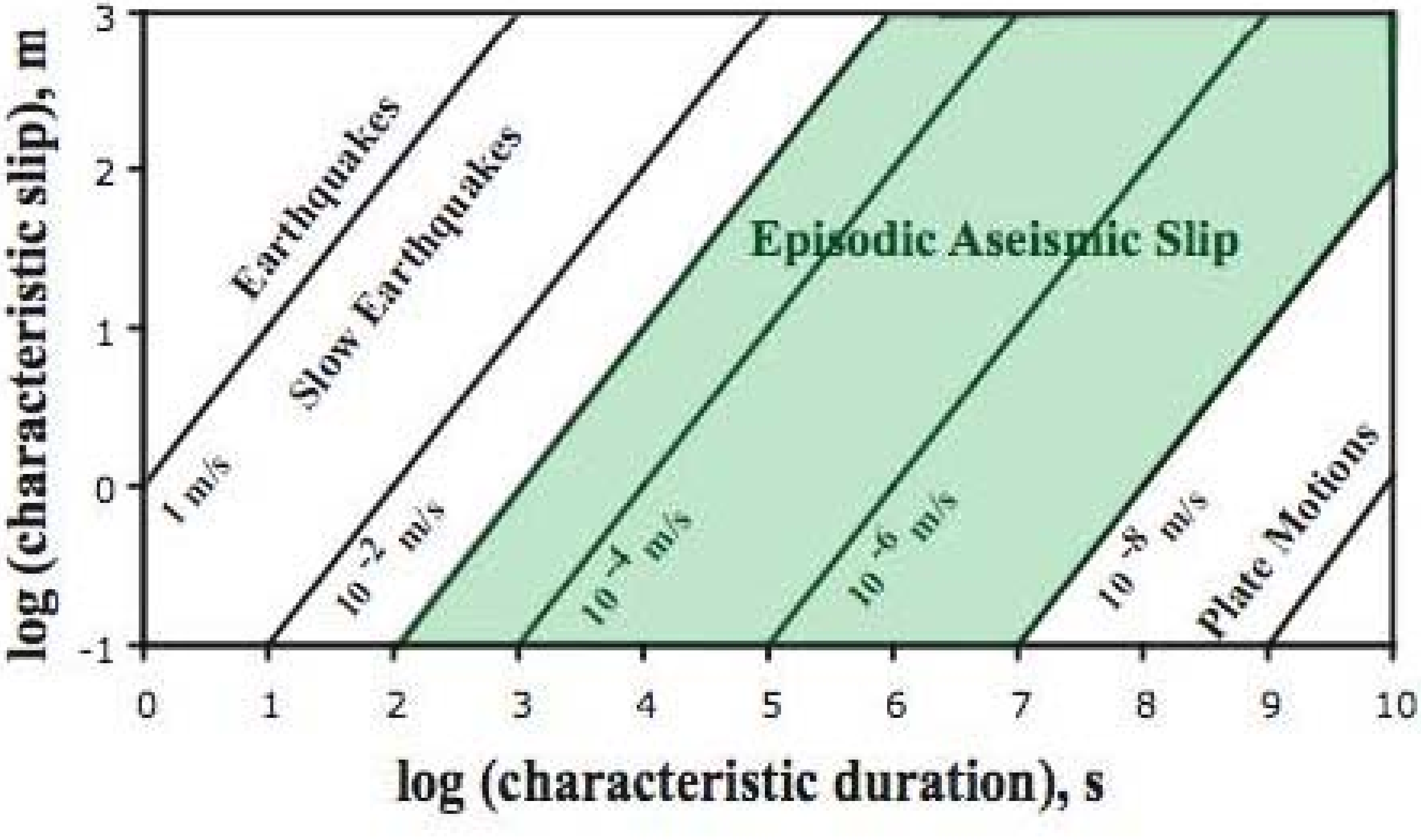
Slow Slip

earthquakes, slow slip, and plate motion

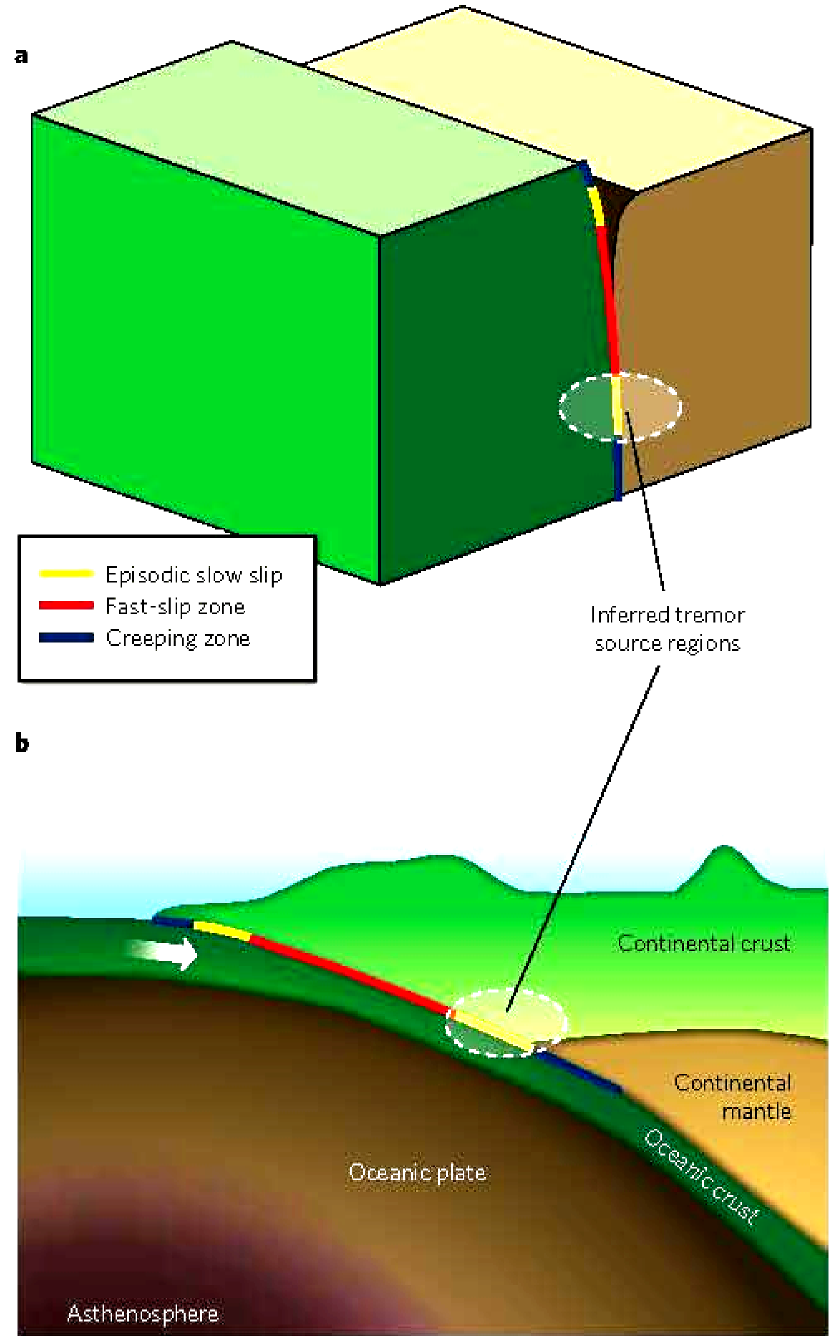
(1m/year=3x10^{-8} m/s)



