
QUAKELOGIC

Highlights of Worst Devastation in Turkey

- Two back-to-back M7.8 and M7.6 earthquakes occurred in Eastern Turkey within 9 hours

- Affected 15 highly populated provinces

- Over 47,000 people lost their lives

- More than 5,000 buildings collapsed

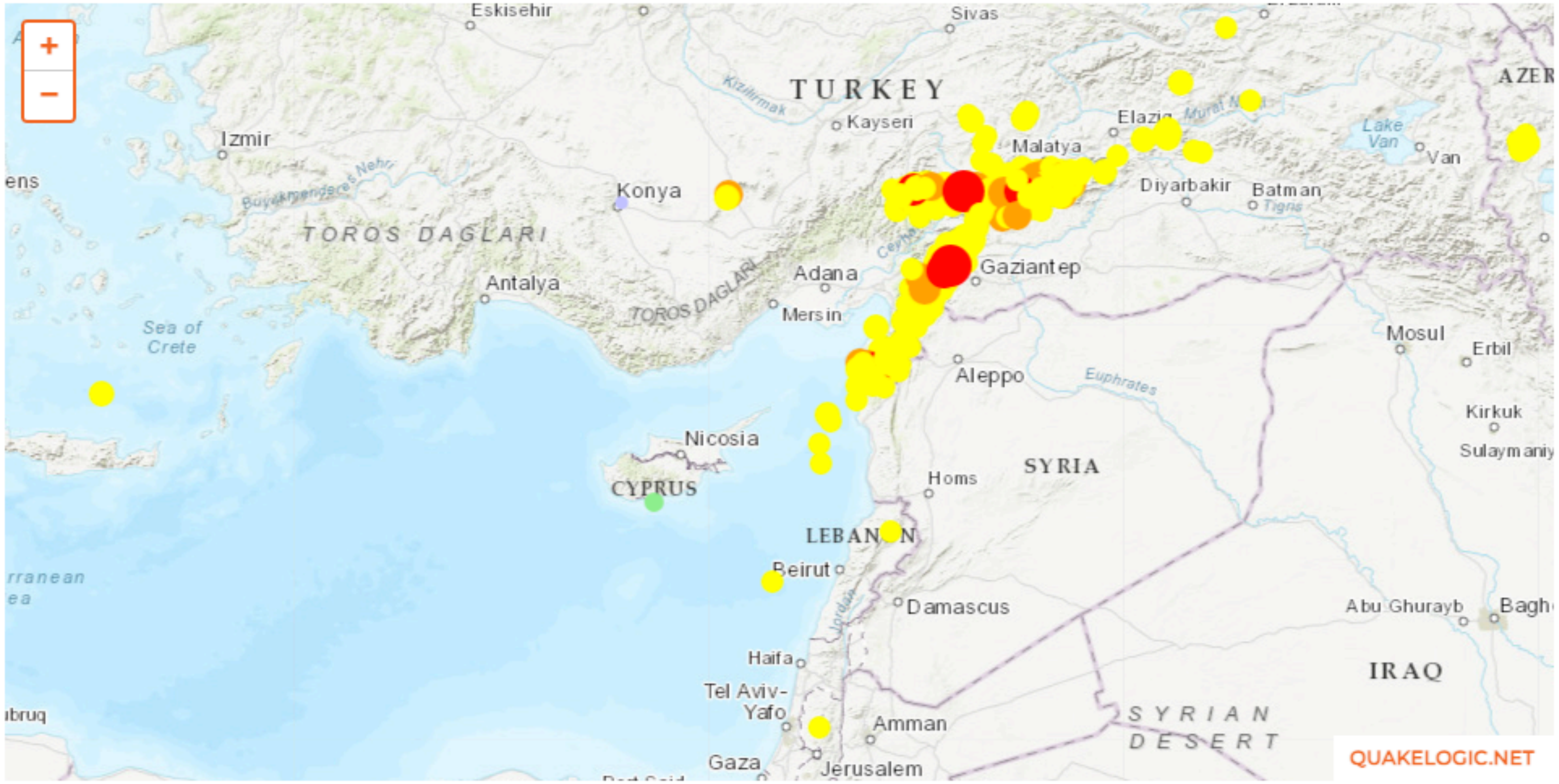
Recent Eartqhuake Sequence in Turkey

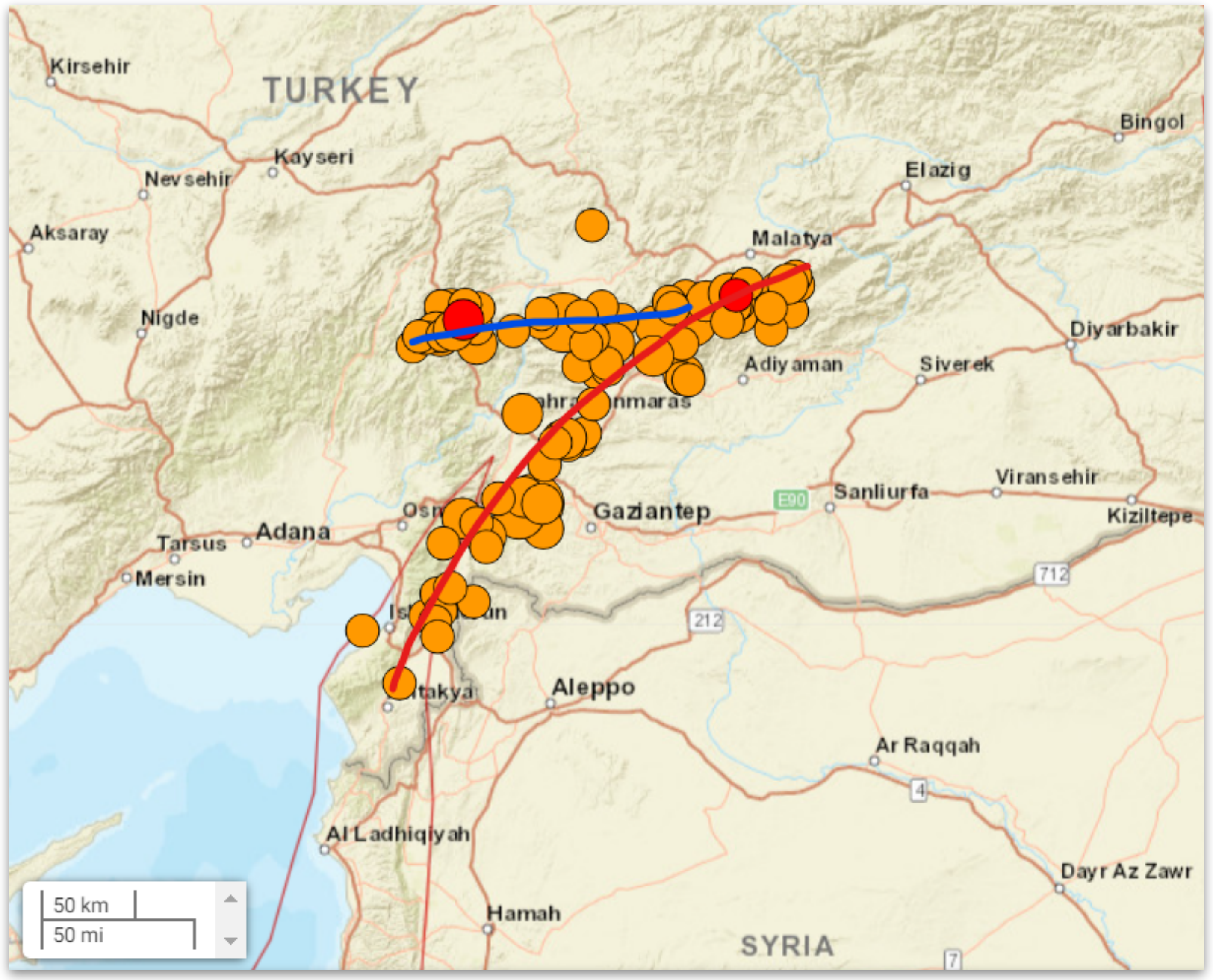
RECENT EARTHQUAKES

30 days of earthquakes (magnitude 2.5 and above) are retrieved from the U.S. Geological Survey

MAGNITUDE SCALE OF EARTHQUAKES

2 - 3 · 3 - 4 · 4 - 5 · 5 - 6 · 6+

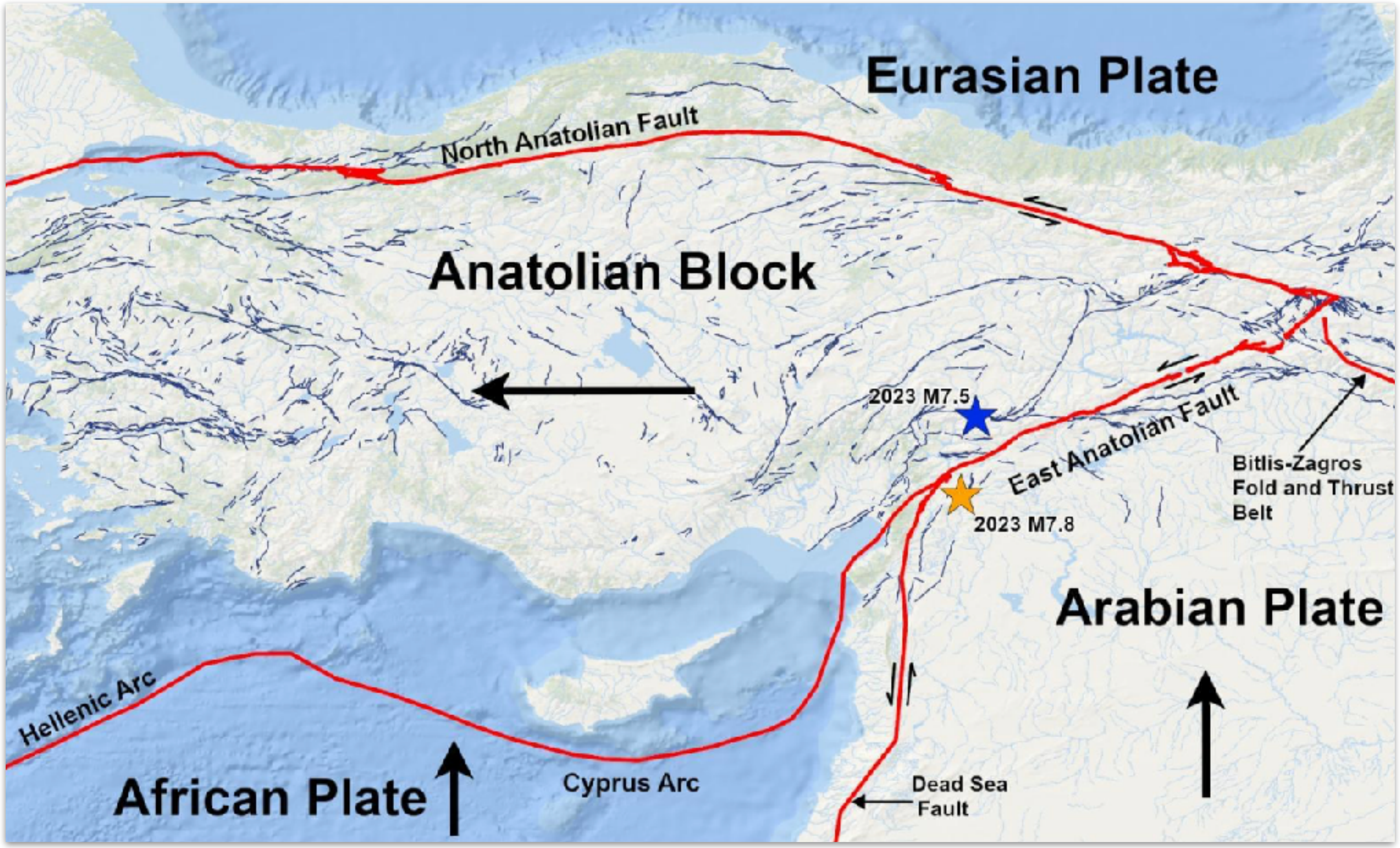


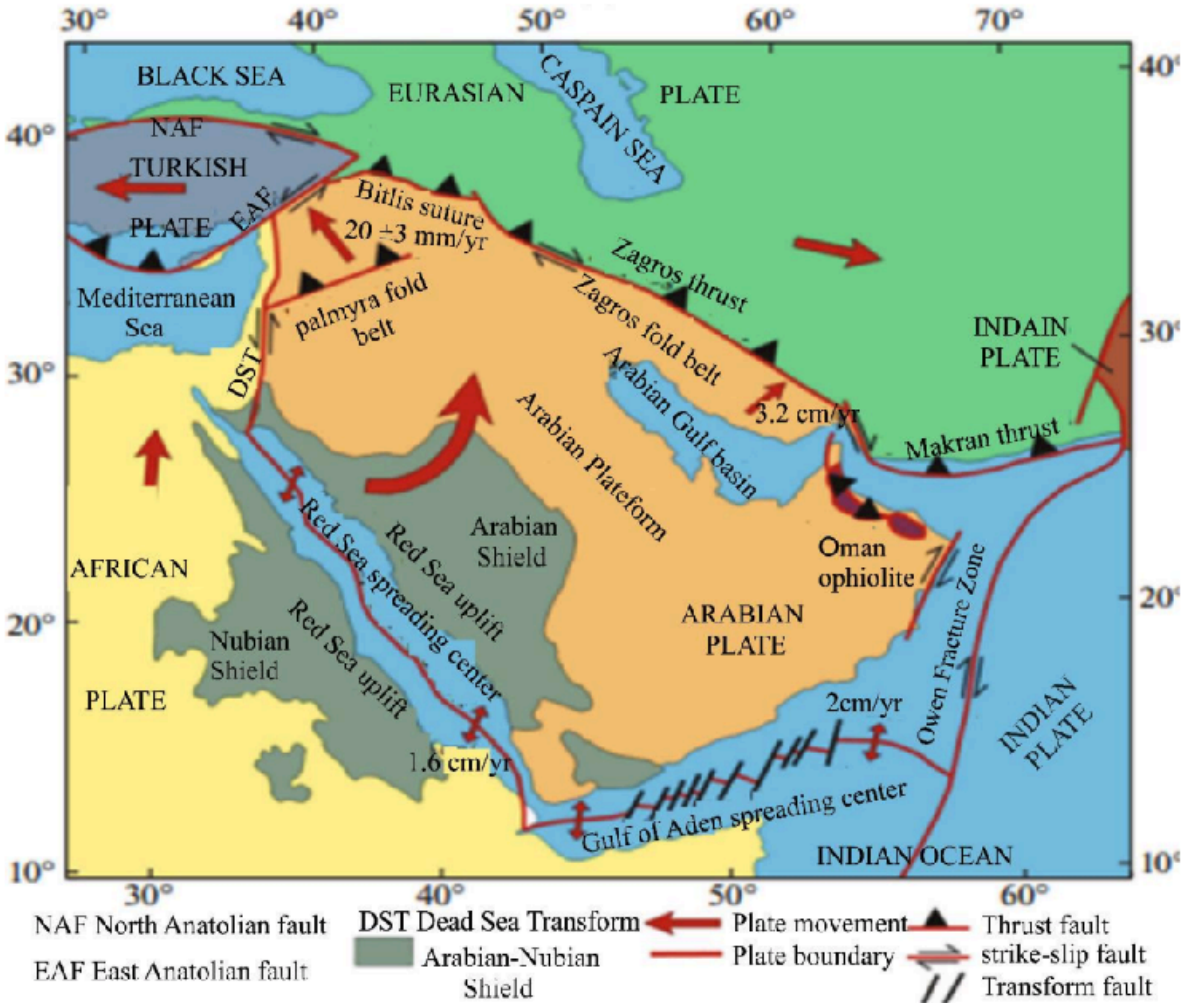


- M7.8 Mainshock
- M7.6 Mainshock

- M6.7 Aftershock
- M6.0 Aftershock
- M6.0 Aftershock
- M6.4 Aftershock (15 days later)

How Did These Earthquakes Occur?

