Earthquakes
focus and epicentre – fault rupture
Rupture on a Fault

Total Slip in the M7.3 Landers Earthquake
Slip on an earthquake fault

Depth Into the earth

Surface of the earth

100 km (60 miles)
Distance along the fault plane

START
Slip on an earthquake fault
Second 2.0
Slip on an earthquake fault
Second 4.0
Slip on an earthquake fault
Second 6.0
Slip on an earthquake fault
Second 8.0
Slip on an earthquake fault
Second 10.0
Slip on an earthquake fault
Second 12.0
Slip on an earthquake fault
Second 14.0
Slip on an earthquake fault
Second 16.0
Slip on an earthquake fault
Second 18.0
Slip on an earthquake fault
Second 20.0
Slip on an earthquake fault
Second 22.0
Slip on an earthquake fault
Second 24.0
17 Ağustos 1999 Kocaeli depreminde fay atımı
Globiale Erdbebenrisikokarte
Seismic waves
A. Directions of vibration of body and surface waves generated by an earthquake associated with the illustrated fault. B. Propagation of body and surface waves. (From Hepp, 1991 and Stewart, 1987.)
Magnitude 6.5 earthquake, near coast of central Chile, 29.2934° S, 71.5471° W

Origin time = 17:37:59.0 GMT 1998/09/03, Depth = 27 km
Station = NNA (Nana, Peru, 11.9875° S, 76.8422° W)
Distance = 17.93° (1993 km), Azimuth = 343°

EW↑ east
↓ west ↑ P

NS↑ north
↓ south ↑ P

Z↑ up
↓ down ↑ P

Love

Rayleigh

(hr:min:sec, GMT, 3 September 1998)
17:42:00  17:44:00  17:46:00  17:48:00

Travel time (minutes)
The diagram illustrates the arrival of different types of seismic waves on a seismogram.

- **Body waves**: These are divided into two types:
  - **Arrival of P-wave**: The first arrival of a body wave is marked by a sharp peak.
  - **Arrival of S-wave**: The second arrival is characterized by a different pattern.

- **Surface waves**: These include:
  - **Arrival of L-wave**: A later arrival, often characterized by longer wavelengths.

**Background noise** and **time marks** are also indicated on the seismogram, with a **P-S time interval** highlighted between the arrival of the P-wave and S-wave.
Determination of earthquake epicenters
Earthquake magnitude
Magnitude of an earthquake is based on the amplitude of the largest seismic wave corrected for distance and period of the wave.

Magnitude scale are logarithmic.

Richter magnitude $M_L$

Surface-wave magnitude $M_S$

Body wave magnitude $M_b$
Richter Magnitude

- Distance (km)
- S-P (sec)
- Magnitude (M)
- Amplitude (mm)

- 85 mm (amplitude)
- S-P = 34 sec
<table>
<thead>
<tr>
<th>M</th>
<th>Approximate TNT</th>
<th>Joule</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>30 g</td>
<td>130 kJ</td>
<td>Large <a href="http://example.com">hand grenade</a></td>
</tr>
<tr>
<td>1.5</td>
<td>2.7 kg</td>
<td>11 MJ</td>
<td>Seismic impact of typical small construction blast</td>
</tr>
<tr>
<td>2.1</td>
<td>21 kg</td>
<td>89 MJ</td>
<td>West fertilizer plant explosion[1]</td>
</tr>
<tr>
<td>3.0</td>
<td>480 kg</td>
<td>2.0 GJ</td>
<td>Oklahoma City bombing, 1995</td>
</tr>
<tr>
<td>3.5</td>
<td>2.7 metric tons</td>
<td>11 GJ</td>
<td>PEPCON fuel plant explosion, Henderson, Nevada, 1988</td>
</tr>
<tr>
<td>3.87</td>
<td>9.5 metric tons</td>
<td>40 GJ</td>
<td>Explosion at Chernobyl nuclear power plant, 1986</td>
</tr>
<tr>
<td>3.91</td>
<td>11 metric tons</td>
<td>46 GJ</td>
<td>Massive Ordnance Air Blast bomb</td>
</tr>
<tr>
<td>6.0</td>
<td>15 kilotons</td>
<td>63 TJ</td>
<td>Approximate yield of the Little Boy atomic bomb dropped on Hiroshima (~16 kt)</td>
</tr>
<tr>
<td>7.9</td>
<td>10.7 megatons</td>
<td>45 PJ</td>
<td>Tunguska event</td>
</tr>
<tr>
<td>8.35</td>
<td>50 megatons</td>
<td>210 PJ</td>
<td>Tsar Bomba—Largest thermonuclear weapon ever tested. Most of the energy was dissipated in the atmosphere. The seismic shock was estimated at 5.0–5.2</td>
</tr>
<tr>
<td>9.15</td>
<td>800 megatons</td>
<td>3.3 EJ</td>
<td>Toba eruption 75,000 years ago; among the largest known volcanic events.</td>
</tr>
<tr>
<td>13.0</td>
<td>100 teratons</td>
<td>420 ZJ</td>
<td>Yucatán Peninsula impact (creating Chicxulub crater) 65 Ma ago (10^8 megatons; over 4×10^{29} ergs = 400 ZJ).</td>
</tr>
</tbody>
</table>
Bigger Faults Make Bigger Earthquakes
Bigger Earthquakes Last a Longer Time

