6 FEBRUARY 2023 KAHRAMANMARAŞ – TÜRKİYE EARTHQUAKES: A GENERAL OVERVIEW

C. Gokceoglu[1]

[1] Dept. of Geological Engineering, Hacettepe University, 06800 Beytepe Ankara, Turkey - cgokce@hacettepe.edu.tr

KEY WORDS: Earthquake, Kahramanmaraş, Pazarcık, Elbistan, Landslide, Rockfall, Liquefaction.

ABSTRACT:

On 6 February 2023, two major earthquakes occurred in the East Anatolian Fault Zone (EAFZ) of Türkiye. The EAFZ forms the east border of the Anatolian Plate. The magnitude 7.7 and 7.5 Kahramanmaraş – Türkiye Earthquakes that struck southern Türkiye and resulted in common destruction in 11 provinces in the region. Total 6 main fault segments of the EAFZ ruptured during the earthquake sequence on 6 February 2023, and approximately 400 km surface rupture occurred. The life losses are reported as over 50000, and approximately 300,000 buildings were collapsed or severely damaged. In addition to damages on the buildings and the infrastructures, liquefactions, landslides, rockfalls, and rock avalanches were also observed during the earthquake sequence. The purpose of this study is to present a general overview on the 6 February 2023 Earthquake sequence.

1. INTRODUCTION

The Anatolian plate is bounded in the north by the North Anatolian Fault Zone (NAFZ) and in the east by the East Anatolian Fault Zone (EAFZ). As a result of the northward movement of the Arabian Plate, the Anatolian Plate between NAFZ and EAFZ moves approximately westward. As a result of the plate movement, in the last century, devastating earthquakes have occurred along the NAFZ. However, the EAFZ had produced relatively few earthquakes in the last 200 years when compared to historical records and has therefore accumulated significant stresses along its length (Nalbant et al., 2002). For this reason, some segments of the EAFZ were seismic gaps, and hence, the region was a high seismic potential. Consequently, some severe earthquakes were expected in the region (Nalbant et al., 2002; Gokceoglu, 2022; Can et al., 2022).

In the last century, only three earthquakes produced surface rupture. These are the 1971 Bingöl Earthquake (Ms=6.8), the 2010 Karakoçan Earthquake (Mw=6.1), and the 2020 Elazığ Earthquake (Mw=6.8). In addition, it is known that the EAFZ to the east of Lake Hazar was also ruptured by the 1874 Ms 7.1, 1875 Ms 6.7, and 1866 Ms 7.2 earthquakes (Ambraseys 1988; Emre et al., 2018). In addition to these earthquakes, before the instrumental period, severe earthquakes occurred along the EAFZ (Figure 1).

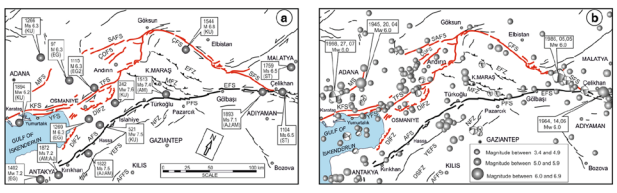

Figure 1. Fig. 2 Distribution of both historical (a) and instrumental (b) earthquakes along the southern segments of the EAFZ (taken from Duman et al., 2020)

As stated, the Erkenek, Pazarcık, Amanos, Antakya, Çardak and Sürgü segments of the EAFZ have not produced a significant earthquake but they have continued to buildup elastic strain energy, until February 6, 2023. On February 6, 2023, at 01:47 UTC, the Narlı, Erkenek, Pazarcık and Amanos segments ruptured and the Mw=7.7 Kahramanmaraş-Pazarcık earthquake occurred. Approximately 9 hours later at 10:24 UTC, the Mw=7.7 Kahramanmaraş-Elbistan earthquake occurred near Ekinözü due to rupture of the Çardak and Sürgü segments (Figure 2). As the results of the successive earthquakes, Kahramanmaraş, Adıyaman, Hatay, Osmaniye, Gaziantep, Kilis, Şanlıurfa, Diyarbakır, Malatya, Adana, and Elazığ were significantly affected. More than 50000 people died and approximately 300000 buildings were collapsed or heavily damaged. In addition to damages on the buildings and the infrastructures, surface ruptures, liquefactions, landslides, rockfalls, and rock avalanches were also observed commonly during the recent destructive earthquakes. The purpose of this study is to present a general overview on the 6 February 2023 Earthquake sequence.

