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RESEARCH ARTICLE

# Coulomb Stress Changes after 11 May 2017 Askale-Erzurum (NE Turkey) Earthquake (Mw = 4.7)

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INFORMATION

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ABSTRACT

Erzurum city (NE Turkey), one of the largest provinces of the eastern Anatolia region are surrounded by many active tectonic units. These tectonic units generated many earthquakes that led to the loss of life and property during the historical and instrumental period. The 4.7 magnitude earthquake in Askale-Erzurum (NE Turkey) on May 11, 2017 reminded us the active tectonic units in the region. In this study, Coulomb Stress change was investigated using Askale earthquake and its aftershocks. Especially after this earthquake, a stress of ~1 bar is observed in Tercan, Maden, Ilıca and N part of Cat region. Erzurum managed by compression tectonics as a result of the orogenic movements, always has the potential to generate a devastating earthquake. Considering these reasons, earthquake-soil-structure relationship should be noted while making constructions in Erzurum and its surroundings.

## 1. Introduction

The eastern Anatolia region is deformed in a north-south direction due to orogenic movements that started in the Miocene era between African - Arabian plate and Eurasian plates. This movement created three main tectonic units in Anatolian Block. These are North Anatolian Fault Zone (NAFZ), East Anatolian Fault Zone (EAFZ) and Aegean Extensional Regime (AER). There are some devastating earthquakes occurred in these tectonic zones. Apart from these main tectonic zones, North-eastern part of Anatolian block is also seismically active. Major earthquakes that occur in the region are generated by this tectonic regime. In the last century are as following: November 8, 1901, Erzurum (Ms=6.1); September 13, 1924 Köprüköy-Erzurum (Ms=6.8); January 3, 1952 Hınıs-Erzurum (Ms=5.8); October 30, 1983 Şenkaya-Erzurum (Mw=6.6); September 18, 1984 Balkaya Erzurum (Mw=5.5); December 3, 1999 Şenkaya-Erzurum (Mw=5.7); March 25 (Mw 5.6) and March 28, 2004 Askale Erzurum (Mw 5.6) (AFAD, 2017; Ozer et al., 2019a).

Erzurum in North-Eastern Anatolia block has an important role in Turkey in terms of industry and economic conditions. For this reason, it is important to examine the seismicity of Erzurum and its surroundings. There are many active faults in Erzurum region. The most important of these are; Askale Fault Fone (AFZ), Başköy-Kandilli Fault Zone (BKFZ), Palandöken Fault Zone (PFZ) and Erzurum-Dumlu Fault Zone (EDFZ) (Ozer et al. 2019a) (Fig. 1). Keskin et al. (1998) presented a detailed study of the volcanic stratigraphy of the plateau, together with new K-At ages and several hundred new major and trace-element analyses in order to evaluate the magmatic evolution of the plateau and its links to collision-related tectonic processes. Yarbasi and Kalkan (2009) emphasized the seismicity potential of Erzurum. They suggested that the design stage must include geotechnical investigations for detailed assessment of the foundation conditions. Aydin (2015) declared that The lowest frequency dependence values were calculated in Erzurum seismic station. Kocyigit and Canoglu (2017) recommended that a large-scale earthquake hazard map should be prepared for Erzurum pull-apart basin according to water-saturated basin fill and active fault parameters. Ozer (2019) observed that the soil amplification values are high especially at low frequencies in the Erzurum city centre located in alluvial units.