![Graph showing the relationship between Magnitude and Seconds. The x-axis represents Magnitude ranging from 5.5 to 8, with ticks at 5.5, 6, 6.5, 7, 7.5, and 8. The y-axis represents Seconds in a logarithmic scale ranging from 1 to 100, with ticks at 1, 10, 100. Data points are plotted showing an increasing trend as magnitude increases.]
Moment magnitude $M_W$ based on seismic moment

Seismic moment $M_0 = \mu A u$

$\mu$ shear modulus $3.3 \times 10^{11}$ dynes/cm$^2$

$A$ area of the fault

$u$ average displacement on the fault plane

$M_W = \frac{2}{3} \log M_0 - 10.7$
Intensity scales are subjective based on damage caused by an earthquake. For a single earthquake there is a single magnitude value but several intensity values depending on the distance from the earthquake epicenter.
Modified Mercalli intensity scale (abridged).

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Not felt except by a very few under especially favorable circumstances.</td>
</tr>
<tr>
<td>II</td>
<td>Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.</td>
</tr>
<tr>
<td>III</td>
<td>Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.</td>
</tr>
<tr>
<td>IV</td>
<td>During the day felt indoors by many, outdoors by a few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building; standing motor cars rocked noticeably.</td>
</tr>
<tr>
<td>V</td>
<td>Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.</td>
</tr>
<tr>
<td>VI</td>
<td>Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.</td>
</tr>
<tr>
<td>VII</td>
<td>Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.</td>
</tr>
<tr>
<td>VIII</td>
<td>Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.</td>
</tr>
<tr>
<td>X</td>
<td>Some well-built wooden structures destroyed; most masonry and frame structures with foundations destroyed; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (stopped) over banks.</td>
</tr>
<tr>
<td>XII</td>
<td>Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.</td>
</tr>
</tbody>
</table>

site amplification
What Controls the Level of Shaking?

- **Magnitude**
  - More energy released
- **Distance**
  - Shaking decays with distance
- **Local soils**
  - Amplify the shaking
Relationship between near-surface earth material and amplification of shaking during an earthquake (Keller and Pinter, 1996).
Horizontal ground motions of an underground nuclear explosion as recorded by accelographs in San Francisco. All materials were subjected to the same seismic waves (Borcherdt, 1975).
Seismic acceleration versus ground shaking intensity for different earth materials (Leed, 1973).
Approximate horizontal acceleration of rocks that, with a 90% probability, is not likely to be exceeded in 50 years.

- **High**: >4 m/sec² (0.4 g*)
- **Medium High**: 2 to 4 m/sec² (0.2 to 0.4 g)
- **Medium**: 1 to 2 m/sec² (0.1 to 0.2 g)
- **Low**: 0.5 to 1 m/sec² (0.05 to 0.1 g)

(*) g is the acceleration of gravity, 9.8 m/sec²

Seismic hazard map of the United States (Algermissen and Perkins, 1976)
TÜRKİYE DEPREM TEHLİYEKE HARİTASI

Bu harita, Afet ve Acil Durum Yönetimi Başkanlığı (AFAD) tarafından Ulusal Deprem Araştırma Programı (UDAP) kapsamında desteklenen UDAP-Ç.13-06 kodlu "Türkiye Sismik Tehlike Haritasının Güncellenmesi" bağılı projenin sonuçları kullanılarak hazırlanmıştır.

Bu harita, zemin koşulu (\(V_{s30}\) = 760 m/s esas alınarak hazırlanmıştır. Yerel zemin koşullarının neden olabileceği svislaşıma, büyümeye, farklı olurma gibi tehlikeleri içermektedir.


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elastic rebound theory for the earthquakes
a. 18.8.1999 Kocaeli depreminden hemen sonra

b. 18.8.1999 Kocaeli depreminden 20 yıl sonra

c. Deprem oluyor! (50-200 yıl sonra)