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Discrete characteristics of the aftershock sequence of the 2011 Van earthquake

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ABSTRACT

An intraplate earthquake of magnitude Mw 7.2 occurred on a NE–SW trending blind oblique thrust fault in accretionary orogen, the Van region of Eastern Anatolia on October 23, 2011. The aftershock seismicity in the Van earthquake was not continuous but, rather, highly discrete. This shed light on the chaotic non-uniformity of the event distribution and played key roles in determining the seismic coupling between the rupturing process and seismogeneity.

I analyzed the discrete statistical mechanics of the 2011 Van mainshock–aftershock sequence with an estimation of the non-dimensional tuning parameters consisting of; temporal clusters (C) and the random (RN) distribution of aftershocks, range of size scales (ROSS), strength change (ε_D), temperature (T), P-value of temporal decay, material parameter R-value, seismic coupling χ, and Q-value of aftershock distribution. I also investigated the frequency–size (FS), temporal (T) statistics and the sequential characteristics of aftershock dynamics using discrete approach and examined the discrete evolutionary periods of the Van earthquake Gutenberg–Richter (GR) distribution. My study revealed that the FS and T statistical properties of aftershock sequence represent the Gutenberg–Richter (GR) distribution, clustered (C) in time and random (RN) Poisson distribution, respectively.

The overall statistical behavior of the aftershock sequence shows that the Van earthquake originated in a discrete structural framework with high seismic coupling under highly variable faulting conditions. My analyses relate this larger dip–slip event to a discrete seismogenesis with two main components of complex fracturing and branching framework of the ruptured fault and dynamic strengthening and hardening behavior of the earthquake. The results indicate two dynamic cases. The first is associated with aperiodic nature of aftershock distribution, indicating a time-independent Poissonian event. The second is associated with variable slip model, varying loading rates and high seismic coupling along the ruptured area. This study concludes that the aperiodic statistical behavior of the Van aftershock sequence is one of the results of the time-independent Poissonian seismic deformation in the 2011 Van earthquake.

1. Introduction

A large intraplate Mw 7.2 earthquake struck the area north of the city of Van in East Anatolia on 23 October 2011 (Toker and Ecevitoglu, 2012a,b; Toker, 2013a,b) (Fig. 1). The mainshock epicenter (38.68°N–43.47°E) and most of the aftershocks were located south of the eastern arm of Lake Van (Fig. 2a). The Disasters and Emergency Situations Directorate of Turkey (AFAD) reported that the Van earthquake led to the death of 604 people and the collapse of a large number of buildings. Toker and Ecevitoğlu (2012a) observed various liquefaction deformations, sand volcanoes, landslides and lateral spreadings along the eastern shore of the lake. Different institutions (CMT, USGS, GFZ, KOERI) estimated the magnitude of the 2011 Van earthquake as varying from Mw 7.1–Mw 7.3 with a depth from 5 to 20 km. Surface displacement was observed within two weeks after the mainshock and the major slip asperity was located at a depth of between 20 and 30 km (Altiner et al., 2013). The fault focal solutions of the mainshock and most of the aftershocks were mainly characterized by thrust and oblique-slip thrust mechanisms (Görgün, 2013) (Fig. 1b and c).

The recent development of a broadband seismic network under the auspices of the Kandilli Observatory and Earthquake Research Institute of Turkey (KOERI) (Fig. 1a) has provided evidence of the ongoing seismic deformation. More than 6000 aftershock events were recorded that had wide and various range of magnitudes, mostly greater than Mw 2.5 (Fig. 2a). During the Van mainshock these events were systematically plotted as a function of time, magnitude and frequency of occurrence (foo) of the recorded

