Structure of the East Anatolian Fault zone at Hazar Basin, Eastern Turkey

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Abstract

Hazar Basin is a transtensional structure located on the central East Anatolian Fault in eastern Turkey. This basin is generally interpreted as a large pull-apart basin because of its onshore geomorphology and fault geometry. However, the structure of the basin beneath Lake Hazar, which occupies almost the entire basin, has never been studied in detail.
This study presents and discusses a new structural map of Hazar basin based on a high-resolution seismic survey undertaken at Lake Hazar during summer 2007. This structural map reveals that the main strand of the East Anatolian fault is continuous across Hazar Basin. Therefore, in contrast to many pre-existing studies, the East Anatolian Fault extends from Palu to Sincik forming a continuous segment of about 130 km.

Introduction

The left-lateral East Anatolian Fault zone (EAFZ) extends for about 600 km trending NE-SW. It forms the boundary between the Arabian and Anatolian plates linking the North Anatolian Fault to the Dead Sea Fault (Fig. 1). The EAFZ is characterized by a segmented fault trace (Barka and Kadinsky-cade, 1988; Şaroğlu et al., 1992) with a slip rate of 10 – 11 mm/yr (Çetin et al., 2003; Reilinger et al., 2006), a total offset of 15 – 30 km (Şaroğlu et al., 1992; Westaway, 1994, 2003) and an estimated age of 3 – 4 Ma (Barka, 1992; Şaroğlu et al., 1992; Westaway & Arger, 1996, Hubert-Ferrari et al., 2008). According to Ambraseys (1997) and Nalbant et al. (2002), the EAFZ is capable of rupturing in earthquakes of up to magnitude 7.4. Two earthquakes occurred in the vicinity of Hazar Basin in 1874 and 1875 of magnitudes 7.1 and 6.7 respectively (Ambraseys, 1989; Ambraseys & Jackson, 1998). Both earthquakes uplifted the south-eastern outlet of Lake Hazar, where the lake used to discharge into the Tigris River, by several metres (Ambraseys, 1989).
Hazar Basin is located on the central EAFZ and occupies an elongate area of about 175 km^2 (Hempton et al., 1983). It is predominantly overlain by Lake Hazar which

covers about 100 km^2 of the basin area. Hazar Basin is generally described as a pull-apart basin with a left-lateral stepping separation of ~3 km between the Palu-Hazar and the Hazar-Sincik segments (Fig. 1) (Hempton, 1982; Hempton et al., 1983; Mann et al., 1983; Hempton & Dunne, 1984; Şengör et al., 1985; Muehlberger & Gordon, 1987; Şaroğlu et al., 1992 Westaway, 1994; Çetin et al., 2003). Although, it has also been interpreted as a basin developed on a continuous fault segment (Barka & Kadisky-Cade, 1988) and as a negative flower structure (Aksoy et al., 2007). Nevertheless, all these hypotheses are based on the on-shore fault geometry and geomorphology. In order to better understand the structure of Hazar Basin and its influence as a segmentation boundary, Hazar L. was the locus of a high-resolution seismic survey during summer of 2007. In this paper, we will discuss the structure of Hazar Basin revealed from that seismic survey and the implications of this structure for our understanding of the EAFZ.

