Imaging shear strength along subduction faults

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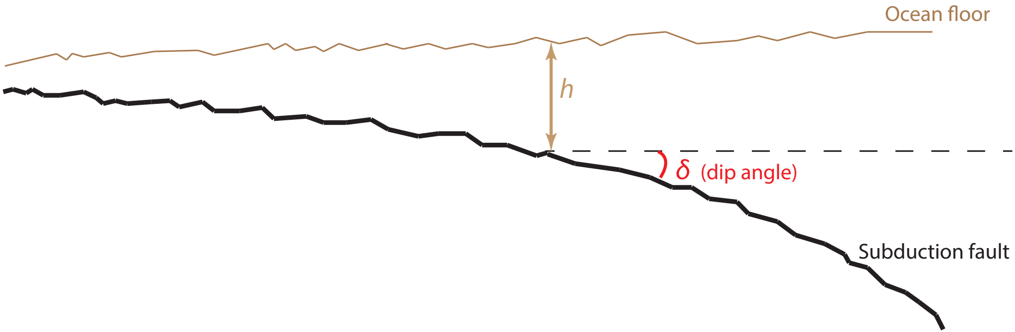
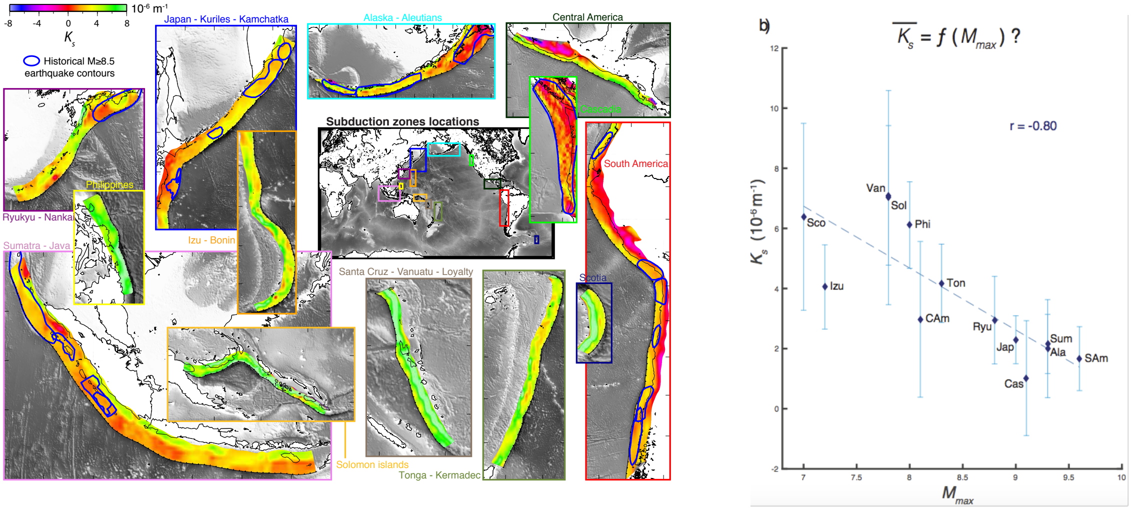
Subduction faut



Mega-earthquakes rupture planar megathrusts (K_s : dip angle gradient)