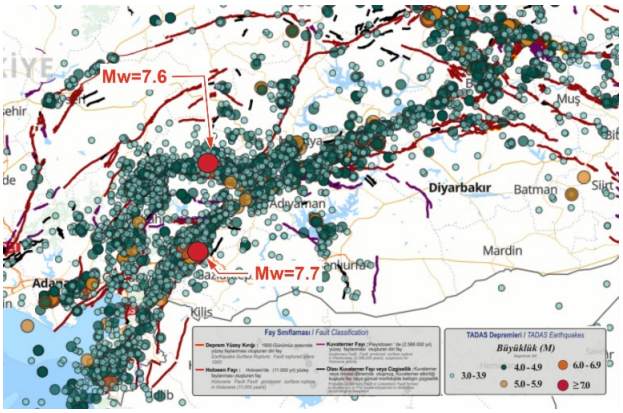

Figure 2. Epicenters of the 6 February 2023 Türkiye Earthquakes (AFAD, 2023)

2. GROUND FAILURES

2.1 Surface Ruptures

The Pazarcik earthquake was initiated on a smaller Narlı fault (326-1 in Figure 3) in the south, jumped to the north, and

ruptured the Pazarcık (2-6 in Figure 3) and Erkenek (2-5 in Figure 3) segments of EAFZ towards NE and the Amanos segment (2-7 in Figure 3) towards SW. This earthquake produced left-lateral surface ruptures and the displacements reached to 4 m (Figure 4).

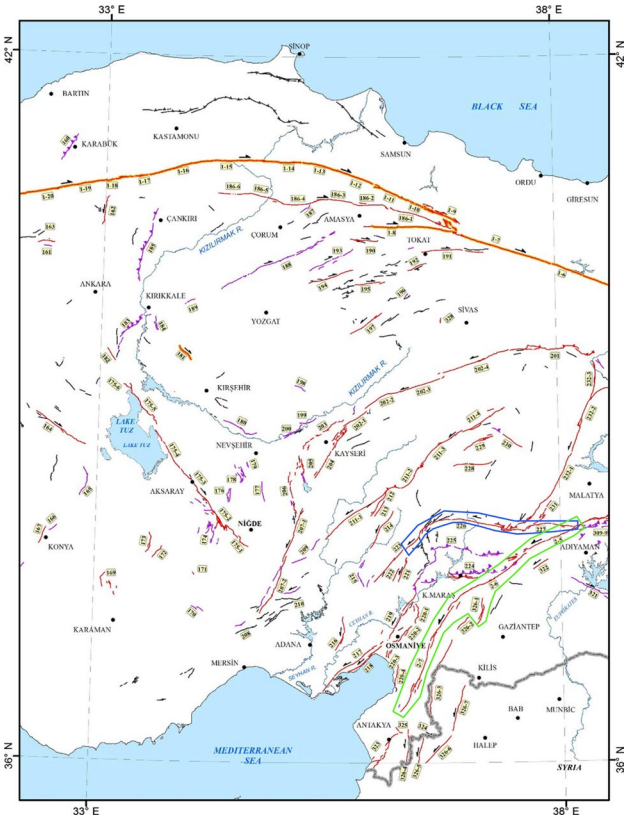

Figure 3. The ruptured segments of DAFZ (yellow frame shows the Pazarcik Earthquake while blue frame shows the Elbistan Earthquake) (modified after Emre et al., 2018).

