Chapter Outlines

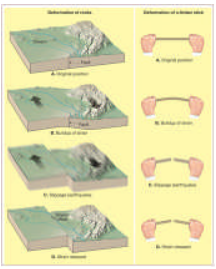
Santa Rosa 1906 SF earthquake damage

NOTE: This is intended to help students 'organize' their understanding of each topic. It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>

Earthquakes

Depending on how strong they are and where they strike, earthquakes can be some of the worst natural disasters, taking thousands of lives and creating billions of dollars of damage. When occurring beneath the sea, an earthquake can result in a huge wave called a **tsunami**. Earthquakes are the result of the sudden movement of rock along a fault zone beneath the surface, usually centered in tectonically active areas. Scientist who study earthquakes are called **seismologists**.

- An **earthquake** is the shaking of the earth caused by the sudden release of energy *(in the form of seismic waves)* from the breaking of rock under tectonic stress.



  - Most earthquakes are associated with rock movement along **faults** below Earth's surface.
  - Friction will not allow movement along a fault until tectonic stress is great enough to overcome the friction. So, the rocks slowly build up strain *(bending under the stress),* then release it suddenly.
  - '**Elastic rebound theory**' suggests these rocks release this built-up strain and then spring back to their previous shape, thereby violently releasing stored energy as seismic waves *(shaking).*

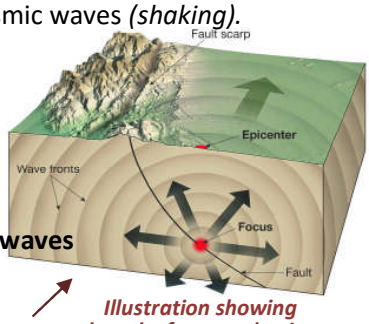
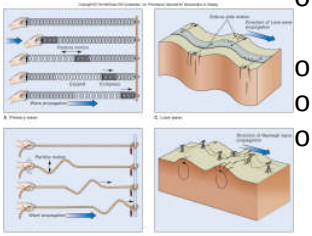


Illustration showing earthquake focus and epicenter

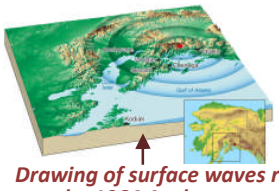
- **Seismic waves**

P wave *Love wave*



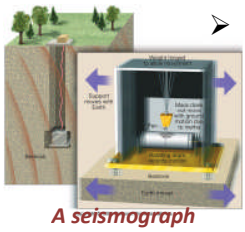
S wave *Rayleigh wave*

  - Seismic waves are released by the rupturing rock, and move outward from the focus *(point of origin).*
  - The **epicenter** is the point on Earth's surface directly above the focus
  - There are two types of seismic waves: **body waves** ***(P and S)*** and **surface waves**
  - Body waves:
    - **P waves** *(primary waves)* are compressional and can travel up to 7 km/sec. Speed varies depending on density of the host rock.
    - **S waves** *(secondary waves)* travel at about half the speed of P waves and cause rock to vibrate at right angles to the direction of wave travel. S waves can pass through solids only ***(not** through liquids)*



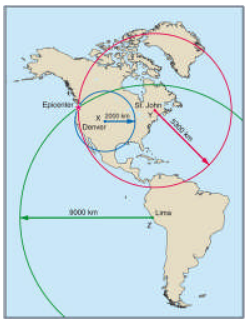
Drawing of surface waves resulting from the 1964 Anchorage earthquake

  - **Surface waves** are the slowest seismic waves and travel outward from the epicenter like ripples do from a stone thrown into water. Surface waves do most of the damage. Surface waves are:
    - **Love wave** – side-to-side motion of the ground surface. Can't travel through fluids.
    - **Rayleigh wave** – ground moves up and down in an elliptical path opposite the direction of wave motion…this is extremely destructive to buildings.



A seismograph

- Measuring Earthquakes
  - **Seismometers** are used to detect earthquakes, **seismograph**s record earthquakes, and a **seismogram** is the recorded paper record.
  - Seismic data can be used to determine location and depth of a focus, and the '**first motion**' of rock.
    - Maximum earthquake depth is ≈670 km. 85% of earthquakes are shallow *(down to 70km),* 13% are intermediate *(70-350km),* and 3% are deep. This pattern is largely due to Earth being most brittle near the surface, becoming more plastic with depth.
    - Using the different monitoring station arrival times of the **P wave** *(faster)* and the **S wave** *(slower),* distance can be calculated back to the focus. By using records from three recording stations ***(triangulation)*** the exact location of a focus can be calculated.