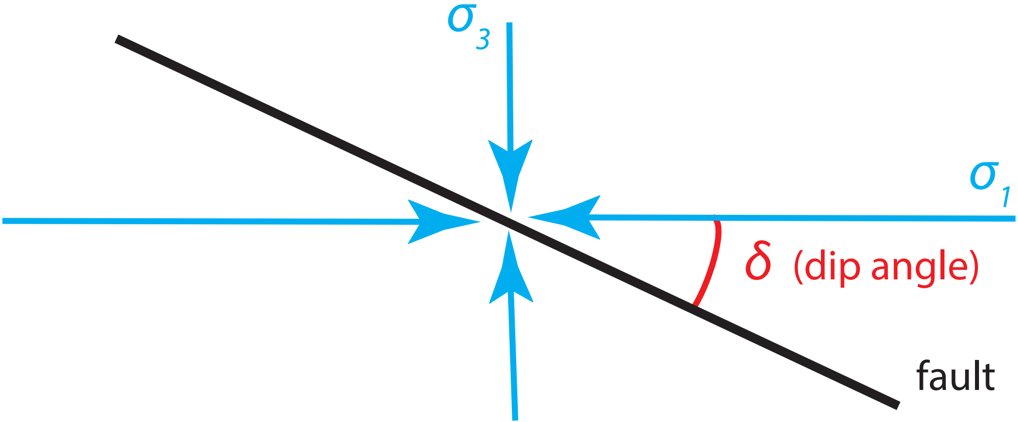
Bletery et al., *Science*, 2016

Control of geometry on the distribution of shear strength ?

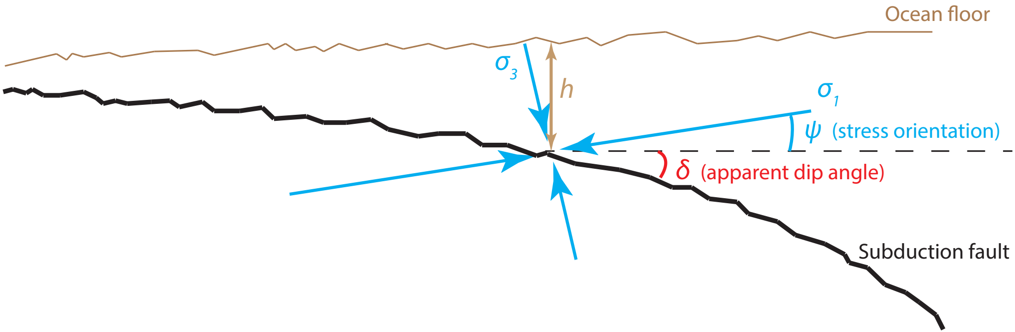
$$\tau^c = \mu(\sigma_n - p)$$

τ^c shear strength
μ coefficient of friction
σ_n normal stress
p pore fluid pressure

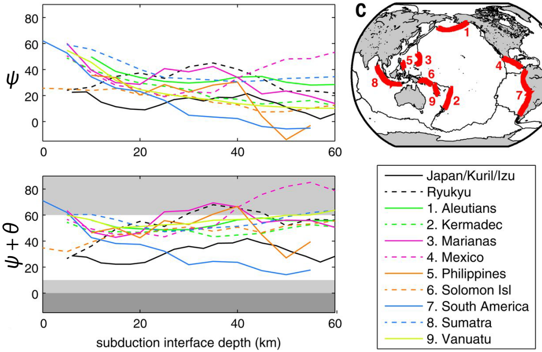
Andersonian theory of faulting



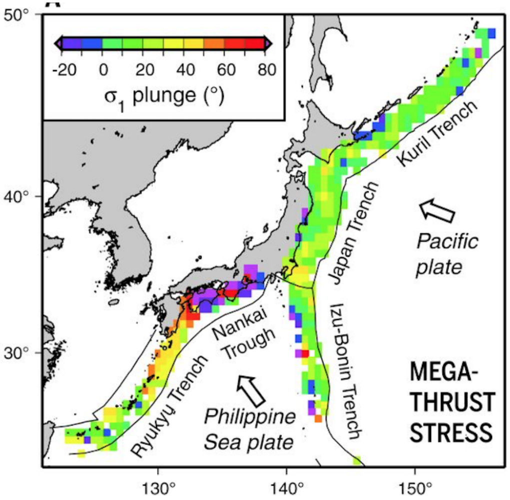
Subduction model



Stress orientation (ψ) on subduction zones



Hardebeck, *Science*, 2015



Hardebeck, *Science*, 2015

Analytic derivation of the shear strength τ^c

$$\boldsymbol{\sigma} = \begin{pmatrix} \sigma_{zz} + \Delta\sigma & \frac{\Delta\sigma}{2}\tan 2\psi \\ \frac{\Delta\sigma}{2}\tan 2\psi & \sigma_{zz} \end{pmatrix}$$

