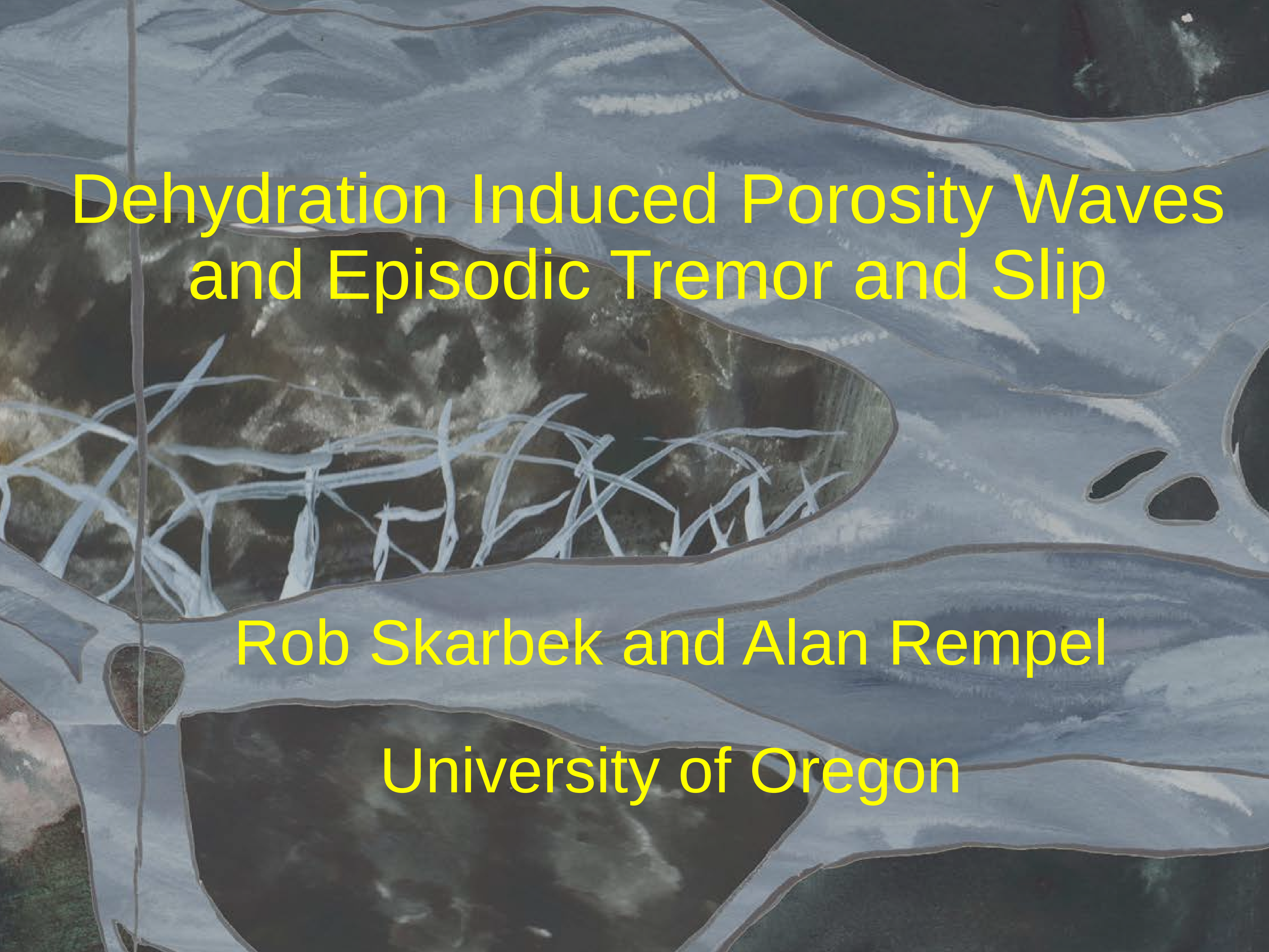
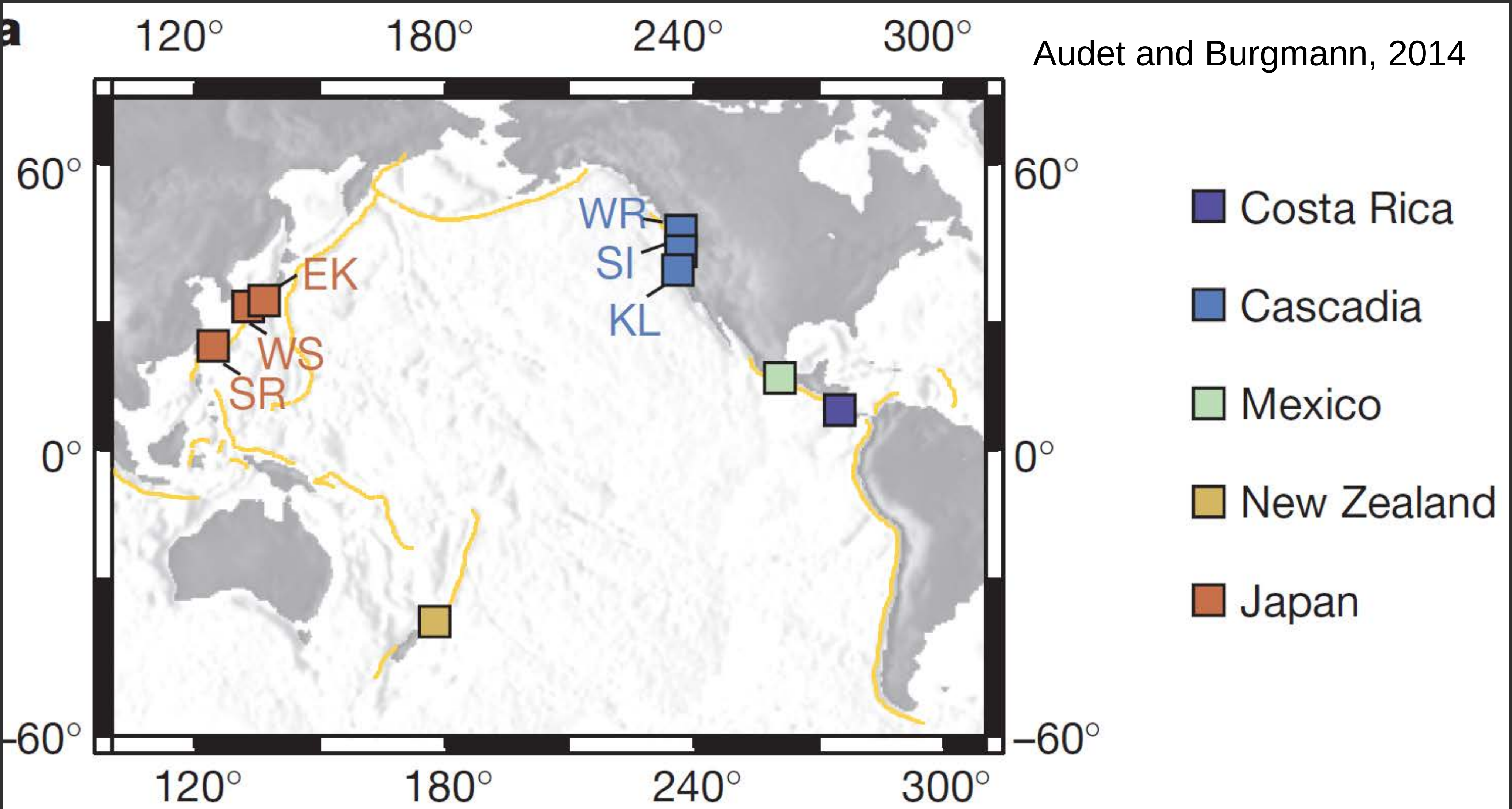


