Faults and Quakes

Dr. W.

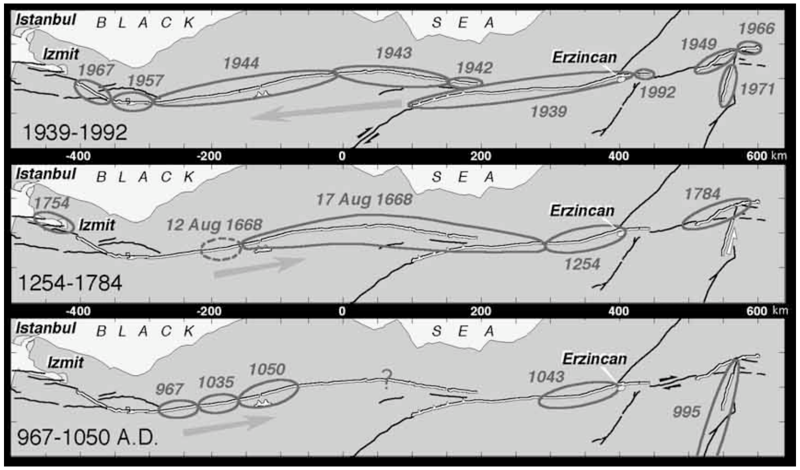
Damage to the Nimitz Freeway in Oakland, California, in the aftermath of the 1989 Loma Prieta quake. . .

Now a bit about quakes. . .

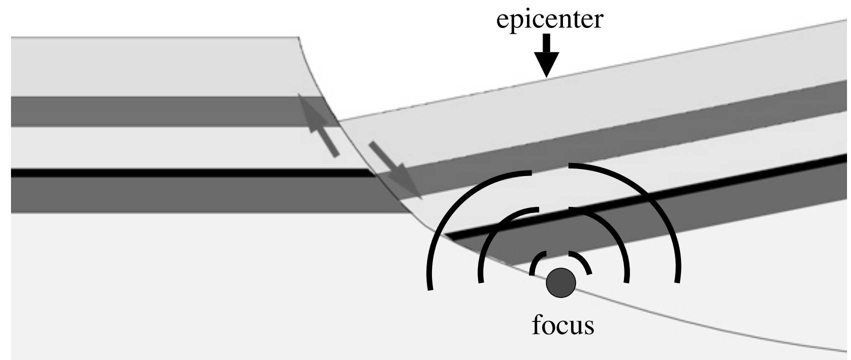
- Motion along some faults is gradual, without significant friction buildup. This motion is called *fault creep*.
- But on most active faults, friction causes *strain* on the fault to build up over time. . .
- . . . and then to be released rapidly.
  - Analogy: Think of breaking a stick. As the stick bends, strain builds up, until it's suddenly released

Fault creep or rapid quakes both cause *displacement* or *offset* along the fault. The bank of this canal was offset by about three meters in the Sept. 2, 1999 quake centered at Izmit, Turkey.

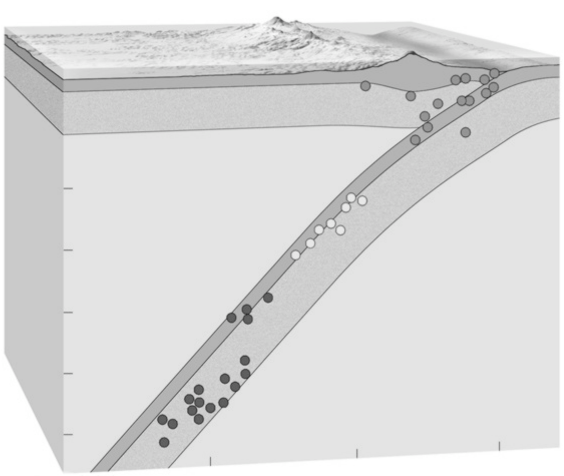
Quakes tend to come in clusters along specific segments of a fault—displacement may relieve stress on one part of a fault but cause stress buildup elsewhere on the fault. This map shows historical quakes on the North Anatolian Fault of north Turkey.

