Geodetic Modelling of the 2023 M_W 7.8 and 7.6 Türkiye Earthquake Sequence

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On 6 February 2023 a M_W 7.8 earthquake occurred at 01:17 UTC in south-eastern Turkey, near the Pazarcık district in Kahramanmaraş province and the northern border of Syria (Fig. 1), followed 9 hours later by a M_W 7.6 earthquake approximately 90 km to the north, resulting in widespread destruction of buildings and significant loss of life. The largest aftershocks occurred on 6 February and 20 February, and their magnitudes have been assessed as M_W 6.7 and 6.4, respectively. According to the information provided by the Earthquake Department of the Disaster and Emergency Presidency (AFAD) there were over 50,000 reported fatalities and over 100,000 injuries from the devastating seismic sequence. The earthquakes were reported to be on different segments of the well-known left-lateral continental strike-slip East Anatolian Fault Zone (EAFZ), which is one of the two major active strike-slip fault systems in Turkey, other being the right-lateral strike-slip North Anatolian Fault Zone (NAFZ). In this study, we analyse the main features of the rupture process during the Kahramanmaras seismic sequence. In this respect, we use Interferometric Synthetic Aperture Radar (InSAR) and Global Navigation Satellite System (GNSS) data to investigate the ground displacement field (inset Fig. 1) and to infer, by using elastic dislocation modelling, the fault geometry and slip distribution of the causative fault segments.

We performed fault slip modelling using rectangular dislocations embedded in an elastic, homogeneous and isotropic half-space (Okada, 1985). We constrain the trace of the rupture surface of the earthquake doublet by examination of the displacements in the near-field InSAR data, extending the fault planes to a depth of 20 km running through the relocated seismicity (Lomax, 2023). The geodetic data is thus inverted for slip magnitude on each fault patch, inferring the optimal geometry iterating over dips and rake angles of the fault planes (Cheloni et al., 2019). In our inversion scheme, we consider 3 main fault segments with variable orientation for the M_W 7.8 main shock (Amanos, Pazarcık and Erkenek segments) and 2 main fault segments for the M_W 7.6 event (the Çardak-Savrun fault and an eastward segment located along the Nurhak complexity). In addition, we also include a segment located in the Narlı Fault Zone, a small splay fault between the Pazarcık and Erkenek segments, and the Pütürge segment located between the previous 2020 Elaziğ seismic sequence and the north-eastern termination of the 2023 earthquake sequence.

The coseismic slip model in the preferred fault network geometry shows the activation of different fault segments during the 2023 Kahramanmaraş seismic sequence. In particular, the M_W 7.8 earthquake ruptured the Amanos segment to the south and the Pazarcık and Erkenek segment to the north (for a total length of about 300 km), in agreement with previous studies (e.g. Barbot et al., 2023), with little slip resolved along the Narlı segment where the mainshock nucleated (Melgar et al., 2023). The maximum slip is observed along the Pazarcık segment (peak slip of about 10 m). In contrast, the geodetic modelling of the M_W 7.6 earthquake, nucleated in the middle of the E-W trending Çardak-Savrun fault and propagated westward to the Savrun fault and eastward along the Nurhak complexity, indicated a more localized rupture primarily within the Çardak-Savrun segment (for a total length of about 150 km), with up to 15 m of slip. Finally, at the southern termination of the mainshock rupture, our modelling revealed that the 20 February M_W 6.4 aftershock activated the Antakya fault.

