TRANSRE CATASTROPHE RESEARCH

Shaking Things Up: The 2023 Turkey Earthquake

May / 2023 / Part I

Executive Summary

On February 6, a M7.8 earthquake and M7.5 aftershock caused widespread destruction across southern Turkey and northern Syria. Over 50,000 deaths have been confirmed and at least 190,000 buildings have been heavily damaged or destroyed. The total insured loss is estimated to exceed $1 to $5 billion.

Part I in this series of articles reviews Turkey's seismicity and investigates the factors contributing to the event's impact. These factors include:

- **Intensity** – The M7.8 mainshock equaled the strongest ever record in Turkey and occurred on a fault that had not suffered a major earthquake in over 500 years.
- **Aftershocks** – A major M7.5 aftershock significantly widened the shake footprint.
- **Construction** – Poor enforcement of building codes increased vulnerability.

Part II in this series explores California's exposure to a major earthquake. Part III gives a global overview of seismic risk.

Event Description

At 4:17 AM local time on February 6, 2023, a M7.8 earthquake struck 38 km southwest of Pazarcık, Turkey (Figure 1).[1] The earthquake ruptured a 400 km segment of the East Anatolian Fault at a depth of 10 km. The relatively long length and shallow depth of the rupture caused shaking that could be felt thousands of kilometers away. The timing of the event in the early morning caught most people by surprise and trapped many under rubble.

Approximately nine hours after the mainshock, a M7.5 aftershock struck 100 km away near Elbistan, Turkey. The earthquake ruptured a branch of the East Anatolian Fault called the Sürgü-Çardak fault. The orientation of the rupture roughly perpendicular to the mainshock greatly widened the shake footprint and further damaged already weakened structures. The

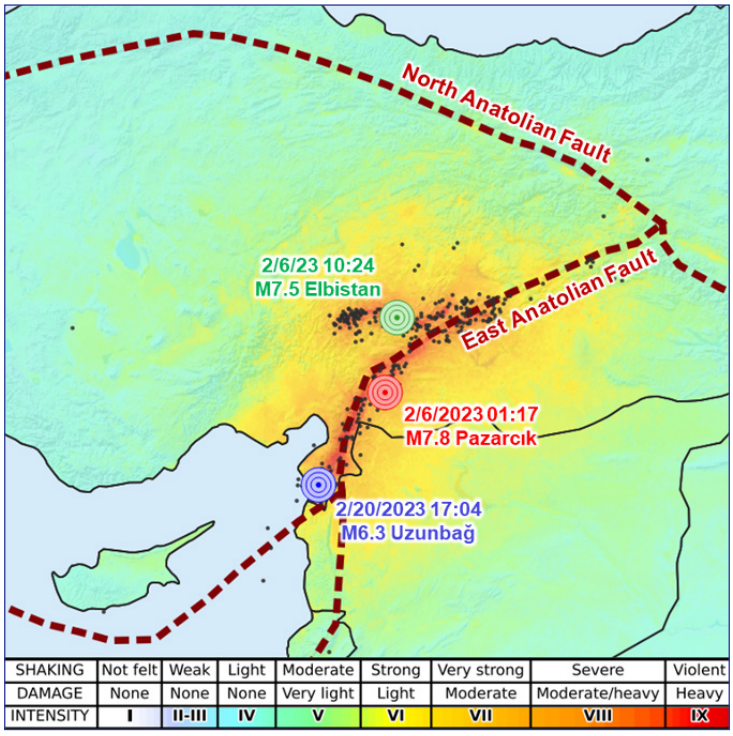

Figure 1 – Peak shake intensity from the M7.8 mainshock and M7.5 aftershock. Epicenters of aftershocks (M > 4).