Slow and silent earthquakes

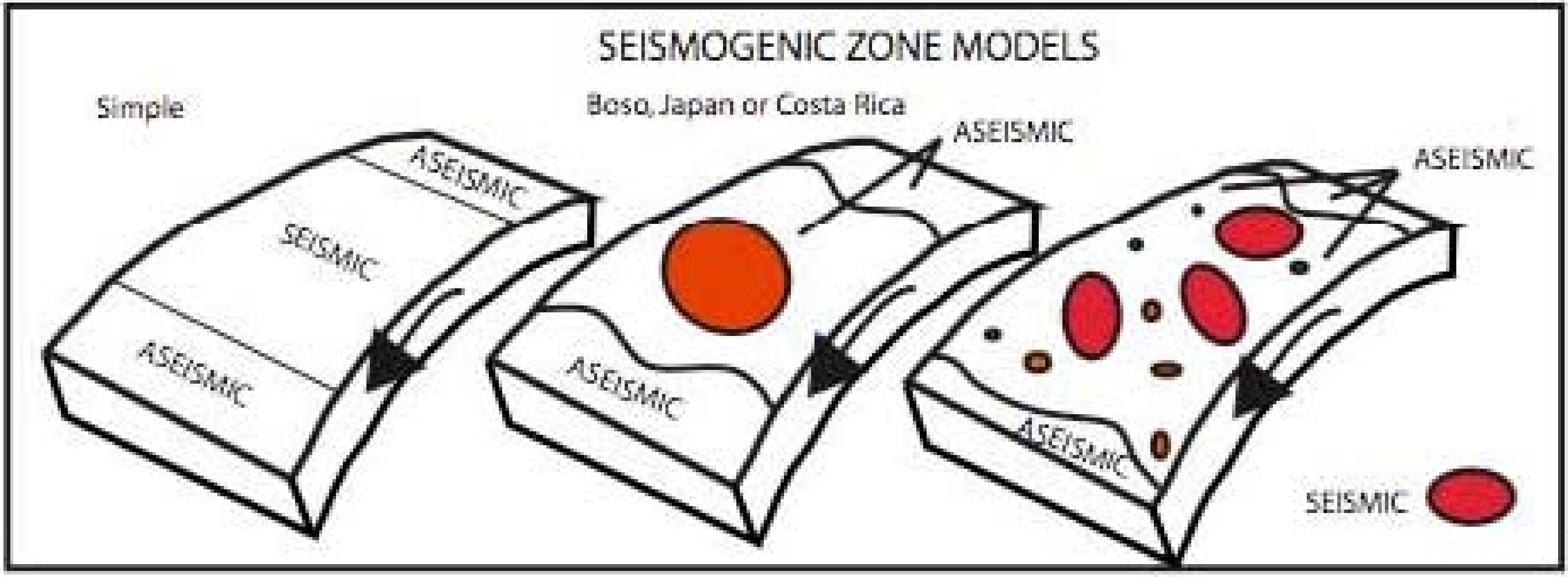
$M_w \sim 7$

speed of slip motion
1m/year



(Modified from Schwartz, 2007)

