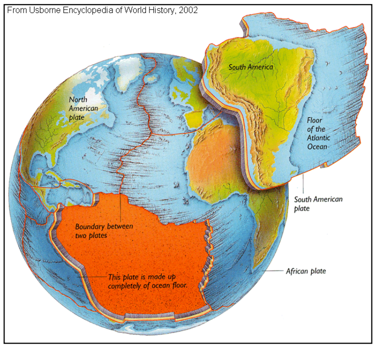
Two ways to describe the shallowest 100 to 200 km of the Earth:



- crust
- mantle

} based on composition

- lithosphere
- asthenosphere

} based on strength

When we say "plate" we mean the lithosphere

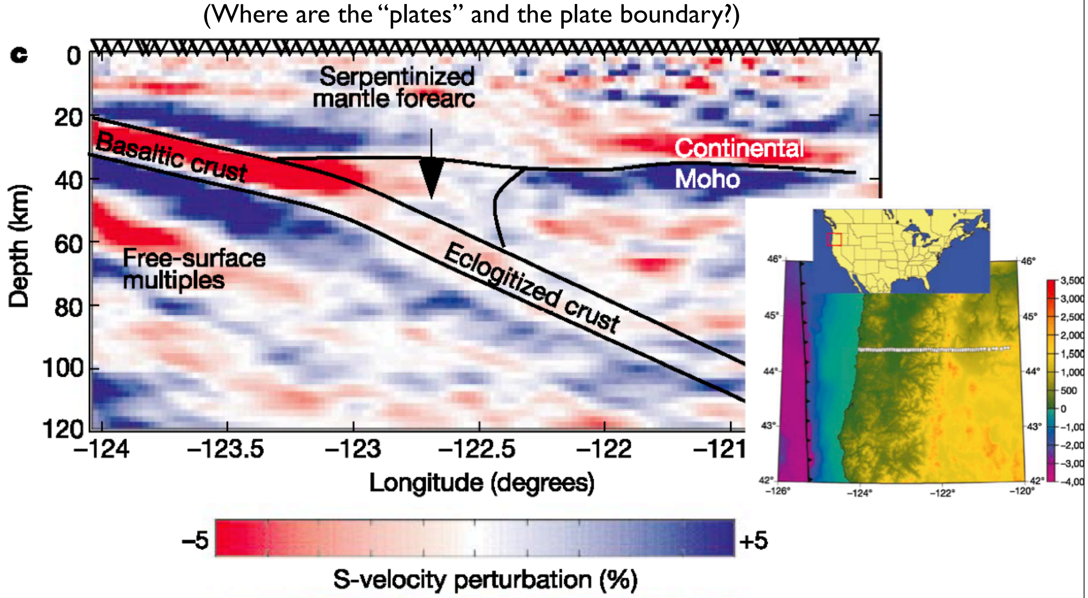
Most faulting occurs in the upper part of the crust: that is, the shallowest part of the lithosphere

In the upper crust, the steady relative motion of plates is allowed by the episodic, relative motion of parts of their boundaries in earthquakes. Below this, the relative motion is aseismic.

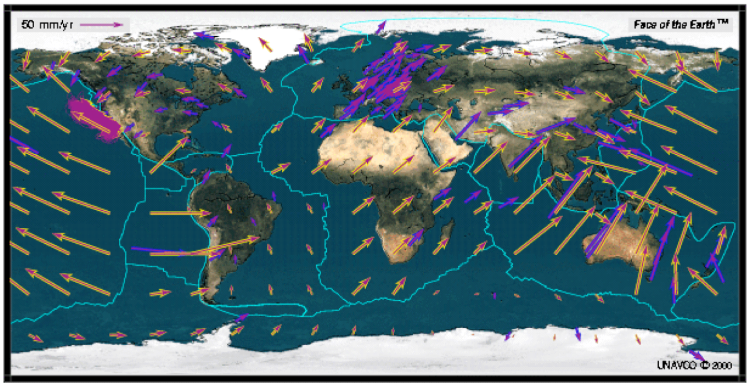
Pacific-North America Plate Boundary

from Michael Bostock's research - last Friday's class

(Where are the "plates" and the plate boundary?)



