001; Akyüz et al., 2006; Altunel et al., 2009; Yönlü et al., 2010; Karabacak and Altunel, 2013). North of the Amik Basin, the Karasu Fault extends along the western side of the Karasu Valley (Fig. 1b). GPS studies indicate a left-lateral strike-slip rate on the northern part of the DSFZ is approximately 4.5 mm/yr (Reilinger et al., 2006; Alchalbi et al., 2009; Mahmoud et al., 2013; Aktuğ et al., 2016). This is consistent with paleoseismological and archeoseismological data (Meghraoui et al., 2003; Altunel et al., 2009; Karabacak et al., 2010; Yönlü et al., 2010).

The left-lateral EAFZ delineates the boundary between the Anatolian and Arabian blocks. The NE–SW-trending EAFZ extends for a distance of about 550 km between Karlıova in the northeast and the Mediterranean Sea in the southwest (Fig. 1a). The fault zone consists of some pure strike-slip faults oriented parallel or subparallel to the general trend. The fault zone was divided into several segments considering major discontinuities (bends and step-overs) by previous researchers, and different nomenclature was used for the segments of the EAFZ (e.g. Barka and Kadinsky-Cade, 1988; Herece, 2008; Şaroğlu et al., 1992; Duman and Emre, 2013; Emre et al., 2013). Between Karlıova and Türkoğlu, the segment geometry of Duman and Emre (2013) synthesizes previous findings with new field observations into the most complete and refined model