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Was the 1899 Menderes Valley Earthquake a double earthquake? Historical and paleosismological constraints

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ABSTRACT

September 20, 1899 Menderes Valley Earthquake is the last destroying event in the Büyük Menderes Graben, Western Turkey, just proceeding the installation of the earliest seismograms in the world. The previous geological studies revealed that this seismic event of estimated Mw = 6.5–6.7 caused a surface rupture of 50 km between Aydın and Kuyucak in the center of the graben. Based on the extremely different positioning of microseismic epicenter of this event in various historical documents, we re-evaluated the 1899 earthquake with a rather multidisciplinary perspective. Quantitative earthquake data including fatalities, damage and various types of aids were gathered from daily journals and special commission reports of the time. These data are corrected with the population statistics and georeferenced. For exact determination of the position of the surface rupture, we benefited the verbal description in historical documents and witnesses of elder local people. Furthermore, morphological and palaeoseismological investigations were realized in the eastern part of the graben where surface deformations were made mention in historical documents. Different ground shake-related indicators conformably revealed two distinct geographically-separated damage zone, one at Yenipazar and the other at Ortakçı, in the middle and east of the graben respectively. Trench studies in the west of the Ortakçı village indicated evidences of a seismic event, presumably the 1899 earthquake, with 180 cm vertical displacement. Bimodal distribution damage unrelated to basement lithology and building types, and the incoherence between the total surface rupture length and the observed vertical offset and earthquake intensity lead us to conclude that the 1899 Menderes Valley Earthquake was an earthquake doublet occurred in two neighboring segments in very close temporal proximity.

1. Introduction

Investigation of past earthquakes is a complex and multidimensional activity which involves distinct methodologies depending on the age of the event at focus. Seismic events of relatively distant past are revealed by morphological and trench studies while the archeological remains, historical documents and instrumental records provide tools of varying puissance from place to place in understanding of relatively recent earthquakes (Gürpınar, 1989; Levret, 2002; Ambraseys, 2006).

Historical documents can be considered "written witnesses" in terms of the source of information. These materials constitute the frozen memory of an earthquake event in a wide range of form from the exaggerated description of the earthquakes often mixed up with supernatural beliefs to the more qualitative news and reports of newspapers and journals in the last several centuries (Caputo and Helly, 2008). "Oral witness" similarly is a valuable source of information for a period up to 3 generations following events. Either written or oral, the earthquake witness should be carefully evaluated by the researcher in the light of individual, social and religious background. Particularly the spatial distribution of the information derived from historical documents and oral witnesses can considerably improve our understanding in terms of intensity, magnitude, epicentral position and the source fault of the earthquake (e.g. Bautista and Oike, 2000; Wahlström, 2004; Ocakoğlu et al., 2006; Ocakoğlu, 2007; Rodriguez and Barba, 2010).

Although the 1899 Menderes Valley Earthquake is frequently cited in the seismological literature of the Aegean region, few geological studies directly focus on it. The magnitude of this event was estimated differently from 5.6 to 5.9 in different studies (e.g. Ambraseys, 1988; Pavlides and Caputo, 2004). Since the installation of early seismological observatories postdates the event, the magnitude of the event and the nature of rupture are not known

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instrumentally. However, according to a news appeared in a journal of the time, a seismogram installed in a French school in İzmir recorded the 1899 event, but this seismograph could not be appropriately interpreted in the Athens Observatory short after the event (Avcı, 2007) Geological investigations during 1960s and 1970s recognized the surface rupture of this event at the north of the graben between Aydın and Kuyucak, and reported up to 3 m vertical displacement (Ambraseys, 1988; Allen, 1975; Sipahioğlu, 1979; Altunel, 1999). The 1899 event was also considered from a rather sociological and disaster management perspectives, using journal news and aid commission reports of the time (Güneş and Özkeş, 2001 ; Avcı, 2007). These later studies surprisingly positioned the macroseismic epicenter at quite different locations, based on gross damage data and some ground deformations, either Nazilli in the west or Sarayköy in the east.

In the present contribution, the written and oral witnesses in relation to 1899 earthquake are evaluated rather in a statistical way to position more precisely the macroseismic epicenter and position of surface rupture. The results of this evaluation are united with new paleoseismological data to provide a more complete picture of the 1899 event.

2. Active faults in the Büyük Menderes Graben

Western Anatolia is known as one of the spectacular example of actively expanding continental terrain, and is characterized by a system of horsts and grabens of distinct orientations. Büyük Menderes Graben (BMG) occurs at the southernmost of this system. It appears on the Aegean Sea coast to the west and extends in grossly E–W direction until south of Buldan for 150 km, where it connects another active depression, namely the Denizli Graben (Fig. 1a and b).

