

Reviewing the Türkiye-Syria Earthquake

a Geo-Structural Engineering Perspective

Kristy Lo, Boya Yin and Ethan Zhang

23 March 2023

Latest figures as of 22 March according to Reuters

Lives affected and statistics

From [Reuters](#) · Updated 13 hours ago

Deaths

At least 56,000 people

Non-fatal injuries

At least 125,626 people

Displaced

At least 2.5M people

People affected

At least 24M people

Buildings destroyed

At least 200,089

Property damage

Approximately US\$109B

Magnitude

7.8

The image shows a Google search interface for the word "earthquake". At the top, there are navigation tabs for "All", "News", "Images", "Videos", "Maps", and "More". Below these are several image thumbnails with labels: "bbc news", "earthquake fault lines", "earthquake video", "magnitude earthquake", and "earthquake today". The main search results area displays a grid of images from various news sources. Each image is accompanied by a small logo and a truncated title. The sources include "The Japan Times", "Mint", "Nature", "DW", "Center for Disaster Philanthropy", "Sky News", "POLITICO", and "Ground Engineering". The images themselves depict scenes of destruction: collapsed buildings, piles of rubble, damaged cars, and people amidst the wreckage.

Content

1. Seismic Hazard & Ground Motion
2. Observations from Engineering Perspective
 - Geotechnical Perspective
 - Structural Perspective

Seismic Hazard & Ground Motion

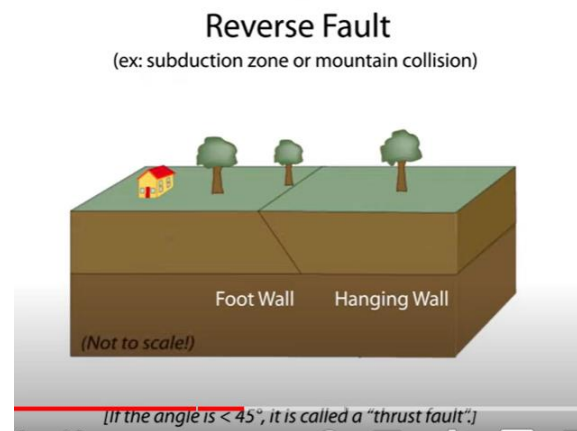
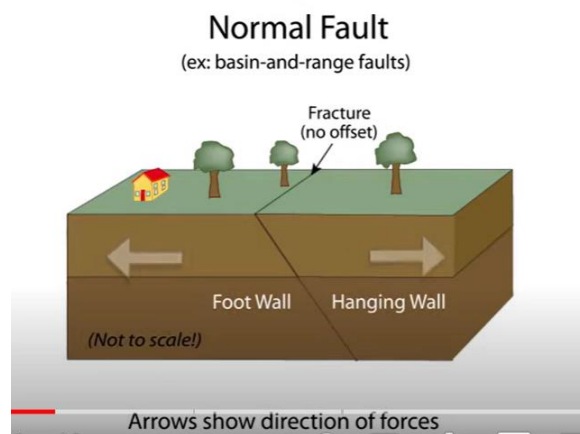
Seismic Hazard

Basics about Earthquake – How it occur?

An earthquake is the vibration of the Earth's surface that follows a release of energy in the Earth's crust.

Stress accumulated in solid rock, the rock breaks along the fault and the energy releases.

*A fault is a fracture in the Earth's crust along which two blocks of the crust have slipped with respect to each other.

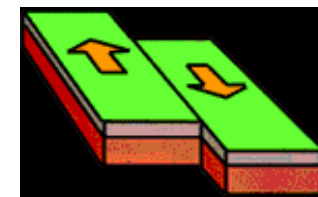


Seismic Hazard

Basics about Earthquake – Where it occur?

Earthquakes occur along the boundaries of the interacting plates – **Tectonic Plates**, the earth's outer shell (called the lithosphere) consists of several large slabs of solid rock called plates, which move 1 to 10 centimeters per year.

1. Transform plate



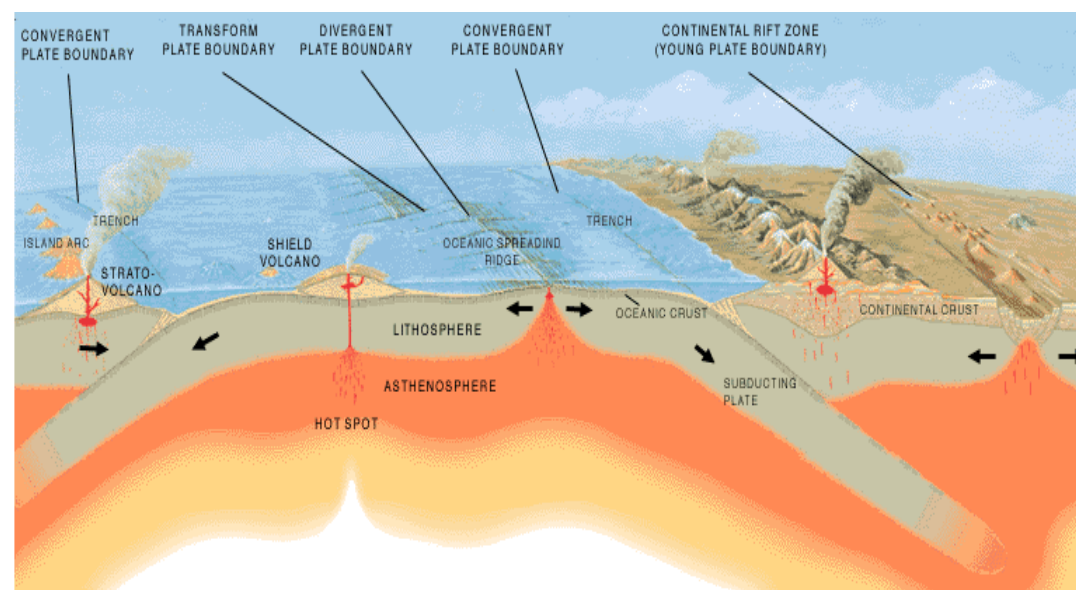
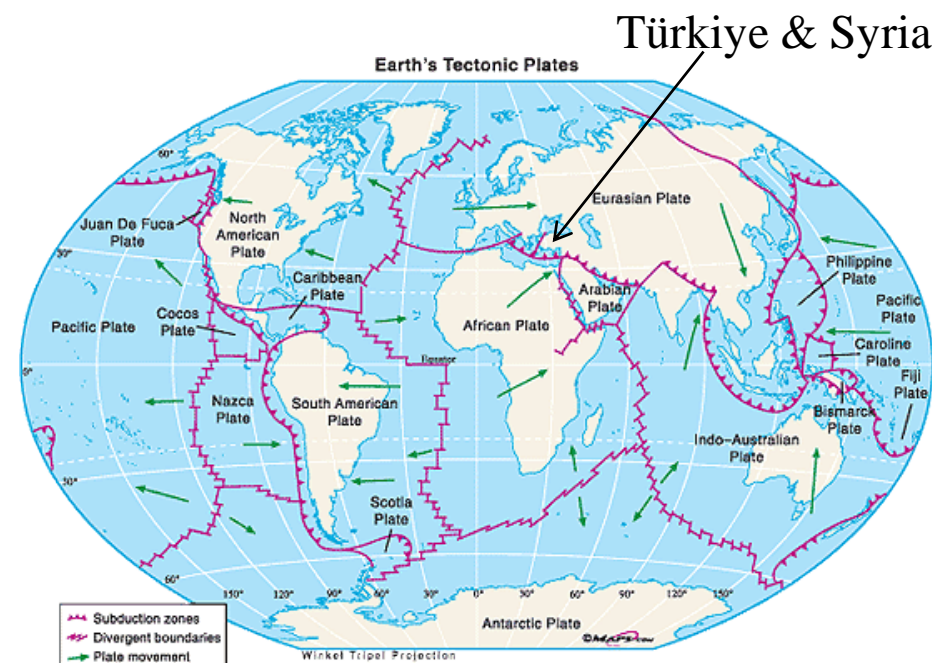
2. Divergent plate