Regional variation of slow slip characteristics



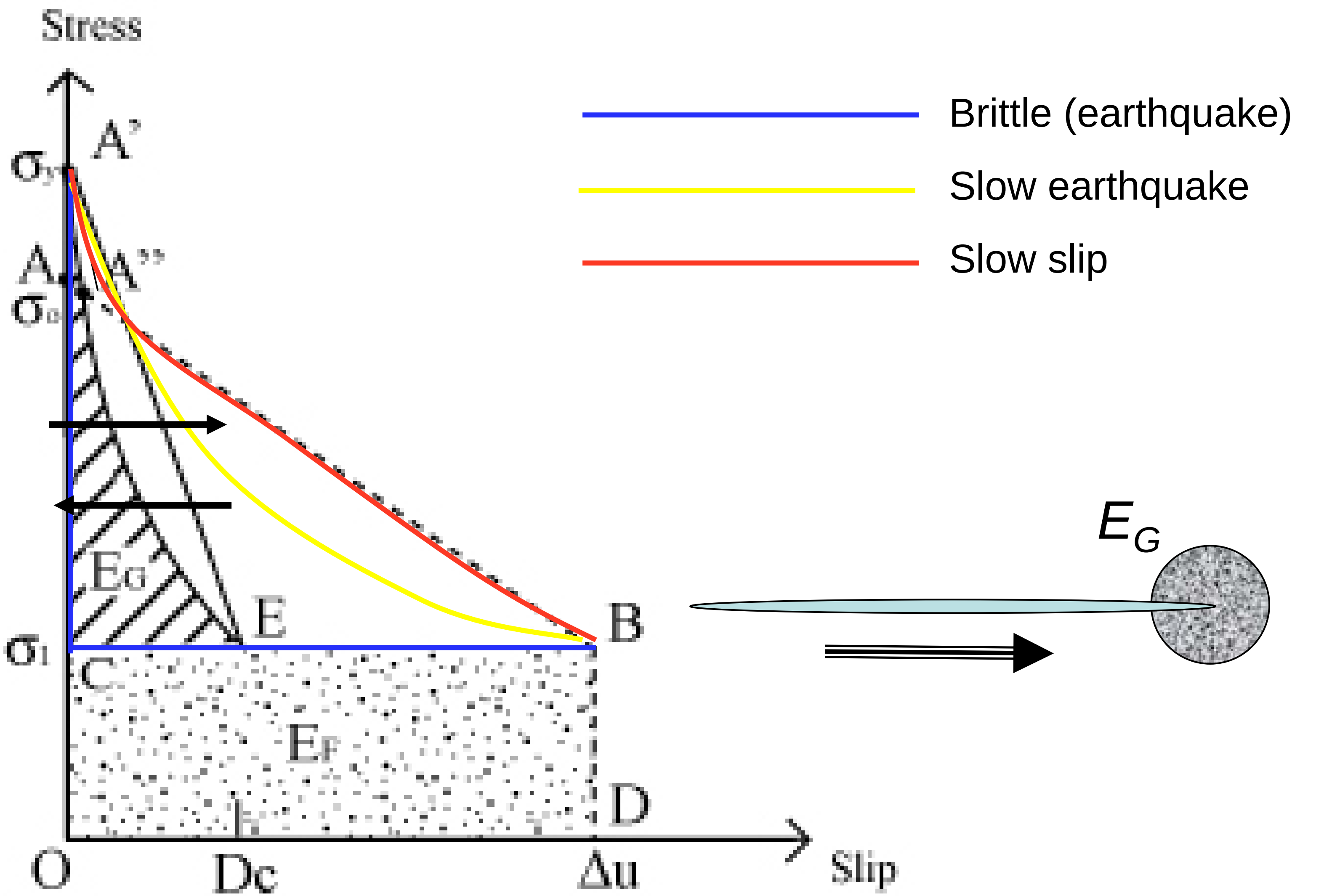
Cascadia, Tokai

Sanriku, Miyagi, Fukushima-oki

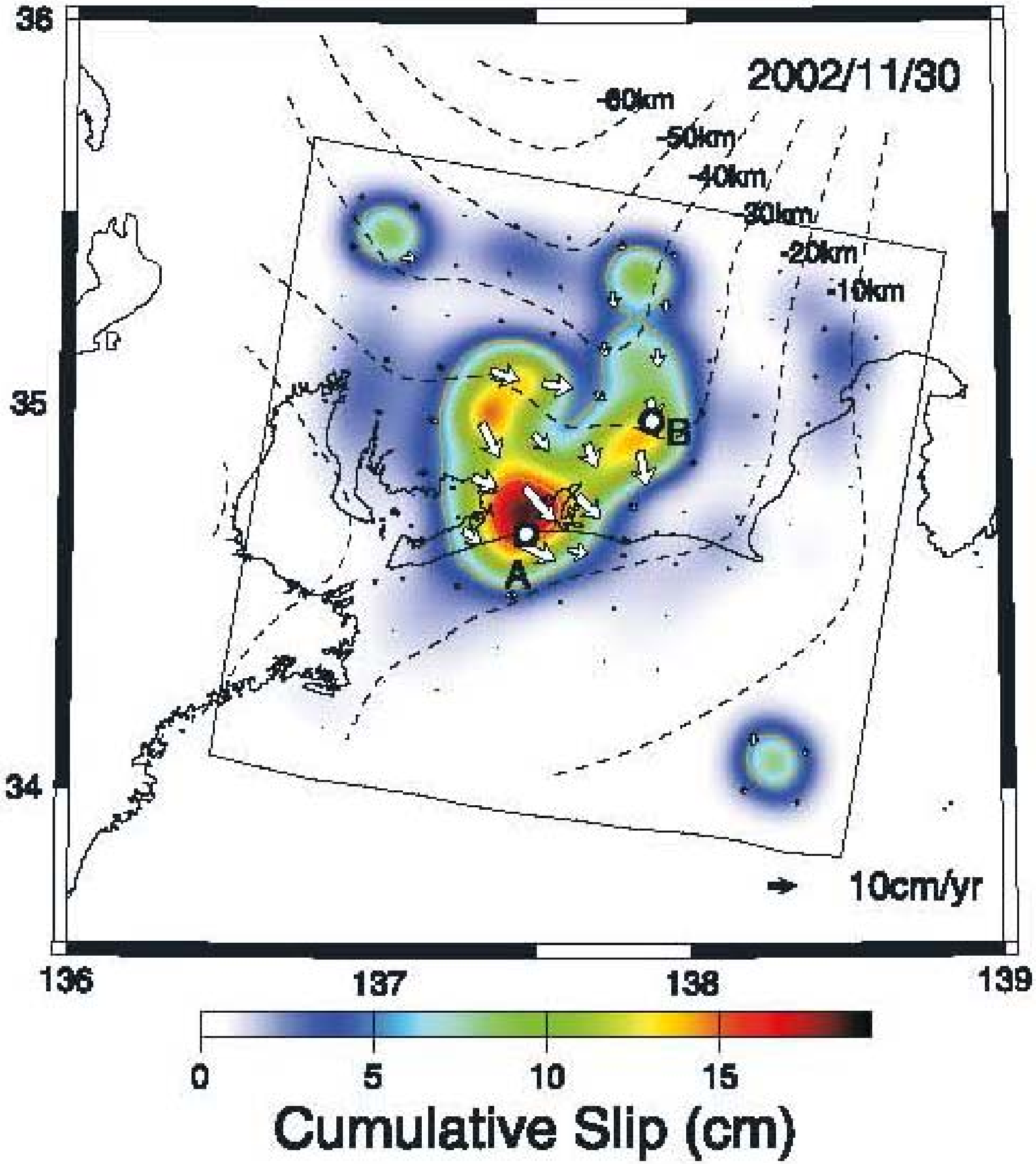
- temperature seismic-aseismic boundary ~350°c
- pore pressure (water)
- plate age

(Schwartz, 2007)