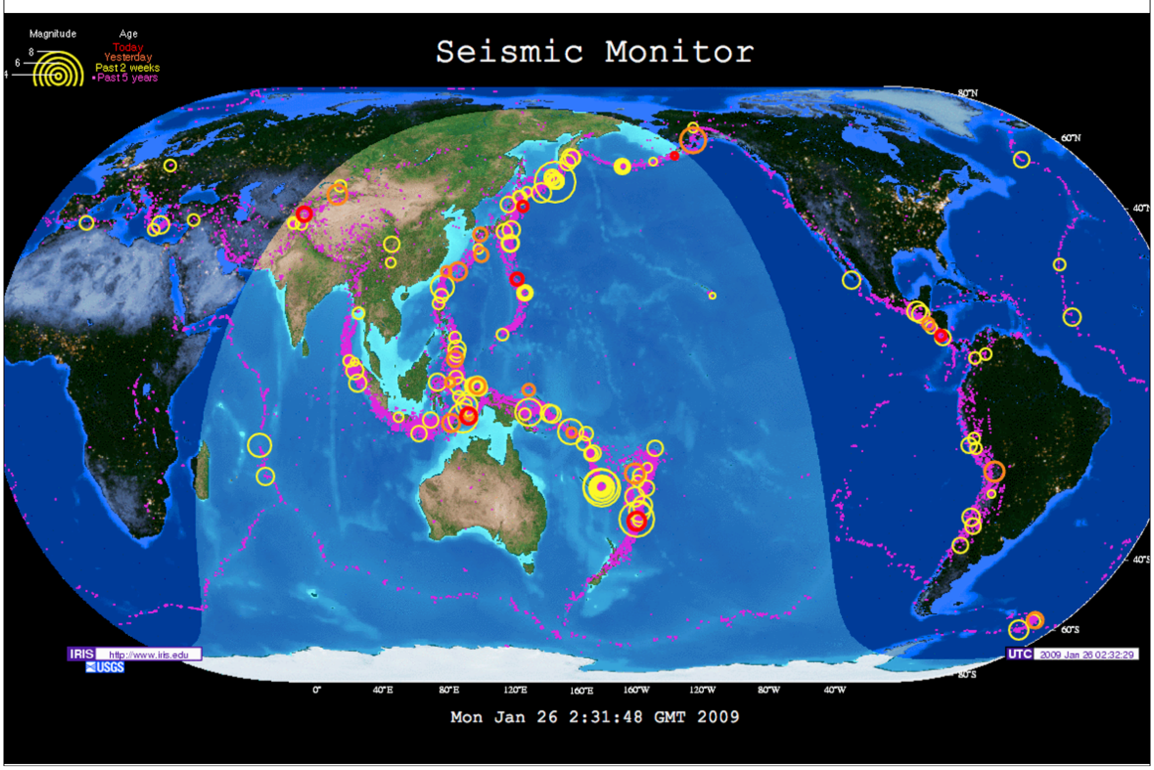
Geological plate motion models and real-time, high-precision GPS velocity data show plate velocities



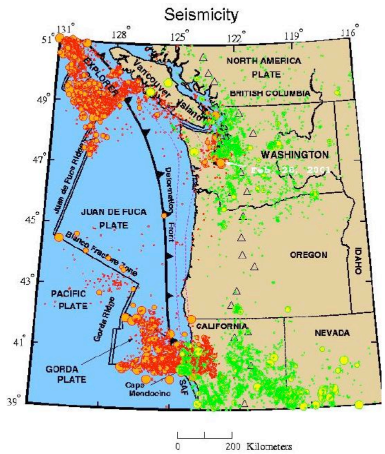
geologic: yellow
GPS: purple
largest vectors
are about 6 cm/yr

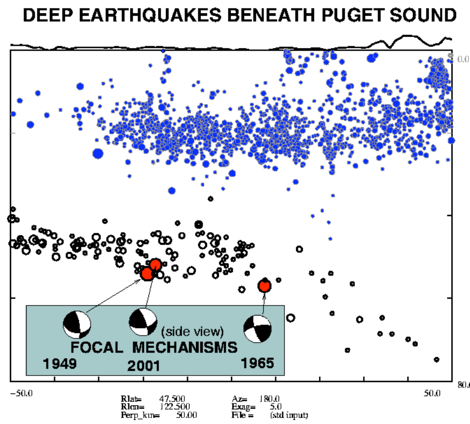
- plates are rigid (I mean they are not deforming)
- plates move relative to each other at a fairly constant rate
  (geodetic and geologic estimates of relative plate velocities match)