Methods and results

The seismic survey consisted of 44-high-resolution seismic profiles along a 500 m spaced grid. The acquisition system comprised a "centipede" multi-electrode sparker (300 J and main frequency of 400 – 1500 Hz) as an acoustic source, and of a 10-hydrophone streamer with an active length of 2.7 m, as a receiver.
The bathymetry map (Fig. 2) shows two distinct areas: an irregular 216-m-deep basin (DB) in the north-eastern half of the lake and a much flatter and shallower basin (FB) in south-western half of the lake. Three additional bathymetric features stand out (Fig. 2), which are from east to west: 1) a plateau (Pl) locally separating the deep basin from the southern lake margin, 2) a small 140-m-deep elongated basin (SeB) located northwest of the plateau and southwest of the deep basin and 3) a promontory (Pr) situated south of the flat basin, from which Kilise Adasi Island (KA) emerges.
We describe the structure revealed by the seismic investigation from west to east. Onshore two main faults approach the lake (Fig. 2): the northern fault (NwF), which accommodates most of the dip-slip, down to the north, and the southern strand (SwF) that is the main strike-slip fault (Hempton, 1982). In the lake, these stands correlate respectively with the north-western (NwF') and master (MF) strike-slip faults. Both faults converge at the north-eastern corner of the promontory giving rise to shortening features associated with the bend of the north-western splay. To the south of their junction a northwardly dipping normal fault (SF) is recognized and extends along the southern margin of the lake with several complex splays. This fault is inferred to accommodate predominantly normal displacement while the master fault accommodates most of the strike-slip which is attributed to strain partitioning. Near the centre of the lake a splay of the master fault forms a sag-pond depression (SeB in Fig. 2). In the northern quartile of the Lake a normal, down to the south, fault (NF) arcs around the northern side of the deep basin. This fault has a conjugate strand in places and forms localised graben structures. At the northeast end of the lake the northern fault converges with the master fault which is correlated to a clear terrestrial fault trace named the Havri fault (Çetin et al 2003). Therefore, the south-western, master and Havri faults are in fact the same continuous fault strand. In the northeast half of the lake the master fault strikes at 6° rotated counter-clockwise relative to its on-shore continuation. This change in strike constitutes a subtle releasing bend and explains the continuing extension around the deep basin (Fig. 2). The southern

marginal fault (SF) correlates to the Gezin fault named by Çetin et al. (2003), although we have interpreted the terrestrial location of this fault differently.

Discussion and Conclusions

The structure of Hazar Basin revealed by this study shows that present-day transtension occurring in this area is related to a subtle releasing bend rather than a step-over. By comparing the structure of Hazar Basin to analogue models of transtensional step-overs (eg. Dooley and McClay, 1997), we propose that the Hazar Basin structure may have initially been a pull-apart basin. However, now the bounding faults have been bypassed and the main strand of the EAFZ is currently continuous across Hazar Basin as inferred by Barka and Kadinsky-Cade (1988). Therefore, Hazar Basin does not constitute a segmentation boundary and Palu-Hazar and Hazar-Sincik segments are one – the 130 km long Palu-Sincik segment. Consequently, the high-magnitude earthquakes of 1874-1875, are probably produced by ruptures of the Palu-Sincik segment.

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Figure Caption

Figure 1: Tectonic map of the East Anatolian Fault zone (north-eastern part) showing fault segmentation according to Şaroğlu et al. (1992) and Çetin et al. (2003). Isoseismals VII and VI of the March 27, 1874 earthquake are indicated (Ambraseys, 1989). Dams, main rivers and cities are shown. The arrows indicate relative fault motions. ***Inset**:* schematic diagram of the continental extrusion of the Anatolian block away from the Arabia-Eurasia collision zone including GPS vectors relative to Eurasia (McClusky et al., 2000; Relinger et at., 2006). NAFZ: North Anatolian Fault Zone; EAFZ: East Anatolian Fault Zone; DSFZ: Dead Sea Fault Zone; MF: Malatia Fault; SF: Sürgü Fault; HSZ: Hellenic Subduction Zone; *KTJ*: Karliova Triple Junction; *TTJ*: Türkoglu Triple Junction. *Projections: Lat/Long-WGS84.*

Figure 2: Bathymetry and fault map of Hazar L. obtained from the seismic survey. Pink circle indicates the uplifted outlet of Lake Hazar during the 1874 and 1875 earthquakes (Ambraseys, 1989). HF: Havri Fault; SwF: South-western Fault; MF: Master Fault; GF: Gezin Fault; AF: Aidin Fault; NwF: North-western fault; NF: Northern Fault; SF: Southern Fault; NwF': North-western Fault in the lake, DB: Deep Basin; FB: Flat Basin; SeB: Small-elongated Basin; Pr: promontory; Pl: Plateau; KA: Kilise Adasi Island. *Projection: UTM-WGS 84, 37N.*