SAKARYA UNIVERSITY
DISASTER MANAGEMENT APPLICATION AND RESEARCH CENTER
and
DEPARTMENT OF GEOPHYSICS

A PRELIMINARY REPORT ON THE 2023 GAZİANTEP (Mw=7.7) and ELBİSTAN (Mw=7.5) EARTHQUAKES IN SOUTHEAST TÜRKİYE

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SAKARYA

Introduction

Two destructive earthquakes struck SE Türkiye on the February 6, 2023. (Figure 1) (AFAD 2023; KOERI 2023; USGS NEIC). The earthquakes occurred along the East Anatolian Fault Zone (EAFZ), within or in close vicinity of a prominent seismic gap known as the Maraş Seismic Gap (Figure 2) (Nalbant et al. 2002; Duman and Emre 2013; Aktuğ et al. 2016; Utkucu et al. 2023). The size of the first destructive shock was *M*w=7.7 while the size of the other one was *M*w=7.5 (Table 1). A large aftershock of *M*w=6.7 also occurred between the destructive shocks. Numerous aftershocks, including several M>6.0 aftershocks, are still continuing to shake the earthquake struck area (Figure 3). The first reports from the earthquake struck area indicates heavy damage and casualties. The hypocentral and source parameters of the earthquakes obtained so far are given in Table 1.

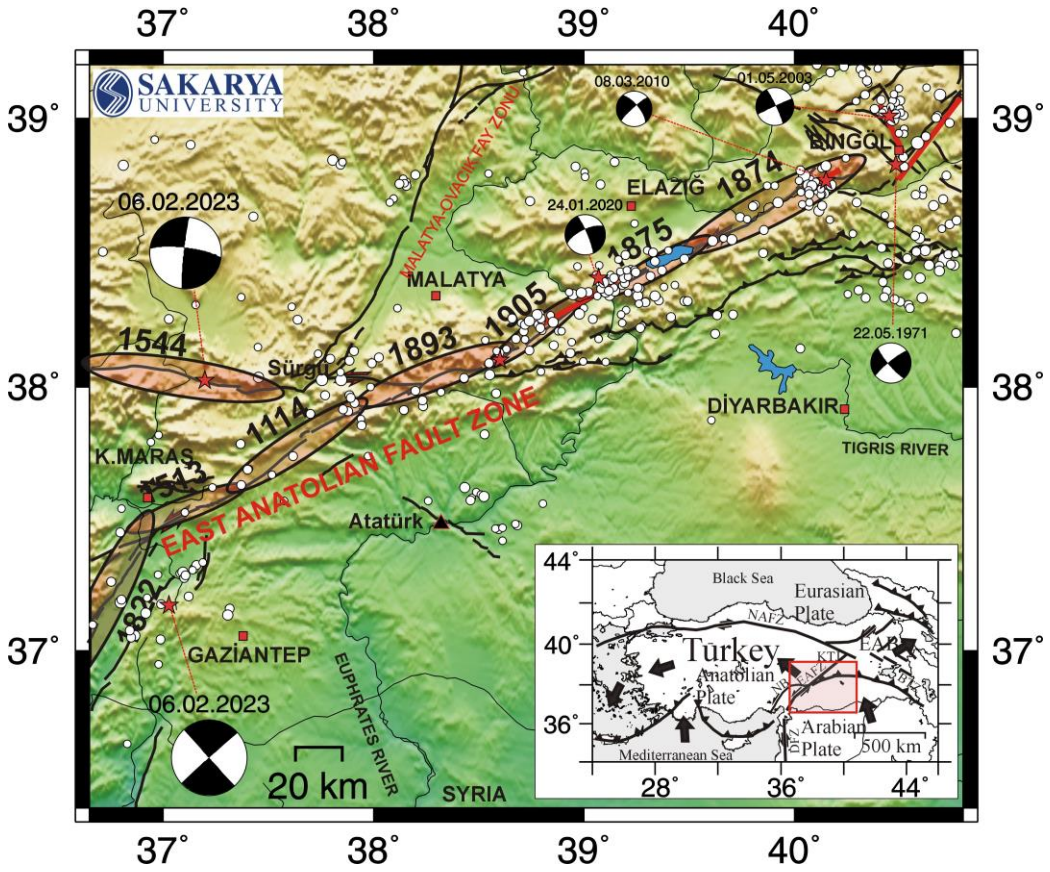

Figure 1. Major tectonic elements of Türkiye (inset map) along with seismicity along the East Anatolian Fault Zone. Seismicty include M≥4.0 earthquakes (white circles) after 1970 and destructive historical (red shaded ellipses) and M≥6.0 instrumental (red stars) earthquakes. The seismicity data is taken from the catalogue of Kandilli Observatory and Earthquake Research Institute of Türkiye. The triangle denotes the largest dam of Türkiye. Information on the map is compiled from Barka and Kadinsky-Cade (1988), Ambraseys (1989), Taymaz et al. (1991), McClusky et al. (2000), Emre et al. (2013), Tan et al. (2011), Utkucu et al. (2018, 2023). NAFZ: North Anatolian Fault Zone, EAFZ: East Anatolian Fault Zone, DFZ: Dead Sea Fault Zone, NB: Northern Branch of the EAFZ

Table 1. The hypocentral and source parameters of the 2023 Gaziantep and Elbistan earthquakes obtained by different seismological institutes.