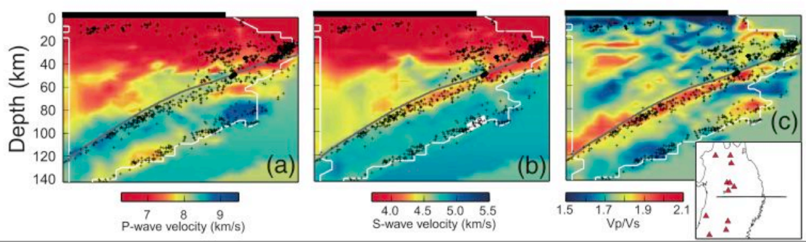
Most earthquakes occur at plate boundaries



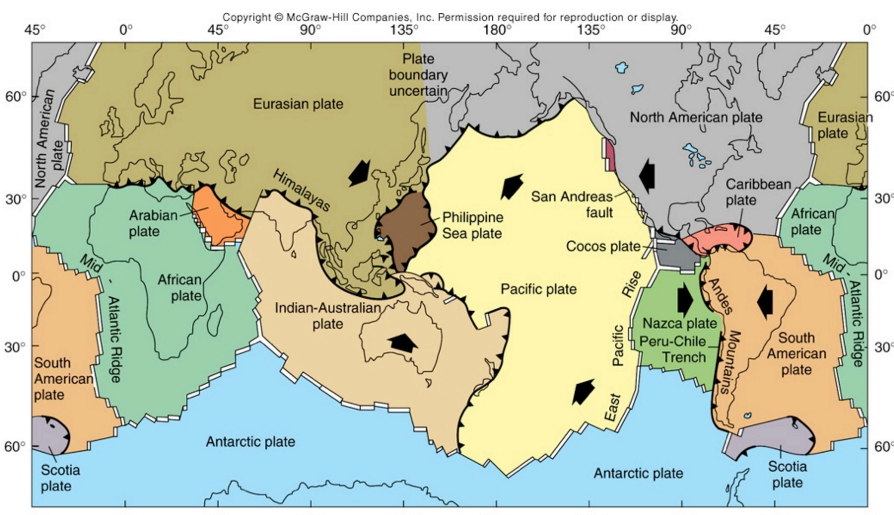
Shallow versus deep earthquakes at subduction zones







Types of faults at tectonic plate boundaries



These cartoon vectors are relative to mantle hotspots (Earth's deep interior)

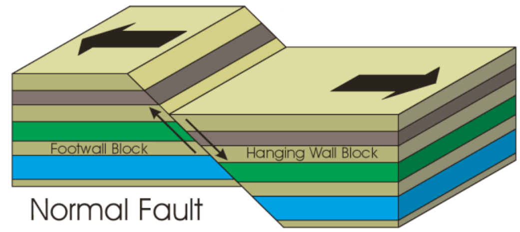
"No Net Rotation" reference frame

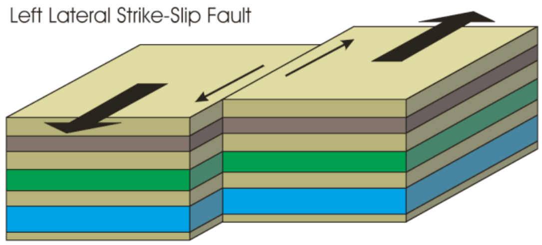
• Compare the orientation of the relative plate motion vector to the strike of the the plate-boundary fault(s).

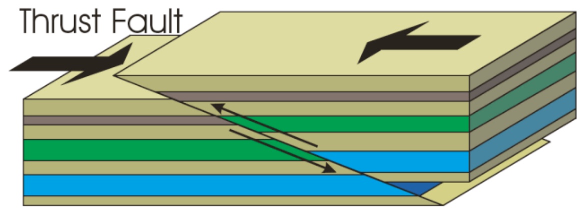
• Vector subtraction gives motion of one plate relative to the other.

• Relative motion can vary along a plate boundary, as can strike of the plate-boundary fault.