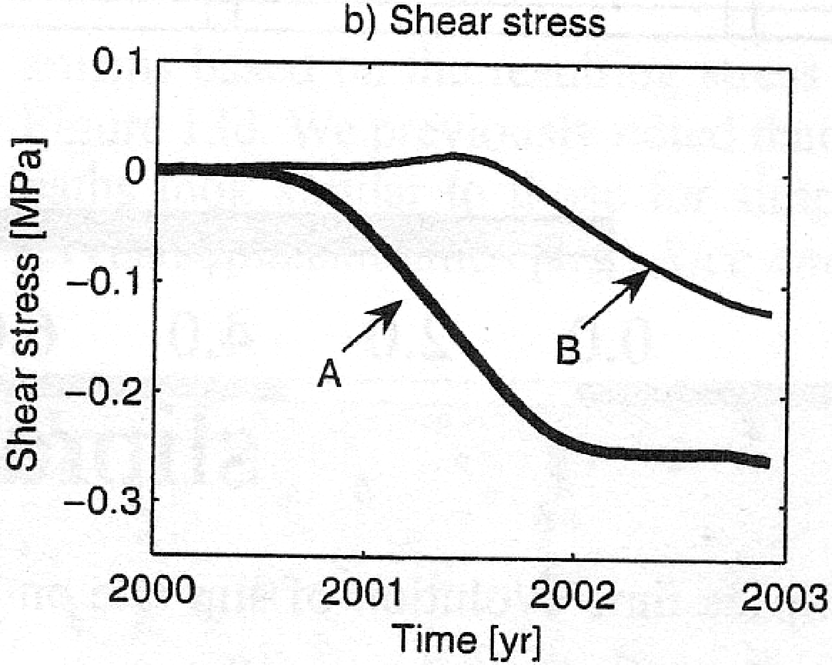
Mechanics (slip-weakening model), brittle (earthquakes) to slow slip

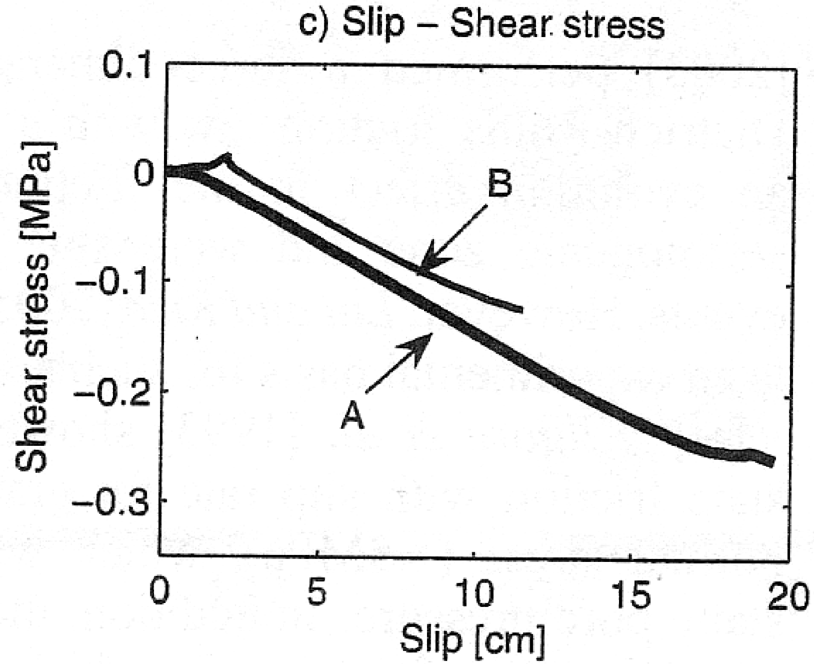


Tokai slow slip (Miyazaki et al., 2006)