Date	Origin Time	Lat (°)	Long (°)	Depth (km)	Mw (GCMT)		NP1 Strike (°)	NP1 Dip (°)	NP1 Rake (°)	NP2 Strike (°)	NP2 Dip (°)	NP2 Rake (°)	CMT Depth (km)	İnstitution
FEBRUARY, 6 2023, MAINSHOCK_1, 01:17 Mw7.7														
06.02.2023	01:17:35	37,1736	37,032	17,9	7,8		228	89	-1	318	89	-179	17,5	USGS
06.02.2023	01:17:31	37,1123	37,1195	5	7,7		222	64	-27	324	65	-152		KOERI
06.02.2023	01:17:32	37,288	37.043	8,6	7,7									AFAD
06.02.2013	01:18:10	37,56	37,47	14,9	7,8		54	70	11	320	80	160		GCMT
FEBRUARY, 6 2023, THE LARGEST AFTERSHOCK, 01:28 Mw6.7														
06.02.2023	01:28:15	37,127	36,943	14,5	6,7									USGS
06.02.2023	01:28:16	37,304	36,920	6,2	6,6									AFAD
06.02.2023	01:28:21	37,18	36,85	25	6,8									GCMT
FEBRUARY, 6 2023, MAINSHOCK_2 10:24 Mw7.5														
06.02.2023	10:24:49	38,024	37,203	10,0	7,5		277	78	4	186	87	168	13,5	USGS
06.03.2023	10:24:46	38,0717	37,2063	5	7,5									KOERI
06.02.2023	10:24:47	38,089	37,239	7	7,6									AFAD
06.02.2023	10:24:59	38,11	37,22	12	7,7		261	42	-8	358	84	-137		GCMT

