Earthquakes & Volcanoes, Lec 2 (Steve Marshak)

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Our Dynamic Planet . . .
Earthquakes and Volcanoes

TOPIC 1 — Where do earthquakes occur? Clues from plate tectonics
TOPIC 2 — The nature of faulting; measurement of earthquakes
TOPIC 3 — Earthquake destruction, and earthquake mitigation
TOPIC 4 — Causes and classification of volcanoes
TOPIC 5 — Volcanic destruction, and eruption forecasting
TOPIC 6 — Tsunamis

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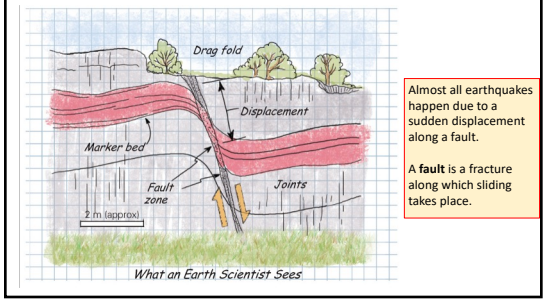

Almost all earthquakes happen due to a sudden displacement along a fault.

A **fault** is a fracture along which sliding takes place.

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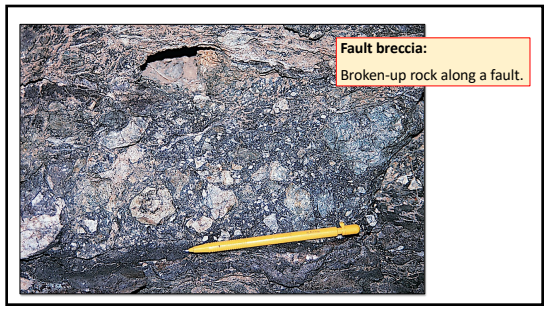

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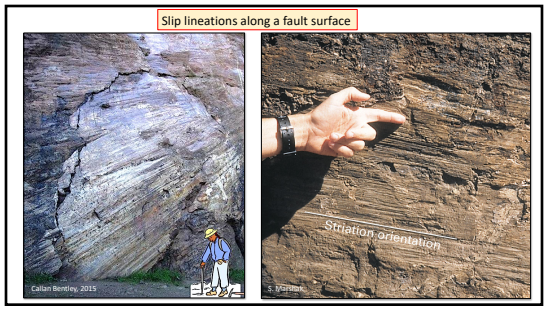

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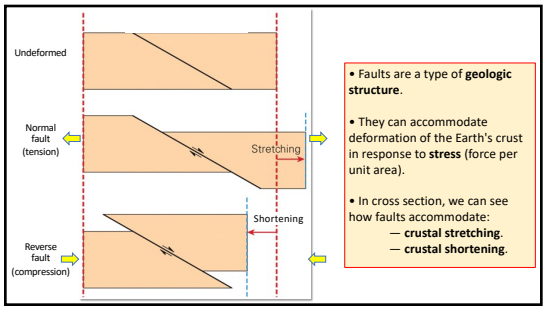

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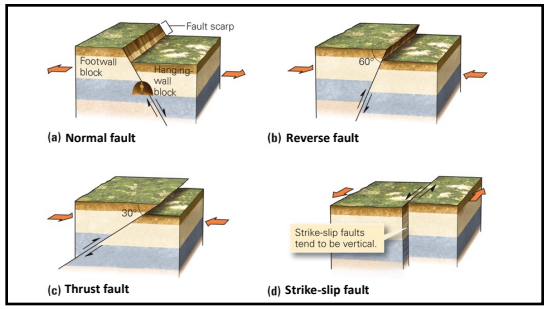

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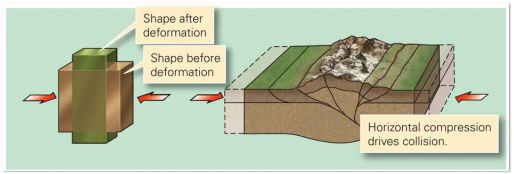
For example . . . .