Figure 4. Some views from the left lateral displacements occurred during the Pazarcık Earthquake.

The surface ruptures resulted in highway and railway damages and the transportation to the earthquake region was blocked. The Tarsus-Adana-Gaziantep Motorway (TAG) was cut by the displacement of the Amanos segment around Nurdağı (Figure 5).

Figure 5. The TAG Motorway cut by the surface rupture (TRT Haber, 2023)

The other important state road cut by the surface rupture is Gaziantep – Kahramanmaraş State Road (Figure 6). Access to the earthquake region was provided by secondary roads due to the highway and the state roads that were cut and damaged by the surface ruptures, which caused delays in the search and rescue efforts for the first few days after the earthquake.

Figure 6. The Gaziantep – Kahramanmaraş State Rod cut by the surface rupture

The railway system under service was constructed in the period of 1927-1937 (Nohab Saabye and Lerche Kampax, 1937). The surface ruptures were cut by various locations (Figure 7).

Figure 7. A view from a railway cut by the surface rupture

The T3 railway tunnel between Gölbaşı and Malatya was cut by surface rupture of the Erkenek segment. The fault cut the tunnel at the 80th m from the portal of Erkenek side and approximately 150 m part of the tunnel collapsed completely (Gokceoglu and Karahan, 2023) (Figure 8). The failure of this tunnel prevented the railway transportation between Malatya and Gaziantep.

Figure 8. A view from the collapsed T3 tunnel

The dam body of the Erkenek dam was cut perpendicular by the Erkenek segment (Figure 9). The dam was damaged heavily but, it is not collapsed. As soon as occurrence of the Pazarcık earthquake, the water in the reservoir was discharged by the authorities. This precaution prevented the occurrence of a secondary hazard.

Figure 9. A view from the Erkenek dam body cut by the surface rupture

In addition to the engineering structures cut by the surface ruptures, surface ruptures caused heavy damage to many buildings and caused their collapse completely (Figure 10).

Figure 10. A view from a double stories building cut by the surface rupture (Tetirlik village, Pazarcık)

During the Elbistan earthquake, the Çardak segment (226 in Figure 3) and the Sürgü segment (227 in Figure 3) ruptured. These segments also produced surface ruptures and the maximum displacement was measured as 6.7 m by Taylan Sancar (Figure 11).

Figure 11. The maximum displacement measured by Taylan Sancar (modified after Özacar et al., 2023).

2.2 Landslides

During the earthquake sequence, more than 2500 landslides were triggered. The south part of the Amanos mountains are generally free from landslides but several landslides in the Amanos mountains were triggered. A landslide dam around Islahiye occurred, and the GoogleEarth images before and after the Earthquake sequence is given in Figure 12. Another large and planar landslide occurred around Tepehan (Figure 13) and such type failures were also observed around this region. In this region, the failure surface was observed clearly (Figure 14). A sakung with a volume of around 70M m^2 occurred near Ekinözü during the Elbistan earthquake (Figure 15). Especially in the northern parts of the earthquake region such as Çelikhan, Kahta, Gölbaşı, Besni, Nurhak and Tut, many landslides were triggered by the earthquakes.

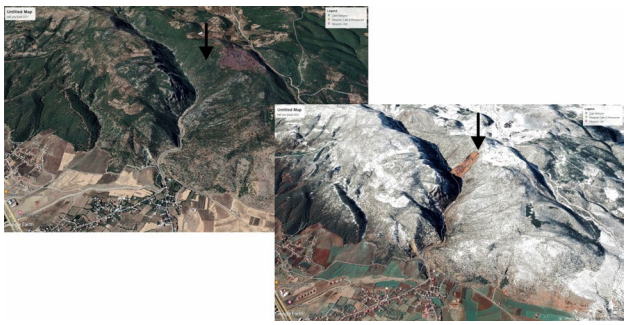

Figure 12. The GoogleEarth images before and after the earthquakes (west of Islahiye, Degirmencik)

Figure 13. A view from the Tepehan planar failure triggered by the earthquake

Figure 14. A view from the failure surface of the planar failure

2.3 Rockfall and Rock Avalanche

The rockfalls were observed commonly in the mountainous areas of the earthquake region. Especially roads and railways were affected by the rockfalls (Figures 16 and 17). In addition to roads and railways, some villages such as Bektaşlı village, Kırıkhan were damaged by rockfall (Figure 18). The rockfall in Bektaşlı village resulted in death of 50 person.