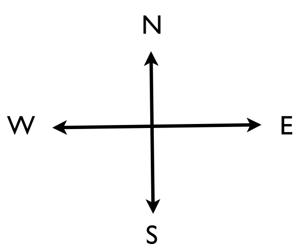
Relating fault type to tectonic plate boundaries







- compare the horizontal component of the relative motion to the fault strike
- easier if you "fix" one plate (make its velocity zero)

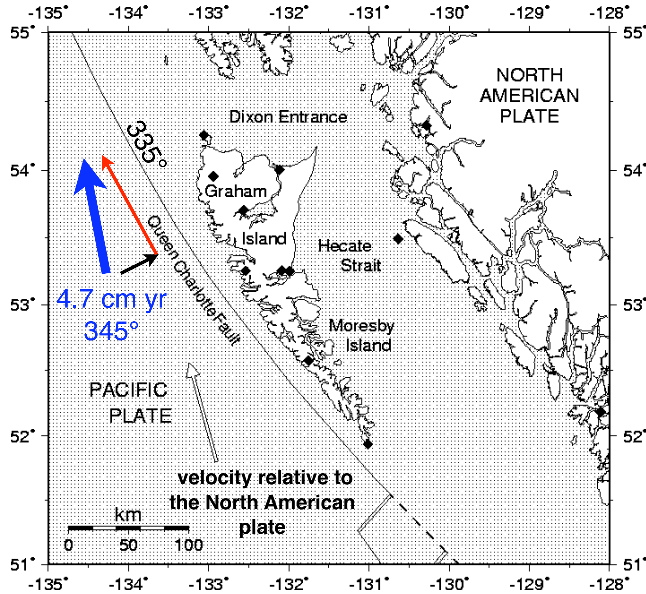


Finding the Pacific plate velocity relative to the North America plate, where they meet in (offshore of) northwest BC

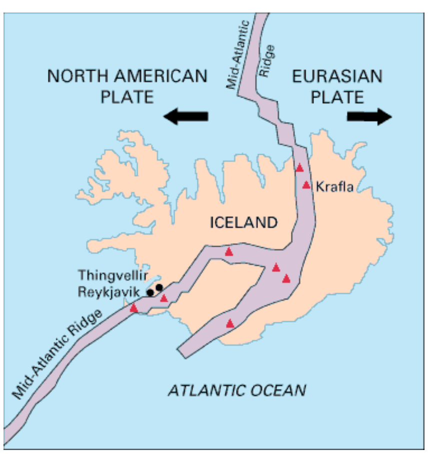
(Pacific Plate, NNR frame)		(North American Plate, NNR frame)		Pacific Plate relative to the North American Plate (in NW BC)
	minus		equals	
3.8 cm yr 318°		2.1 cm yr 220°		4.7 cm yr 345°

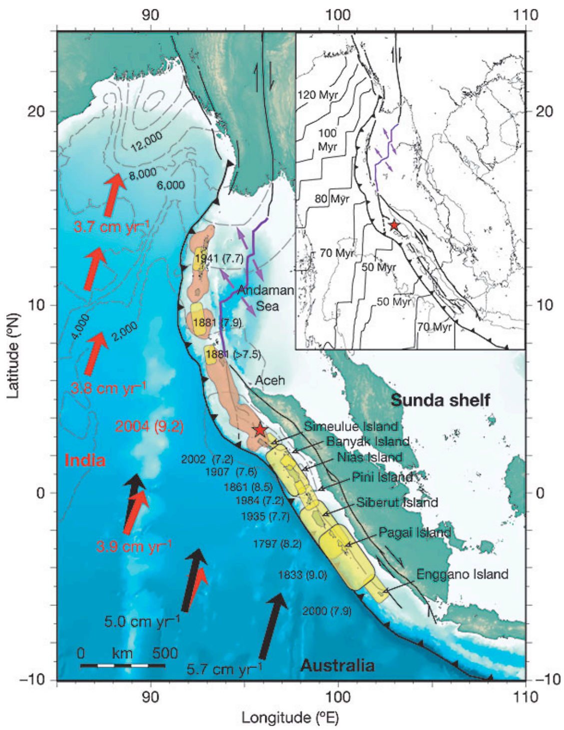
$$\begin{bmatrix} -2.5 \\ 2.8 \end{bmatrix} \text{ minus } \begin{bmatrix} -1.3 \\ -1.6 \end{bmatrix} \text{ equals } \begin{bmatrix} -1.2 \\ 4.4 \end{bmatrix} \text{ (cm/yr)}$$

