Earthquakes

Earthquakes: Big Ideas

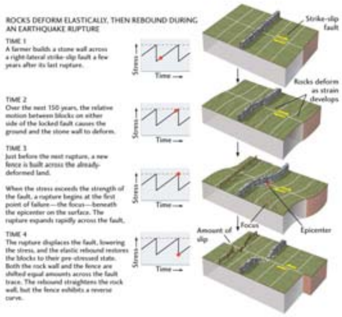
- Humans cannot eliminate natural hazards but can engage in activities that reduce their impacts by identifying high-risk locations, improving construction methods, and developing warning systems
- Water's unique physical and chemical properties are essential to the dynamics of all of Earth's systems
- Understanding geologic processes active in the modern world is crucial to interpreting Earth's past
- Over Earth's vast history, catastrophic processes have produced enormous changes
- Earth scientists do reproducible experiments and collect multiple lines of evidence.

Earthquakes

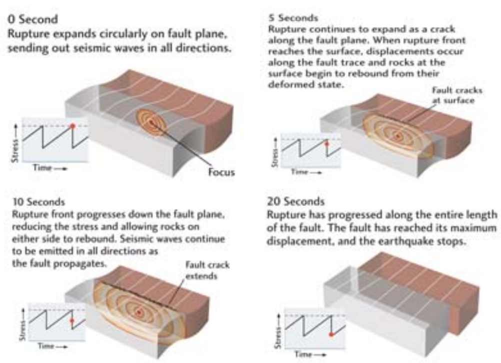
- earthquake: movement of rock bodies past other
- fault: locus of the earthquake movement
- faults come at all scales, mm to separation of lithospheric plates (*e.g.*, San Andreas).

Elastic Rebound

- Stress builds up in rocks until it exceeds the strength of rock
- Elastic deformation is expressed in rocks between earthquakes

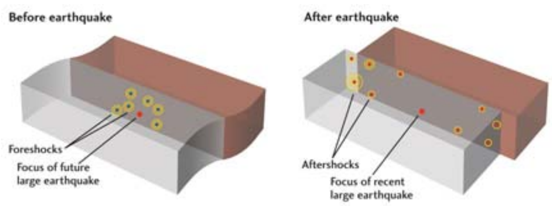


Stress versus Time



A fence built across the San Andreas fault near Bolinas, California, is offset by nearly 3 m after the great San Francisco earthquake

Before and After

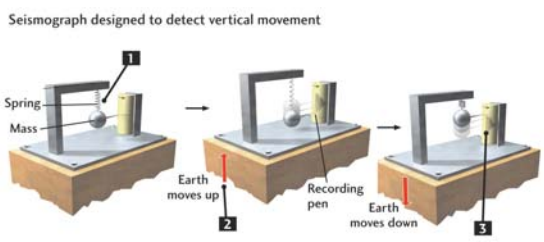


Earthquake terms

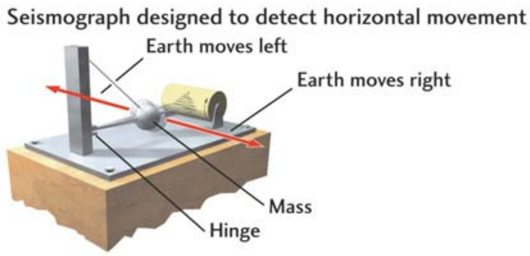
focus: site of initial rupture

epicenter: point on surface above the focus

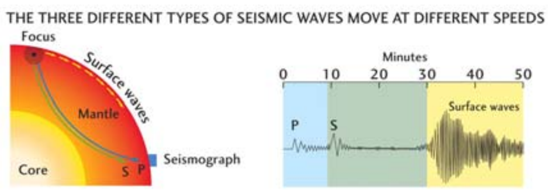
Recording Earthquakes: Vertical



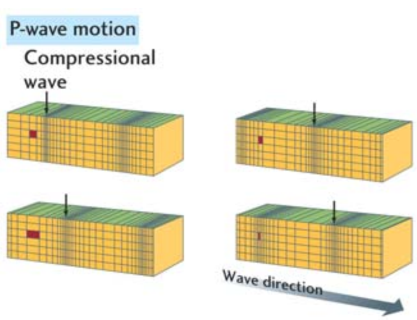
Recording Earthquakes: Horizontal



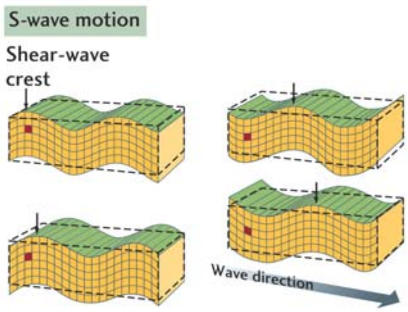
P, S and Surface Waves



P waves (compressional) 6–8 km/s. Parallel to direction of movement (slinky), also called primary waves. Similar to sound waves.