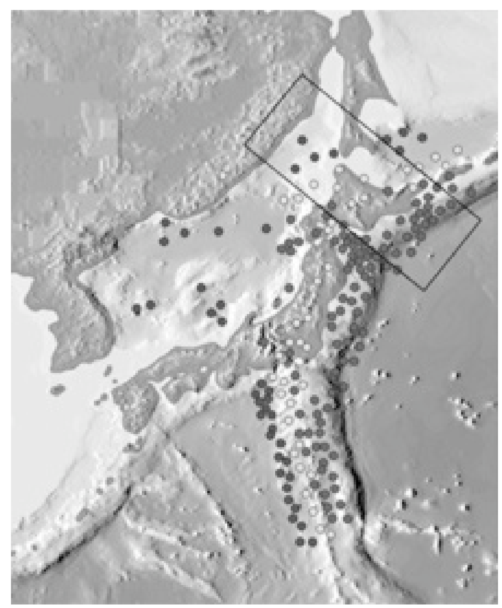


The point where strain is released along a fault is the *focus* of an earthquake. The *epicenter* is the point on the surface of the Earth that's directly above the focus.



Deep-focus earthquakes (red dots) are especially associated with subduction zones. . .

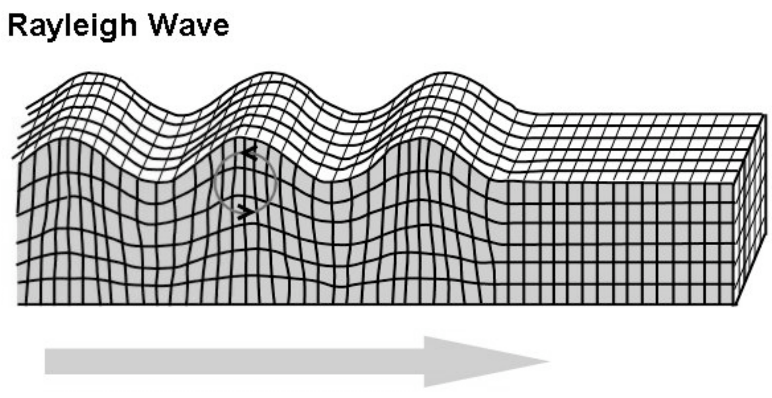




Note that the *deep-focus earthquakes* (red dots) have epicenters farther away from the subduction zone.

