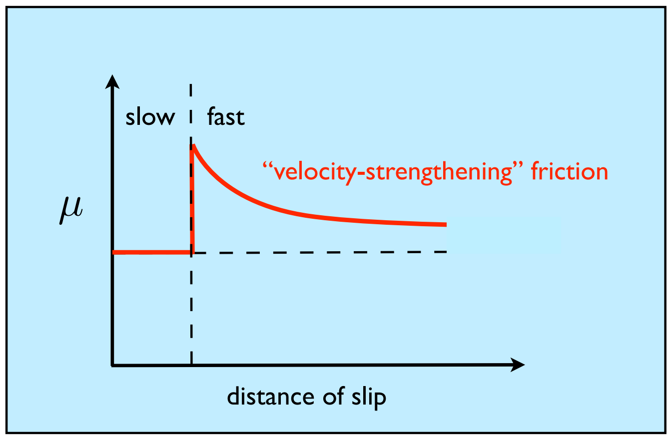
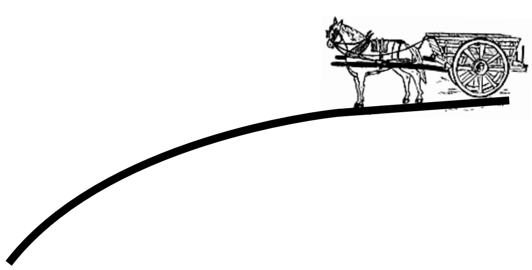
μ increases during sliding

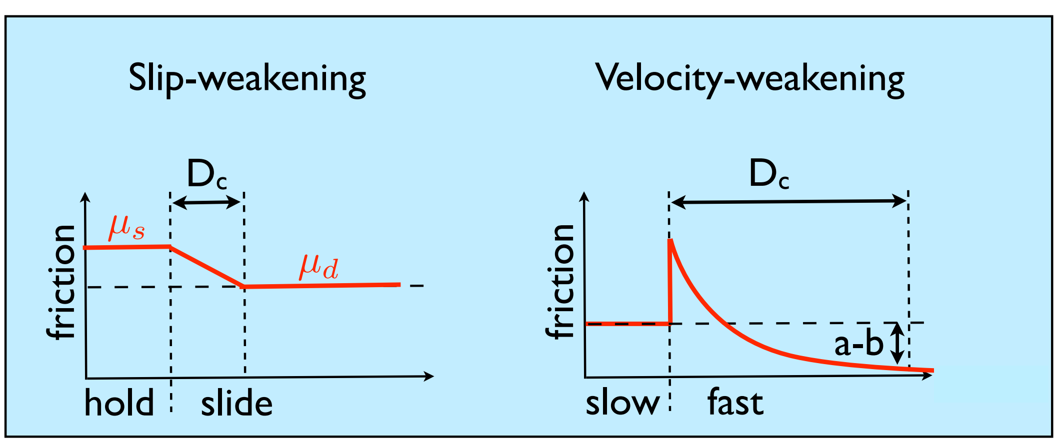
- faster sliding --> stronger fault --> slows sliding
- leads to stable slip: no earthquakes can start
- “velocity-strengthening” friction





μ decreases during sliding:

- instability may be possible
- “velocity weakening”
  or
  “slip weakening”

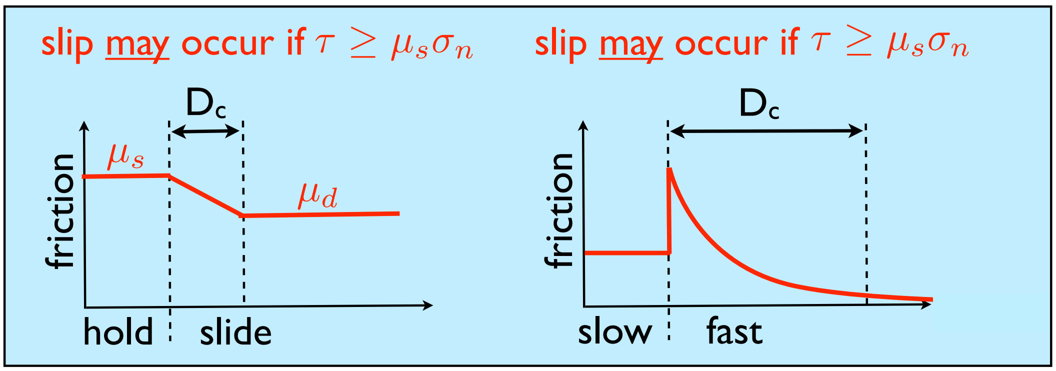


With velocity-weakening or slip-weakening friction:

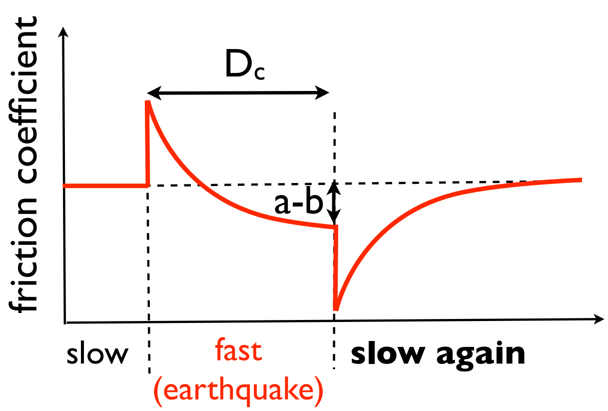
- fault eventually does stop sliding (stick-slip, Friday)
- fault is **still** not always unstable

---> you saw this with one case on Friday - which one?

Slip-weakening | Velocity-weakening

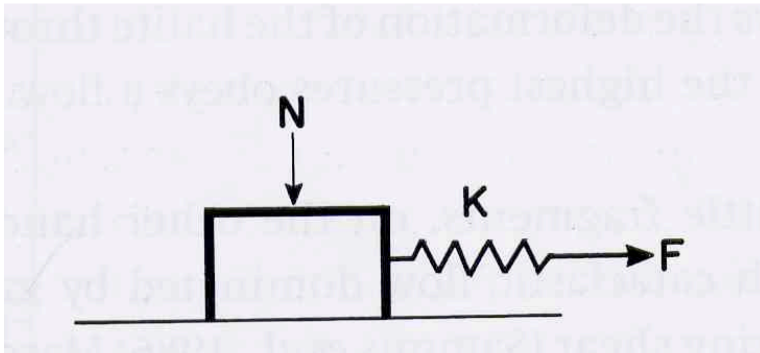


Only velocity-weakening friction addresses how the fault recovers its frictional strength between earthquakes

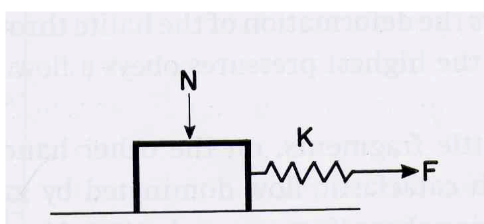


D_c is the distance over which steady-state friction is re-established at the new sliding velocity

Spring-slider activity: slip stopped because...



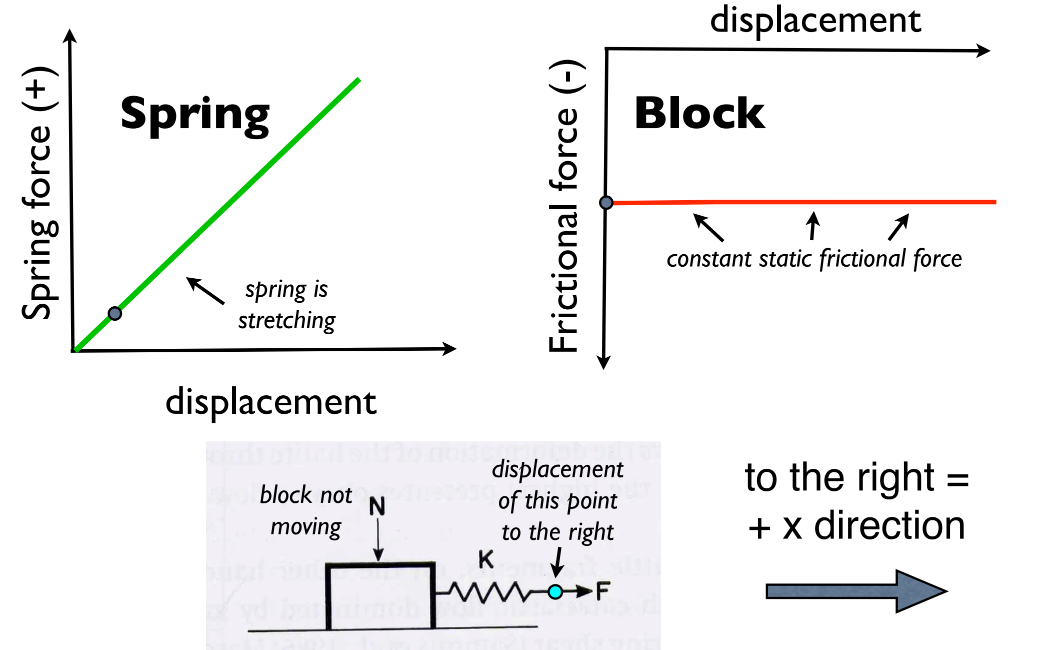
Today: a closer look at the conditions leading to instability, and why the earthquake ends.