Dehydration Induced Porosity Waves and Episodic Tremor and Slip

Rob Skarbek and Alan Rempel

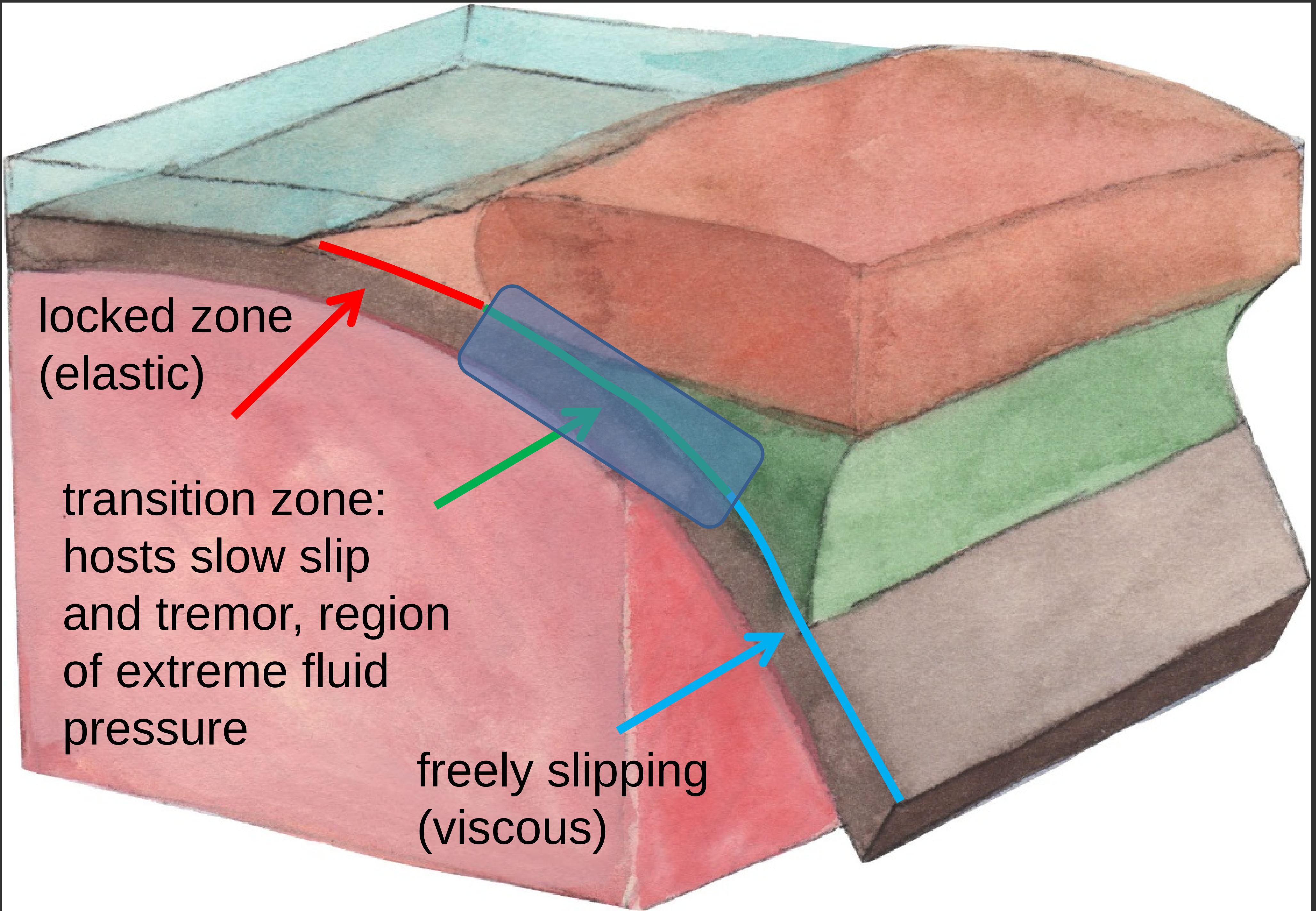
University of Oregon

Slow Slip and Tremor Around the World

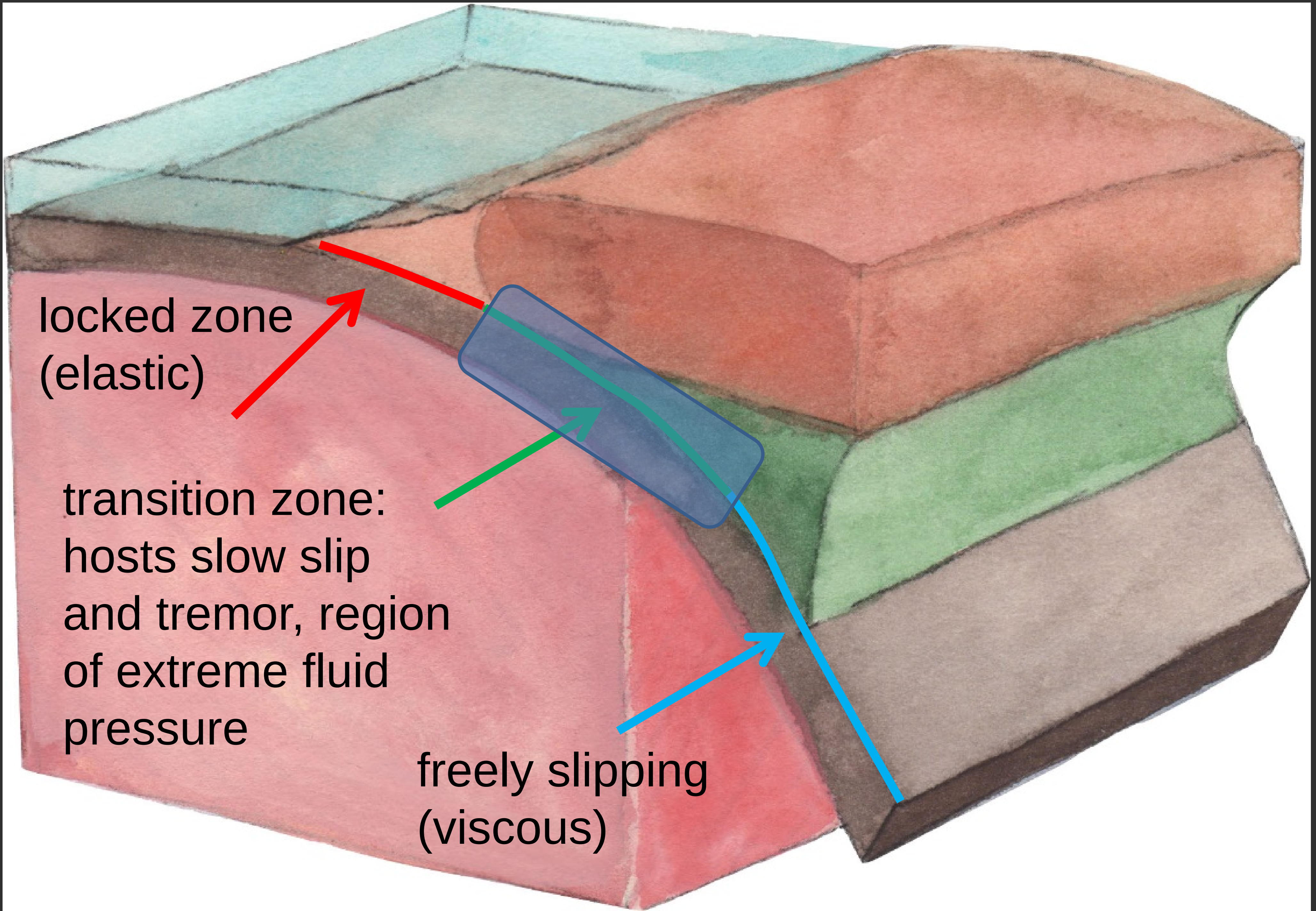


Recurrence interval ~1 to 10 years

Slow Slip in Subduction Zones



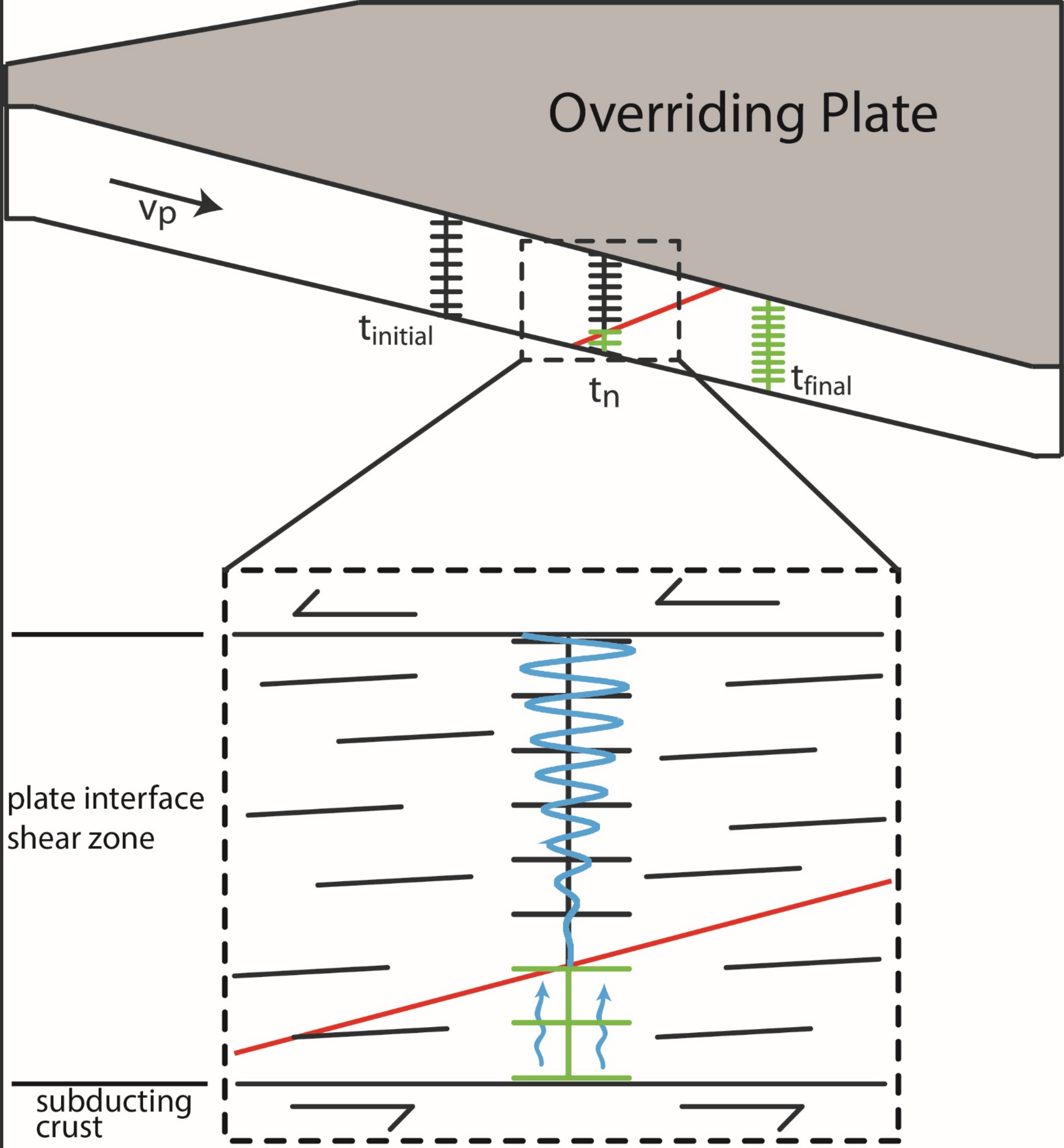
Slow Slip in Subduction Zones



