6 FEBRUARY 2023 KAHRAMANMARAŞ (PAZARCIK, Mw:7.7 and ELBİSTAN, Mw:7.6) and SAMANDAĞ (Mw:6.3) EARTHQUAKES, SE TÜRKİYE

Süha ÖZDEN¹, Tolga BEKLER², Alper DEMİRCİ², Özkan ATEŞ³, Seray ÇINAR YILDIZ⁴

¹Department of Geological Engineering, Çanakkale Onsekiz Mart University, 17100, Çanakkale, Turkey ²Department of Geophysical Engineering, Çanakkale Onsekiz Mart University, 17100, Çanakkale, Turkey ³Çan Vocational School, Çanakkale Onsekiz Mart University, 17400, Çan, Çanakkale, Turkey ⁴School of Graduate Studies, Çanakkale Onsekiz Mart University, 17100, Çanakkale, Turkey Corresponding Author: ozden@comu.edu.tr

Abstract

There were two major earthquakes on the Eastern Anatolian Fault (EAF) and its segments on February 6, 2023, with magnitudes of Mw: 7.7 (Pazarcık) and Mw: 7.6 (Elbistan). There was another earthquake with a magnitude of Mw: 6.3 (Samandağ) on February 20, 2023. There have been many devastating earthquakes in the region throughout the historical and instrumental period. During these earthquakes have seen important left lateral displacements on the fault segments along the EAF. The distribution of the February 6 earthquakes and the aftershocks clearly revealed the broken fault segments (Pazarcık, Erkenek, Amanos, Çardak) in the region. Within the scope of the study, significant displacements were measured on fault segments that broke during earthquakes. The data obtained in the field and the focal mechanism solutions of the earthquakes show that, as a result of the collision of the Eurasian and Arabian Plates in this region, a compressional tectonic regime in approximately N-S direction is still active today and this tectonic regime result in a transtensional character. These earthquakes showed that the Arabian Plate, separated from the African Plate, moved to the north and the Anatolian Plate (block) moved to the west.

Keywords: Kahramanmaraş, East Anatolia Fault, Earthquakes, Surface Ruptures

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I. INTRODUCTION

The Earth's crust has been constantly changing and renewing in terms of shape, form and content for millions of years. In this process, the stress (energy) accumulated in the earth's crust results in tectonic deformation (earthquakes). Earthquakes have been effective not only in human history but also before. In Anatolia; there have been very large earthquakes in prehistoric, historical and instrumental periods. Among these earthquakes, the most destructive earthquake known in the historical period is the Great Anatolian earthquake that occurred in 1668 (It is known that the magnitude of this earthquake was 8 and created a surface fracture of approximately 600 km in length (KRDAE; Zabcı et al., 2011). Starting from the 1912 Mürefte (Şarköy) and 1939 Erzincan earthquakes on the North Anatolian Fault in the instrumental period, the traces of deformations caused by large earthquakes that occurred within the borders of Turkey in the last century, scientific evaluations can be made about the next earthquake or earthquakes. In particular, thanks to the field data related to the 1999 Kocaeli and Düzce earthquakes (Mw: 7.4; 7.2), it is tried to prevent loss of life and property before the next earthquake by determining new construction areas in these regions, reducing risks and making changes in earthquake regulations.

In this study, the significant displacements caused by the February 6 Kahramanmaraş earthquakes were recorded by following the surface ruptures on the earth's surface. It was also tried to reveal which fault segments were affected by these earthquakes (Figure 1).

II. RESULT AND DISCUSSION

2.1. Current Tectonics and Geodynamics of the Region

Geologically, the Anatolian Block (Anatolian micro plate) is located within the Alpine-Himalayan Mountain Belt (continental-continental collision front). The part of this collision front within Anatolia is bounded by the Lavrasian Plate to the north and the African and Arabian Plates to the south. For the last ten million years, the Anatolian Micro Plate has been caught between the southward movement of the Lavrasian Plate and the northward movement of the African and Arabian Plates that broke away from it. The Anatolian Block has been trying to escape this compression by moving westward. About five million years ago, the right-lateral strike-slip North Anatolian Fault bounding Anatolia from the north and the left-lateral strike-slip East Anatolian Fault bounding from the south were formed (Şengör and Yılmaz, 1981). These two faults have been behaving in a similar manner and producing earthquakes for the last few million years. Thus, the Anatolian Block has been sliding westward from the eastern continental collision front (Figure 1).



