How earthquakes occur

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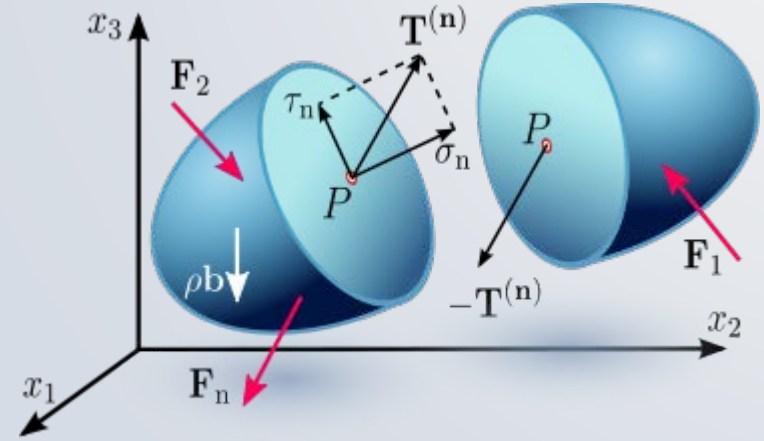
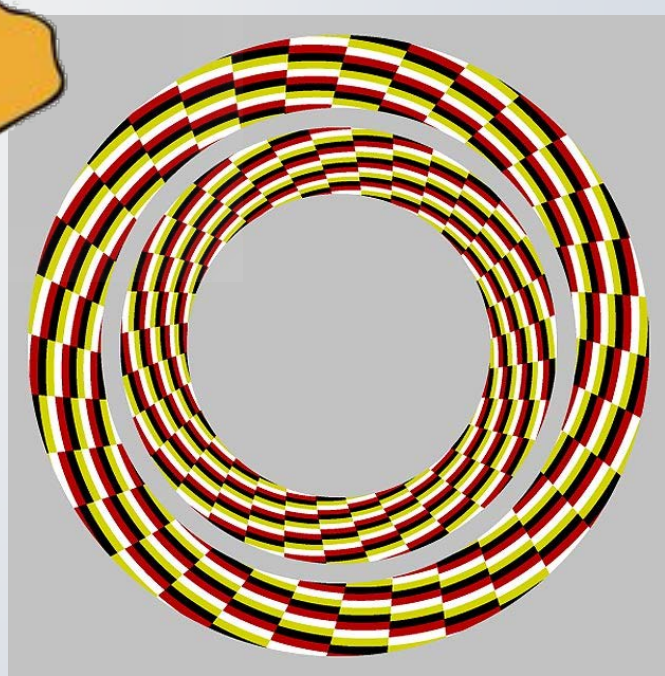
A brutal surprise

Avenue de La Gare, Nice 1887 (The Illustrated London News)

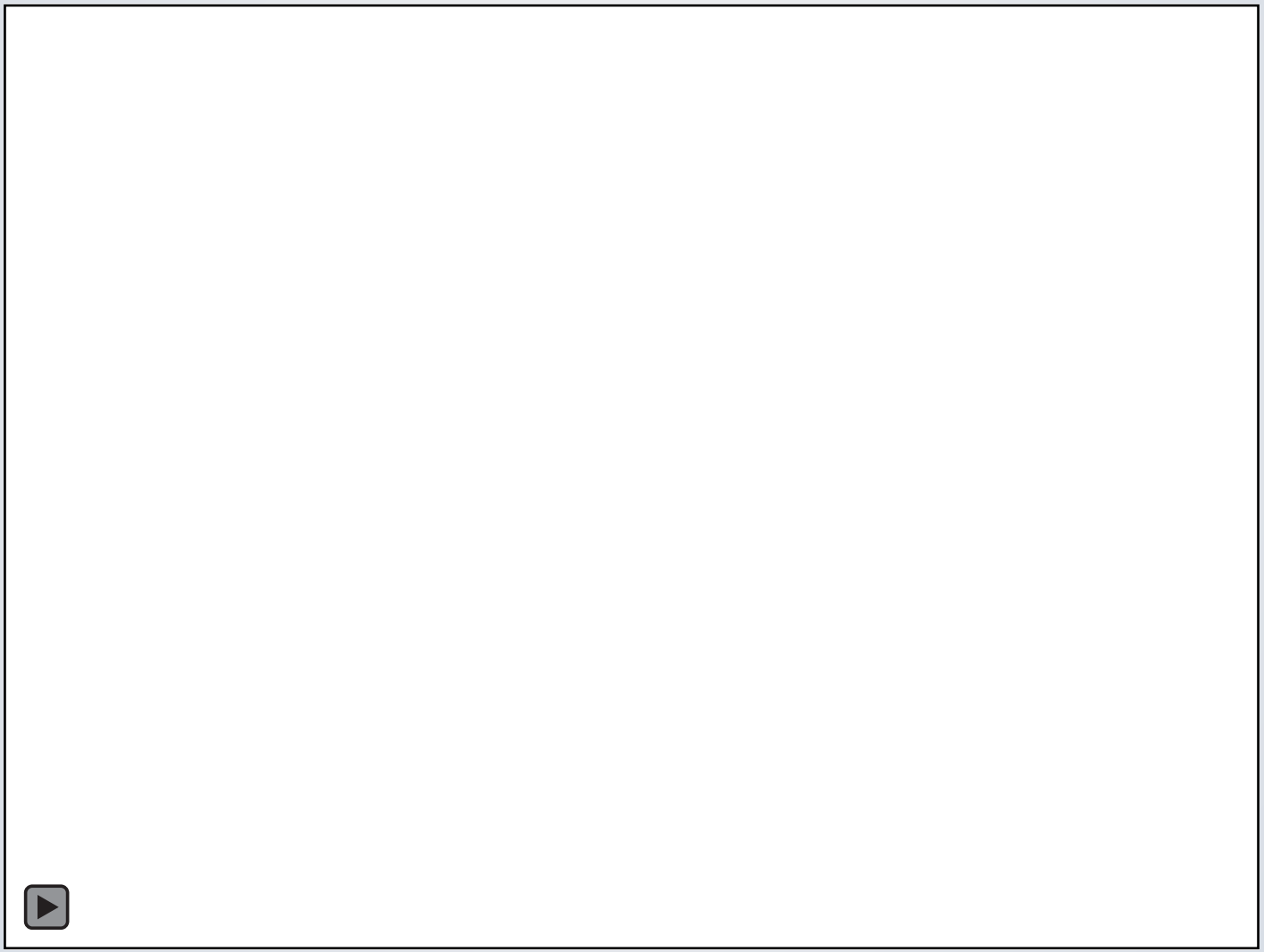
A question of stress





Stable / unstable displacement

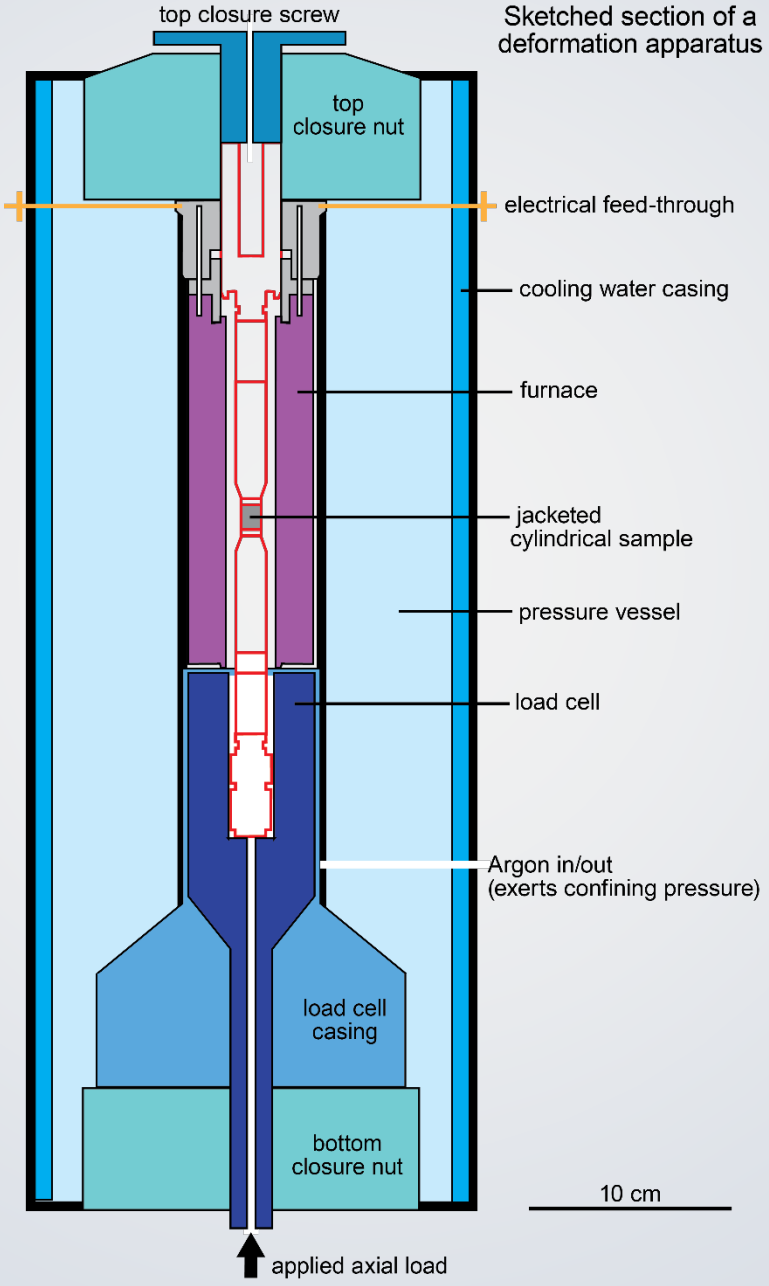
http://earthquake.usgs.gov/research/modeling/animations/