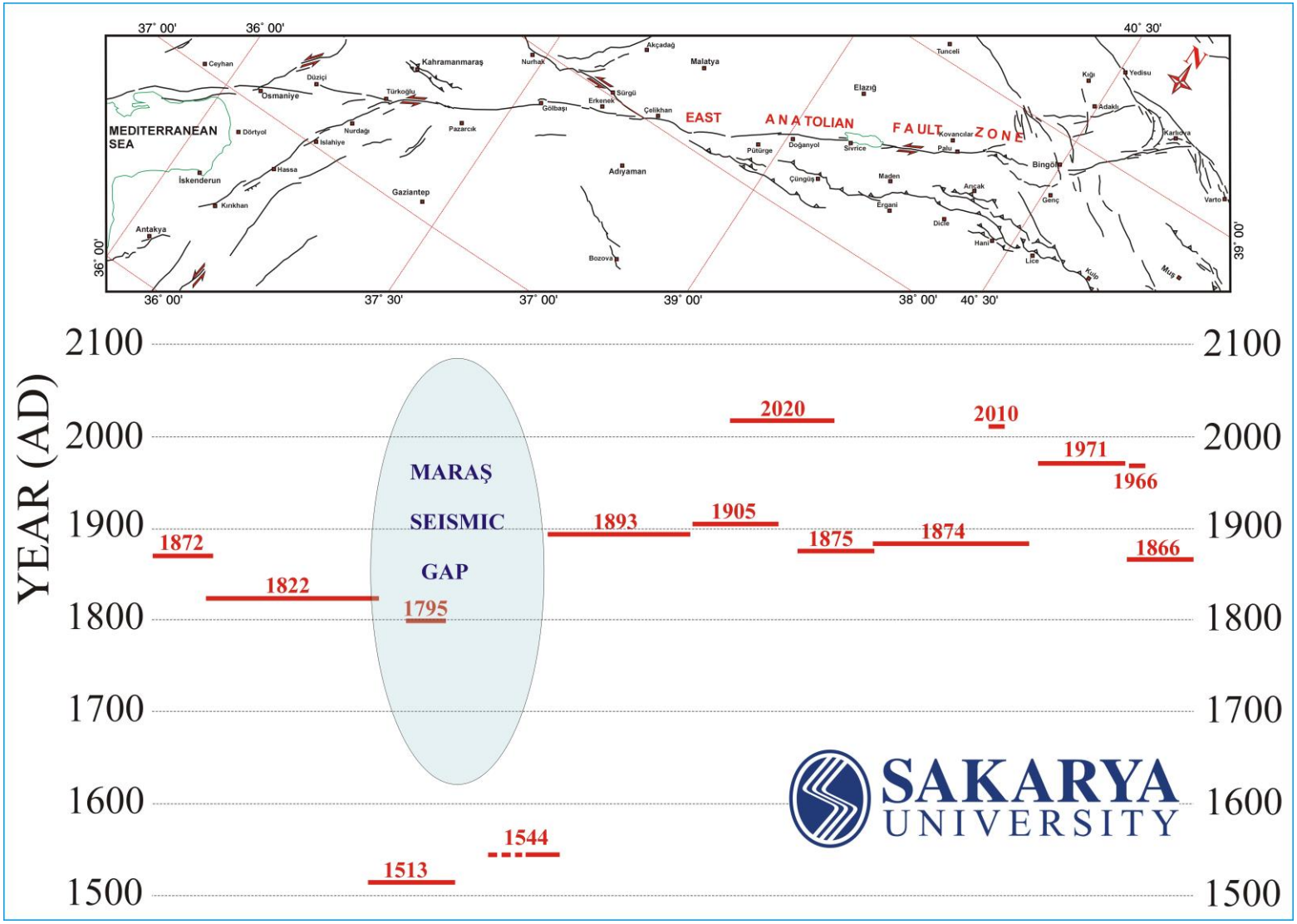

Figure 2. Earthquake occurrence model of the East Anatolian Fault Zone after the 1513 Kahramanmaraş earthquake.

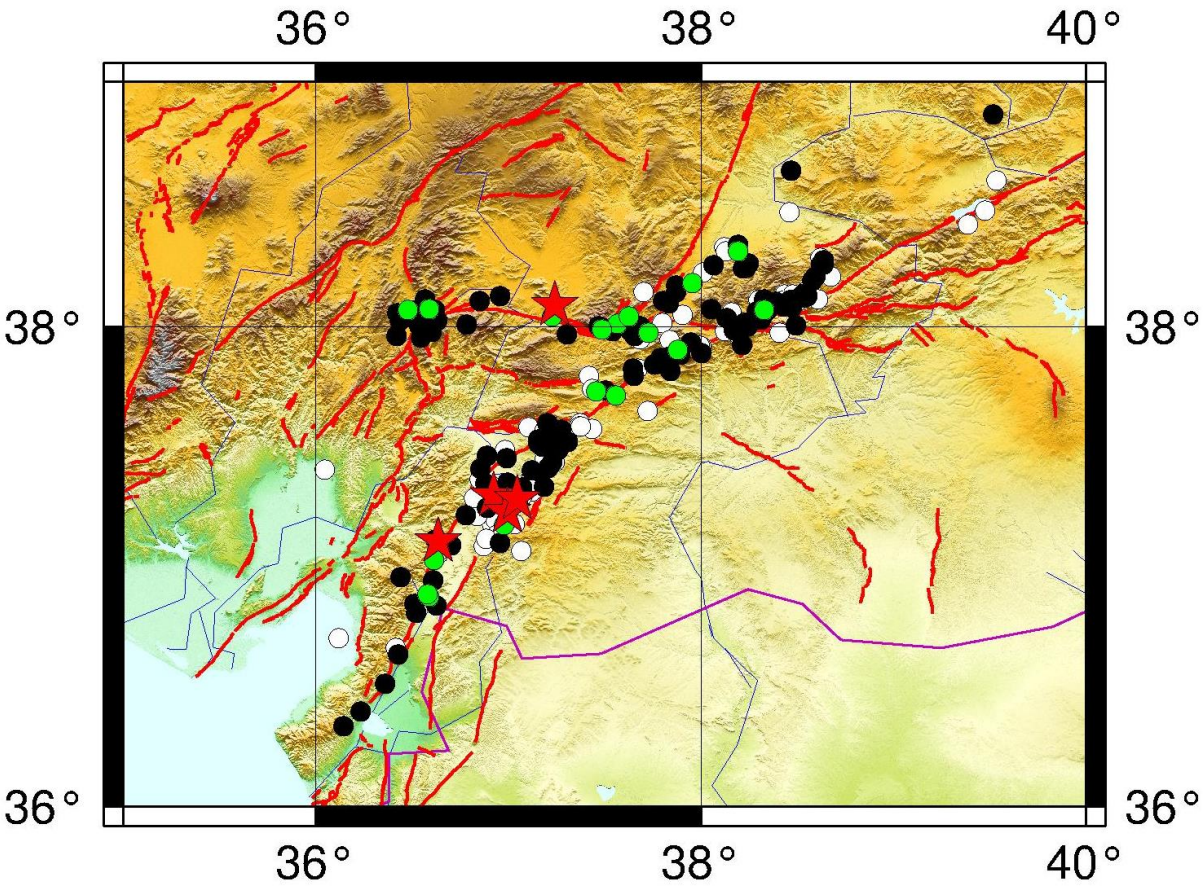

Figure 3. The 2023 Gaziantep and Elbistan earthquake sequence as located by AFAD of Türkiye. The stars depict the Mw≥6.0 shocks, while green, black and white circles represent 5.0≤*M*w<6.0, 4.0≤*M*w<5.0 and *M*w<4.0 aftershocks, respectively.