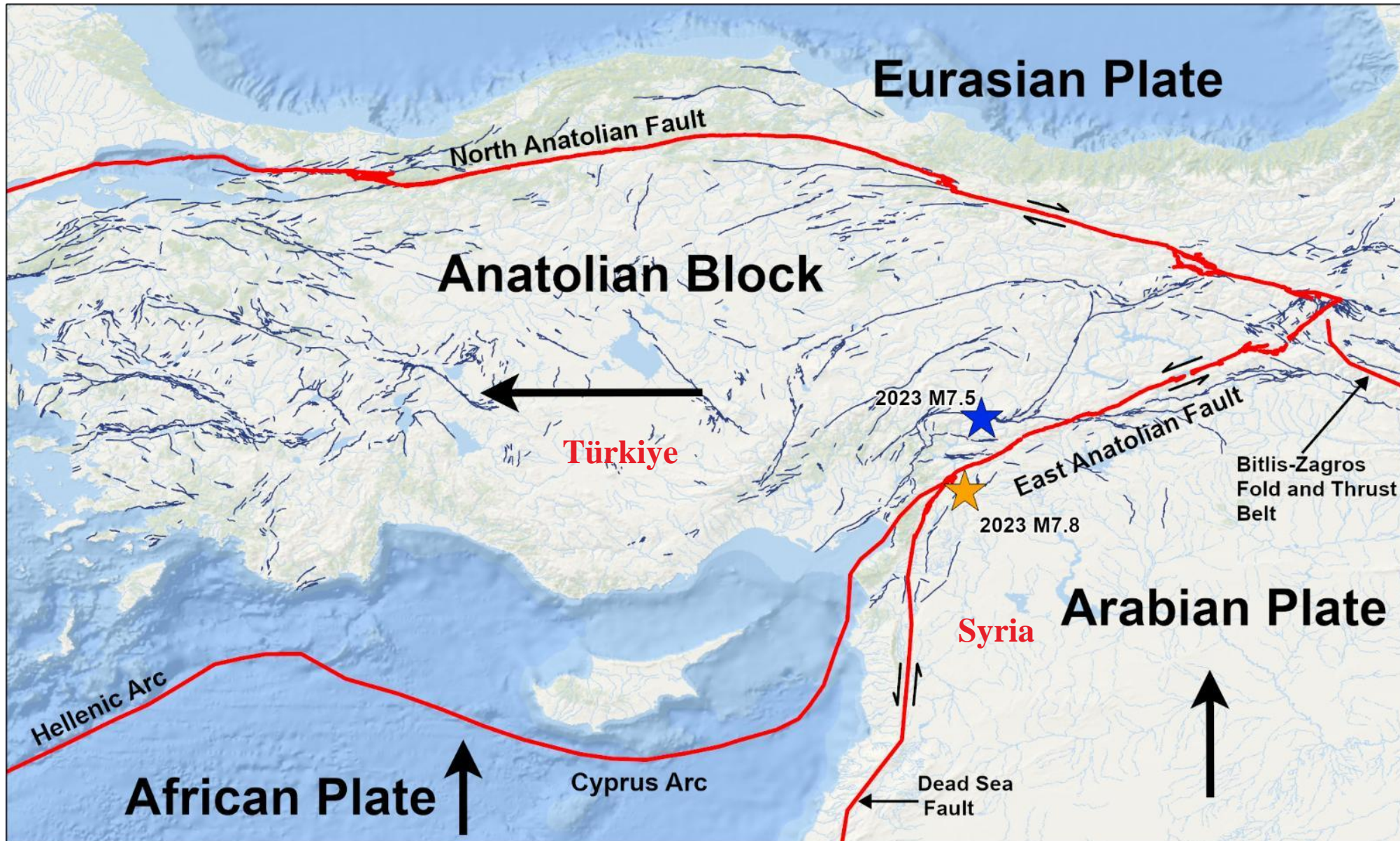
3. Convergent plate



Türkiye & Syria

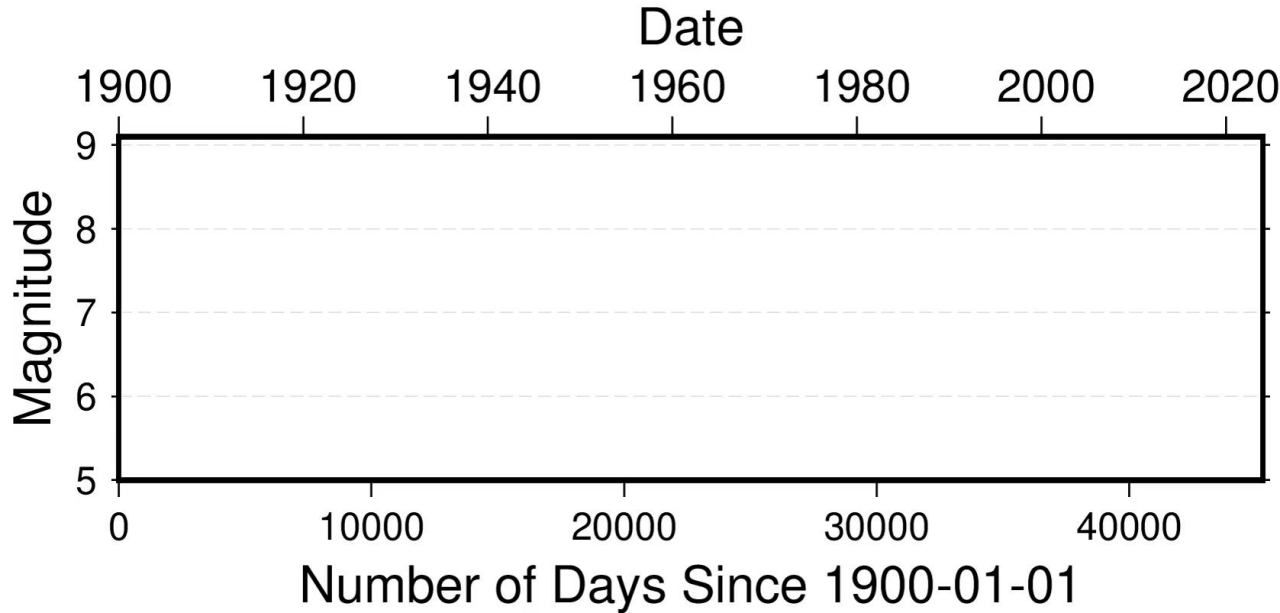
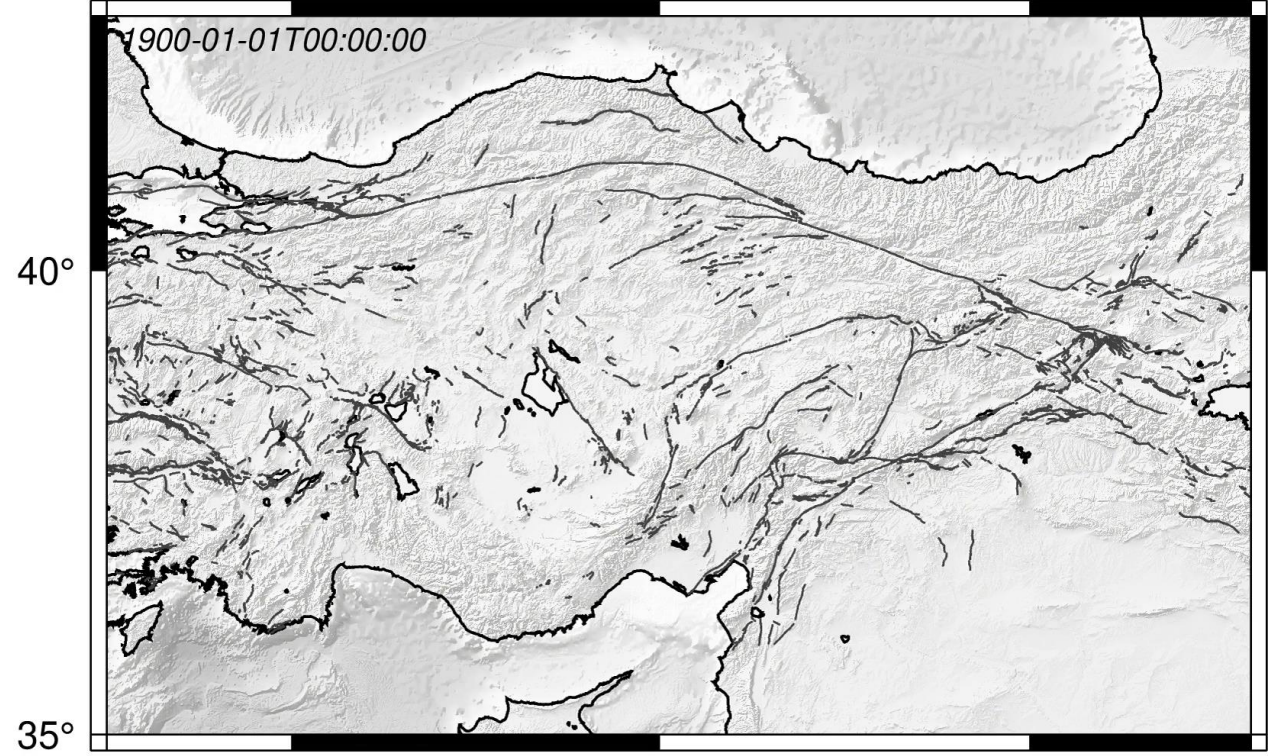
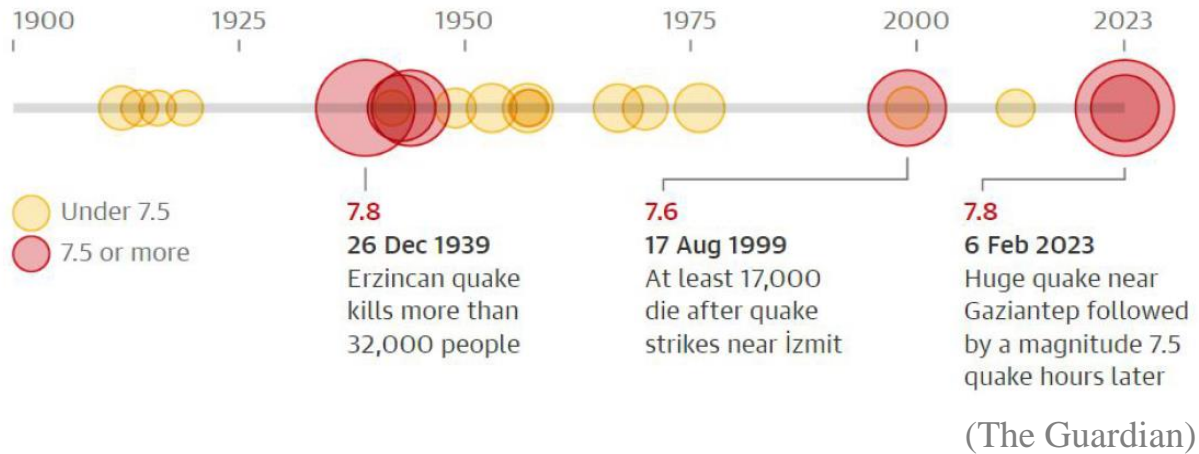


Tectonic Setting



Seismicity

Türkiye has been hit by 21 earthquakes of magnitude 7 or higher since 1900.



The 2023 Türkiye-Syria Earthquake Sequence

The M7.8 Earthquake

Date & Time	06 Feb 2023 01:17:36 UTC
Location	Türkiye's Gaziantep province
Focus Depth	20km
Fault rupture	~240km long, ~20km wide
Mechanism	Strike-slip
Aftershocks	Numerous



