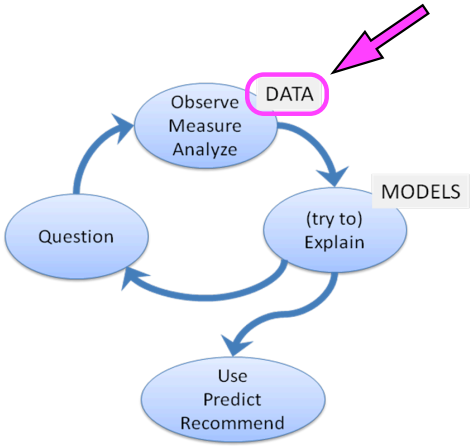
Circa 1900: Evidence that faults, not collapses, explosions, cause earthquakes

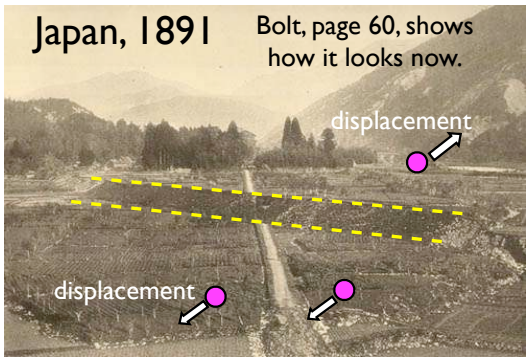
- seismograms: displacement versus time (temporary shaking)
- land surveys: (1) displacement versus position (permanent strain)
  (2) discontinuities in the ground (ruptures and scarps)

strain is the *derivative* of displacement with respect to position (more later!)
velocity and acceleration are derivatives of displacement with respect to time



By the late 1800's it was becoming apparent that sudden breakage of rock along surfaces (faults) causes earthquakes

surface ruptures:
photos and surveys



Photograph of the 1891 Nobi (Mino-Owari) earthquake scarp at Midori, taken by **B. Koto**, a professor of geology at the Imperial University of Tokyo. Based on his geological investigations, Koto concluded, "The sudden elevations, depressions, or lateral shiftings of large tracts of country that take place at the time of destructive earthquakes are usually considered as the effects rather than the cause of subterranean commotion; but in my opinion it can be confidently asserted that the sudden formation of the 'great fault of Neo' was the actual cause of the great earthquake."

surface displacements
(units of length):
points on surface moved relative to their pre-earthquake positions

fault slip:
displacement of one side relative to the other

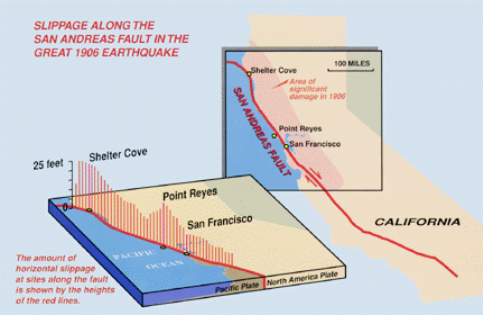
(delete the cartoon)

1908: Incredibly detailed Lawson Report describing the effects of the 1906 San Francisco earthquake

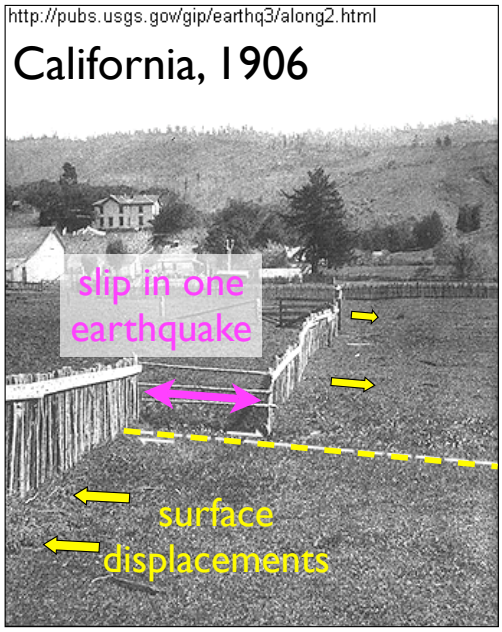
surface displacements
(units of length)
points on surface moved relative to their pre-earthquake positions

