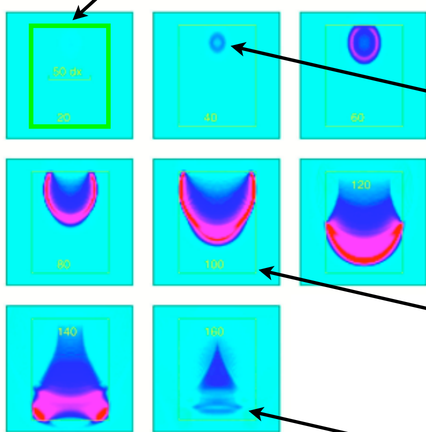
In a large earthquake, the slipping patch grows: the rupture propagates into previously unbroken parts of the fault

set model up to keep slip inside the green box. How?



start earthquake in model on a patch where...

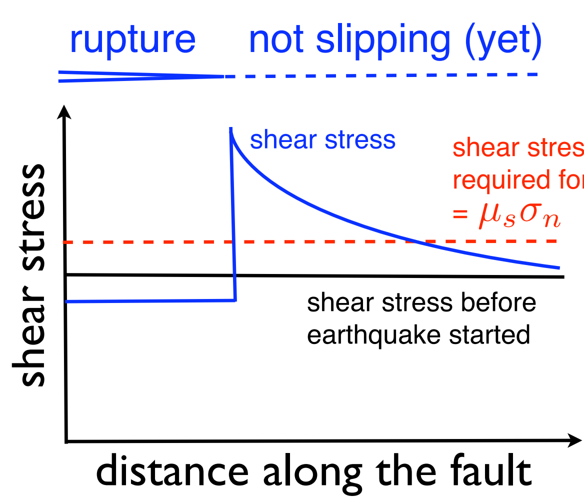
earthquake rupture is growing. slip has already stopped at the source.

slip stays inside the green box

slip fizzles out.

from a numerical model
Madariaga et al.

Good conditions for rupture propagation



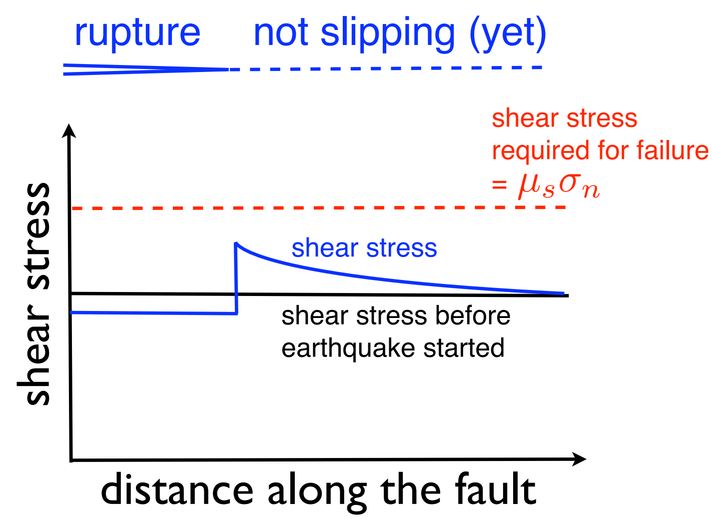
shear stress on unbroken fault next to the rupture increases!

the shear stress increase is proportional to the earthquake stress drop* and (1/ the square root of distance to the rupture tip)

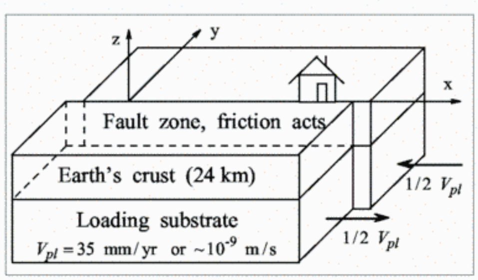
neighboring parts of the fault can be driven to failure by this domino effect **if they are already close to failure**