Source: INGV

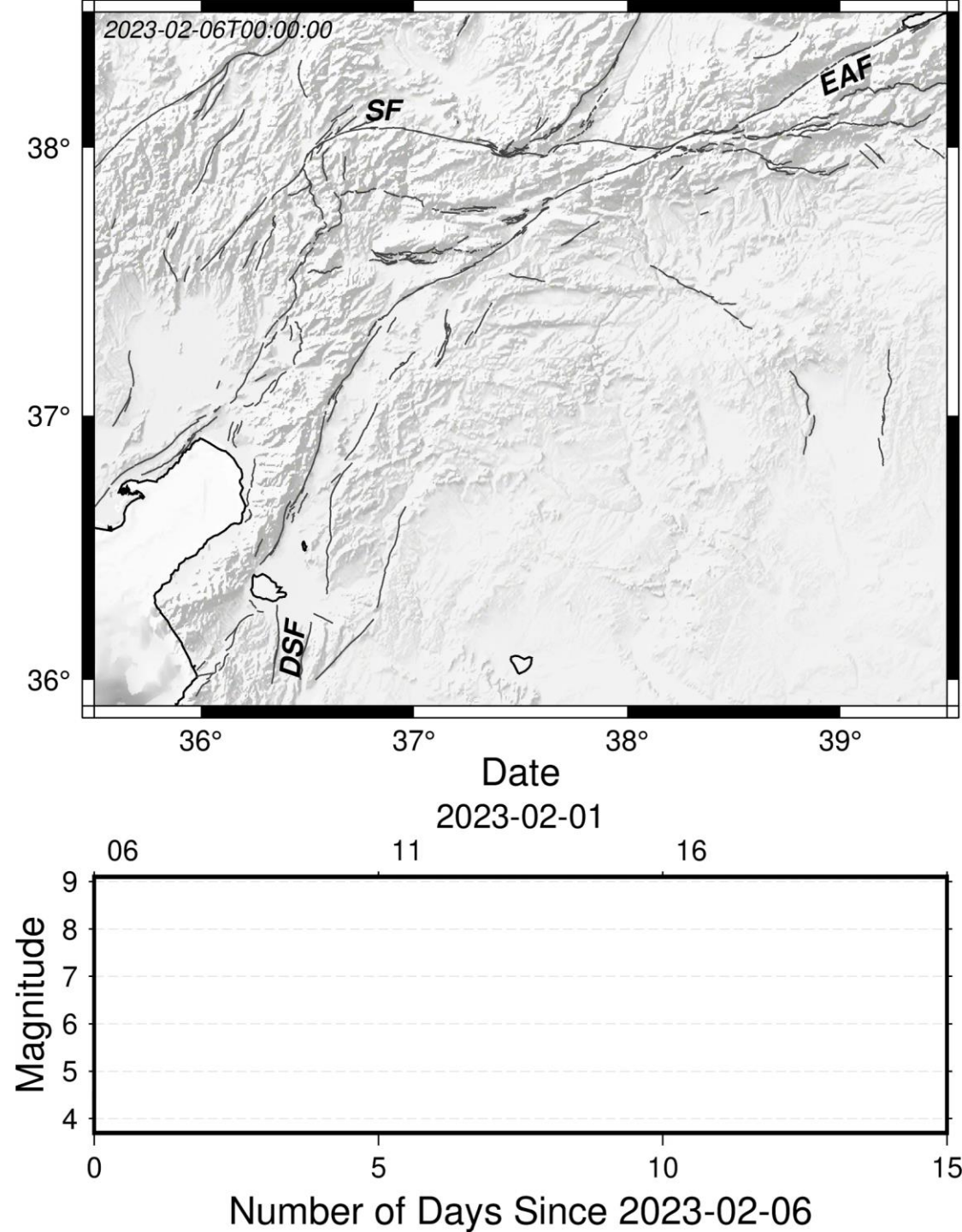


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 Aftershocks Numerous

Date	Time (UTC)	Magnitude	Long. [°]	Lat. [°]	Depth [km]	Mechanism*
06-02-2023	01:17:36	7.8 or 7.7	37.08	37.17	20	Strike-Slip
06-02-2023	01:28:19	6.7 or 6.6	36.81	37.13	40	Strike-Slip
06-02-2023	10:24:49	7.5 or 7.6	37.24	38.11	10	Strike-Slip
20-02-2023	17:04:29	6.3 or 6.4	36.02	36.11	16	Strike-Slip

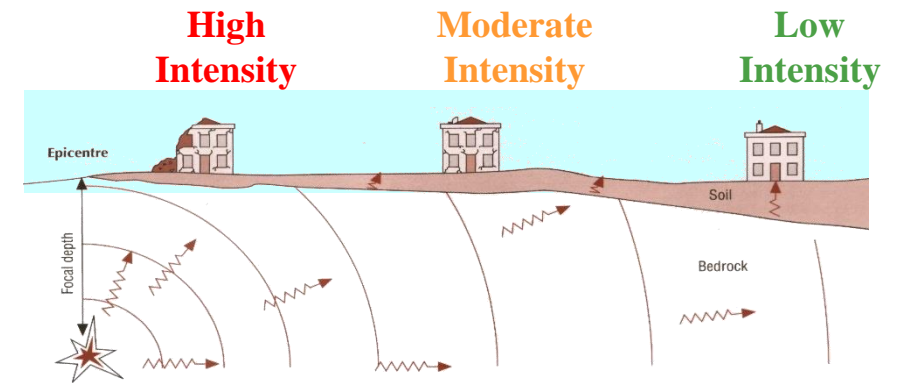


Seismic Hazard

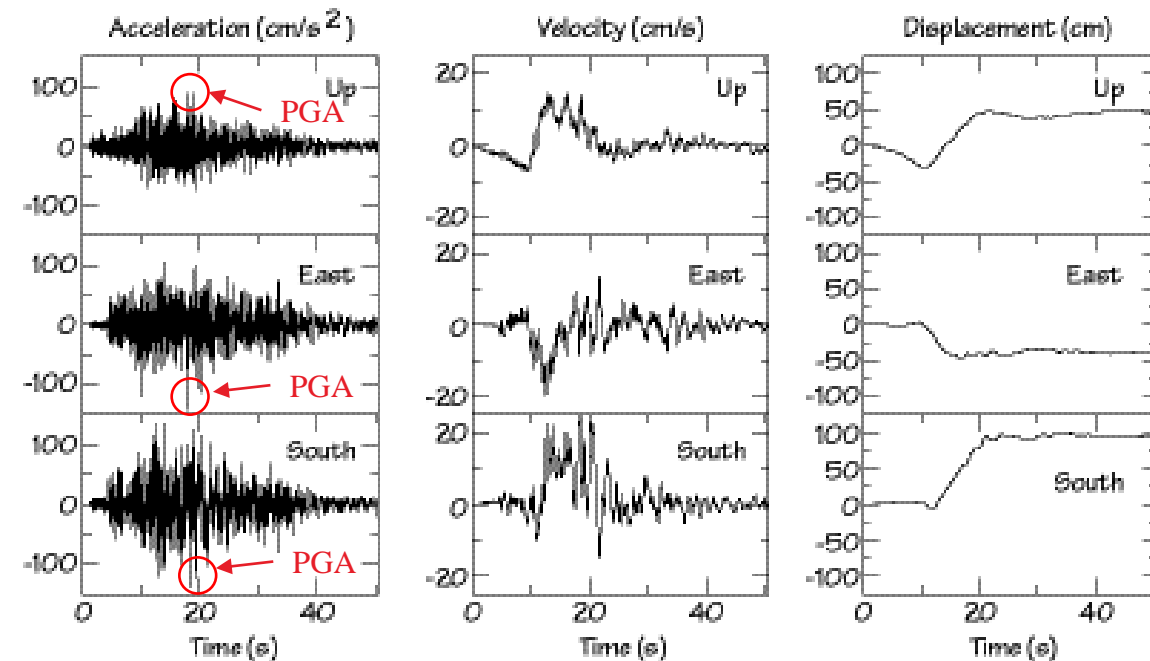
Basics about Earthquake – Size of Earthquake

Magnitude measures the size of the earthquake:

1. **Richter Scale (M_L)**
based on ground motion displacement
2. **Moment Magnitude Scale (M_w)**
based on total rupture energy release
3. **Peak Ground Acceleration (PGA) and response spectrum**



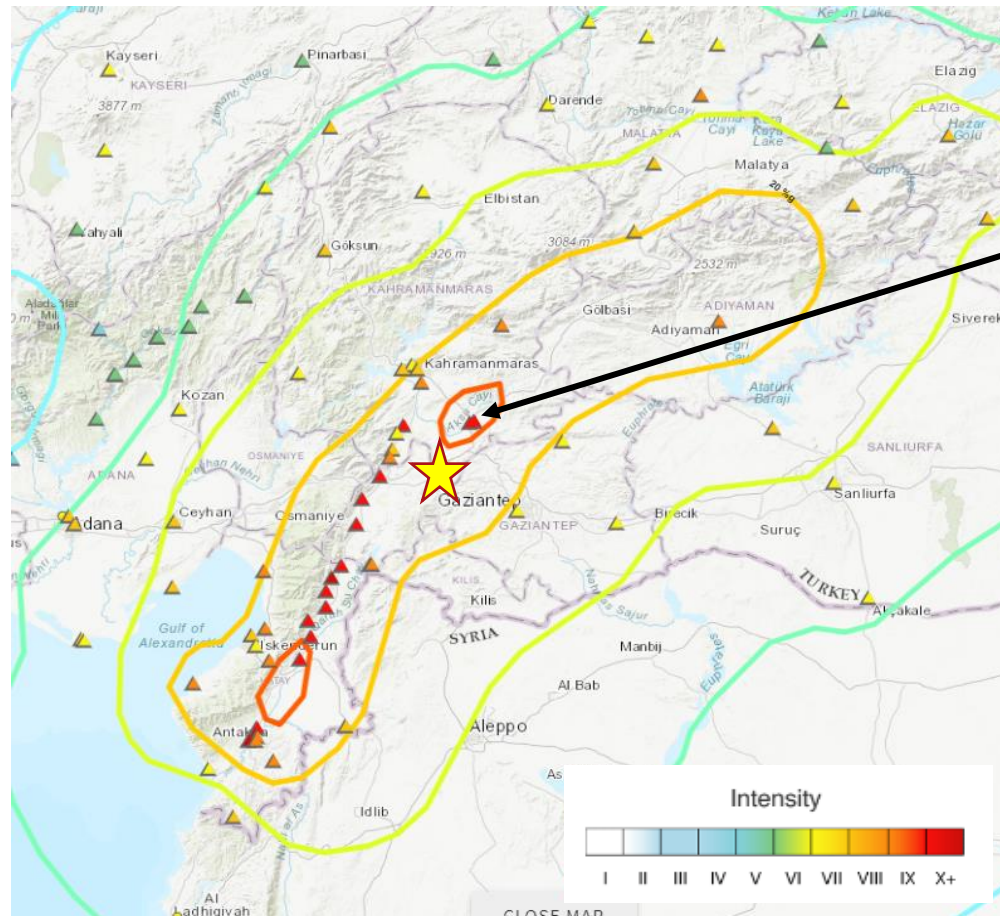
Intensity is distance dependent (can be correlated to PGA)
e.g. Intensity 7 ~ PGA = 0.1g to 0.15g