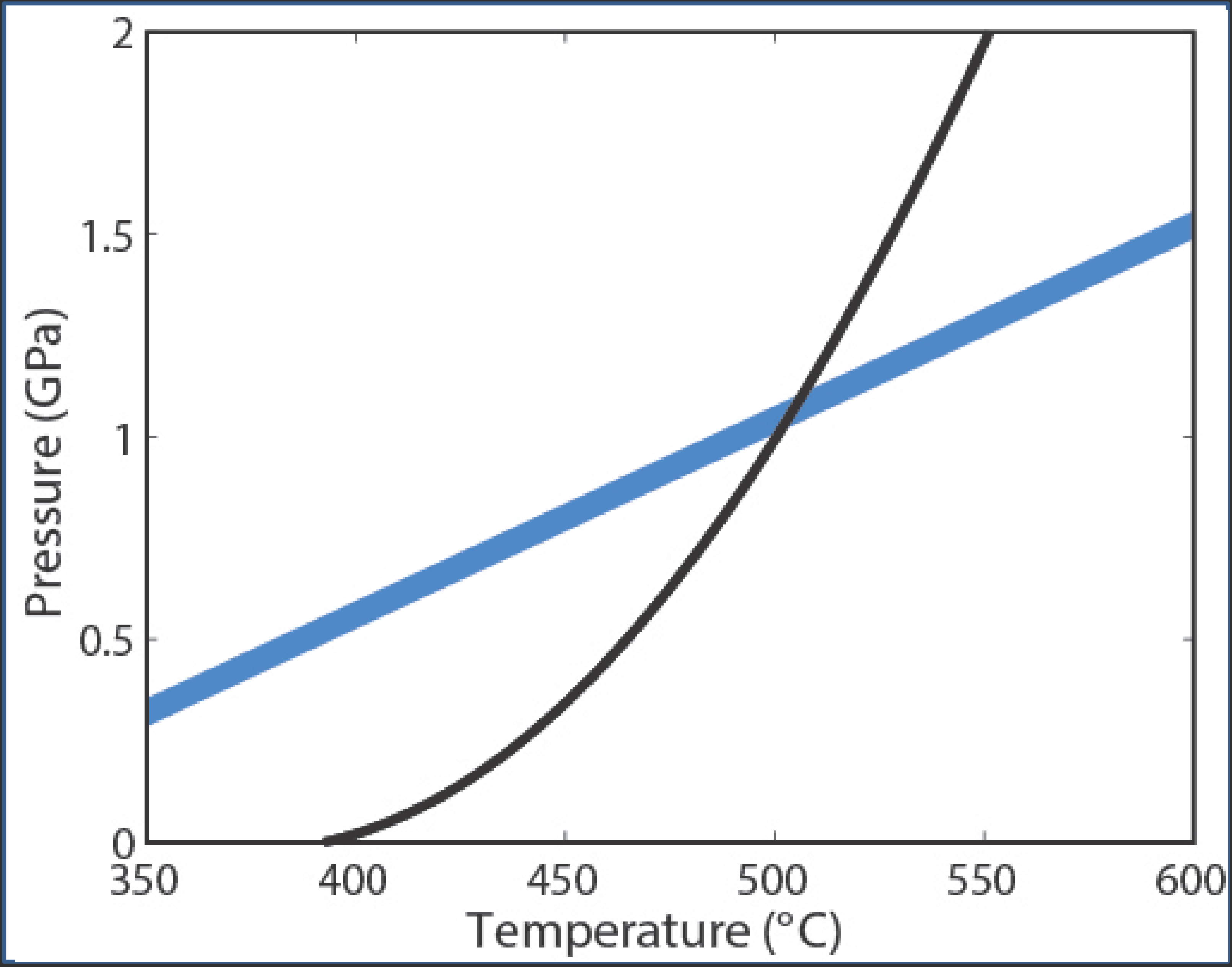
Salient points and Research Questions

- Dehydration of viscous material within the plate interface takes place in a high fluid pressure background.
- Viscous deformations leads to the formation of porosity waves due to excess porosity created by dehydration.
- Under what conditions is the period of porosity waves comparable to the recurrence interval of slow slip?