$$=> \begin{cases} \sigma_n = (\boldsymbol{\sigma} \cdot n) \cdot n = \sigma_{zz} + \frac{\Delta\sigma}{2}(1 - \cos 2\delta + \tan 2\psi \sin 2\delta) \\ \tau = (\boldsymbol{\sigma} \cdot n) \cdot s = -\frac{\Delta\sigma}{2}(\sin 2\delta + \tan 2\psi \cos 2\delta) \end{cases}$$

$$|\tau^c| = \mu(\sigma_n^c - p) \text{ (Mohr-Coulomb failure criterion)}$$

$$\boxed{\tau^c = \frac{\mu(\sigma_{zz} - p)\sin(2\delta + 2\psi)}{\sin(2\delta + 2\psi) + \mu[\cos(2\delta + 2\psi) - \cos 2\psi]}}$$

τ^c : shear strength
μ : coefficient of friction
σ_{zz} : vertical stress
p : pore fluid pressure
δ : apparent dip angle
ψ : stress field orientation

Numerical computation

$$\text{Assumptions}: \begin{cases} \sigma_{zz} = \rho g h & \text{Pressure of the upper plate} \\ p = \rho_w g h & \text{Hydrostatic pore pressure} \end{cases}$$

$$\tau^c = \frac{\mu(\rho - \rho_w) g h \sin(2\delta + 2\psi)}{\sin(2\delta + 2\psi) + \mu(\cos(2\delta + 2\psi) - \cos 2\psi)}$$

$$\delta = \arctan(\sin(\phi - \lambda) \tan\theta)$$

μ : coefficient of friction

ρ : bulk density of the crust

ρ_w : bulk density of water

g : gravity acceleration

δ : apparent dip angle

h : depth (slab1.0 + ETOPO2 models)

ϕ : strike angle (slab1.0)

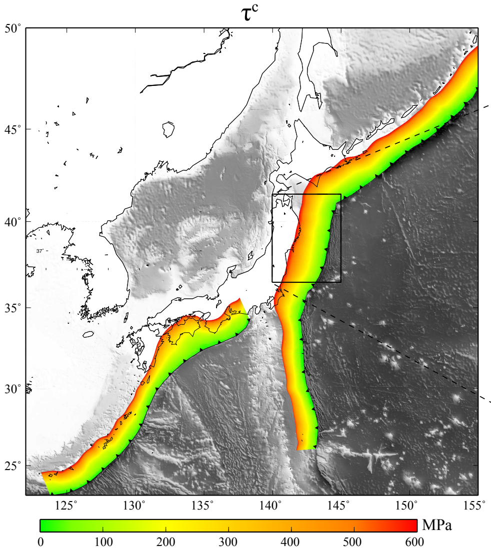
θ : dip angle (slab1.0)

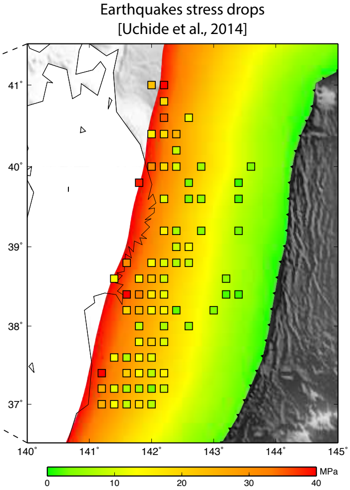
λ : convergence direction (NNR-MORVEL56)

ψ : stress field orientation (Hardebeck, *Science*, 2015)