- Compression can produce or reactivate thrust faults.
- This can happen during continental collision.



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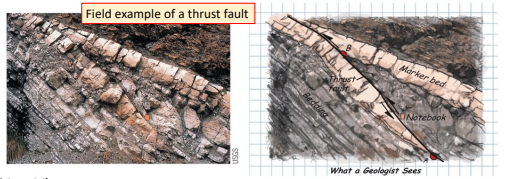
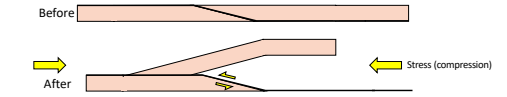
Field example of a thrust fault



Interpretation



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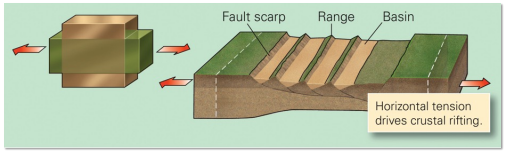
For example . . . .

- Stretching (extension) can produce or reactivate normal faults.
- This can happen during rifting or sea-floor spreading.



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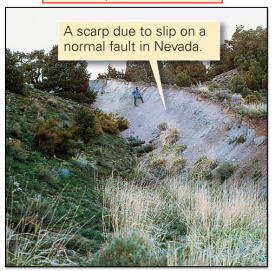
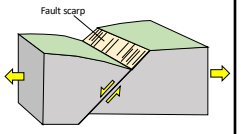
Field example of a normal fault





Tensional stress causes stretching.

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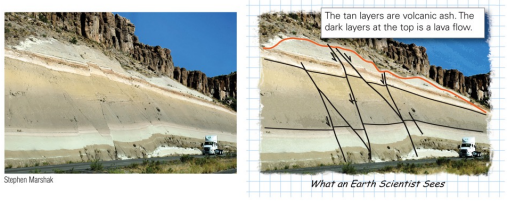
Roadcut showing normal faults in Arizona



Layers of volcanic ash are offset along steep normal faults.

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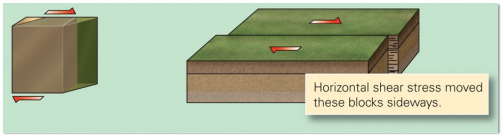
Horizontal shear stress along a strike-slip fault.



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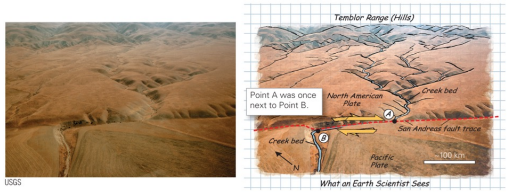
View from an airplane of the San Andreas strike-slip fault in California



Faulting breaks up rocks, so they are more easily eroded.
So the fault trace becomes a topographic feature.

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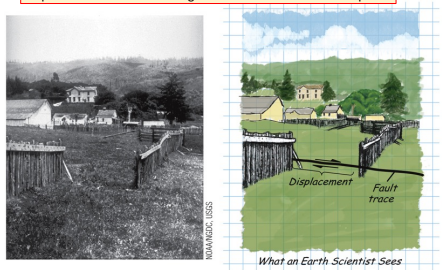
Displacement of a fence during the 1906 San Francisco Earthquake



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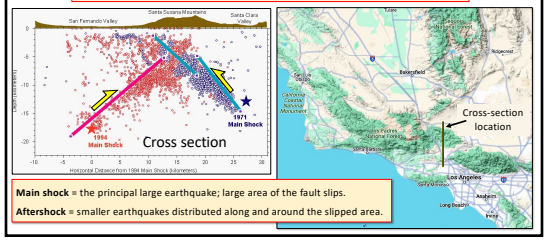
Very important . . .

- Not all earthquake generating faulting intersects the ground surface!
- Many (most?) seismically active faults are completely underground.