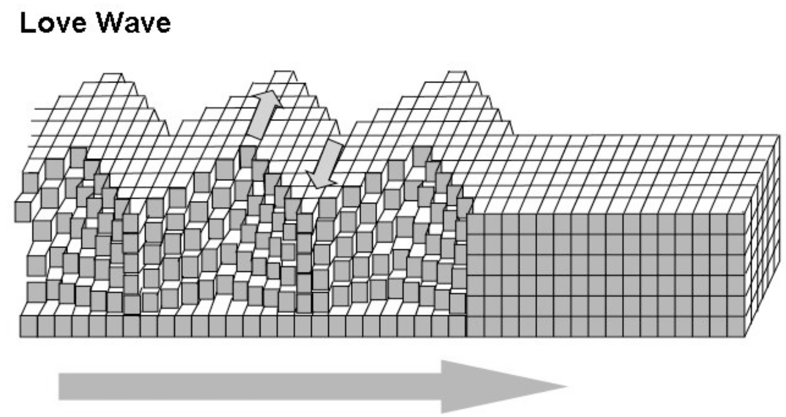
Surface Seismic Waves

- *Rayleigh waves—* "up-and-down" waves



Surface Seismic Waves

- *Love waves—* "side-to-side" waves

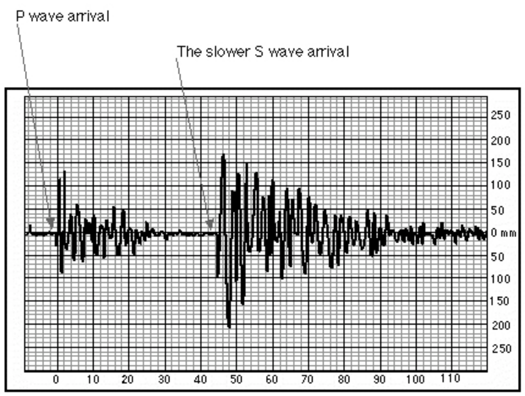


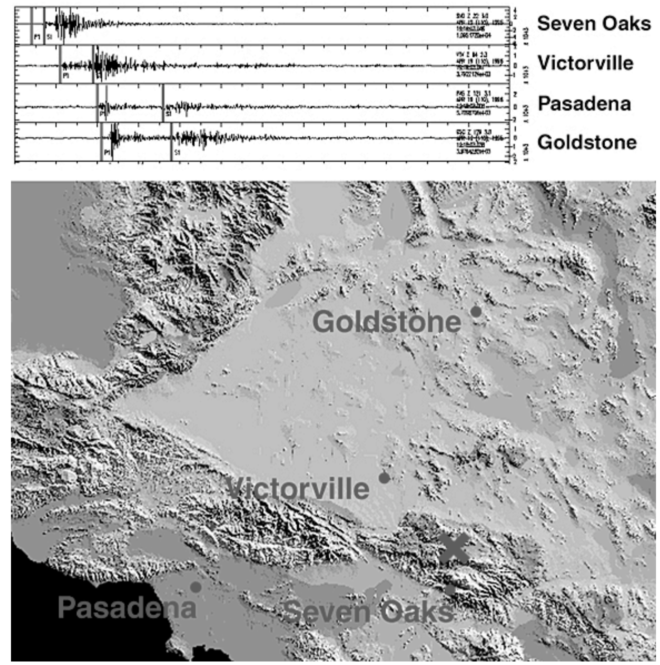
Why Surface Waves Can Be A Problem

Body Seismic Waves

- *P waves—*"push-pull" waves of compression and expansion, parallel to the direction of travel (similar to sound waves).
  - P waves change the *volume* of what they pass through
  - P waves can pass through solid, liquid or gas
- *S waves—* "ocean waves" of movement at right angles to the direction of travel.
  - S waves change the *shape* of what they pass through
  - S waves can't pass through liquid or gas

P waves always travel faster than S waves. Here’s a seismogram of a typical quake.





Data from a small quake recorded on April 13, 1996, near Big Bear Lake, CA. The seismograms at the top are shown in sync. Note how the distance between P waves (red) and S waves (blue) is greater for the more distant stations.

Rapid shaking of wet soil causes it to suddenly start behaving like a liquid. This *liquefaction* is bad news for any buildings that happen to be built on it. . . (Niigata, Japan, 1964)

Liquefaction is also no good for roads built on it, either. (Loma Prieta quake, 1989)

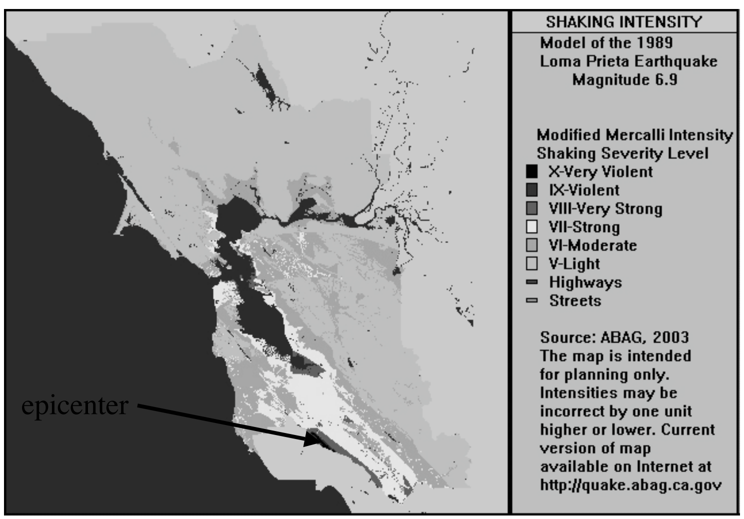
How big is the quake?