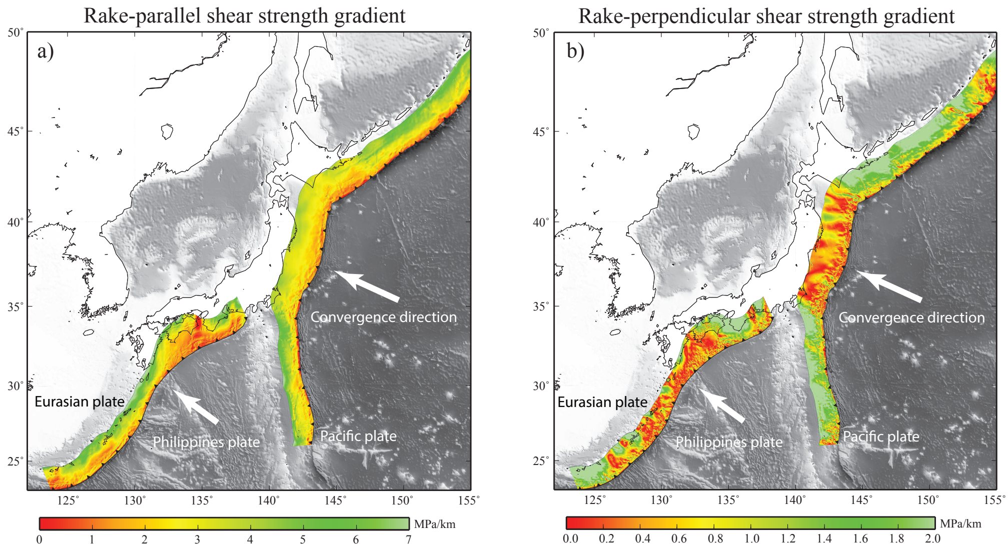
$$g = 9.8\mathrm{m/s}^2,\ \rho = 2700\mathrm{kg/m}^3,\ \rho_w = 1000\mathrm{kg/m}^3,\ \mu = 0.6$$