Figure 15. A view from the sakung near Ekinözü

Figure 16. A view from the rockfall on the Gölbaşı – Nurhak road

Figure 17. A view from the rockfall at the south of Fevzipaşa Railway Station

Figure 18. A view from the rockfalls in Bektaşlı village, Kırıkhan

In addition to rockfalls, the rock avalanches were observed during the 6 February 2023 Türkiye Earthquakes. Rock avalanches result from rapid fragmentation of very fast-moving, initially intact rock masses during transport (Hungr et al., 2001). Especially, along the east slopes of the Göksu river, east of Tut, Adiyaman, several rock avalanches were triggered (Figure 19). These failures are observed clearly by comparing before and after earthquake orthophotos presented on the HGM Küre platform of the General Directorate of Mapping (HGM, 2023) (Figure 20).

Rock avalanches observed near Nurhak and Tut did not cause loss of life or great damage in this earthquake, because rock avalanches triggered by the 6 February 2023 Earthquakes took place in locations far from settlements. However, this slope failures should be considered during the site selection efforts.

Figure 19. A view from the rock avalanches along the east slopes of the Göksu river

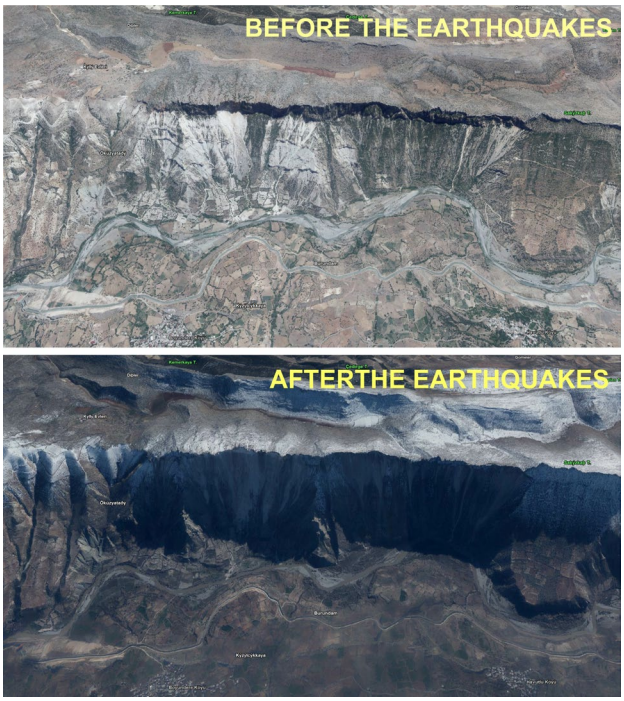

Figure 20. The HGM Küre images before and after earthquake (along the east slopes of the Göksu river)

2.4 Liquefaction

During the 6 February 2023 Earthquakes, the liquefactions occurred commonly. A liquefaction and lateral spreading map was prepared by Üstün et al. (2023) (Figure 21). As can be seen from Figure 20, severe liquefactions were observed in Elbistan, Gölbaşı, Türkoğlu, Antakya, Samandağı and İskenderun.