(Mostly) transform boundary



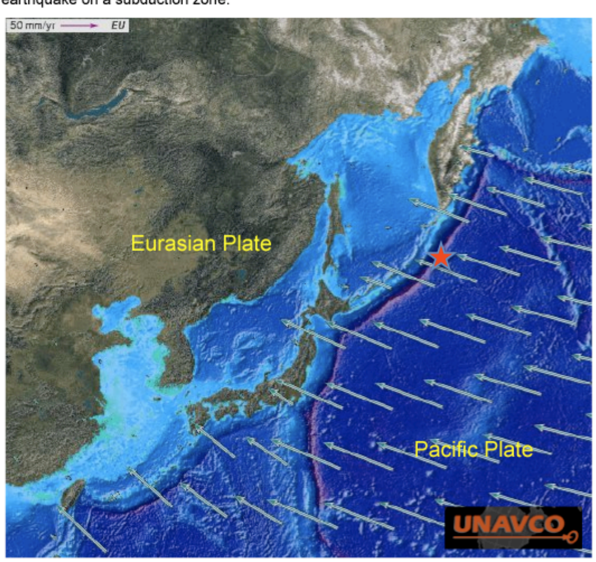
Images are from the Geological Survey of Canada



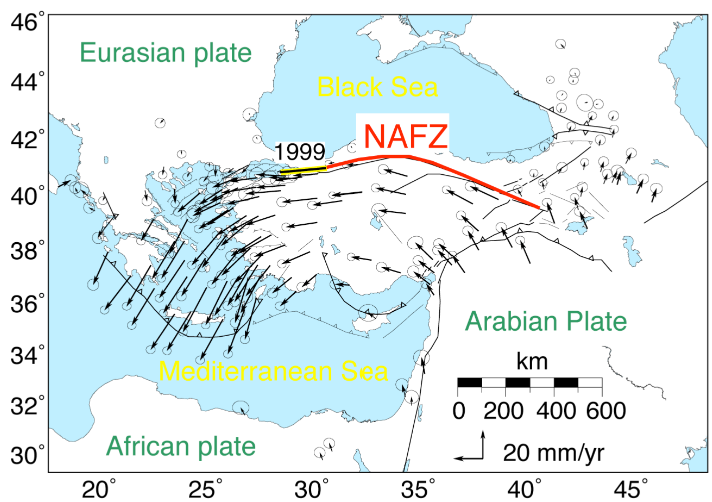


Relative plate motions in the area of the M 7.4 earthquake January 15

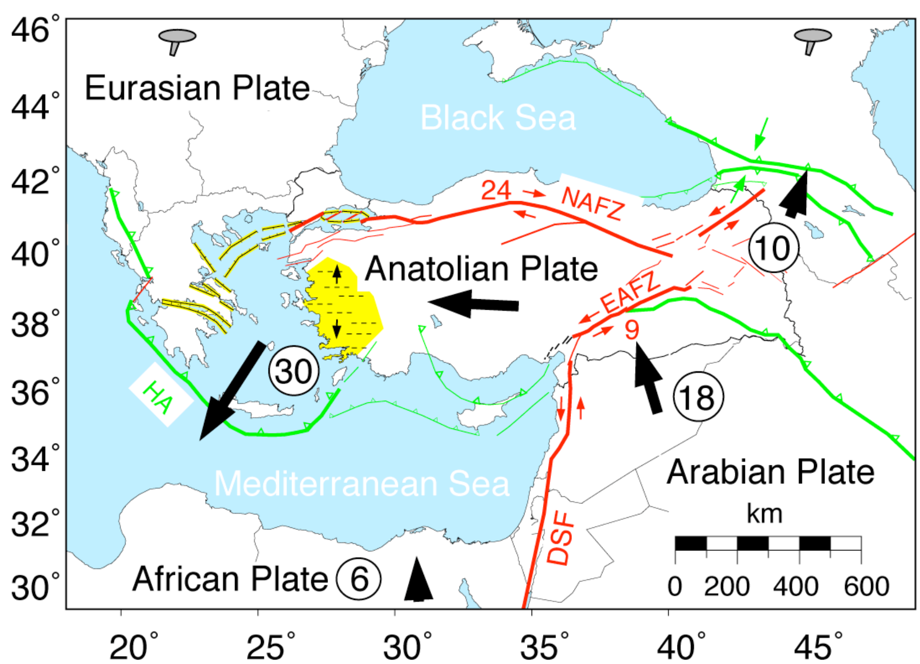
The epicenter of the earthquake that occurred January 15, 2009 is indicated by the red star on the map below. The arrows on this map show the rate and direction of motion of the Pacific Plate with respect to the Eurasian Plate in the Northwestern Pacific Ocean. The rate of convergence at this plate boundary is about 90 mm/yr (9 cm/year). This is a fairly high convergence rate and this subduction zone is very seismically active. For comparison, the convergence rate of the Juan de Fuca Plate beneath the North American Plate at the Cascadia subduction zone is about 35 mm/yr (3.5 cm/year). The earthquake that occurred January 15 is an example of a shallow earthquake on a subduction zone.