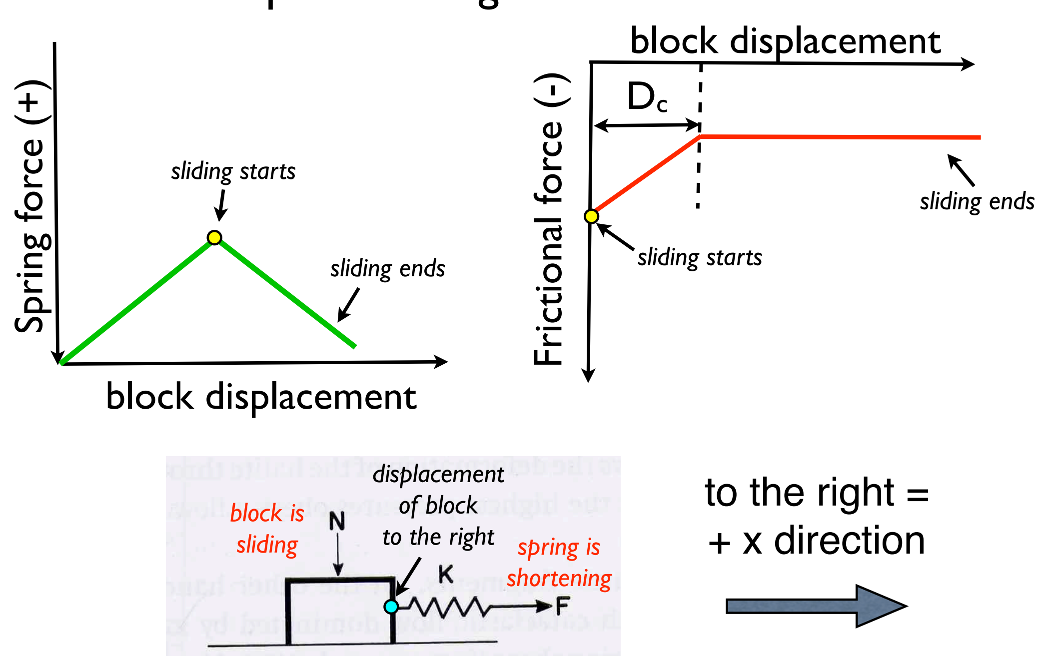
This is a battle between the shear force pulling the block and the friction force resisting it

$$\tau \times A = k \times x = F_{spring} =$$
$$\sigma_n \times A \times \mu = N \times \mu = F_{friction}$$

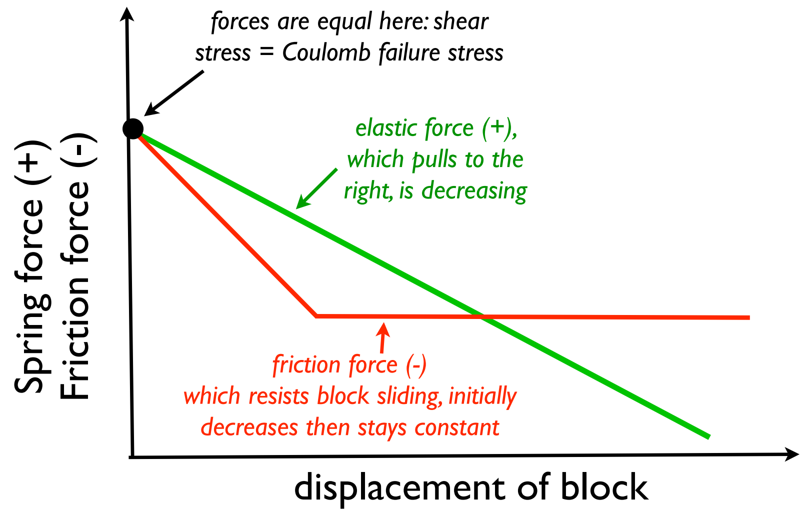
Before the block started to slide...

