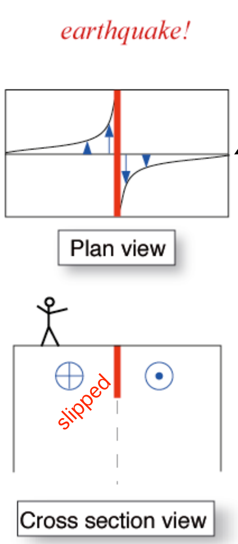
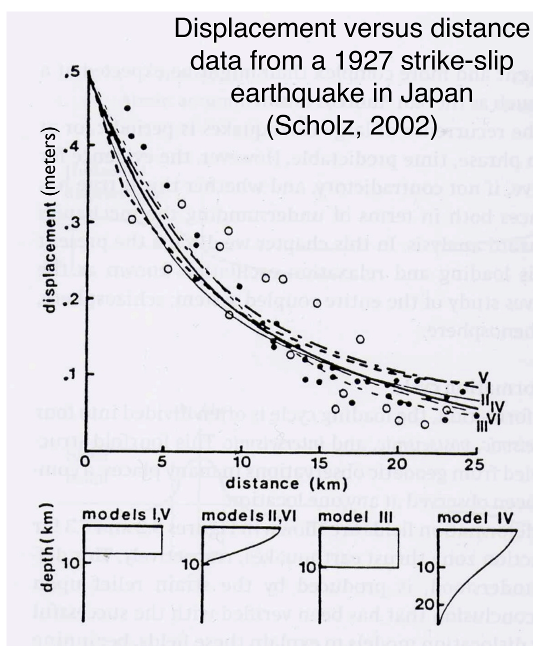
Elastic Rebound Theory
The Earthquake Cycle

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



Homework 1: your displacement versus distance plots



Displacement versus distance data from a 1927 strike-slip earthquake in Japan (Scholz, 2002)

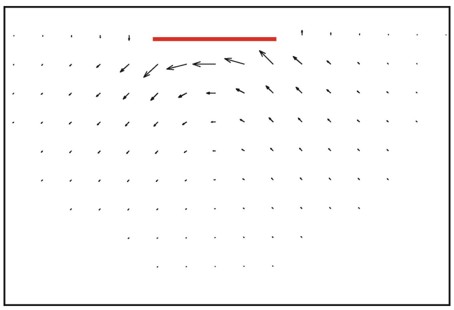
Displacement vectors for a shorter rupture

Note the vectors off the ends of the rupture are NOT parallel to the fault.
They are perpendicular to the fault along strike beyond the ends of the rupture.

Both the east component and the north component of displacement can vary with position.

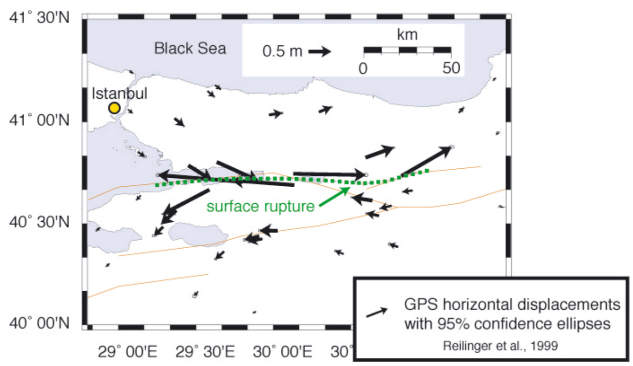
Displacement magnitude decreases with distance.