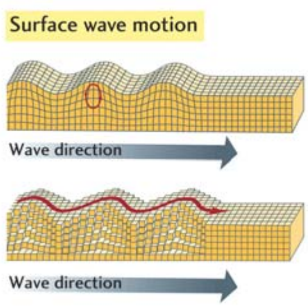


S waves (shear) 4–5 km/s. Perpendicular to direction of movement (rope); also called secondary waves. <u>Do not pass through liquids</u>.



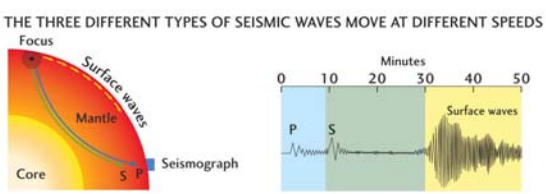
Surface Waves

- Slowest
- Highest Amplitude
- Decay with depth



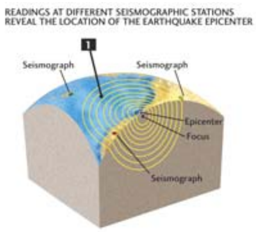
Locating an Epicenter

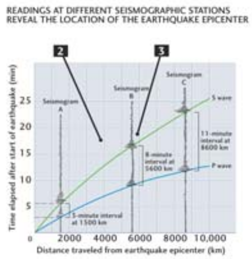
- The difference between the arrival times of the P and S waves at a recording station is a function of the distance from the epicenter.

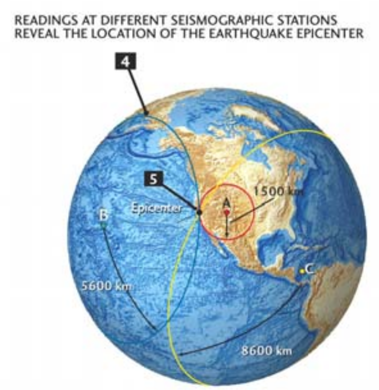


- But it does not tell you direction
- Therefore, you need at least three stations to determine the location of an epicenter.

Locating an Epicenter







Measuring the Force of Earthquakes

1. *Surface displacement*
   - 1964 Alaska earthquake displaced some parts of the seafloor by ~ 50 ft.
   - 1906 San Francisco earthquake moved the ground ~8.5 ft.
2. *Size of area displaced*

   Alaska — 70,000 sq. miles

Measuring the Force of Earthquakes

3. *Duration of shaking*

   Up to tens of seconds

4. *Intensity scales*

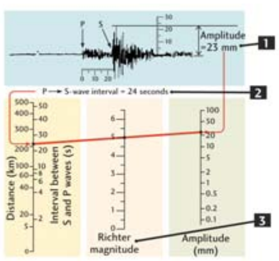
   Based on damage and human perception

5. *Magnitude scales*

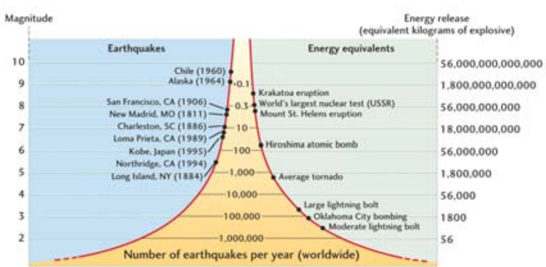
   based on amount of energy released

Richter scale

- Richter scale: amount of energy received 100 km from epicenter
- Largest quake ever recorded = 8.9 (rocks not strong enough for more).
- Earthquakes less than M = 2 are not felt by people.
- Scale is *logarithmic*:
  - Increase 1 unit = 10 times greater shaking
  - Increase 1 unit = 30 times greater energy