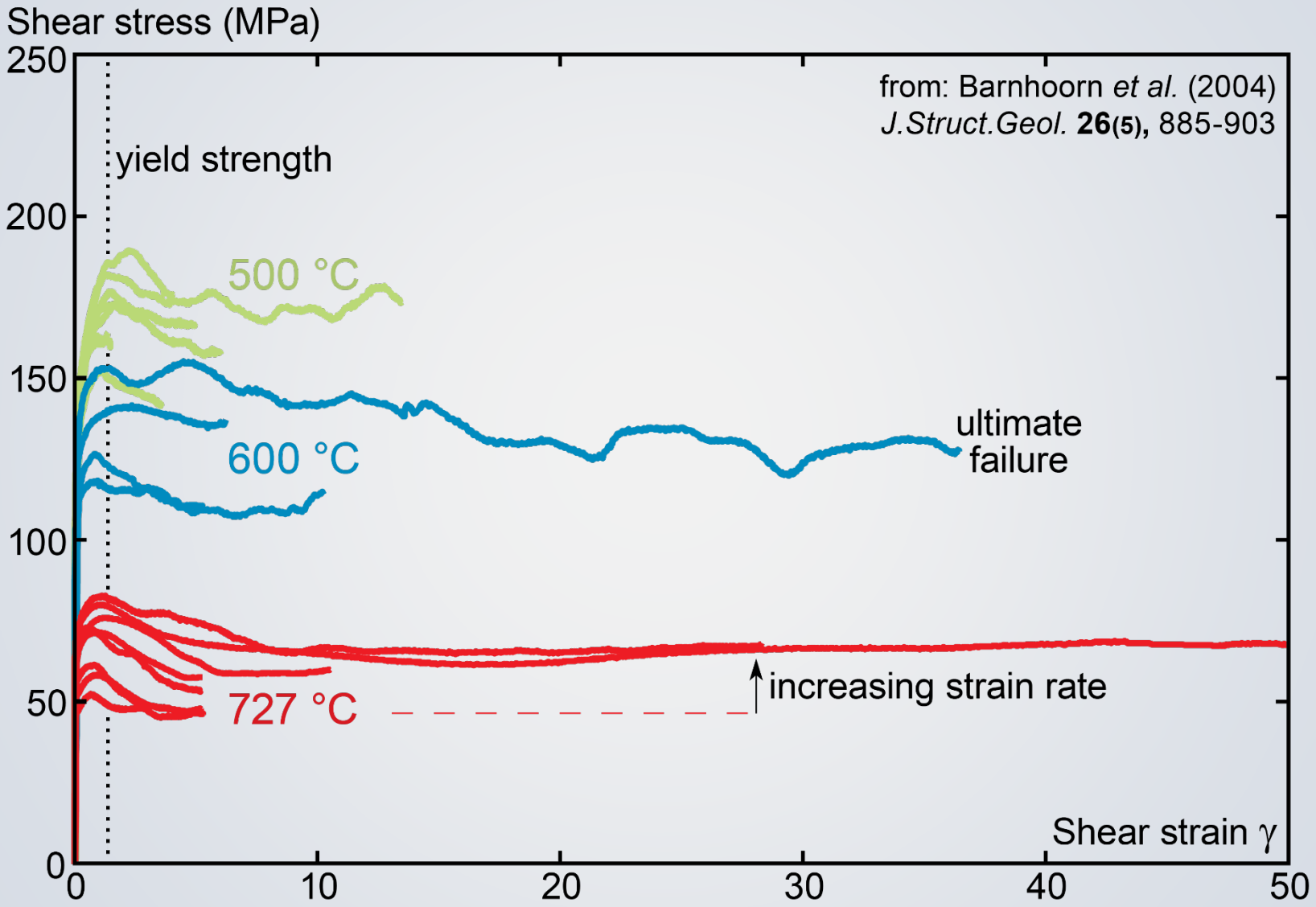
http://www.youtube.com/watch?v=8AKJNK0c7tk

Experimental deformation of rocks

Sketch of a gas-medium deformation rig



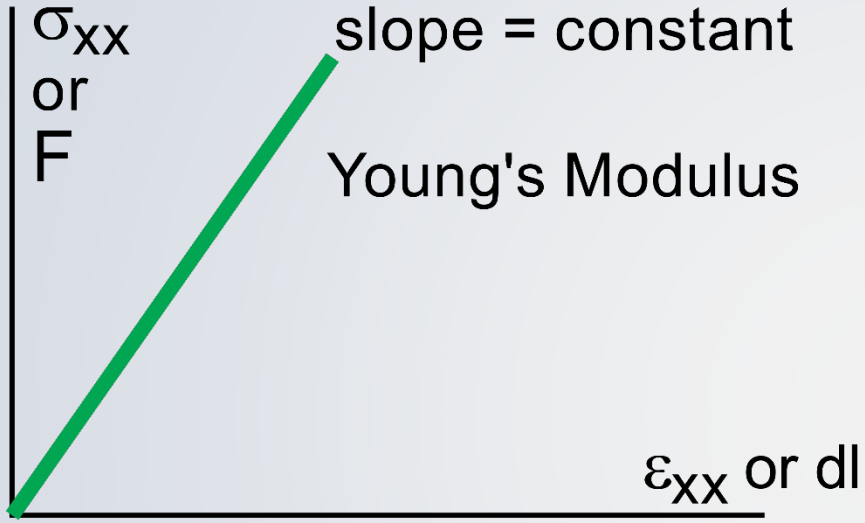
Material behaviour

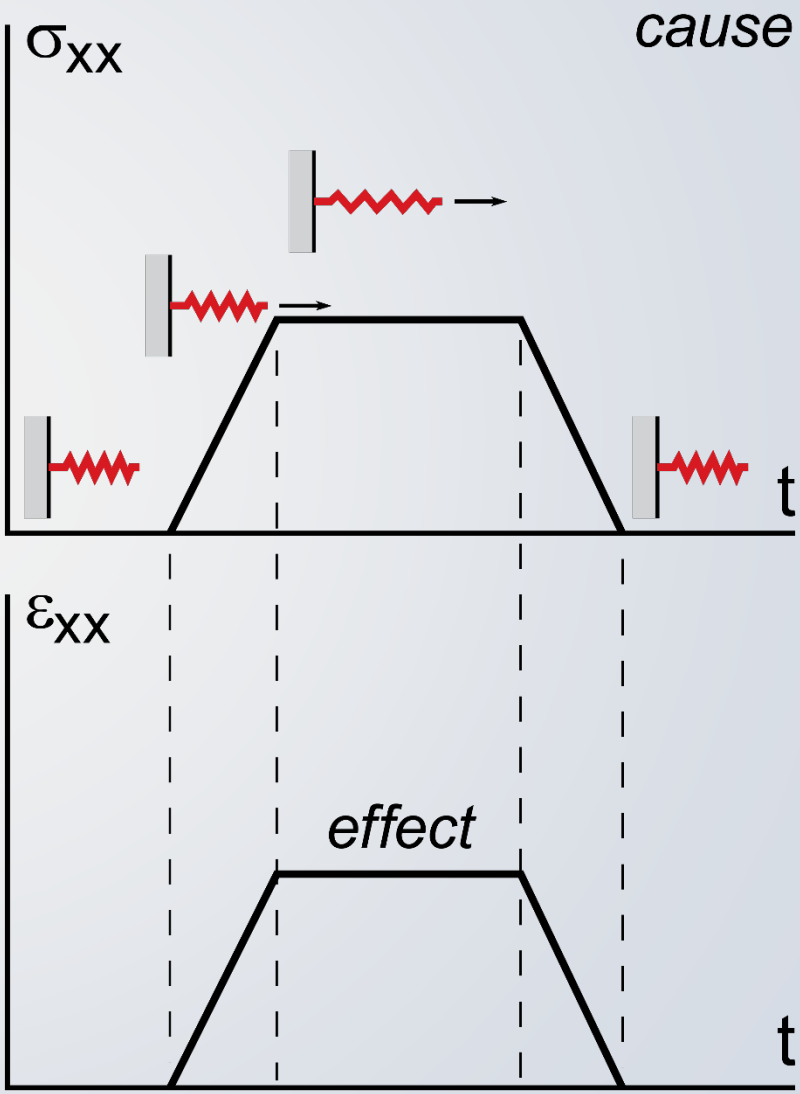


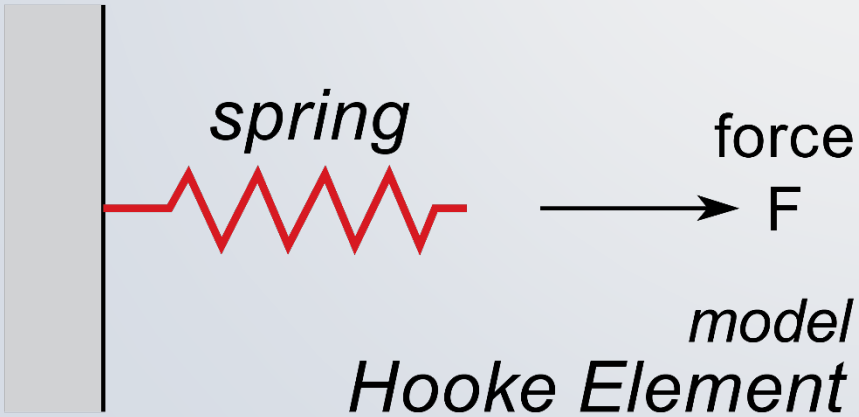
Rheological data from deformation experiments on Carrara marble under constant shear strain rate

Elastic deformation

linear, elastic deformation







Elastic deformation

- No permanent strain i.e. reversible strain

- linear relationship between stress and deformation

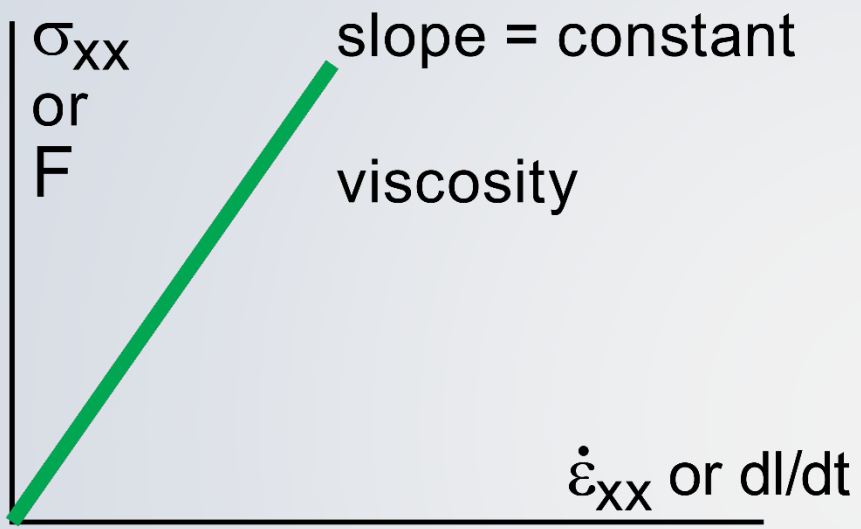
$$\sigma = E\,\varepsilon = E\left(\ell - \ell_0\right)/\ell_0$$