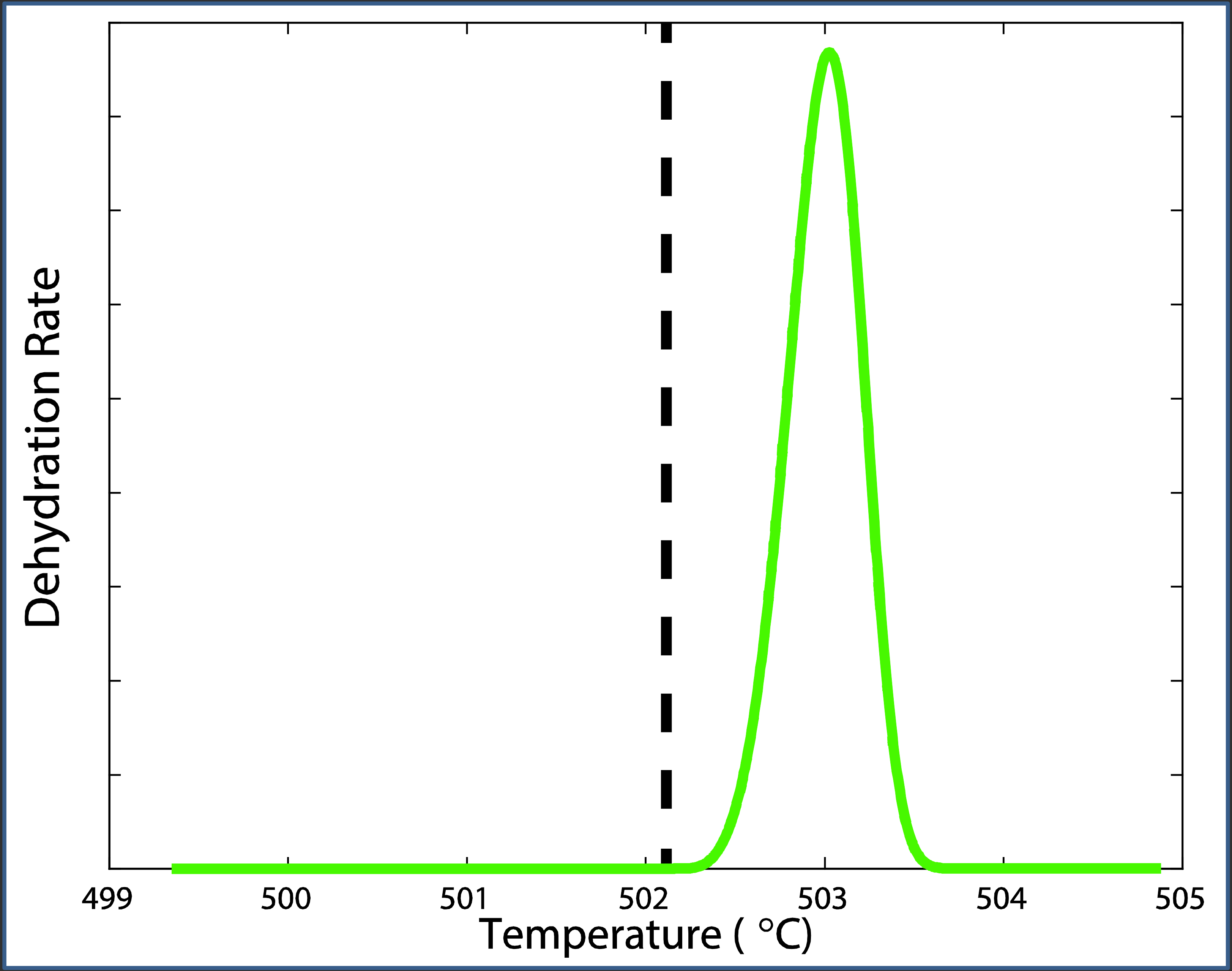
Model Geometry



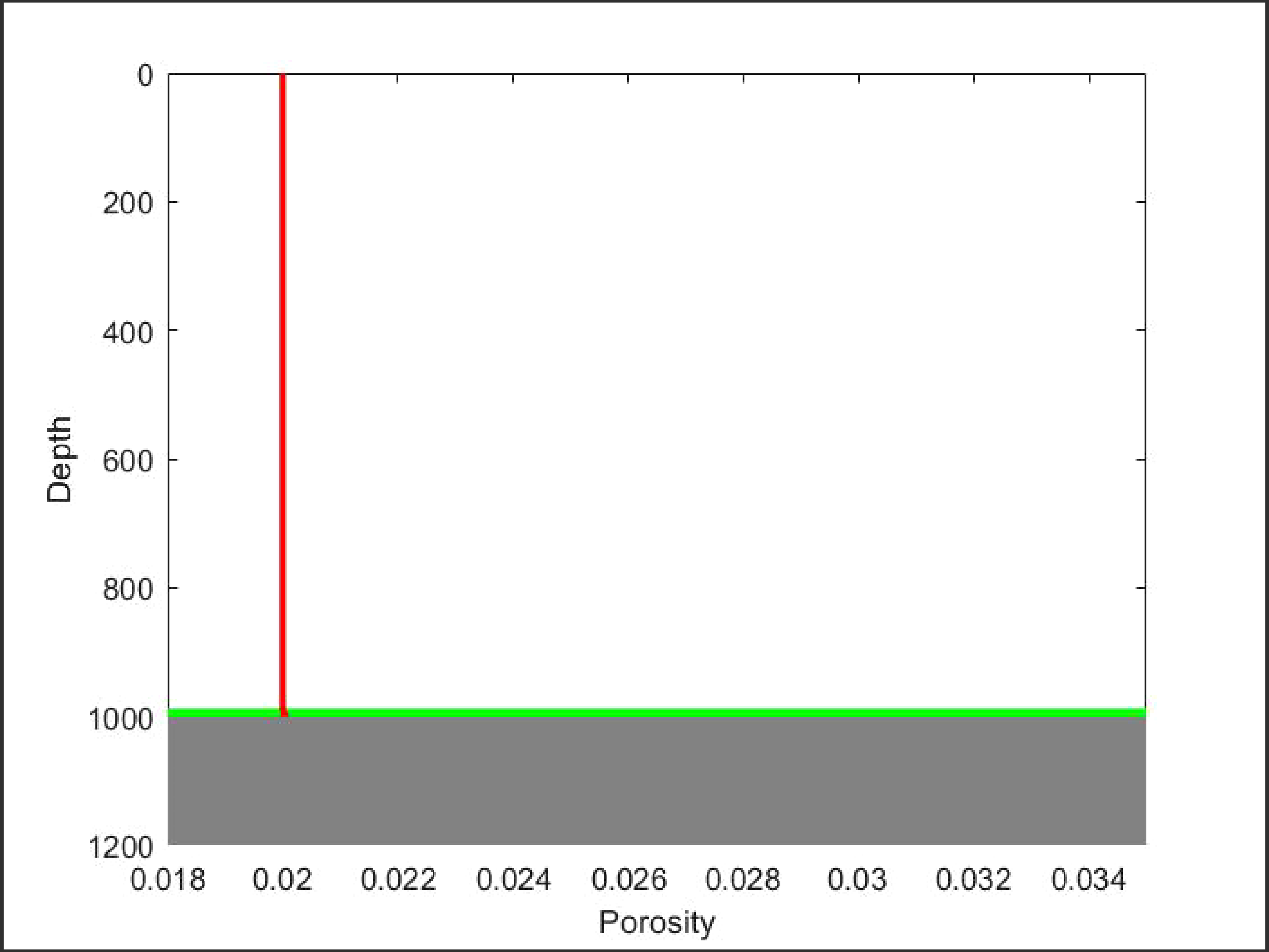
Generalized Dehydration Reaction



Generalized Dehydration Reaction



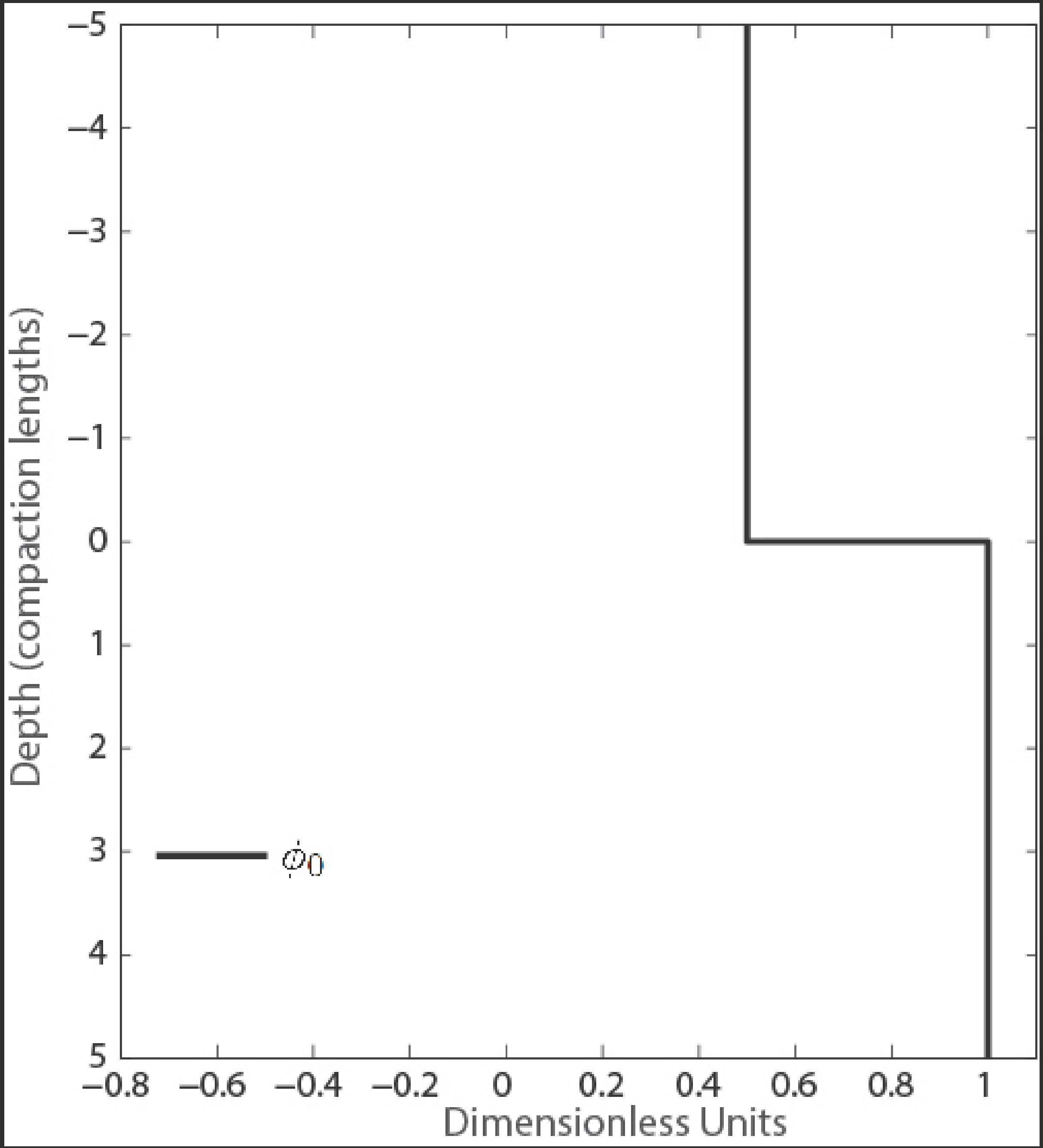
Porosity Movie



How Do Porosity Waves Form?

1. Initial porosity step at t = 0 (black line)

$$k = k_0 \left(\frac{\phi}{\phi_0} \right)^3$$



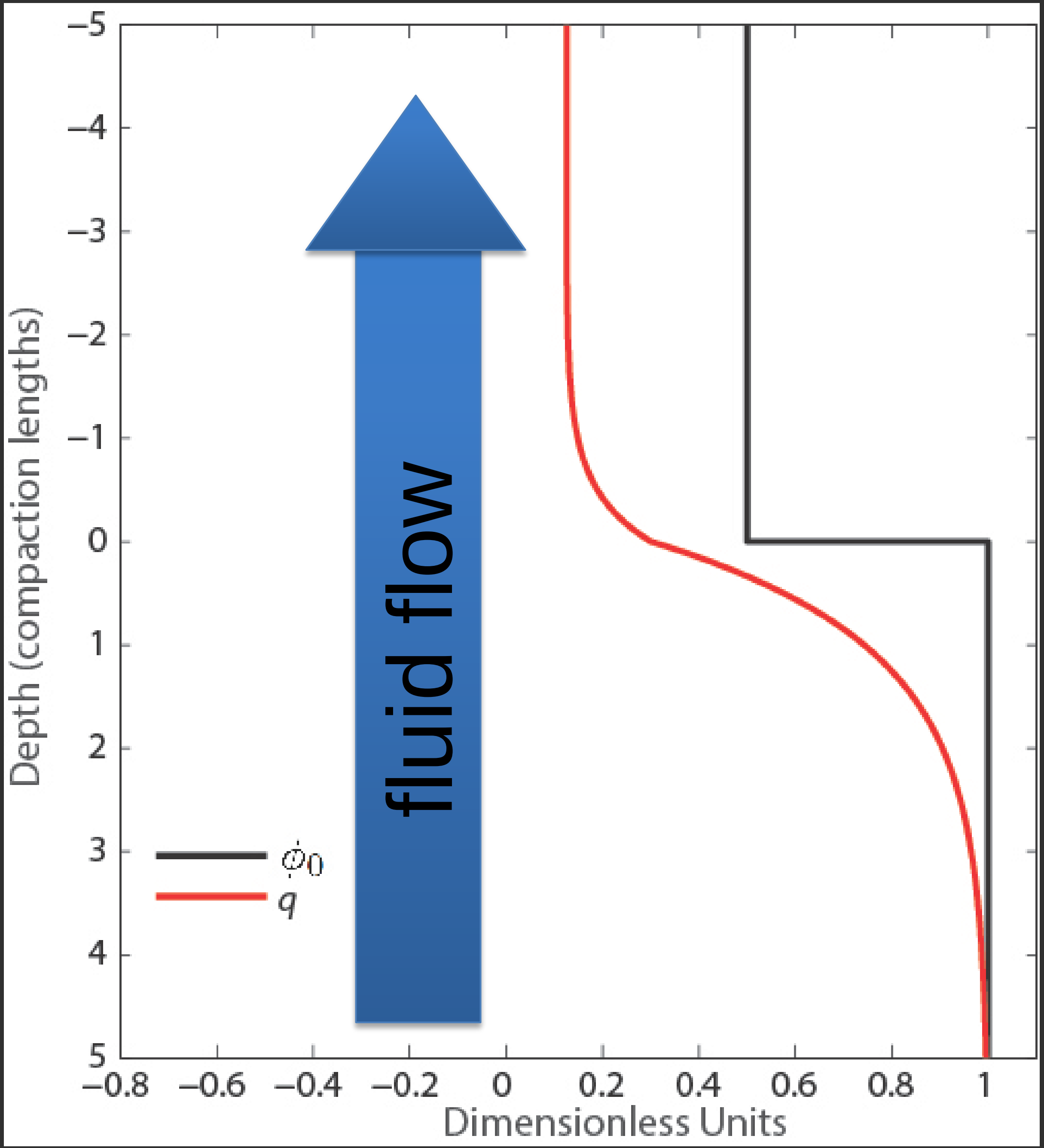
after Spiegelman 1993

How Do Porosity Waves Form?