GPS horizontal velocities relative to Eurasia 1988-1997

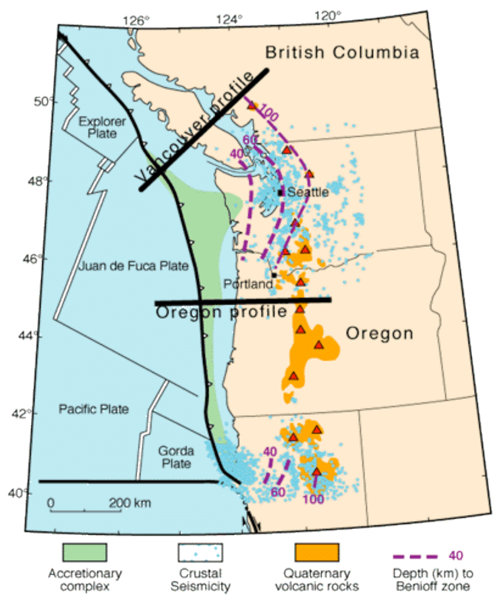


from McClusky et al., JGR, 2000



Relative Plate Motion Activity

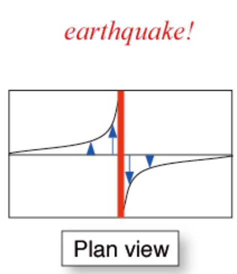
New and improved? Let me know.
Will be marked as an "activity" (part of that 10% of your grade, along with the reading questions etc.)



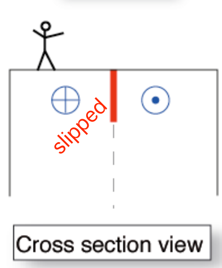
What is the relative rate of plate motion?

Does the subduction look oblique?

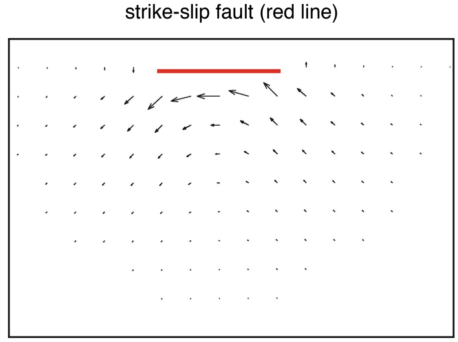
Coseismic surface displacements from a typical, large strike-slip earthquake.



Homework 1: your displacement versus distance plots



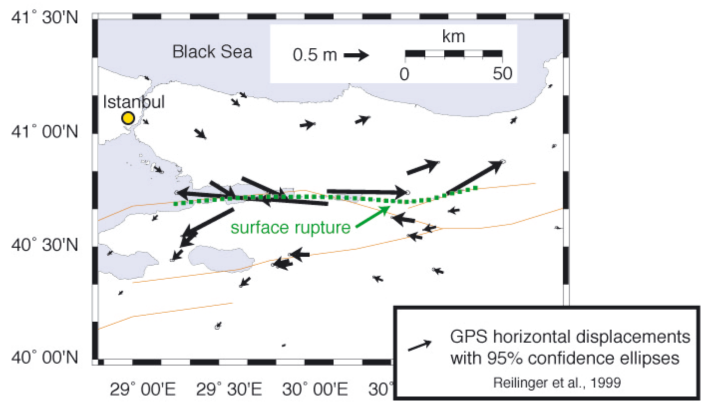
2D horizontal displacement pattern at the Earth's surface, from a model of a short strike-slip fault (red line)



Plan view

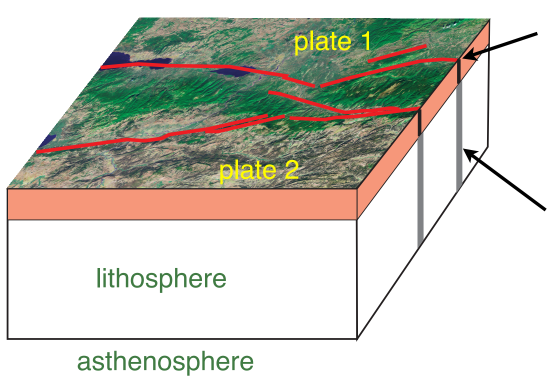
Here are horizontal surface displacements from a typical, large strike-slip earthquake.