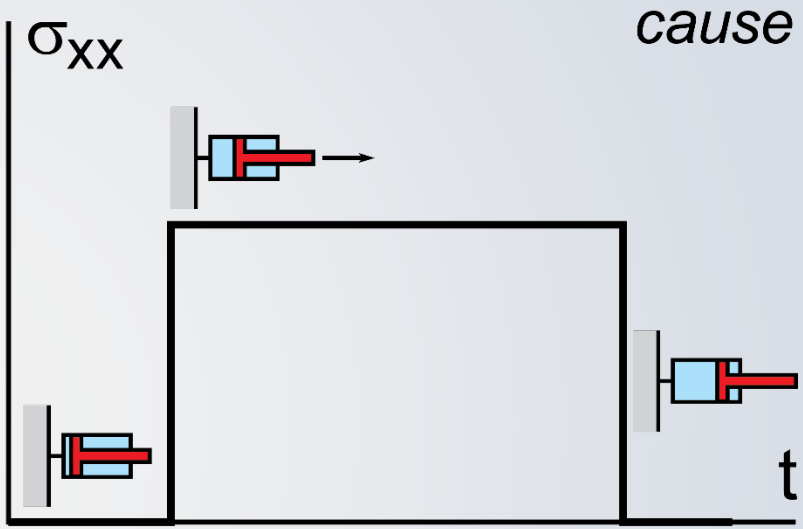
- E = proportionality coefficient

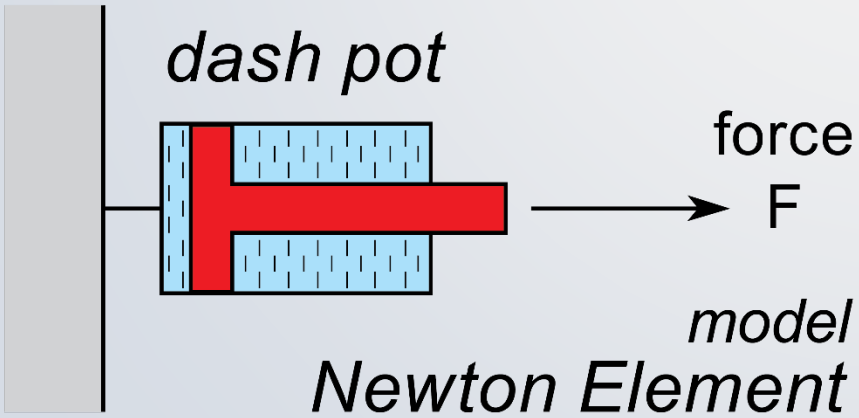
- **Young's** or **Elasticity-Modulus** (same dimensions as stress)

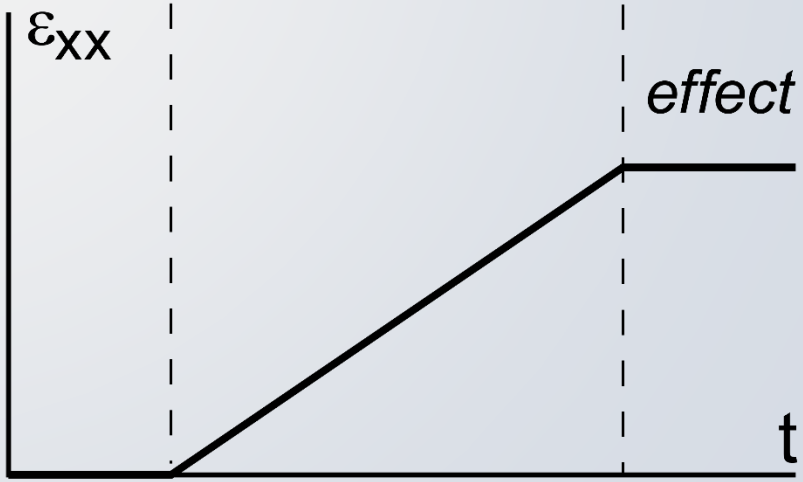
Viscous deformation

ideal, viscous deformation









Viscous deformation

- **Newtonian** or **ideally viscous** materials are able to undergo large and permanent strain whose magnitude depends on time

$$\sigma = \eta \dot{\varepsilon}$$

- Stress is proportional to strain rate; strain is continuous under constant stress

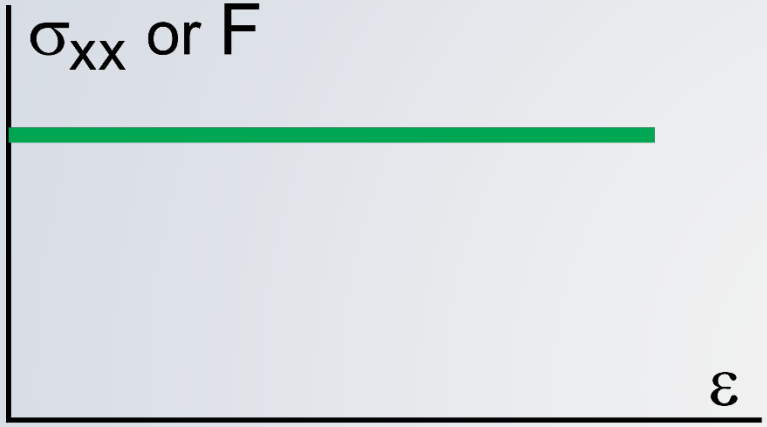
- Proportionality coefficient η = **viscosity**

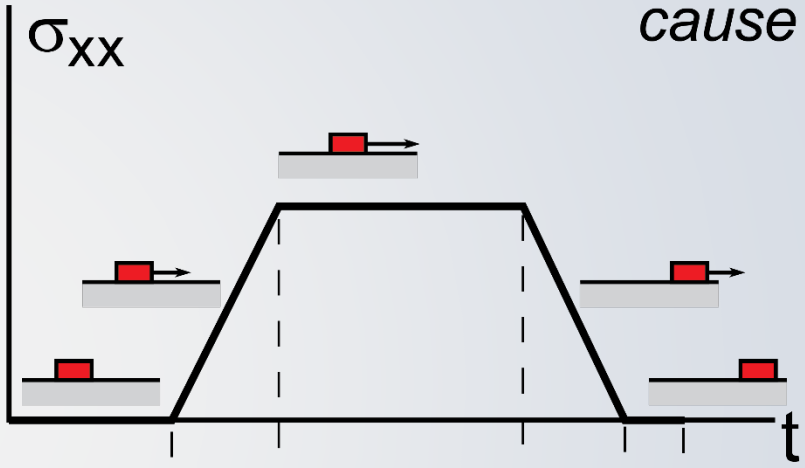
Unit : Poise = Dimension of stress multiplied by time