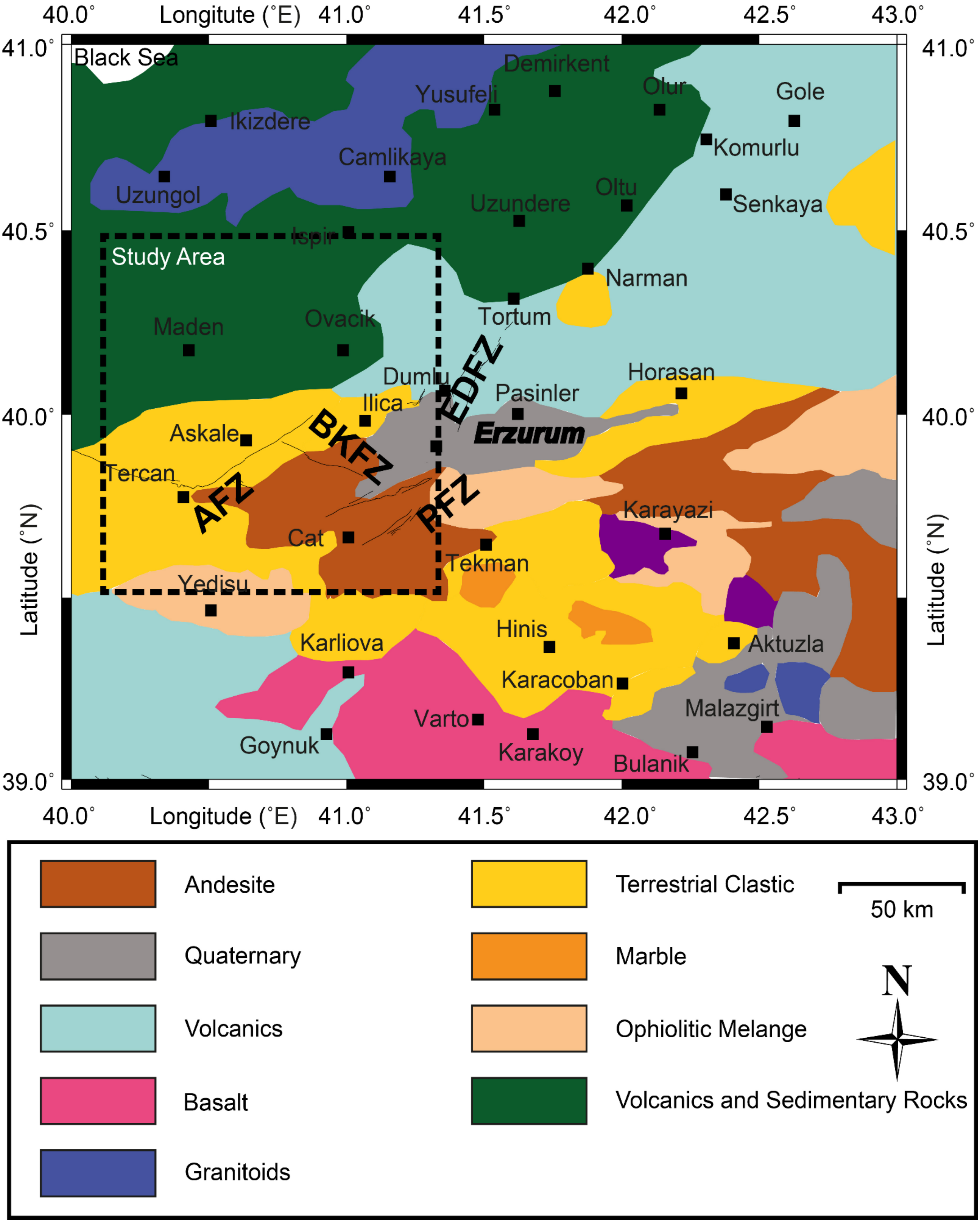


Fig. 1. Figure 1. Geology and tectonic units of Erzurum and its surroundings. Black thick lines symbolize active faults in the region (Emre et al. 2013; Emre et al. 2018; Ozer and Ozyazicioglu, 2019; Ozer et al. 2019a). AFZ: Askale Fault Fone, BKFZ: Başköy-Kandilli Fault Zone), PFZ: Palandöken Fault Zone and EDFZ: Erzurum-Dumlu Fault Zone

