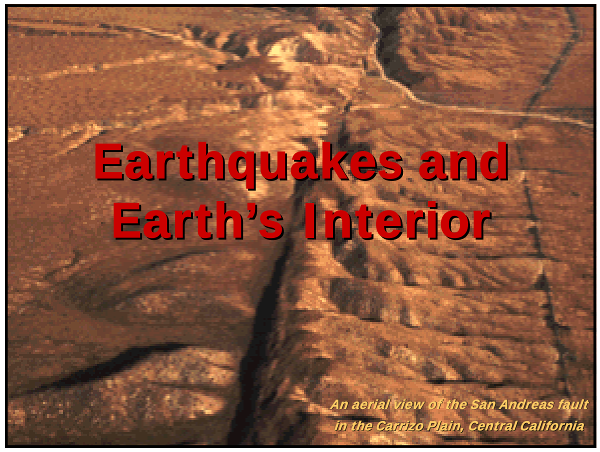
Essentials of Geology

David Sallee

Chapter 14

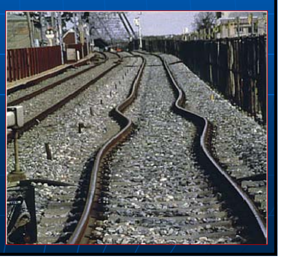


Earthquakes and Earth's Interior

An aerial view of the San Andreas fault in the Carrizo Plain, Central California

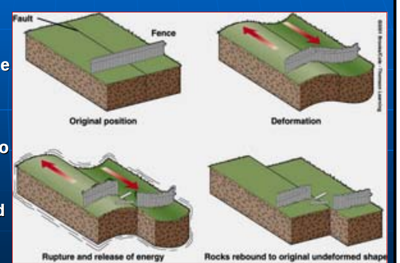
What are Earthquakes?

- The shaking or trembling caused by the sudden release of energy
- Usually associated with faulting or breaking of rocks
- Continuing adjustment of position results in aftershocks

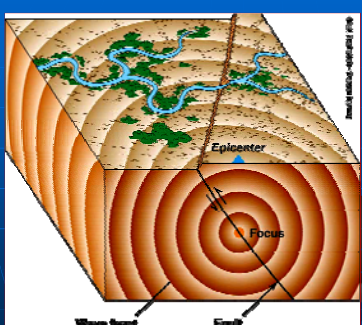


What is the Elastic Rebound Theory?

- Explains how energy is stored in rocks
  - Rocks bend until the strength of the rock is exceeded
  - Rupture occurs and the rocks quickly rebound to an undeformed shape
  - Energy is released in waves that radiate outward from the fault



What is Seismology?

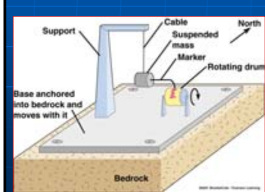


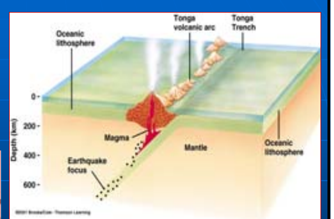
- The Focus and Epicenter of an Earthquake

- The point within Earth where faulting begins is the focus, or hypocenter
- The point directly above the focus on the surface is the epicenter

What is Seismology?

- Seismographs record earthquake events

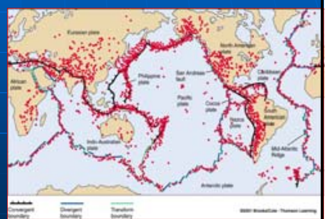




- At convergent boundaries, focal depth increases along a dipping seismic zone called a Benioff zone

Where Do Earthquakes Occur and How Often?

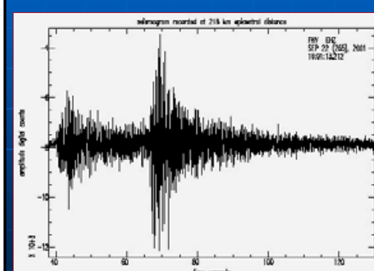
- ~80% of all earthquakes occur in the circum-Pacific belt
  - most of these result from convergent margin activity
  - ~15% occur in the Mediterranean-Asiatic belt
  - remaining 5% occur in the interiors of plates and on spreading ridge centers
  - more than 150,000 quakes strong enough to be felt are recorded each year



Where do Earthquakes Occur and How Often?

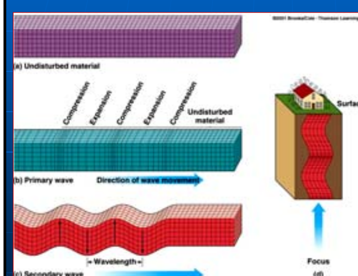
Damage in Oakland, CA, 1989

What are Seismic Waves?



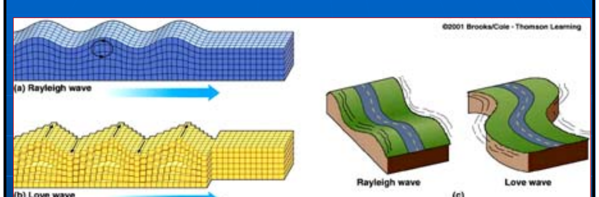
- Response of material to the arrival of energy fronts released by rupture
- Two types:
- Body waves
  - P and S
- Surface waves
  - R and L

What are Seismic Waves?