"Blind faults"



Main shock = the principal large earthquake; large area of the fault slips.
Aftershock = smaller earthquakes distributed along and around the slipped area.

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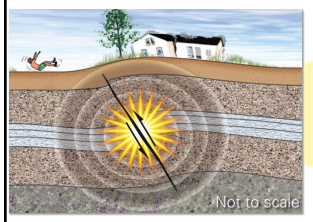

What causes earthquakes?

- Most are due to **slip on faults**.
  - initiation of a new fault
  - slip on a preexisting fault

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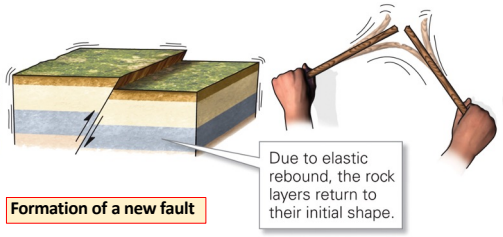
Left from WEB; right from Google Maps

The vibrations are generated by elastic rebound of rock bordering the fault.



Formation of a new fault

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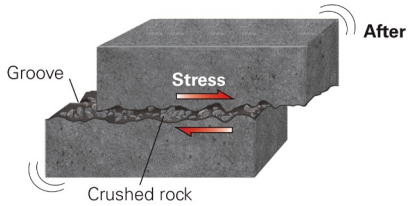

Reactivation of a preexisting fault

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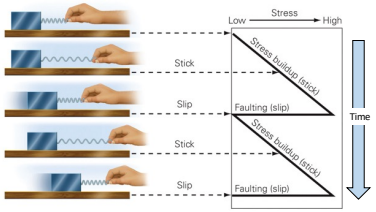

Stick-slip behavior

- Once formed, a fault is weaker than surrounding rock, so it gets reactivated.
- But friction prevents it from slipping all the time.
- It slips only when stress builds up and overcomes friction.

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TABLE 3.1 Types of Seismic Waves

Name	Abbreviation	Motion
P-waves	**P**rimary	Compressional body waves (first to arrive)
S-waves	**S**econdary	Shear body waves (second to arrive)
L-waves	**L**ove	Surface waves that cause a back-and-forth, snake-like shimmying
R-waves	**R**ayleigh	Surface waves that cause up-and-down wave-like undulations

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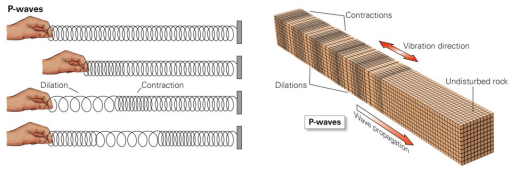
P-waves: Compressional body waves



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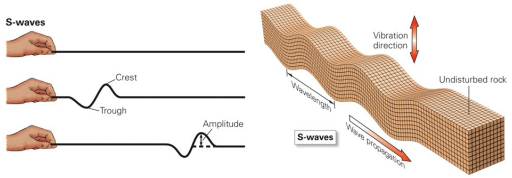
S-waves: Shear body waves



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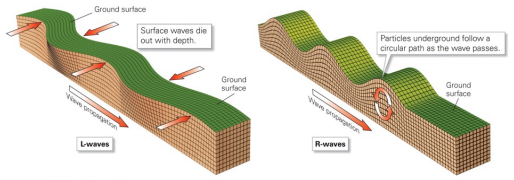
L- and R-waves: Surface waves



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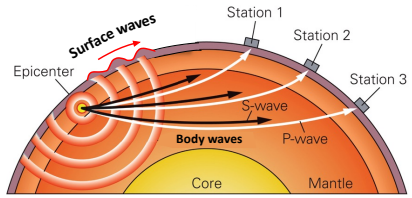
- Body waves pass through the interior of the Earth.
- Surface waves move along the surface of the Earth.