1 poise = 1 dyne cm^{-2} * 1 second

Plastic deformation

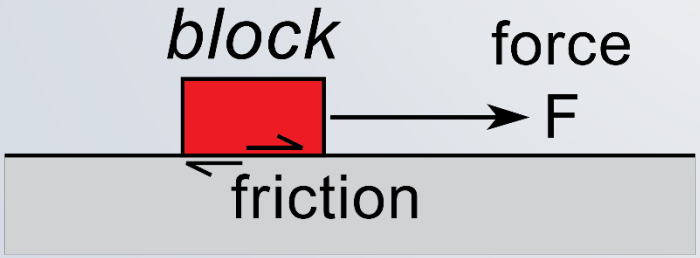
ideal, plastic deformation

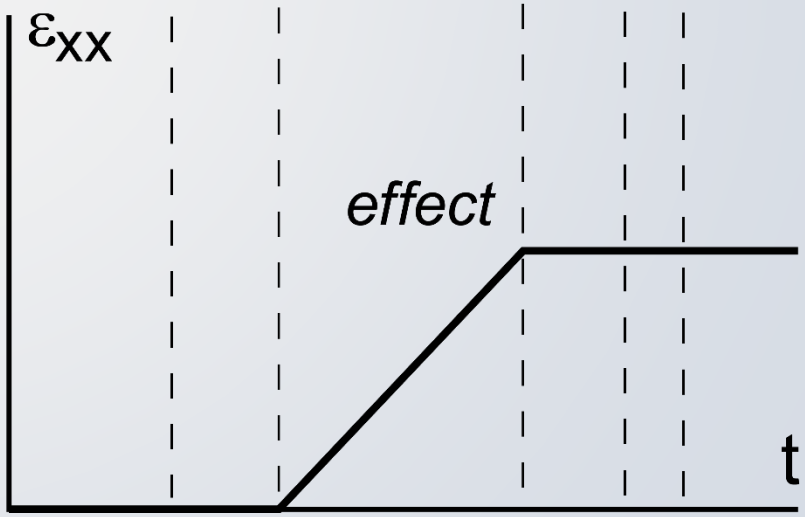




model

Saint-Venant Element

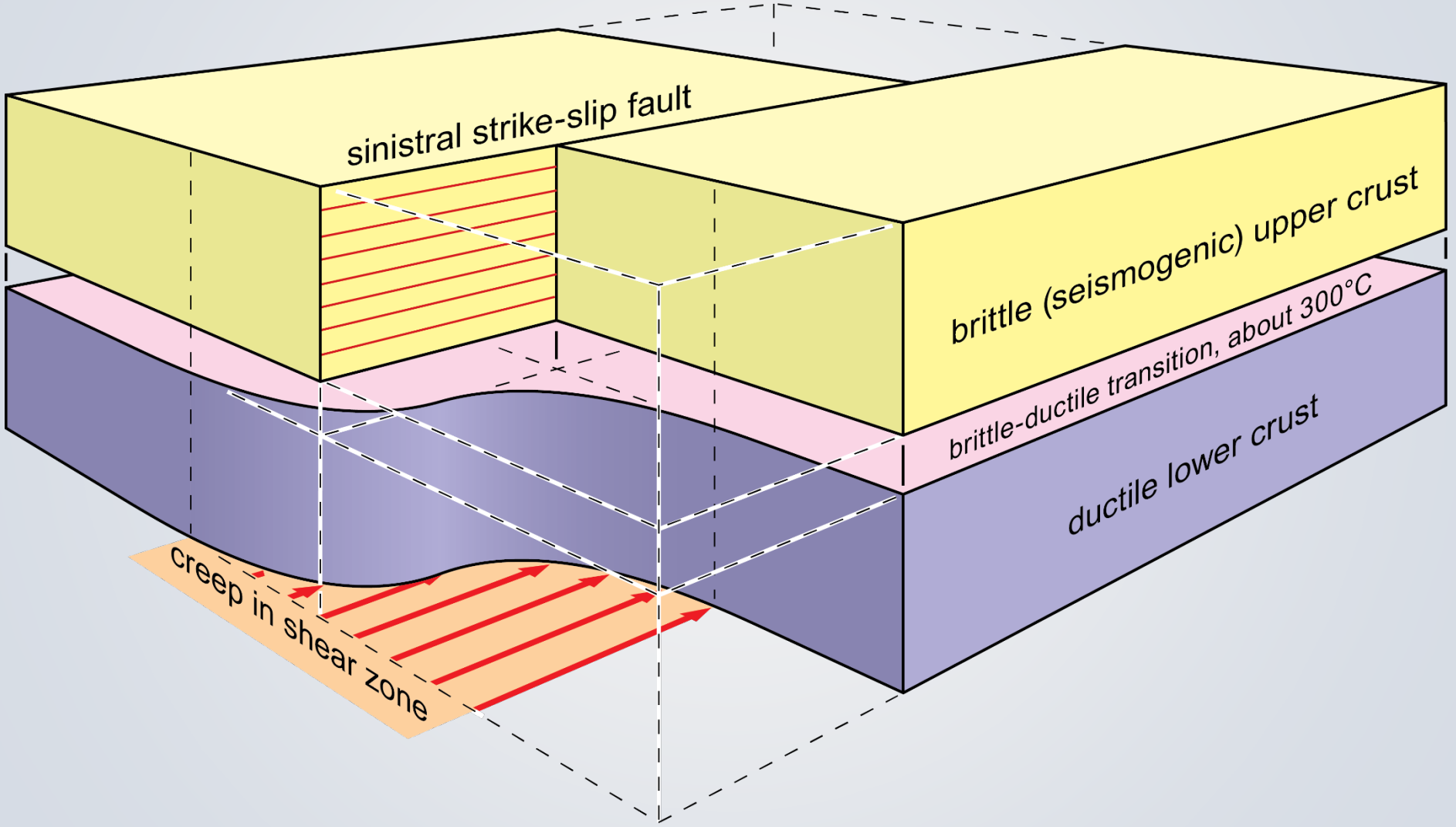




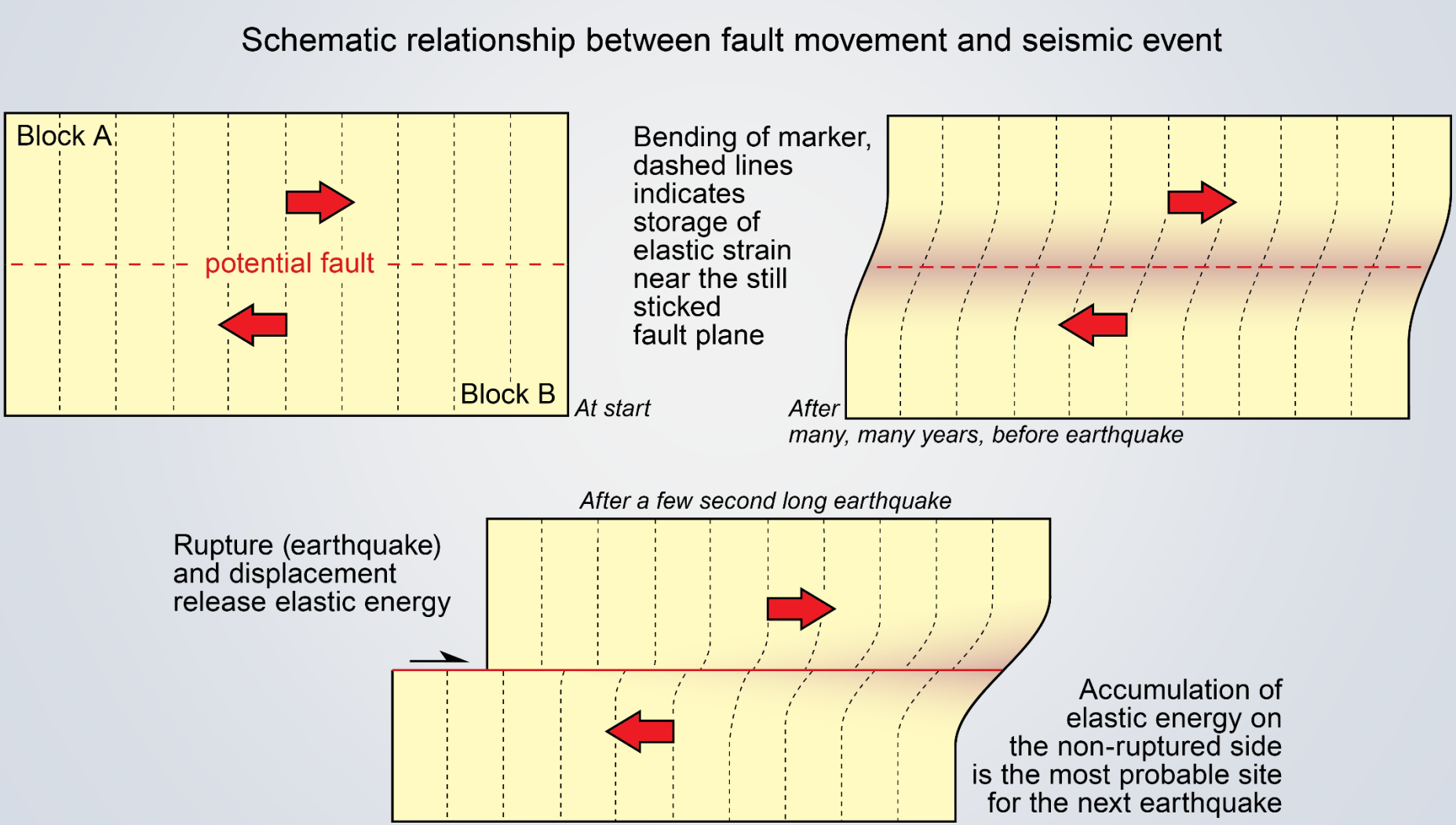
Plastic deformation

- No strain below the **critical stress** or **Yield point**
  - At the **critical stress**, permanent strain.
- The flow stress = a constant (**von Mises criterium**)