1. Initial porosity step at t = 0 (black line)

2. Fluid flux at t = 0 (red line)

$$k = k_0 \left(\frac{\phi}{\phi_0} \right)^3$$



after Spiegelman 1993

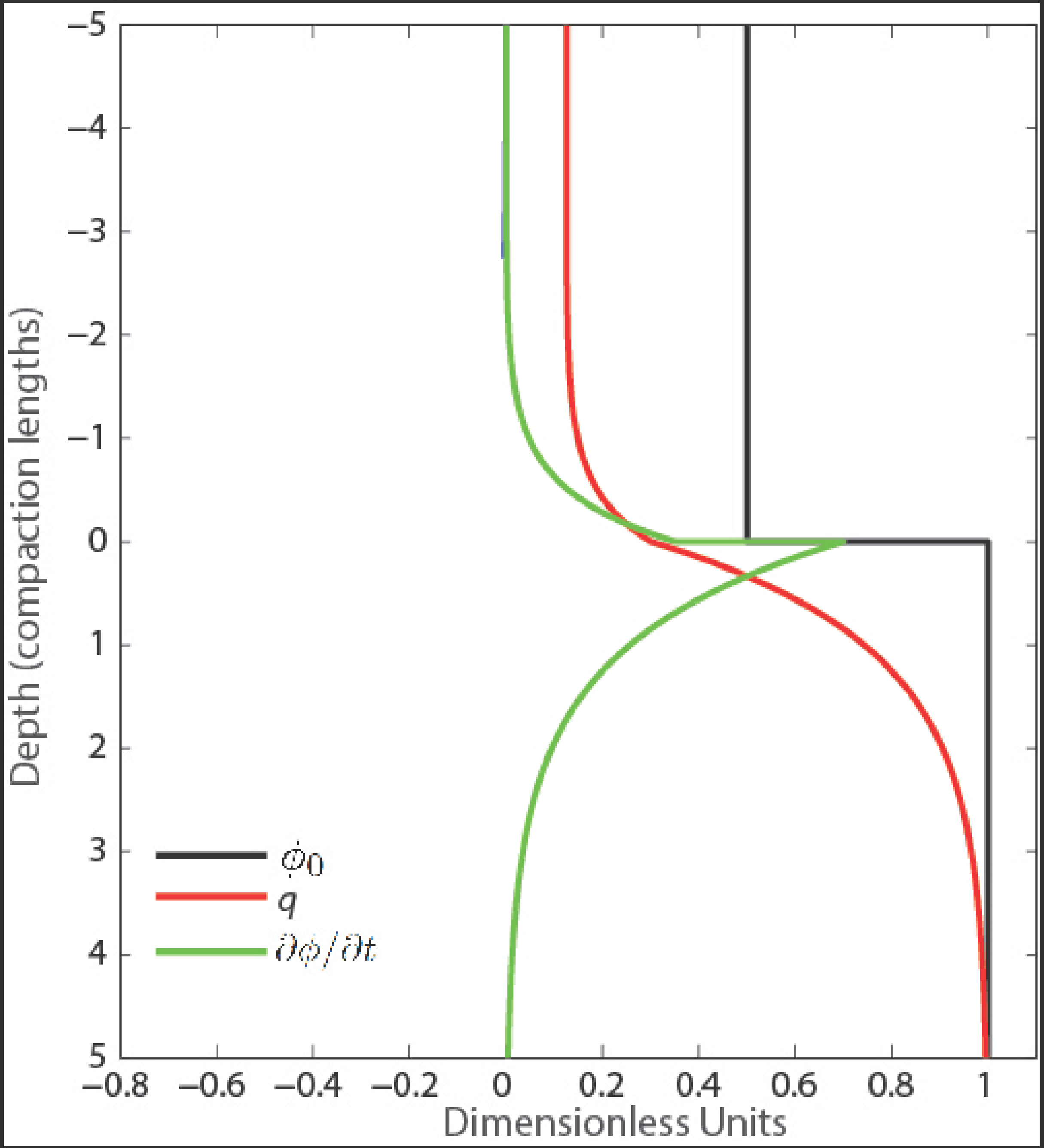
How Do Porosity Waves Form?