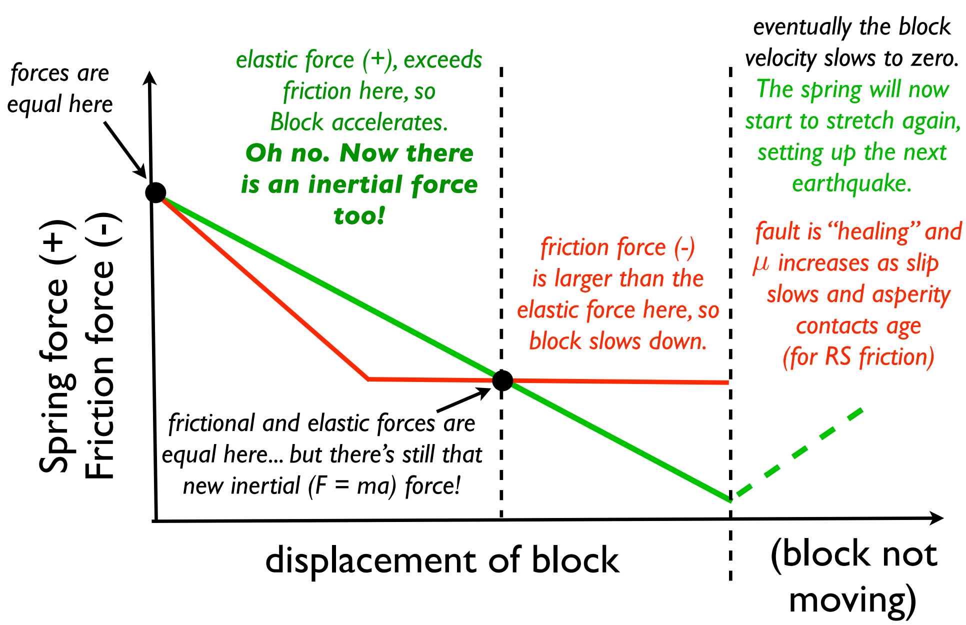


Now block sliding begins... assume slip weakening friction



Redraw this with absolute values of forces so the lines cross where |friction force| = |spring force|





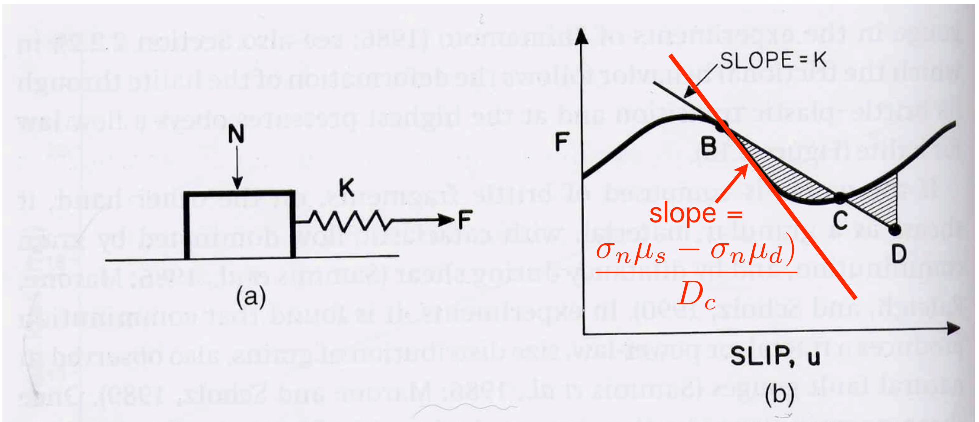
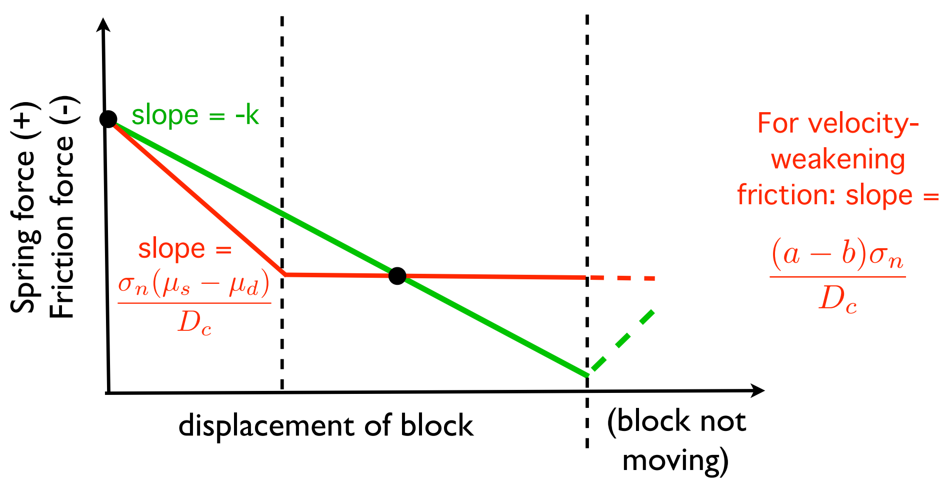


Fig. 2.16. Schematic diagram illustrating the origin of frictional instability: (a) a block-slider model; (b) a force–displacement diagram showing a hypothetical case in which the frictional resistance force falls with displacement at a rate faster than the system can respond.