The EAFZ and the North Anatolian Fault Zone (NAFZ) are continental strike-slip faults that undertake westward movement of the Anatolian Plate with frequent generation of large destructive earthquakes (Figures 1 and 2) (Barka and Kadinsky-Cade 1988; Ambraseys 1989; Taymaz et al. 1991; Hubert-Ferrari et al. 2003; Şengör et al. 2005; Ambraseys 2009; Bulut et al. 2012; Duman and Emre 2013). The EAFZ constitutes the southern boundary of the Anatolian plate and is a sinistral fault extending between Karlıova in the north, where it connects with the NAFZ, and Antakya, where it meets with the Dead Sea Fault (Figure 1) (Barka and Kadinsky-Cade 1988; Duman and Emre 2013). Additionally, it has a branch, called the Northern Branch, separates from the main fault in the immediate west of the Çelikhan and extends through Adana Basin to the Mediterranean Sea (Figures 1 and 2) (Westaway 2004; Duman and Emre 2013; Seyrek et al. 2014). GPS studies indicate 9-10 mm/year slip rate for the EAFZ (McClusky et al. 2000; Reilinger et al. 2006; Aktuğ et al. 2016), about one third of which is shared by the Northern Strand after the bifurcation (Westaway 2004; Altunel et al. 2009; Mahmoud et al. 2012; Emre et al. 2013). The geologic slip rate of about 8 mm/year has also been proposed from the data coming from the field studies (Herece 2008; Duman and Emre, 2013).

The EAFZ was relatively quiescent in the 20th century comparing to its activity in the 19th century as indicated by the historical seismicity studies (Ambraseys 1989; Nalbant et al. 2002). Only the 1905 Malatya and 1971 Bingöl earthquakes occurred along the EAFZ in the 20th century. Recent occurrence of the 2003 Bingöl, 2010 Başyurt and 2020 Sivrice-Doğanyol earthquakes and current occurrence of the 2023 Gaziantep and Elbistan earthquakes suggest that the fault is much more active in the 21st century. In this preliminary report Coulomb stress background of the 2023 earthquakes are studied to search for stress interactions of those earthquakes with the earthquakes in the past.

The Background Coulomb Stress Changes of the 2023 earthquakes

The fault segments in the Maraş seismic Gap that produced the 2023 Gaziantep earthquake were lastly and partly ruptured by the both 1114 and 1513 earthquakes (Ambraseys 1989; Ambraseyss 2009; Yönlü 2012). This fact indicates that these fault segments unruptured for at least about 500 years and constitutes a seismic gap (Fig. 3). The fault segments that produced the 2023 Elbistan earthquake were lasly ruptured by the 1544 earthquake. Regarding this fact 1513 and 1544 are chosen as time treshhold in the past. The 2023 Gaziantep earthquake is considered to rupture the 1114, 1513 and 1822 earthquake rupture segments while the 2023 Elbistan earthquake is deemed to rupture the 1544 earthquake rupture segments. The results of coseismic stress changes are depicted in Figs 4-8. In these figures, enhancement and reduction in the stresses are represented with red and blue colours, respectively.