- *Richter Scale*
  - Measures amount of energy released
    - An increase of 1 on the scale equals 32 times more energy released; thus a quake of magnitude 6 releases 32 times more energy than a quake of magnitude 5
    - Highest recorded was 9.6 (Chile, 1960), but there is no upper limit
  - Now often replaced by a slightly different measure, the *moment magnitude* (M_w), based on the amount of displacement on the fault. This is more accurate for larger quakes.
    - Quake that caused the 2004 tsunami was 9.3.

How big is the quake?

- Modified Mercalli Intensity Scale
  - Unlike the Richter scale, the Mercalli varies from place to place, since a quake isn't equally destructive everywhere
  - Measures amount of damage on the surface, rated from I to XII. For example:
    - I: Not felt
    - IV: Felt by many
    - VI: Scares people but little building damage
    - VIII: Considerable building damage except for specially designed structures
    - XII: Total devastation; objects thrown into air.

Map of the Mercalli intensity for the Loma Prieta quake

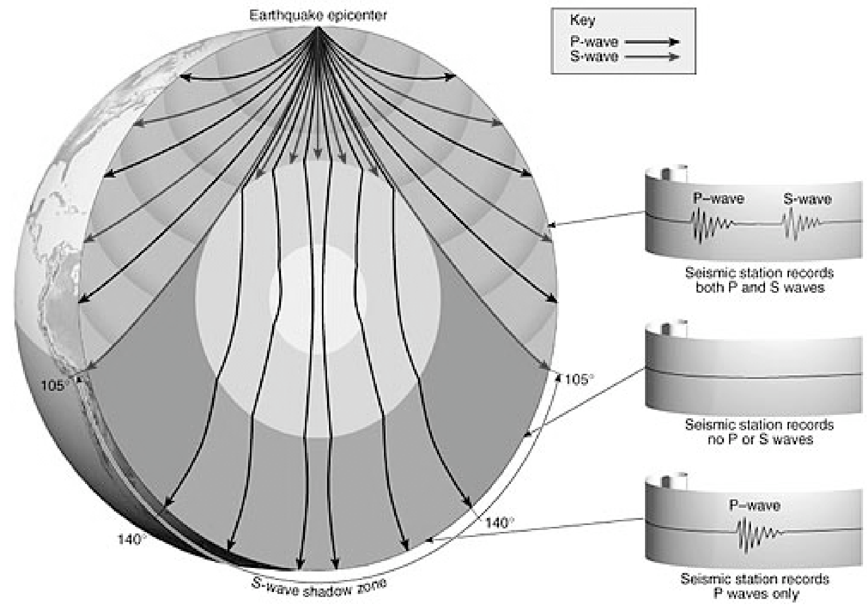


Quakes and the Earth's Interior

- Whenever a wave passes from one medium to a different medium, its path is bent (refracted)
- S waves can't pass through liquid, but P waves can
- Seismic waves move fastest through cold rock and more slowly through hot rock
- Seismic wave origins and travel times can be measured very precisely (especially those from nuclear test explosions)
- All this makes it possible to work out the internal structure of the Earth. . .