fault slip is the relative displacement across the fault

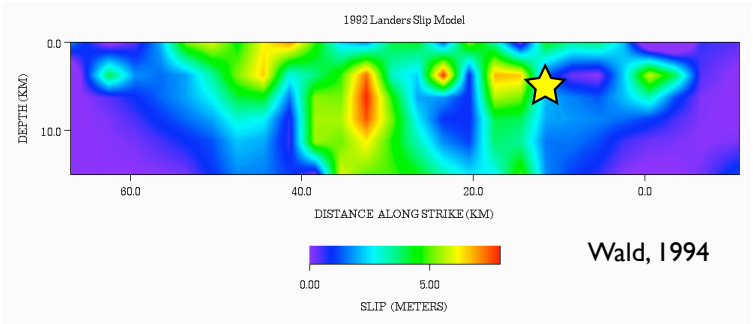
this can vary along the fault



http://pubs.usgs.gov/gip/earthq3/along2.html

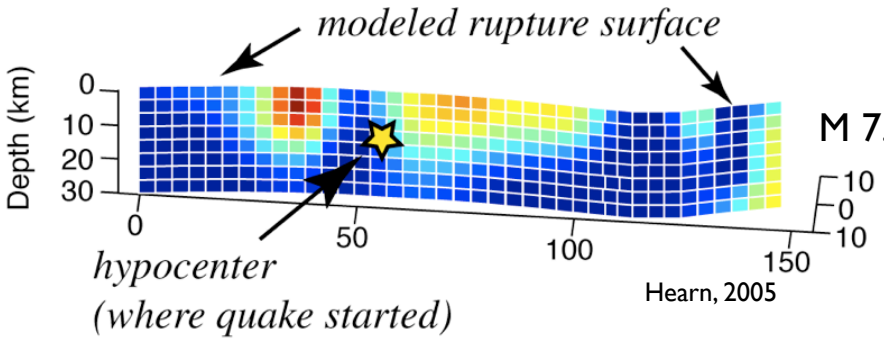


Coseismic slip can vary a LOT along the earthquake rupture and with depth



M 7.4 Landers EQ

Wald, 1994



M 7.5 Izmit EQ

Hearn, 2005

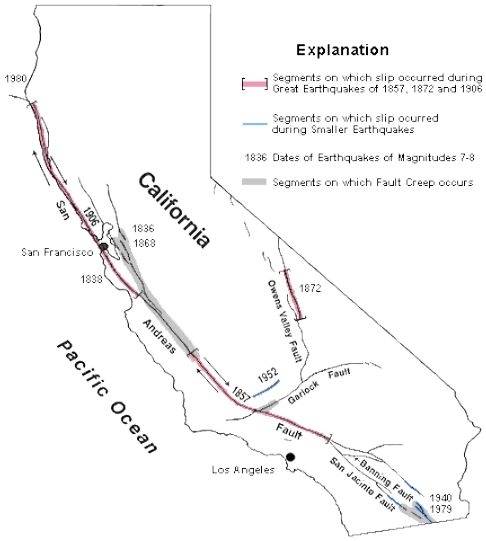
Land surveys from before and after the 1906 earthquake showed the rupture and strain (deformation) around it.

The earthquake of April 18, 1906, was occasioned by a fault slip which produced horizontal displacements on opposite sides of the fault, ranging from a maximum offset of twenty-one feet to nothing at the ends of the fault. Differential movement in the vertical was slight and not satisfactorily determined. Relative movements of this kind, though not previously unknown, are unusual; and their extent and amount in this instance stimulated inquiry into their causation.

Work of the United States Coast and Geodetic Survey established the fact that the horizontal offsetting was greatest along the rupture, dying away gradually but relatively rapidly in directions at right angles to the fault. Further, the fault plane stood approximately in the vertical position.

"In the earthquake of 1906, points on opposite sides of the fault moved in opposite directions; those to the eastward of the fault in a southerly direction and those to the westward in a northerly direction. Second, the displacements of all points were approximately parallel to the fault. Third, the displacements on each side of the fault were less the greater the distance from the fault. Fourth, for points on opposite sides of the fault and the same distance from it, those on the western side were displaced on an average about twice as much as those on the eastern side."*

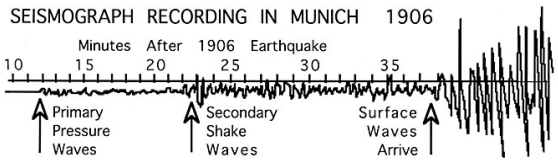
Text is from H. Wood's 1909 review of the Lawson Report and A. McAdie's 1911 paper on earthquake displacement (based on data from the Lawson Report)