Computed shear strength

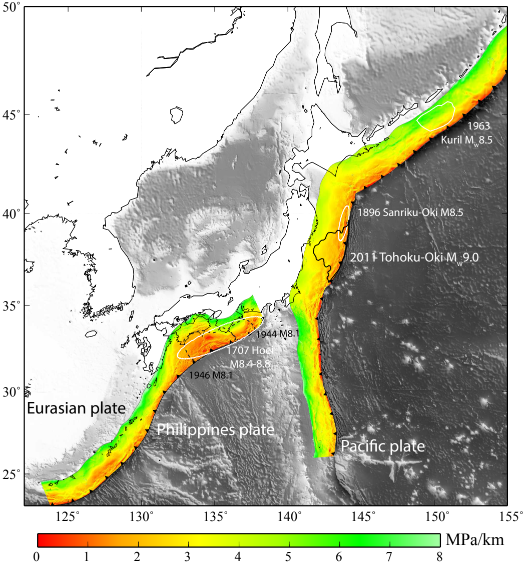




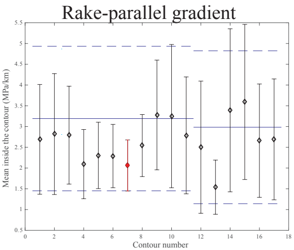
Shear-strength gradient

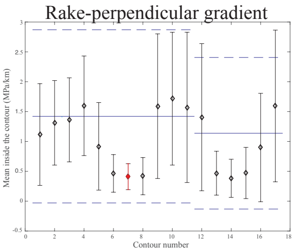


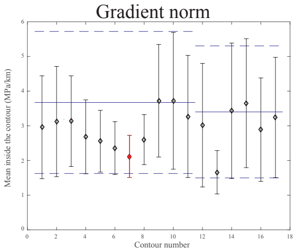
Norm of the shear-strength gradient

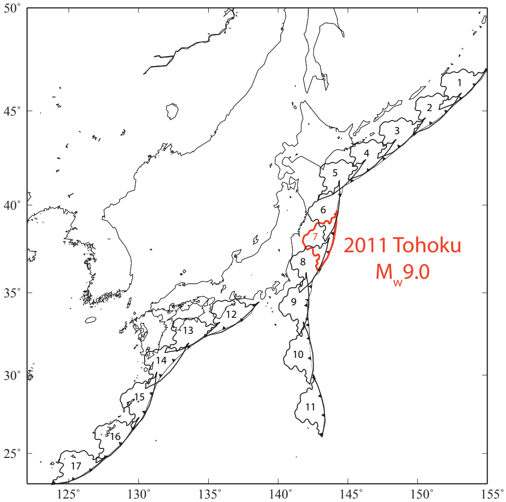


Mega-earthquakes occur on areas of homogeneous τ^c (i.e. low τ^c gradient)









Conclusions

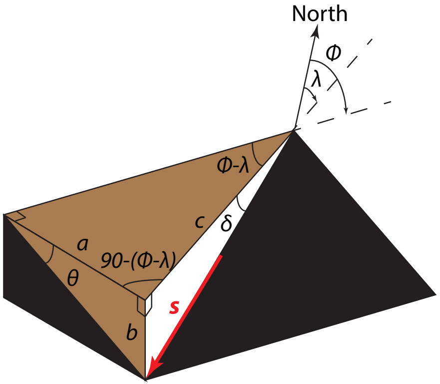
Variations of the shear strength (τ^c) may be estimated along subduction faults.

Mega-earthquakes seem to occur on areas of homogeneous shear strength.

Limitations : hydrostatic pore pressure $p = \rho_w gh$ and constant μ assumptions
possible larger variations of ψ at small scale.

Perspectives : explore different pore pressure laws and variable coefficient of friction.
Other subduction faults.

Apparent dip angle



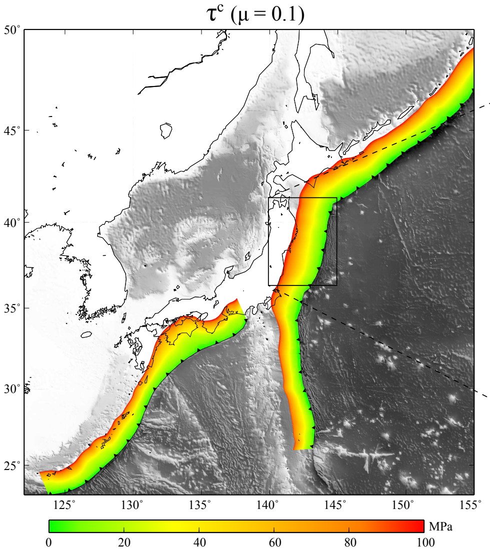
$$\delta = \arctan[\sin(\phi - \lambda)\tan\theta]$$

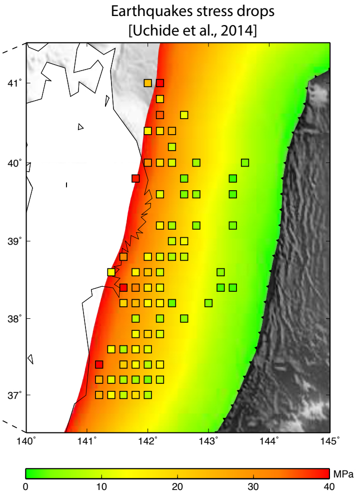
$$a = c\sin(\phi - \lambda)$$
$$b = a\tan\theta$$
$$b = c\tan\delta$$

$$c\tan\delta = a\tan\theta$$

$$\tan\delta = \sin(\phi - \lambda)\tan\theta$$

Computed shear strength assuming $\mu = 0.1$ instead of $\mu = 0.6$





Mega-earthquakes occur on areas of homogeneous τ^c ($\mu = 0.1$)