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New observations on the 1939 Erzincan Earthquake surface rupture on the Kelkit Valley segment of the North Anatolian Fault Zone, Turkey

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ABSTRACT

The 1939 Erzincan Earthquake ($M = 7.8$), occurred on the North Anatolian Fault Zone (NAFZ), was one of the most active strike-slip faults in the world, and created a 360-km-long surface rupture. Traces of this surface rupture are still prominently observed. In the absence of detailed mapping to resolve the fault characteristics, detailed observations have been conducted at 20 different points on the 70-km-long Kelkit Valley Segment (KVS) of the NAFZ's between Niksar and Koyulhisar. Field data defining fault character and slip amounts were found at eight points and show right-lateral slip varying between 1.8 and 4.25 m and the vertical slip varying between 0.5 and 2.0 m.

The KVS developed in the most morphologically prominent and narrowest part of the NAFZ. Therefore, the chances of finding evidence of more than one historical earthquake in trenches opened to investigate palaeoseismological aspects are higher. Faults observed in foundation and channel excavations opened for energy purposes in the Reşadiye region show this clearly and evidence for up to four seismic events including the 1939 Erzincan Earthquake have been discovered. Further studies are required to discover whether right-lateral deformation on at some locations on this segment is surface ruptures associated with the 1939 earthquake or later creep.

1. Introduction

The North Anatolian Fault Zone (NAFZ), which forms the boundary between the Eurasian Plate in the north and blocks comprising central Anatolia to the south, is one of the most seismically active continental strike-slip fault zones in the world. The NAFZ is 1200 km long and extends from Karlıova in the east and to reach as far as the Greek mainland in the west (Fig. 1). The presence of a seismic belt starting from Saros Bay in Thrace and reaching Kızılırmak through Izmit Bay, Bolu and Gerede was first observed in 1930s although its characteristics were interpreted differently at that time (Herece and Akay, 2003). It was then considered to be an "adhesion zone" between the continent in the north and Gondwana in the south, and named the "Paphlagonian scar" by Nowack (1928). Salomon-Calvi (1936), interpreted Nowack's "Paphlagonian scar" as the continuation of the Alpine Tonale Line to the east. Since then many Turkish and foreign workers have conducted research on the fault although full agreement on the nature of this fault system has not yet been reached (Şengör et al., 2005).

Historical earthquakes in the historical period are important sources of information for predicting future activity and much evidence for them has survived. Important publications on significant historical earthquakes in Turkey and surrounding areas are available (Ergin et al., 1967; Soysal et al., 1981; Guidoboni et al., 1994; Ambraseys and Melville, 1995; Ambraseys and Jackson, 1998, 2000; Ambraseys and Finkel, 2006; Tan et al., 2008). These publications reveal that the large-scale faults such as the NAFZ, the East Anatolian Fault Zone (EAFZ) and the Aegean Horst-Graben System have been profoundly seismically active during historic times. Palaeoseismological research conducted during the last 35 years has recognized surface ruptures due to many large earthquakes and traces of these faults can be located through trench excavations. The location of the active faults is determined using morphotectonic and geomorphologic findings and important information on their frequency can be obtained by dating these faults. Important information has been gathered using palaeoseismological techniques in the western regions of the NAFZ during the 1980s (İkeda, 1988; Okumura et al., 1990, 1993, 1994; İkeda et al., 1991; Yoshioka et al., 1991; Barka and Wesnousky, 1994; Okumura and Yoshioka, 1994; Okumura et al., 1994).

In general, the NAFZ becomes wider from east to west (Şengör et al., 2005). Whilst the zone is generally extremely narrow, hardly

