History of Earthquakes

- **856AD - Corinth, Greece**
  - First well documented, 45,000 killed
- **1556 - Shensi, China**
  - Most disastrous quake in known history
  - 830,000 killed
- **1663 - St. Lawrence River, Canada**
  - Broke chimneys in Massachusetts
- **1755 - Lisbon, Portugal**
  - Very well documented, 70,000 killed, caused a great tsunami

History, continued

- **1811 - New Madrid, Missouri**
  - Largest known earthquake in the U.S.
  - Several large quakes followed into 1812
- **1906 - San Francisco, California**
  - Richter scale 8.25, caused the San Francisco Fire
- **1960 - Southern Chile**
  - Largest quake of this century (8.5)
- **1975 - Liaoning Province, China**
  - First predicted earthquake, few deaths

The Phenomenon of Elastic Rebound

- Stress begins; fault is locked; elastic deformation begins.
- Stress builds; deformation continues.
- Fault slips; stress released; rocks return to unstressed dimensions.

Earthquakes

- Acceleration/shaking of ground caused sudden release of strain (rupture) along faults.
- Fault - fracture (system/zones) along which rocks have been displaced (fault segment).
  - Fault trace, scarp.
- Focus - point where strain is released (along a fault deep in earth interior).
- Epicenter - point on surface above focus.

Modes of generation

- **1) Tectonic earthquakes**
  - Most common, occur most frequently along plate boundaries
Modes of generation

1) Tectonic earthquakes
   - Most common, occur most frequently along plate boundaries
2) Volcanic earthquakes
3) Collapse earthquakes
   - Includes mine bursts and landslides
4) Explosion earthquakes
   - Some nuclear explosions have reached amplitudes of moderate sized earthquake
Seismic waves

- Energy in an earthquake is released as seismic waves.
- Seismic waves are what cause the destructive shaking in a quake.
- There are four wave types which fall into two main categories:
  1. Body waves
  2. Surface waves

Body Waves

- P-waves (fastest of all the wave types)
- Can travel through solids and liquids

Body waves

- S-wave (slower than P-waves)
- More destructive shaking at the surface
- Can only go through solids

Surface waves

- Love wave (extremely damaging)
- Similar to an S-wave with no vertical movement
Surface waves

- Rayleigh wave (like ocean waves)
- Moves objects vertically and horizontally in an elliptical motion

Measuring earthquakes

- Instruments that measure the intensity of shaking are called seismographs
- The earthquake records produced by these instruments are called seismograms
- The first instrument ever used to detect earthquakes was invented by Chang Heng in China about 132 A.D.
Earthquakes

Richter Scale (Magnitude):
- Energy released during earthquake.
- Depends on the displacement along fault plane and the rebound of rocks.
- Logarithmic scale

Mercalli (Intensity):
- Perception of residents (felt) and damage caused.
- Depends on soilrock through which earthquake wave travels and construction techniques and materials.

Locating the Epicenter

1) Use seismometers to measure the difference between P-wave and S-wave arrival times
2) Use known velocities of these waves to calculate the distance of the epicenter from the seismometer
3) Use distance calculations from three stations to triangulate the exact position of the earthquake epicenter
Exploring the Earth Interior

- Use of seismic waves to look inside the Earth can be thought of as the first form of remote sensing.
- Seismic waves reflect and refract (bend) within the Earth and can reveal layers of differing composition and physical state.
- Because S-waves cannot travel through liquids, we can also delineate non-solid portions of the Earth interior.

Buzz Aldrin (Apollo 11) stands next to a newly deployed seismometer, 1969.

Earthquake Damage

1) Shaking
   - Causes objects and buildings to fall.
   - Foreshocks are little quakes before the big one, aftershocks are little quakes after the big one.
   - Smaller aftershocks can topple buildings initially damaged by the main shock.
Freeway Damage From an Earthquake

A

B

Earthquake: Pancake-Style Collapse of Fifteen-Story Building
Earthquake Damage

1) Shaking
   - Causes objects and buildings to fall
2) Wave amplification
   - Unconsolidated sediment
   - Damping and reinforcing of waves
   - Resonance
3) Liquefaction

LIQUIFACTION
Earthquake Damage

- **1) Shaking**
  - Causes objects and buildings to fall

- **2) Wave amplification**
  - Unconsolidated sediment
  - Damping and reinforcing of waves
  - Resonance

- **3) Liquefaction**

- **4) Fire**

Earthquake Damage—continued

- **5) Ground rupture**
  - Usually a surface expression of the fault that broke to cause the quake
5) Ground rupture
   - Usually a surface expression of the fault that broke to cause the quake

6) Landslides

7) Tsunamis
   - Also known as “Tidal Waves”
   - Tallest one recorded was 24 meters
   - Geological evidence for even taller waves
Dec. 26 Earthquake and Tsunami

- Shifted N-pole by approximately 1 inch to the East.
- Decreased the Earth’s oblateness.
- Increased the daily rotation by 2.68 microseconds.
- Earthquake had a depth of 10 km.

Trinka Island
150,000 dots, the number of people who died on Dec. 26 as a result of the tsunami.

Predicting Earthquakes - Dubious techniques
- Animal Behavior

“Chickens fly up to trees and hogs stay quiet. Ducks go out of water and dogs bark wildly.”

Predicting Earthquakes - Dubious Techniques
- Animal Behavior
- Earthquake weather
- Glow in the sky
- Tidal pull of sun and moon (and other planets)
  - Semi-successful near volcanoes for minor quakes
- Psychic Friend Hotline
Predicting Earthquakes

More Reliable Techniques

- Changes in P-wave velocity
- Ground uplift and tilt
- Radon emission
- Electrical resistivity of the rocks
- Number of local earthquakes (foreshocks)
- Geyser activity (changes in water table)
- Very Low Frequency (VLF) EMR
  - Two satellites recently launched to measure magnetic field of the Earth

Predicting earthquakes

- Paleoseismicity
  - If we can determine when past earthquakes took place we may be able to judge the frequency of major events
    - Tree ring data
    - Sand boils
    - Sea terraces due to uplift
    - Historical records

Reducing the Risk

- Instead of predicting earthquake occurrence, the U.S. has chosen to focus on predicting earthquake intensity
- Building codes designed to match expected earthquake intensity
- Can distribute information to people in hazardous areas on how to prepare for and protect yourself from earthquakes

Reducing the Risk

- May be possible to induce earthquakes
- Rocky Mountain arsenal began pumping contaminated water into ground in 1962, and earthquakes were felt in Denver soon after.
- Ceased pumping in 63, earthquakes diminished, began again in 64-65, earthquakes increased