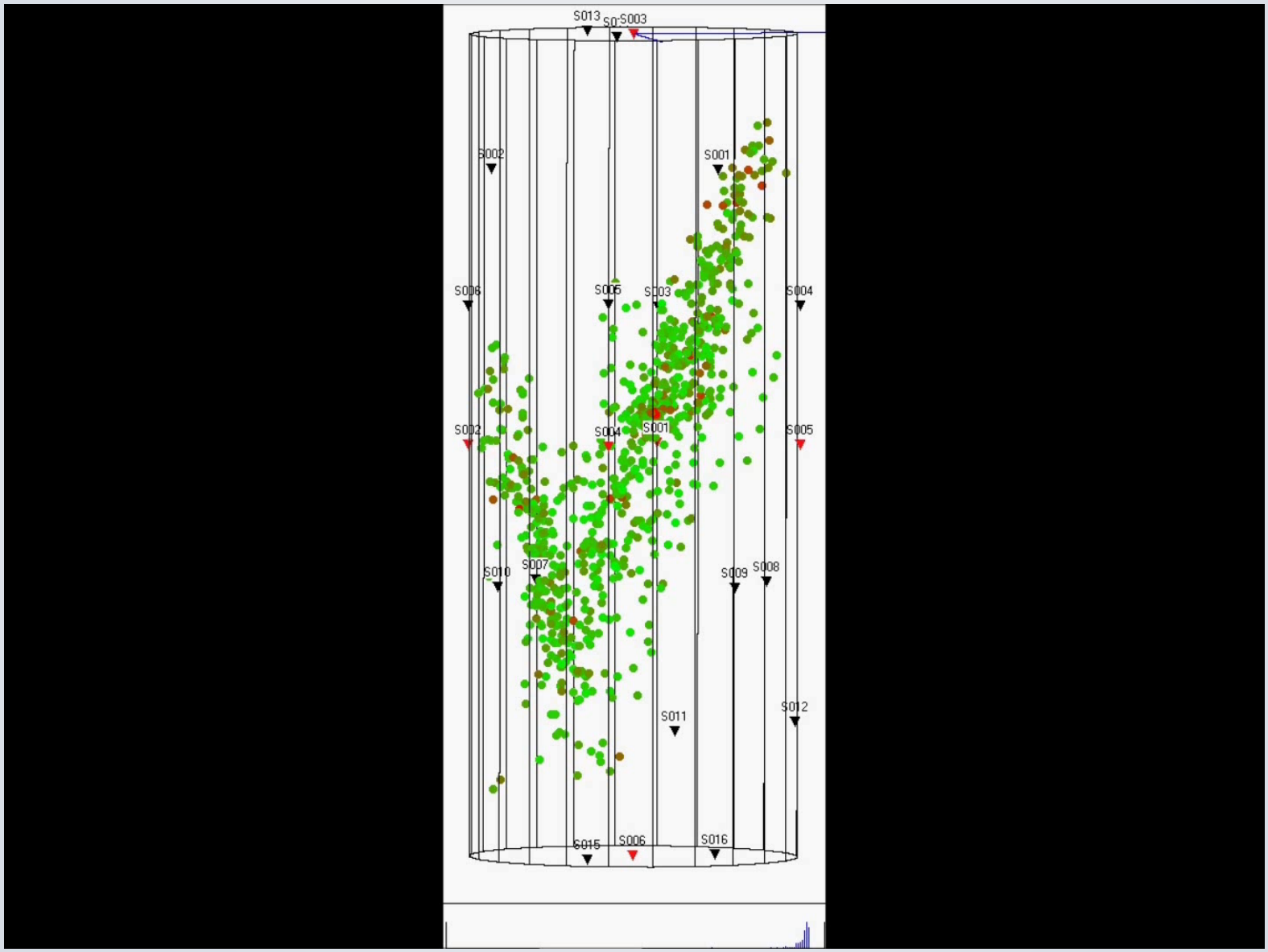
Rocks are elasto-visco-plastic



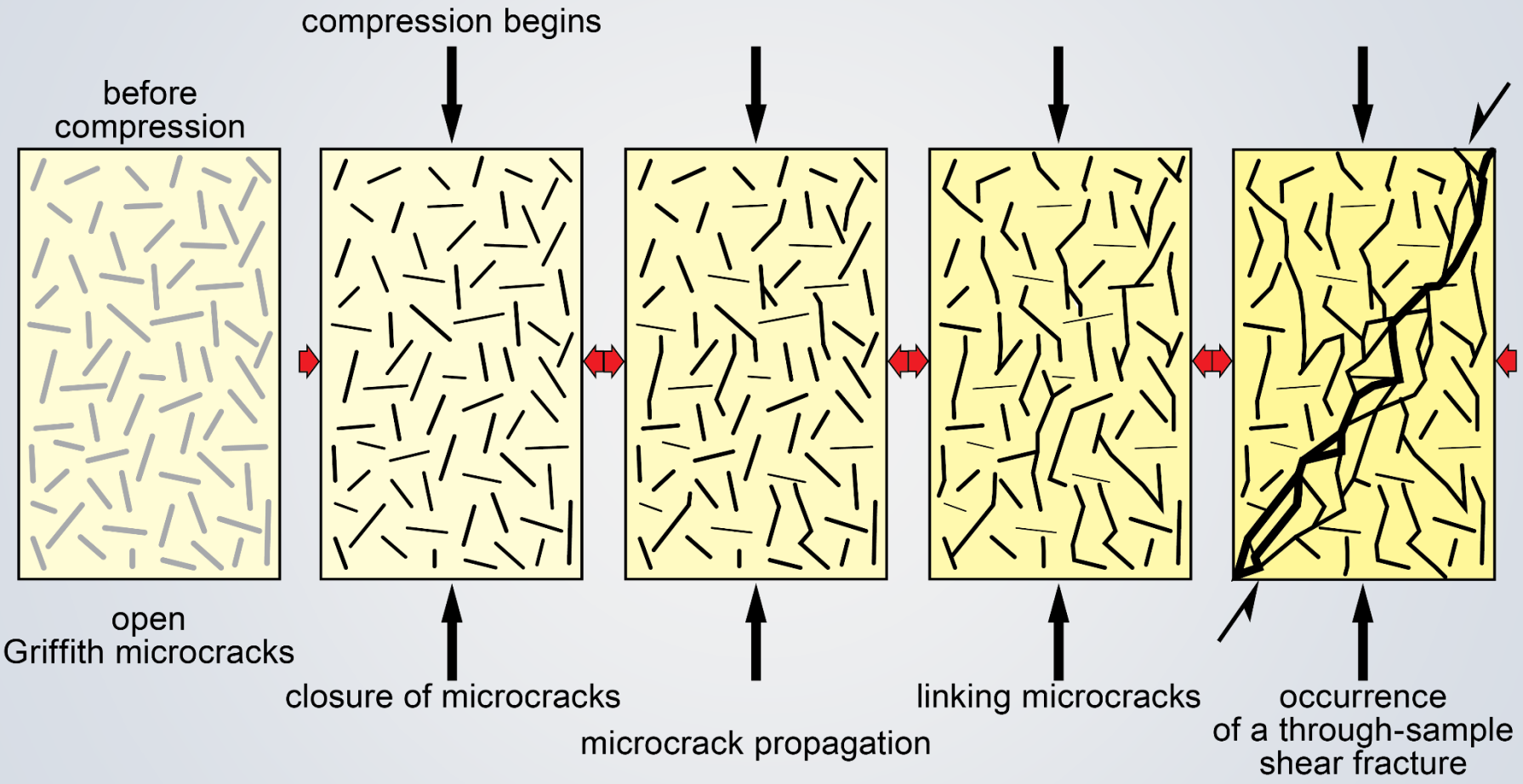
stable/unstable frictional displacement



Experimental faulting (acoustic emission)

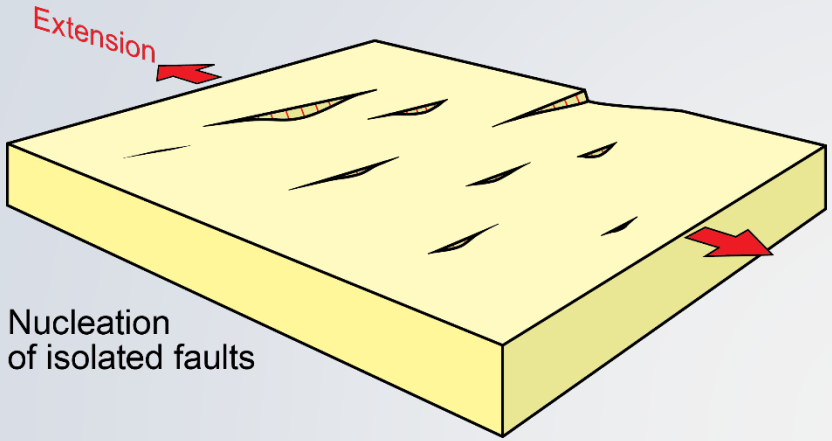


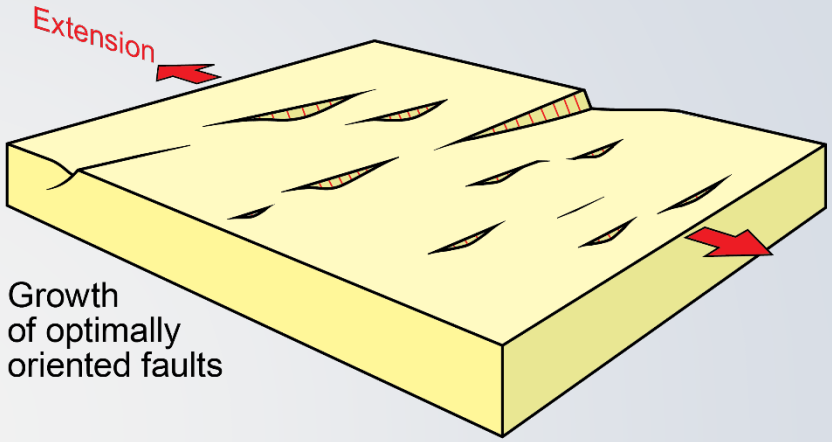
Fault growth

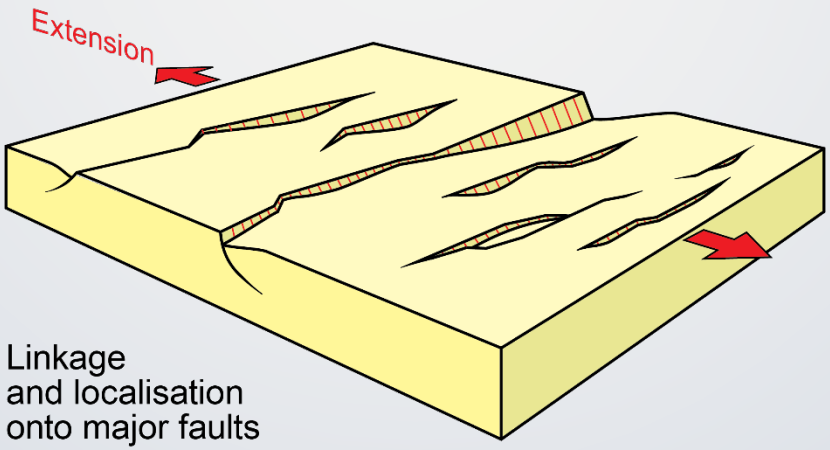


Development of a shear fracture in compression through coalescence of Griffith microcracks