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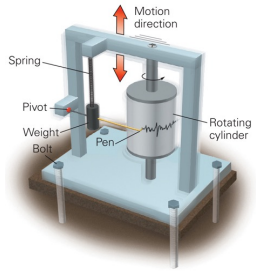
Detecting earthquakes . . .

- Seismographs are used to detect earthquakes.
- They are so sensitive that they can detect earthquakes that happen on the other side of the Earth
- A mechanical seismograph consists of a weight that stays in place during vibrations because of inertia. A pen is attached to the weight.
- An earthquake causes the frame and a recording cylinder to move.
- The pen stays in place, so it traces out a line that represent seismic waves.



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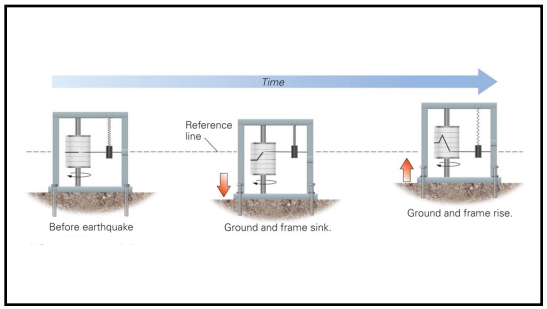

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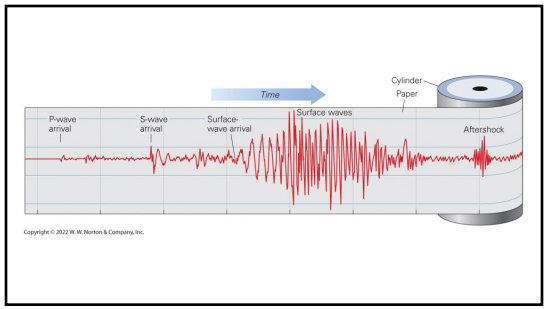

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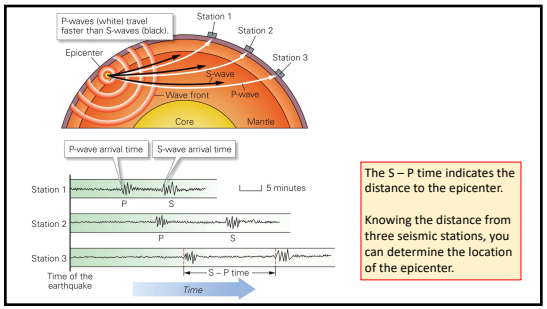

The S – P time indicates the distance to the epicenter.

Knowing the distance from three seismic stations, you can determine the location of the epicenter.

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Measuring the "size" of an earthquake . . .

- **Earthquake intensity** = An indication of the amount of damage and of human perception of the vigor of ground shaking at a location on the surface of the Earth.
  - — indicated by **Modified Mercalli Intensity** (**MMI**) scale.
- **Earthquake magnitude** = A measure of the energy release by an earthquake.
  - — now indicated by **Moment Magnitude** (M_w) scale.
  - — in the past, it was given by the "Richter Magnitude" scale.