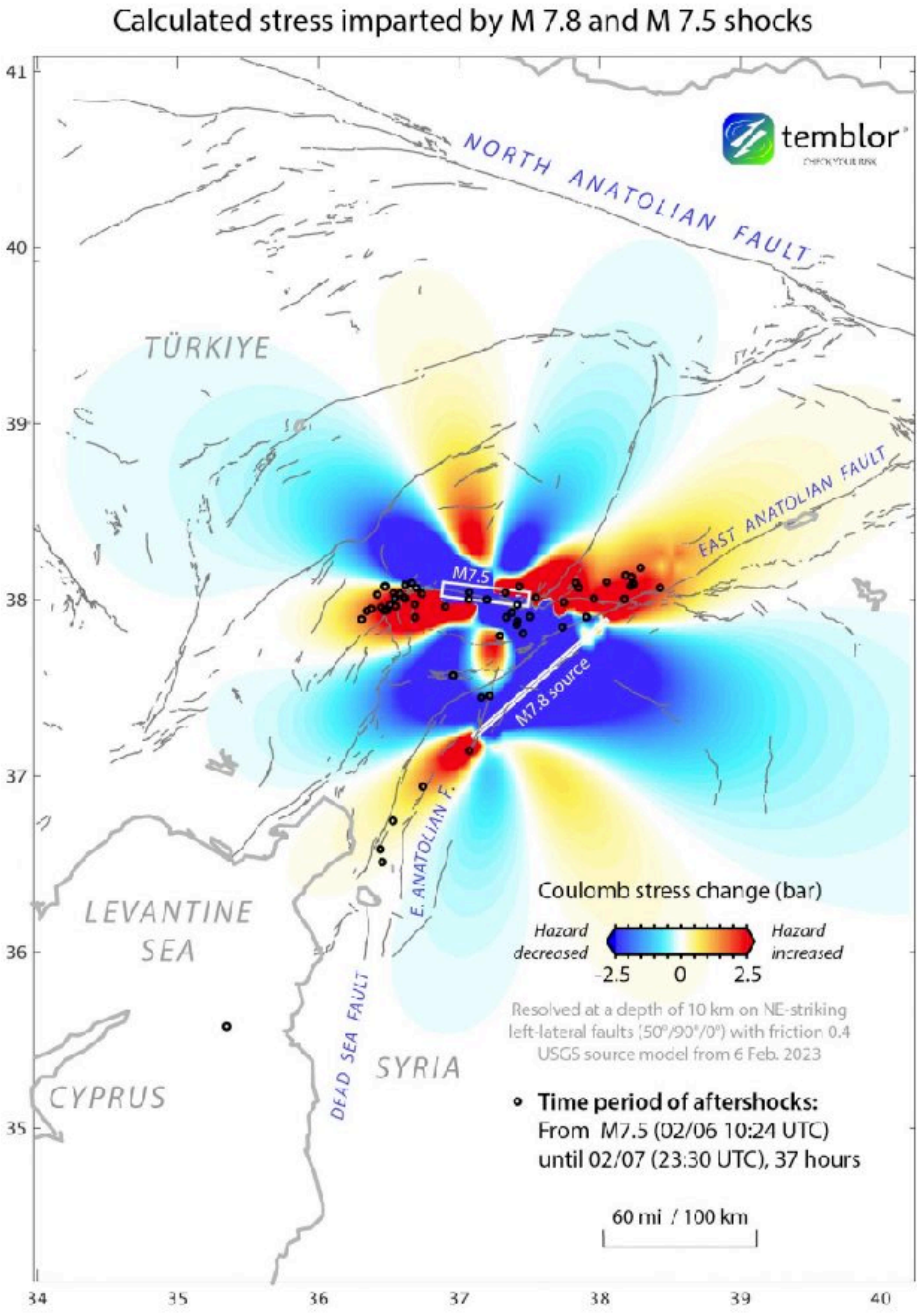




- The recent earthquakes were caused by the complex interaction of the Eurasian and African tectonic plates along the North Anatolian Fault Zone.

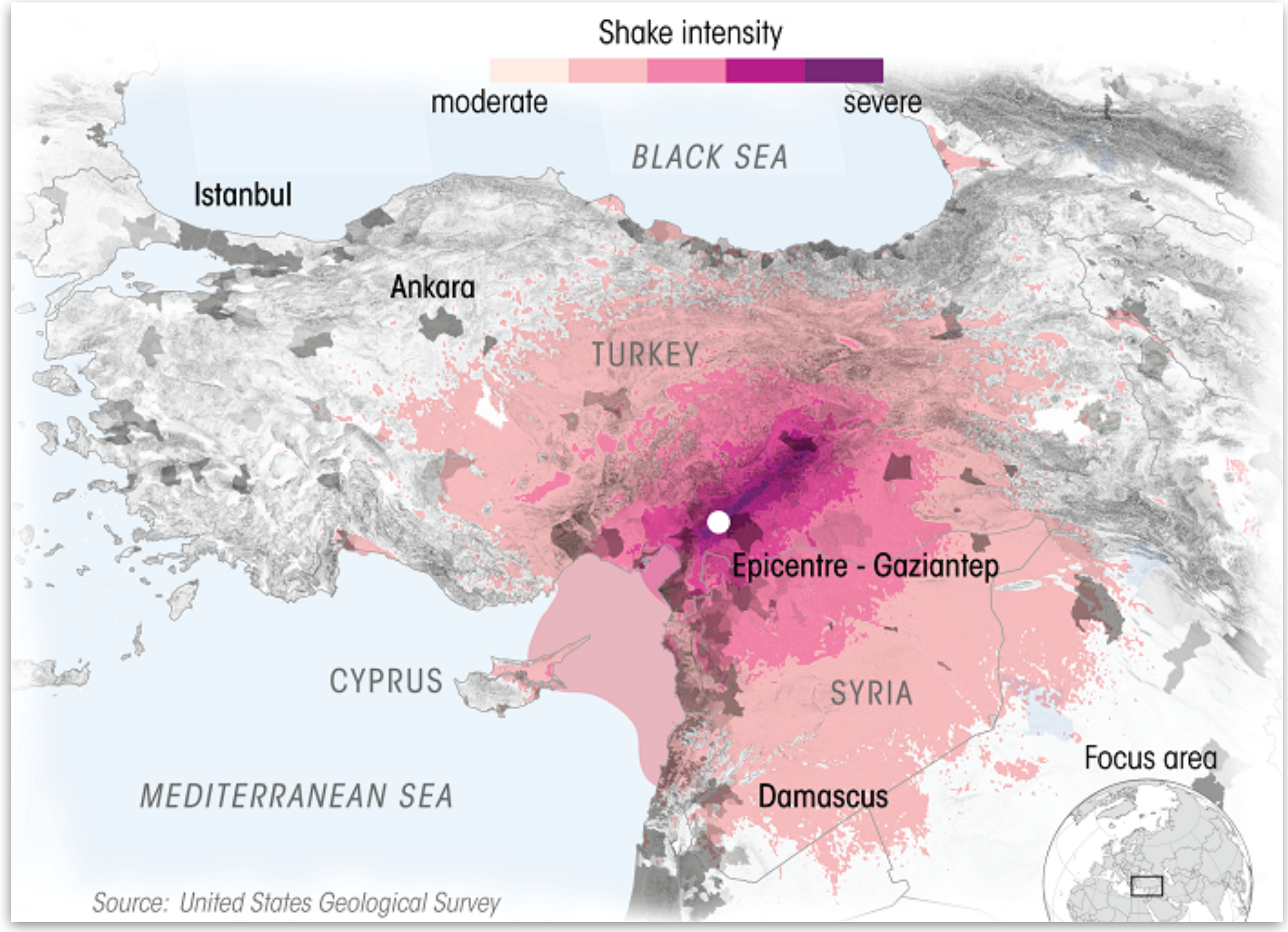
Earthquakes Like Domino Pieces

- The frequency of big earthquakes on the Eastern Anatolian Fault varies, but it is estimated that major earthquakes occur on this fault every few decades.
- Earthquakes can propagate like domino pieces, where one earthquake triggers another one on a nearby fault.
- When an earthquake occurs, it can create additional stress on the next segment of the fault, which increases the risk of another earthquake happening in that area

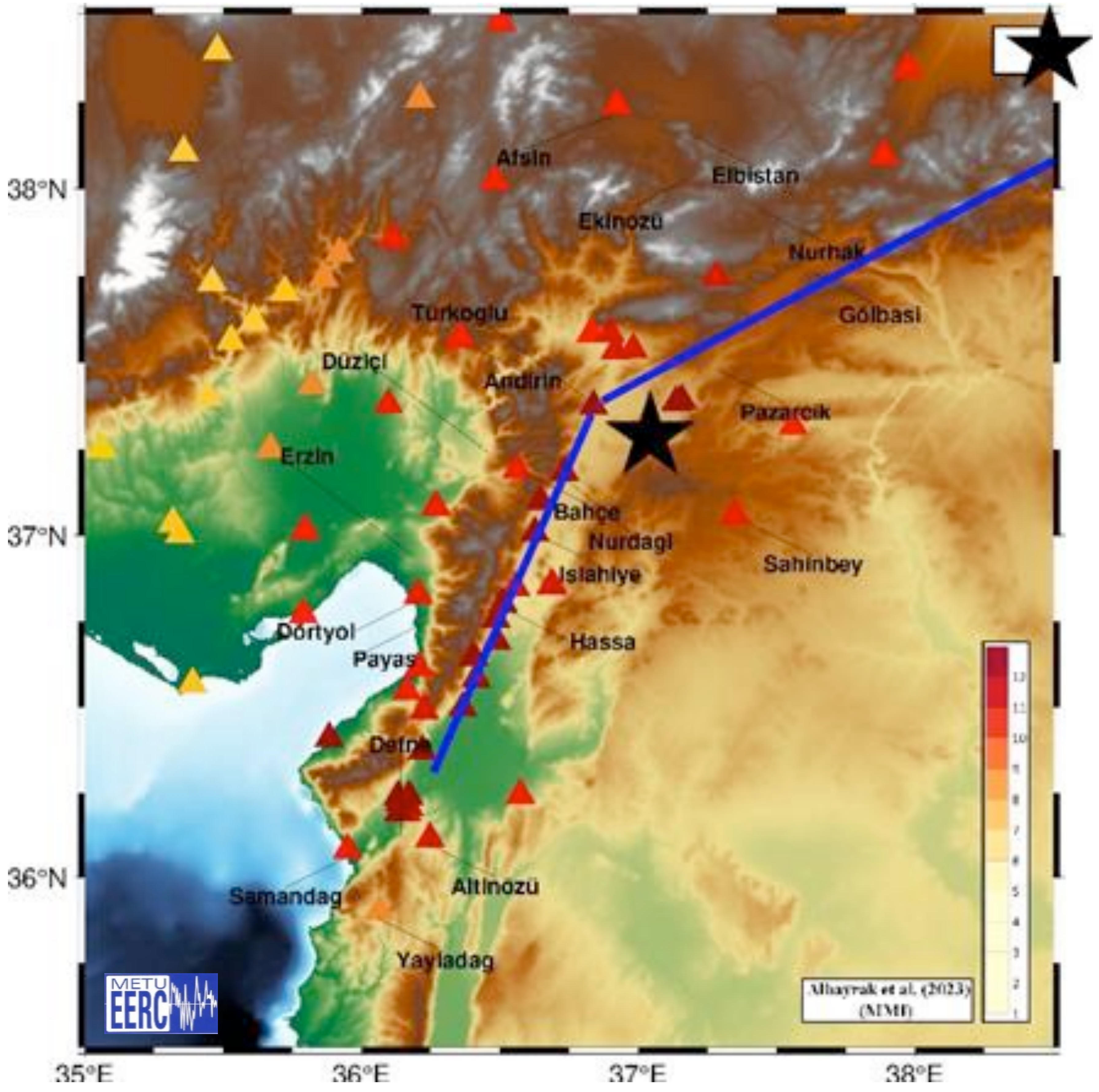


Widespread Shaking

- MMI scale is based on observable earthquake damage. In other words, the magnitude scale of an earthquake is based on seismic recordings while the MMI is based on observable data which can be subjective.



I. Not felt	Not felt except by very few under especially favorable conditions.
II. Weak	Felt only by a few people at rest, especially on upper floors of buildings.
III. Weak	[LOW]: Felt quite noticeably by people indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Vibrations similar to the passing of a truck.
IV. Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building.
V. Moderate	[MEDIUM]: Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned.
VI. Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII. Very strong	[MEDIUM-HIGH]: Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII. Severe	[HIGH]: Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Heavy furniture overturned.
IX. Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Liquefaction.
X. Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI. Extreme	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII. Extreme	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