From Scholz, 1998



Instability happens if friction decrease during sliding is steeper than elastic force decrease...

Instability if

$$k < \frac{\sigma_n(b-a)}{D_c}$$

Instability happens if friction decrease during sliding is steeper than elastic force decrease...

Instability if

$$k < \frac{\sigma_n (b - a)}{D_c}$$

Friday, what happened in the “stiff spring” experiment?

Instability happens if friction decrease during sliding is steeper than elastic force decrease...

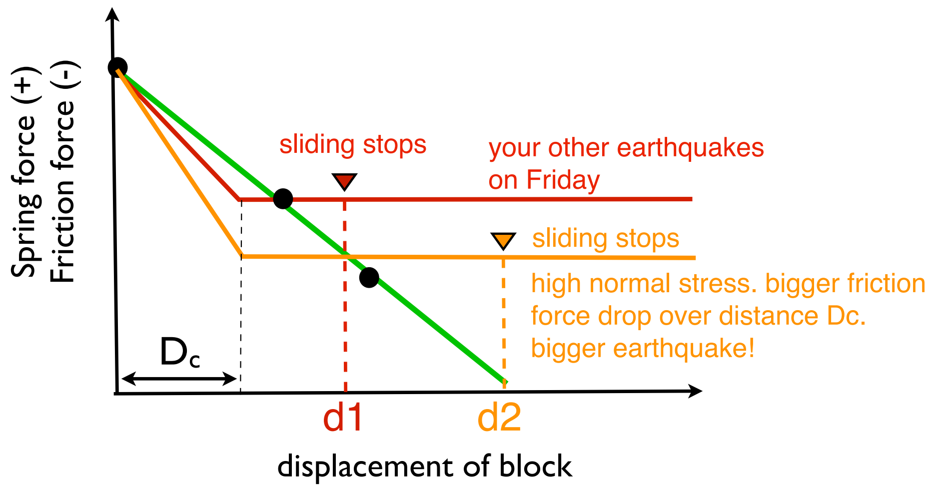
Instability if

$$k < \frac{\sigma_n (b - a)}{D_c}$$

- stiff spring?
- high normal stress?
- weak spring?
- low normal stress?

What about those big earthquakes you made by adding weight to the block?

- high normal stress (added a weight)
- no change to the spring stiffness (same old spring)



What does this mean in the Earth?

$$k < \frac{\sigma_n (b-a)}{D_c}$$

D_c and (a-b) : from lab experiments

σ_n : from (approx.) $\rho g h$

k? ... this needs to relate slip to elastic stress decrease along a slipping patch of the fault

Equation for stiffness k for a small, elliptical crack is:

$$k = \frac{G}{(1-\nu)L}$$

G = shear modulus
ν = Poisson's ratio
L = length of slipping area

$$k < \frac{\sigma_n(b-a)}{D_c}$$

$$\frac{G}{(1-\nu)L} < \frac{\sigma_n(b-a)}{D_c}$$

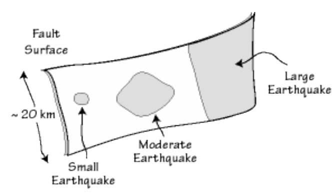
k = crack stiffness
G = shear modulus
ν = Poisson's ratio
L = length of slipping area
$(b-a)$ = friction weakening parameter
σ_n = normal stress
D_c = friction weakening distance

$$L > \frac{D_c G}{(1-\nu)(b-a)\sigma_n}$$

This tells us that the slipping patch of fault must be bigger than a critical size to go unstable, *even* for a velocity weakening fault

The slipping patch of fault must be bigger than a critical size to go unstable

Determine the minimum earthquake size (magnitude and moment) assuming: G=30 GPa, normal stress = 50 MPa, b-a = 0.01, ν= 0.25, and Dc = 10^{-4} m.



$$L > \frac{D_c G}{(1-\nu)(b-a)\sigma_n}$$

Get L and then get moment and moment magnitude using equations from Feb 23 notes. Assume offset (slip) is 0.01 times L.