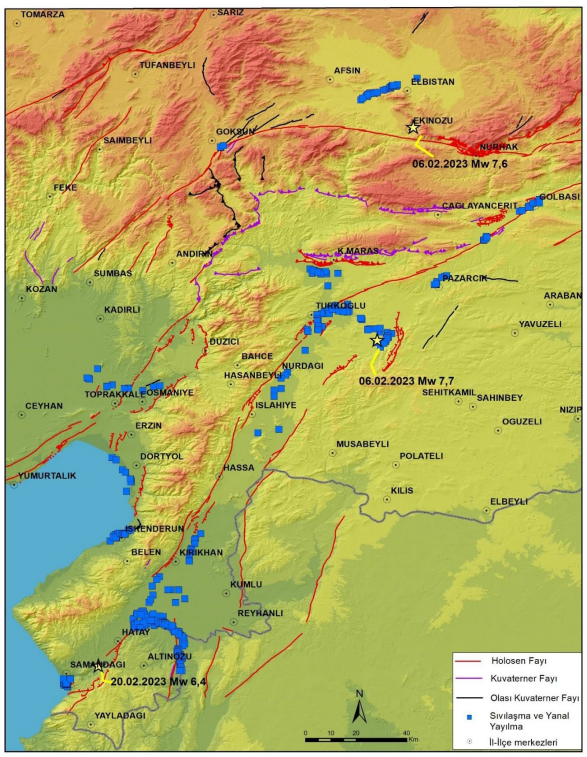

Figure 21. The liquefaction and lateral spreading map of the Earthquake region (Üstün et al., 2023).

In Gölbaşı, liquefaction damaged the buildings, roads and railways severely (Figure 22), because the main lithology of this region is lake sediments.

Figure 22. A toppled building due to liquefaction in Gölbaşı

Along the İskenderun coastline, severe liquefactions occurred, and as a result of liquefactions, the İskenderun Port was damaged heavily (Figure 23), and a serious fire was initiated. In addition, the İskenderun coastline settled more than 1.5 m (Figure 24).

Figure 23. A view from the İskenderun Port after the earthquake

Figure 24. The settled coastline of İskenderun

In the Amik Plain, severe liquefactions and lateral spreadings were also observed (Figure 25). The liquefactions in this plain damaged the Antakya – Cilvegözü road, and the runway of the Hatay Airport (Figure 26).

Figure 25. A typical view from liquefaction occurred in the Amik Plain

Figure 26. A view from the runway damages of the Hatay Airport

3. CONCLUSIONS

The general characteristics of the 6 February 2023 Kahramanmaraş – Türkiye Earthquakes are given in this study. The main conclusions can be drawn as follows:

(a) As a result of the rupture of the Narlı, Erkenek, Pazarcık and Amanos segments in the East Anatolian Fault Zone, a 7.7 magnitude earthquake with a Pazarcık epicenter occurred on February 6, 2023, at 04:17 local time. On the same day, another large Mw 7.6 earthquake occurred at 13:24 with the epicenter in Elbistan, as a result of the rupture of Çardak and Sürgü faults.

(b) During the successive earthquakes, approximately 100000 km^2, more than 13 million people and 11 provinces were affected directly.

(c) According to the official data, death toll is more than 50000, and approximately 300000 buildings were collapsed or heavily damaged.

(d) Approximately 400 km surface rupture occurred, and these ruptures cut railways and highways. This resulted in a serious transportation problem during the first few days.

(e) More than 2500 different types of landslides were triggered, and a landslide dam occurred in the Amanos mountains. In addition, a sakung with an approximate volume of 70M m^3 was triggered.

(f) In mountainous part of the earthquake region, rockfalls were triggered commonly, and the rockfalls contributed to the increase in damage and loss of lifes. Additionally, around Nurhak and Tut, some rock avalanches were observed.

(g) Liquefactions and lateral spreadings were observed commonly in the coastlines and plains. These soil

behaviours also contributed to increase in earthquake damages.