Fault growth







stable/unstable friction gliding

http://earthquake.usgs.gov/research/modeling/animations/

http://www.youtube.com/watch?v=lJ9yjhvjHZw

stable/unstable friction gliding

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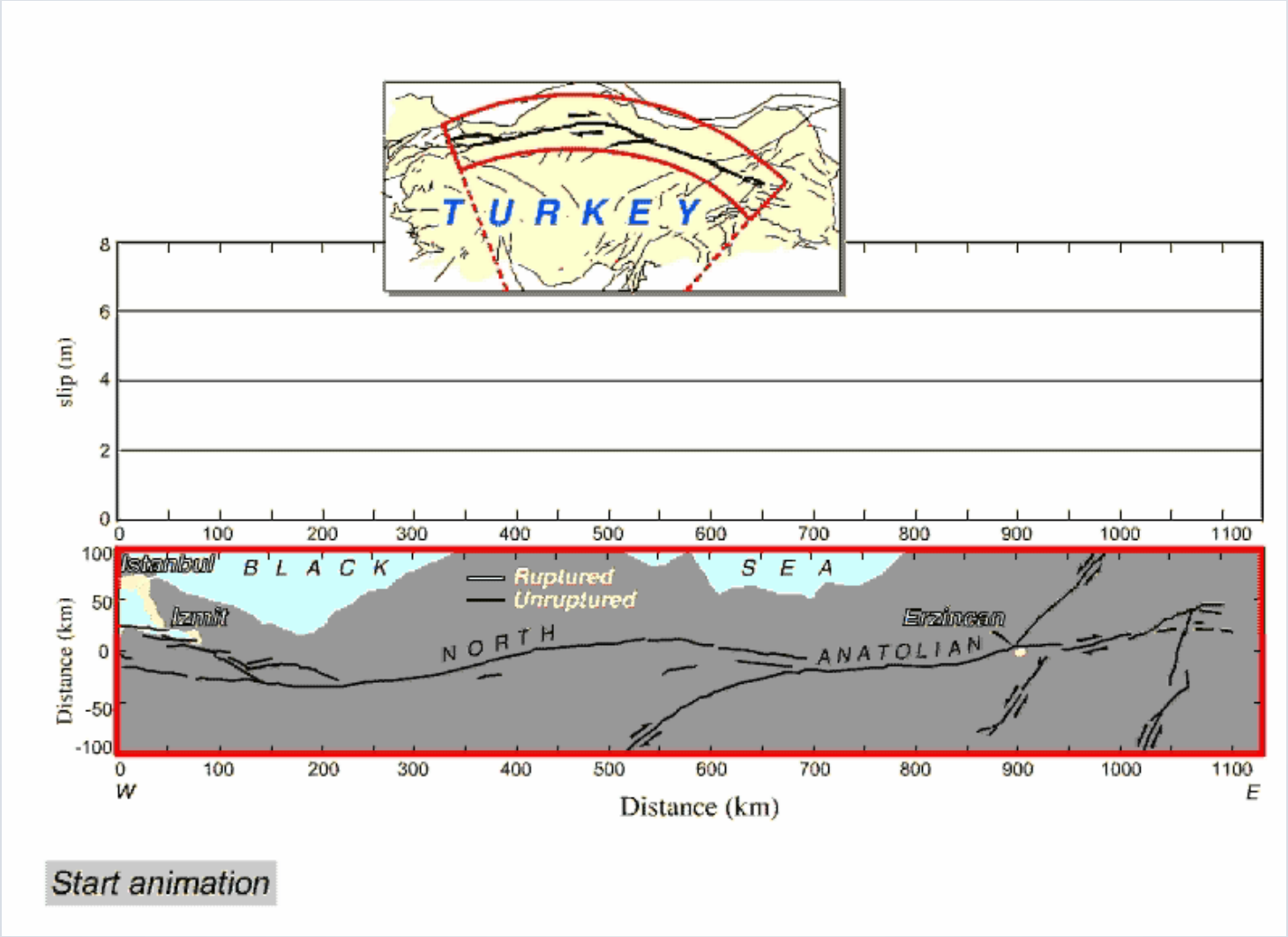
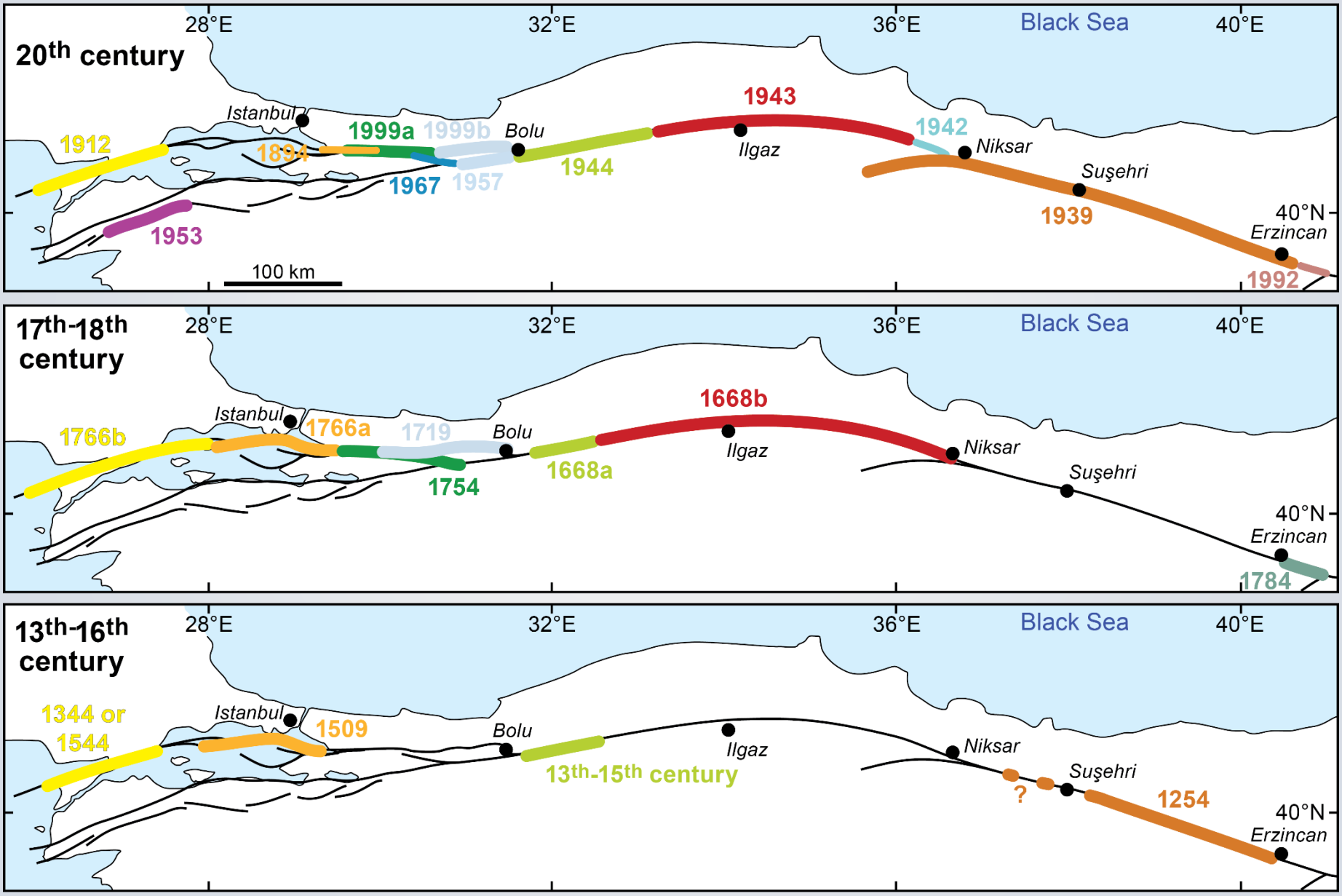


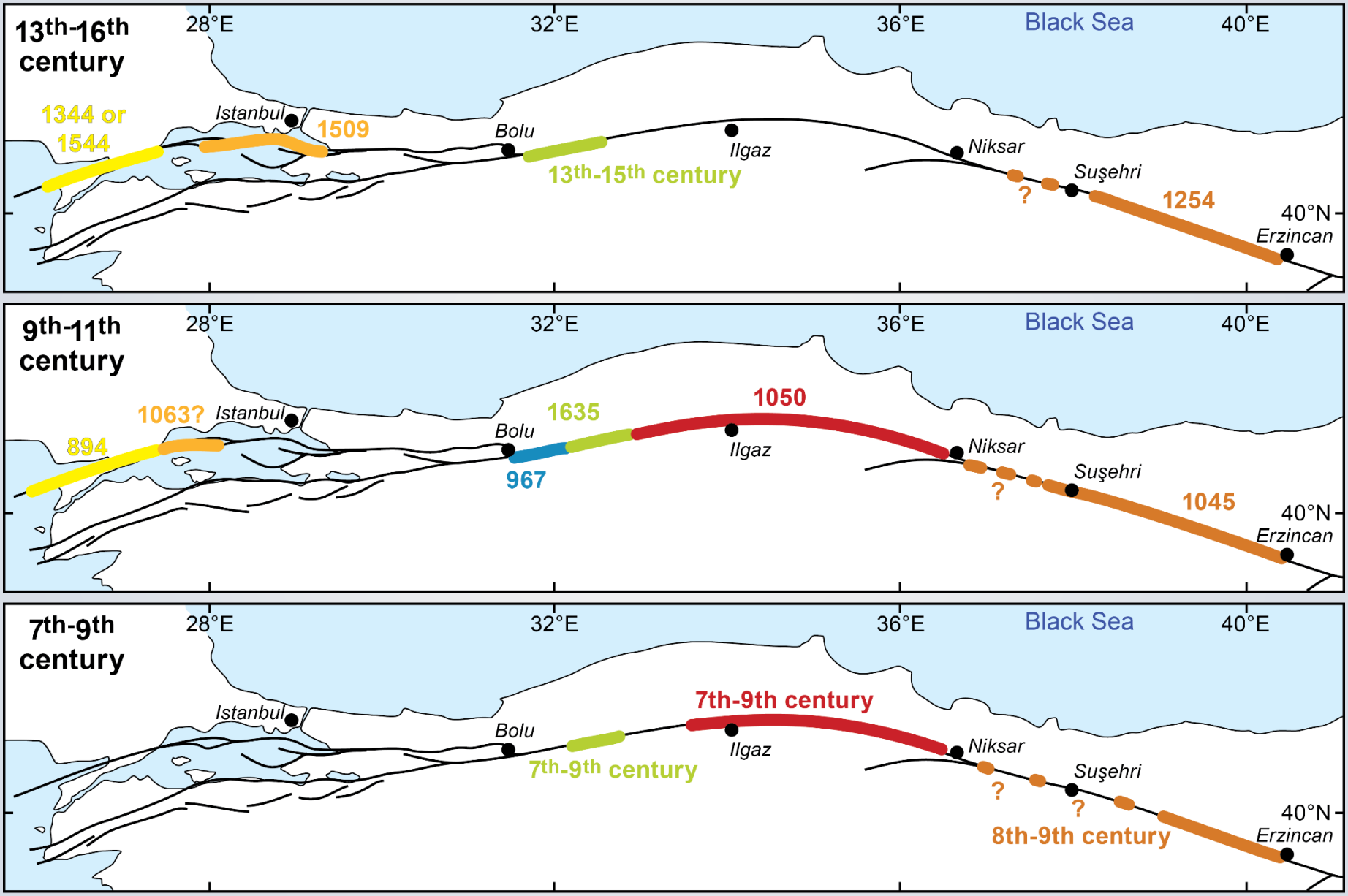
http://www.youtube.com/watch?v=lJ9yjhvjHZw