How Much Energy Released Versus How Often



Intensity Scale

Table 19.1 Modified Mercalli Intensity Scale

Intensity Level	Description
I	Not felt except by a very few under especially favorable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck.
IV	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. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

Intensity Scale

Table 19.1 Modified Mercalli Intensity Scale

Intensity Level	Description
VII	Damage negligible in buildings of good design and construction; slight to moderate damage in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	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.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

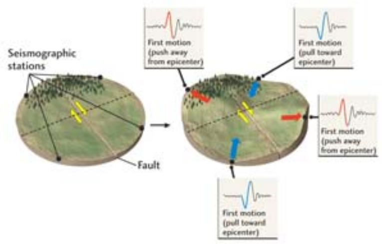
Intensities Associated With the 1811 Earthquake at New Madrid, Missouri

note a shortcoming of intensity scales: not very many people lived to the west of this EQ so no intensity observations are available.

Determining the Type of Earthquake From Seismic Data

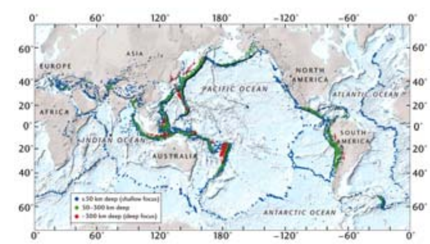
Fault motion of different kinds of faults (normal, reverse, shear) will produce distinctive seismic wave characteristics

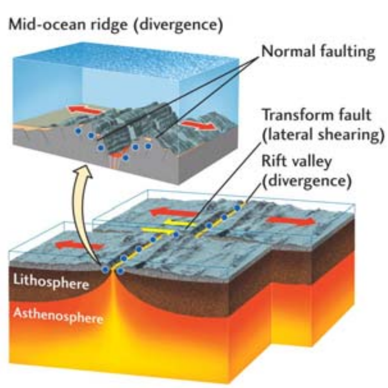
Atom Bomb is push in all directions

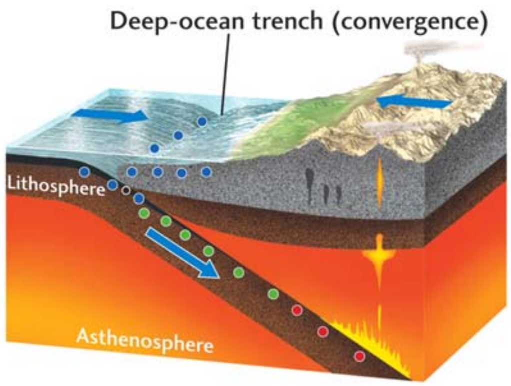


Distribution of Earthquakes

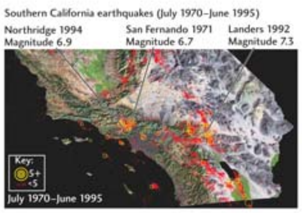
- not random
- focused around plate margins (but also seen in plate interiors)







California: Broad Zone of Deformation between Plates & Lots of Earthquakes



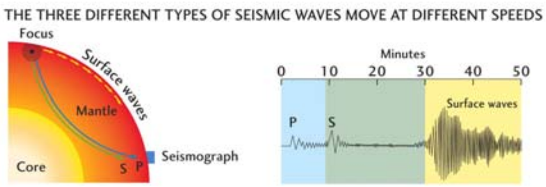
Damage depends on Construction/Population

Table 19.2 Recent Earthquakes of Special Interest

Event	Magnitude	Geologic Effects	Destruction
Loma Prieta, California October 1989	7.1	Maximum intensity in parts of Oakland and San Francisco; landslides; soil liquefaction; small tsunami at Monterey	60 killed; 3757 injured; U.S. $7 billion in damage
Landers, California June 1992	7.3	Surface faulting along a 70-km segment with as much as 5.5 m of horizontal displacement and 1.8 m of vertical displacement	1 killed; 400 injured; substantial damage
Northridge, California January 1994	6.9	A maximum uplift of 15 cm occurred in Santa Susana Mountains; many rockslides; ground cracks; soil liquefaction	➔ 58 killed; 7000 injured; 20,000 homeless; U.S. $20 million in damage
Northern Bolivia June 1994	8.2	At 637 km depth, the largest deep earthquake on record; first earthquake from this part of South America to have been felt in North America including Canada	Several people killed
Kobe, Japan January 1995	6.9	Surface faulting for 9 km with horizontal displacement of 1.2 to 1.5 m; soil liquefaction	➔ 5502 killed; 36,896 injured; 310,000 homeless; severe damage

Earthquake Damage: Ground Motion

- 3 waves hit at different times and with different times of motion
- Highest amplitude comes last when buildings are already damaged



"Earthquakes don't kill people, buildings kill people."