GPS surface displacements: 1999 Izmit, Turkey earthquake



Not the relative motion of two non-deforming plates (or blocks) because fault slip is only down to about 20 km

One idea about how faults work at depth

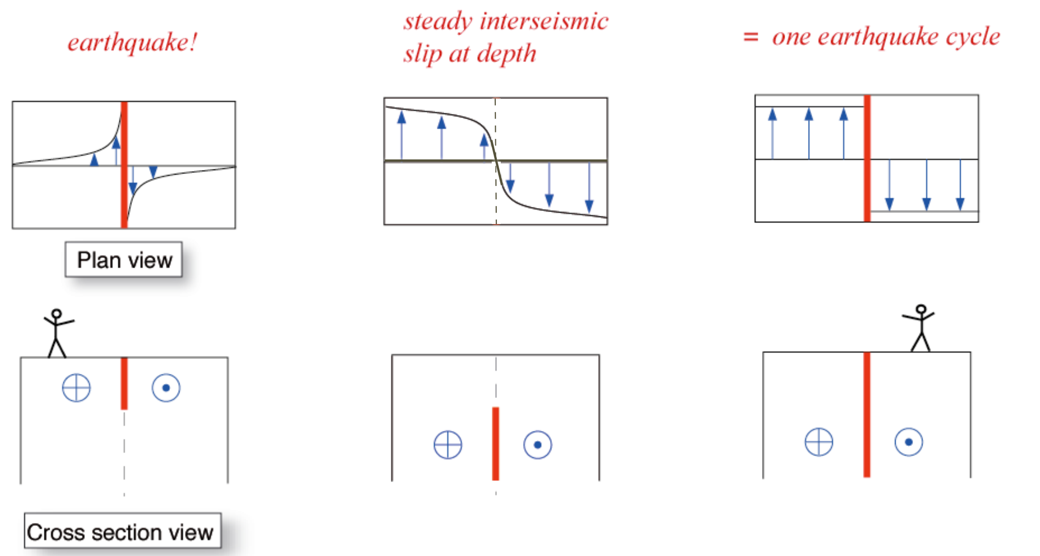


faults and earthquakes in the upper crust
plates are STUCK together in the top 15 km, except when an earthquake allows relative motion

slowly flowing (creeping) narrow zone at depth: extends plate boundary down to the asthenosphere
STEADY* "interseismic" relative motion of plates at this depth

*not exactly... but ok for now

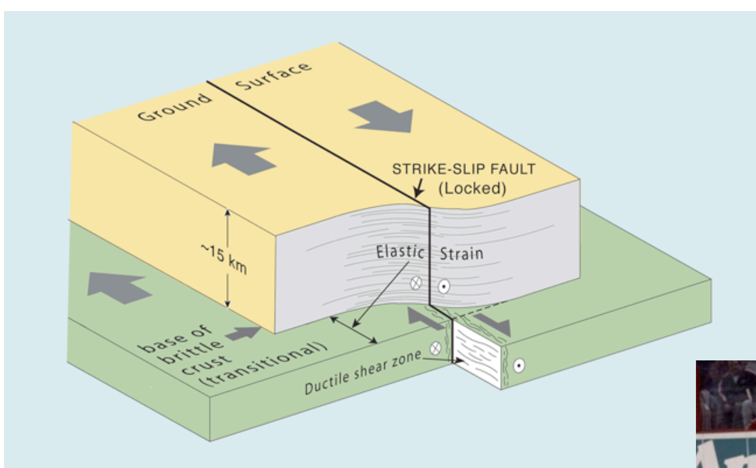
SAF model based on survey data in the Lawson Report

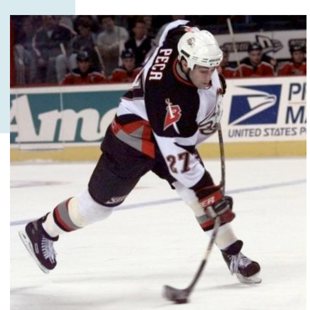


(1906 displacements)

slow steady motion
in this sense
(noted 1857-1906)