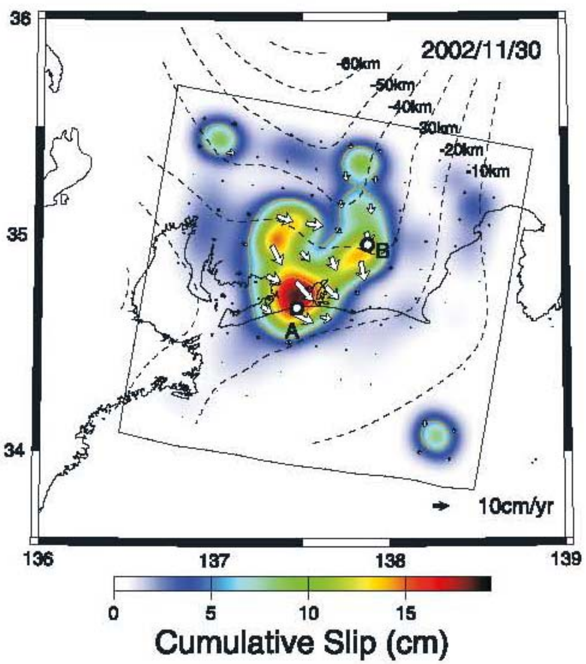


Tokai Slow Slip

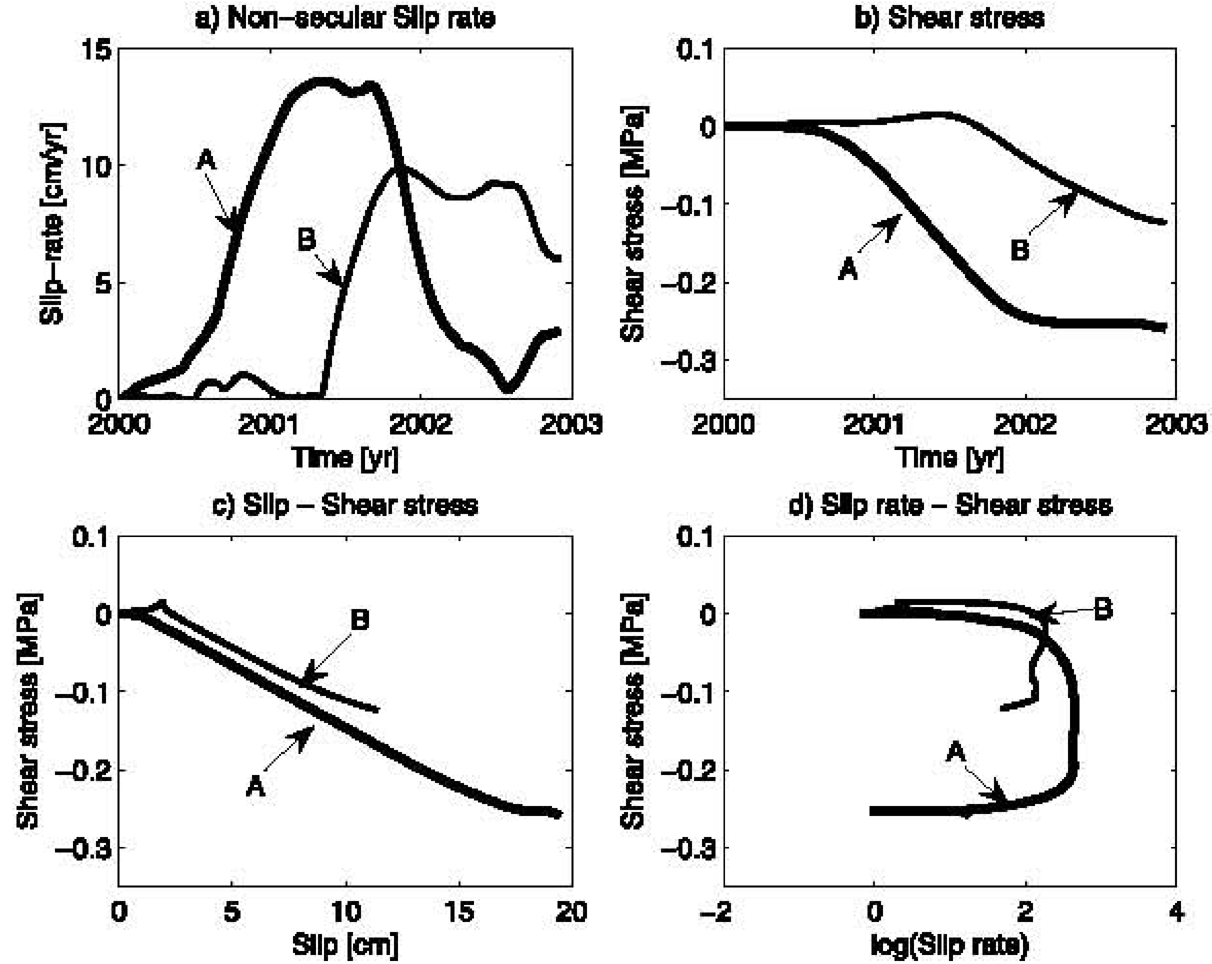




Miyazaki et al., 2006

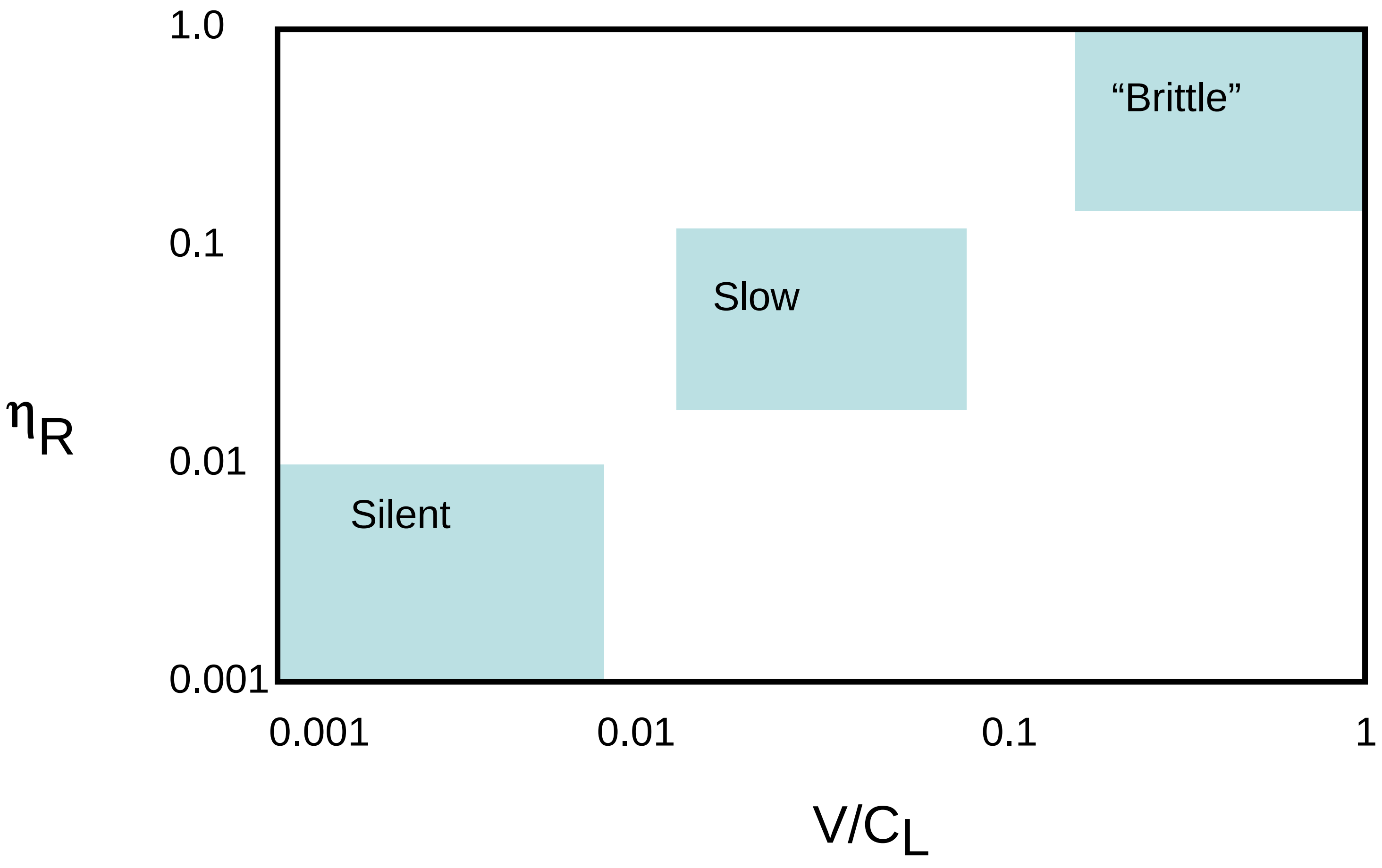


2002/11/30
-60km
-50km
-40km
-30km
-20km
-10km
A
B
10cm/yr
36
35
34
136
137
138
139
0
5
10
15
Cumulative Slip (cm)