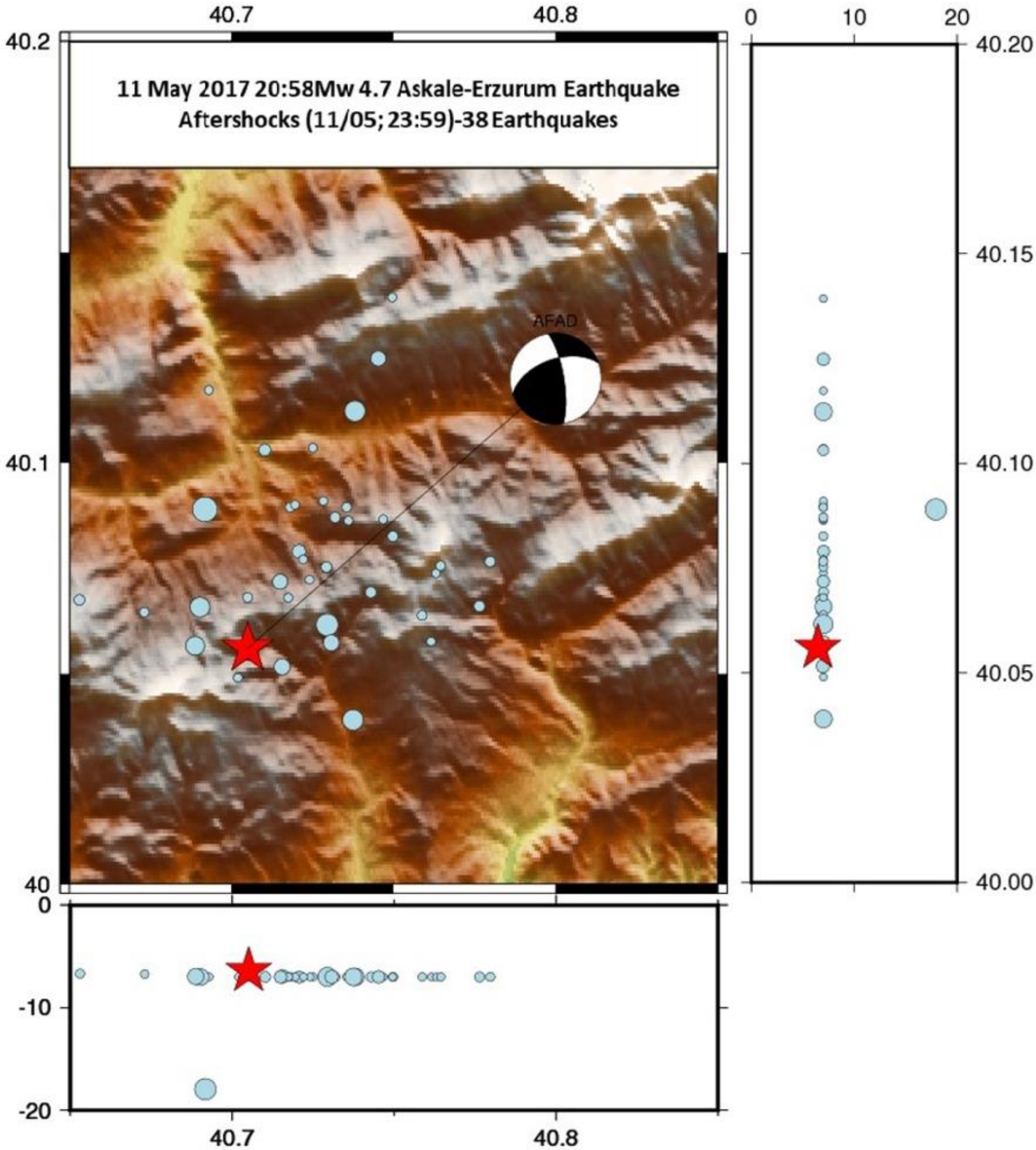


Fig. 2. Distribution of the main shock and aftershocks of the Askale-Erzurum earthquake. The star and the light blue circles show the mainshock and aftershocks, respectively

The lowest soil amplification values were calculated at Şenkaya and Narman stations located in volcanics. Ozer et al. (2019b) demonstrated seismic tomography images and low Vp and high Vp/Vs models are remarkable along local faults of Erzurum. Ozer and Ozyazicioglu (2019) determined the 3-D P-wave velocity and Vp/Vs model of the Erzurum basin using the local earthquake tomography technique for the first time to understand new possible geothermal regions by developing tomographic sections using a dense seismic array. Bayrak et al. (2020) reported that the greatest acceleration value after the 2017/05/11 Askale earthquake (Mw4.7) was calculated as 14.21 gal at the station located in Tercan (Erzincan-2407). All these studies clearly reveal the seismic activity potential of Erzurum.

On 11.05.2017, at 20:58, an earthquake occurred in Askale-Erzurum, is the epicentre. The magnitude was calculated as Mw= 4.7, obtained as a result of the analysis acquired with data taken from the Disaster and Emergency Management Authority (AFAD), Ankara, Turkey. 38 (11/05/2017 Time: 23:59) aftershocks with magnitudes ranging from 1.0 to 2.5 occurred immediately after the earthquake (Fig. 2).