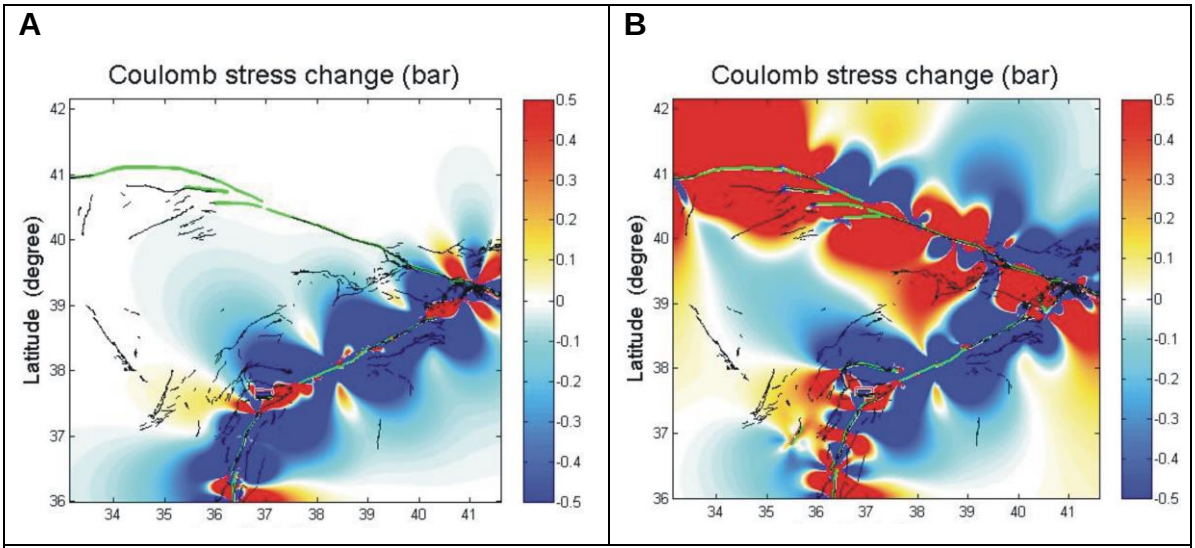

Figure 4. (a) The stress changes caused by the earthquakes after the 1795 Kahramanmaraş earthquake that occurred along the EAFZ. The stress changes are estimated along the faults with strike 218°, dip 90° and rake 0°, representing the southern segment of the 1513 earthquake. **(b)** The stress changes imparted by the earthquakes occurred along the NAFZ and EAFZ after the 1513 Kahramanmaraş earthquake earthquakes. The stress changes are estimated along the faults with strike 237°, dip 90° and rake 0°, representing the general strike of fault segments within the Maraş Seismic Gap. Faults are from Emre et al. 2013. The stress changes are in bar units.

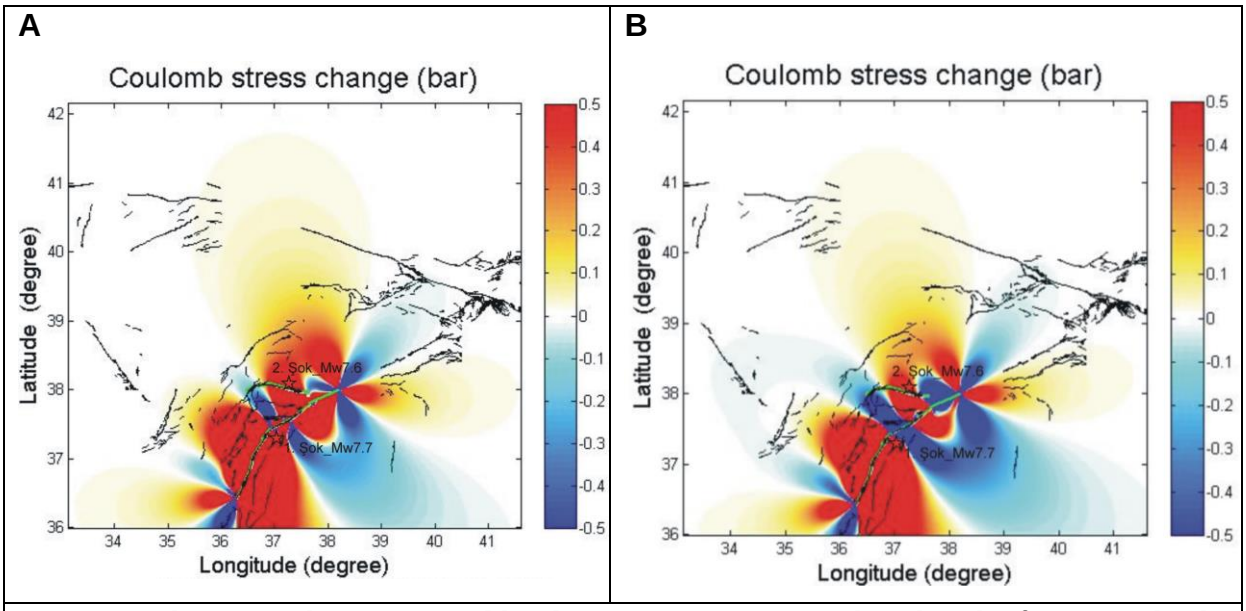

Figure 5. The stress changes caused by the 2023 Gaziantep earthquake (the first mainshock) calculated **(a)** along a fault with parameters 285º, dip 90º and rake 0º, representing the fault segment that host the 2023 Elbistan earthquake's (the second mainshock) epicenter, and **(b)** along a fault with parameters 274º, dip 90º and rake 0º.