relative motion of rigid plates



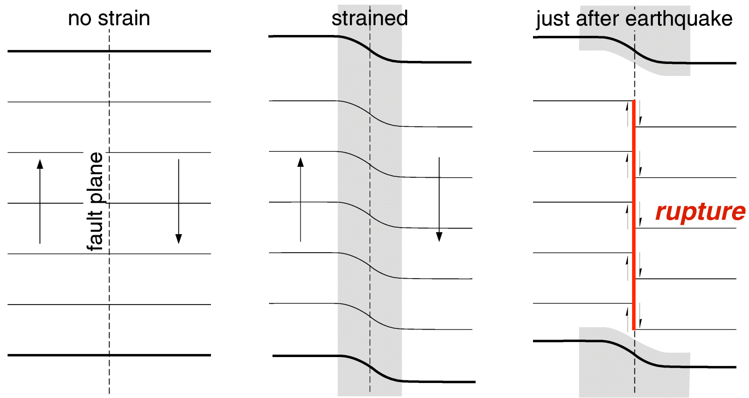


If the lithosphere is elastic, then stresses
build up as it warps.

Elasticity: more distortion (strain) --> more stress

Recall **Hooke's Law** from 1st year (or high school)
physics: stretch a spring --> elastic force resists pulling

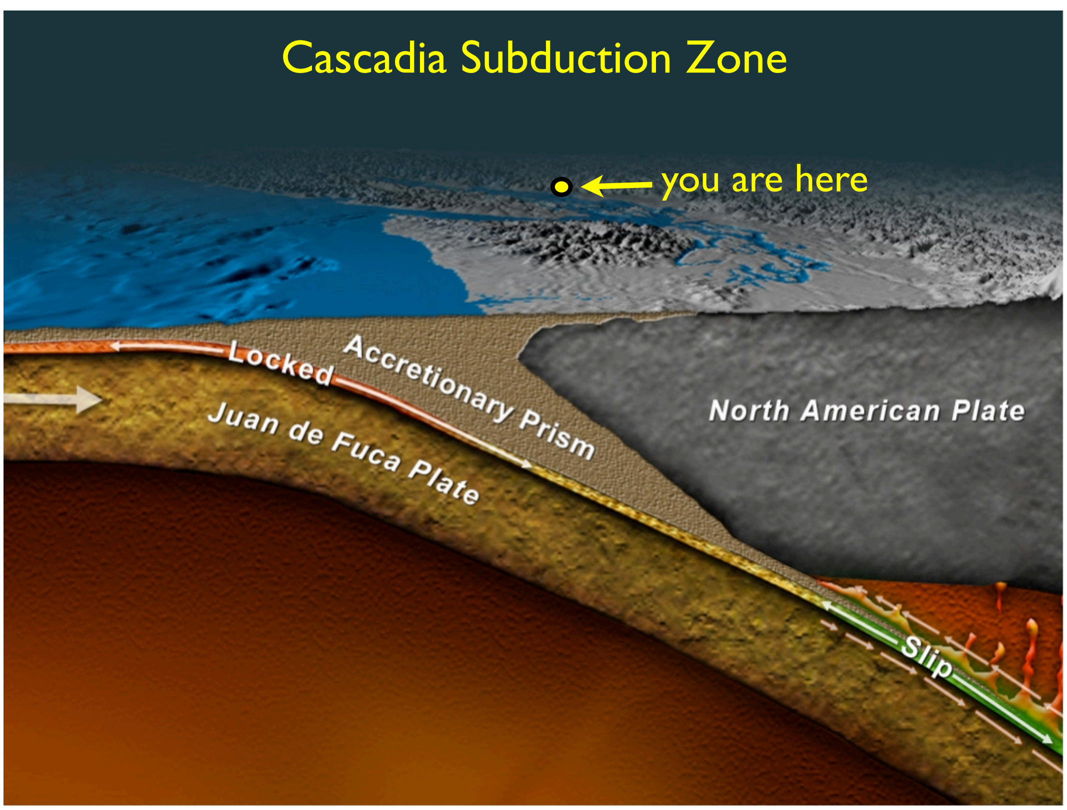
Elastic Rebound Theory of Reid (1908), based on survey data from the 1906 Lawson Report



Elastic stresses build up as rock deforms slowly over time

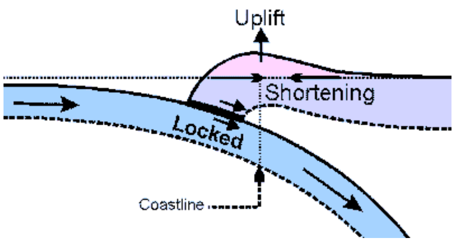
Rupture occurs when elastic stresses exceed what the fault can bear (friction).

Rocks along fault spring back to undeformed state ("elastic rebound")



Cascadia subduction zone earthquake cycle

interseismic (300-600 yr)



coseismic (minutes)