The M7.8 Earthquake

Ground Motion

Ground Motion Intensity Recorded for M7.8 Earthquake

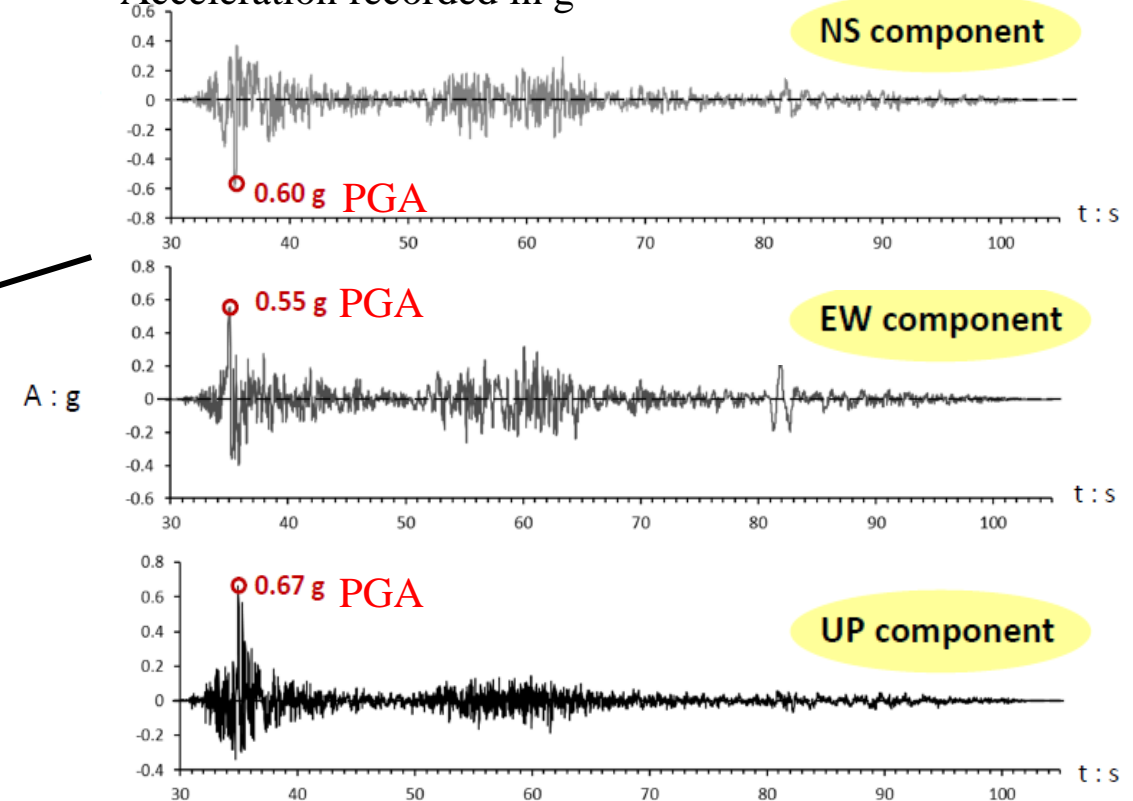


<https://earthquake.usgs.gov/earthquakes/eventpage/us6000jllz/executive>

IX
mmi

Station 4615 (Epicenter distance: ~20km)

Acceleration recorded in g



(Baltzopoulos, 2023)

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

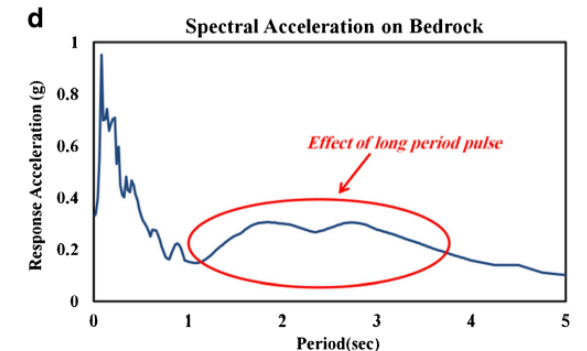
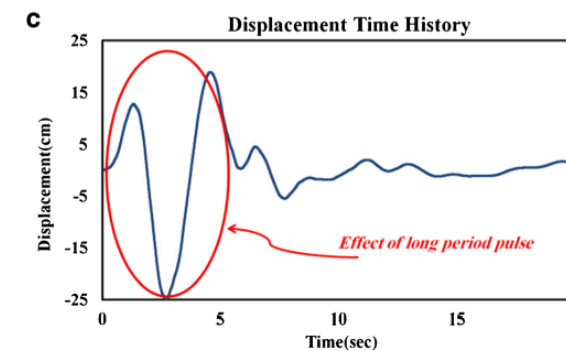
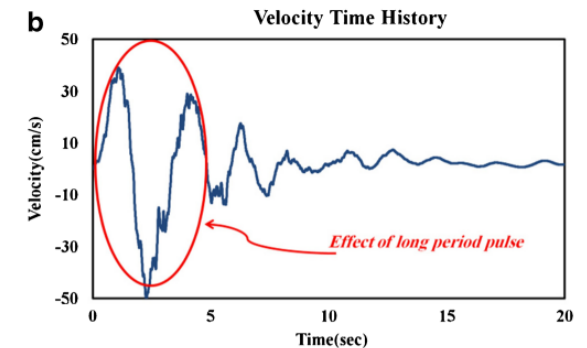
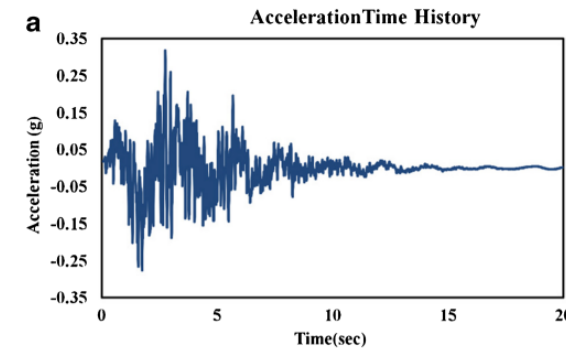
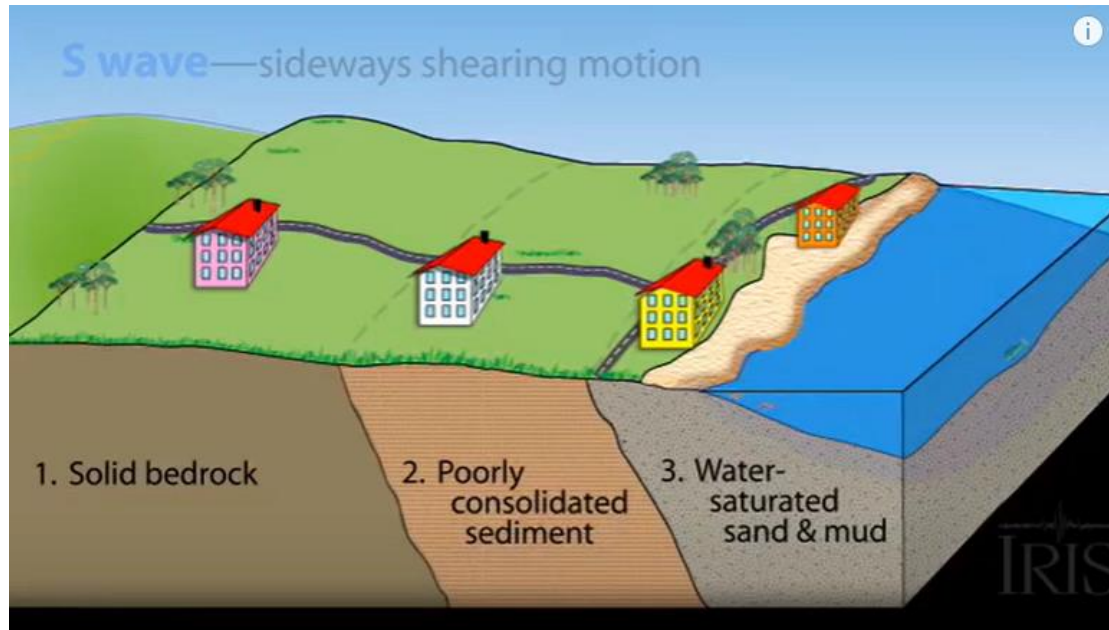
Scale based on Worden et al. (2012) Version 13: Processed 2023-02-19T06:06:00Z
 Δ Seismic Instrument ○ Reported Intensity ★ Epicenter □ Rupture

Ground Motion Differs by Site

Same earthquake – different ground motions

The following factors would affect the magnitude of ground motion:

- 1) Ground condition - soil amplification
- 2) Distance to fault
- 3) Near-fault effect (velocity pulse)



