Journal of Asian Earth Sciences 111 (2015) 459–469

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Seismicity of the 24 May 2014 M_w 7.0 Aegean Sea earthquake sequence along the North Aegean Trough

Ethem Görgün *, Burçak Görgün

Department of Geophysical Engineering, Istanbul University, 34320 Avcılar, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 2 February 2015
Received in revised form 12 May 2015
Accepted 9 June 2015
Available online 23 June 2015

Keywords:
Aftershock
Coulomb stress analysis
Focal mechanism
Moment tensor inversion
Aegean Sea earthquake
North Aegean Trough
Stress tensor inversion

ABSTRACT

The northern Aegean Sea was hit by a large size (M_w = 7.0) earthquake on 2014 May 24. Centroid moment tensor solutions for 40 events with moment magnitudes (M_w) between 3.3 and 7.0 are computed by applying a waveform inversion method on data from the Turkish and Greek broadband seismic networks. The time span of data covers the period between 2014 May 24 and 2014 June 26. The mainshock is a shallow focus strike–slip event at a depth of 15 km. Focal depths of aftershocks range from 6 to 30 km. The seismic moment (M_o) of the mainshock is estimated as 4.60×10^{19} Nm. The calculated rupture duration of the North Aegean Sea mainshock is 40 s. The focal mechanisms of the aftershocks are mainly strike–slip faulting with a minor normal component. The geometry of focal mechanisms reveals a strike–slip faulting regime with NE–SW trending direction of *T*-axis in the entire activated region. A stress tensor inversion of focal mechanism data is performed to acquire a more accurate picture of the northern Aegean Sea stress field along the North Aegean Trough. The stress tensor inversion results indicate a predominant strike–slip stress regime with a NW–SE oriented maximum principal compressive stress (σ_1). In the development of the North Aegean Trough in Aegean Sea is in good agreement with the resolved stress tensors. With respect the newly determined focal mechanisms, the effect of the propagating of the North Anatolian Fault into Aegean Sea is very clearly pronounced. According to high-resolution hypocenter relocation of the North Aegean Sea seismic sequence, three main clusters are revealed. The aftershock activity in the observation period between 2014 May 24 and 2014 July 31 extends from the mainshock cluster from NE to the SW direction. Seismic cross-sections indicate that a complex pattern of the hypocenter distribution with the activation of seventeen segments. The eastern cluster is associated with a fault plane trending mainly ENE–WSW and dipping vertical, while the western is related to a fault plane trending NE–SW and dipping towards NNW. The best constrained focal depths indicate that the aftershock sequence is mainly confined in the crust (depth $\leqslant$ 30 km) and is operating in the approximate depth range from 1.5 to 30 km. Consequently, Coulomb stress analysis is performed to calculate the stress transfer and correlate it with the activated region. Positive lobes with stress more than 3 bars are obtained, indicating that these values are large enough to increase the Coulomb stress failure towards ENE–WSW direction.

1. Introduction

The North Aegean Sea (NAS) earthquake (EQ) occurred at 09:25:02.5 GMT on 2014 May 24. The mainshock was a large size (M_w = 7.0) event at a depth of 15 km. The NAS EQ is directly located in the North Aegean Trough (NAT) of the western North Anatolian Fault (NAF) extension system (Fig. 1). NAF propagates into Aegean Sea by the 300 km long NAT (Fig. 1; Le Pichon and Kreemer, 2010). The mainshock is revealed by strike–slip motion on a NE–SW trending fault (Fig. 2). Fault rupture zone of an earthquake of this size extends typically from 20 to 80 km length. The Marmara region and NW Anatolia are characterized by very uniform (in magnitude and orientation) plate velocity vectors from Global Positioning System (GPS) indicating W-SW motion at about 15–25 mm/yr (Fig. 1, McClusky et al., 2000; Reilinger et al., 2006, 2010). This region is one of the most seismically active parts of the Marmara Sea and NAF tectonic regime. The westward motion of Marmara region produces deformation on its northern and southern boundaries. Defined Marmara–Eurasia motion across the NAF and NAT is 23 mm/yr of almost pure right-lateral strike-slip (Nyst and Thatcher, 2004; Reilinger et al., 2010). The Marmara/Anatolia relative motion decreases from 11 mm/yr of

* Corresponding author.
E-mail address: ethem.gorgun@istanbul.edu.tr (E. Görgün).