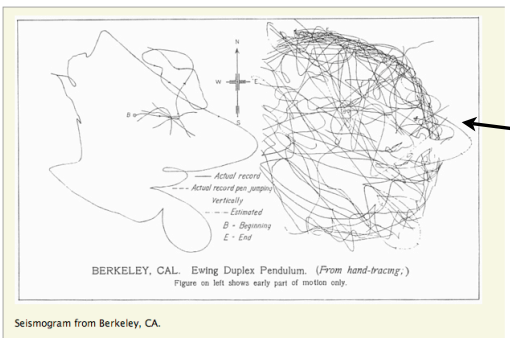


What were people doing with seismographs around 1900?

records of acceleration, velocity, and displacement versus time.

- Not many seismometers existed worldwide
- Mainly used to get timing and location of earthquakes





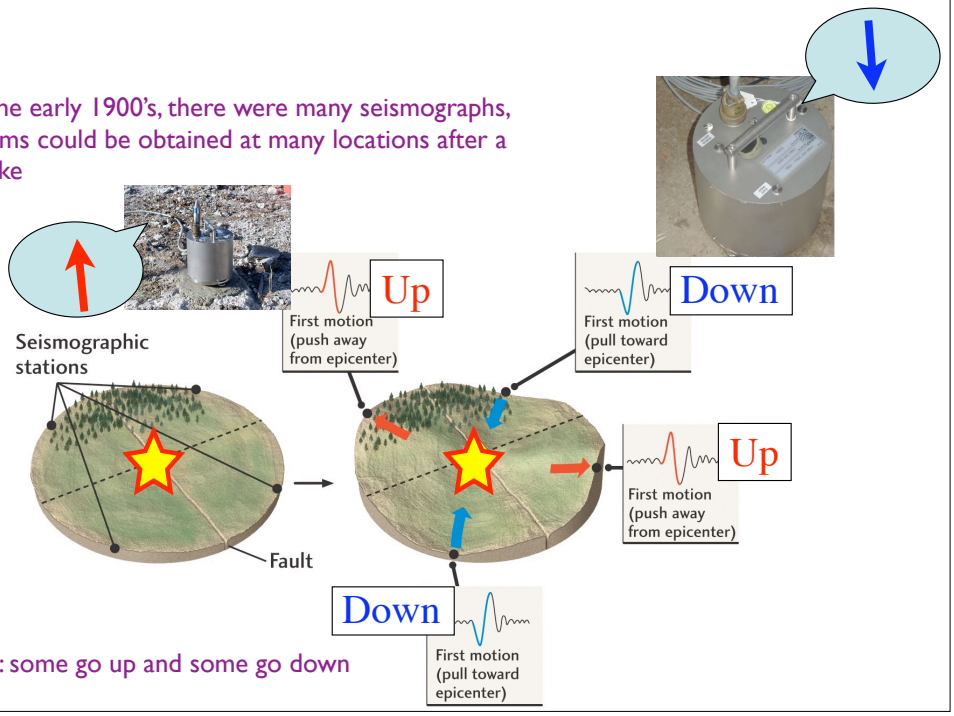
Seismogram from Berkeley, CA.

?!!!