1. Initial porosity step at t = 0 (black line)

2. Fluid flux at t = 0 (red line)

3. Instantaneous porosity change (green line)

$$k = k_0 \left(\frac{\phi}{\phi_0} \right)^3$$

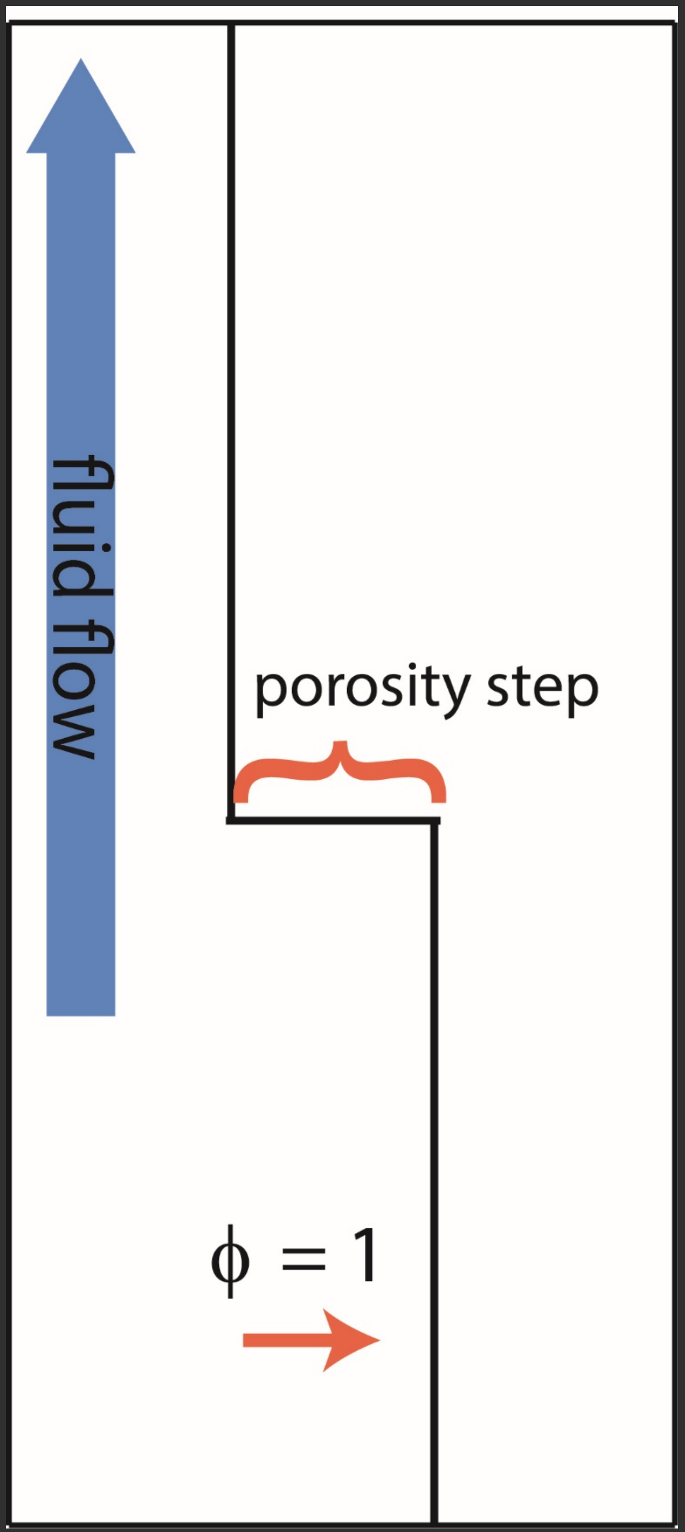


after Spiegelman 1993

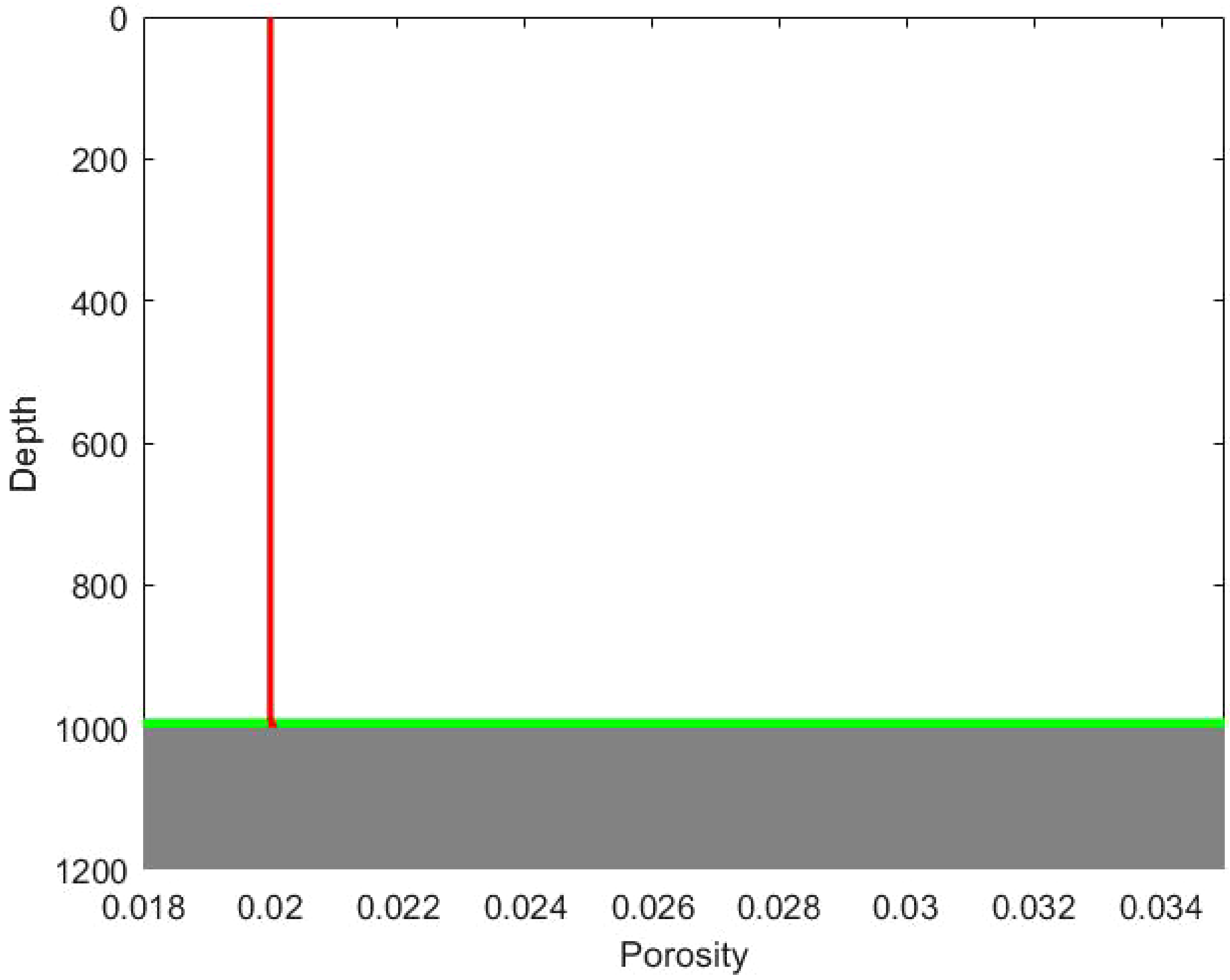
Solitary Wave Behavior

$$\frac{\partial \phi}{\partial t} = \frac{\partial}{\partial z}\left[\phi^3 + \phi^2\left(\frac{\partial^2 \phi}{\partial t \partial z}\right) - \phi\left(\frac{\partial \phi}{\partial t}\frac{\partial \phi}{\partial z}\right)\right]$$