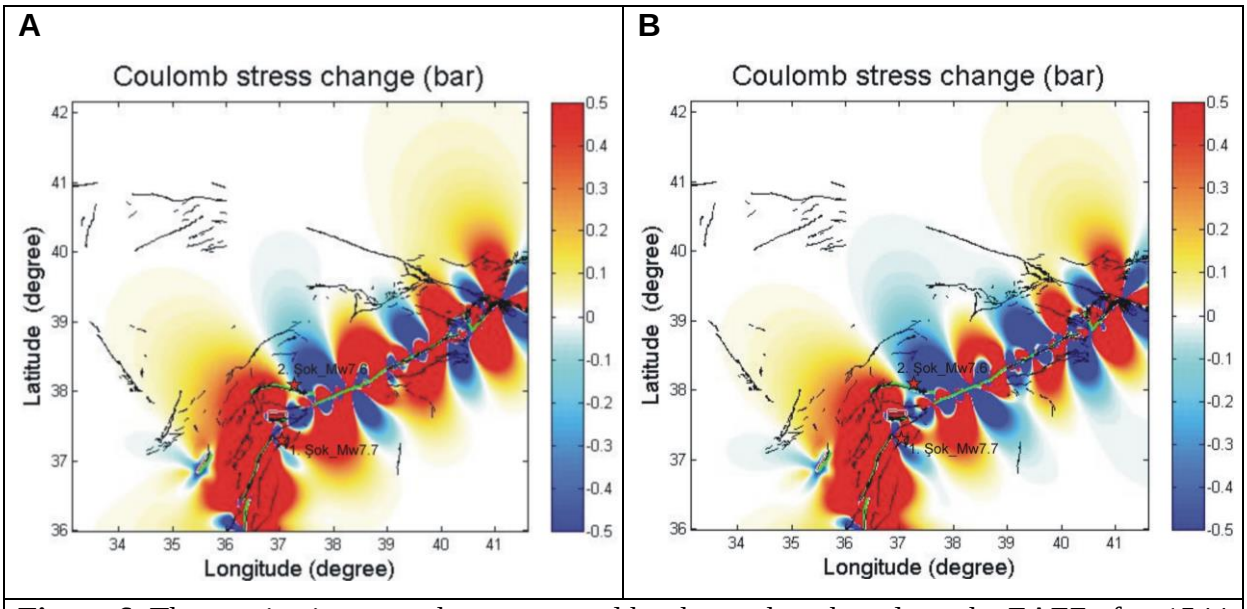

Figure 6. The coseismic stress changes caused by the earthquakes along the EAFZ after 1544 calculated **(a)** along a fault with parameters 285º, dip 90º and rake 0º, representing the fault segment that host the 2023 Elbistan earthquake's (the second mainshock) epicenter, and **(b)** along a fault with parameters 274º, dip 90º and rake 0º.

Figure 4 indicates that the Maraş Seismic Gap under the stress load caused by the earthquakes along the EAFZ alone and the earthquakes along the both EAFZ and NAFZ, giving a reasonable ground for interactions of the current earthquakes with the background earthquakes. Figure 5 apparently shows that the 2023 Elbistan earthquake (the second mainshock) is triggered by the 2023 Gaziantep earthquake. Nevertheless, Figure 6 suggests that the 2023 Elbistan earthquake's epicentre is under the stress shadow of the all of the earthquakes along the EAFZ after 1544. When the earthquakes occurred along the NAFZ

are added to the the earthquakes along the EAFZ results apparently indicates strong correspondance between the background coseismic stress changes and the occurrence of the 2023 Elbistan earthquake.

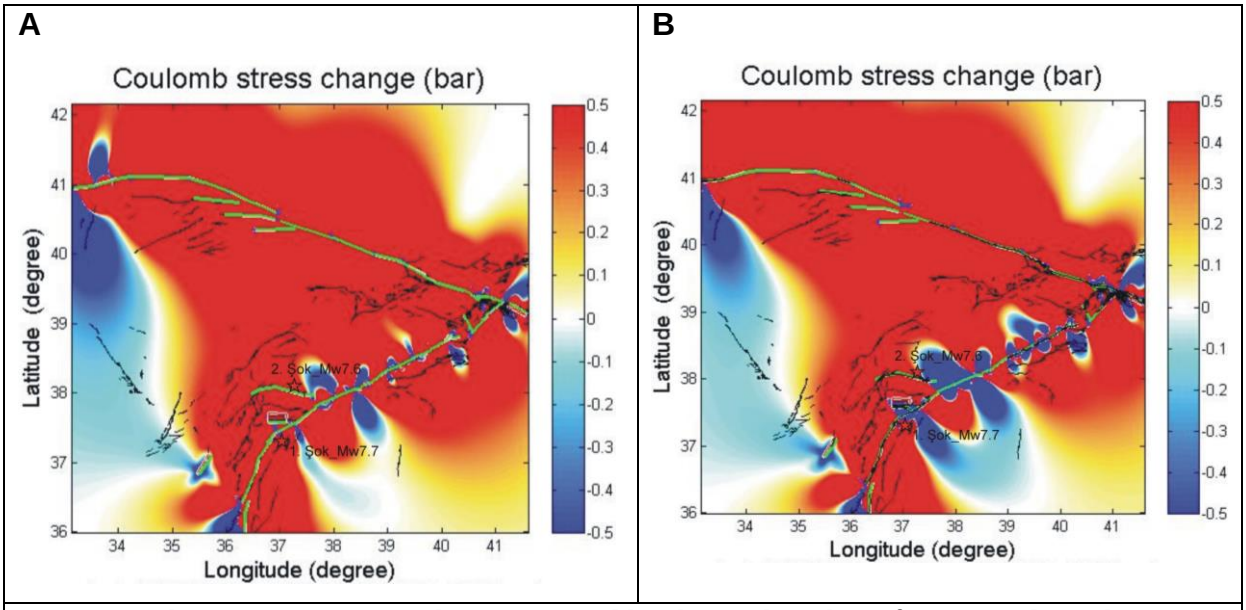

Figure 7. The coseismic stress changes caused by the earthquakes after 1544 along the NAFZ and EAFZ calculated **(a)** along a fault with parameters 285º, dip 90º and rake 0º, representing the fault segment that host the 2023 Elbistan earthquake's (the second mainshock) epicenter, and **(b)** along a fault with parameters 274º, dip 90º and rake 0º.