Earthquake Related Geohazards

Examples from this earthquake

- Fault Rupture



Source: https://twitter.com/Panthalassa_Z/status/1623040975848280107

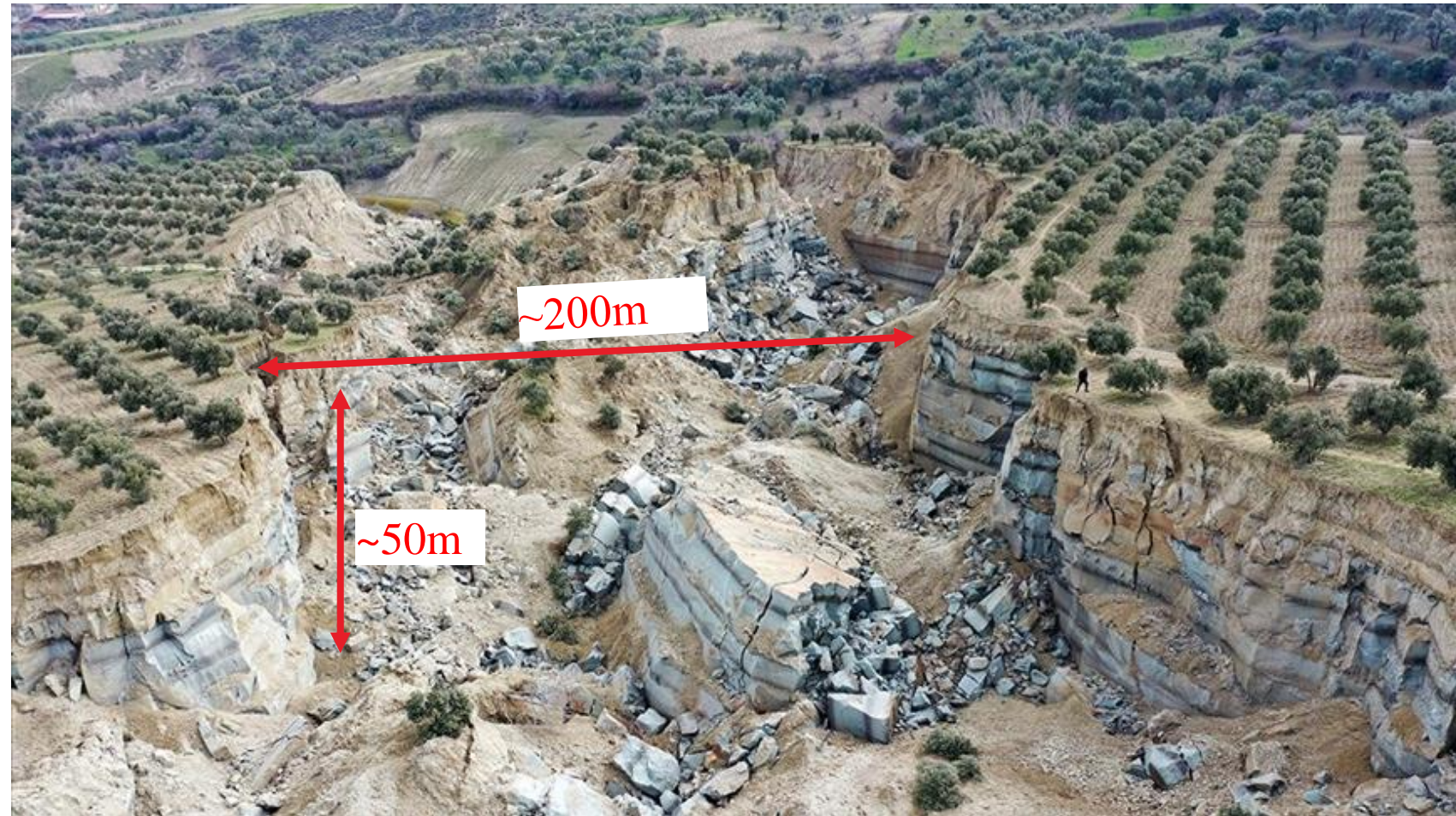


Source: Cengiz Zabci @CengizZabci

Earthquake Related Geohazards

Earth surface rupture

- Earth surface rupture
 - ✓ Width ~200m
 - ✓ Length ~400m
 - ✓ Depth ~ 50m



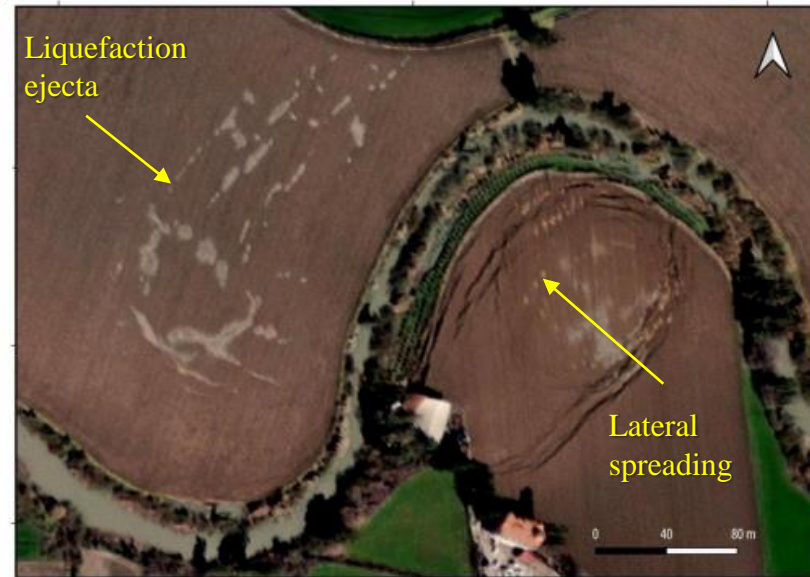
Source: https://www.aa.com.tr/tr/gudem/hatayda-depremde-olusan-yarik-havadan-goruntulendi/2815814?trk=public_post_comment-text

Earthquake Related Geohazards

- Soil liquefaction, ground subsidence and lateral flow



Soil liquefaction after the New Zealand Christchurch Earthquake in 2011. (Source: Stuff.co.nz)



Mapping liquefaction and lateral spreading features in detail. An example from Orontes (Asi) river, north-east of Antakya.

Source: Taftoglou et al (2023)



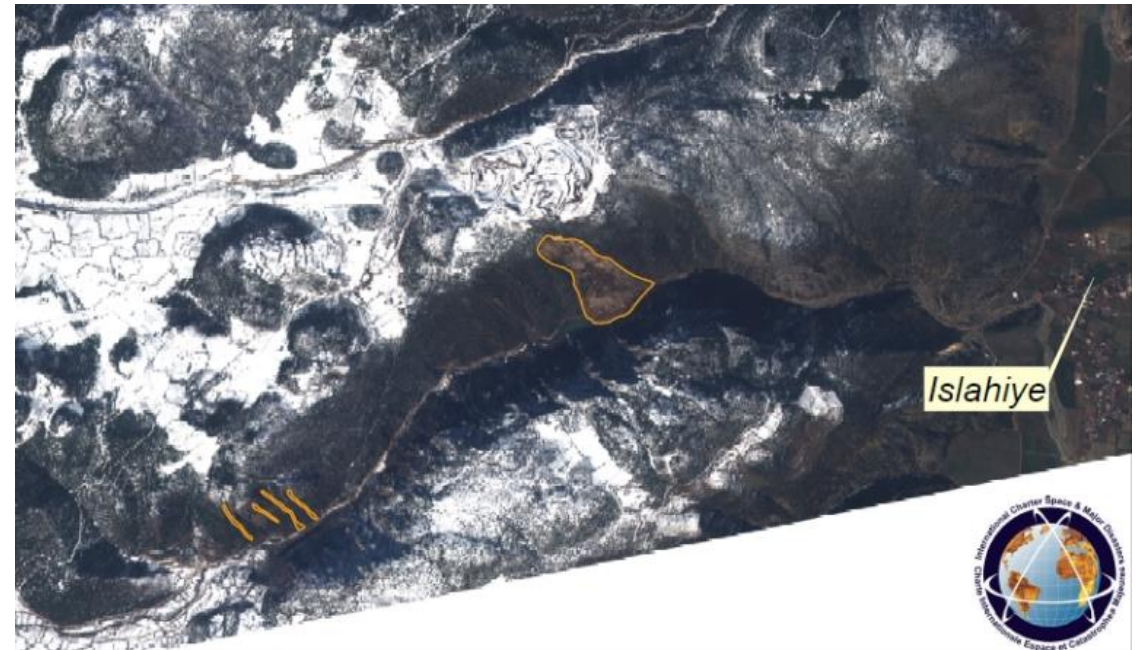
Effects of liquefaction, depicting a tilted building in the 2023 Turkey earthquake

Earthquake Related Geohazards

- Landslides



A view of terrain after a landslide that occurred in the aftermath of a deadly earthquake, in Tepehan, Turkey February 10, 2023.—
Reuters



Preliminary Landslide Inventory Following 6 February 2023 Turkey-Syria Earthquake

Source: The International Charter Space and Major Disasters

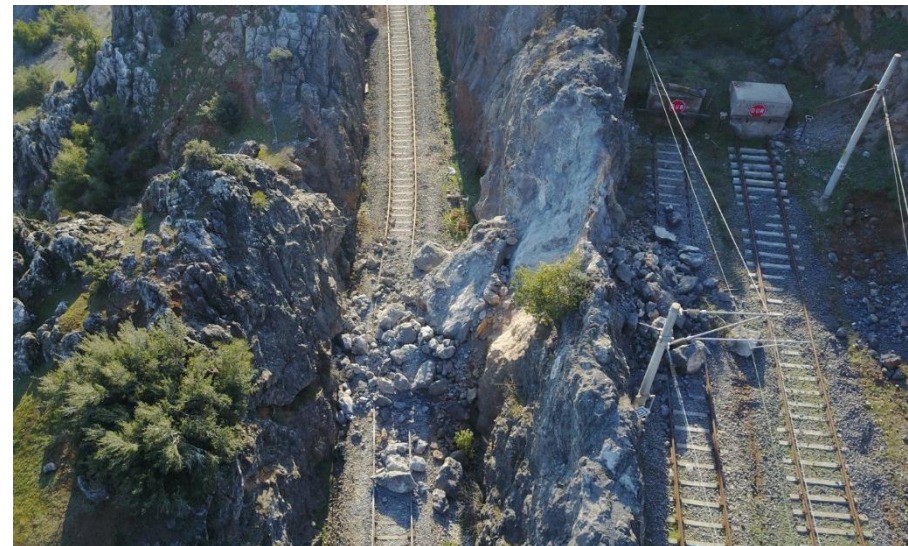
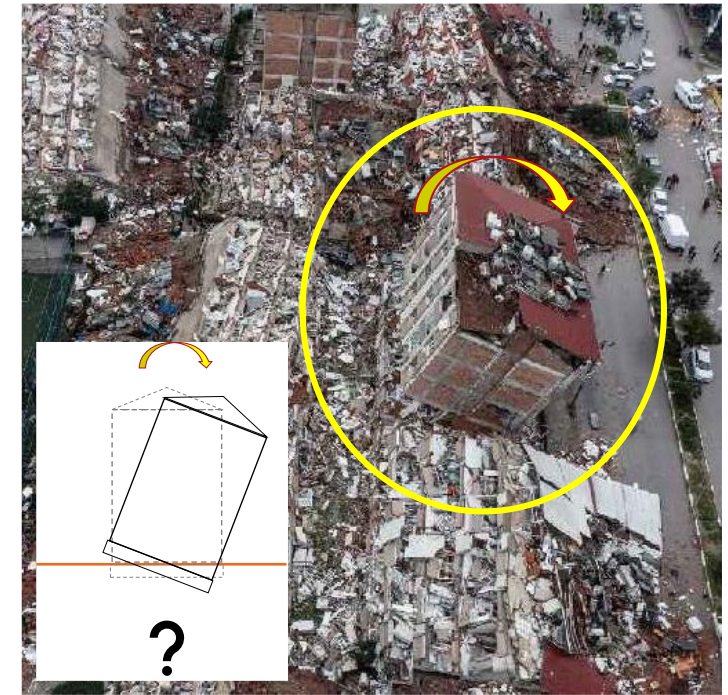
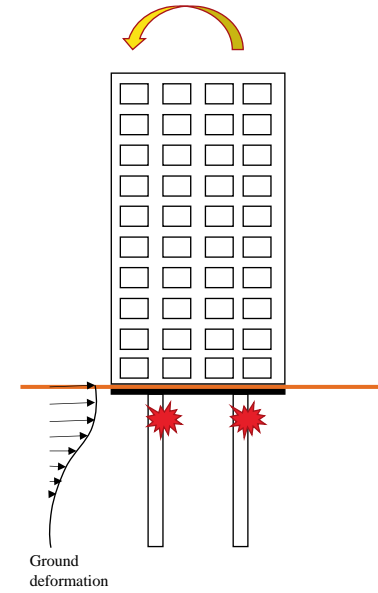
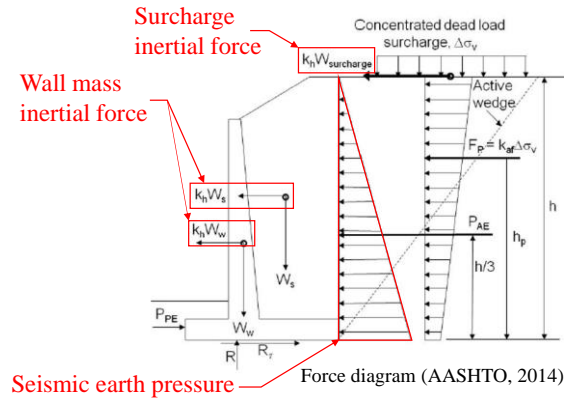
Observations from Engineering Perspective

Geotechnical Perspective

Geo-seismic

Main hazards

- Shallow/pile foundations
- Liquefaction
- Lateral spreading
- Slopes stability
- Earth retaining structures
- Landslides and Rockfalls
- etc.