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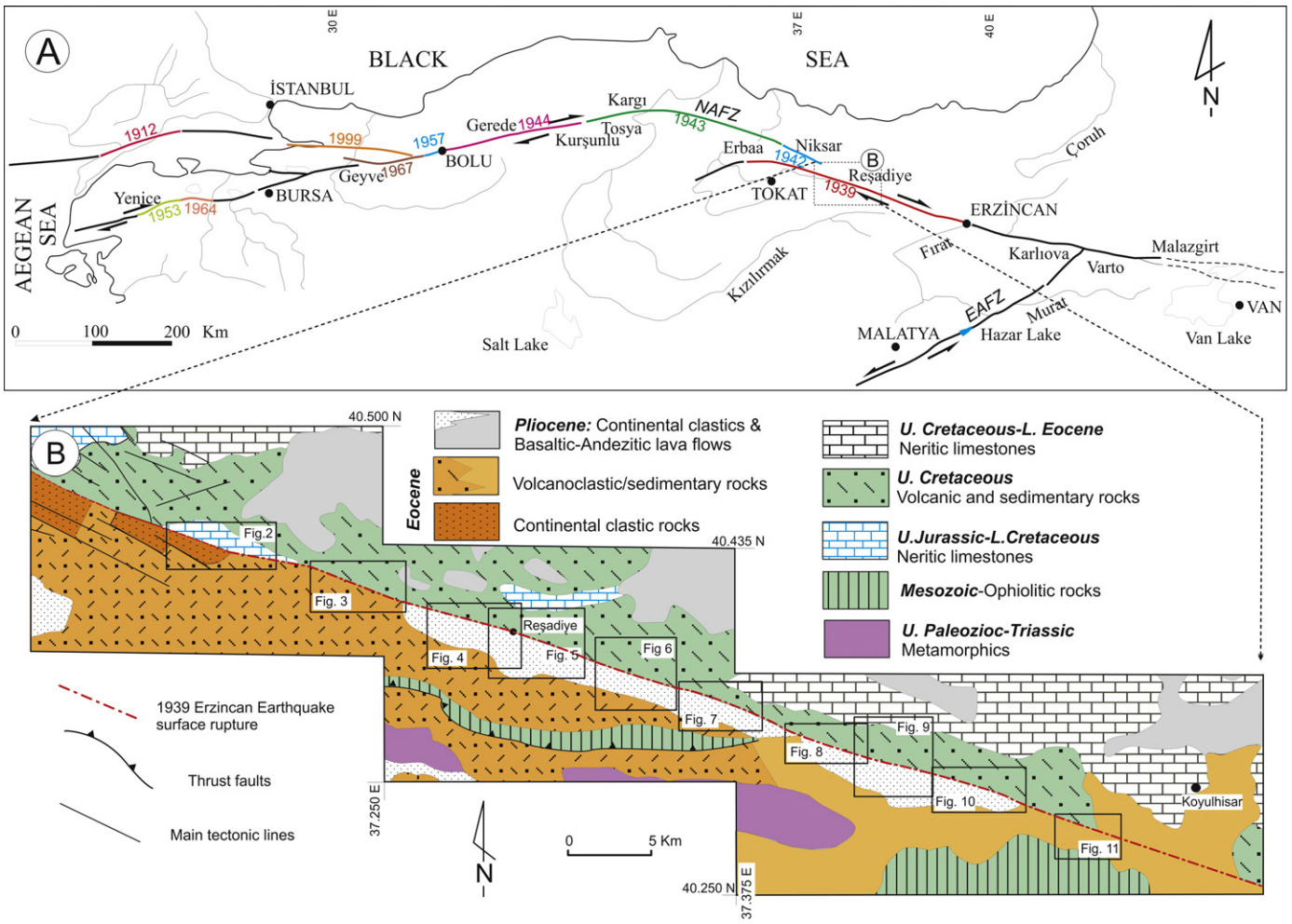

Fig. 1. Site location and regional geological map of the study region.

wider than 10 km (Herece and Akay, 2003), between the Karlıova triple junction and the Niksar basin (Fig. 1) in eastern Turkey, it becomes a shear zone of a few hundred km wide around the Marmara region in northwest Turkey. The long-term geological slip rates have been estimated between 10 mm/year and 20.5 mm/year along different segments of the NAFZ, based on different geological, seismological and paleomagnetic methods (Barka and Kadinsky-Cade, 1988; Kasapoğlu and Toksöz, 1983; Kiratzi and Papazachos, 1995; Kozacı et al., 2007; Pınar et al., 1996; Piper et al., 1997; Tatar et al., 1995; Taymaz et al., 1991). Tatar et al. (2012) calculated an average slip rate of 20.1 ± 2.4 mm/year and a locking depth of 12.5 ± 3.5 km for the eastern part of the North Anatolian Fault Zone including the present study area by using GPS measurements.

2. The surface rupture of the December 26, 1939 Erzincan Earthquake

The contemporary importance of the NAFZ was first noticed with the occurrence of the December 26, 1939 Erzincan Earthquake (Ms = 7.8) and the existence of an active fault with an east-west elongation in northern Anatolia was first discovered by Pamir and Ketin (1941) and Parejas et al. (1942). Six major earthquakes subsequently migrated to the west to create surface ruptures between 1942 and 1967 in the North Anatolian Region following the 1939 Earthquake (Barka, 1996), and greatly contributed to a fuller understanding of the NAFZ. Ketin (1948) investigated further earthquakes occurring over a ten-year period following the Erzincan Earthquake and was the first researcher to identify this fault as an active right-lateral strike-slip fault. The 1939 Erzincan Earthquake created the longest surface rupture during the instrumental period with a 360-km-long surface rupture on five different segments (Barka, 1996) and also caused the most loss of life (32,962 people) in Turkey during the 20th century.

The characteristics of the surface ruptures created by major earthquakes identified by factors such as length, displacement amount and areal distribution of damage are most usefully the subject of research immediately after the earthquake has struck. Just after the 1939 Erzincan Earthquake and in subsequent years observations have been carried out by researchers at a number of points on the NAFZ (Pamir and Ketin, 1941; Parejas et al., 1942; Blumenthal, 1943, 1945a,b; Taşman, 1944; Ketin, 1948, 1957, 1969). It was found that 1–2-m-long vertical slips had developed on the Erzincan Earthquake surface rupture with 3.7 and 7.5-m-long right-lateral displacements (Ketin, 1969; Koçyiğit, 1989). However, no detailed mapping studies of the surface rupture have been undertaken except in the region between Suşehri-Erzincan (Koçyiğit and Tokay, 1985; Koçyiğit, 1989) and near the towns of Reşadiye (Seymen, 1975) and Koyulhisar (Toprak, 1989). According to Barka (1996), until a few additional measures were taken in the 50-km-part between Suşehri-Gölova by Koçyiğit (1989, 1990) the presence of only one displacement on the 360-km-long surface rupture of the 1939 earthquake had been noted. F five different segments comprising Erzincan, Mihar-Tümekar, Ortaköy-Suşehri,