Figure 1. Location of the study areas in the geodynamics of Anatolia

However, another fault in the Eastern Mediterranean is the left-lateral strike-slip Dead Sea Fault. This fault bounds the Arabian and African Plates. Within the Mediterranean Sea, the boundary between the Anatolian and African Plates starts from Antakya, passes south of Cyprus and continues westward. Today, this boundary operates as a fault with a left-lateral strike-slip component (Figure 1). At the crustal scale, there are many areas where three plates come together (Triple Junctions). One of these is located in Turkey. The Amik Plain is a junction point where the Anatolian-African-Arabian Plates come together (Över et al., 2004). This region is the only example of three plates coming together in the terrestrial environment on Earth. Amik Plain is a depression area formed in this way.

The main fault in the earthquake zone is the Eastern Anatolia Fault and its segments (Figure 2). These segments start from Karliova in the east and extend to Antakya in the south. These are Pütürge, Erkenek, Sürgü-Çardak, Pazarcık, Amanos and Antakya (Samandağ) segments or faults (Figure 2).

2.2. Historical and Instrumental Period Earthquake Activity of the Region

The region has experienced major earthquakes in historical and instrumental periods (Figure 2). Two large earthquakes were recorded on the Amanos segment in 1822 and 1872. Similar large earthquakes were recorded on Pazarcık and Erkenek segments in 1114, 1513 and 1893. The last major earthquake was recorded in 1544 on the Çardak Fault, which is a splay fault and separated from the East Anatolian Fault. Thus, it is seen that there has been no earthquake on the Eastern Anatolia Fault, especially on the Pazarcık and Çardak faults for 500 years, this is a serious seismic gap and the two major earthquakes in 2023 occurred on these two faults. Although there have been earthquakes in the last century in Adana in 1998 and Elazığ in 2020, it is known that the Eastern Anatolia Fault has been silent for a very long time. Although 150-200 years have passed since the last two earthquakes on the Amanos segment, this fault was also broken in the first earthquake on February 6, 2023.



Figure 2. Historical and instrumental earthquakes in the study area (Revised from Över et al., 2023).

2.3. February 6, 2023 Mw:7.7 (Pazarcık), Mw:7.6 (Elbistan) and February 20, 2023 Mw:6.3 (Samandağ) Earthquakes

The epicenter of the Pazarcık earthquake falls just to the SE of Türkoğlu, at the junction of the Pazarcık and Amanos segments. During this earthquake, Pazarcık-Erkenek and Amanos segments ruptured. The earthquake occurred at a depth of 10 km. A 6.7 magnitude aftershock occurred minutes after this earthquake. The epicenter of the Elbistan earthquake was located near Nurhak and broke the Çardak Fault. This earthquake also occurred at a depth of 10 km. The Elbistan earthquake occurred only 8 hours after the first earthquake. Thousands of aftershocks occurred after both earthquakes. The aftershocks were mostly on the faults that broke. The Samandağ earthquake occurred just GB of Hatay and is thought to be related to the Cyprus-Antakya Transform Fault (CAT) (Figure 3 and Table 1).



Figure 3. View of the earthquakes of 6 February 2023 (7.7 and 7.6) and 20 February 2023 (6.3) and the aftershocks that occurred with a magnitude greater than 4.0, as well as the compression-expansion directions of the earthquakes

Event ID	Date	Origin Time (UTC)	Lat (Degree)	Long (Degree)	Mw	Depth (km)	NP1 (Str/Dip/Rake)	NP2 (Str/Dip/Rake)	References
1	06.02.2023	01:17:35	37.13	37.13	7.7	10	324/65/-152	222/64/-27	KOERI
2	06.02.2023	10:24:48	38.05	37.26	7.6	10	273/67/-9	6/81/-157	KOERI
3	20.02.2023	17:04:29	36.16	36.02	6.3	16	330/68/-143	225/56/-25	KOERI

Table 1. Parameters of the earthquakes of February 6, 2023 (7.7 and 7.6) and February 20, 2023 (6.3)

2.4. Surface Ruptures and Pulse Distributions of the February 6 Earthquakes

In the literature, the Pazarcık Segment starts from Türkoğlu in the west, passes through the north of Pazarcık in the east and passes to the Erkenek segment in the east. On the Pazarcık segment, left lateral displacements were measured at Türkoğlu (333 cm), Kıllı village (410 cm), Pazarcık south (410 cm), Pazarcık center (430 cm) and Gölbaşı (400 cm) (Kürçer et al., 2023). Gölbaşı is a depression area where the left-lateral fault bounced to the left. The earthquake, which passed from here to the Erkenek segment, created many displacements on the Erkenek segment, and a left lateral displacement of 360 cm was measured in the northeast of Gölbaşı (Kürçer et al., 2023).