stable/unstable friction gliding

Paleoseismic record of large earthquakes along the North Anatolian Fault

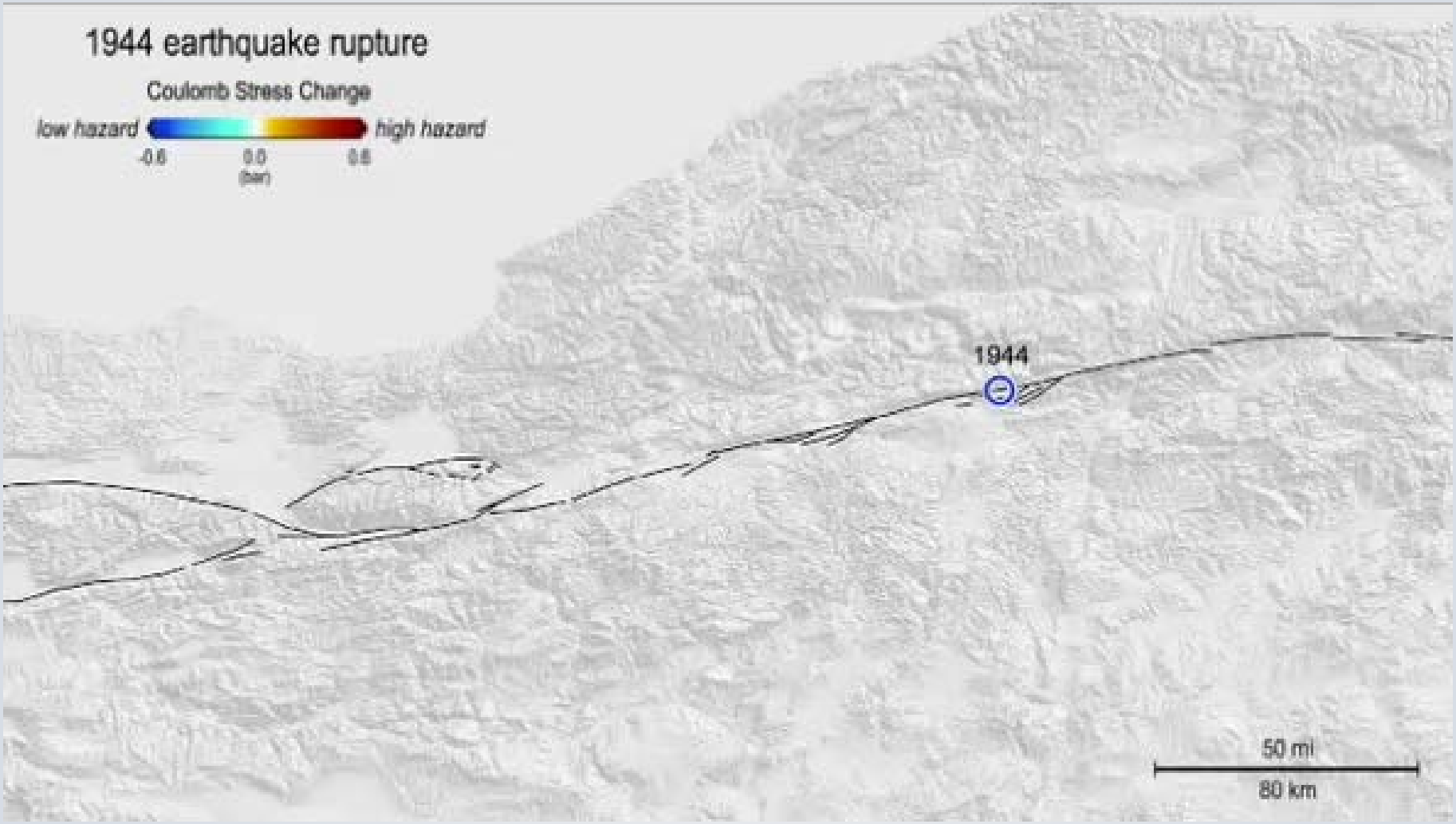


stable/unstable friction gliding

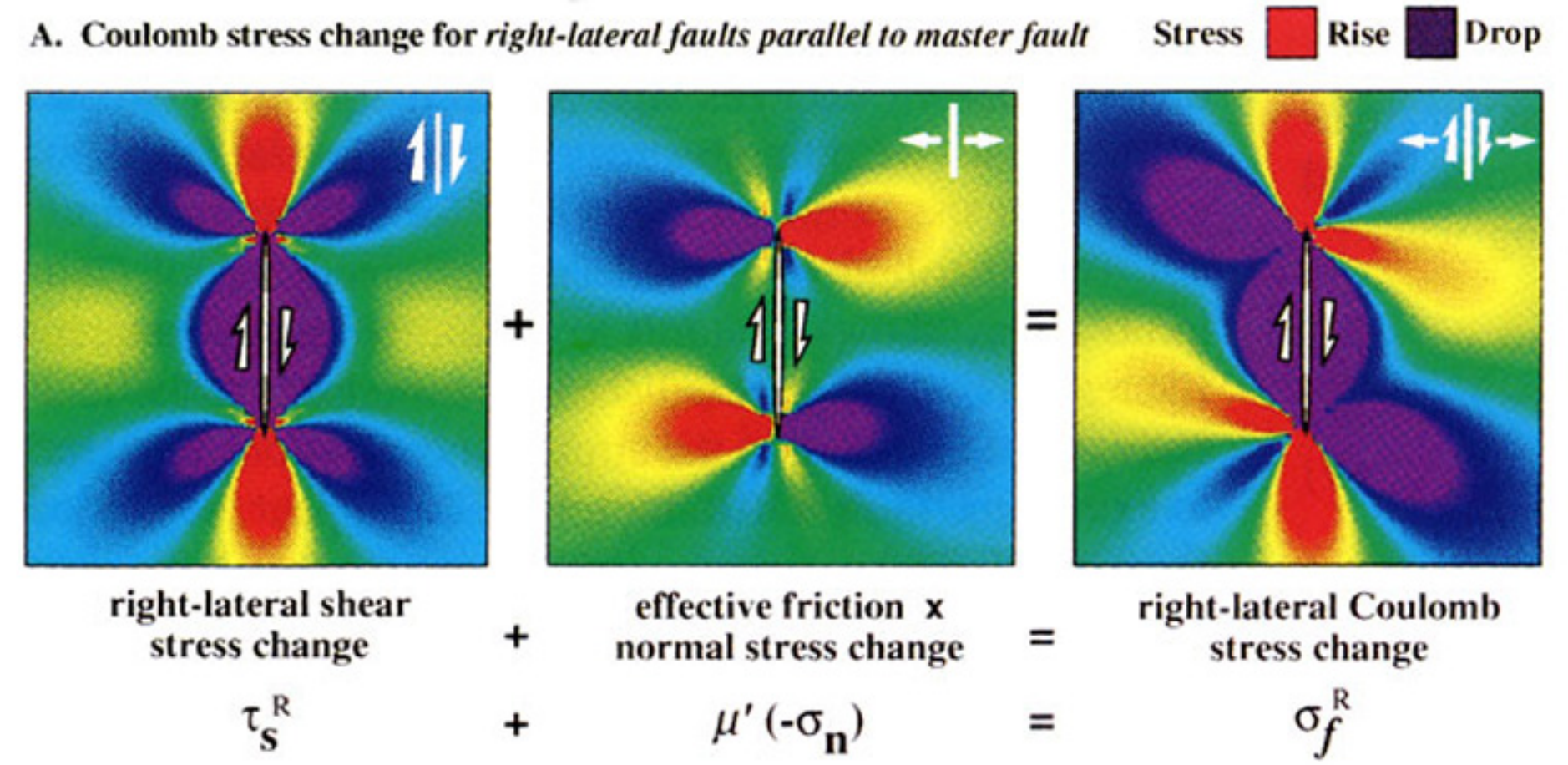


Modified after Kozaci *et al.* 2011 *Lithosphere* **3** 37-54 *doi: 10.1130/L118.1*