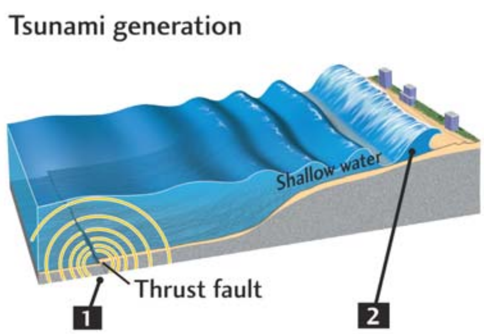
Earthquake Damage: Fire

Troops patrolling Market Street, San Francisco

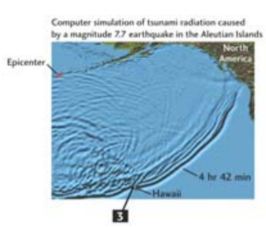
Earthquake Damage: Landslides

- all kinds of mass wasting
- liquefaction – sudden loss of strength in water-saturated sediment buildings fall down intact

Earthquake Damage: Tsunami



Earthquake Damage: Tsunami



Indonesia - 1992

Earthquake Prediction

- Long term—imprecise (but possible)
- Short term—precise (very difficult)
- We can't stop earthquakes, so we have to be prepared for them

Potential Earthquake Hazard, USA

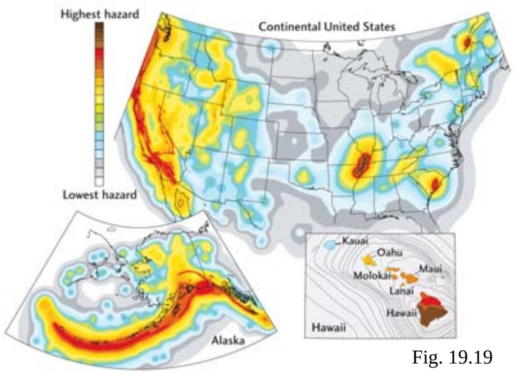
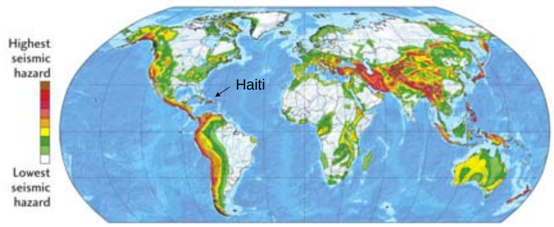


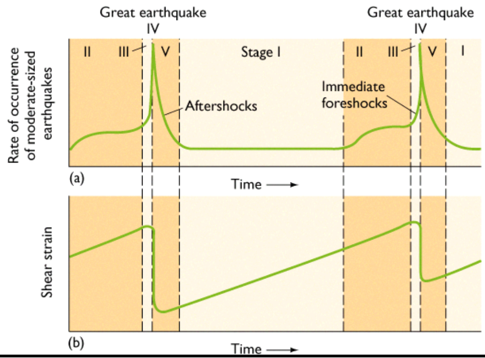
Fig. 19.19

Potential Earthquake Hazard, Worldwide



Loss of Life/Property in Haiti primarily due to poor construction

Earthquake Prediction: Seismic Gap Method
Areas which have not had a recent large earthquake
at highest risk because energy is stored in rocks

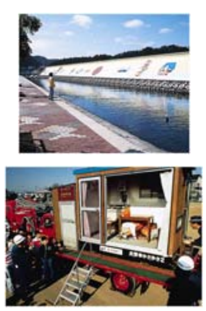


Earthquake Prediction

- Small earthquakes
- Ground tilting
- Change in water levels in wells
- Change in acoustic
  or electrical properties
- Animal behavior?

Be Prepared!

California



Japan