1.3 AN INSIGHT INTO THE EAST ANATOLIAN FAULT ZONE AND SURROUNDINGS THROUGH EARTHQUAKE TOMOGRAPHY: THE RELOCATION OF FEBRUARY 6, 2023 MAIN AND AFTERSHOCKS USING PAST SEISMIC ACTIVITY

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ABSTRACT

The North Anatolian Fault and the East Anatolian Fault Systems are two of the most significant fault zones in Turkey. Over thousands of years, they have witnessed substantial and destructive earthquakes. The most recent of these devastating earthquakes occurred on February 6, 2023, along the East Anatolian Fault System (EAFS) in a manner rarely observed. On February 6, 2023, two major earthquakes, with magnitudes of 7.8 and 7.6 Mw, respectively, occurred. Despite nine months having passed since these earthquakes, aftershocks are still ongoing, causing considerable destruction and loss of life. Since the first day, more than 40,000 earthquakes have occurred in the region in total. In order to shed light on the occurrence of these earthquakes, the region's 3D subsurface seismic velocity structure was determined using the local earthquake tomography method. A two-stage tomography study was conducted. In the first stage, earthquakes that occurred in the region from 1900 to February 6, 2023, were used, while in the second stage, earthquakes, including main shocks and aftershocks, from that date to the present were considered. This study focuses on the first stage's research and its results. Out of the approximately 37,000 earthquakes that occurred in the region before the Kahramanmaraş earthquakes, 1951 earthquakes were selected based on criteria such as the GAP and RMS values. Travel time data for 16,865 P-waves and 9,438 S-waves recorded at 29 stations were utilized. Initially, a 1-D velocity model with seven layers down to 50 km depth was established for the region, and subsequently, a 3-D tomographic velocity structure of the region was obtained by modeling in the lateral direction with 20x20 km grid points and in the vertical direction with 5 km node spacing. The distribution of low and high seismic velocity anomalies, Moho topography, magmatic intrusions, and similar structures were identified from the tomographic images, and attempts were made to determine their relationship with earthquakes. Additionally, using the 3-D velocity model obtained from tomographic inversion, the coordinates and depths of the Kahramanmaraş earthquakes with magnitudes of 7.8 and 7.6 that occurred on February 6, 2023, were calculated more precisely.

KEYWORDS : Tomography, earthquake, Kahramanmaraş, seismicity, relocation.

DATA and METHOD

To determine the 3-D deep seismic velocity structure of a region using the local earthquake tomography method, travel times of the P and S phases of earthquakes that have occurred in the same region are required. For this purpose, earthquakes that occurred within the period from 1900 to the first mainshock of the Kahramanmaraş earthquake on February 6, 2023, in the vicinity of the Eastern Anatolian Fault Zone (EAFZ) as shown in Figure 1 were utilized. Out of approximately 44,000 earthquakes, those with a GAP value less than 180°, an RMS value below 2 seconds, and at least 10 P-wave observations at various stations were used for calculations. All earthquake-related data were obtained from the ISC data portal. The data were collected solely from operational earthquake observation stations within the region. Despite the presence of various types of 82 stations belonging to AFAD and Kandilli Observatory Earthquake Research Institute from 1900 to the present in the region, data could only be acquired from 55 stations. The distribution of these stations is also depicted in Figure 1. Initially, the 1-D velocity structure of the region was determined using the VELEST (Kissling, 1988; Kissling vd.,1994; Kissling vd., 1995) algorithm. For this purpose, 1576 selected earthquakes were used based on specific criteria. In this stage, first the 1-D P-wave velocity structure was determined, and then, additional data with at least 5 S-wave readings to P-phase observations were incorporated to calculate the 1-D P&S wave velocity structure of the region. Finally, the obtained velocity model was also utilized as a reference velocity model for 3-D tomographic solutions. The SIMUL2000 (Thurber 1983, 1993; Eberhart-Phillips 1993; Thurber and Eberhart-Phillips, 1999) algorithm was employed for obtaining the 3-D tomographic velocity model of the region. Similar to the 1-D velocity model, the Vp velocity structure was initially determined, and then the Vp/Vs structure was computed. For these studies, only the P-wave observation count was reduced to eight, while the other criteria remained the same. Consequently, 1825 earthquakes were used in the inverse modeling processes. Given the extensive coverage of the region, horizontal grid points were set at 20x20 km spacing, and vertical spacing was set at 5 km intervals.