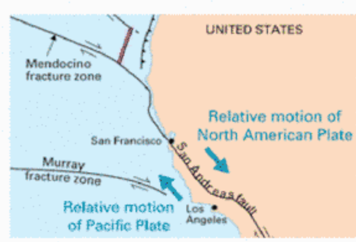
*biggest for high normal stress and velocity weakening (**big frictional force drop with slipping**)

Bad conditions for rupture propagation



Example of modeling with rate and state law





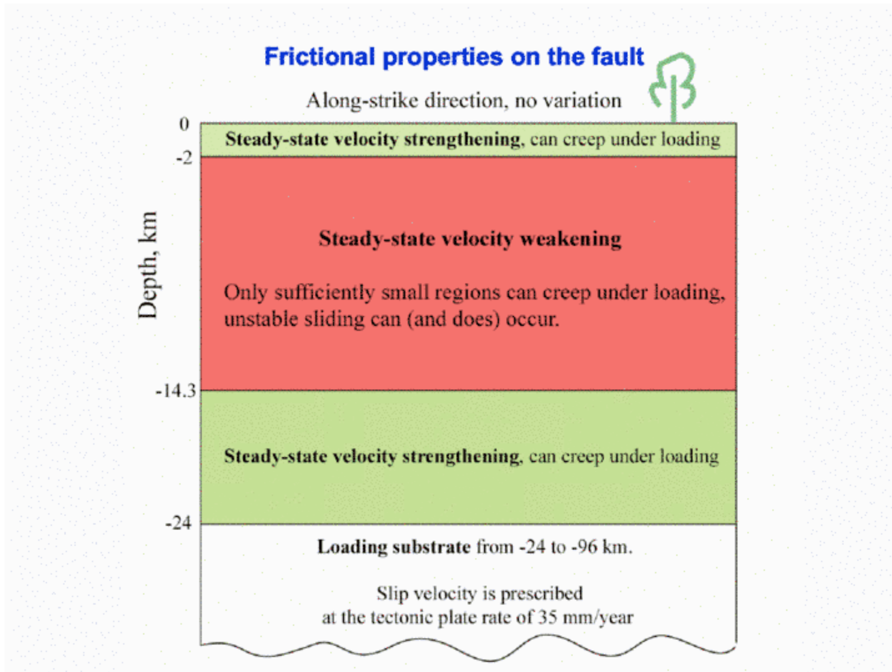
http://pubs.usgs.gov/publications/text/dynamic.html

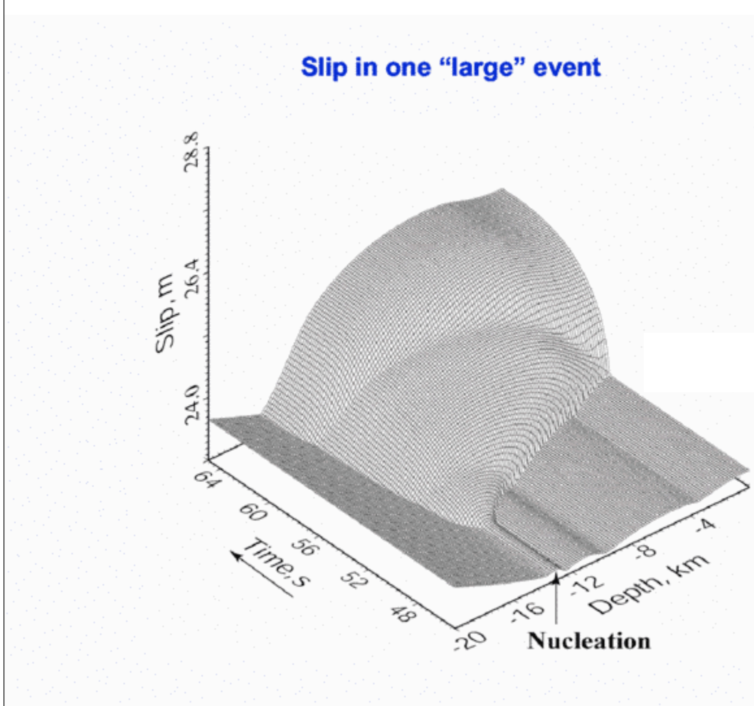
2D depth-variable model
Variations with z and y only,
no variation with x (Rice, 1993)