- Body waves
  - P or primary waves
    - fastest waves
    - travel through solids, liquids, or gases
    - compressional wave, material movement is in the same direction as wave movement
  - S or secondary waves
    - slower than P waves
    - travel through solids only
    - shear waves - move material perpendicular to wave movement

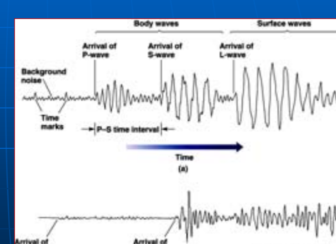
What are Seismic Waves?



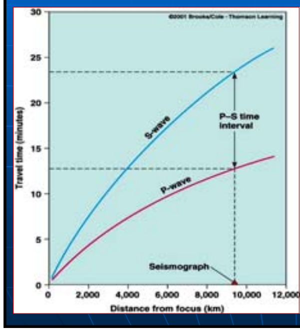
- Surface Waves
  - Travel just below or along the ground's surface
  - Slower than body waves; rolling and side-to-side movement
  - Especially damaging to buildings

How is an Earthquake's Epicenter Located?

- Seismic wave behavior
  - P waves arrive first, then S waves, then L and R
  - Average speeds for all these waves is known
  - After an earthquake, the difference in arrival times at a seismograph station can be used to calculate the distance from the seismograph to the epicenter.



How is an Earthquake's Epicenter Located?

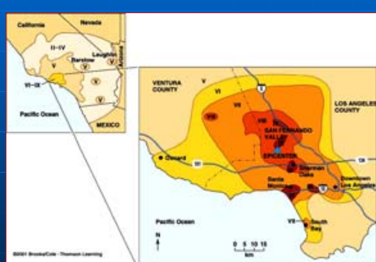


- Time-distance graph showing the average travel times for P- and S- waves. The farther away a seismograph is from the focus of an earthquake, the longer the interval between the arrivals of the P- and S- waves

How is an Earthquake's Epicenter Located?

- Three seismograph stations are needed to locate the epicenter of an earthquake
- A circle where the radius equals the distance to the epicenter is drawn
- The intersection of the circles locates the epicenter

How is the Size and Strength of an Earthquake Measured?

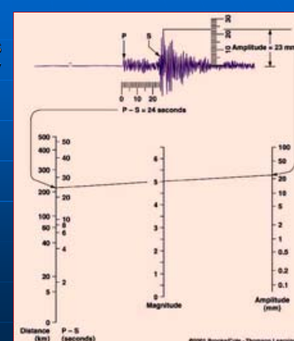


- Modified Mercalli Intensity Map
  - 1994 Northridge, CA earthquake, magnitude 6.7

- Intensity
  - subjective measure of the kind of damage done and people's reactions to it
  - isoseismal lines identify areas of equal intensity

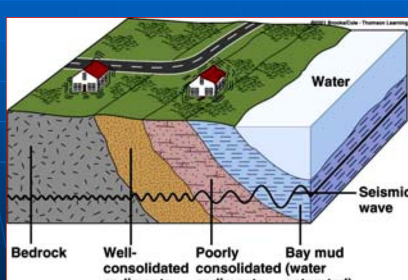
How is the Size and Strength of an Earthquake Measured?

- Magnitude
  - Richter scale measures total amount of energy released by an earthquake; independent of intensity
  - Amplitude of the largest wave produced by an event is corrected for distance and assigned a value on an open-ended logarithmic scale



What are the Destructive Effects of Earthquakes?

- Ground Shaking
  - amplitude, duration, and damage increases in poorly consolidated rocks

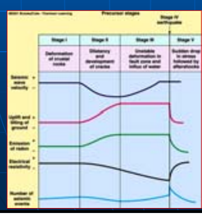


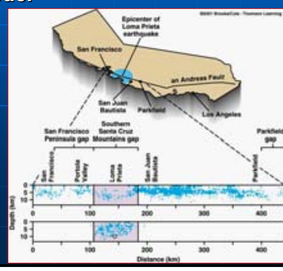
What are the Destructive Effects of Earthquakes?

- Building collapse
- Fire
- Tsunami
- Ground failure

Can Earthquakes be Predicted?

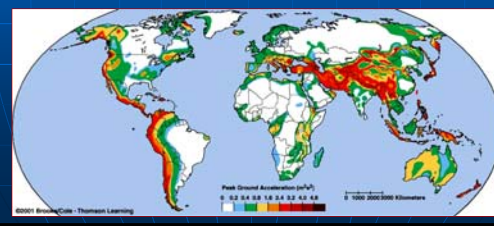
- Earthquake Precursors
  - changes in elevation or tilting of land surface, fluctuations in groundwater levels, magnetic field, electrical resistance of the ground
  - seismic dilatancy model
  - seismic gaps





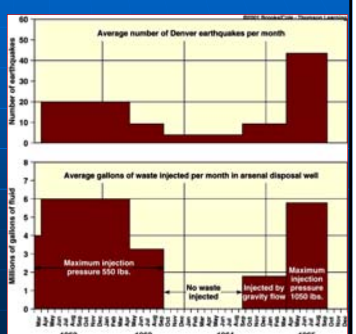
Can Earthquakes be Predicted?