1 USGS Earthquake Hazards Program.

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occurrence of a large earthquake followed by a similarly sized aftershock is rare. Empirical studies show that on average an earthquake's largest aftershock is between 1.1-1.2 units smaller in magnitude.[2]

On February 20, two weeks after the main shock, a M6.3 aftershock struck near Uzunbag, Turkey. More than 325 aftershocks with magnitude greater than 4 have been recorded to date. The rate of aftershocks following an earthquake is roughly proportional to the inverse of the elapsed time (e.g. there are about 10 times as many aftershocks on the first day as on the tenth day).[3]

Insurance Market

Earthquake insurance for residential dwellings is obligatory in Turkey and is covered by the Turkish Catastrophe Insurance Pool (TCIP). Though compulsory, however, TCIP take-up is commonly low due to a lack of regulatory enforcement. Insurance penetrations in the private market can vary widely from higher take-up in urban areas to significantly lower in rural areas.

Estimates of the total insured loss for the recent event range from $1 to $5 billion.[4] Several factors have complicated the estimation of losses. Turkish inflation and currency devaluation are both near all-time highs and are likely to increase replacement costs. Many heavily damaged structures will likely be demolished rather than repaired in lieu of safety concerns. Finally, extensive retrofits of moderately damaged structures will likely be required to ensure code compliance.

Turkey's Seismic Profile

Turkey is located between the converging Eurasian and Arabian plates (Figure 2). The stress from this motion is concentrated along two major faults – the North and East Anatolian Faults. The 2,000 km Anatolian fault system is amongst the most active in the world and the driver of seismic risk in the region.

Much of Turkey's seismic activity since the 20th century has been along the North Anatolian Fault. This period saw the progressive westward rupture of the fault beginning with the 1939 Erzincan (M7.8) earthquake and culminating with the 1999 Izmit (M7.6) earthquake east of Istanbul. This sequence was caused by the successive westward transfer of stress on the fault that triggered subsequent events.[5] Based on this progression, a major earthquake impacting Istanbul in the near future is considered likely. The nearest segment of the North Anatolian Fault to Istanbul, known as the Marmara Seismic Gap, last ruptured with the 1766 Istanbul Earthquake (M7.1) and has an estimated return period of 200-250 years.[6] Istanbul accounts for 30% of Turkey's GDP and 20% of its population.