The Amanos segment (Fault), which is approximately 110 km long and strikes N30°E, extends between Türkoğlu (Kahramanmaraş) in the northeast and Kırıkhan (Hatay) in the southwest. The lengths of surface ruptures measured on the Amanos Fault vary between a few 100 m and a few km. The largest displacement on the surface fracture that developed along this fault was measured as a left lateral slip of 460 cm in Altınözüm village, located around Hassa (Kürçer et al., 2023). However, along the fault, from south to north, Kırıkhan (220 cm), Hassa (330 cm), Yeşilyurt (450 cm), Altınözüm (460 cm), İslahiye (160 cm), Nurdağı (250 cm), Beşpınar (320 cm), Left lateral pulses and vertical displacements of up to 1 m developed as far as Bademli

(360 cm), Şekeroba (280 cm) and Türkoğlu (180 cm) (Kürçer et al., 2023). In addition, during the 06 February 2023 Pazarcık (Kahramanmaraş) Earthquake (Mw: 7.7), the ductile deformation that occurred on the train tracks east of Şekeroba village, northwest of Nurdağı district center, occurred along a line in the N45°E direction with a displacement of 370 cm.

The Narlı segment is approximately 20 km long and extends southwards, starting from Narlı (N20°E). On this segment, Kürçer et al. (2023) detected left lateral displacements, the largest of which was 325 cm.

An earthquake of magnitude Mw:6.4 and a depth of 16 km occurred on 20.02.2023 at 20.04 local time, with the earthquake epicenter in Defne (Hatay). In the approximately 20-hour period following the 20.02.2023 Defne (Hatay) earthquake Mw:6.4, a series of earthquakes with magnitudes ranging from Mw:3.0 to 5.2 occurred. 20.02.2023 Defne (Hatay) earthquake (Mw: 6.4) occurred in the approximately 22 km long northern segment of the 45 km long Antakya Fault Zone. According to the earthquake focal mechanism solutions, it was evaluated that the earthquake in question was caused by a north-east-southwest oriented, northwest-inclined oblique-slip normal fault with a left-lateral strike-slip component. Focal mechanism solutions of the main earthquake may be the northern part of the Antakya Fault Zone. Antakya Fault Zone is an active oblique-slip fault zone that extends from the northeast of Antakya to the west of Yayladağı, generally consisting of North and South fault segments, presenting a fragmented geometry in places, extending in the N40°E direction and inclined to the northwest. At the same time, this zone is the starting point of the left-lateral Cyprus-Antakya transform fault. Examinations along the entire fault zone, from the foothills of Nacar Mountain in the north to the west of Yayladağı in the south, revealed that no surface rupture occurred in this earthquake (MTA Report, 2023).

The Narlı segment is approximately 20 km long and extends southwards, starting from Narlı (N 200 E). On this segment, Kürçer et al. (2023) detected left lateral displacements, the largest of which was 325 cm.

After the February 06, 2023 Elbistan (Kahramanmaraş) Earthquake (Mw:7.6), there was an aftershock distribution starting from Malatya Yeşilyurt in the east to Doğanşehir, Nurhak, Ekinözü, Çardak and Göksun respectively towards the west. This earthquake took place on the Çardak Fault between Nurhak and Çardak. Seismic data show that the earthquake first broke the E-W trending Çardak fault and continued eastwards towards Malatya via the NE-SW trending Doğanşehir fault zone (Özacar et al., 2023). The total length of the rupture formed by the main shock is approximately 160 km, and large surface displacements of the order of 2-8 m are observed in the field (Özacar et al., 2023). The Sürgü Fault was not ruptured in these earthquakes. A 58 km long surface rupture occurred along the Nurhak Fault, and the largest left lateral displacement in this earthquake was measured as 670 cm in the north of Nurhak and east of the Çardak Fault (Akyüz et al., 2023).

The displacements that occur after earthquakes are the traces they leave behind at different points and especially in cultural artifacts. Data obtained from different studies are presented above. Within the scope of this study, the displacements on the faults after both earthquakes were determined on site.