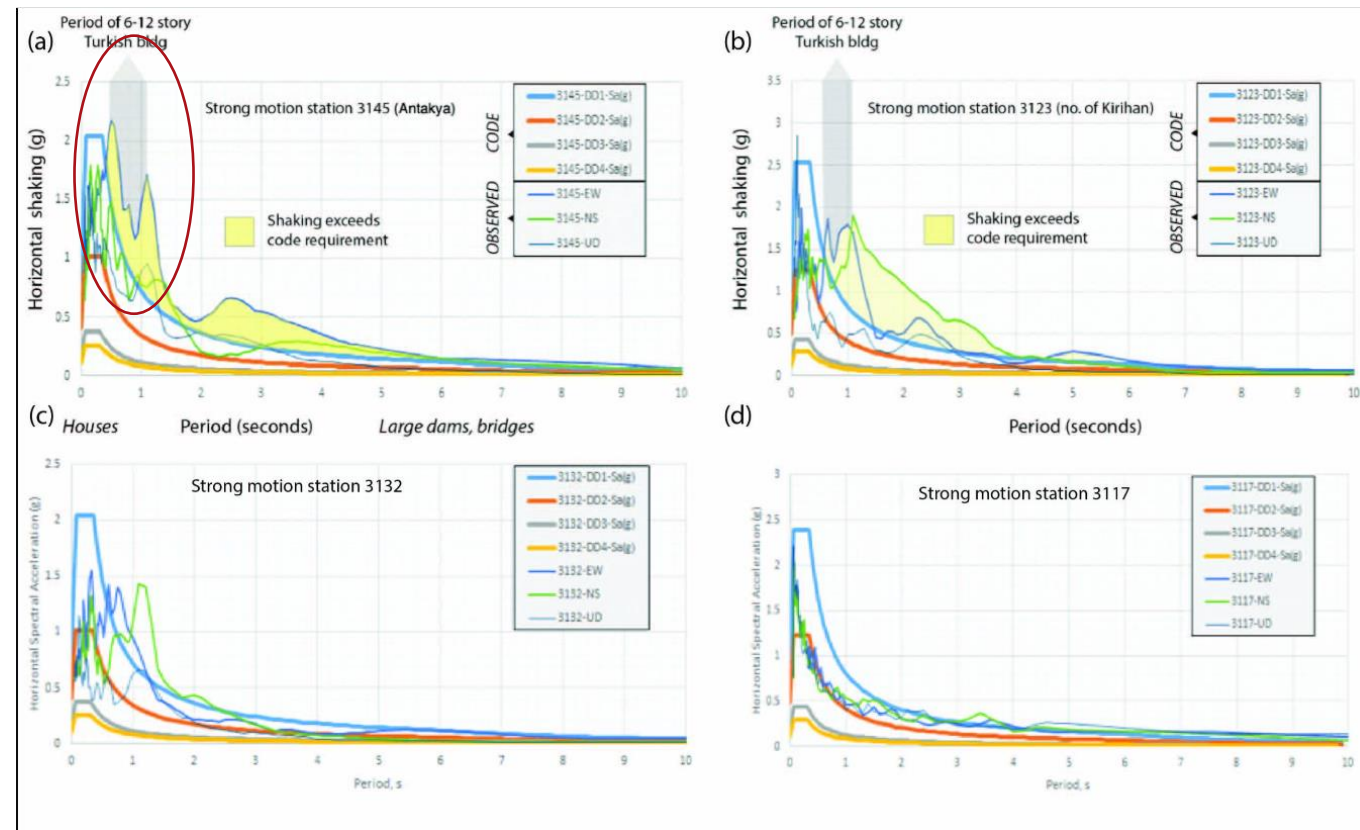
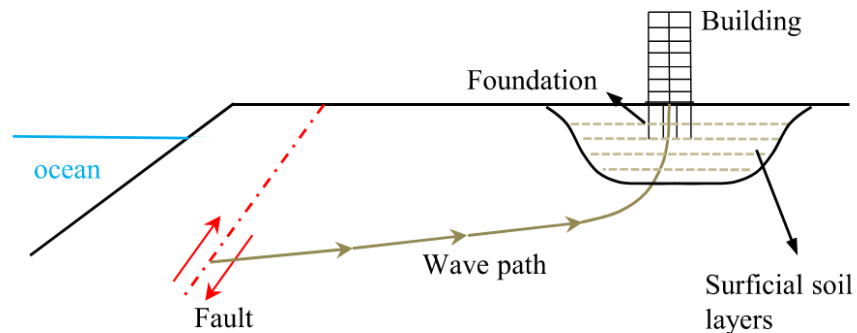
https://www.dailysabah.com/turkey/roads-railways-walls-fields-moved-by-turkiye-quake-report/news?gallery_image=undefined#big

An extraordinary lateral spread in an embankment, triggered by the 2023 Turkey-Syria earthquakes. [Image from a video posted to Twitter by @Sabah.](#)

Geo-seismic

Local ground conditions and earthquake amplification

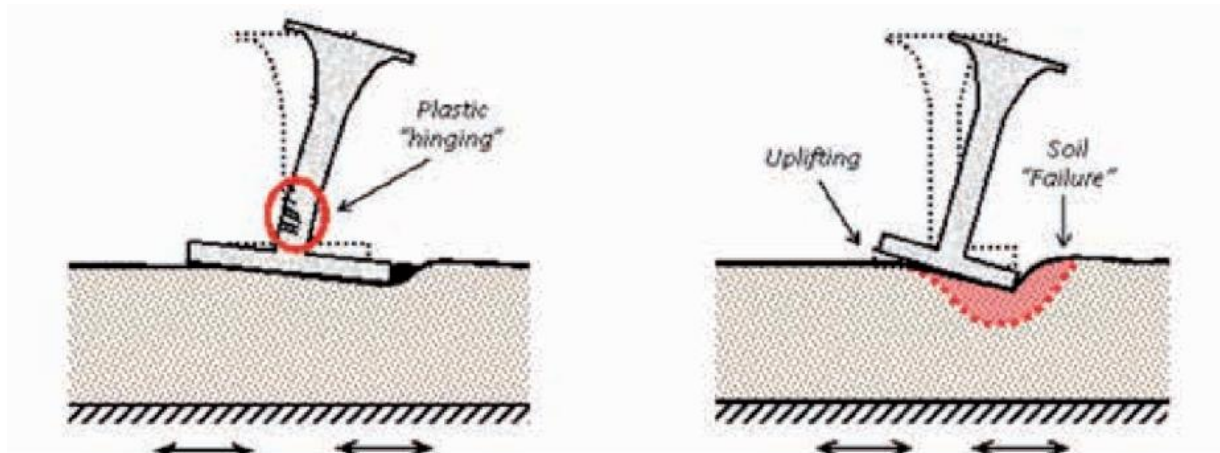
- The dominant period range coincides with structures of 6 to 12 stories and has certainly contributed to the damage of such buildings in those areas.



Geo-seismic

Liquefaction and rocking isolation

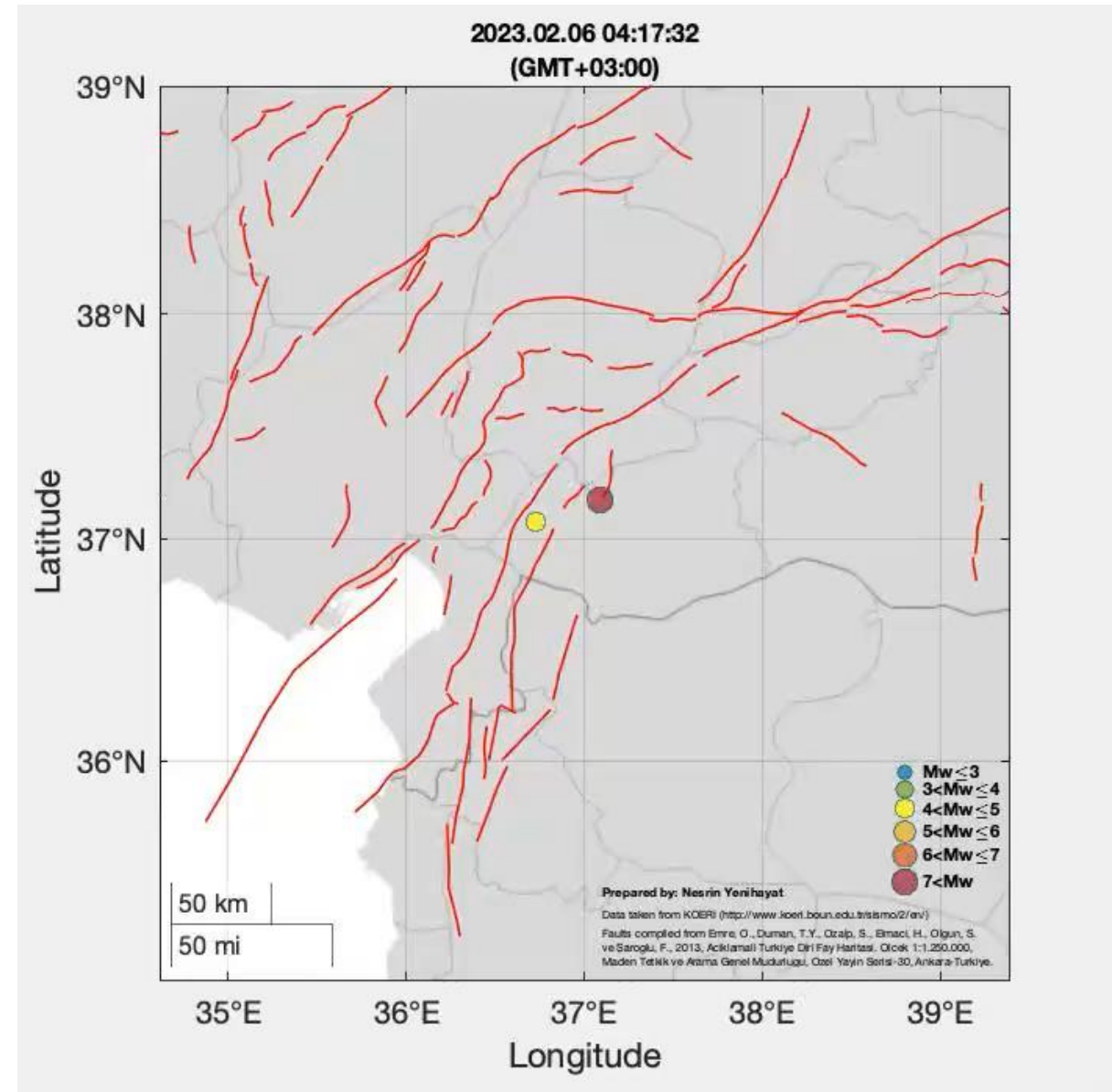
- Would the structure survive if the foundation performed well?