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The intensity scale

MMI	Destructiveness (Perceptions of the Extent of Shaking and Damage)
I	*Not felt*: Detected only by seismic instruments; causes no damage.
II	*Weak shaking*: Felt by a few stationary people, especially in upper floors of buildings; suspended objects, such as lamps, may swing.
III	*Weak shaking*: Felt indoors; standing automobiles sway on their suspensions; it feels as though a heavy truck is passing.
IV	*Light shaking*: Shaking awakens some sleepers; dishes and windows rattle.
V	*Moderate shaking*: Most people awaken; some dishes and windows break, unstable objects tip over; trees and poles sway.
VI	*Strong shaking*: Shaking frightens some people; plaster walls crack, heavy furniture moves slightly, and a few chimneys crack, but overall little damage occurs.
VII	*Very strong shaking*: Most people are frightened; plaster cracks, windows break, some chimneys topple, and unstable furniture overturns; poorly built buildings sustain considerable damage.
VIII	*Severe shaking*: Many chimneys and factory smokestacks topple; heavy furniture overturns; substantial buildings sustain damage, and poorly built buildings suffer severe damage.
IX	*Violent shaking*: Frame buildings separate from their foundations; most buildings sustain damage, and some buildings collapse; the ground cracks, underground pipes break, and rails bend; some landslides occur.
X	*Extreme shaking*: Most masonry structures are destroyed; the ground cracks in places; landslides occur; bridges collapse; facades on buildings collapse; railways and roads suffer severe damage.
XI	*Extreme shaking*: Few masonry buildings remain; many bridges collapse; broad cracks form in the ground; most pipelines break; severe liquefaction of sediment may occur, causing the ground to fissure; many landslides develop; some dams collapse.
XII	*Extreme shaking*: Earthquake waves cause visible undulations of the ground surface; objects fly up off the ground; there is complete destruction of buildings and bridges of all types.

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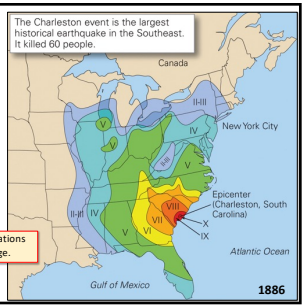
Intensity depends on several factors . . .

- **Distance from the epicenter**: In general, intensity decreases with increasing distance from the epicenter
- **Depth of the focus**: In general, deep-focus slip causes less intense earthquake at the ground surface.
- **Strength of crustal rocks**: Stronger rocks transmit energy further.

You can make a map of intensity variations by studying the distribution of damage.



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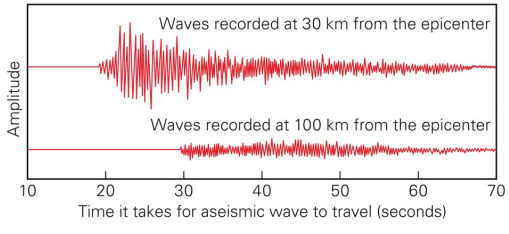
Seismic waves weaken as distance traveled increases, so a seismogram recorded closer to the epicenter shows larger amplitude waves than one recorded far away.



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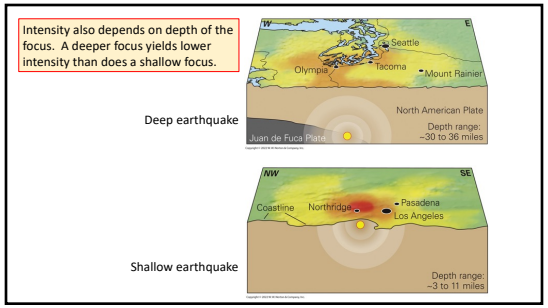
Intensity also depends on depth of the focus. A deeper focus yields lower intensity than does a shallow focus.



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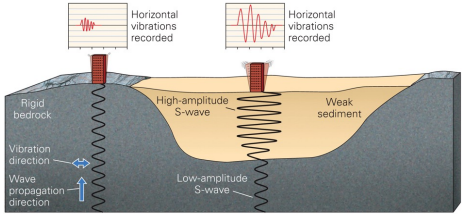
Local geological features, such as a basin of weak sediment, can locally amplify seismic waves and cause larger vibrations.



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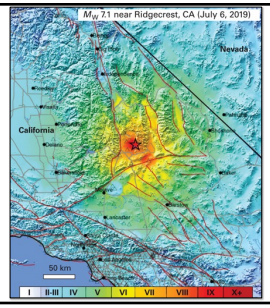
Modern intensity maps are calculated quickly from information on the magnitude, depth, and rock strength.