There are three different fault zones in the BMG whose initiation ages have been highly disputed in the literature. The northernmost zone of the depression, the Outer Fault Zone (OFZ) hereafter, extended from the West of Germencik to the East of Kuyucak with a highly indented plan view (Fig. 2). This fault zone was first

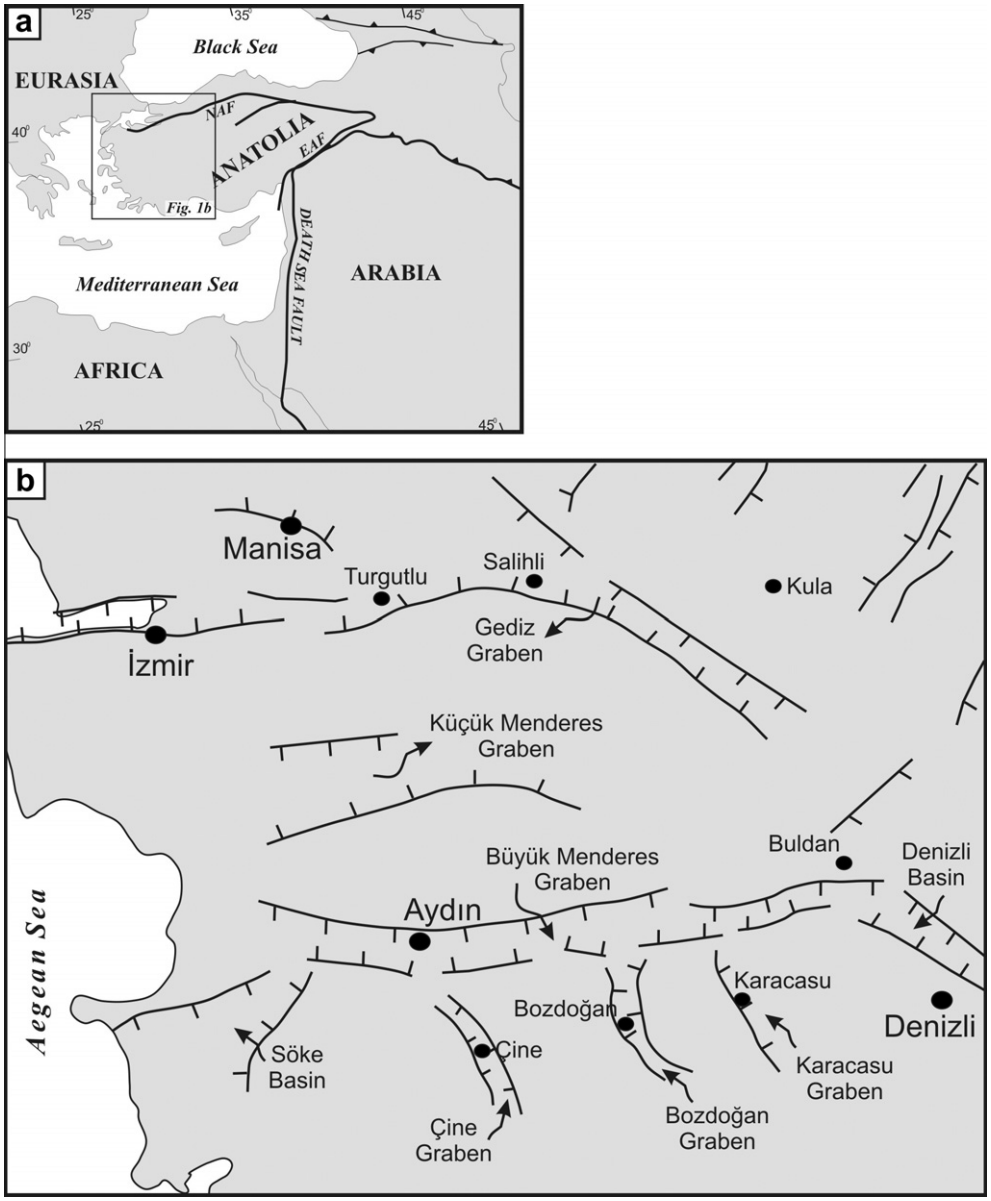

Fig. 1. (a) Modern tectonic frame of Anatolia (NAF: North Anatolian Fault, EAZ: East Anatolian Fault). (b) Tectonic outlines of the Büyük Menderes Graben and vicinity.