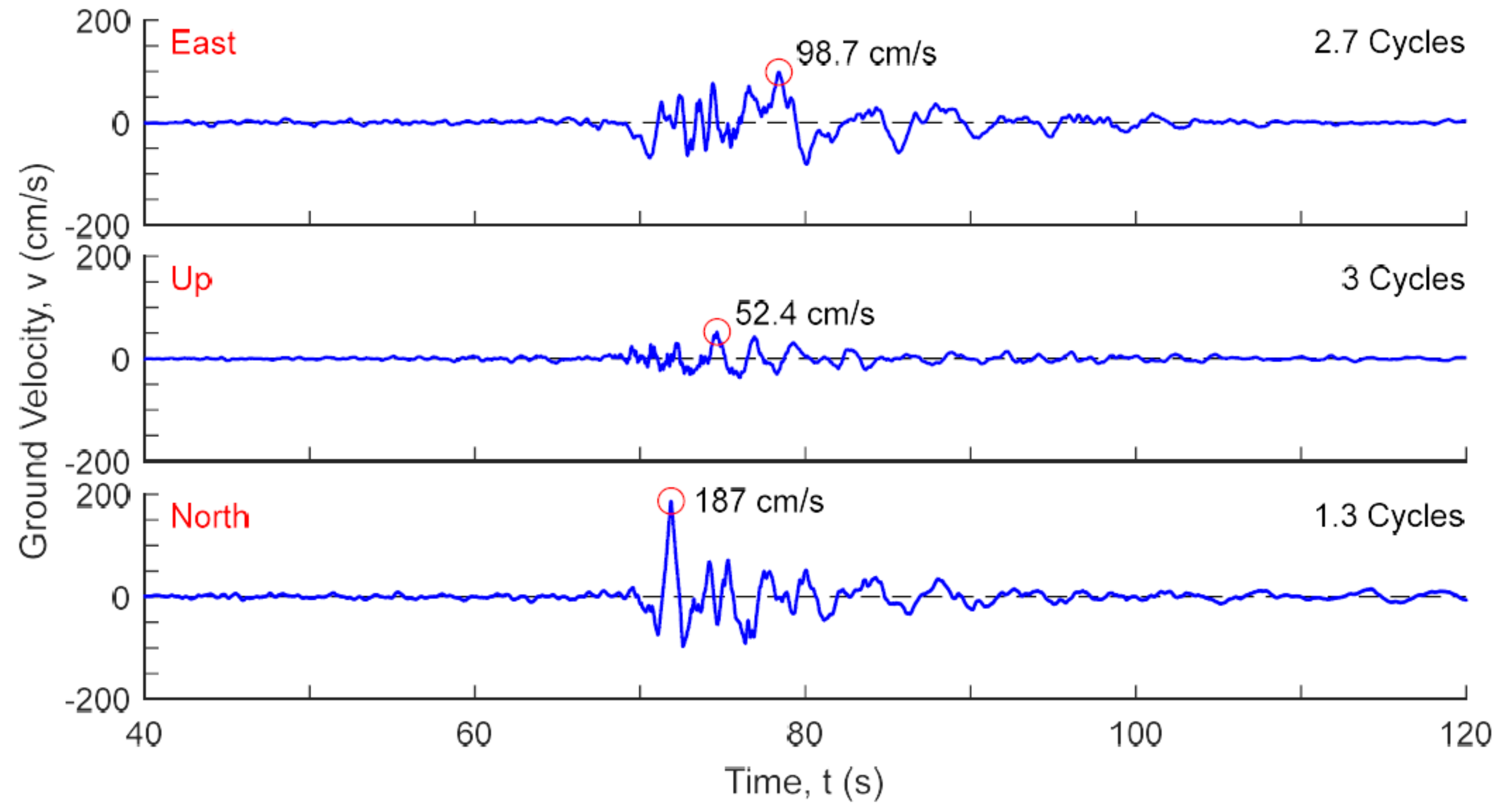


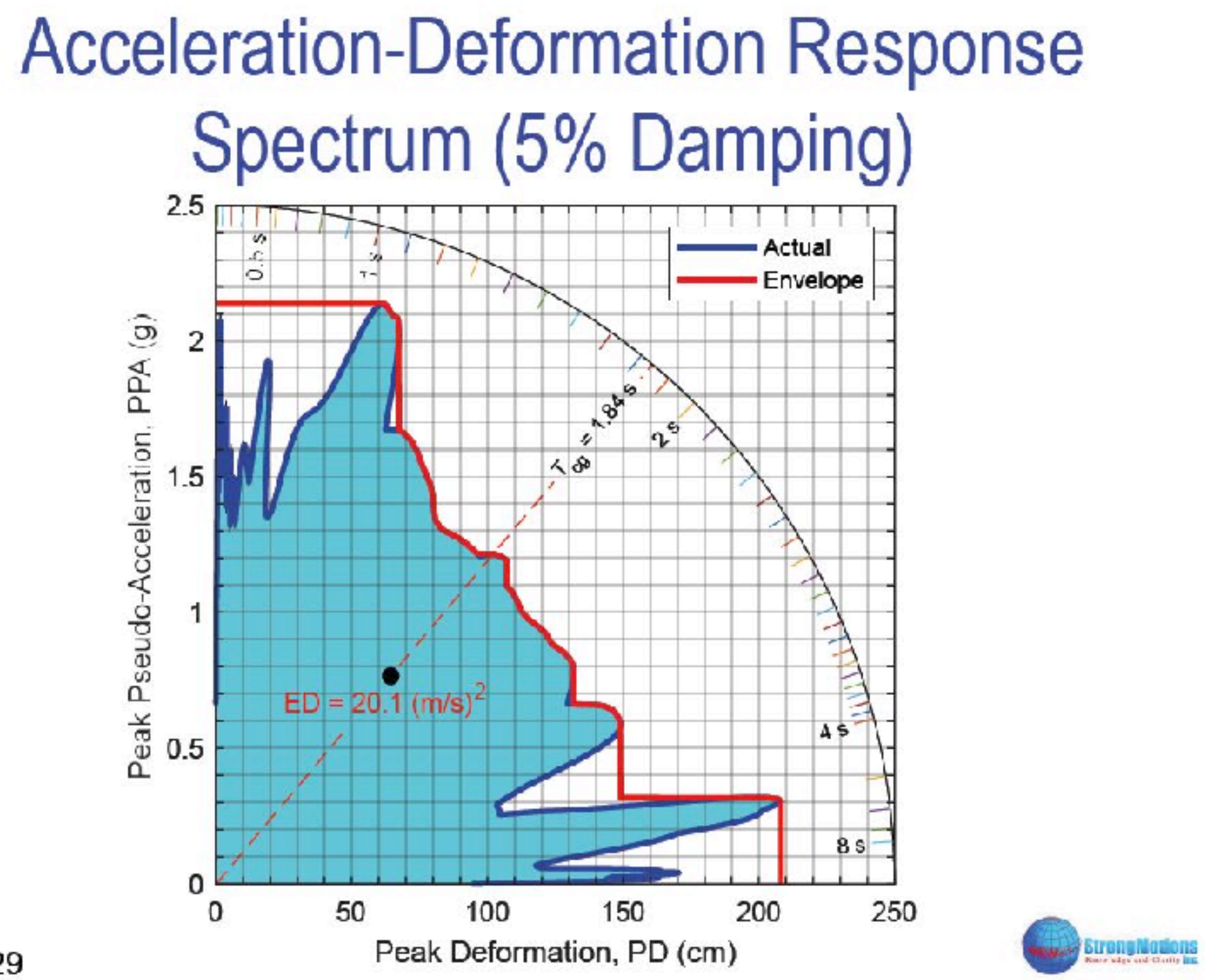
Earthquake Damage

Ground Motions

- The severity of structural damage in the city of Hatay could be due to several factors, including the earthquake's proximity to the city, the local geology and soil conditions, the age and quality of the buildings, and the area's vulnerability to earthquakes.

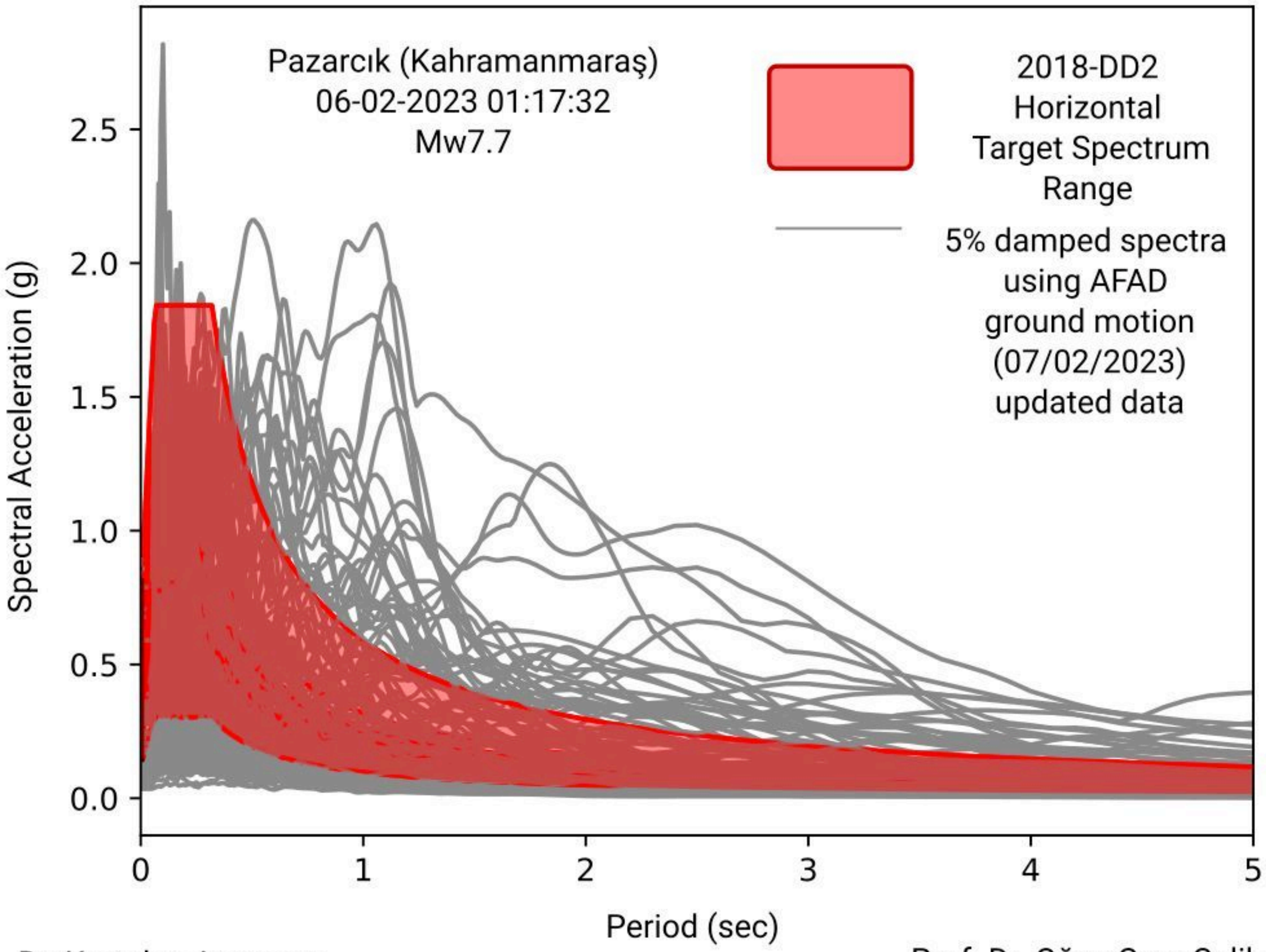
- One observation from ground motion data is so striking that peak ground velocity (PGV) reached 188 cm/s at the seismic station in Hatay. This is the largest PGV recorded during this earthquake.





This station has VS30 of 470 m/s (NEHRP site category C -- very dense soil and rock)

Ground Motions vs Design Spectra



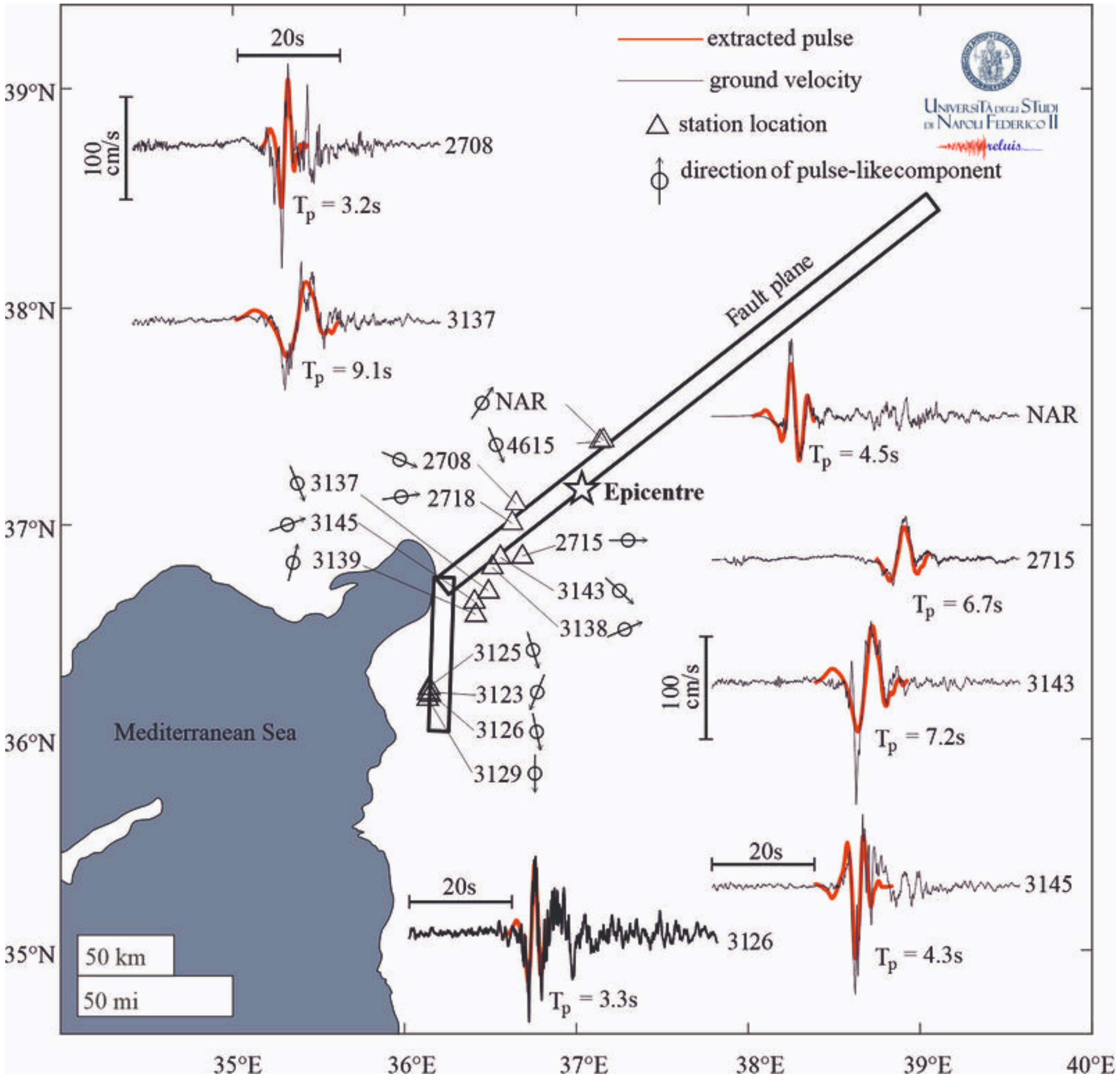
Dr. Kurtulus Atasever

Prof. Dr. Oğuz Cem Çelik

- Spectral ordinates at 0.5 second and above periods were much higher than the design values.

- These plots show only the spectral accelerations. Equally important were the large deformation demands associated with high ground velocities responsible for widespread structural damage.