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

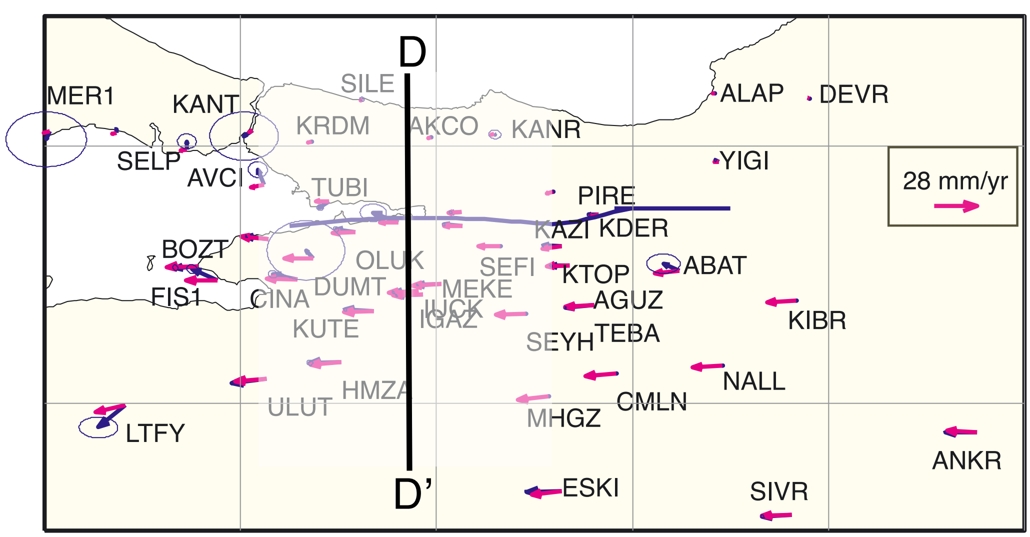


Plan view

GPS surface displacements: 1999 Izmit, Turkey earthquake

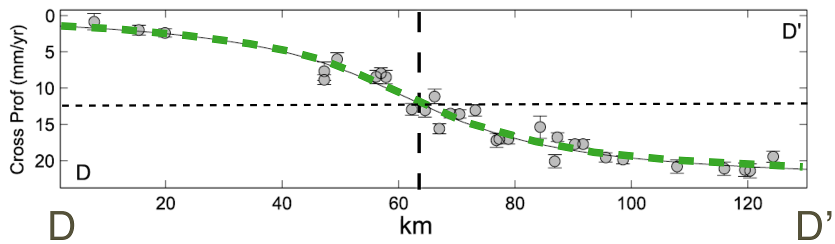


Here is what interseismic (between-earthquake) velocities of points on the ground around a fault look like



Blue = pre-Izmit earthquake GPS site velocities, 1-sigma errors. Pink = modeled velocities.

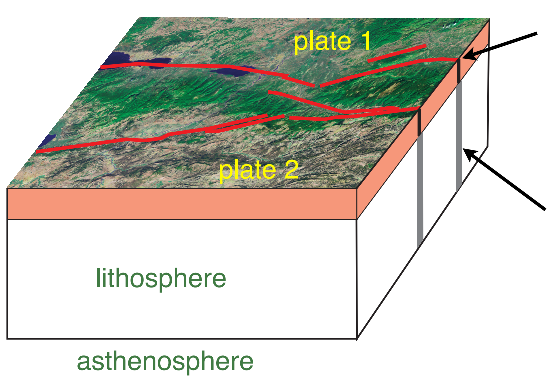
Interseismic (between-earthquake) velocities of points on the ground: magnitude versus distance



this can be modeled using a simple arctangent function

the relative plate motion rate is 25 mm per year
but there is no sudden jump in velocity across the plate-boundary fault

One idea about how faults work at depth



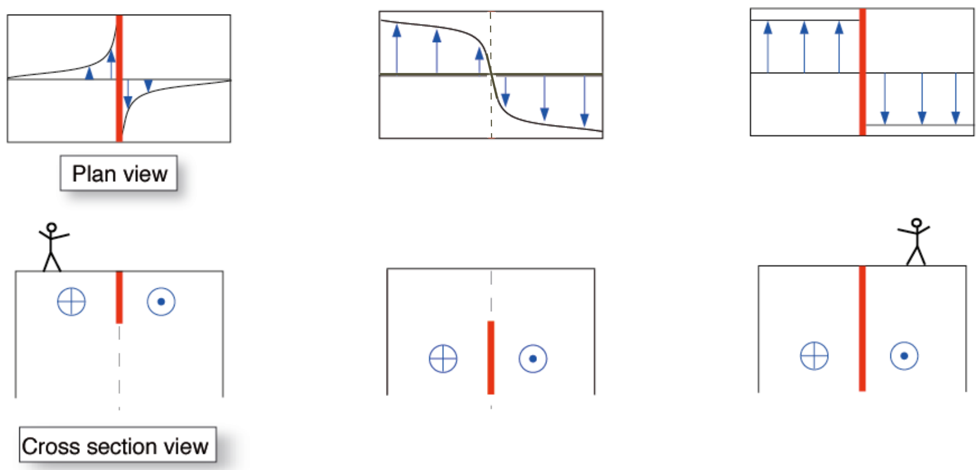
faults and earthquakes in the upper crust
plates are STUCK together in the top 20 km, except when an earthquake allows sudden relative motion