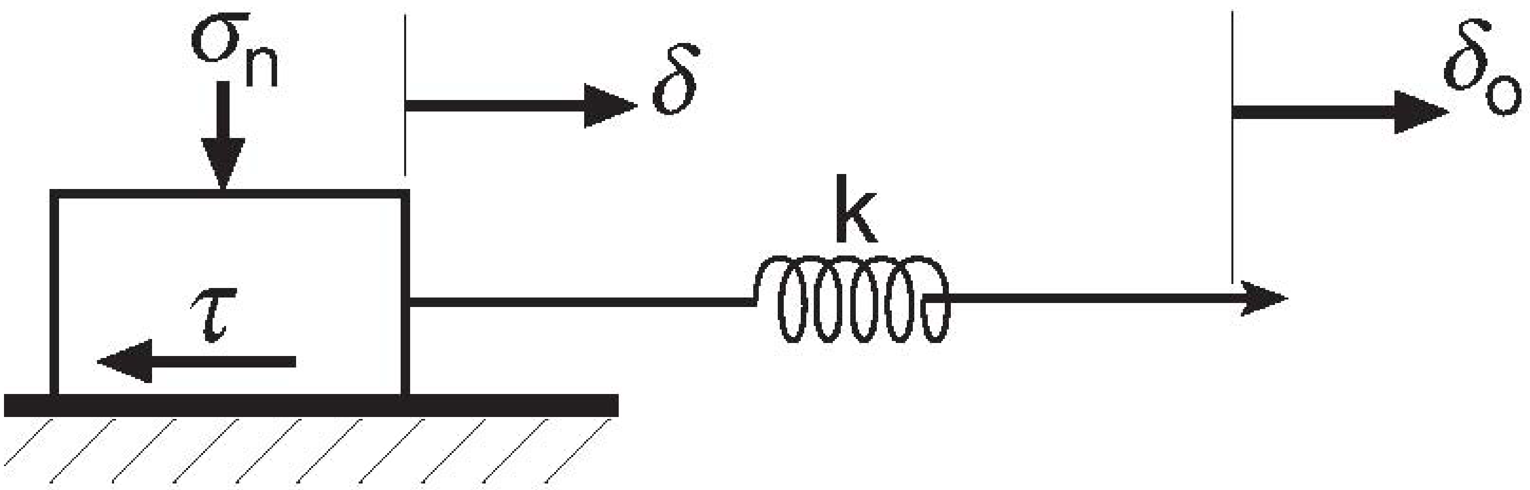


a) Non−secular Slip rate
Slip−rate [cm/yr]
Time [yr]
b) Shear stress
Shear stress [MPa]
Time [yr]
c) Slip − Shear stress
Shear stress [MPa]
Slip [cm]
d) Slip rate − Shear stress
Shear stress [MPa]
log(Slip rate)
A
B

Regular, Slow and Silent Earthquakes



Slider block model



Coefficient of friction

$$\mu = \frac{\tau}{\sigma_n}$$

Steady state (rate dependence)

Constant normal stress

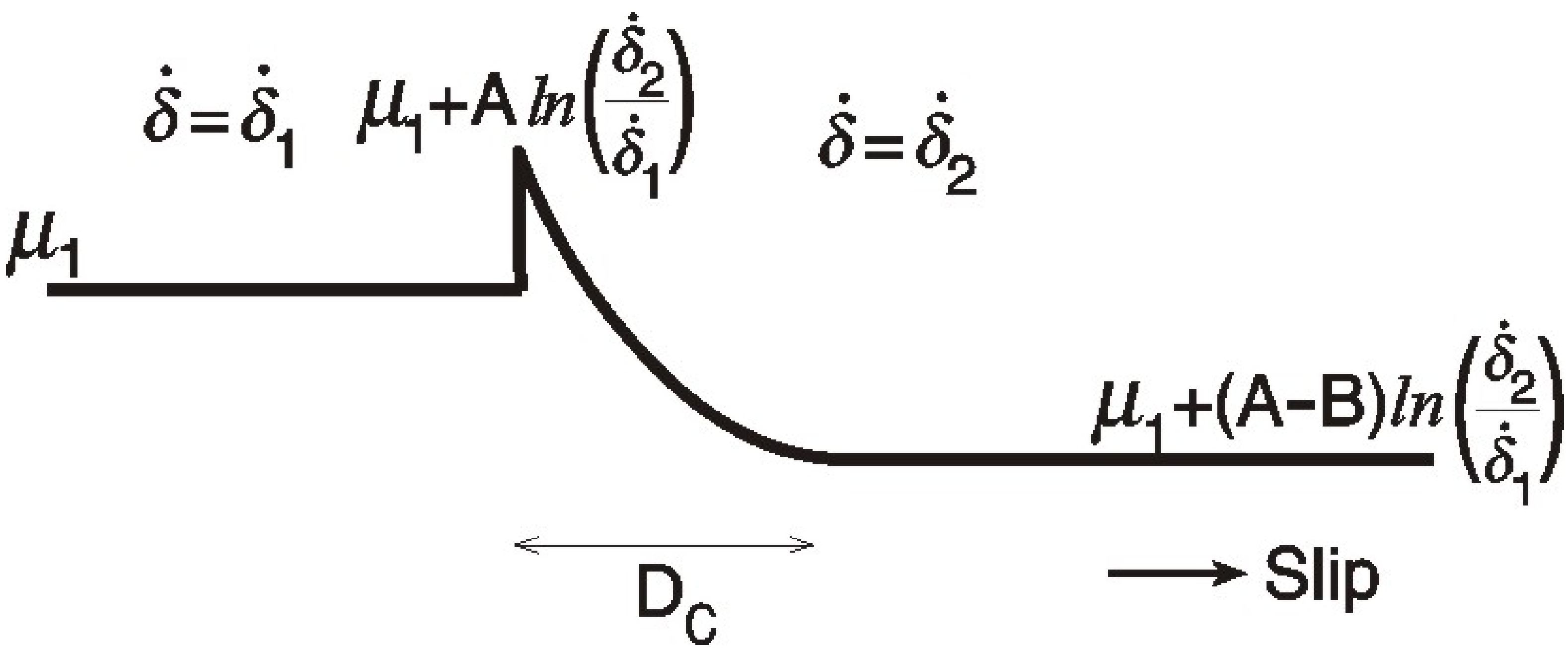
$$\mu_{ss} = \mu_0 + (a-b)\ln\left(\frac{\dot{\delta}}{\dot{\delta}^*}\right)$$

a-b<0 velocity weakening unstable → brittle (earthquakes)