Near-fault Directivity Pulses



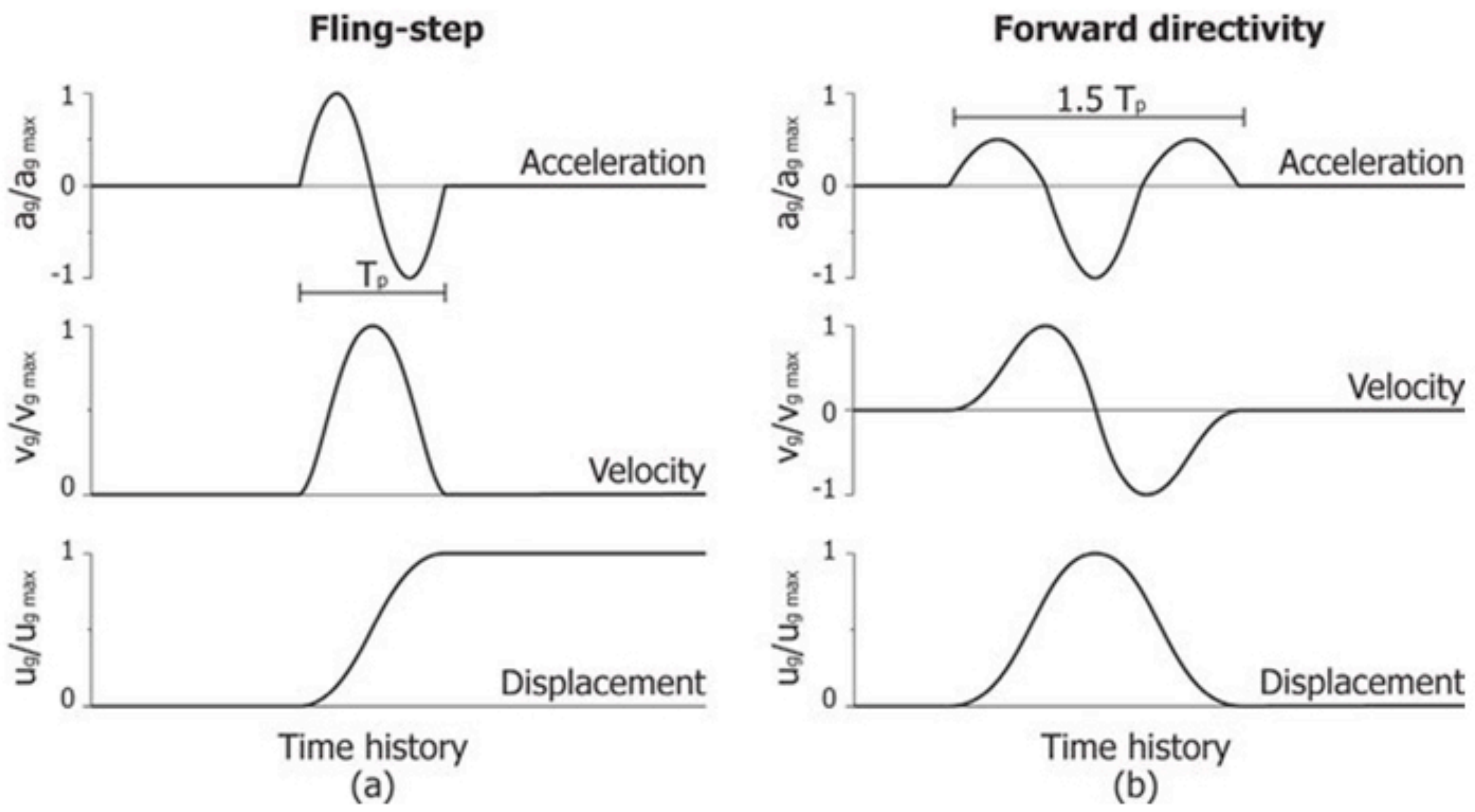
- Top Image: Prof. Iunio Iervolino

Effects of Fling Step and Forward Directivity on Seismic Response of Buildings

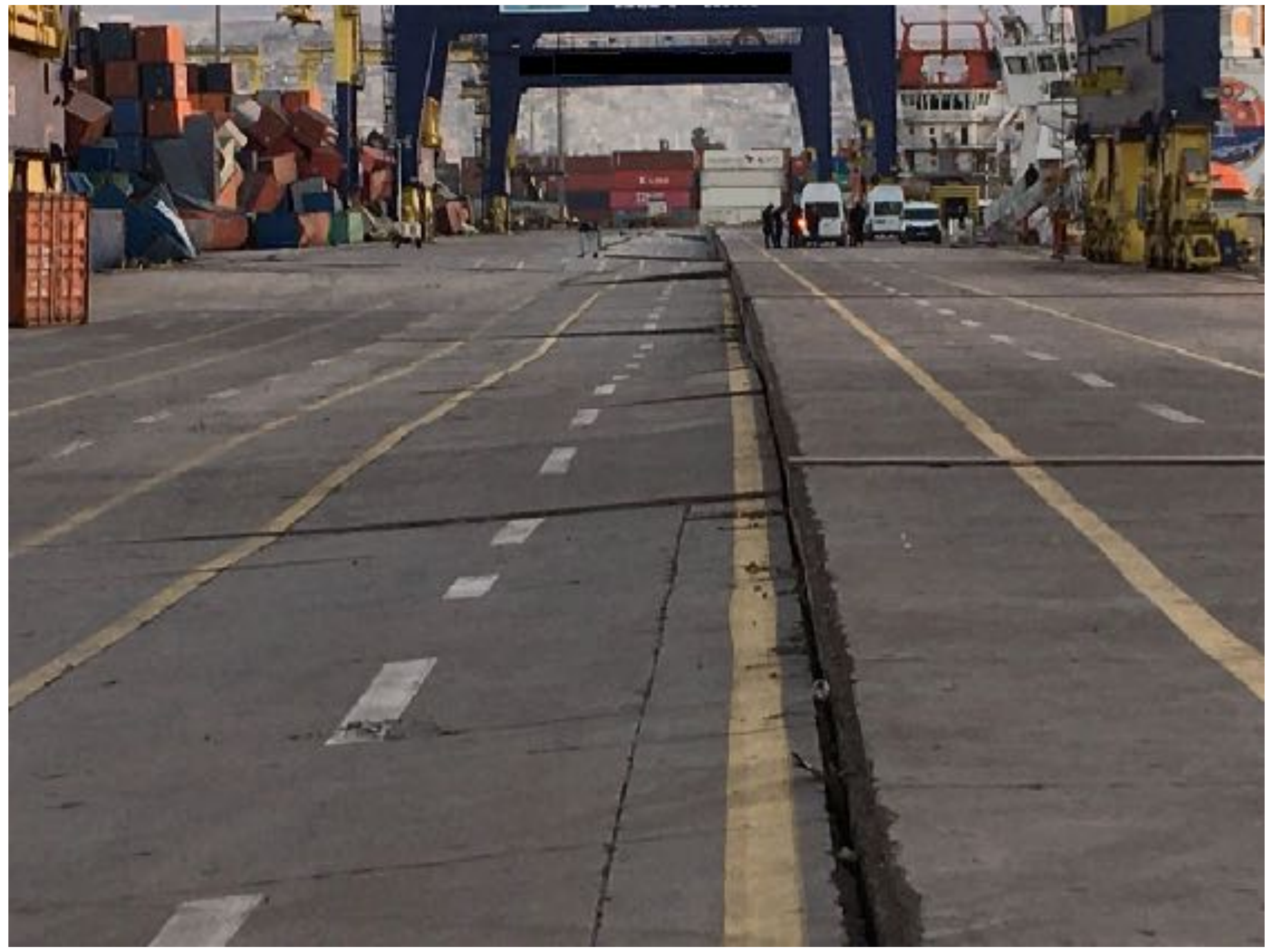
Erol Kalkan,[a] S.M.EERI, and Sashi K. Kunnath,[a] M.EERI

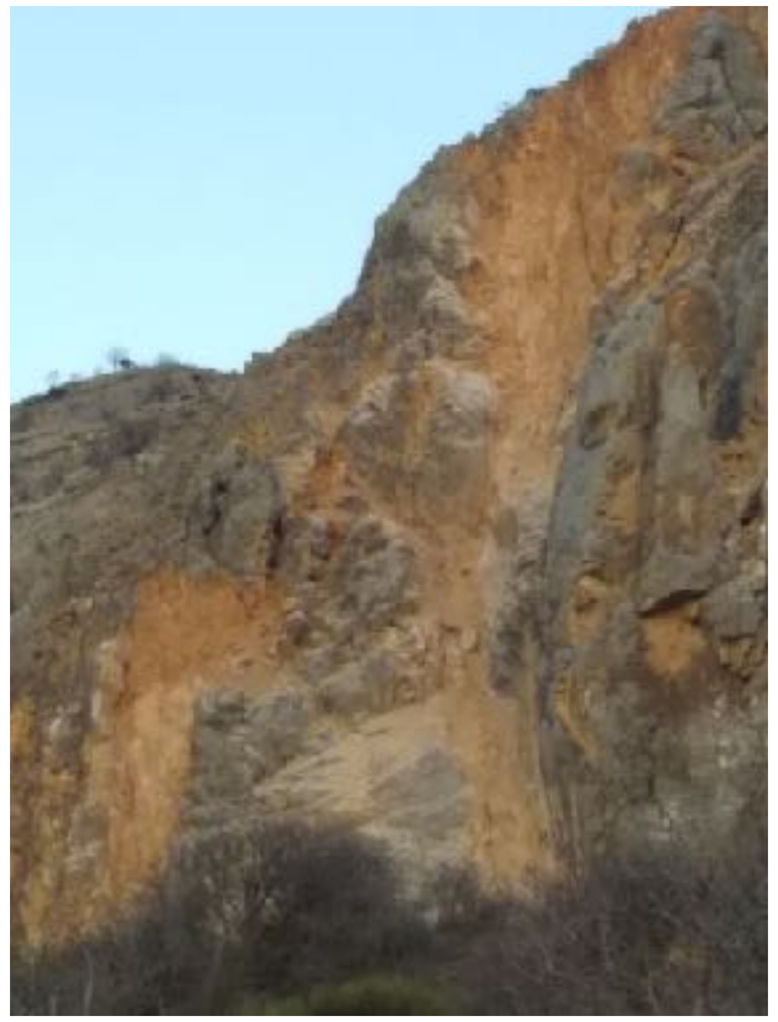
This paper investigates the consequences of well-known characteristics of near-fault ground motions on the seismic response of steel moment frames. Additionally, idealized pulses are utilized in a separate study to gain further insight into the effects of high-amplitude pulses on structural demands. Simple input pulses were also synthesized to simulate artificial fling-step effects in ground motions originally having forward directivity. Findings from the study reveal that median maximum demands and the dispersion in the peak values were higher for near-fault records than far-fault motions. The arrival of the velocity pulse in a near-fault record causes the structure to dissipate considerable input energy in relatively few plastic cycles, whereas cumulative effects from increased cyclic demands are more pronounced in far-fault records. For pulse-type input, the maximum demand is a function of the ratio of the pulse period to the fundamental period of the structure. Records with fling effects were found to excite systems primarily in their fundamental mode while waveforms with forward directivity in the absence of fling caused higher modes to be activated. It is concluded that the acceleration and velocity spectra, when examined collectively, can be utilized to reasonably assess the damage potential of near-fault records. [DOI: 10.1193/1.2192560]

- https://quakelogic.net/Pubs/38.pdf



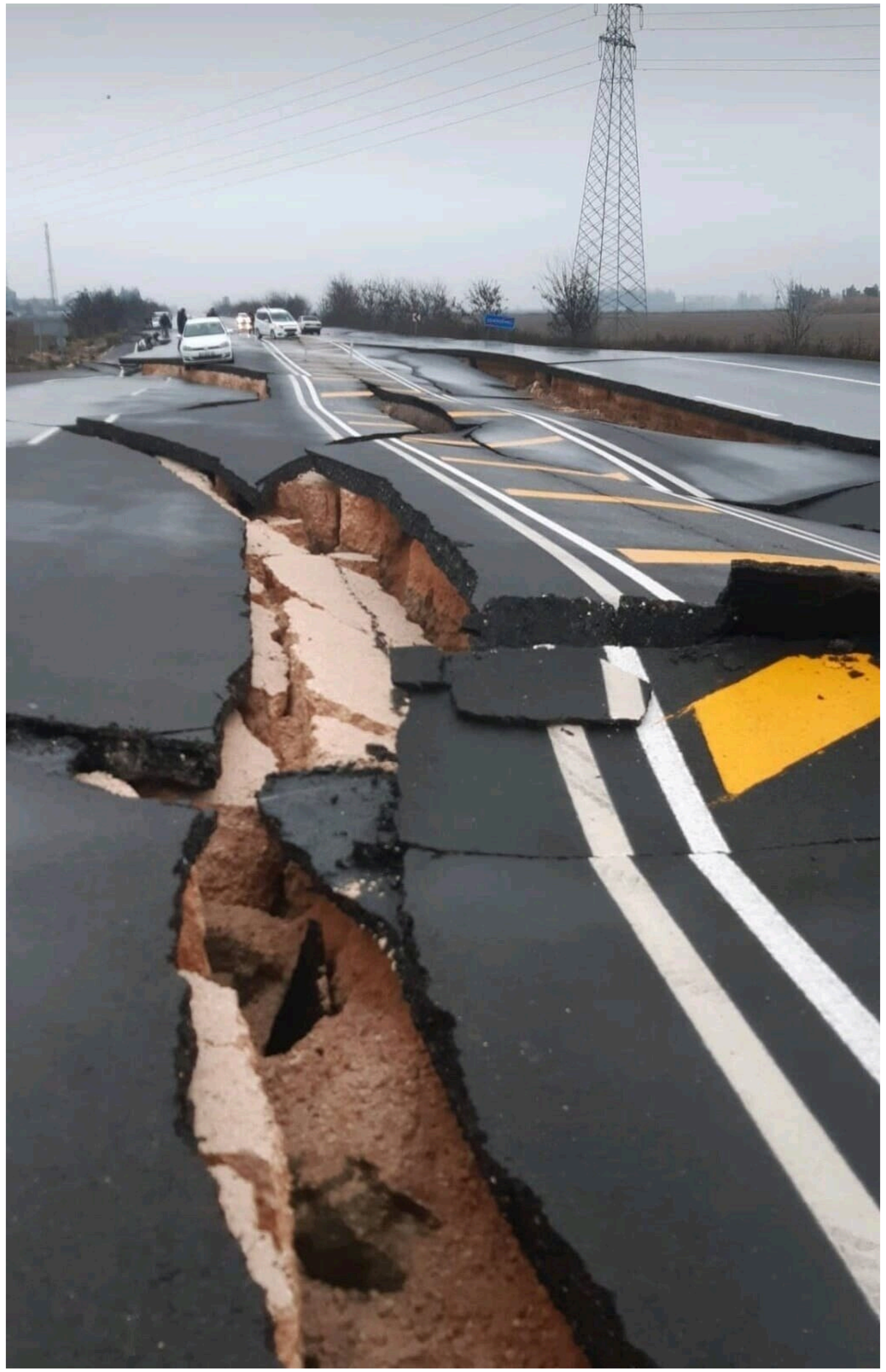
Field Observations





- Credit for photos: Dr. Mutafa Kockar and SkyNews

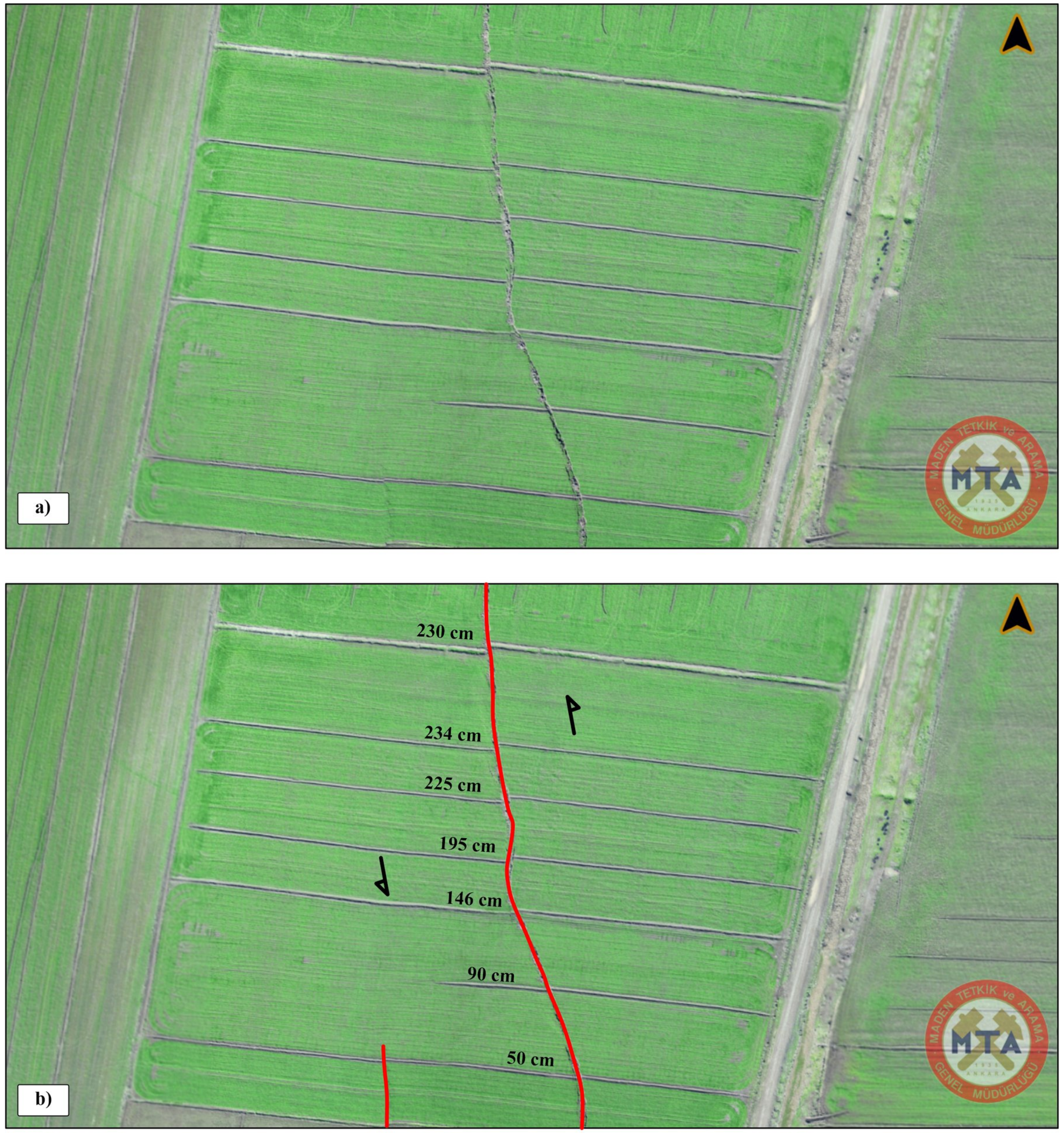
Ground Failure & Surface Rupture



Surface Cracks

- Earthquake split an olive field in Hatay. A giant rift, 30 meters deep, about 200 meters wide, formed as the ground was coming down.