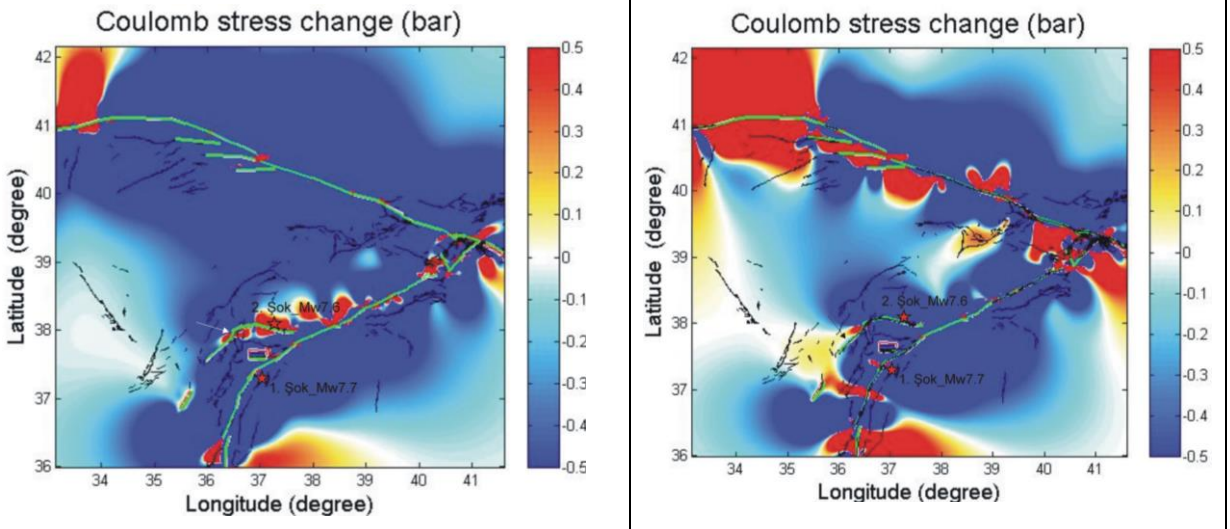

Figure 8. The coseismic stress changes caused by the earthquakes after 1544 along the NAFZ and EAFZ calculated **(a)** along a fault with parameters 203º, dip 90º and rake 0º and **(b)** along a fault with parameters 228º, dip 90º and rake 0º. Both fault segments represent the EAFZ northern strand's south continuation.

Finally, the coseismic stress changes resulted from the all earthquakes along the NAFZ and EAFZ after 1544 are calculated along the fault segments constituting southern continuation of the Northern Branch of the EAFZ (Figure 8). Notice that the fault continuation is generally

under stress shadow with exception of its northern part, suggesting that this section of the fault branch is not get close to trigger by the total stress changes of the previous earthquakes.

Concluding Remarks

The part of the EAFZ where the 2023 Gaziantep and Elbistan earthquakes occurred was lastly broken by the earthquakes of 1114 and 1513, and since then there has been no earthquakes for at least 500 years. This part has been classified as a seismic gap by earth science studies. It is understood that this assessment is correct, as these two large and destructive earthquakes filled the gap. This fact demonstrates the importance of earthquake science studies in Türkiye.

Coseismic stress change calculations indicate that the stress changes caused by the 2023 Gaziantep earthquake triggered the 2023 Elbistan earthquake rupture. Additionally, there is a strong correspondence by means of earthquake stress interaction between the NAFZ and the EAFZ.

The magnitude of the earthquakes, their impact areas and the interruption in socio-economic life reveal the significance of the earthquake risk in Türkiye, and proves again the fact that " Türkiye is an earthquake country".

Acknowledgement

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References

AFAD (2023). www.afad.gov.tr

Aktuğ B, Özener H, Dogru A, Sabuncu A, Turgut B, Halicioglu K,Yilmaz O, Havazli E (2016). Slip rates and seismic potentialon the East Anatolian Fault System using an improved GPSvelocity field. J Geodynamics 94-95: 1-12

Altunel E, Meghraoui M, Karabacak V, Akyüz S H, Ferry M, Yalçıner Ç, Munschy M (2009). Archaeological sites (tell and road) offset by the dead sea fault in the Amik Basin, southern Turkey. Geophys J Int 179(3), 1313-1329

Ambraseys N N (1989). Temporary seismic quiescence: SE Turkey. Geophys J Int 96(2), 311-331

Ambraseys N N (2009). Earthquakes in the Mediterranean and Middle East: a multidisciplinary study of seismicity up to 1900. Cambridge University Press

Barka A A, Kadinsky-Cade K (1988). Strike-slip fault geometry in Turkey and its influence on earthquake activity. Tectonics 7(3) 663-684