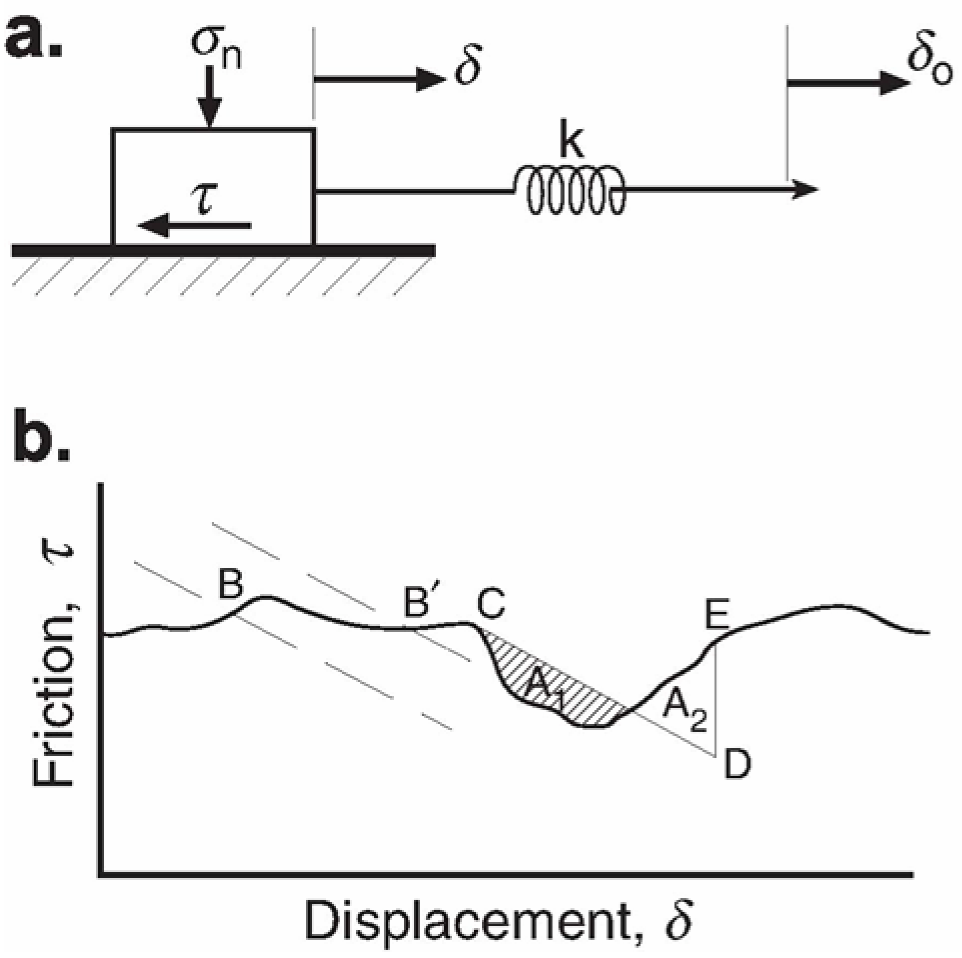
a-b>0 velocity strengthening stable → creep (slow slip)

transient behavior (state dependence)

$$\dot{\delta}_1 \rightarrow \dot{\delta}_2$$



stability-instability



$k\Delta\delta < \Delta\tau$ unstable (earthquake)

$k\Delta\delta > \Delta\tau$ stable

$k\Delta\delta < \Delta\tau$ unstable (earthquake)