Goal: To simulate ***spontaneous*** slip accumulation on the interface by solving the system

Shear traction on the interface =

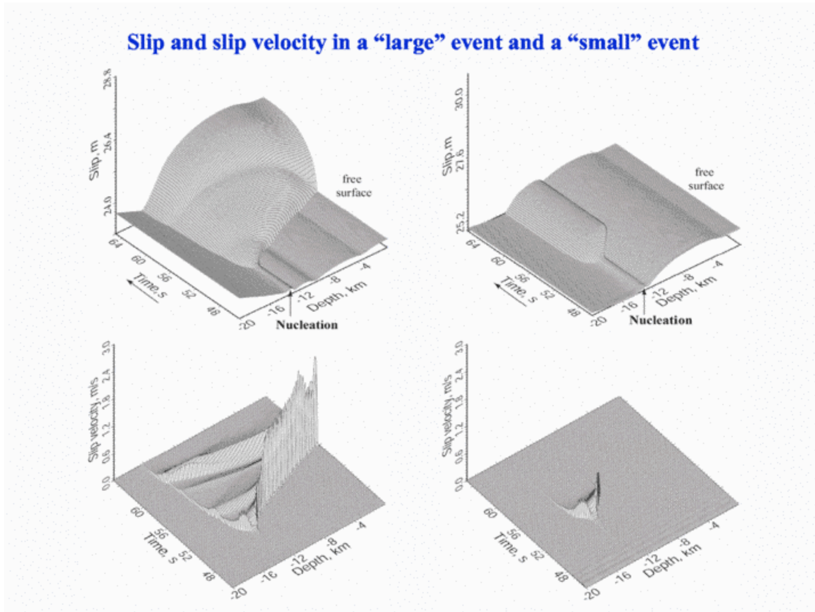
Friction strength of the interface





Coulomb failure criterion:

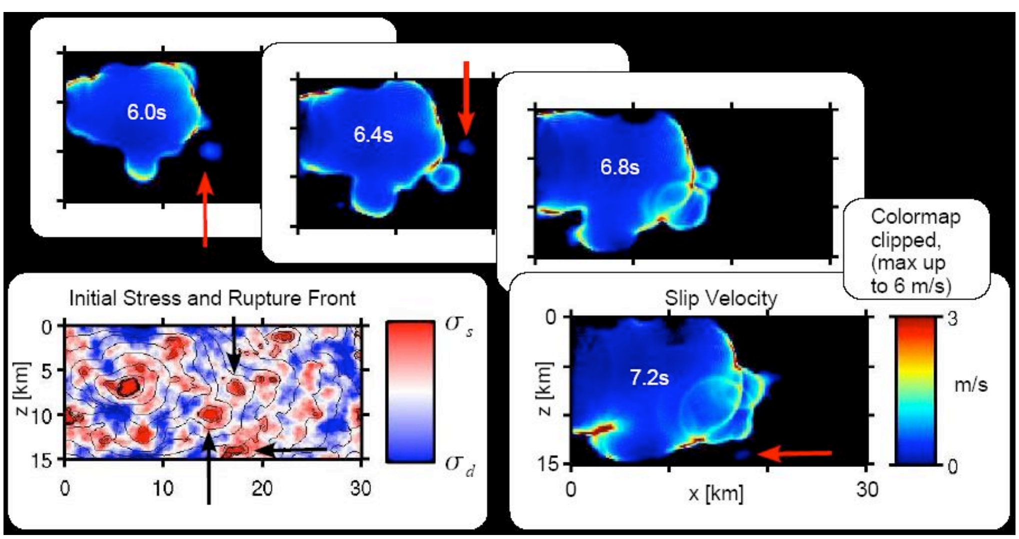
$$\sigma_n \ \mu_s = \tau$$



At the start, large and small earthquakes look the same

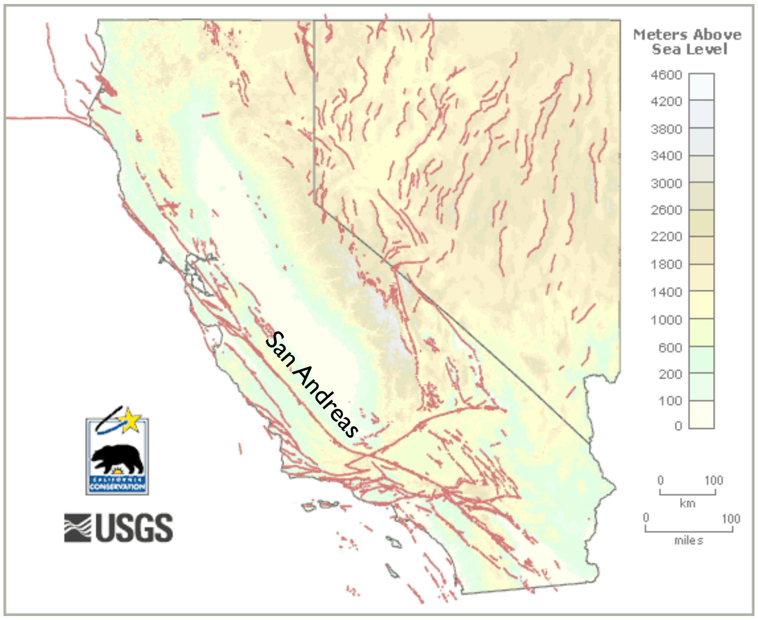
Nadia Lapusta

Frictional strength and shear stress are heterogeneous on real faults



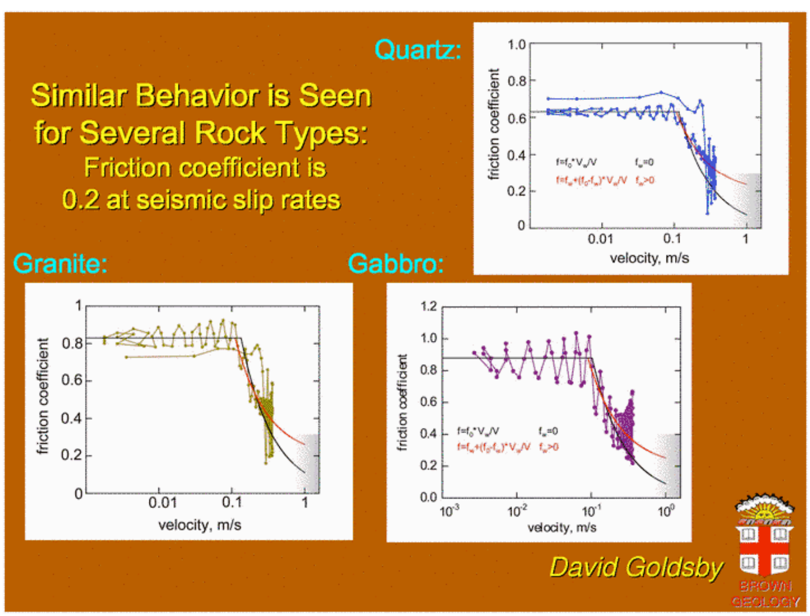
Rupture propagation model from J. Ampuero et al.

• Long, continuous fault with shear stress near the Coulomb threshold
• Large normal stress and velocity weakening friction --> big frictional force drop and large “kick” to adjacent parts of the fault



And yet another thing…“extreme weakening”

Lab experiments show that if slip speed gets up to about 0.1-0.2 m/s, dynamic friction may drop to near zero



the quake has already begun at this point, but this frictional strength drop will encourage the earthquake to keep going.

Effect of water on fault friction (that is, strength) and fault stability

Consider liquefaction of saturated sand

Grains are not touching. This is a fluid with grains floating in it.