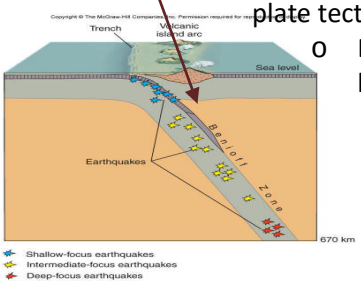


Using triangulation to locate an epicenter

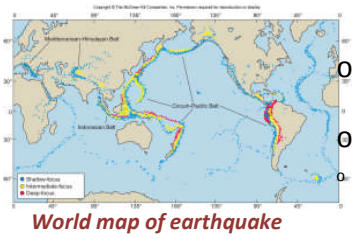
- By determining whether the 'push' or 'pull' component of the compressional P wave arrived first ***('first motion')***, it can be determined whether rock at the fault moved away from the station or toward the station.

- How intense?
  - Intensity is measured by the **Modified Mercalli scale**. This is a measurement of the amount of damage. It is subject to inconsistencies due to variations in populations, building quality, etc.
  - The **Richter scale** is most commonly used by the public. It measures magnitude on a logarithmic scale of about 2 to 8.6. An increase of one represents a 10x increase in vibration amplitude, and a 32x increase in energy released.

Earthquakes occurring along a descending plate



- Earthquakes and Plate Tectonics – Earthquakes occur mostly in well-defined belts that correspond to plate tectonic zones *(plate boundaries).*
  - Earthquakes are caused by plate interaction along tectonic plate boundaries. Plate boundaries are often identified by earthquakes.
    - **Transform faults** produce shallow earthquakes – this includes the San Andreas fault in California
    - **Mid-ocean ridges** *(divergent boundary)* produce shallow earthquakes.
    - **Deep ocean trenches** *(convergent boundaries)* produce shallow to very deep earthquakes. Earthquakes foci at subduction zones follow a pattern descending from near the surface down, at an angle, to where the descending cold plate becomes hot and ductile. This zone of earthquakes is called a **Benioff zone**.
  - **Circum-Pacific belt** *(the ring of fire)* follows the rim of the Pacific Ocean and hosts 80% of all earthquakes. This includes the western states and Alaska.
  - The **Mediterranean-Himalayan belt**
  - Earthquakes occur throughout the U.S., but are much more common in the western states and Alaska.

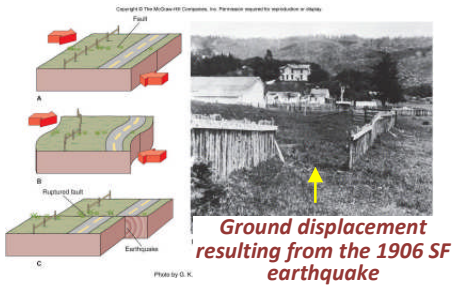


World map of earthquake occurrences

- Effects of Earthquakes
  - Collapse of buildings & bridges and fires from broken gas lines *(remember – broken water lines mean no way to extinguish these fires!)*
  - **Liquefaction** – soil *(mostly water saturated soil)* becoming fluid during shaking thereby causing buildings to partially *(and unevenly)* sink and possibly fall over.
  - Mass wasting events – mudslides etc. can be triggered
  - Permanent displacement of land surface – fractures, scarps, displacement along faults.
  - Seismic sea waves (**tsunamis)** – generally only with very large earthquakes of magnitude 8+.
    - Tsunamis can travel across open oceans at >700km/hr *(at very low heights)* and reach great heights when they approach shore.

A result of liquefaction

- Prediction and Control *(accurate prediction not possible…yet)*
  - Stories of animal behavior being an indicator of a coming earthquake is not widely supported.
  - Some other methods produce mixed results:
    - Release of radon gas
    - Water table changes
    - Small movements along faults
    - Changes in magnetism and electrical properties near faults
  - History of previous earthquakes can help in predicting future earthquakes.
    - Study of the slip rate along a fault
    - Paleoseismology studies to determine when earthquakes have occurred in the past
  - Can earthquakes be reduced in magnitude?
    - Using injection or extraction of groundwater to alternately 'lock' and 'release' portions of a fault. *(hypothetical only!)*
  - **Seismic Early Warning** – is currently being deployed in many high-risk populated areas, it gives seconds/minutes warning of incoming seismic shaking from a nearby 'seismic event'



Ground displacement resulting from the 1906 SF earthquake