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

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

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 the Size and Strength of an Earthquake Measured?

- Intensity
  - Subjective measure of the kind of damage done and people’s reactions to it
  - Isoseismal lines identify areas of equal intensity

What are the Destructive Effects of Earthquakes?

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

- 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?

- 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

What is Earth’s Interior Like?

- 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

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