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

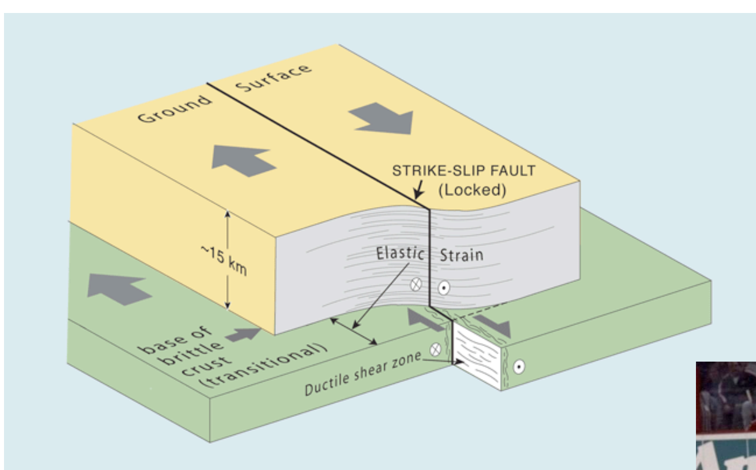
earthquake! | *steady interseismic slip at depth* | *= one earthquake cycle*

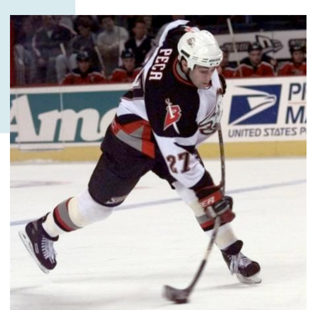


(1906 displacements)

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

relative motion of rigid plates



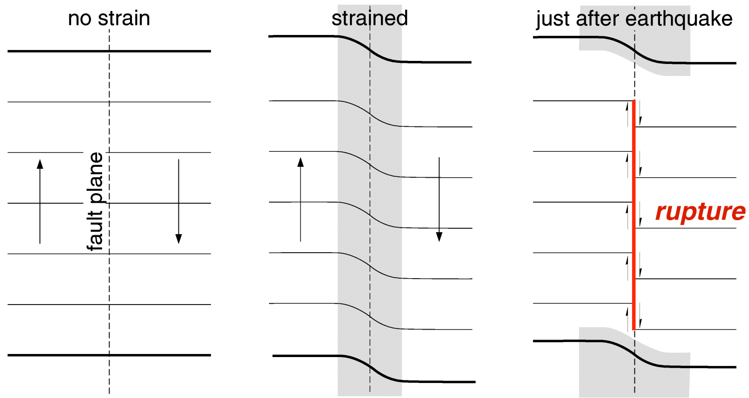


If the lithosphere is elastic, then stresses
build up as it warps.