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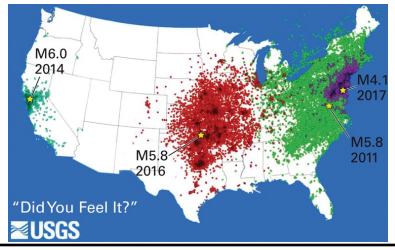
Energy from Midwest earthquakes travels further than that from California earthquakes, because rocks of California are broken-up and weak, whereas rocks of Midwest are strong and solid.



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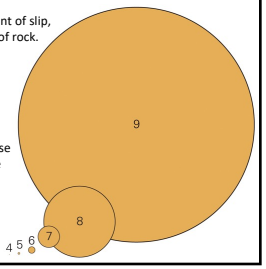
Earthquake magnitude: A representation of energy release.

- Energy release, in turn, depends on the amount of slip, the size of the slipped area, and the strength of rock.
- There is one magnitude number for a given earthquake.
- So, magnitude does not depend on distance.
- A magnitude scale is logarithmic. Each increase by 1 represents and increase in the amplitude of a given wave on a seismograph by 10X.
- An increase by 1 means a 32X increase in the energy release.



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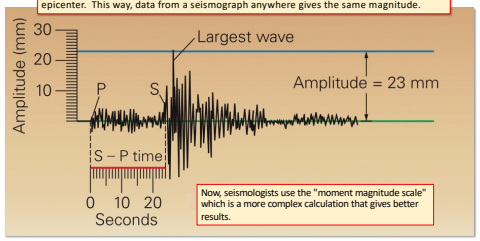
Richter magnitude: This was the first magnitude scale. The number was calculated by measuring the height of the largest displacement on a seismogram. This number was then converted to indicate height at an imaginary seismograph located 100 km from the epicenter. This way, data from a seismograph anywhere gives the same magnitude.



Now, seismologists use the "moment magnitude scale" which is a more complex calculation that gives better results.

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TABLE 3.3 Adjectives for Describing Earthquakes

Adjective	Magnitude (M_W)	Intensity at Epicenter	Effects
Great	>8.0	X to XII	Total destruction
Major	7.0 to 7.9	IX to X	Extreme damage
Strong	6.0 to 6.9	VII to VIII	Moderate to serious damage
Moderate	5.0 to 5.9	VI to VII	Slight to moderate damage
Light	4.0 to 4.9	IV to V	Felt by most; slight damage
Minor	<3.9	III or smaller	Felt by some; hardly any damage

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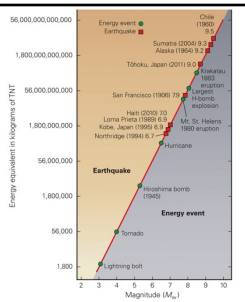
Comparison of earthquake energy release to the energy release from other kinds of energy events



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Earthquakes and Volcanoes

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Earthquakes cause casualties and destruction in many ways . . .

- Ground shaking (and building collapse)
- Ground displacement
- Landslides
- Liquefaction
- Fire
- Tsunami
- Disruption of society, transportation, economy, etc. etc.

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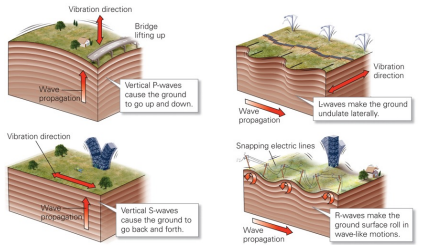
Different kinds of seismic waves cause different kinds of ground-surface movement.
Net consequence can be chaotic movement.



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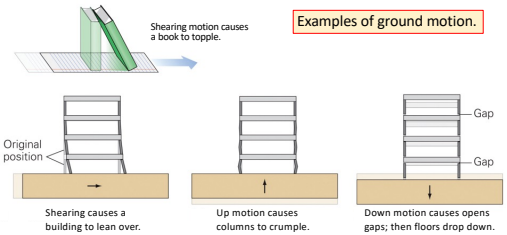

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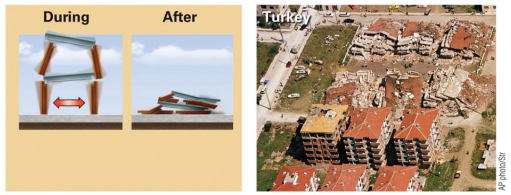
Shearing and pancaking . . .