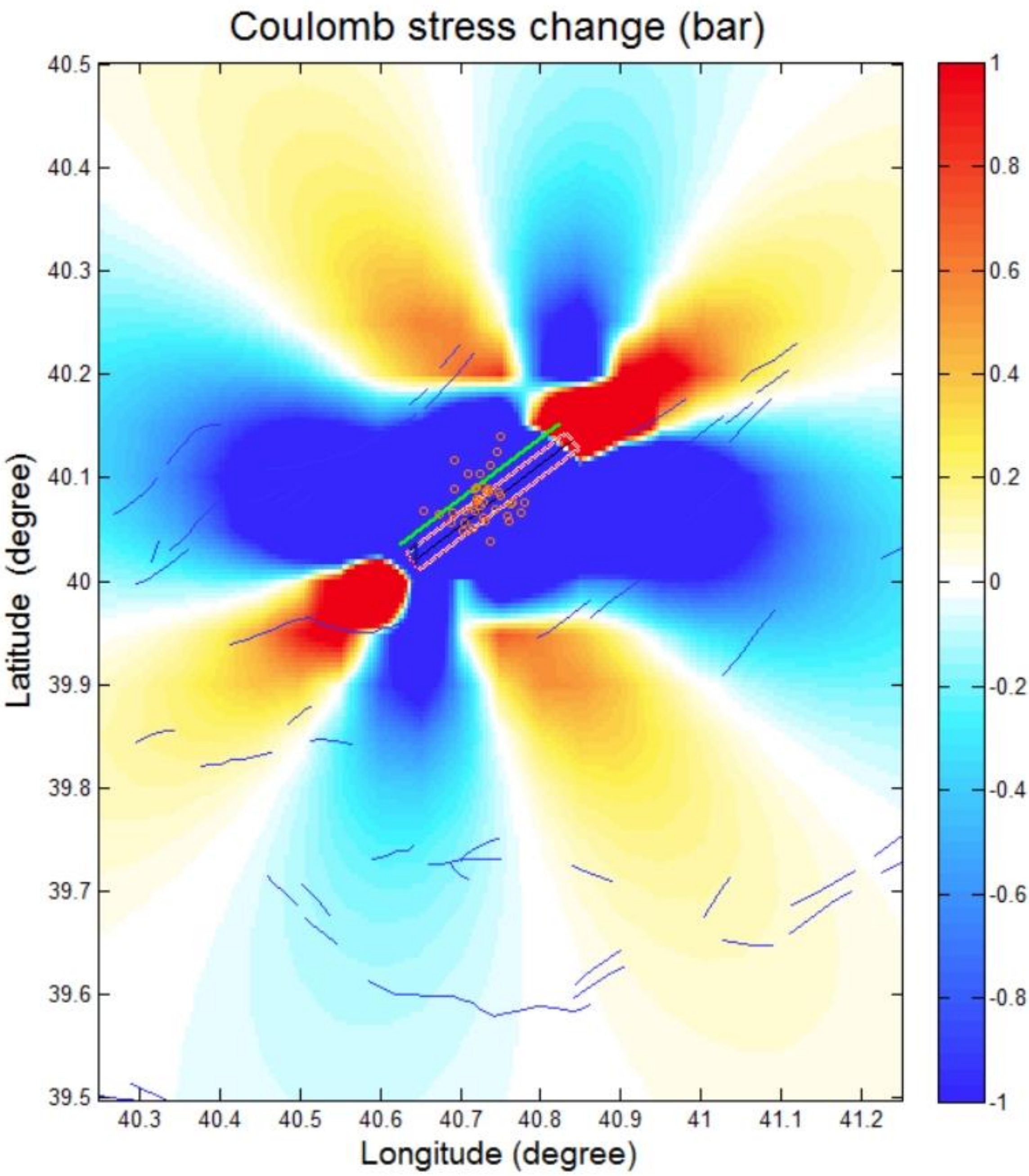


Fig. 3. The Askale-Erzurum earthquake Coulomb Stress Change (blue lines indicate tectonic units in the study area (Emre et al., 2013; Emre et al., 2018))

The closest settlement to the epicenter of the earthquake is Halılkaya Village (3.96 km) of Ilıca District of Erzurum province. The intensity of the earthquake was calculated as VI (strongly felt). The highest acceleration values at Erzincan Tercan Station, 41 km from the outer center of the earthquake, were measured respectively as 13.89 gal in the North-South component, 14.21 gal in the East-West component and 5.98 gal in the vertical component (AFAD, 2017). The fault kinematics solution points to dominant reverse faulting with minor strike-slip components.