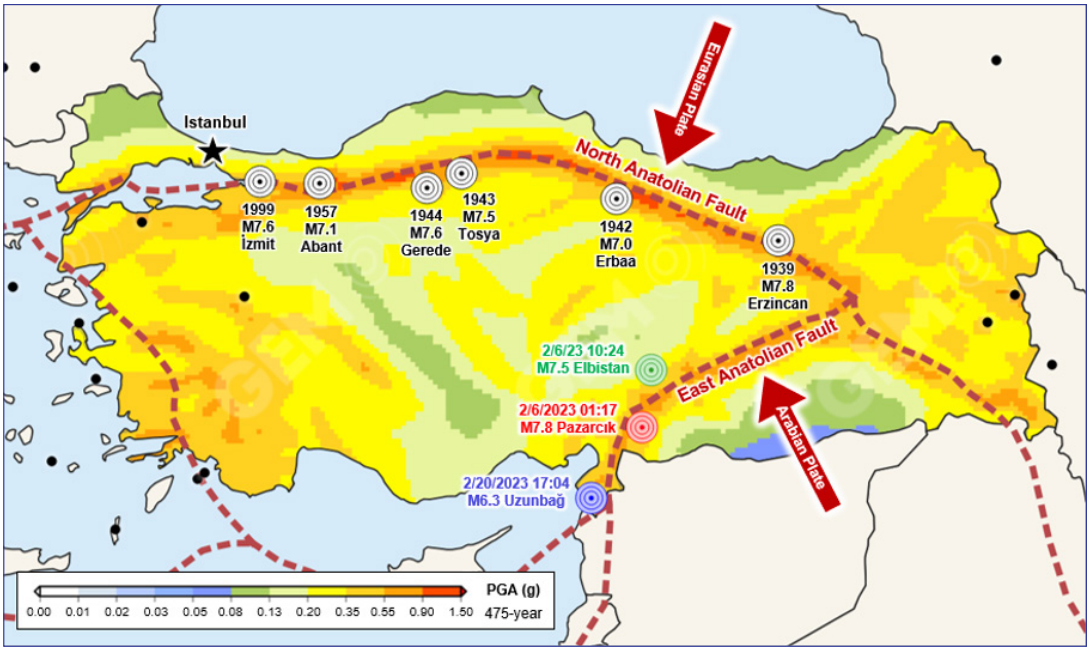

Figure 2 – Seismic Hazard Map and historic events (M > 7) in last century.

2 The largest aftershock: How strong, how far away, how delayed?
3 USGS Aftershock Forecast Overview.
4 S&P Global (2023). Turkey quake insured loss estimates rise as damage takes shape.
5 Stein et al. (1997). Progressive failure on the North Anatolian fault since 1939 by earthquake stress triggering.
6 Bohnhoff et al. (2017). Repeating Marmara Sea earthquakes: indication for fault creep.

The East Anatolian Fault, site of the February 6, 2023 earthquake, has been relatively inactive in recent times. There have only been four earthquakes with magnitude 6 or greater (none above M6.7) within 250 km of the epicenter in the last century. The segment of the fault which ruptured last experienced a major earthquake in 1114 and 1513.[7]

Damage Observations

Shake damage to structures in Turkey was widespread and devasting. Over 190,000 buildings have collapsed or are in need of demolition, 36,000 are moderately damaged and 350,000 are slightly damaged.[8] A common observation has been so-called "pancake collapses" where weakness in load-bearing columns triggers a sudden vertical collapse of a building's floors (Figure 3). This type of failure provides no time for evacuation and can significantly increase the number of causalities. Furthermore, several construction deficiencies have been noted including poor material quality, insufficient concrete reinforcement, and improper column design. Most alarming is that approximately half of households affected by the earthquake lived in building constructed after 2001.[9]

Despite relatively robust seismic requirements developed from a long history of earthquakes, the enforcement of building codes in Turkey's rapidly growing economic has been a longstanding issue. Several issues have been highlighted:

- **Amnesties:** The Turkish government has periodically offered construction amnesties that legally exempted new construction from certain design requirements for a fee.[10]
- **Regularization:** Existing buildings not satisfying code requirements are periodically regularized without necessary retrofits. An estimated 294,000 impacted by the earthquake were regularized in 2018.[11]
- **Illegal Construction:** Illegal addition of floors or removal of columns is commonplace.[12]
- **Poor Inspection:** Required auditing of construction sites is frequently done by inspectors selected and paid for by contractors themselves.[13]
- **Soft-Stories:** Most residential dwellings have a ground floor commercial space with an open floor plan. This decreased lateral resistance relative to the rest of the building creates a "soft-story" that can initiate building collapse.[14]

Figure 3 - Residential building in Gaziantep with a "pancake collapse."[15]

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7 Temblor (2023). A preliminary report on the February 6, 2023 earthquakes in Türkiye.
8 ReliefWeb (2023). Türkiye Earthquake February 2023, Bi-Weekly Highlights.
9 Turkish Statistical Institute.
10 BBC (2023). Turkey earthquake: Why did so many buildings collapse?
11 London School of Economics (2023). Earthquake in Turkey: Geography is Destiny, but Negligence is a Choice.
12 Daily Sabah (2021). Renovation may curb Istanbul's risk of quake damage in 5 years.
13 The New York Times (2023). Turkish Builders Come Under Intense Scrutiny Over Shoddy Construction.
14 New Civil Engineer (2023). Turkey earthquake: Experts believe collapse of buildings was preventable.
15 The Washington Post (2023). See the earthquake's total devastation through before and after images.

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