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Tipping . . .

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Crushing (due to dynamic loads) . . .

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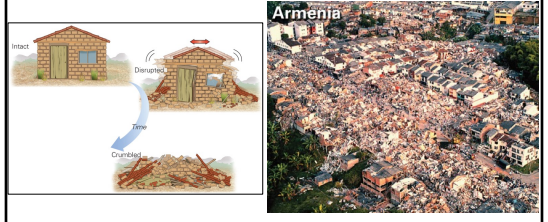
Fracturing and disaggregation . . .



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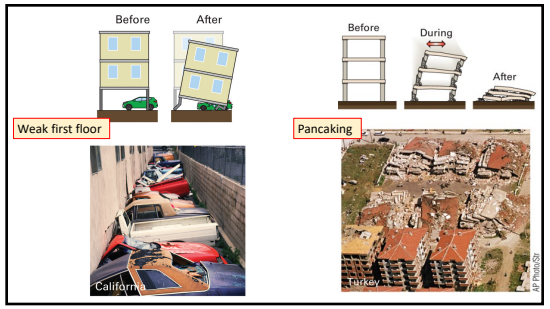

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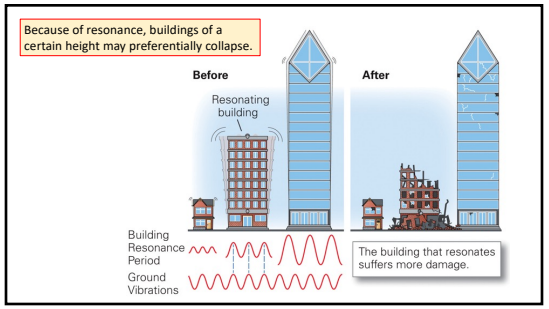

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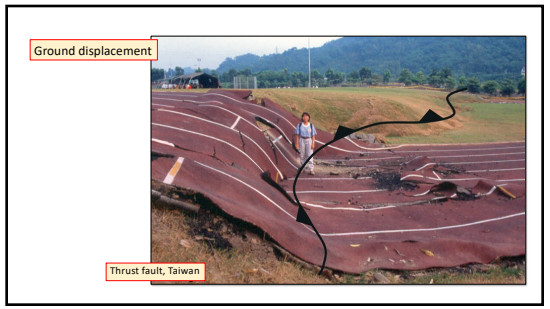

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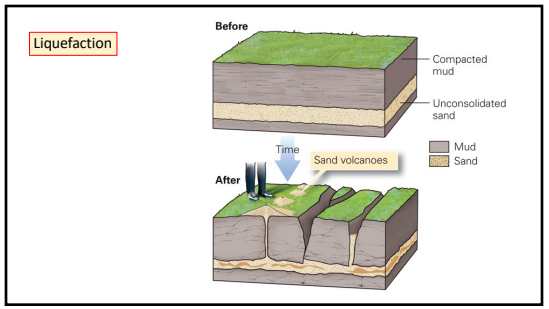

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Liquefaction . . .

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Landslides

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Collapsing sea cliff, California coast

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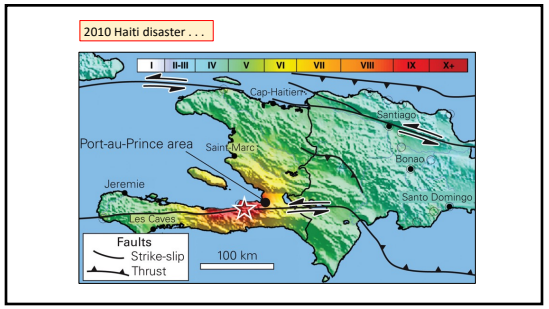