Pendulum seismograph vertical motion actually lifted pen from the page

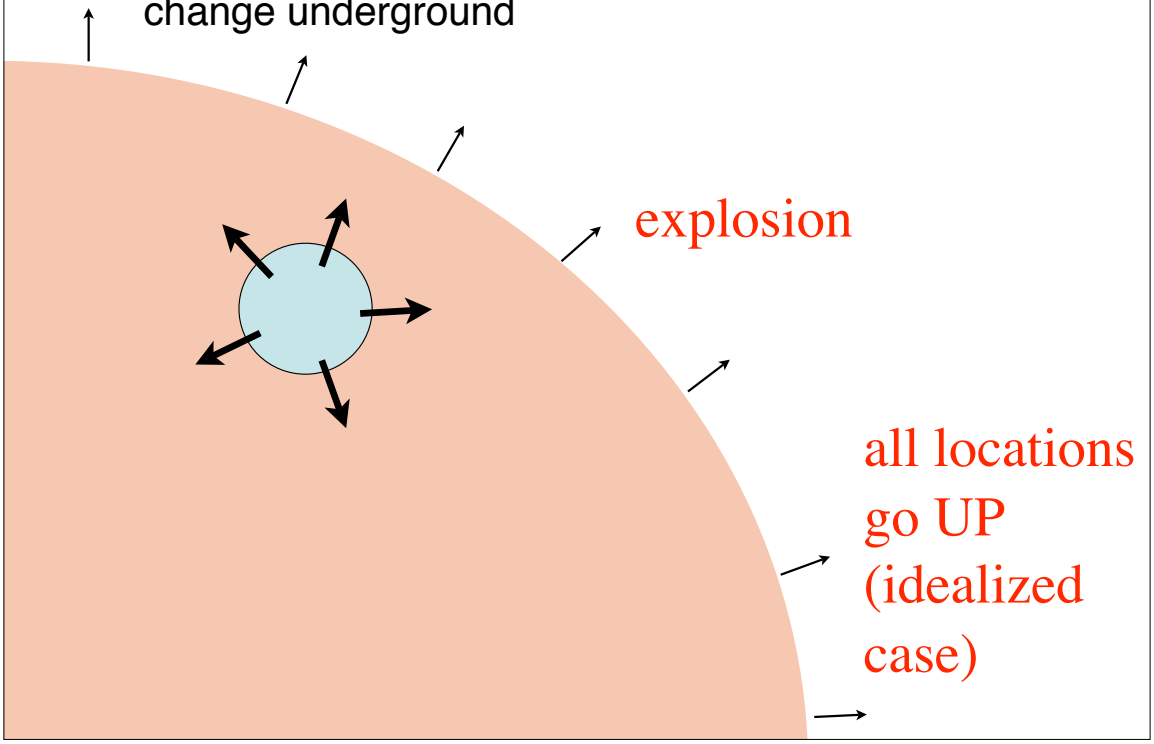
Proof that even earthquakes that don't break the surface are due to faults: Japan 1923

- In Japan in the early 1900's, there were many seismographs, and seismograms could be obtained at many locations after a local earthquake



First motion: some go up and some go down

Non-earthquake source: Underground Bomb Test or Aristotle's winds are associated with a volume change underground



multiple records of a single quake (up vs. down first motion)

+

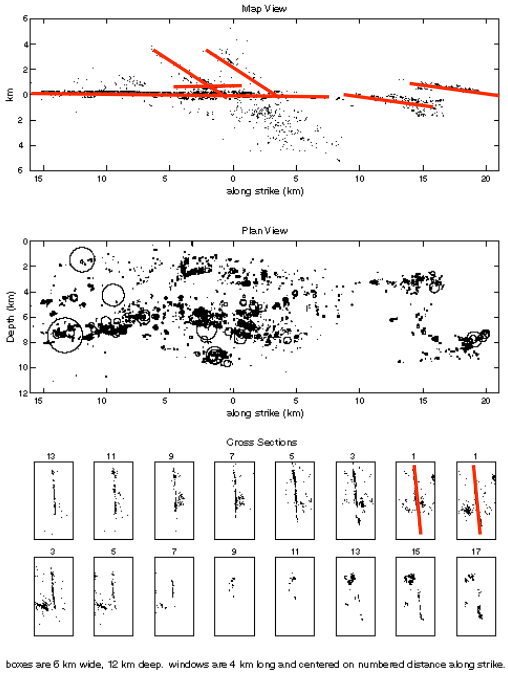
elasticity theory (which tells us how points on the Earth's surface should move as the result of different kinds of displacements inside the Earth)

Seismograms prove that there is no volume change underground.

Earthquakes are caused by relative displacement of rock on either side of a surface, not by collapses or explosions.

This is consistent with faults we see at the surface.

As earthquake catalogues became more complete and locations became precise, epicenters outlined definite patterns: faults!

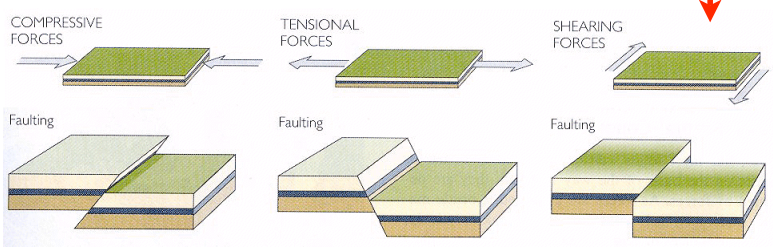


map view

profile along the fault surface

profile views perpendicular to the fault

Today's focus



'reverse' or 'thrust' fault

'normal' fault

'strike-slip' or 'transform' fault