- Earthquake Prediction Programs
  - include laboratory and field studies of rocks before, during, and after earthquakes
  - monitor activity along major faults
  - produce risk assessments



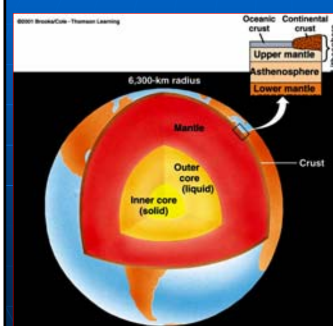
Can Earthquakes be Controlled?

- Graph showing the relationship between the amount of waste injected into wells per month and the average number of Denver earthquakes per month
- Some have suggested that pumping fluids into seismic gaps will cause small earthquakes while preventing large ones



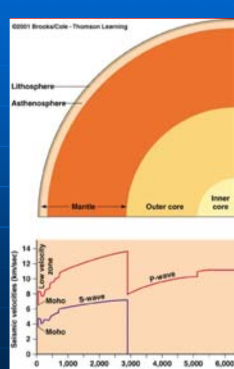
What is Earth's Interior Like?

- Crust, mantle, core
  - behavior and travel times of P and S waves helps define interior structure
  - velocity of waves is dependent on the density and elasticity of material they travel through
  - waves are bent (refracted) or bounced (reflected) as they pass through different materials in Earth



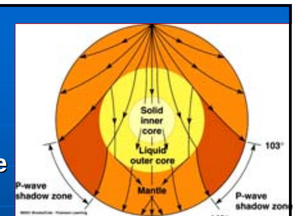
What is Earth's Interior Like?

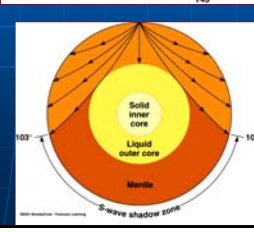
- A profile showing seismic velocities versus depth
  - several discontinuities indicate changes in Earth materials or their properties
  - discontinuities are the basis for subdividing Earth's interior into concentric layers



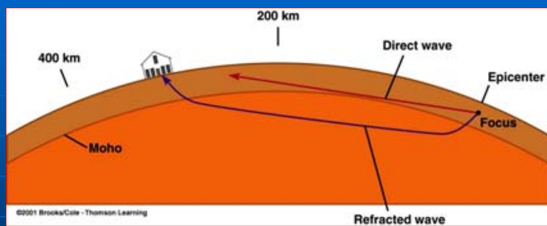
The Core

- Density and Composition of the Core
  - behavior of P and S waves indicates a solid inner and liquid outer core
  - inner core is iron/nickel, rotates more rapidly than outer core
  - outer core is iron mixed with sulfur, density of 9.9 to 12.3 gm/cm³





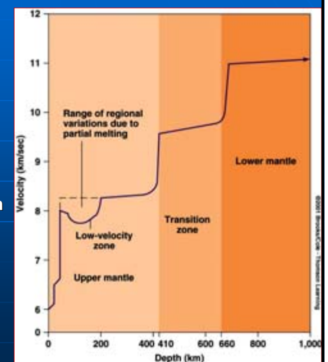
The Mantle



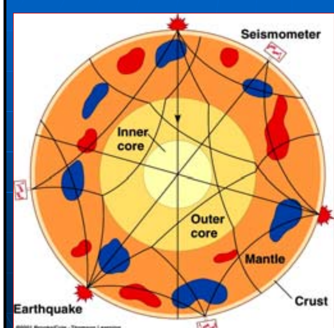
- Discontinuities
  - Sharp velocity increase in wave travel times at a depth of about 30km - called the Moho
  - The Moho separates the crust from the mantle

The Mantle

- Structure and Composition of the Mantle
  - Seismic wave velocities generally increase with depth, but several other discontinuities exist
  - The low-velocity zone is inferred to represent zones of partial melting in the asthenosphere
  - Composition believed to be that of the igneous rock peridotite



Seismic Tomography



- Three-dimensional models of Earth's interior
  - More complete analysis of seismic waves indicated hot and cold areas within the mantle
  - Hot areas underlie spreading centers and volcanic areas
  - Cold areas underlie the older interior portions of the large continents

The Crust

- Continental crust
  - Overall composition similar to granite
  - Low density (2-3gm/cm²)
  - Averages 35km thick, more under mountain ranges
- Oceanic crust
  - Gabbro/basalt composition
  - Higher density (3gm/cm²)
  - Between 5 and 10 km thick

Earth's Internal Heat

- Geothermal gradient
  - Temperature increases with depth
  - Averages 25°C/km
  - Gradient is higher in areas of active or recently active volcanism
  - Most heat is generated by radioactive decay
  - Maximum temperature at the center of the core is estimated to be about 6,500°C