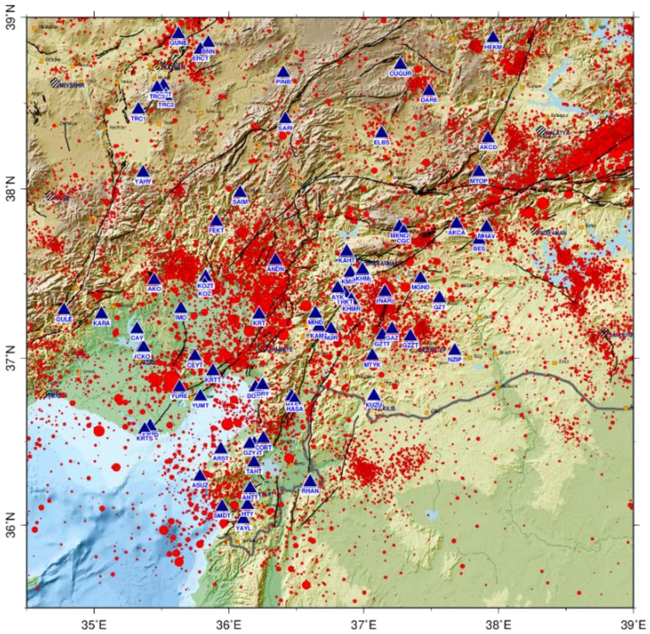

Figure1 The distribution of earthquakes (red dots) and stations (blue triangles) in the region.

RESULTS

This study has yielded the following results:

• 1-D P- and S-wave velocity structure of the region.

• 3-D Vp and Vp/Vs structure of the region.

• Relocation of earthquakes.

• Recalculation of the locations of Kahramanmaraş earthquakes and aftershocks.

The 1-D velocity structure of the region could be modeled down to a depth of approximately 50 km. It has been observed that up to this depth, the region consists of approximately seven layers (Figure 2). It was determined that there is a low-velocity layer (Vp~2.8 km/s; Vs~0.7 km/s) up to a depth of 5 km from the surface, and after this depth, there is a sudden increase in velocity. The Moho depth was estimated to be approximately 35-36 km from the 1-D crustal velocity model (Figure 2).

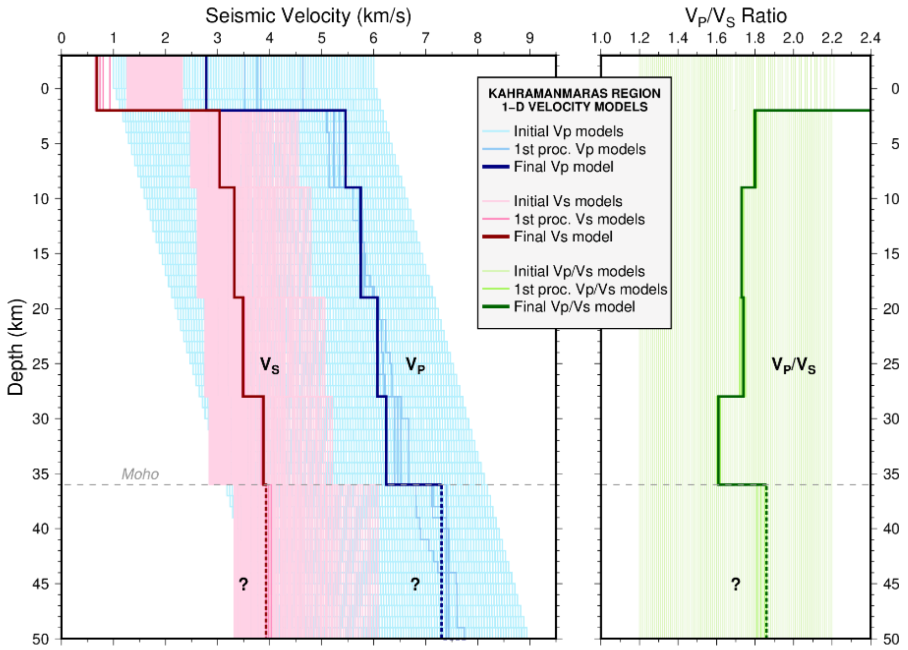

Figure2 1-D crustal velocity model for P- and S- wave in the region.

When examining the tomographic velocity models (Vp and Vp/Vs) obtained through 3-D inversion, it was observed that Vp values fall within the range of 2.7-8.8 km/s, and Vp/Vs ratios are between 1.4 and 2.0 down to a depth of approximately 50 km. In the 3-D velocity structure, where tomographic anomalies are observed down to about 50 km depth, it was determined that the Moho discontinuity is located at depths of 30-35 km (Figure 3). Additionally, in basin-like areas, low Vp values were observed, while anomalies with high Vp values occasionally extend from deeper regions towards the surface.