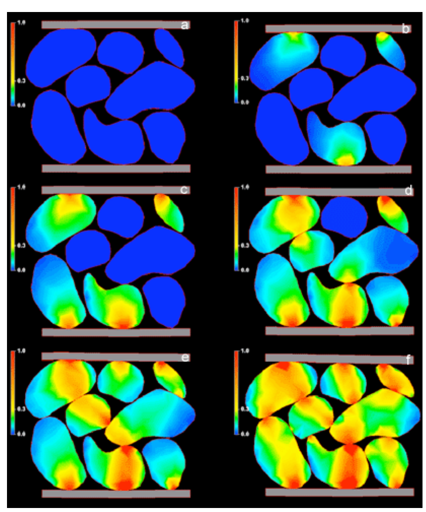


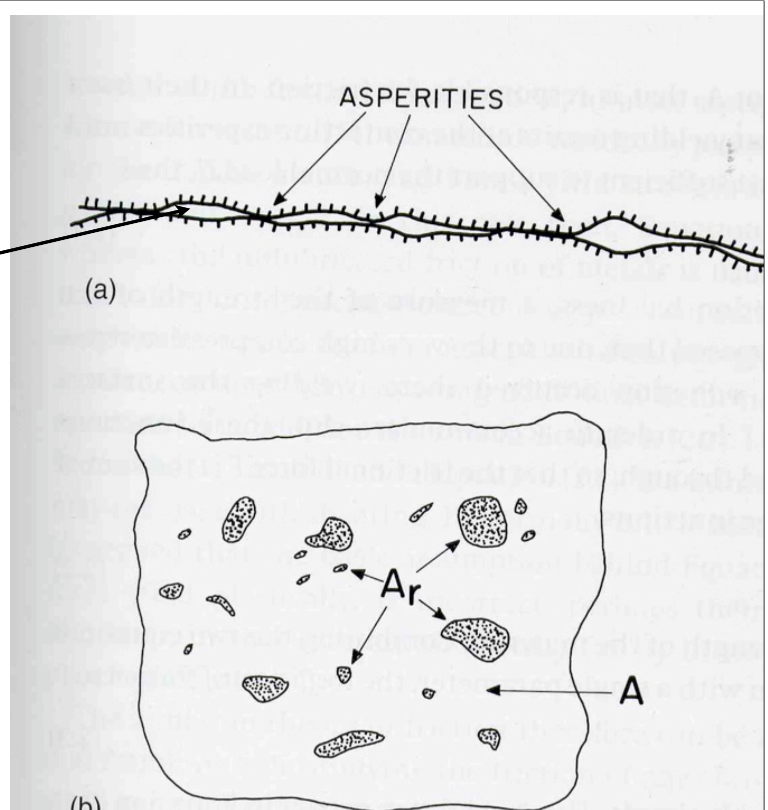
Image from Stanford University Rock Physics Lab

Grains are touching and are supporting the load (stressed parts of grains are red).

B

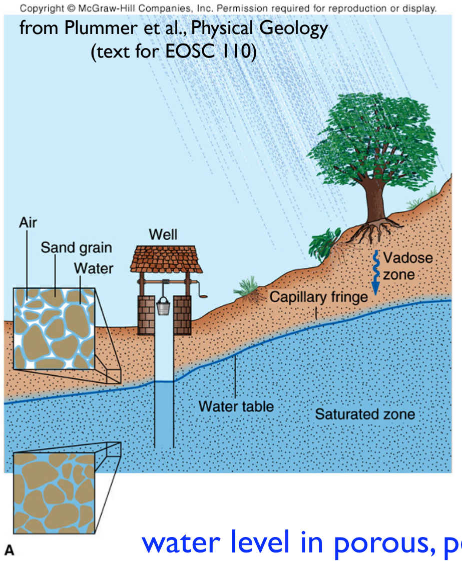
Photo by National Geophysical Data Center

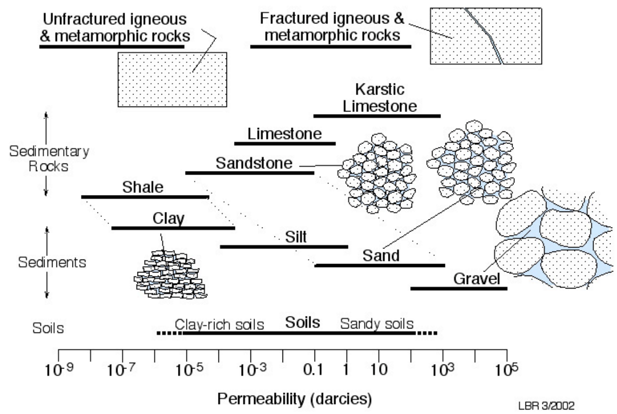
just add water at high pressure. what will happen?