http://dx.doi.org/10.1016/j.jseaes.2015.06.018
1367-9120/

Fig. 1. Tectonic map of northern Aegean Sea showing GPS velocities with respect to Eurasia and 95% confidence ellipses for eastern Anatolia (McClusky et al., 2000; Reilinger et al., 2006). Seismically active faults are shown by red lines (Şaroğlu et al., 1992). Blue, red, black and yellow triangles with station codes depict locations of the AUTH, KOERI, NOA and AFAD broadband seismic stations, respectively. The epicenter of the 2014 NAS EQ is indicated by the red star. The yellow star indicates 9 August 1912 $M_s = 7.3$ Ganos EQ. For reference, focal mechanisms of the previous significant earthquakes are plotted (Karabulut et al., 2006; Tan et al., 2008). Black and white circles on beach-balls exhibit *P* and *T*-axes, respectively. The inset in the above left shows whole Turkey. Two closely spaced red single arrows display shear sense of major faults (NAT: North Aegean Trough, NAF: North Anatolian Fault, EAF: East Anatolian Fault, BSZ: Bitlis Suture Zone; FBFZ: Fethiye–Burdur Fault Zone). Boundaries (heavy colored red lines) of the Aegean Sea (AS) and Anatolian (AT) plates, which are surrounded by the African (AF), Arabian (AR) and Eurasian (EU) plates (Bird, 2003). The solid black rectangle shows the study area, which is enlarged in this figure. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

oblique extension SE of Marmara Sea to 5 mm/yr of strike–slip motion at Aegean Sea (Nyst and Thatcher, 2004; Le Pichon and Kreemer, 2010). The velocity field relative to the south Marmara block demonstrates that the NAT is in the exact of the NAF and that both the NAF and NAT are pure right-lateral strike–slip at a constant slip rate of ~25 mm/yr. Thus the NAF, including its north Aegean extension, is sliding along its whole length of 1500 km at a constant 25 ± 1 mm/yr (Taymaz et al., 1991; Koçyiğit et al., 2000; Bozkurt, 2001; Reilinger et al., 2006; Le Pichon and Kreemer, 2010). The fault motion suggest that the mainshock and the large aftershocks belong to the NAT, where a right-lateral strike–slip zone between the Anatolian and Eurasian plates in the northern Aegean Sea takes place (inset in Fig. 1).

The 9 August 1912 Ganos (Gaziköy) $M_s = 7.3$ earthquake produced widespread damage and considerable loss of life (Fig. 1, yellow star). Surface disruptions along the Ganos Fault (GF) were described in contemporary reports as cracks (Macovei, 1912; Sadi, 1912; Mihailovich, 1927). No fault rupture was reported as such, but pictures of mole tracks and en echelon cracks clearly suggest prevalent right-lateral slip (Ambraseys and Finkel, 1987). From the Gulf of Saros to the Marmara Sea the total 1912 rupture length is probably about 140 km, not 50 km as previously thought (Armijo et al., 2005). Altunel et al. (2004) showed that this earthquake was caused by a right-lateral strike–slip faulting (Fig. 1). The GF forms a 45 km long linear fault system and represents the link between the northern strand of the NAF in the Sea of Marmara region and the NAT where slip partitioning results in branching of the fault zone (e.g. Barka and Kadinski-Cade, 1988; Okay et al., 1999). It is note that the last earthquake (2003 July 6, $M_w = 5.7$) occurred in the Gulf of Saros region where the 2014 NAS EQ took place. Consequently, this area should be considered as a case of special interest having the potential to generate large earthquakes.

The epicenter distribution of the large earthquakes ($M \geqslant 5.0$) that have occurred since 1965 around the NAT is shown in Fig. 1. The distribution of these epicenters indicates a very low activity along the NAT. These earthquakes are mostly shallow depth (<35 km) events (Karabulut et al., 2006; Tan et al., 2008). The seismic pattern of NAT and surrounding area are characterized by the occurrence of these moderate events. These events are highlighted in Fig. 1, where beach balls indicate focal mechanisms of important moderate-size events. Among them, the 1965 August 23 ($M_b = 5.2$), 1975 March 27 ($M_b = 5.5$) and the 2003 July 6 ($M_w = 5.7$) are significant events that can be related to the active NAT right-lateral strike–slip system. These events occurred along the NAT during the instrumental period (>1900) and indicate a complex strike–slip fault zone which has also normal and reverse faults. We interpret their orientation and spatial distribution in terms of the major strike–slip fault strands and the basin boundaries (for the normal faults). The 6 July 2003 event was followed by intense aftershock activity (Karabulut et al., 2006). This event clearly revealed that the slip during the 2003 event was confined at depths larger than