Surface Offsets



06 Şubat 2023 Pazarcık (Kahramanmaraş) Depremi (Mw 7,7) sırasında Ölü Deniz Fay Zonu'nun Narlı Segmenti üzerinde meydana gelen deprem yüzey kırıkları ve yer değiştirme miktarları, ilk defa Maden Tetkik ve Arama Genel Müdürlüğü (MTA) ekipleri tarafından İnsansız Hava Aracı (İHA) ile kaydedilmiştir.

Fire Follows Earthquake

- Fire in Iskenderun port after the earthquake

Damage to Dams

- Embankment failures during the earthquake

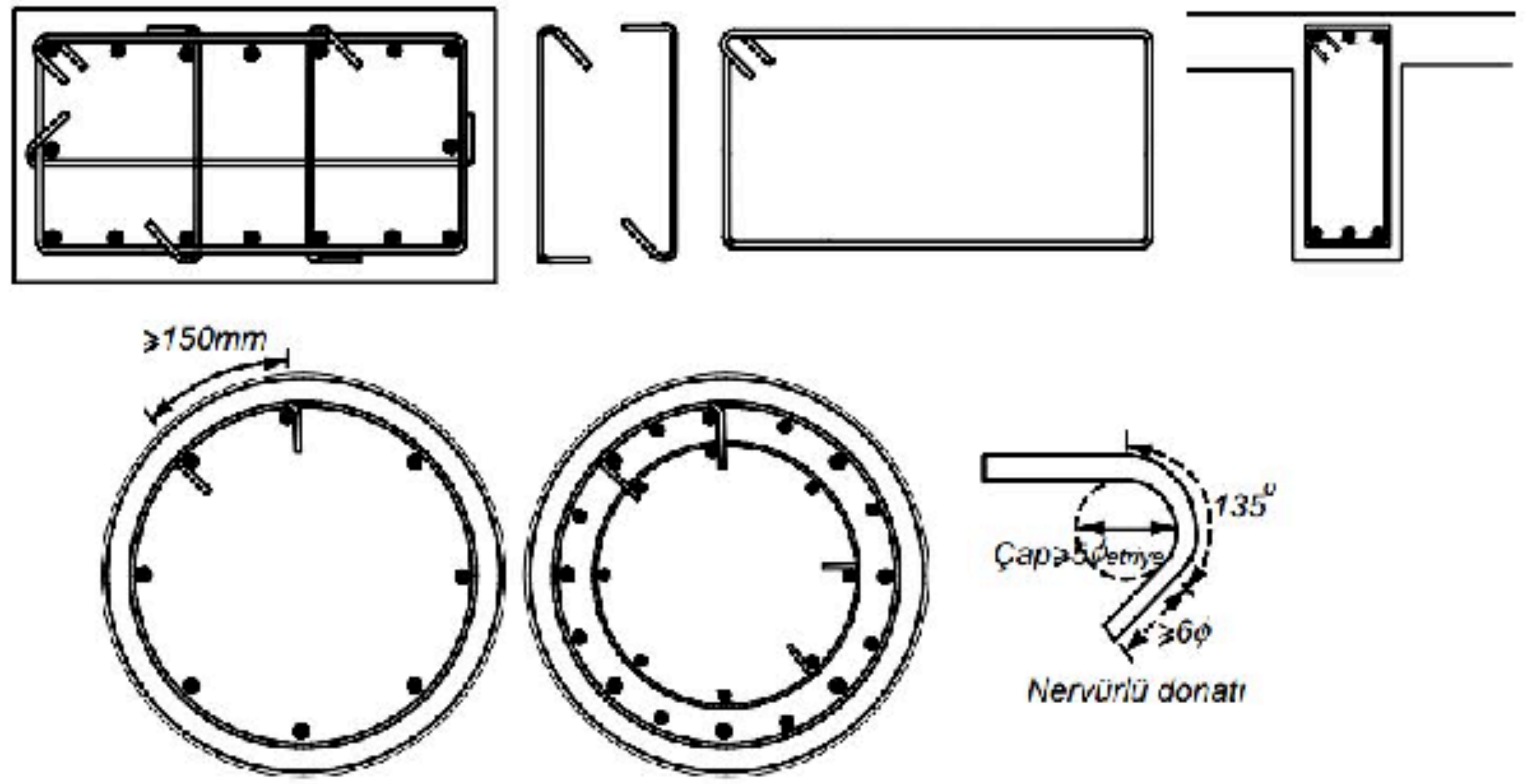
Damage to Overpasses

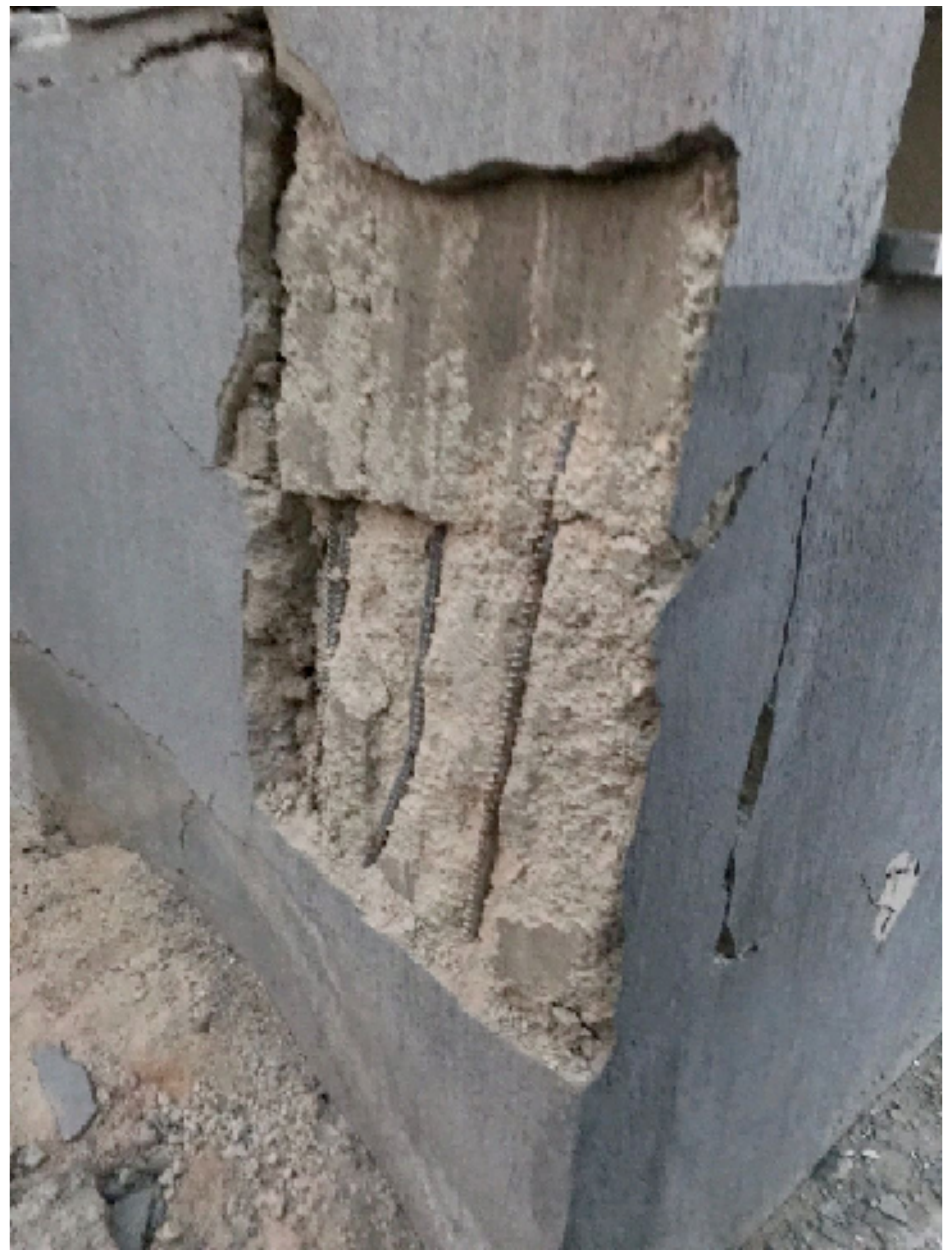
- Embankment failures during the earthquake

What Did Go Wrong?

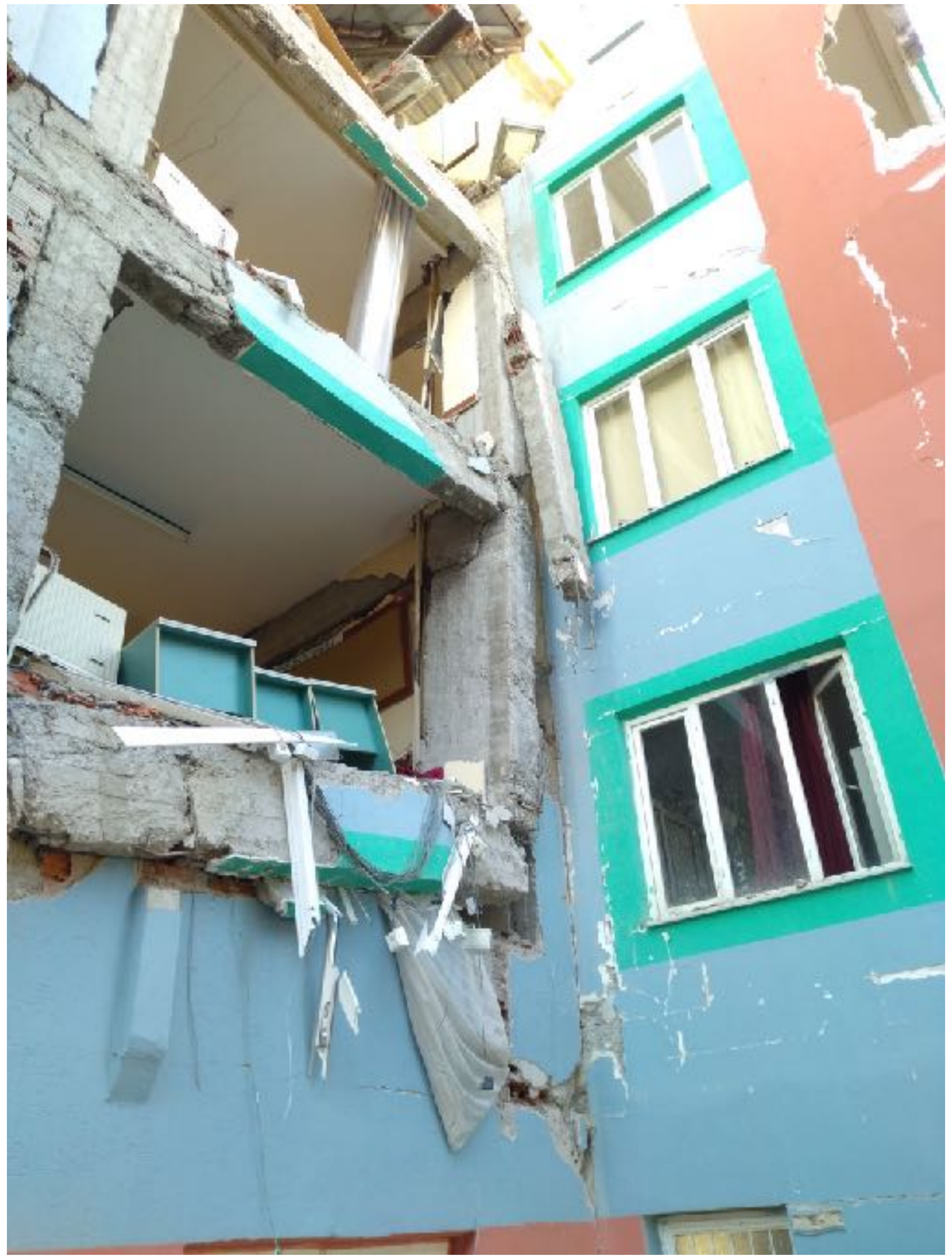
- Multi-story construction in the area with ground liquefaction
- Illegal Construction & Lack of Construction Quality Checks / Control
- Errors in Project Design
- Poor Concrete Quality and Large Aggregate Diameters
- Plain Rebars and Poor Workmanship
- Failure to Tighten Stirrups
- Elevation differences between adjacent buildings
- Corrosion in rebars
- Hammering effect due to the elevation difference between adjacent building floors
- Strong beam weak column
- Soft story
- Non-Audit of Local Governments
- Additional constructions made with the expectation of Zoning Amnesty
- Incredible mistakes made in stair reinforcement and static calculations
- Short columns
- Lack of proper foundation embedment