Turkiye Earthquake 2023

Aftershock Activity

- Over 570 aftershocks were recorded within 24 hours of the Mw 7.8 earthquake and 10,000 recorded three weeks later.
- Many buildings survived the main shock, but not the aftershocks.
- How well aftershocks are considered in the current design practice/codes?



Turkiye Earthquake 2023

Infrastructures damage

- Roads, railways, airports, ports, pipeline, hospitals, dams, ...



09/02/2023 27 Gaziantep, 46 Kahramanmaras, Mediterranean Region, RAILWAYS, Southeastern Anatolia Region, GENERAL, HEADLINE, TURKEY



Damaged runway at Hatay Airport

SOURCE: <https://aviationsourcenews.com>



Earthquake Cracks Occured at Sultansuyu Dam in Malatya

SOURCE: <https://expatguideturkey.com/earthquake-cracks-occured-at-sultansuyu-dam-in-malatya-dam-is-being-evacuated/>

Turkiye Earthquake 2023

Infrastructures damage

- Roads, railways, pipelines:
 - ✓ The hydrocarbon pipelines, roads, and railways were mainly damaged at the fault rupture crossings, landslides and liquefaction.
 - ✓ These damages reportedly have been remedied and their functionality is mostly resumed in the first ~10days.
- Airports:
 - ✓ Hatay airport: damage to runway due to soil and foundation problems and was closed to air traffic in the first three days.
 - ✓ All airports in the region were operational as of 15th of Feb.
- Bridges (~1000no.):
 - ✓ 15no. bridges had problems that could be remedied quickly / open to normal traffic within two days.
 - ✓ Two bridges collapse (one due to rockfall and the other one due to liquefaction)
- ✓ Dams (~150no.):
 - ✓ Two dams reported damage
 - ✓ Only one dam in Turkiye had cracks that led to controlled water release.
 - ✓ Afrin embankment dam in Syria (75-m height) had cracks.

Turkiye Earthquake 2023

Infrastructures damage

- *While significant damage to infrastructure is reported, the damage to major infrastructure in the earthquake-affected region is reportedly less than buildings,*
- *This arguably, indicates better design and construction practices associated with infrastructure as compared to buildings.*

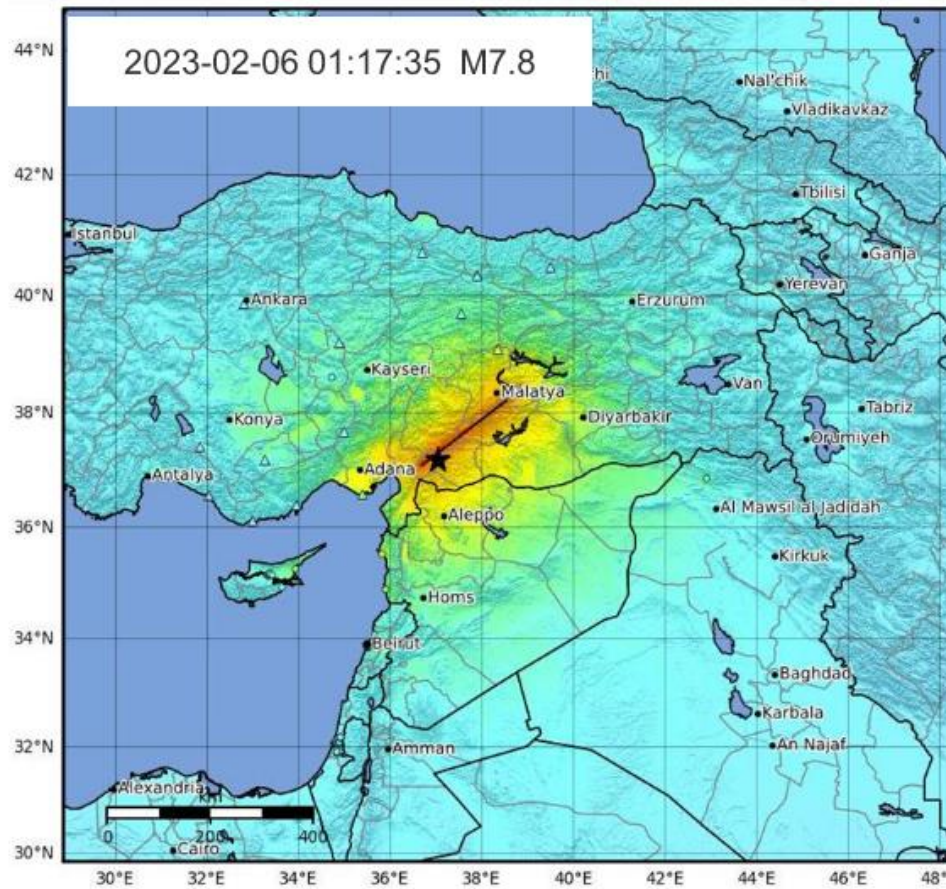
Structural Perspective

Why was it so deadly?



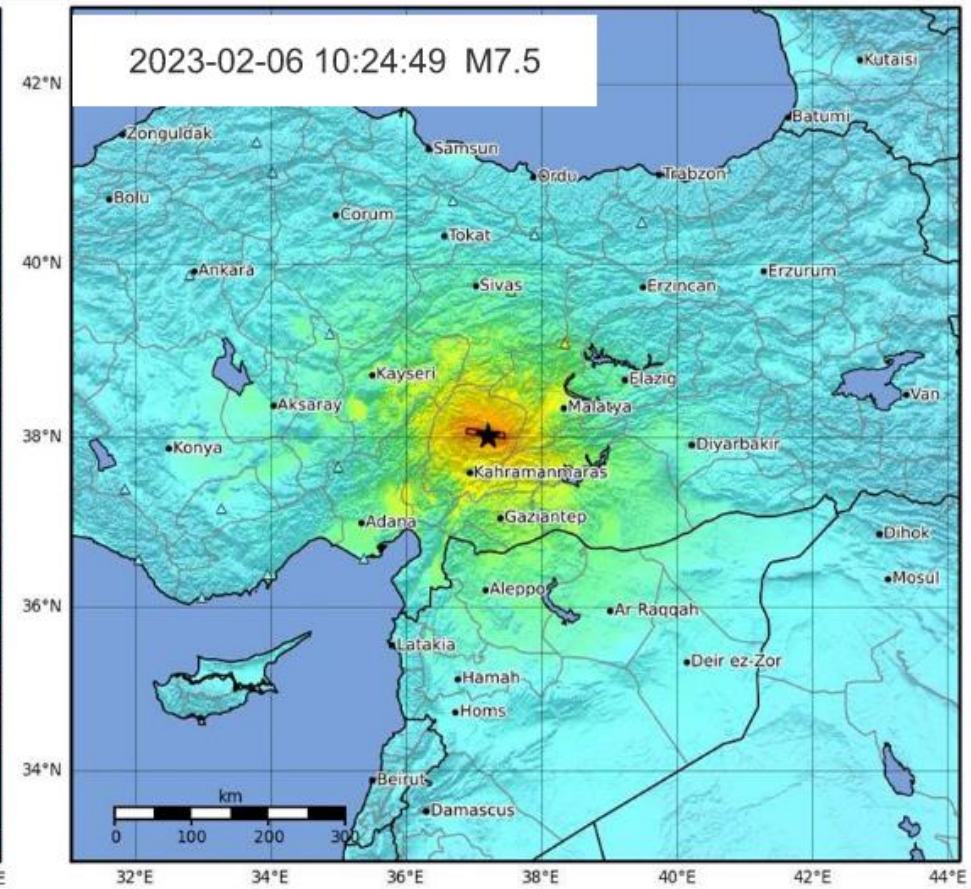
Over 56,000 people death, over 160,000 buildings collapse or severe damaged
Earthquakes don't kill people; collapsed buildings do

1. The Intensity of Earthquake



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X-XI

Scale based on Worden et al. (2012) Version 5: Processed 2023-02-06T05:11:59Z
 △ Seismic Instrument ○ Reported Intensity ★ Epicenter □ Rupture



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
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PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
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Scale based on Worden et al. (2012) Version 4: Processed 2023-02-06T12:57:28Z
 △ Seismic Instrument ○ Reported Intensity ★ Epicenter □ Rupture

It is a monster earthquake and several strong aftershocks

1. The Intensity of Earthquake

Modified Mercalli Intensity Scale (MMI)

Intensity	Characteristics
I	Shaking not felt under normal circumstances.
II	Shaking felt only by those at rest, mostly along upper floors in buildings.
III	Weak shaking felt noticeably by people indoors. Many do not recognize this as an earthquake. Vibrations similar to a large vehicle passing by.
IV	Light shaking felt indoors by many, outside by few. At night, some were awakened. Dishes, doors, and windows disturbed; walls cracked. Sensation like heavy truck hitting a building. Cars rock noticeably.
V	Moderate shaking felt by most; many awakened. Some dishes and windows broken. Unstable objects overturned.
VI	Strong shaking felt by all, with many frightened. Heavy furniture may move, and plaster breaks. Damage is slight.
VII	Very strong shaking sends all outdoors. Well-designed buildings sustain minimal damage; slight-moderate damage in ordinary buildings; considerable damage in poorly built structures.
VIII	Severe shaking. Well-designed buildings sustain slight damage; considerable damage in ordinary buildings; great damage in poorly built structures.
IX	Violent shaking. Well-designed buildings sustain considerable damage; buildings are shifted off foundations, with some partial collapse. Underground pipes are broken.
X	Extreme shaking. Some well-built wooden structures are destroyed; most masonry and frame structures are destroyed. Landslides considerable.
XI	Few structures are left standing. Bridges are destroyed, and large cracks open in the ground.
XII	Total damage. Objects thrown upward in the air.