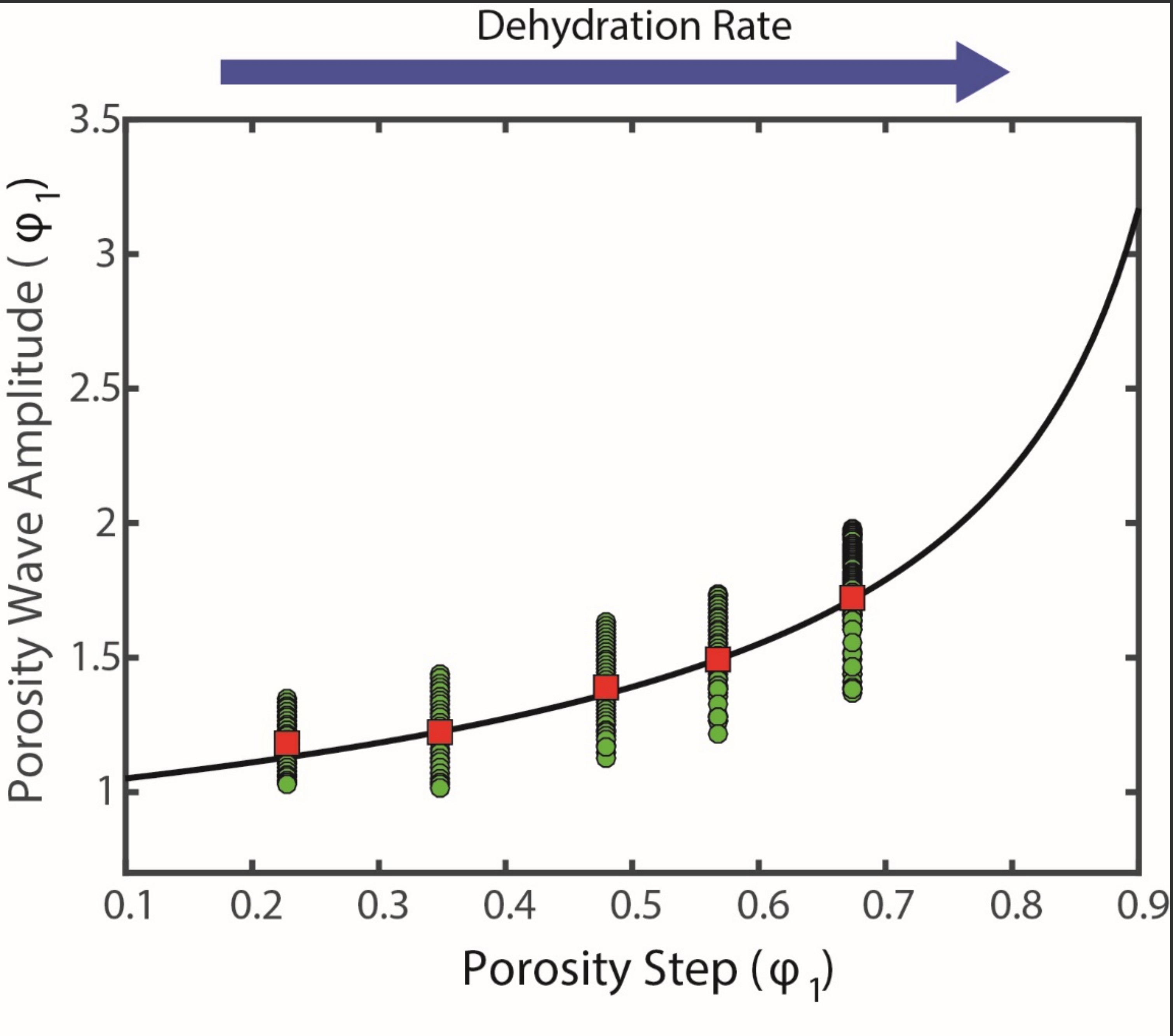
$$\phi(z,t) = f(z - ct)$$

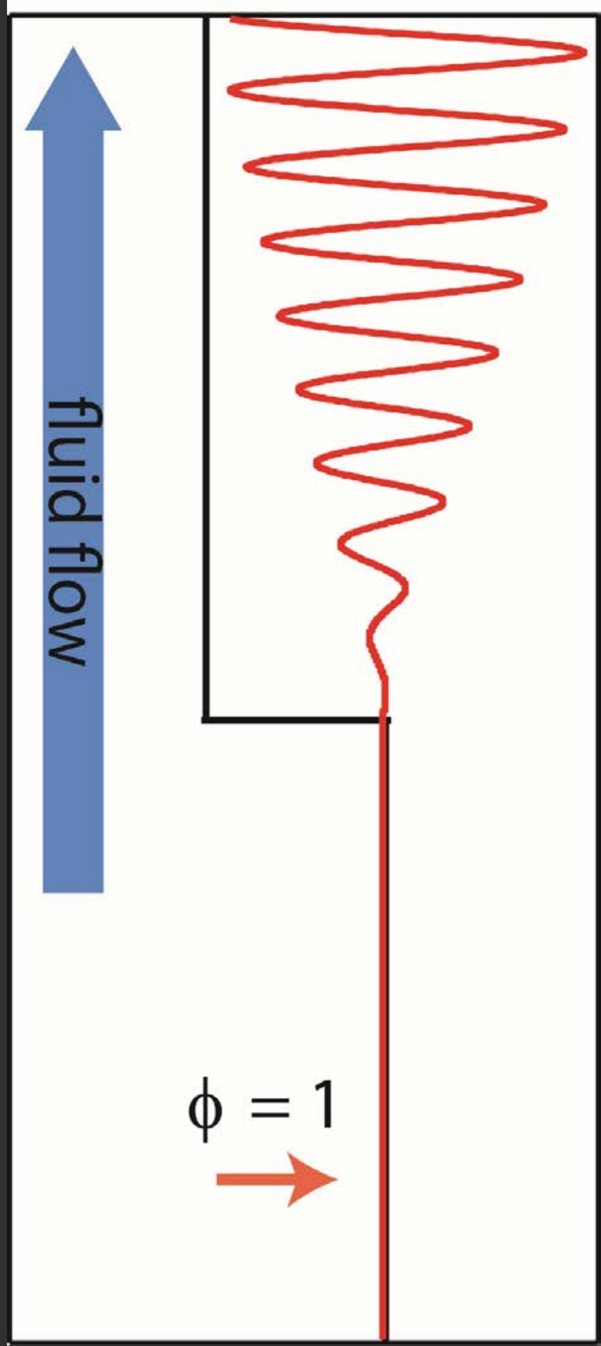


Porosity Movie



Solitary Wave Behavior



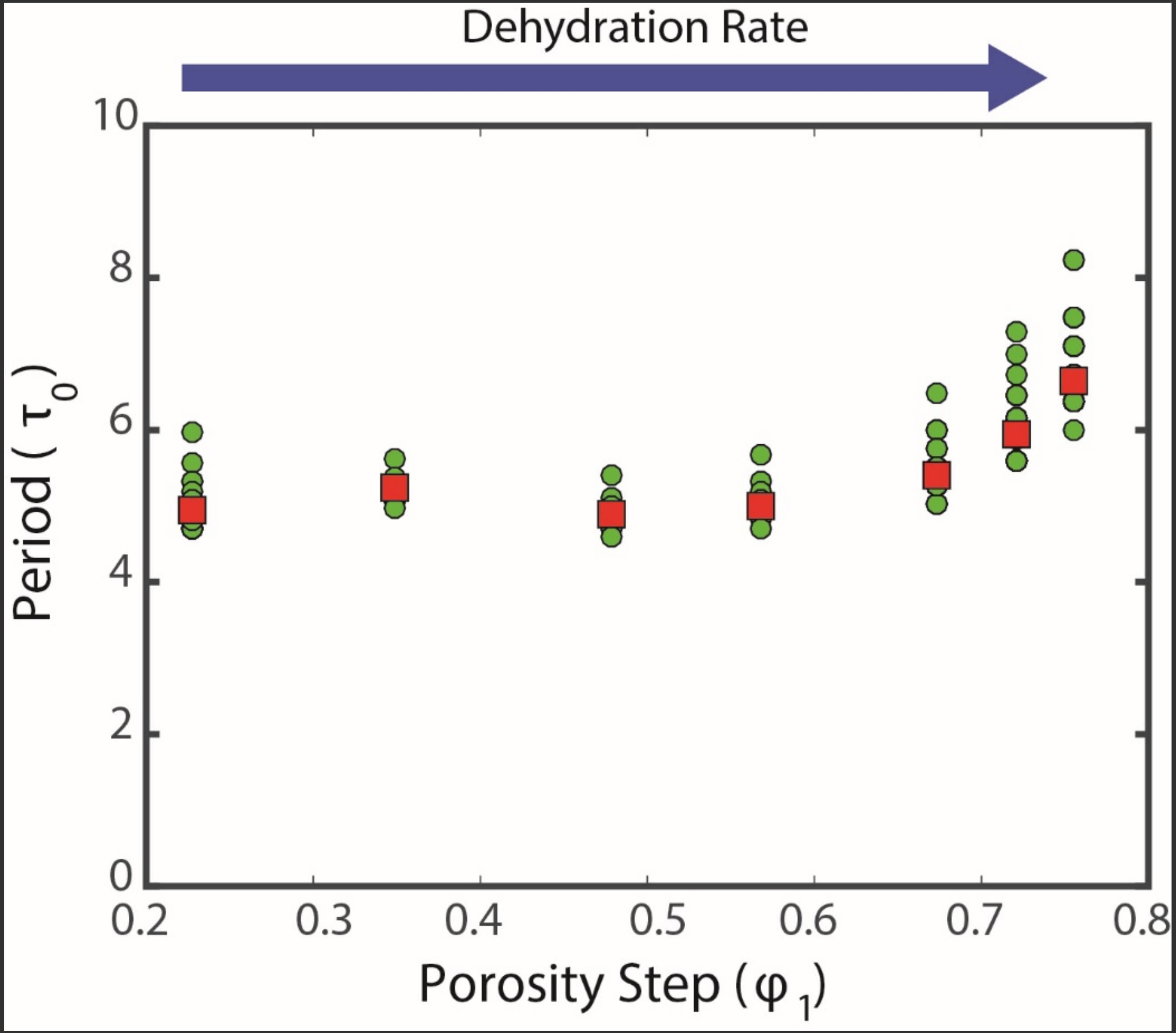


Porosity Wave Period

$$\tau_0 \propto \sqrt{\frac{\text{viscosity}}{\text{permeability}}}$$

Period ~ 5 τ_0

To match SSE recurrence interval 1 – 10 yrs, need τ_0 = 0.2 – 2 yrs

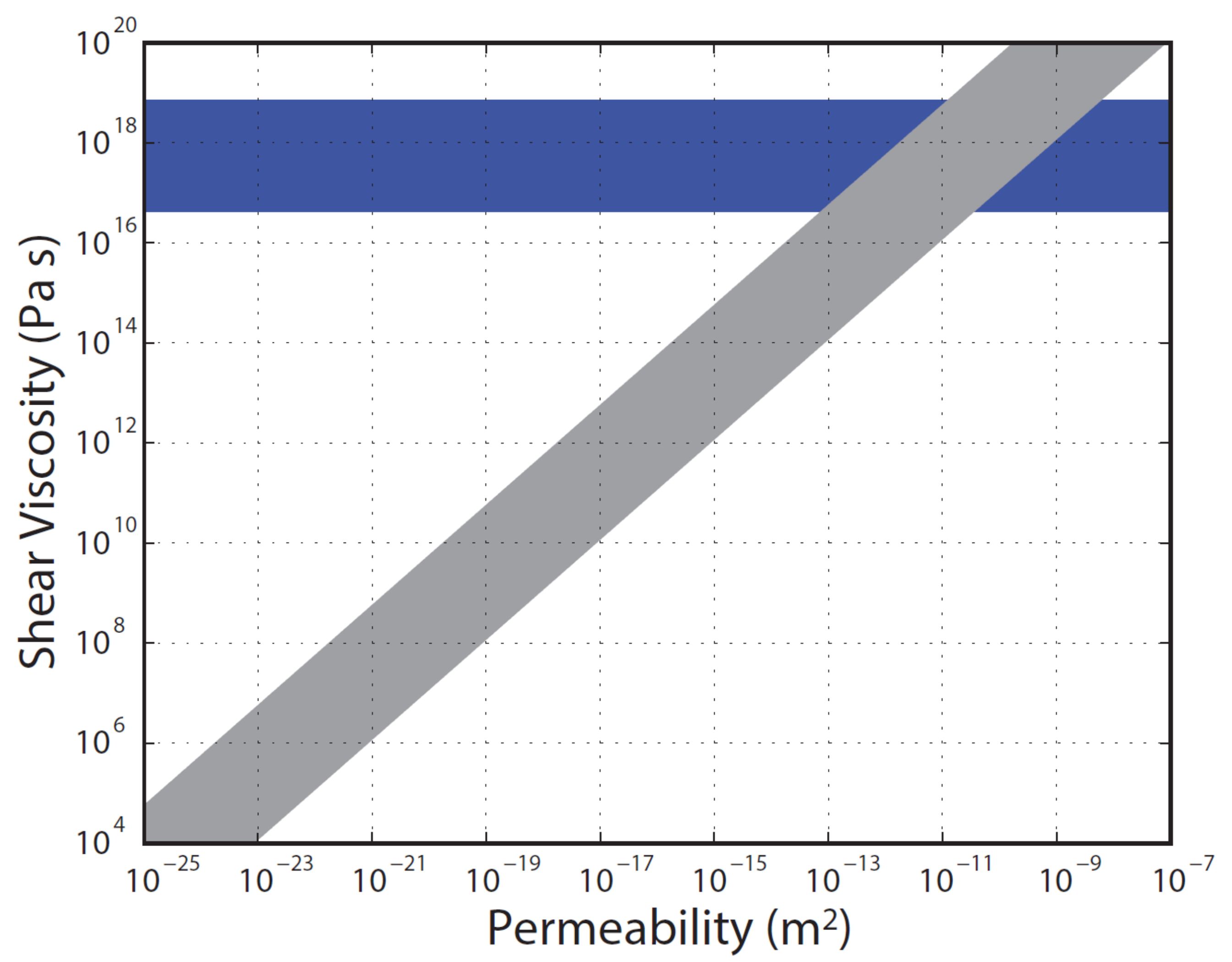


Dehydration Time Scales

$$\tau_0 \propto \sqrt{\frac{\text{viscosity}}{\text{permeability}}}$$

If τ_0 = 0.2 - 2 years, permeability must be 10^{-13} – 5×10^{-9} m^2

viscous transport of fluid pressure at time scales comparable to slow slip recurrence interval (1 - 10 years)