Insufficient Reinforcement and Detailing





Insufficient Reinforcement and Detailing



- Credit for photos: Murat Nas

Inadequate Reinforcement - Punching Shear

- Credit for photos: Murat Nas

Inadequate Concrete Strength

- Credit for photos: Murat Nas

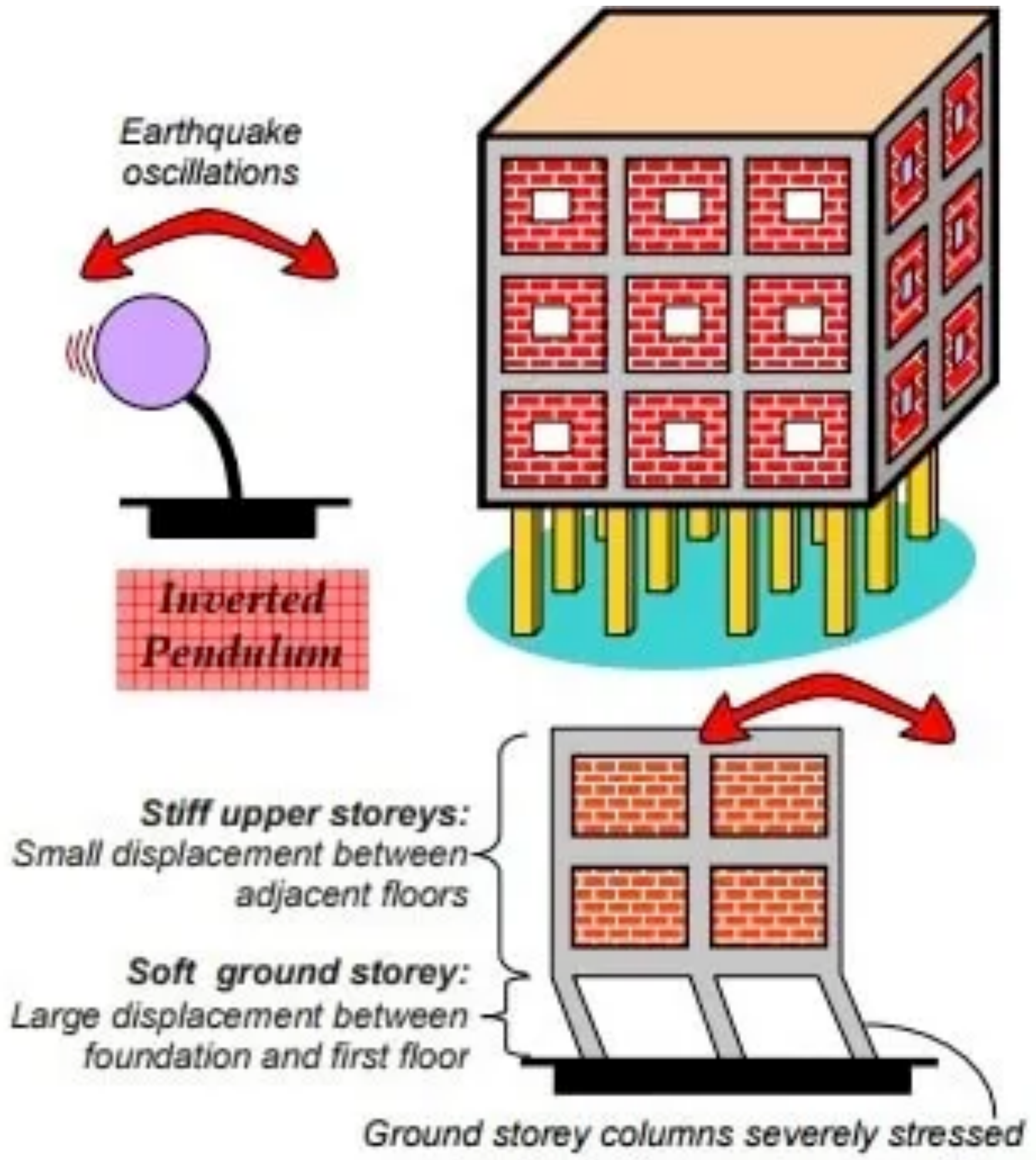
Inadequate Foundation Embedment

- Credit for photos: Ayse Hortascu

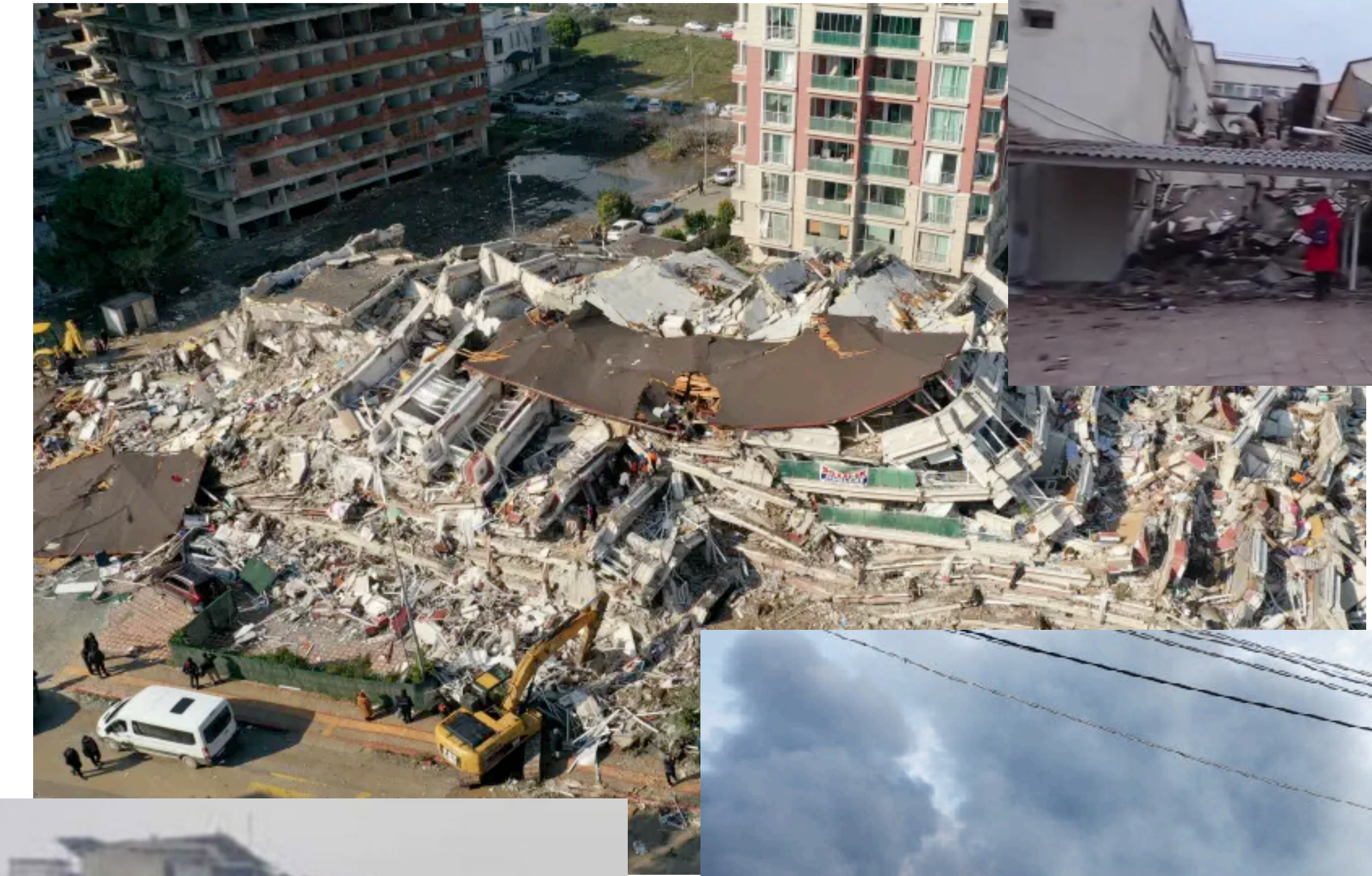
Collapse of 2,200 Years Old Heritage

- Dating back to the Roman empire, around the second, third, and fourth centuries A.D., the structure was originally built as a lookout.

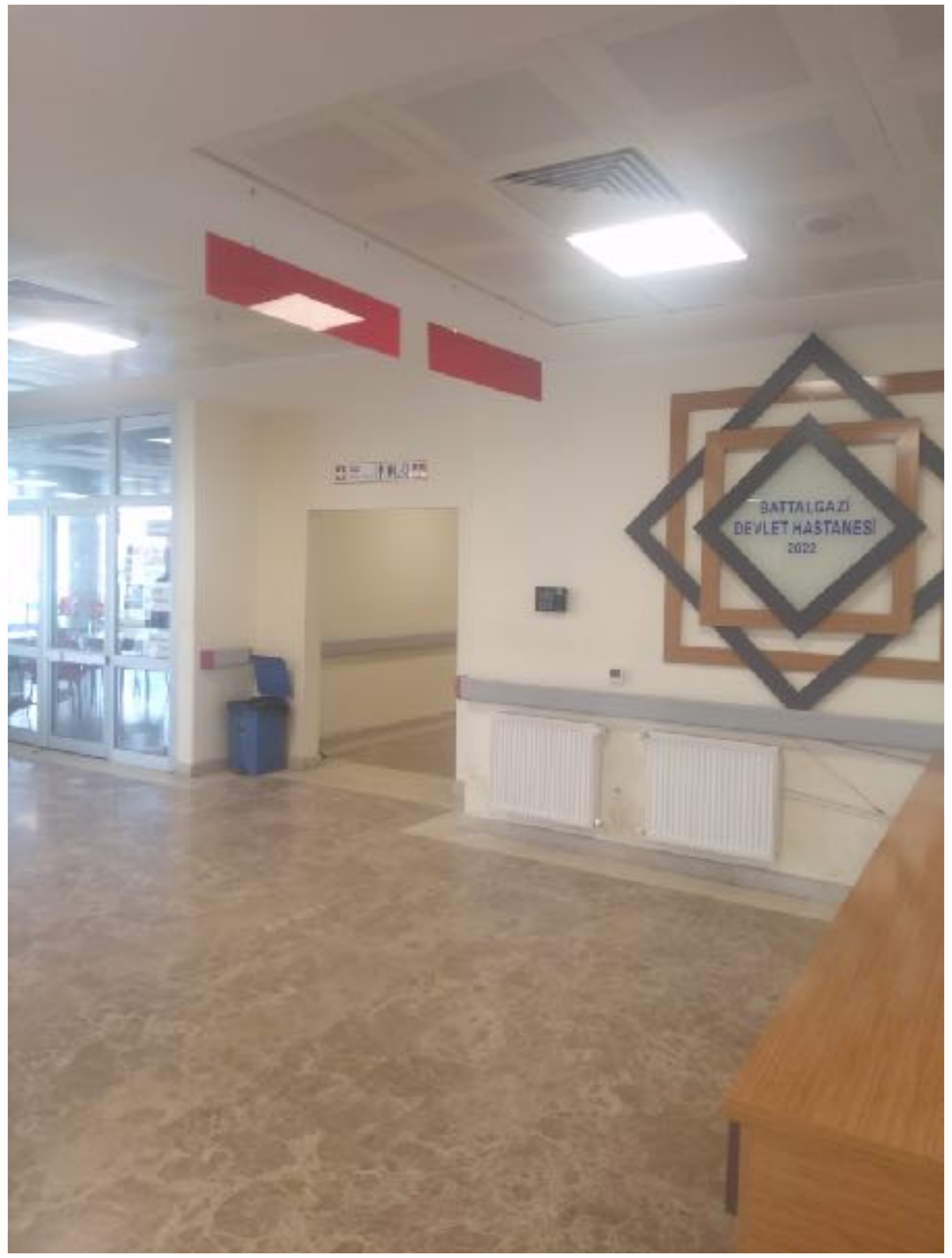
Soft Story Mechanism



Performance of Hospital Buildings



Performance of Based-Isolated Hospitals



- No structural damage
- Base-isolators have residual displacement of 1.2 cm
- Total displacement +/- 9 cm

Performance of Based-Isolated Hospitals

What Did Work? Tunnel Form Buildings

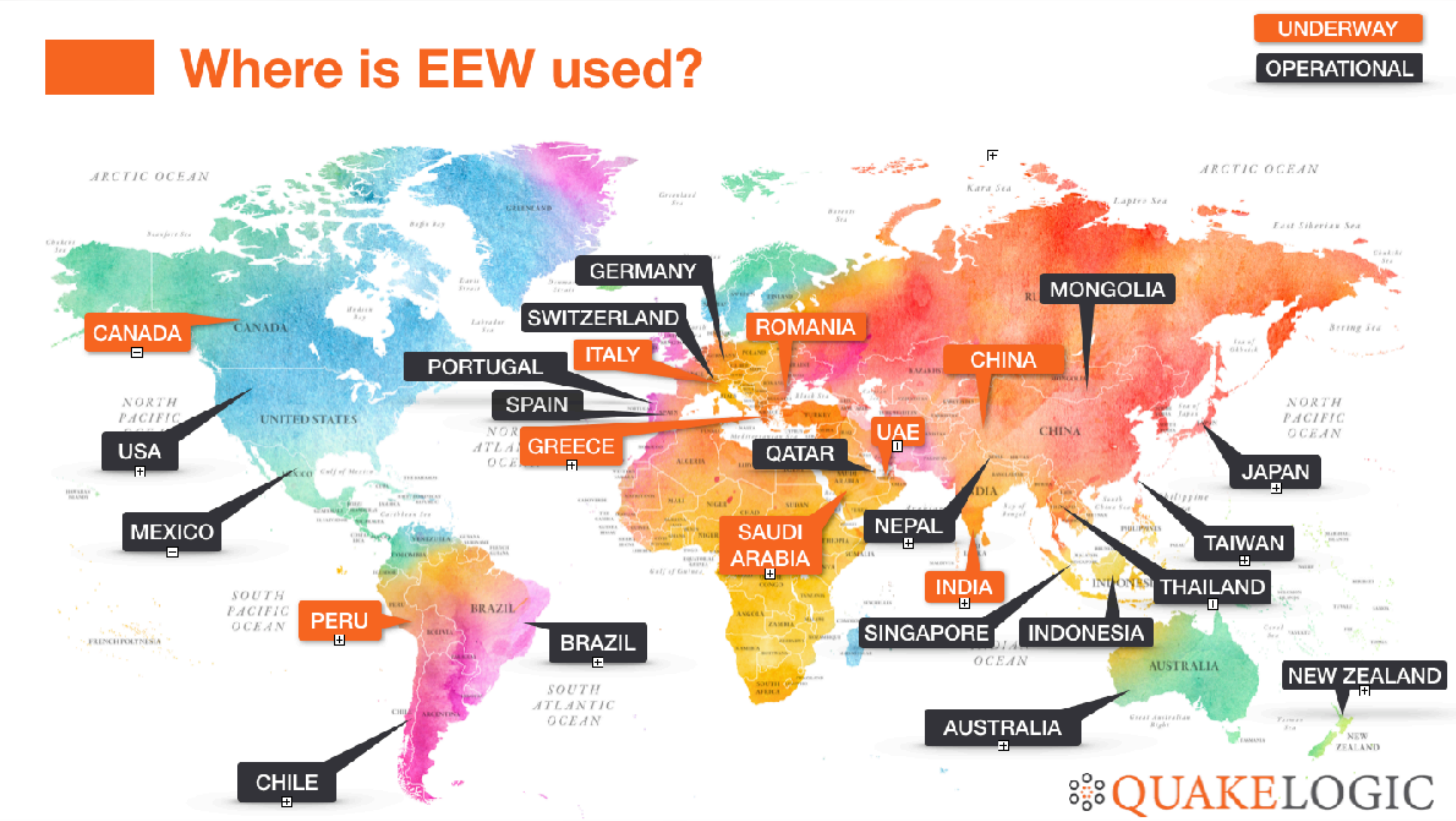
- 130,000 condo unit exposed to earthquakes
- No collapse
- Minor repairable structural damage

What Is Tunnel Form Building?

- Tunnel form construction is a method of building reinforced concrete structures in which the walls and floor slabs are cast together in situ, forming a monolithic structure.
- The monolithic structure provides a much stronger and more rigid structure, which is better able to resist seismic forces. The walls and floor slabs are continuous and integral, forming a unified system that is able to distribute lateral loads evenly throughout the structure.
- The tunnel form method also eliminates the need for vertical joints, which can be a source of weakness in conventional beam-column concrete frame-type constructions.
- Tunnel form construction is also highly efficient and cost-effective.
- The foundation of tunnel-form buildings is a mat type, more desirable than conventional footings with tie beams.

What Could Have Been Done?