As a result of the relocation conducted based on the obtained 3-D velocity model, all earthquakes that occurred in the region have been relocated as accurately as possible in terms of their real coordinates and depths. Furthermore, the obtained new 3-D velocity model of the region has allowed for a more accurate calculation of the locations and depths of the main shocks of the Kahramanmaraş earthquakes (Figure 4). The depth of the first shock was approximately 20 km, while the depth of the second main shock was determined to be 13 km."

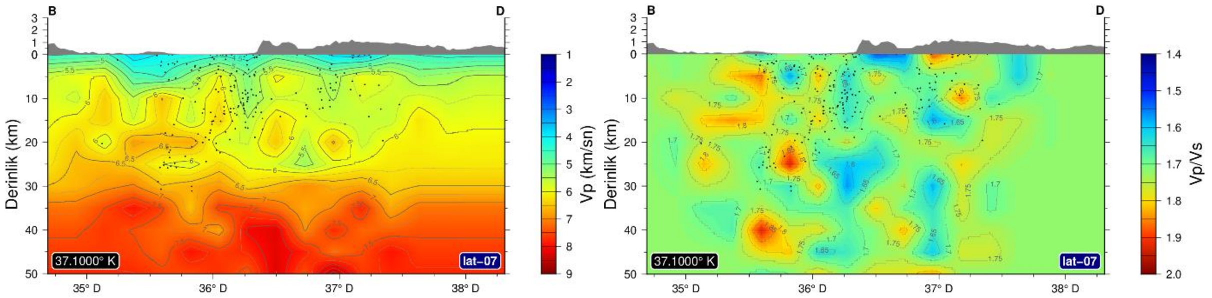

Figure3 The vertical cross-section derived from the 3D tomographic inverse solution velocity model. The left side represents the Vp, while the right side depicts the Vp/Vs model.

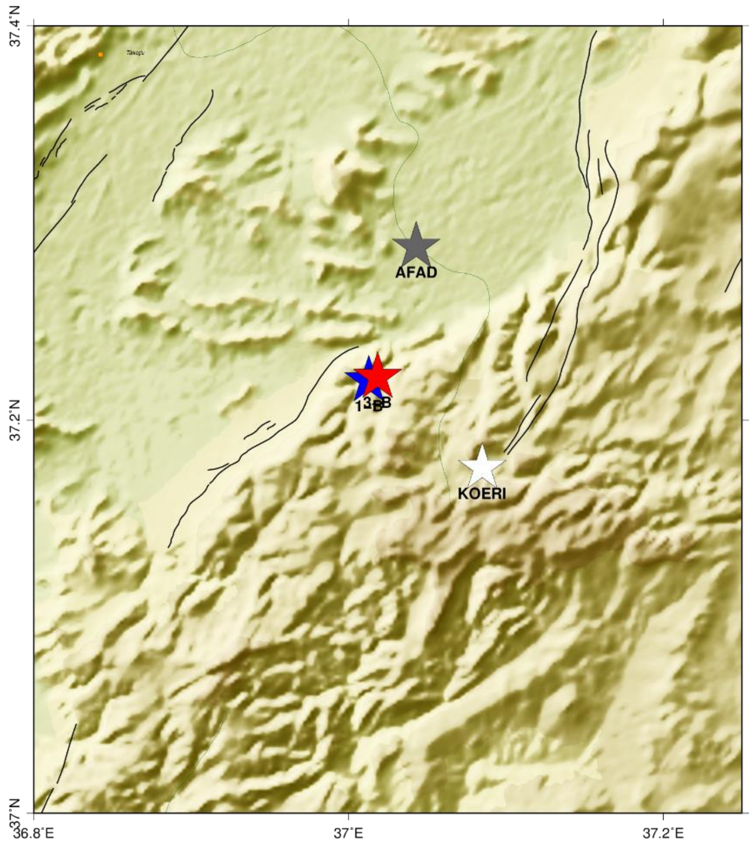

Figure4 The new location of the first main shock of Kahramanmaraş earthquake (red and blue stars) calculated using the 3-D velocity model.

CONCLUSION

The deep traces of the complex tectonic structure of the region have been determined with the tomographic velocity structures obtained along the EAFZ. The effects of the region being a tectonic plate boundary can also be observed in the deep velocity structures. Structures with anomalous features, such as the continuation of surface faults in the depths, structures resembling mantle uplifts within the crust, and fundamental depths of basin areas, have been revealed. Furthermore, the positioning errors arising from lateral velocity deficiencies in the earthquake locations determined using 1-D velocity models have been rectified with 3-D velocity models. As a result, the locations of the main shocks of the Kahramanmaraş earthquakes have been more accurately determined. The second part of this study, which constitutes the initial section of tomographic imaging, will address tomographic studies conducted with the aftershocks of the Kahramanmaraş earthquakes after February 6, 2023.

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