The aim of this study is to investigate Coulomb stress change after Askale earthquake (Mw 4.7) using mainshock and aftershock event data. The Coulomb stress changes are conducted for the first time to understand stress transfer of the complex study area.

## 2. Data and Method

The distribution of main shock and aftershock was presented using the earthquake catalogue published by earthquake research department of AFAD (Fig. 2). Also, it has been used by AFAD catalogue as a base for Coulomb stress change calculations. After main shock, 38 earthquakes occurred in first five days. We used total of 39 earthquakes to obtain Coulomb stress changes. The Coulomb stress change calculations were calculated using the Coulomb 3.1 program. The purpose of Coulomb stress change is to delay the occurrence of some earthquakes after earthquakes occur or vice versa, to bring forward its occurrence. This situation can be revealed by examination of stress areas. Coulomb stress change is calculated as follows (Toda et al., 1998; Temiz and Gokten, 2011):

$$\Delta\sigma_f = \Delta\tau - \mu'\Delta\sigma_n \quad (1)$$

In this formula; $\Delta\sigma_f$ is the change in Coulomb stress, $\Delta\tau$ is the change in shear stress on the fault, $\Delta\sigma_n$ is the change in normal stress change that develops perpendicular to the fault plane and μ' refers to the angle of internal friction.

In this study, 0.4 was taken as constant. The positive calculation of Coulomb stress change indicates that the stress in the region is increasing, while it being negative indicates that the stress is decreasing. Some fault parameters have to be known when calculating stress change. Based on the focal mechanism results published by AFAD, strike, dip and rake values were accepted as 250, 55 and 162 respectively. Accepting this, the SW-NE directional fault plane was taken as a basis considering earthquake distributions in Fig. 2 and the region in the last decade and fault geometries.

## 3. Results

In this study, Coulomb Stress variation of Askale earthquake (Mw 4.7) were examined using mainshock and aftershock data. The mainshock and aftershock earthquake locations presents a SW-NE directional distribution in the region. Moreover, the results of focal mechanism show that, the presence of a reverse fault is important and this indicates a compression in the region. The Coulomb Stress change of Askale earthquake present that, a discharge in the areas denoted with blue, and in the red areas it shows regions where stress values increase (Fig. 3). Especially after this earthquake, a stress of ~1 bar is observed in the Tercan (Erzincan), Maden (Erzurum), Ilıca (Erzurum) and the north part of Cat (Erzurum) region. In the East-West directional area of Askale district, Coulomb stresses are observed to decrease.

## 4. Discussion

Parsons et al. (2000) stated the threshold value required for one earthquake to trigger another earthquake as 1 bar. After Askale earthquake (Mw 4.7), a stress of ~1 bar is observed in Tercan, Maden, Ilıca and the north part of Cat region. Ozturk (2018) reported the low b-values with the Dc-values greater than 2.2 in the Askale region. This seismotectonic characteristics could illustrate the earthquake hazard potential of Askale. Kocyigit and Canoglu (2017) especially specified that the seismicity of the Erzurum pull-apart basin is quite high. Furthermore, Sunbul and Sunbul (2018) showed that earthquakes along the EAFZ line were related to each other, and that a pre-formed earthquake affected the next earthquake. So the study area should definitely be investigated with more detailed stress analysis to understand characteristic of basins more clearly.

## 5. Conclusions

The Askale-Erzurum earthquake illustrates that the region is active in terms of earthquake activity. As can be understood from the acceleration values, this earthquake was felt strongly in Erzurum and its surroundings. Erzurum, which is steered by compressive tectonics, always has the potential to generate a destructive earthquake. Tercan, Maden, Ilıca and N part of Cat region stress values increased according to Coulomb stress analysis of Askale earthquake (Mw 4.7). Considering these reasons, earthquake-soil-structure relationship should be observed while making constructions in Erzurum and its surroundings.

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The data was provided by AFAD. Some images were created using GMT (Wessel et al., 2013). Faults and geology of Erzurum were digitized in the geoscience map viewer and drawing editor licensed to the General Directorate of Mineral Research and Exploration (MTA), Ankara, Turkey (Akbas et al., 2013; Emre et al., 2013; Emre et al. 2018). Coulomb 3.1 program developed and distributed by Toda et al. (1998) was used in Coulomb stress calculations. It is available at: http://quake.usgs.gov/research/deformation/modeling/Coulomb/download.html.

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