Quakes and the Earth's Interior

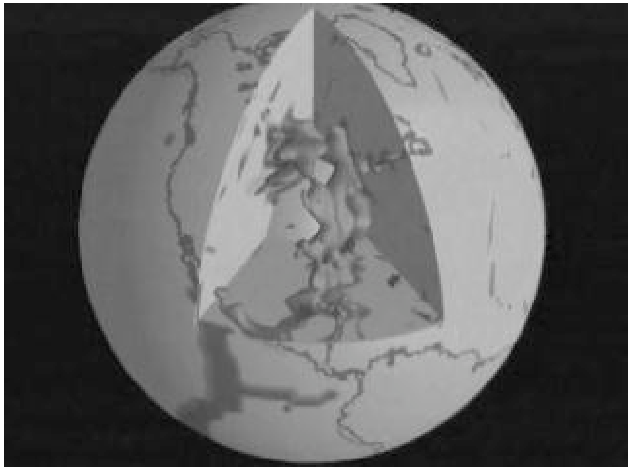
- 1909: Andrija Mohorovicic uses seismic wave travel times to discover the division between the Earth's *crust* and *mantle*, a division called the *Mohorovicic discontinuity* (or just the *Moho*).
- 1912: Benno Gutenberg discovers the "shadow zone", leading him to reason that the earth has a liquid *core*.
- 1935: Inge Lehmann's more detailed study shows that the core has two zones, an *inner core* and an *outer core*.



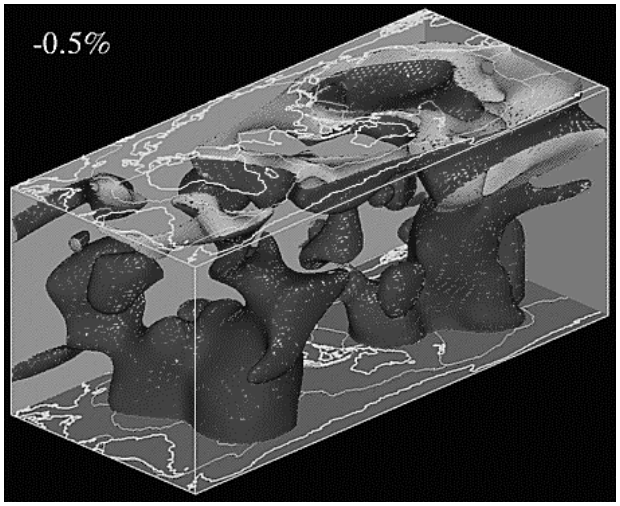
Earth Layers

- *Crust:* average 100 km thick; average 2.7 g/cm^3 (continents), 3.0 g/cm^3 (oceanic)
- *Mantle:* 2900 km thick; 3.3 g/cm^3; made mostly of ultramafic rock (peridotite)
- *Outer Core:* 2270 km thick; 11 g/cm^3; made of iron and nickel
- *Inner Core:* 1216 km thick; made of iron and nickel

Careful study of transit times of earthquake waves can be used to create 3-D images. . . This image shows the remains of the Farallon Plate subducted underneath North America.



And this one shows areas in the mantle that are unusually warm, including massive *mantle plumes* of upwelling material



Tsunami

- Caused by displacement along an undersea fault, or by an undersea landslide or volcano
  - The name “tidal wave” isn’t accurate, since these waves don’t have anything to do with tides
  - A related phenomenon, *splash waves*, occur when an above-water landslide or rockfall dumps massive amounts of material into the ocean
- Any of these may displace a large amount of water that moves up to 600 miles an hour
- Out to sea, tsunamis are quite low and gentle—but as they approach a shore, they slow, “pile up”, and create massive waves, as high as 100 feet.

A man watches as the 1946 tsunami that hit Hilo, Hawaii rolls in. . .

These pictures were found in a tourist's camera recovered from the wreckage of the 2004 East Asian tsunami. . .

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The largest wave of all was the *splash wave* that hit Lituya Bay, Alaska, on July 9, 1958. An earthquake triggered a massive landslide into the bay. . .

. . . and the resulting wall of water destroyed trees on the shore as high as 1740 feet (about a quarter-mile) above sea level.