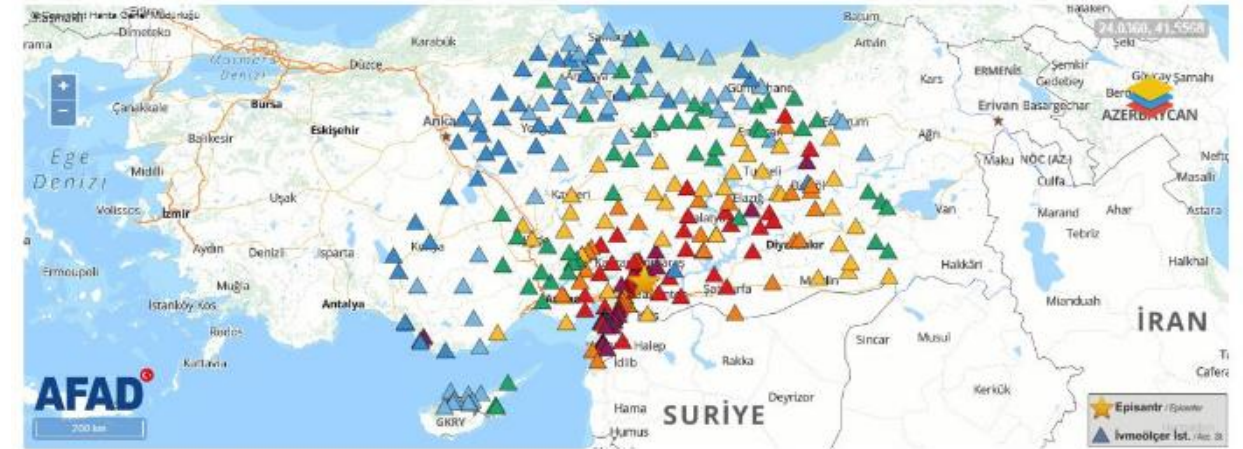
- The lesser degrees of the MMI scale generally describe the manner in which the earthquake is felt by people
- The greater numbers of the scale are based on observed structural damage.

1. The Intensity of Earthquake

Peak Ground Acceleration (PGA)

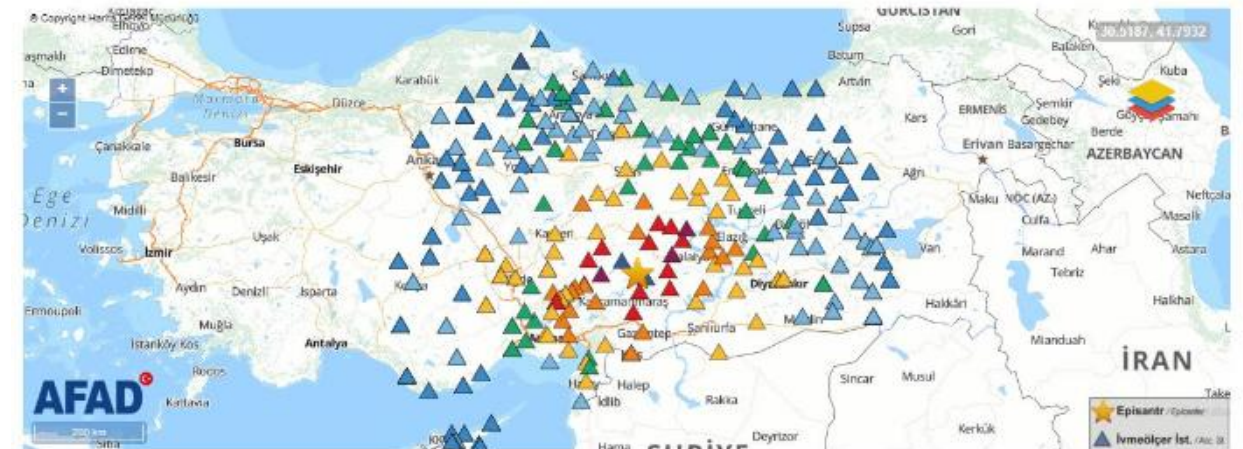
2023-02-06 01:17:35 M7.8

M7.8 earthquake maximum PGA > 1g, most observations recorded PGA > 0.5g



2023-02-06 10:24:49 M7.5

M7.8 earthquake maximum PGA > 0.9g



2. URM's structural vulnerabilities



RC frame with Unreinforced masonry (URM) infill walls

- Cost effective; easy to construction; flexible layout
- Severe seismic vulnerabilities without proper design and detailing

2. URM's structural vulnerabilities

Global vulnerabilities: **Weak/soft storey mechanism**



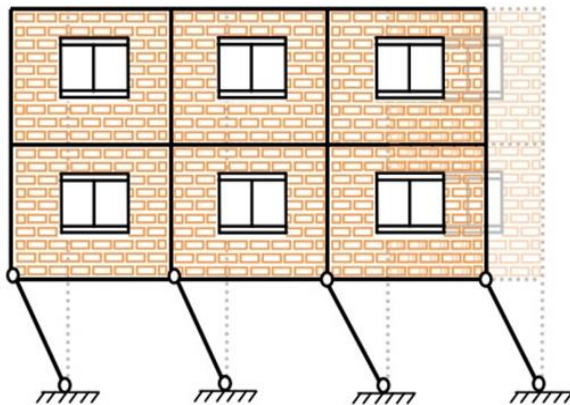
(Pancaking collapse of soft storey 1999 Izmit earthquake)



(Soft storey failure of infilled frame during the 1999 Izmit earthquake)



2023 Turkey/Syria earthquake



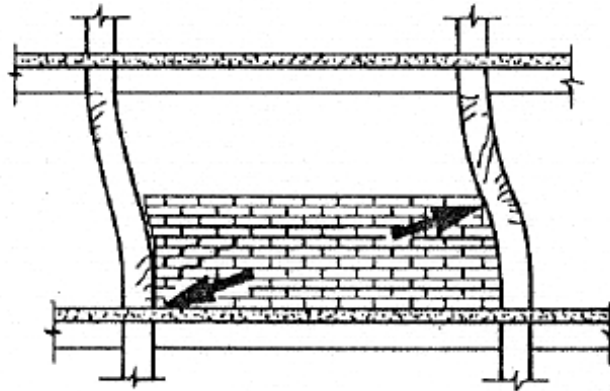
- ✓ Abrupt change in vertical stiffness lead to **vertical irregularity**
- ✓ Especially common in the ground floor since wide open are occupied for accommodating commercial or parking space

2. URM's structural vulnerabilities

Local vulnerabilities: **Short column/BCJ/Out of plane**



- ✓ Force transfer path **totally different**
- ✓ Unexpected short columns are formed from confinement of **partial storey height** masonry infill panels for functional openings
- ✓ Out of plane throw off failure



3. Design and construction quality issue



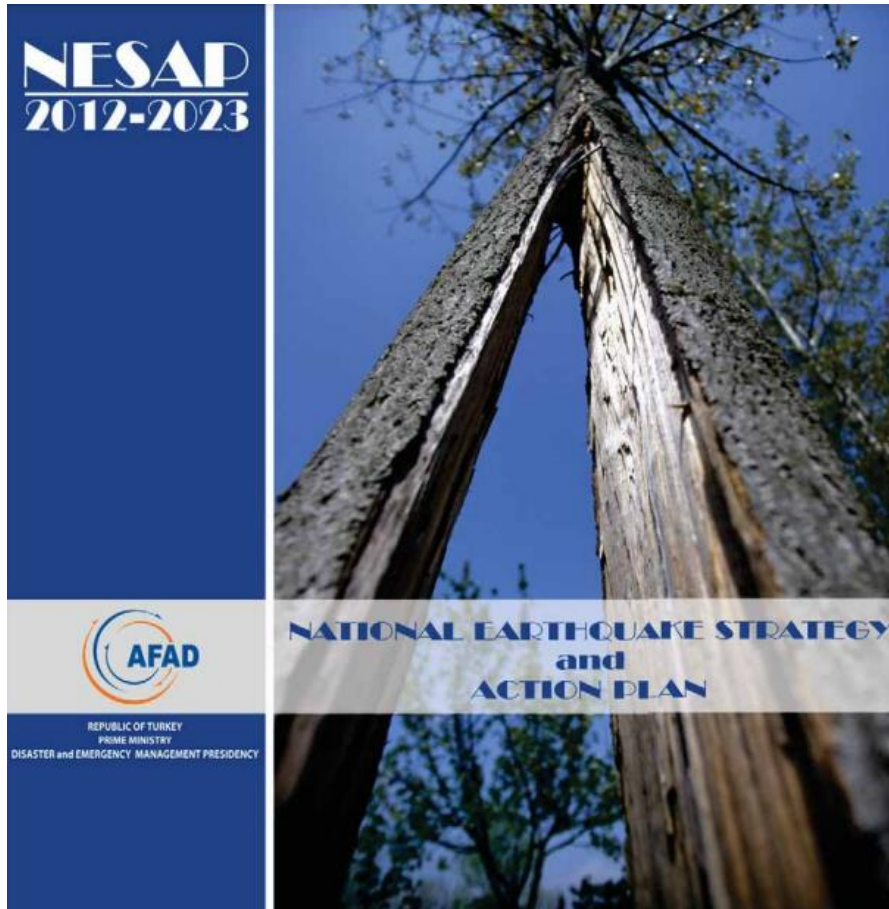
Before and after: A recently built apartment block in Iskenderun

- ✓ the latest standards, updated in 2018, which require structures in earthquake-prone regions to use high-quality concrete reinforced with steel bars. Columns and beams must be distributed to effectively absorb the impact of earthquakes.

Cobblestone found in concrete, round bar not ribbed bar
Seismic design Building Regulations failure to be enforced?



3. Design and construction quality issue



Turkey’s National Earthquake Strategy and Action Plan for 2012 to 2023 highlighted massive and rapid migration during the 1950s led to poorly supervised urban development, making cities “critically vulnerable” to natural hazards.

The Current Situation

Source: NYT

Shattered Homes and Lurking Disease: Quake Hardships Pile Up

Hundreds of thousands are sheltering in tents, breathing air thick with pollutants unleashed from tombs of rubble, fearful that a new disaster could strike at any moment.

Source: WSJ



Source: Maxar Technologies



Selected Charities



**Relief
International**

<https://www.ri.org/>



**Save the
Children**

<https://www.savethechildren.net/>



**Ahbap (Türkiye-
specific)**

<https://ahbap.org/>



**Afad (Türkiye-
specific)**

[https://en.afad.gov.t
r/](https://en.afad.gov.tr/)

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Q&A

ARUP