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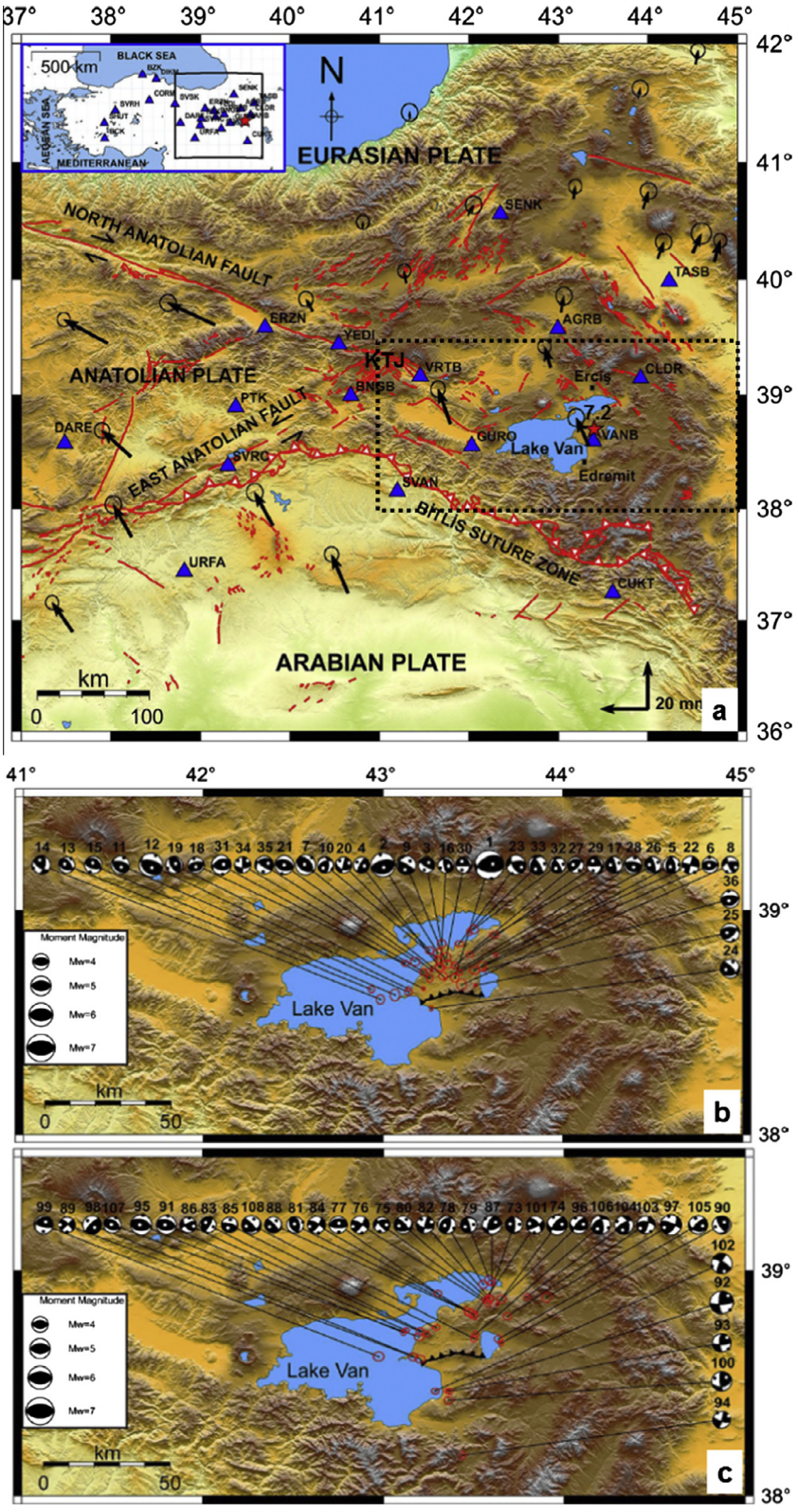

Fig. 1. A tectonic map of E-Anatolia showing GPS velocities with respect to Eurasia (McClusky et al., 2000; Reilinger et al., 2006; Görgün, 2013) (a). The seismically active faults are shown by red lines (Şengör et al., 2008). The blue triangles with station codes depict locations of the KOERI broad-band seismic stations. The epicentre of the 2011Van earthquake (Mw 7.2) is indicated by a red star. The inset in the top left displays the distribution of seismometers (blue triangles) and the study area (the solid black rectangle). The Lake Van area is shown by dotted black rectangle and detailed in 1b and c (KTJ: Karliova Triple Junction). The topographic map views of CMT solutions for 72 events (Mw $\geqslant$ 4.0) by the waveform inversion from Nakano et al. (2008) (from Görgün (2013)) according to time intervals over the period October 23–24, 2011 (36 events) (b) and from November 1, 2011 to February 24, 2012 (36 events) (c). The focal mechanisms are projected on the lower hemisphere, scaled with magnitude then numbered according to the appearance of the event occurrence (1–36 and 73–108, events between 36 and 73 are omitted in this study). The bold black line indicates the Van earthquake surface rupture as mapped by Emre et al. (2011). Maps reprinted from Görgün (2013) with kind permission of Oxford University Press Publication. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)