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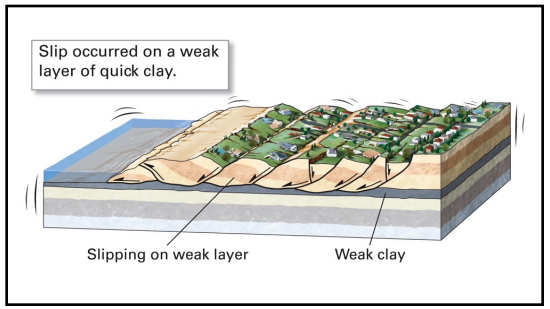

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Liquifaction and slumping . . .

1964 Good Friday earthquake, Alaska

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Palu, Indonesia

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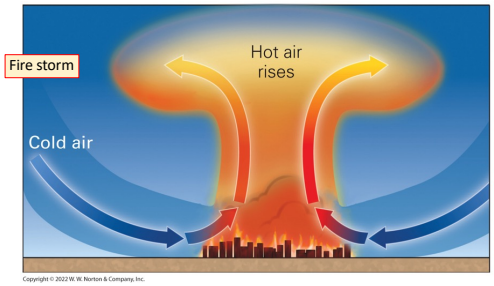
Fire:
- sparking wires
- tipped over furnaces and lamps
- broken gas pipes
- broken water mains
- debris-blocked streets

76

Fire storm



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Lisbon, 1755

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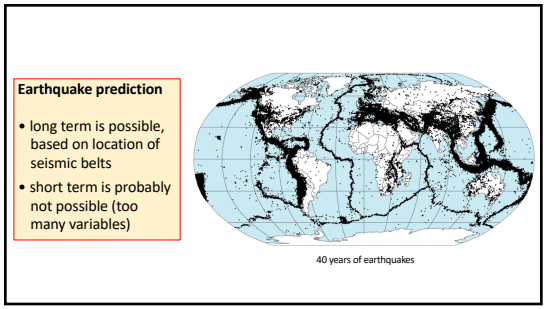

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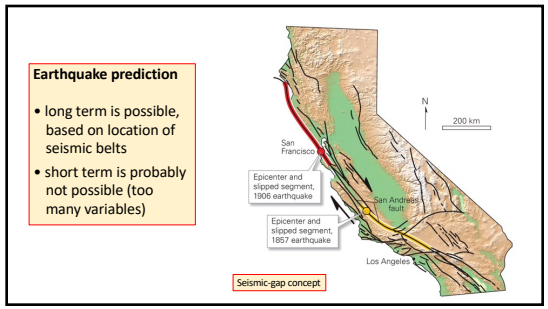
From WEB



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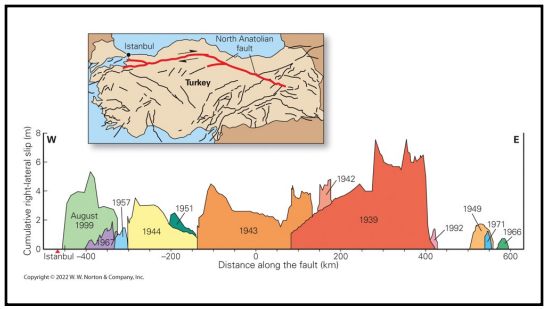

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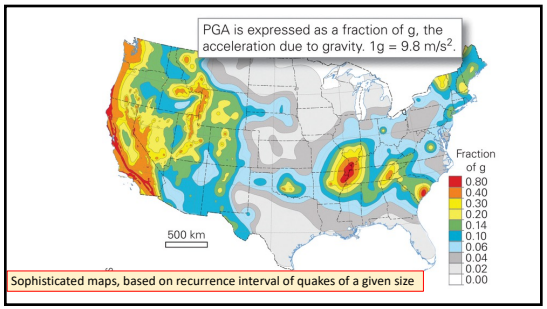

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