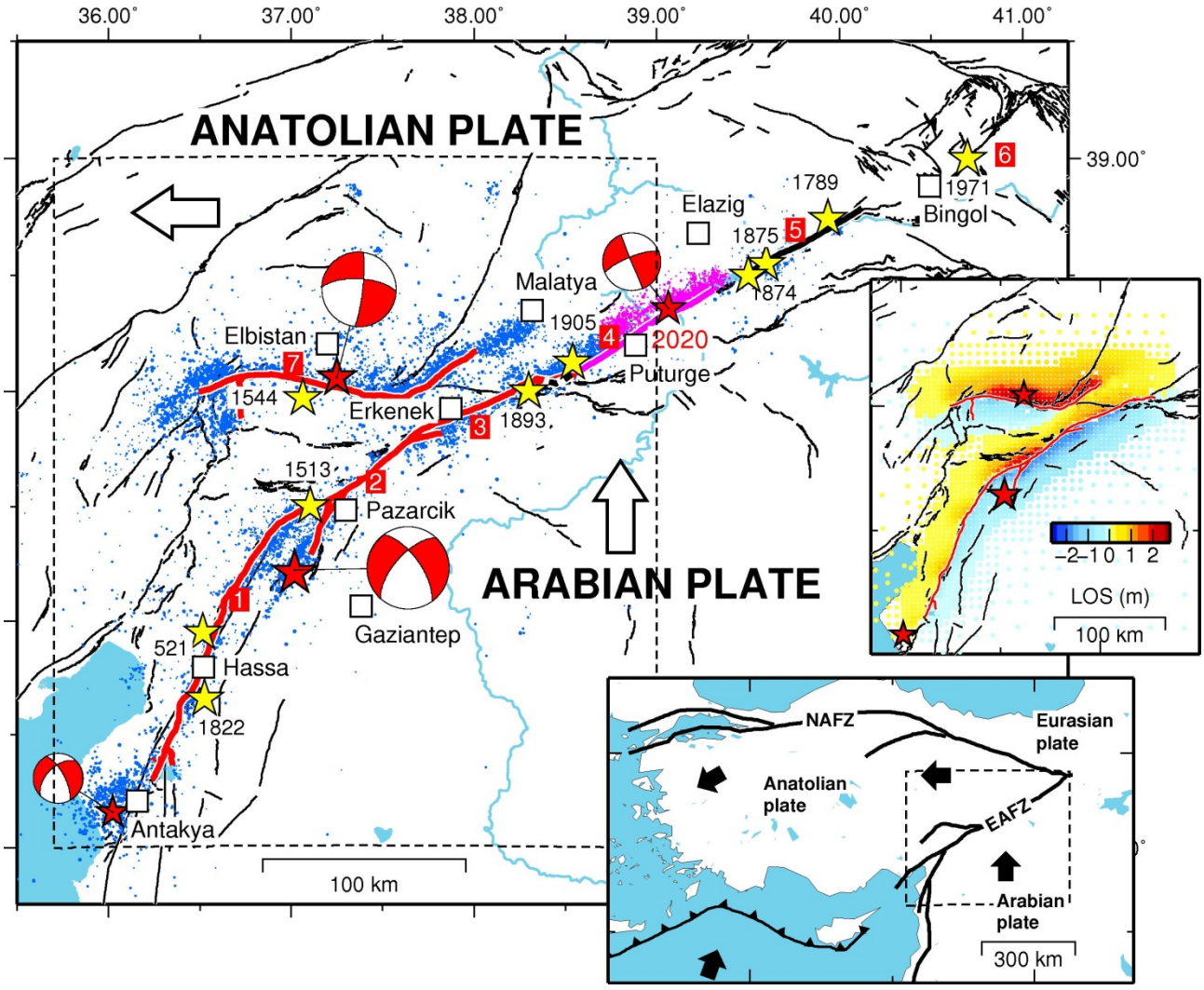

Fig. 1 – Seismotectonic settings of the study area. The solid lines are the main fault segments of the EAFZ (after Duman and Emre, 2013): (1) Amanos, (2) Pazarcık, (3) Erkenek, (4) Pütürge, (5) Palu, (6) Bingöl and (7) Sürgü-Çardak - Savrun segments, respectively. Seismicity: the blue dots are relocated aftershocks of the 2023 sequence (Lomax, 2023); red stars are the location of the main events and their moment tensor solution (KOERI); yellow stars represent the major historical events (Ambraseys 1989). The bottom inset shows a sketch of the main fault systems in and

around Turkey, and the dashed box is the area of the main figure. The upper inset shows an example of InSAR data: the unwrapped interferogram showing the cumulative coseismic displacement field from the ALOS-2 ascending track.

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