- Earthquake early warning system (seismic network based and on-site)
- Structural health monitoring system

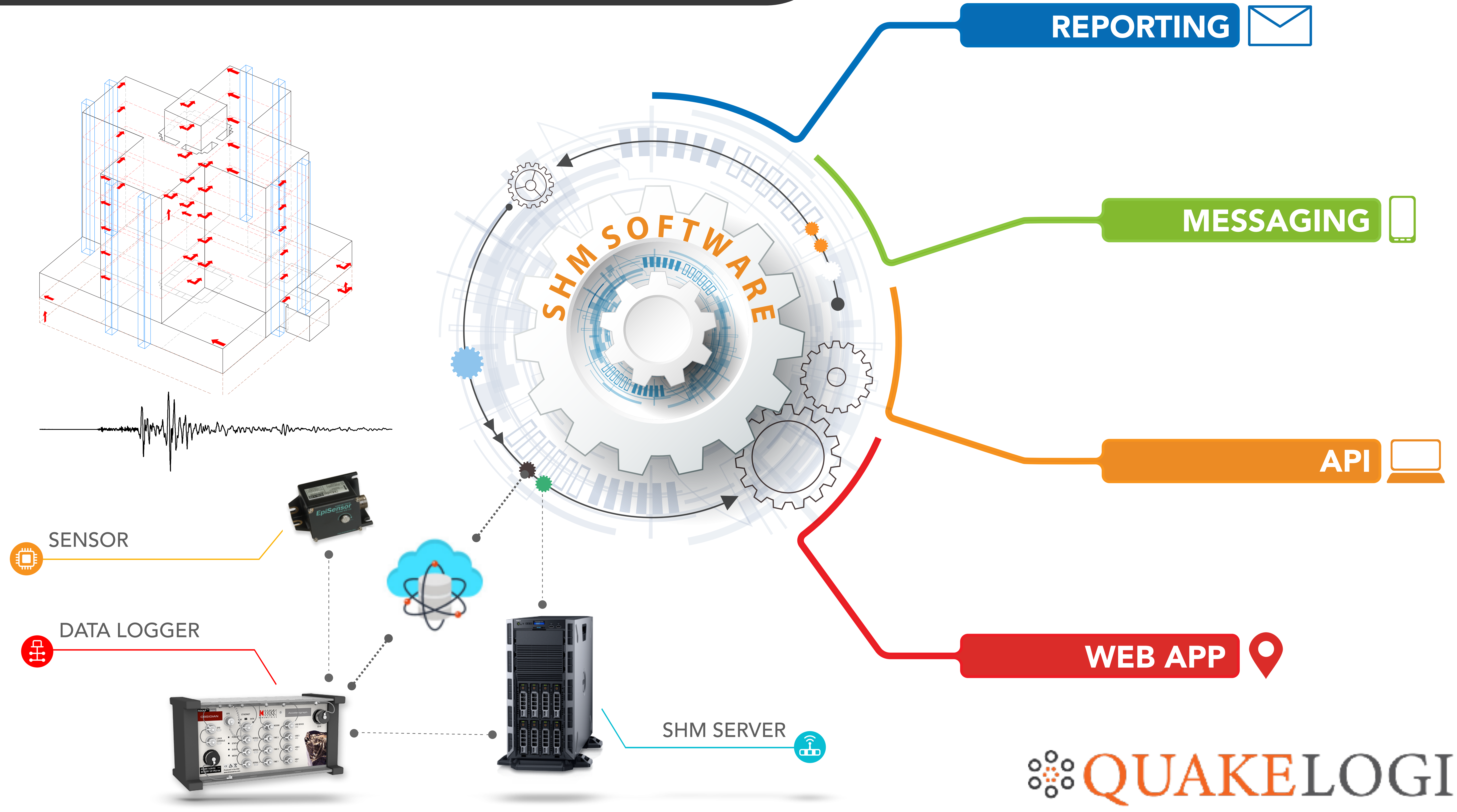


- P-wave travels ~6 km/s and S-wave is ~2 km/s. If your facility is 40 km away from the fault rupture, the warning you will get is the difference between the travel times so it will be about 9-10 seconds.

Technology

Sensors and data logging devices positioned on each structure are connected to our tech platform in the cloud or on-premise

- **Most advanced** structural health monitoring (SHM) software in the market
- **No vendor lock in** (compatible with most sensors and data loggers)
- **Realtime** structural health assessment
- Realtime **earthquake monitoring**
- **Fully automated**



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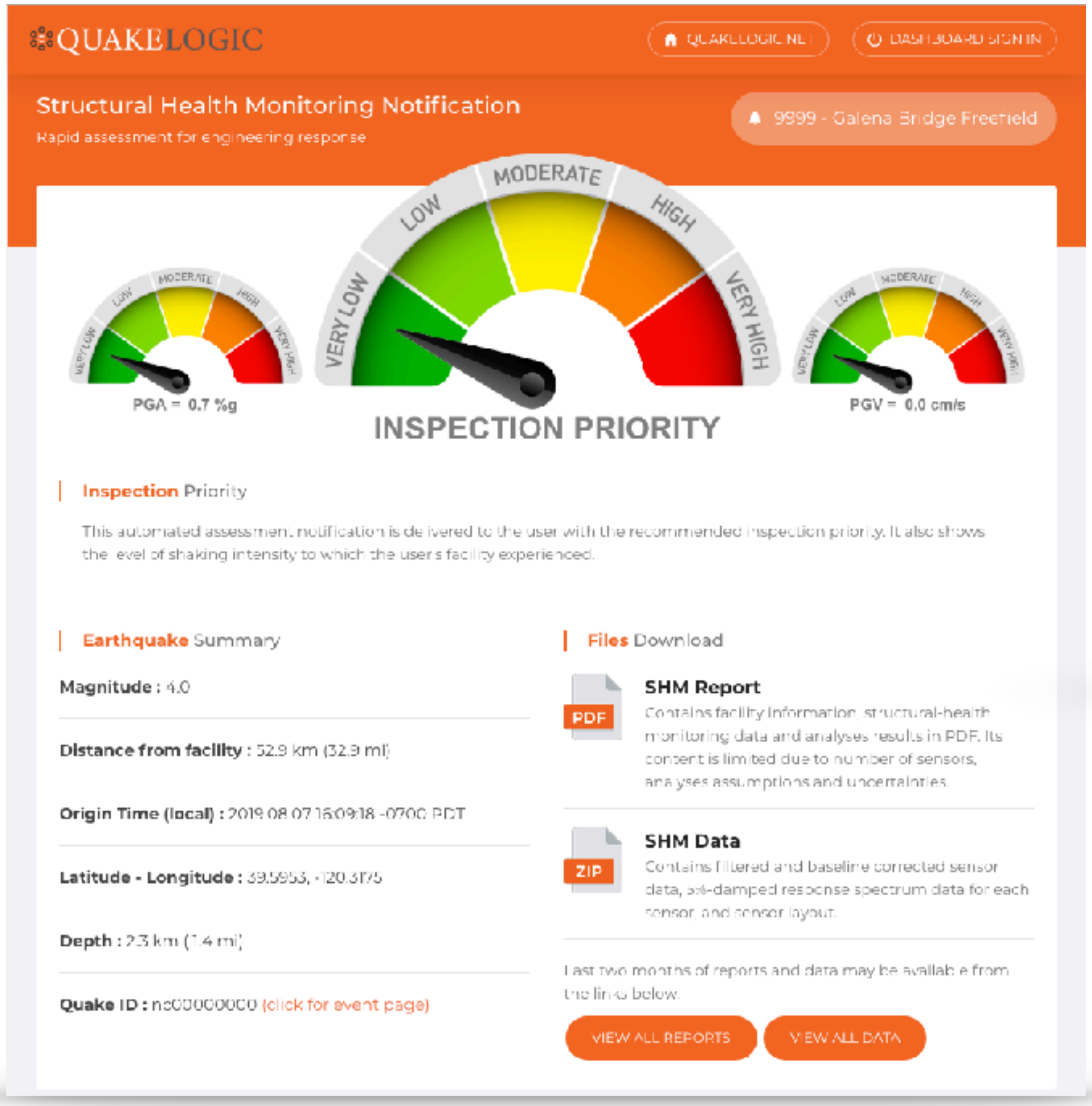
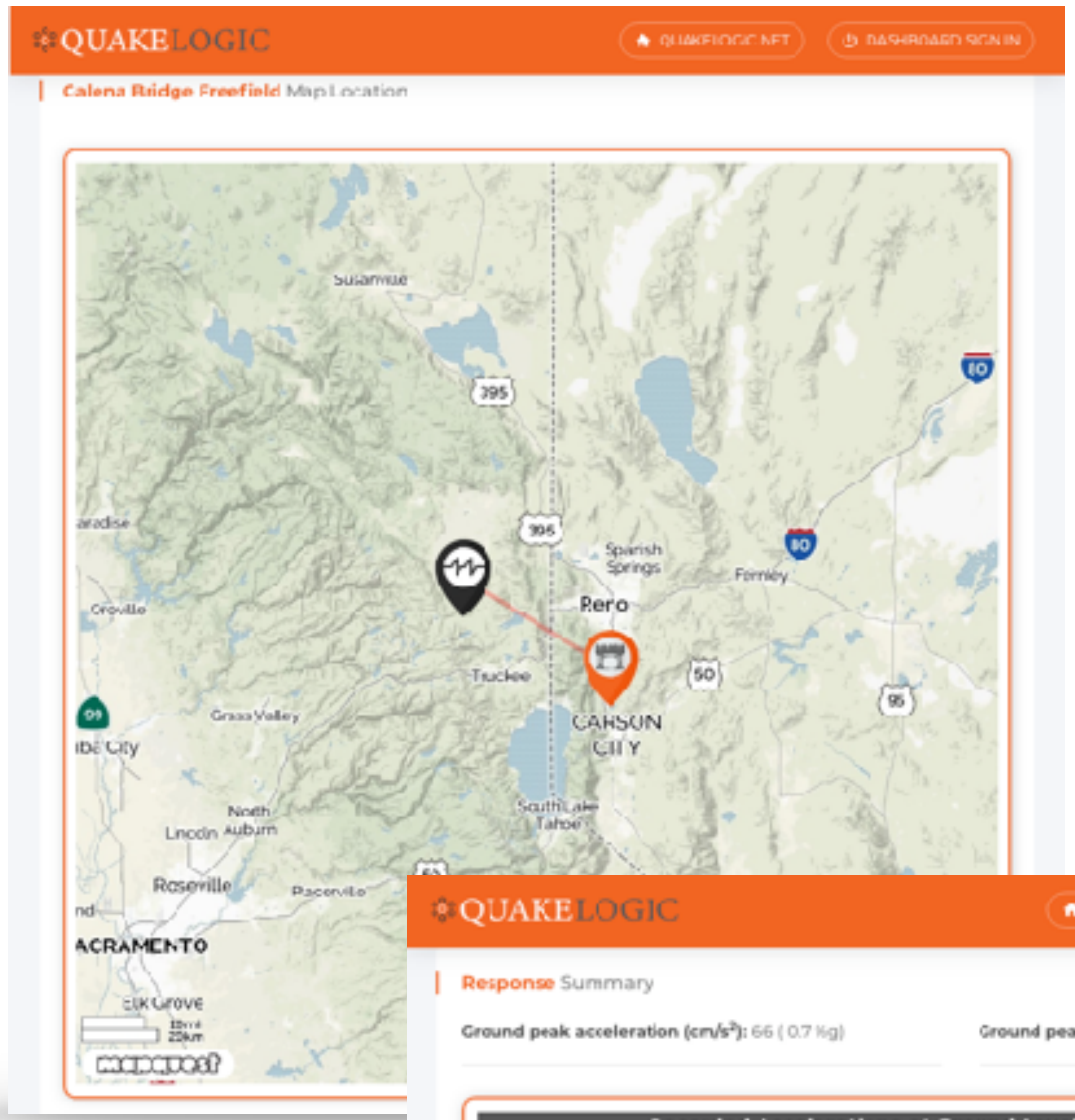
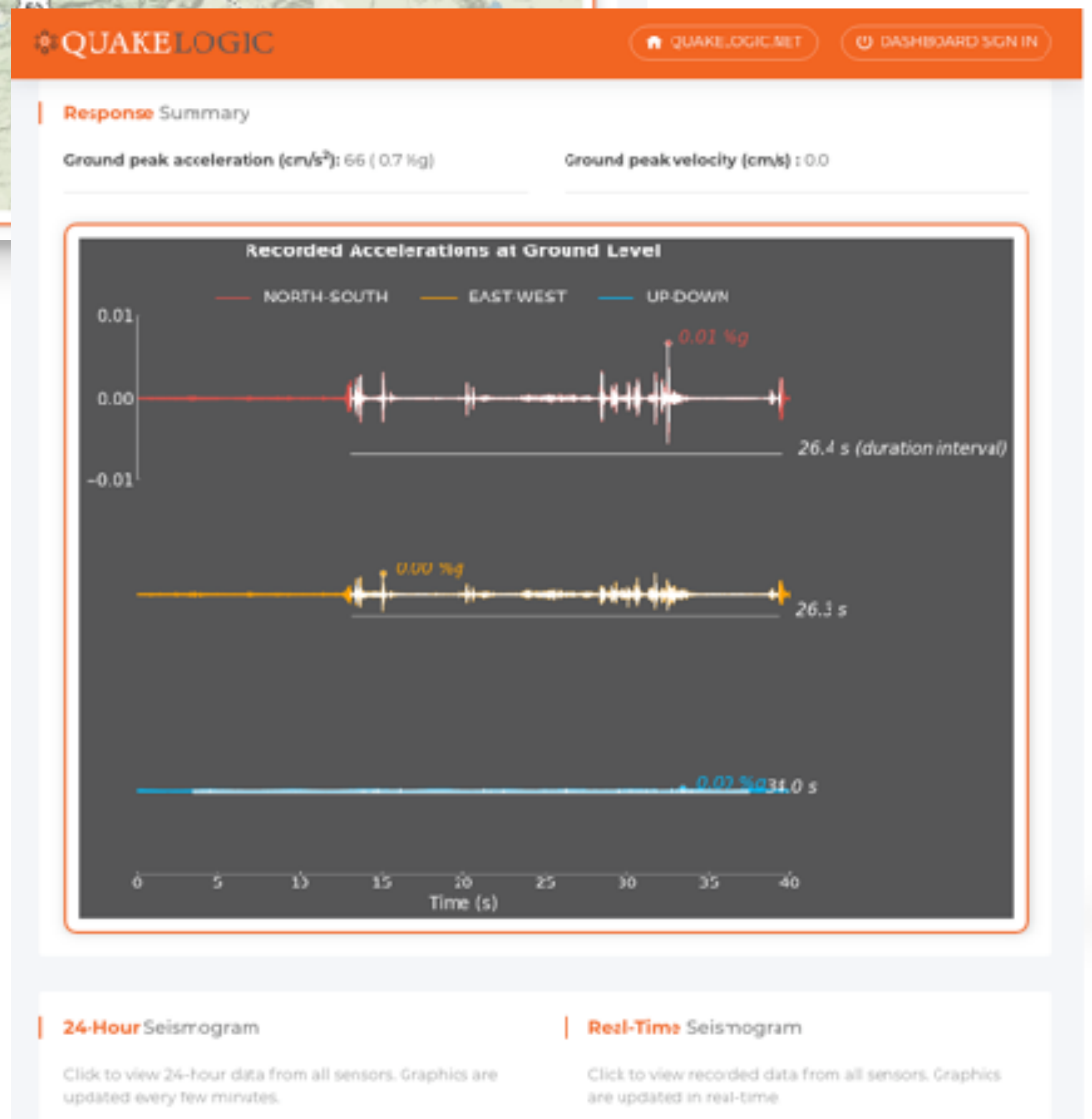
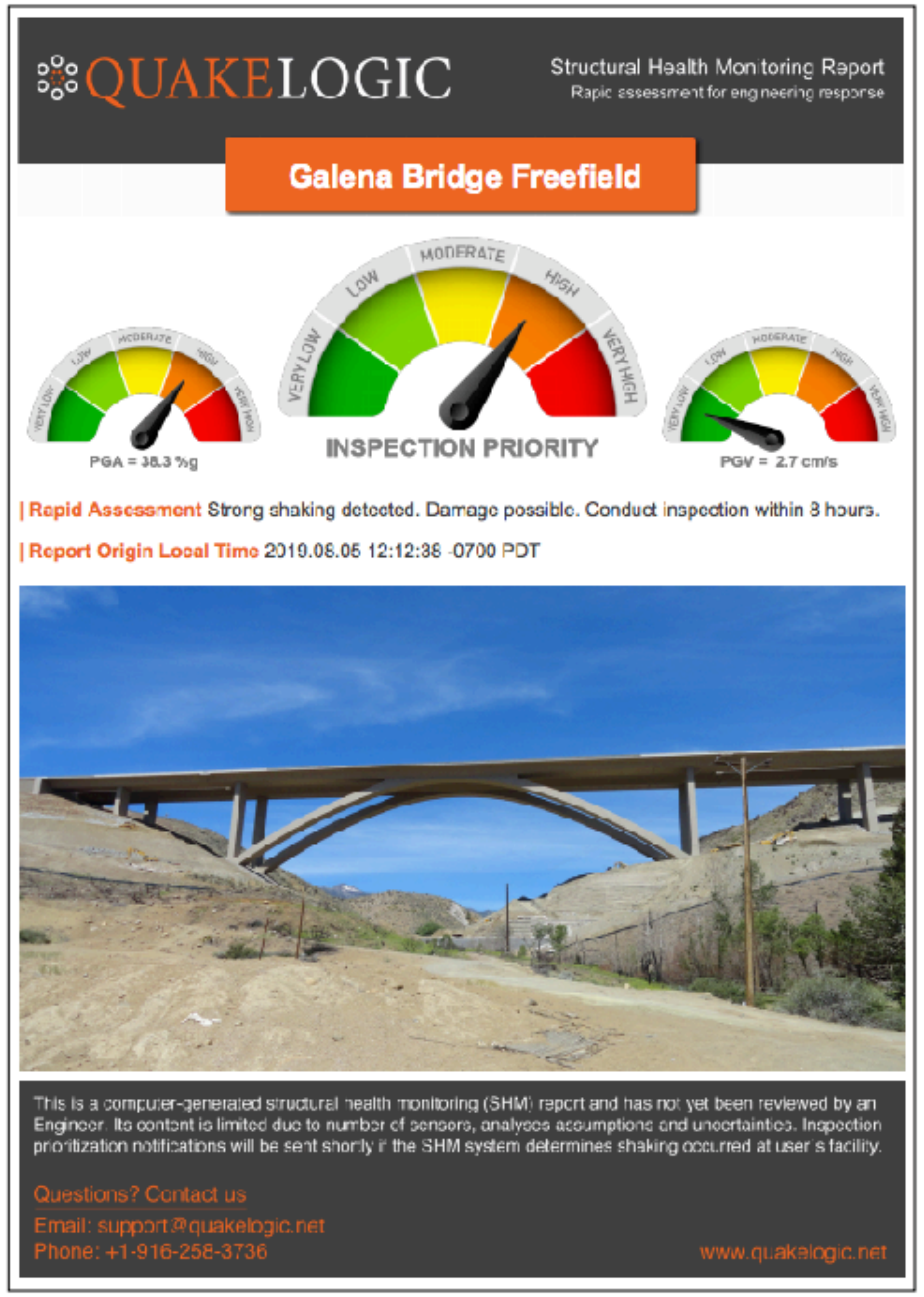
Notification & Reports

Shows quake intensity to which the structure experienced and whether its integrity is compromised.