In this study; On the Amanos and Pazarcık segments of the 06 February 2023 Pazarcık (Kahramanmaraş) Earthquake (Mw:7.7); 90 cm on the road in front of the cemetery at Alibeyçağıllı (Kırıkhan, Hatay) Village Headman's Office (Figure 4a), 295 cm on the Hassa (Hatay) central cobblestone road (Figure 5b), 254 cm on the Akbez (Hassa, Hatay) road (Figure 5c), Yeşilyurt Village (Islahiye, Gaziantep) garden fences measured 278 cm (Figure 5d). Towards the north, 167 cm on the Islahiye (Gaziantep) State Hospital Road (Figure 6a), 259 cm on the Nurdağı (Gaziantep) Aşağıolucak Village Cemetery side road (Figure 6b), 190 cm on the northern exit channel of Narlı town (Pazarcık, Kahramanmaraş) (Figure 6c) and Narlı The formation of a two-way fracture (Figure 6d) was detected at the northern exit of the town.

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Figure 4. (a) Alibeyçağıllı (Kırıkhan, Hatay) Village Road in front of the cemetery (UTM: 37 S 0266605-4054803), **(b)** Hassa (Hatay) central cobblestone road (37 S 0278604-4075776), **(c)** Akbez (Hassa, Hatay) road (37 S 0280649-4081480), **(d)** Yeşilyurt Village (Islahiye, Gaziantep) garden wire fences (37 S 0282502-4084680)



Figure 5. (a) Islahiye (Gaziantep) State Hospital Road (37 S 0289210-4102872), (b) Nurdağı (Gaziantep) Aşağıolucak Village Cemetery side road (37 S 0297055-4117046), (c) Narlı Town (Pazarcık, Kahramanmaraş) north exit channel (37 S 0336493-4141241), (d) Narlı Village northern exit three-way fracture (37 S 0336493-4141241).

The surface ruptures formed by the 06 February 2023 Elbistan (Kahramanmaraş) Earthquake (Mw:7.6) started from the west of Nurhak in the east and extended to Göksun in the west. On this fault; Left lateral pulses of 557 cm (Figure 6a-b) were measured on the stone wall in the field west of Barış Village (Nurhak, Kahramanmaraş) and 540 cm (Figure 6c) on the garden wire fence west of Barış District. Additionally, vertical displacements were observed along the surface fracture on the side of the main road west of Barış Village.



Figure 6. (a) Stone walls west of Barış Village (Nurhak, Kahramanmaraş) (37 S 0350350-4208683), (b) Google Earth Image of the left lateral slip in the masonry stone wall west of Barış Village (37 S 0350350-4208683), (c) Garden wire fence west of Barış Village (37 S 0348017-4208937) and (d) Vertical displacements along the surface fracture on the side of the main road west of Barış Village.

III. CONCLUSION

On February 6, 2023, two major earthquakes of magnitude Mw:7.7 and Mw:7.6 occurred in SE Anatolia, centered in Kahramanmaraş. These earthquakes affected 11 provinces in our Southeastern Anatolia Region. More than 50,000 people lost their lives in earthquakes. Earthquakes activated the Pazarcık, Erkenek and Çardak segments of the left lateral slip Eastern Anatolian Fault, which has not had an earthquake for 500 years, the Amanos segment, which has been silent for 150-200 years, and the Cyprus-Antakya Transform Faults. Left lateral displacements reaching 5 m in the first earthquake and 6 m in the second earthquake were observed. During the earthquakes in the region compressed in the N-S direction, the Arabian Plate moved towards the north and the Anatolian Plate moved towards the west-southwest.

Although it is seen that the stress accumulated in the region was largely released by these two earthquakes, after these earthquakes, stress started to be loaded on the Çardak Fault west to the south of Göksun, to the north of Erkenek around Malatya, and to the Akdeniz and Ölüdeniz faults in the south.

Damage resulting from earthquakes; In addition to the fact that the earthquakes are large and last long, the cities are built on active faults and the soils are not good, it has been observed that the construction in the region is not resistant to earthquakes. The construction to be done in the region after the earthquakes; According to the earthquake and building regulations, it is thought that ground improvement will be made in places deemed necessary, away from active faults, depending on the characteristics of the ground, and planning and construction with low-rise and horizontal architecture will reduce earthquake losses and damages.

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