REFERENCES

AFAD (Afet ve Acil Durum Yönetimi Başkanlığı). 2023. 06 Şubat 2023 Pazarcık (Kahramanmaraş) Mw 7.7 ve Elbistan (Kahramanmaraş) Mw 7.6 Depremlerine İlişkin Ön Değerlendirme Raporu. (https://deprem.afad.gov.tr/ assets/pdf/ Kahramanmaras%20%20Depremleri_%20On%20Degerlendirme%20Raporu.pdf)

Ambraseys NN (1988) Engineering seismology. *J Earthq Eng Str Dyn*. 17:1–105

Can, A., Baskose, Y., and Gokceoglu, C., 2022. Stability assessments of a triple-tunnel portal with numerical analysis (south of Turkey). *Geotechnical Research*. 9 (2), 116-128, https://doi.org/10.1680/jgere.21.00028

Duman, T.Y., Elmacı, H., Özalp, S., Kürçer, A., Kara, M., Özdemir, E., Yavuzoğlu, A., Güldoğan, Ç.U., 2020. Paleoseismology of the western Sürgü–Misis fault system: East Anatolian Fault, Turkey. *Mediterranean Geoscience Reviews*. 2: 411–437. https://doi.org/10.1007/s42990-020-00041-6

Emre, Ö., Duman, T.Y., Özalp, S., Şaroğlu, F., Olgun, Ş., Elmacı, H., Çan, T., 2018. Active fault database of Turkey. *Bull Earthquake Eng*. 16, 3229-3275, https://doi.org/10.1007 /s10518-016-0041-2

Gokceoglu, C., 2022. Assessment of rate of penetration of a tunnel boring machine in the longest railway tunnel of Turkey. *SN Applied Sciences*. 4, 19, https://doi.org/10.1007/s42452-021-04903-y

Gokceoglu, C., Karahan, S., 2023. Seismic Performance Of Transportation Tunnels In The Region Affected By 6 February 2023 Türkiye Earthquake Sequence: A General Assessment. 57th U.S. Rock Mechanics / Geomechanics Symposium, ARMA 23-0960.

HGM (General Directorate of Mapping), 2023. HGM Küre Application. URL: https://hgmkure.btk.gov.tr/ (accessed on 1 May 2023).

Hungr, O., Evans, S.G., Bovis, M.J., Hutchinson, J.N., 2001. A review of the classification of landslides of the flow type. Environmental & Engineering Geosciences. 7 (3), 221-238, 10.2113/gseegeosci.7.3.221

Nalbant SS, McCloskey J, Steacy S, Barka AA (2002) Stress accumulation and increased seismic risk in eastern Turkey. *Earth Planet Sci Lett*. 195, 291-298. https://doi.org/10.1016/ S0012-821X(01)00592-1

Nohab Saabye and Lerche Kampax, 1937. Construction des lignes de chemins de fer: Irmak-Filyos and Fevzipaşa Diyarbekir. Technical Report, 258p.

Özacar, A.A., Uzel, B., Bozkurt, E., Sançar, T., Sopacı, E., Okay, H.B., Kaymakçı, N., Rojay, B., Gülerce, Z., Kıncal, C., Köksal, D., Gregory, L., 2023. Active Tectonic Setting and Seismic Source. Reconnaissance Report on February 6, 2023 Kahramanmaraş-Pazarcık (Mw=7.7) and Elbistan (Mw=7.6) Earthquakes, 485p.

TRT Haber Website, 2023. https://www.trhaber.com/gundem/ deprem-sonrasinda-hangi-yollar-tarafige-kapandi-adana-maras-gaziantep-nurdagi-h87054.html. Accessed on February 8, 2023.

Üstün, A.B., Altuntaş, G., Demirörs, U., Karayazı, O., 2023. 6 Şubat 2023 Kahramanmaraş Depremleri ve 20 Şubat 2023 Defne (Hatay) Depremi Sonucu Gelişen Sıvılaşma Yapıları Saha Gözlemleri ve Değerlendirmeler. MTA Jeoloji Etüdleri Dairesi Başkanlığı, 16s.