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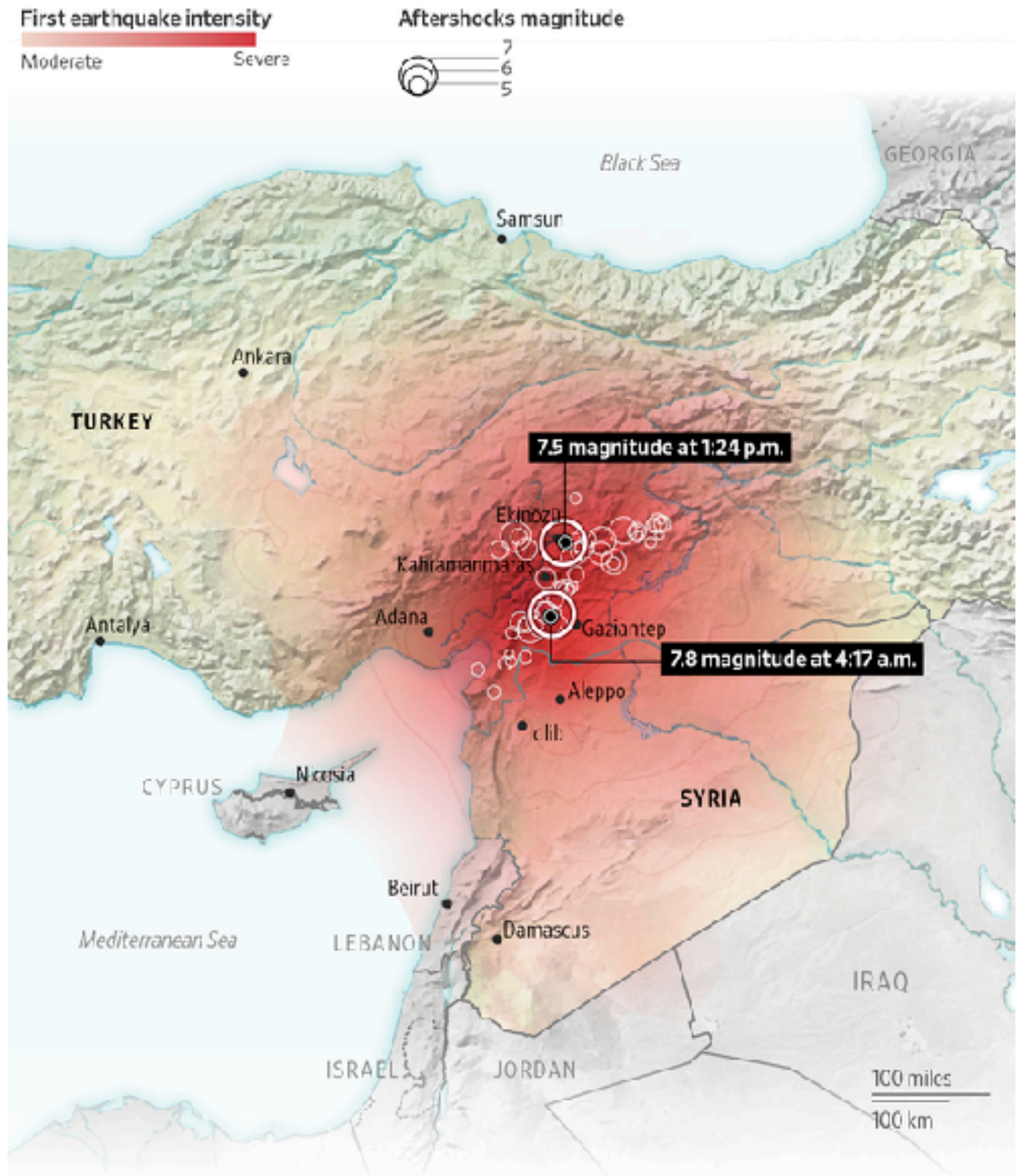
Take Home Message

- Despite **exceeding the design spectrum** level, moment resisting frame buildings that were designed with **appropriate reinforcement detailing and sufficient concrete strength** were able to withstand the earthquakes.

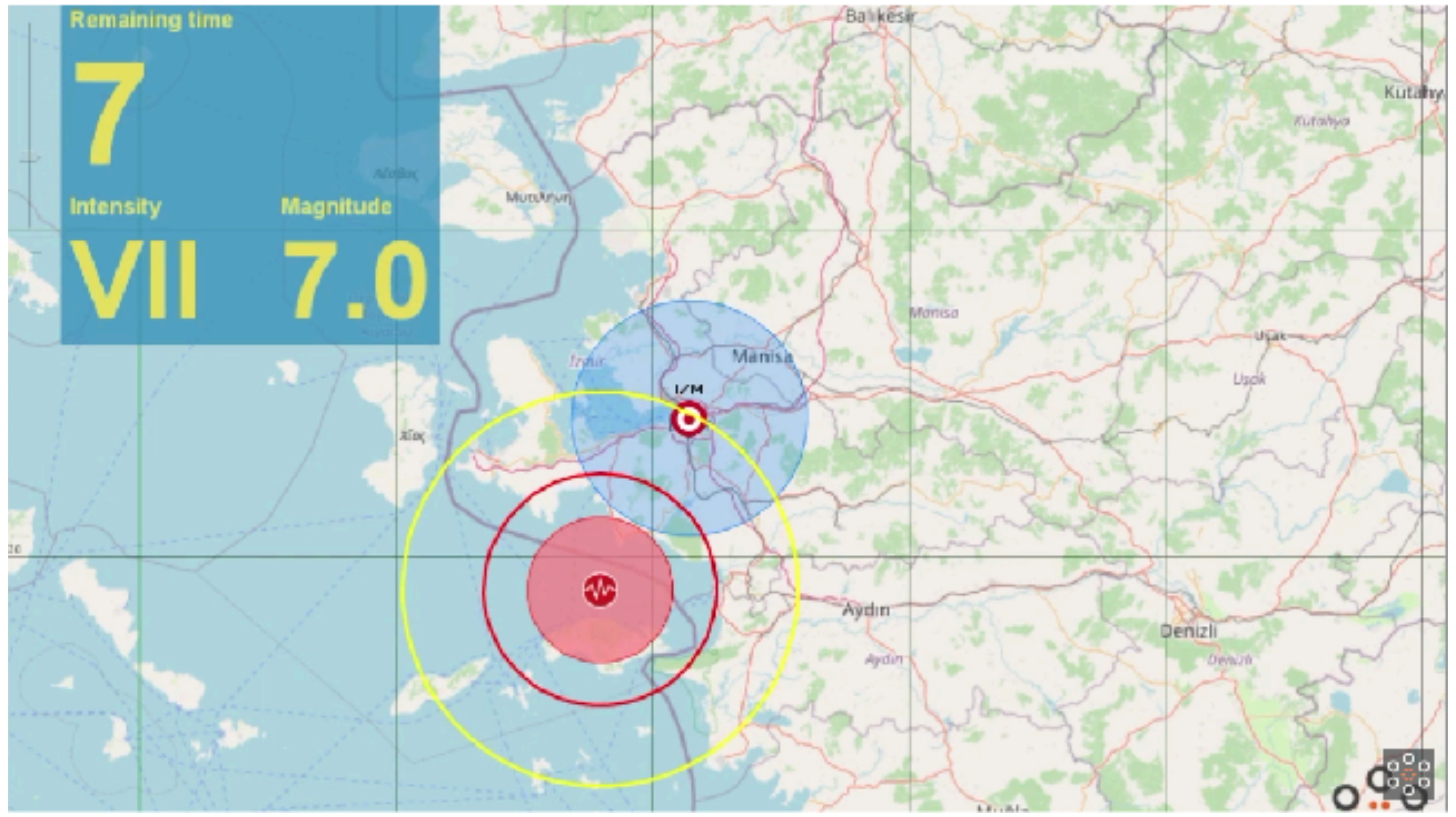
- It is important to consider **back-to-back earthquakes** in the design because multiple earthquakes can happen in a short period of time. This can lead to an increased risk of damage to structures, as the **cumulative effect** of the seismic forces can exceed the design limits of the structure.



Take Home Message

- Earthquake early warning (EEW) is important because it can provide crucial seconds to minutes of advance notice before an earthquake strikes, allowing individuals and communities to take protective actions and minimize damage and loss of life.

- Structural health monitoring (SHM) is needed because it provides continuous, real-time information about the condition of a structure, allowing for early detection of potential problems and enabling timely repairs or maintenance.



Take Home Message

- Tunnel form structures provide a practical approach to constructing earthquake-resistant residential buildings.

THE STRUCTURAL DESIGN OF TALL AND SPECIAL BUILDINGS
Struct. Design Tall Spec. Build. (2007)
Published online in Wiley Interscience (www.interscience.wiley.com). **DOI**: 10.1002/tal.368

PROS AND CONS OF MULTISTORY RC TUNNEL-FORM (BOX-TYPE) BUILDINGS

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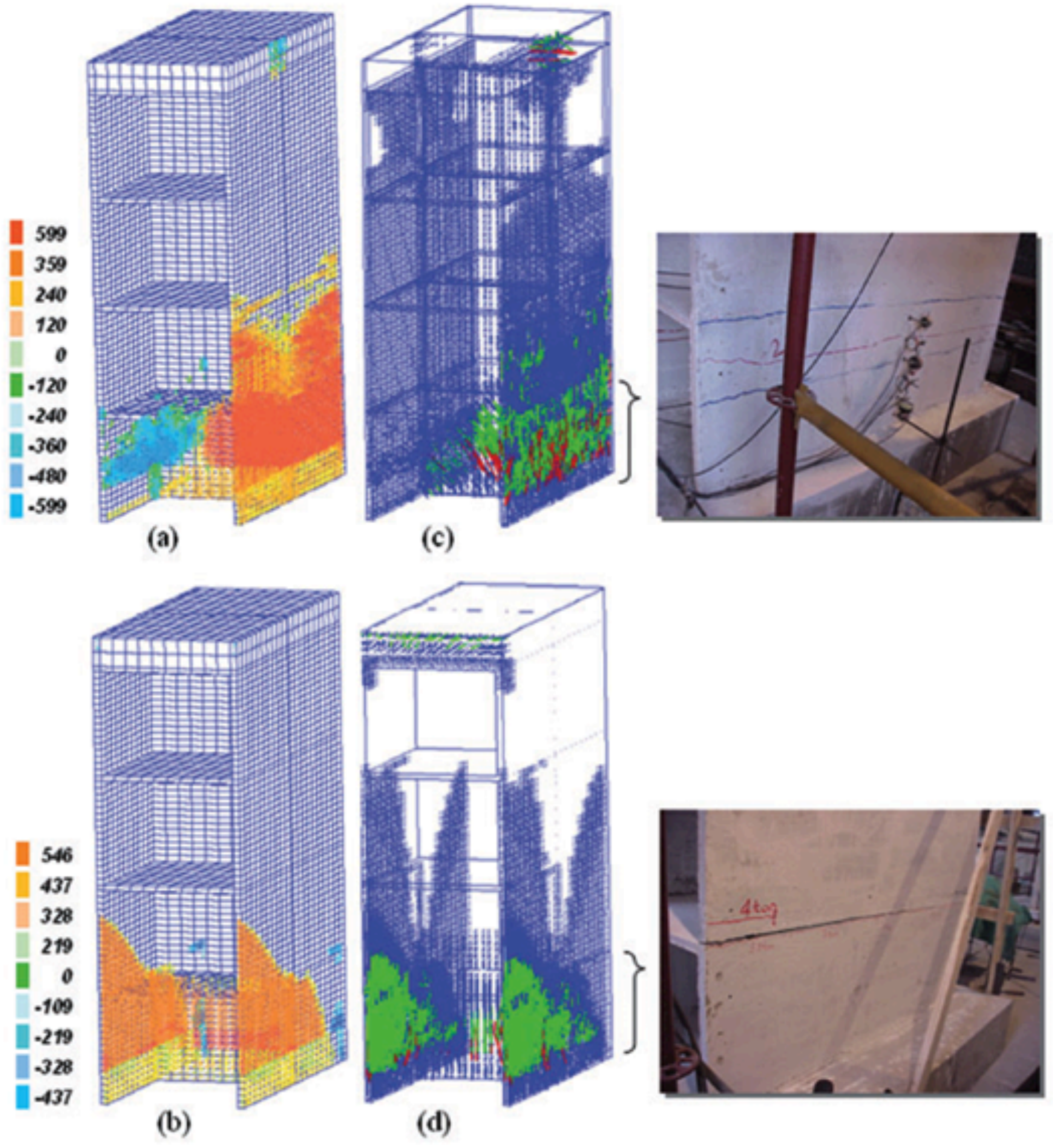
SUMMARY

Tunnel-form structural systems (i.e., box systems), having a load-carrying mechanism composed of reinforced concrete (RC) shear walls and slabs only, have been prevailingly utilized in the construction of multistory residential units. The superiority of tunnel-form buildings over their conventional counterparts stems from the enhanced earthquake resistance they provide, and the considerable speed and economy of their construction. During recent earthquakes in Turkey, they exhibited better seismic performance in contrast to the damaged condition of a number of RC frames and dual systems (i.e., RC frames with shear wall configurations). Thus the tunnel-form system has become a primary construction technique in many seismically active regions. In this paper, the strengths and weaknesses of tunnel-form buildings are addressed in terms of design considerations and construction applications. The impacts of shear wall reinforcement ratio and its detailing on system ductility, load-carrying capacity and failure mechanism under seismic forces are evaluated at section and global system levels. Influences of tension/compression coupling and wall openings on the response are also discussed. Three-dimensional nonlinear finite element models, verified through comparisons with experimental results, were used for numerical assessments. Findings from this projection provide useful information on adequate vertical reinforcement ratio and boundary reinforcement to achieve enhanced performance of tunnel-form buildings under seismic actions.



https://www.quakelogic.net/publications

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AI-POWERED DISASTER RISK MANAGEMENT SOLUTIONS

got SHM?

"By working with QuakeLogic, we're finally able to have an accurate realtime structural monitoring of our largest bridge for rapid disaster response."

Troy Martin, P.E.

Nevada Department of Transportation