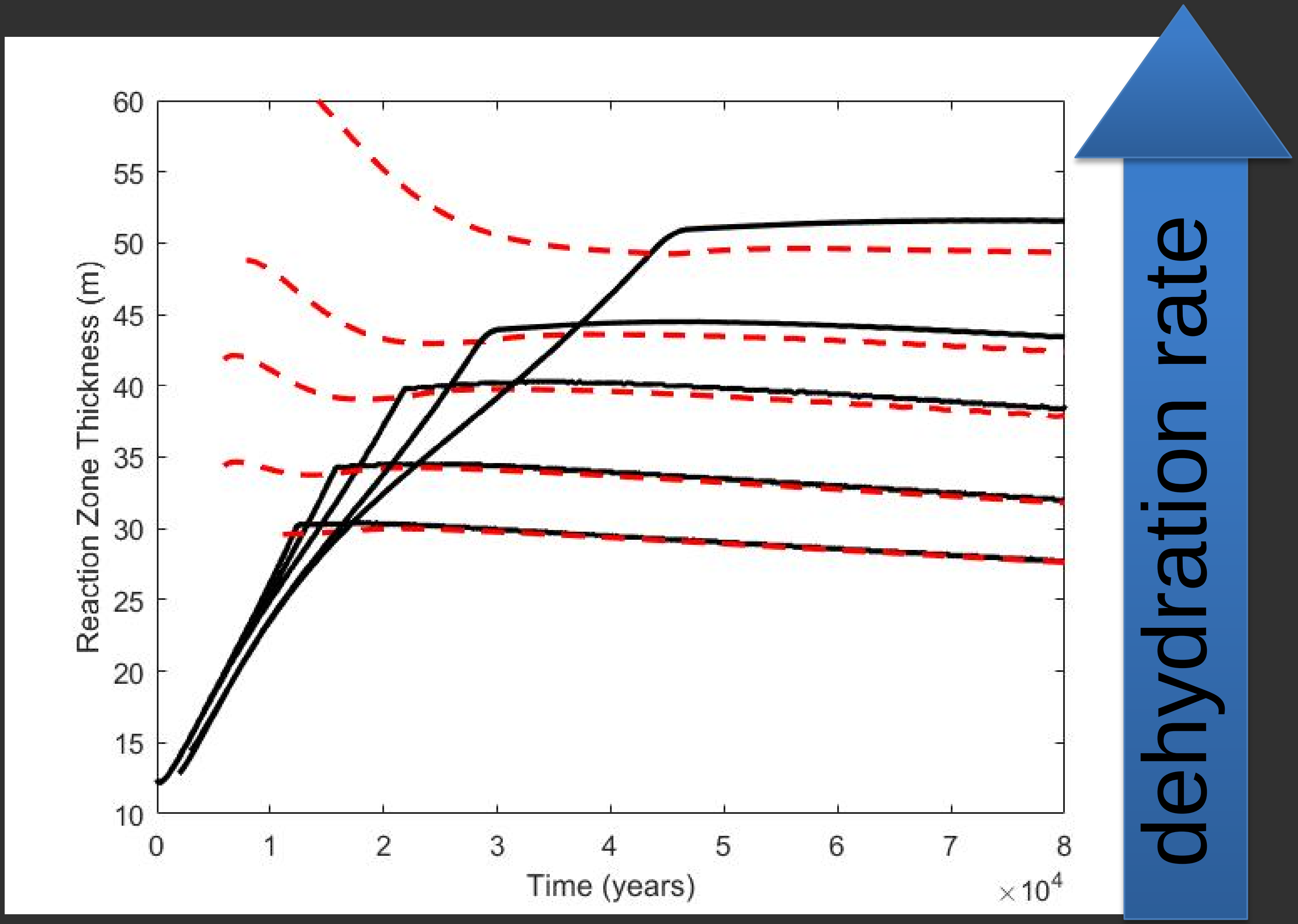


Viscosity (blue region) determined from experimental data of Hilairet et al. 2007 for antigorite as a function of temperature and pressure

Reaction Zone Thickness

$$\Gamma = c(T)A|\Delta G(p,T)|^{n_r}$$

$$z_r \propto \left(\frac{\partial \Delta G}{\partial z}\right)^{-\frac{n_r}{1+n_r}}$$



Concluding Remarks

- Porosity waves expected to form in fluid saturated, viscously deformable material.
- Propagation of porosity waves in the subduction channel probably cannot explain the recurrence interval of slow slip. Need to construct 2-D models.
- Interaction of elastic and viscous materials in the plate interface is an important feature and needs to be considered in any numerical model of slow slip

Governing Equations: Pore Pressure

$$\mathrm{De}_p \frac{\partial p}{\partial t} = \frac{\partial}{\partial z}\left(\phi^n \frac{\partial p}{\partial z}\right) - \frac{\partial \phi^{\mathrm{in}}}{\partial t} + Ж \frac{\partial m_d}{\partial t} + \gamma \mathrm{De}_p \dot{\sigma}_{11}$$

= 1 - 2 + 3 + 4

$$k = k_0 \left(\frac{\phi}{\phi_0}\right)^3$$

1. Elastic deformation
2. Inelastic deformation
3. Dehydration reaction
4. Tectonic loading

Governing Equations: Porosity

Overall Change in Porosity

$$\frac{\partial \phi}{\partial t} = (\mathrm{De}_p - \mathrm{De}_\phi \phi)\frac{\partial p}{\partial t} + \frac{\partial \phi^{\mathrm{in}}}{\partial t} - \gamma \mathrm{De}_p \dot{\sigma}_{11}$$

= 1 + 2 - 4

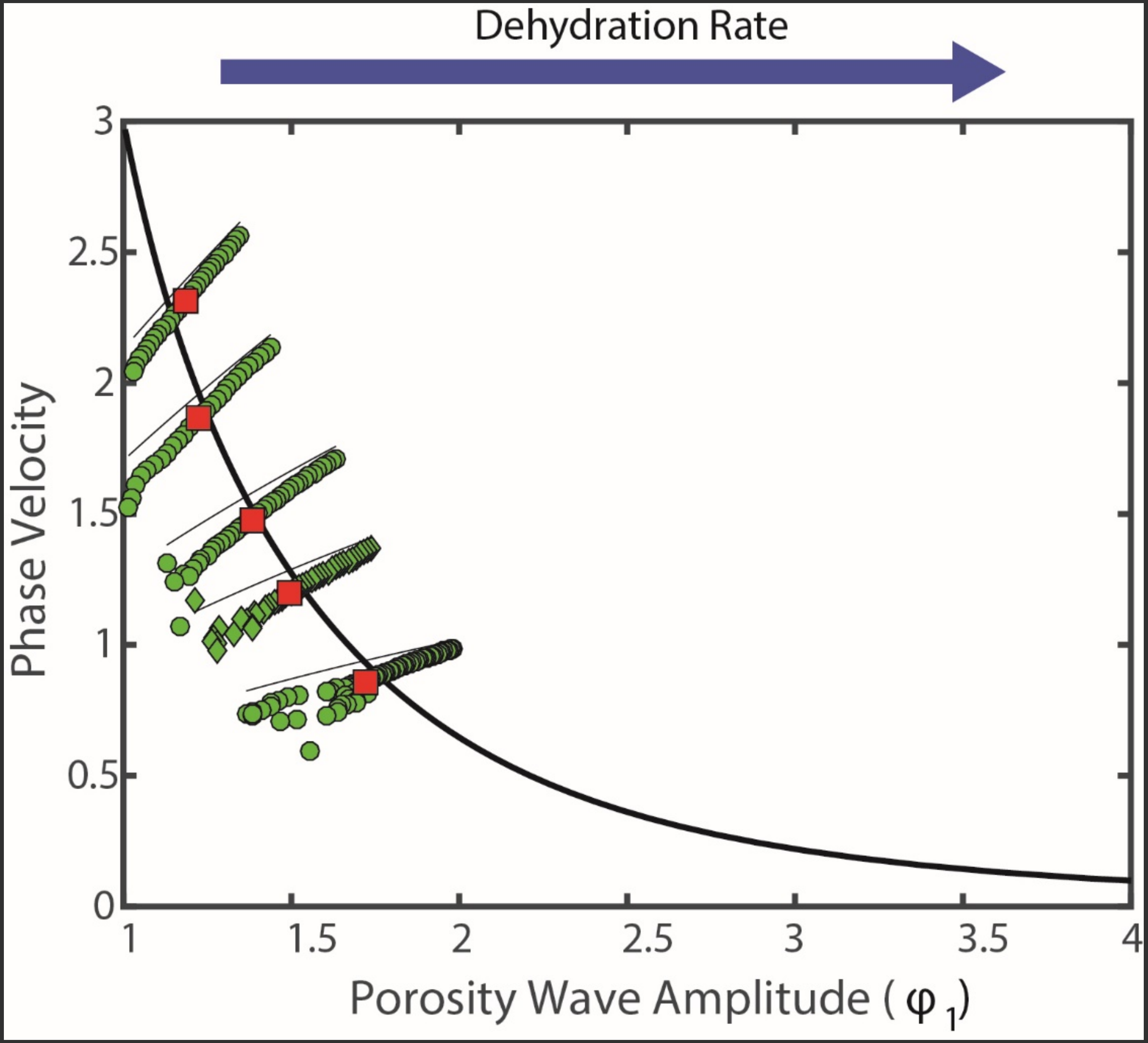
Inelastic Change in Porosity

$$\frac{\partial \phi^{\mathrm{in}}}{\partial t} = \xi \text{Ж} \frac{\partial m_d}{\partial t} - \phi p_{\mathrm{eff}}$$

2 = 3 - 5

1. Elastic deformation
2. Inelastic deformation
3. Dehydration reaction
4. Tectonic loading
5. Viscous deformation

Solitary Wave Behavior



Temperature Environment