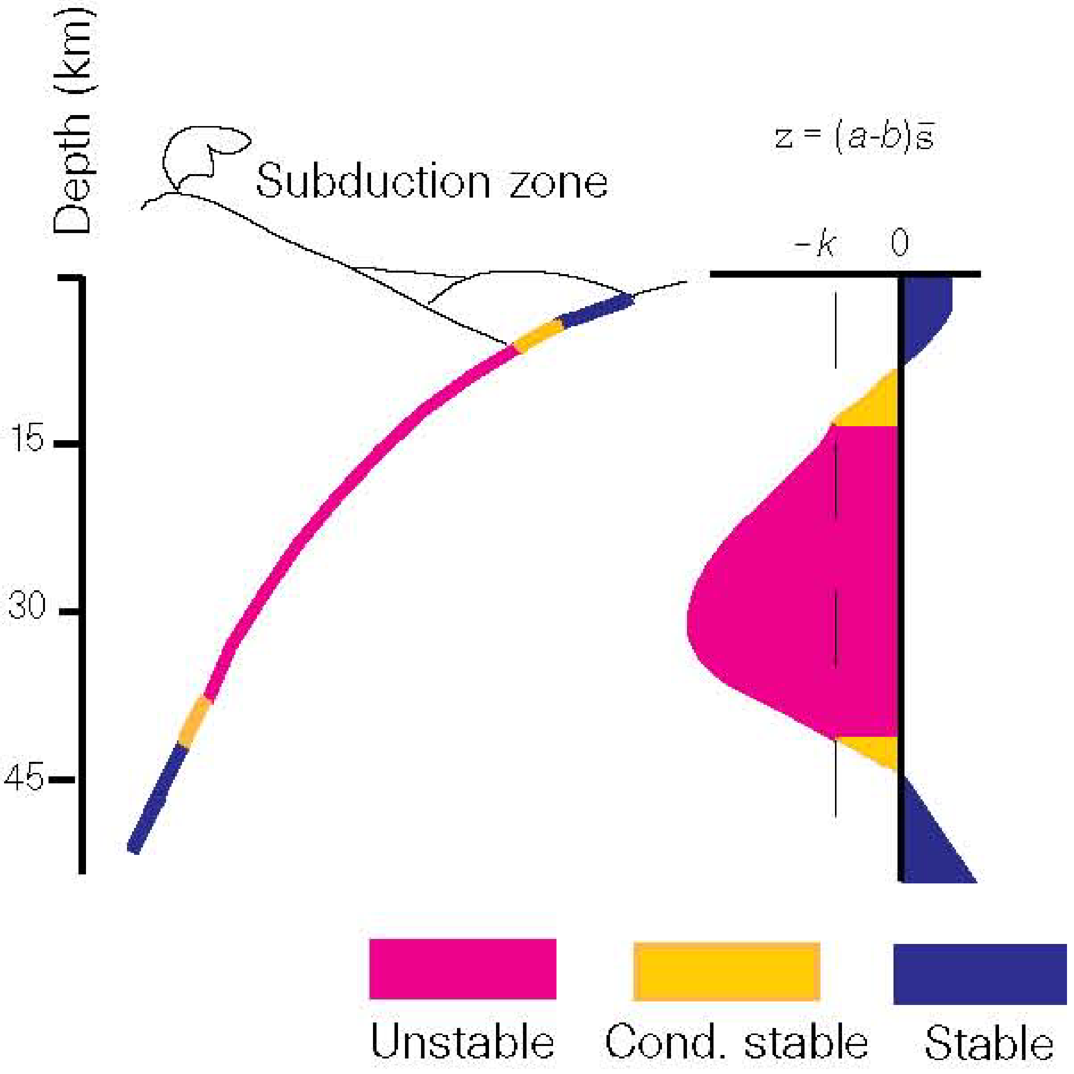
$k\Delta\delta > \Delta\tau$ stable

Critical stiffnes $k_c = \dfrac{\Delta\tau}{\Delta\delta}$ If $k < k_c$ unstable

$$k_c = \frac{(b-a)(\sigma_n - P)}{D_c}$$

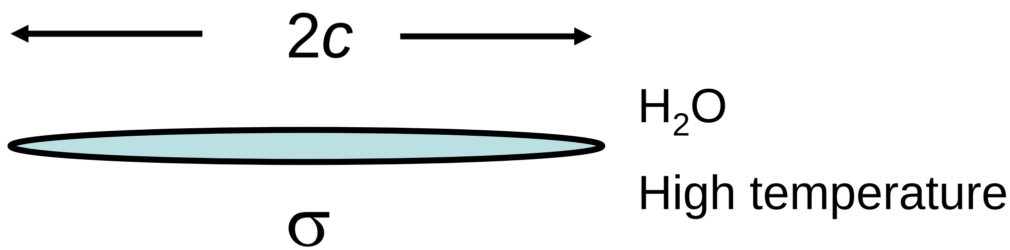
P increase → k_c decrease → brittle to slow slip

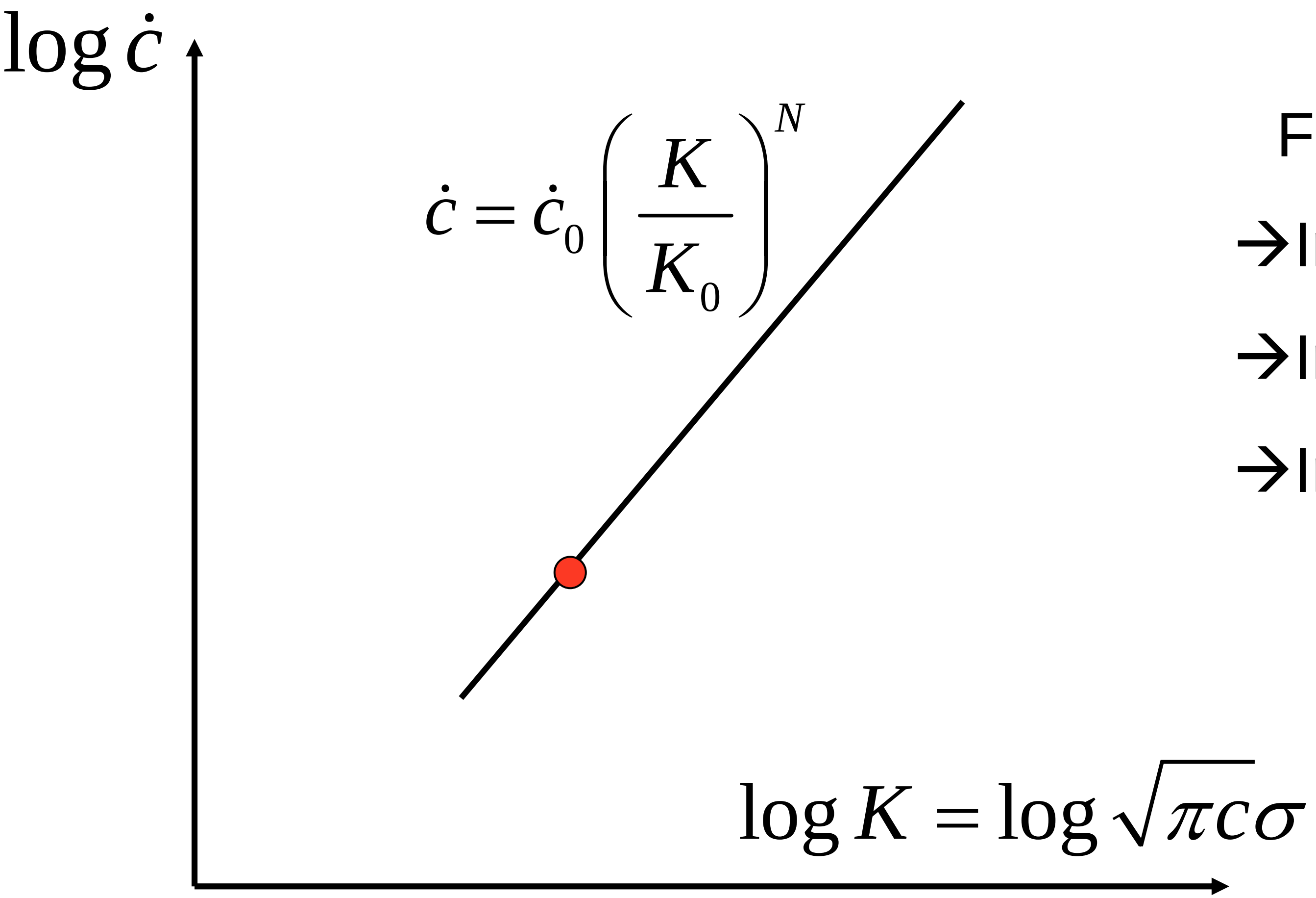
Stability on a subduction-zone boundary



Scholz (1998)

Stress corrosion (Das and Scholz (1981) "predicts slow earthquakes, multiple events, doublets, afterslip, foreshocks, aftershocks")





Finite $\dot{c}$

→Increase c

→Increase K

→Increase $\dot{c}$

Slow and brittle slips offshore of Fukushima Prefecture (Aug. 1, 2008, GSI)