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

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

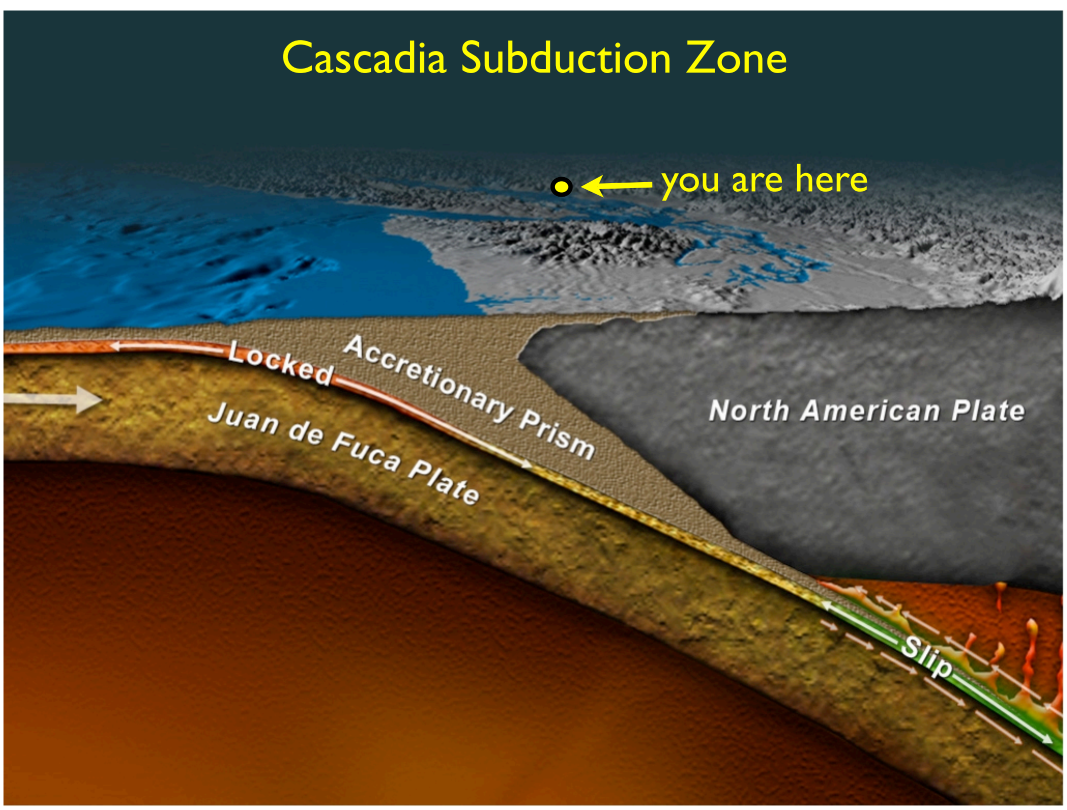
Elastic Rebound Theory of Reid (1908), based on survey data from the 1906 Lawson Report



Elastic stresses build up as rock deforms slowly over time

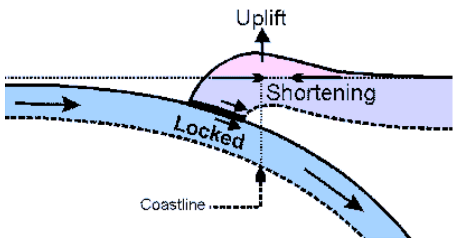
Rupture occurs when elastic stresses exceed what the fault can bear (friction).

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

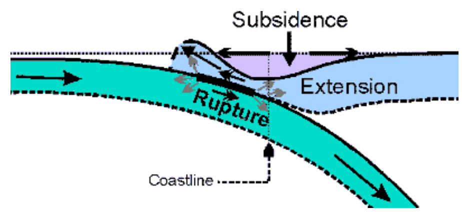


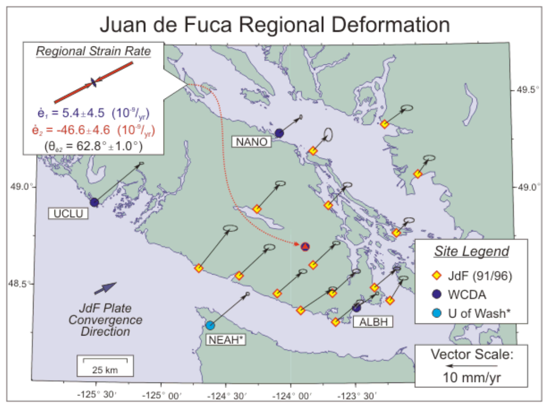
Cascadia subduction zone earthquake cycle

interseismic (300-600 yr)



coseismic (minutes)





How to make an earthquake:
Build up enough shear stress to exceed the frictional strength of a fault, *over a large enough spatial surface area of a frictionally unstable ("velocity weakening") fault*

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We must define strain, elasticity, and stress (shear stress and normal stress). First: strain and how we measure it with GPS.

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(3) Other required conditions ("velocity-weakening friction", "large enough area" of the fault:

We must understand the stability criteria for failure on the fault, that is, conditions leading to an earthquake rather than steady frictional creep on the fault