Bulut F, Bohnhoff M, Eken T, Janssen C, Kılıç T, Dresen G (2012). The East Anatolian Fault Zone: Seismotectonic setting and spatiotemporal characteristics of seismicity based on precise earthquake locations. J Geophys Res-Sol Ea doi:10.1029/2011JB008966

Duman TY, Emre Ö (2013). The East Anatolian Fault: geometrysegmentation and jog characteristics. Geol Soc London SpecPubl 372: 495-529

Emre Ö, DumanTY, Özalp S, Elmacı H, Olgun Ş, Şaroğlu F (2013). Active Fault Map of Turkey. General Directorate of Mineral Research and Exploration, Special Publication Series-30. Ankara Turkey

Hubert-Ferrari A, King G, Manighetti I, Armijo R, Meyer B, Tapponnier P (2003). Long-term elasticity in the continental lithosphere; modelling the Aden Ridge propagation and the Anatolian extrusion process. Geophys J Int 153(1), 111-132

KOERI (2023) 06 Şubat 2023 Sofalaca Şehitkamil Gaziantep Depremi Basın Bülteni. B.Ü. Kandilli Rasathanesi ve Deprem Araştırma Enstitüsü Bölgesel Deprem-Tsunami İzleme ve Değerlendirme Merkezi, İstanbul Şubat 2023, 4 sayfa

Mahmoud Y, Masson F, Meghraoui M, Cakir Z, Alchalbi A, Yavasoglu H et al (2013) Kinematic study at the junction of the East Anatolian fault and the Dead Sea fault from GPS measurements. J Geodyn 67, 30-39

McClusky S, Balassanian S, Barka A, Demir C, Ergintav S, Georgiev I et al (2000) Global Positioning System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus. J Geophys Res-Sol Ea 105(B3), 5695-5719

Milkereit C, Grosser H, Wang R, Wetzel H U, Woith H, Karakisa S et al (2004) Implications of the 2003 Bingoel Earthquake for the interaction between the North and East Anatolian faults. Bull seism Soc Am 94(6), 2400-2406

Nalbant S S, McCloskey J, Steacy S, Barka A A (2002) Stress accumulation and increased seismic risk in eastern Turkey. Earth Planet Sc Lett 195(3), 291-298

Reilinger, R., McClusky, S., Vernant, P., Lawrence, S., Ergintav, S., Çakmak, R., Özener, H., Kadirov, F., Guliev, I., Stepanyan, R., Nadariya, M., Hahubia, G., Mahmoud, S., Sakr, K., ArRajehi, A., Paradissis, D., Al-Aydrus, A., Prilepin, M., Guseva, T., Evren, E., Dmitrotsa,A., Filikov, S.V., Gomez, F., Al-Gha R. and Karam, G., 2006. GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for thedynamics of plate interactions. Journal of Geophysical Research, 111, B05411, doi:10.1029/2005JB004051.

Şengör A M C, Tüysüz O, İmren C, Sakınç M, Eyidoğan H, Görür N et al (2005) The North Anatolian fault: A new look Annu Rev Earth Planet Sci 33, 37-112

Seyrek A, Demir T, Westaway R, Guillou H, Scaillet S, White T S, Bridgland D R (2014) The kinematics of central-southern Turkey and northwest Syria revisited. Tectonophysics 618, 35-66

Taymaz T, Eyidoğan H, Jackson J (1991) Source parameters of large earthquakes in the East Anatolian Fault Zone (Turkey). Geophys J Int 106(3), 537-550

Tan O (2021) A Homogeneous Earthquake Catalogue for Turkey. Nat. Hazards Earth Syst. Sci. 21, 2059–2073, 10.5194/nhess-21-2059-2021

Tan O, Pabucçcu Z, Tapırdamaz C, İnan S, Ergintav S, Eyidoğan H, Aksoy E, Kuluöztürk F (2011) Aftershock study and seismotec-tonic implications of the 8 March 2010 Kovancılar (Elazığ, Turkey) earthquake (Mw = 6.1), Geophys. Res. Lett., 38, L11304, doi:10.1029/2011GL047702.

USGS NEIC 2023. https://earthquake.usgs.gov/earthquakes/eventpage/us6000jllz/executive

Utkucu M, Budakoğlu E, Çabuk M (2018) Teleseismic finite-fault inversion of two Mw=6.4 earthquakes along the East Anatolian Fault Zone in Turkey: the 1998 Adana and 2003 Bingöl earthquakes. Arab J Geosci 11, 721. https://doi.org/10.1007/s12517-018-4089-y

Utkucu, M., Kurnaz T.F. and İnce Y., (2023) The seismicity assessment and probabilistic seismic hazard analysis of the plateau containing large dams around the East Anatolian Fault Zone, Eastern Türkiye. Submitted to Environmental Earth Sciences.

Westaway R (2004) Kinematic consistency between the Dead Sea Fault Zone and the Neogene and Quaternary left-lateral faulting in SE Turkey. Tectonophysics 391(1), 203-237