C. Scholz 2002

Groundwater is present throughout the upper crust

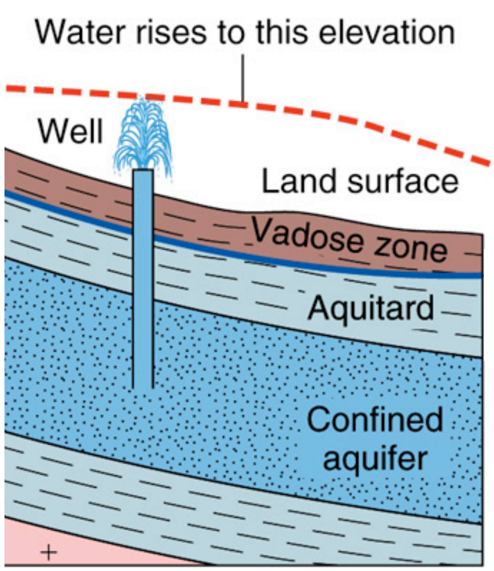




After Freeze and Cherry, *Groundwater*, Table 2.2. "Soils" line is largely an LBR inference.

water level in porous, permeable rock = water level in well

water pressure at depth is same as for a column of water
("unconfined" shallow aquifer)



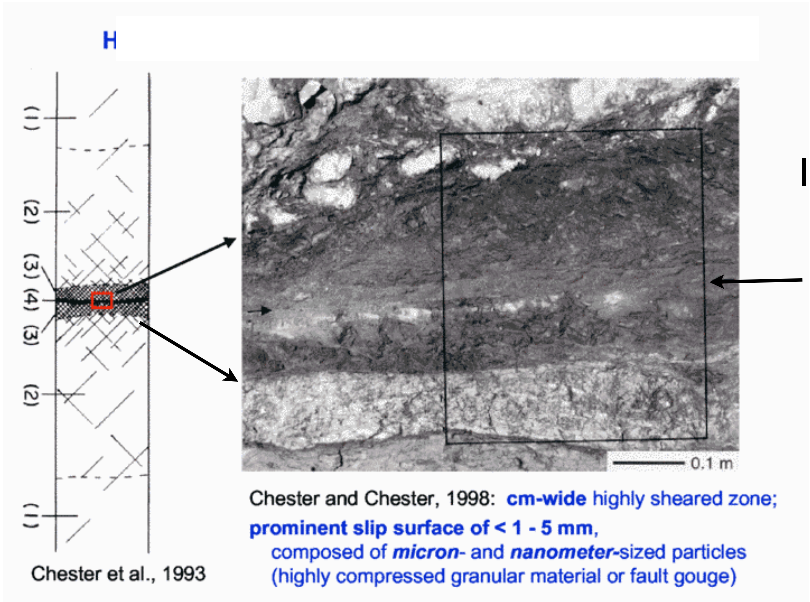
In some aquifers, and deeper in the crust, water in pores and cracks may become trapped.

Fluid cannot flow out faster than compaction is occurring, so water pressure goes up.

"pore fluid pressure" can approach the lithostatic pressure!

from Plummer et al., Physical Geology
(text for EOSC 110)

Water may become trapped inside low-permeability faults



low permeability

pore pressure may increase dramatically!

Pore pressure can dramatically reduce effective normal stress

$$|\sigma_e| = |\sigma_n| - P_p$$

At a depth of 10 km:

σ_e if water is not overpressured?

σ_e if pore pressure = 0.9 x lithostatic pressure?