Fault propagation



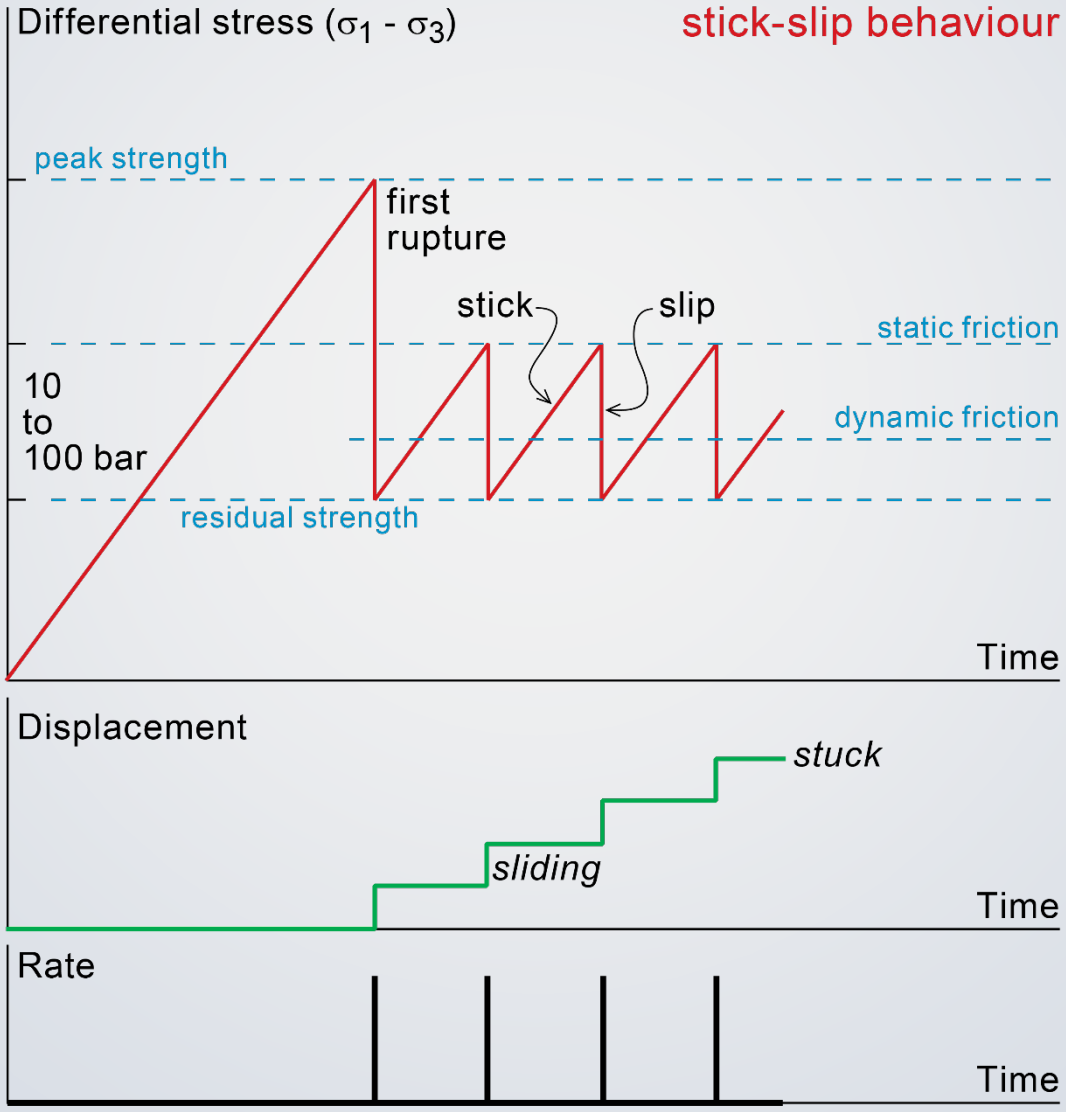
Coulomb stresses



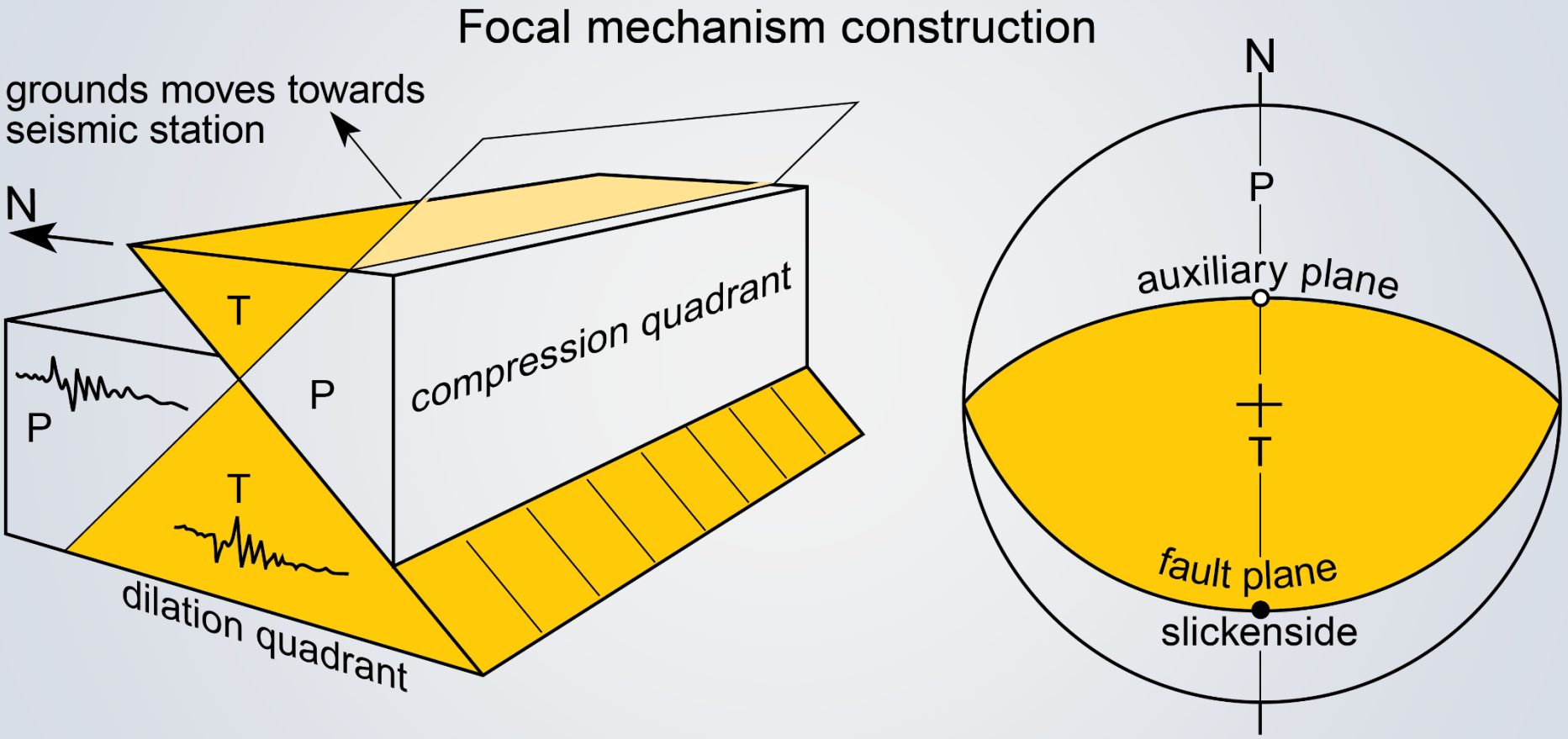
https://pangea.stanford.edu/projects/structural_geology/chapters/chapter09/chap09_figures.html

stable/unstable friction gliding

Idealised relationship between stress and displacement
for initial shear failure and
subsequent unstable shear movement on the fault surface



Focal mechanisms

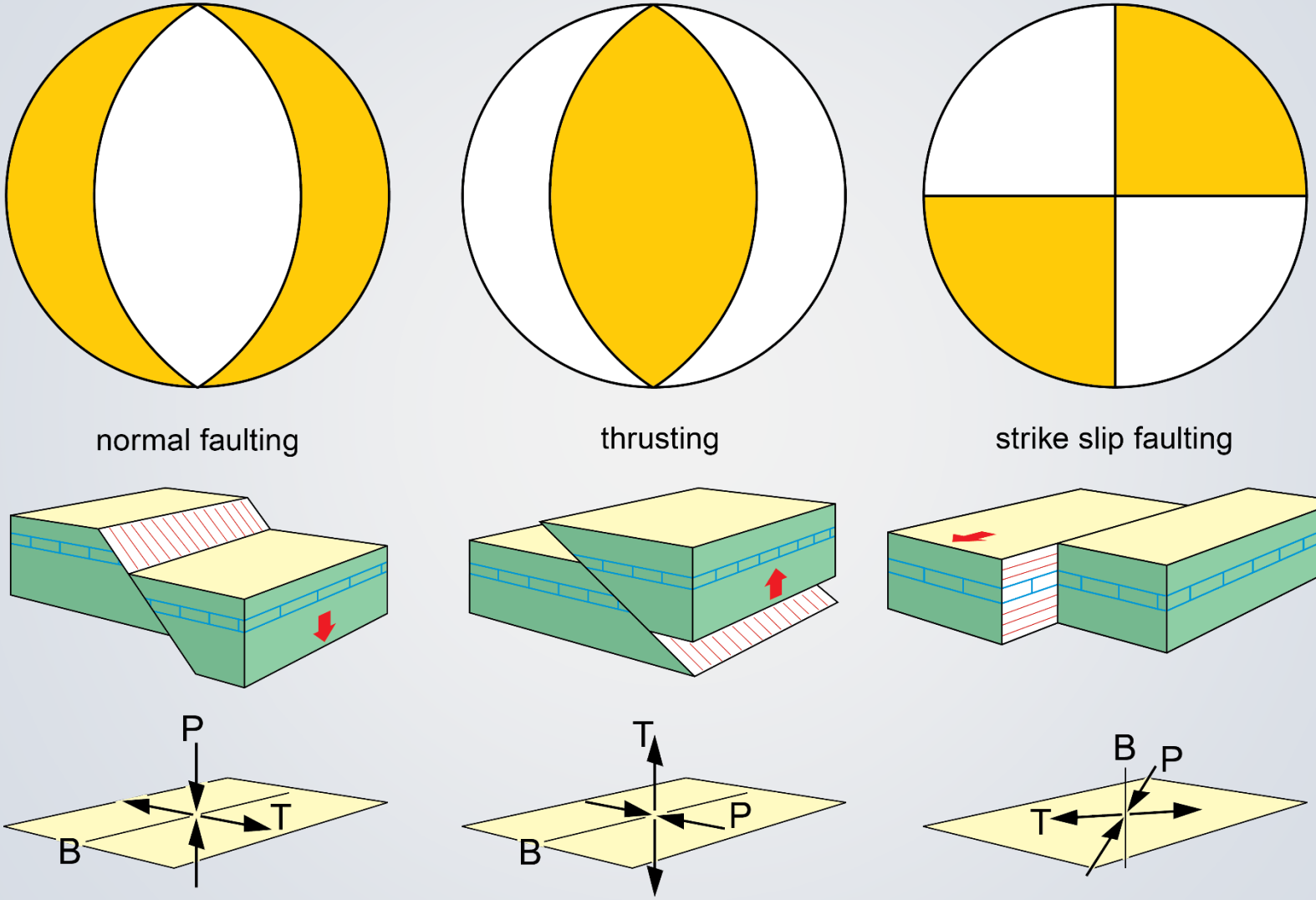


Thrust-fault with P- and T-quadrants and first motion seismograms and associated, lower hemisphere stereographic projection

first motion up = push away from epicenter; first motion down= pull toward epicenter

Focal mechanisms

representative focal mechanisms



Orientation of the principal stresses
P (maximum, compression) T(minimum, extension) and B (intermediate)

Faults at plate boundaries