

Scaling of Free Subduction on a Sphere

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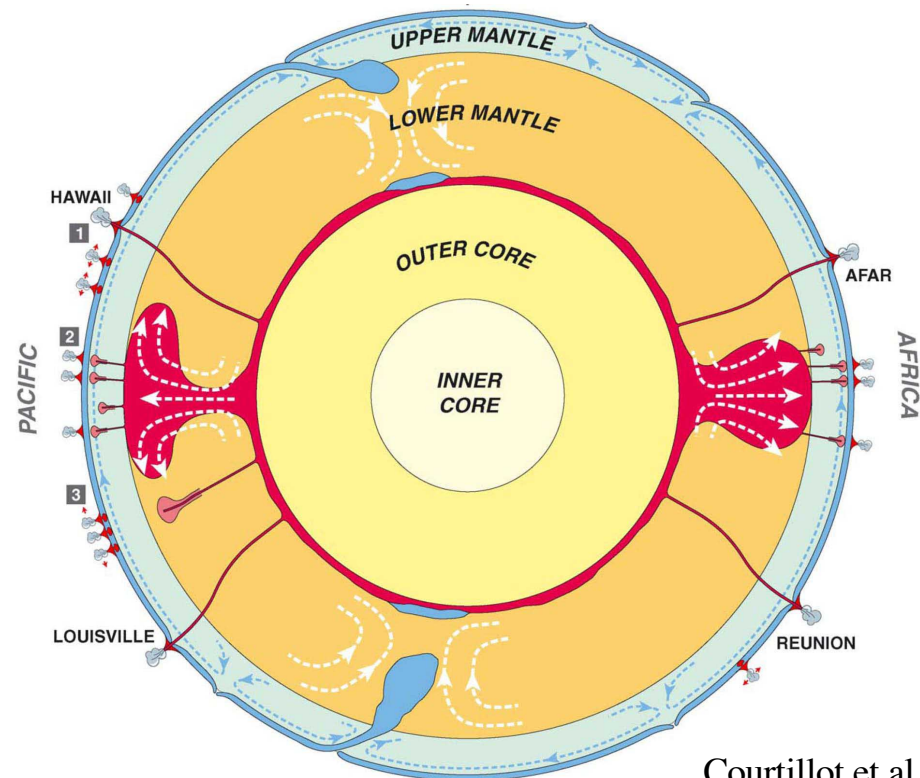
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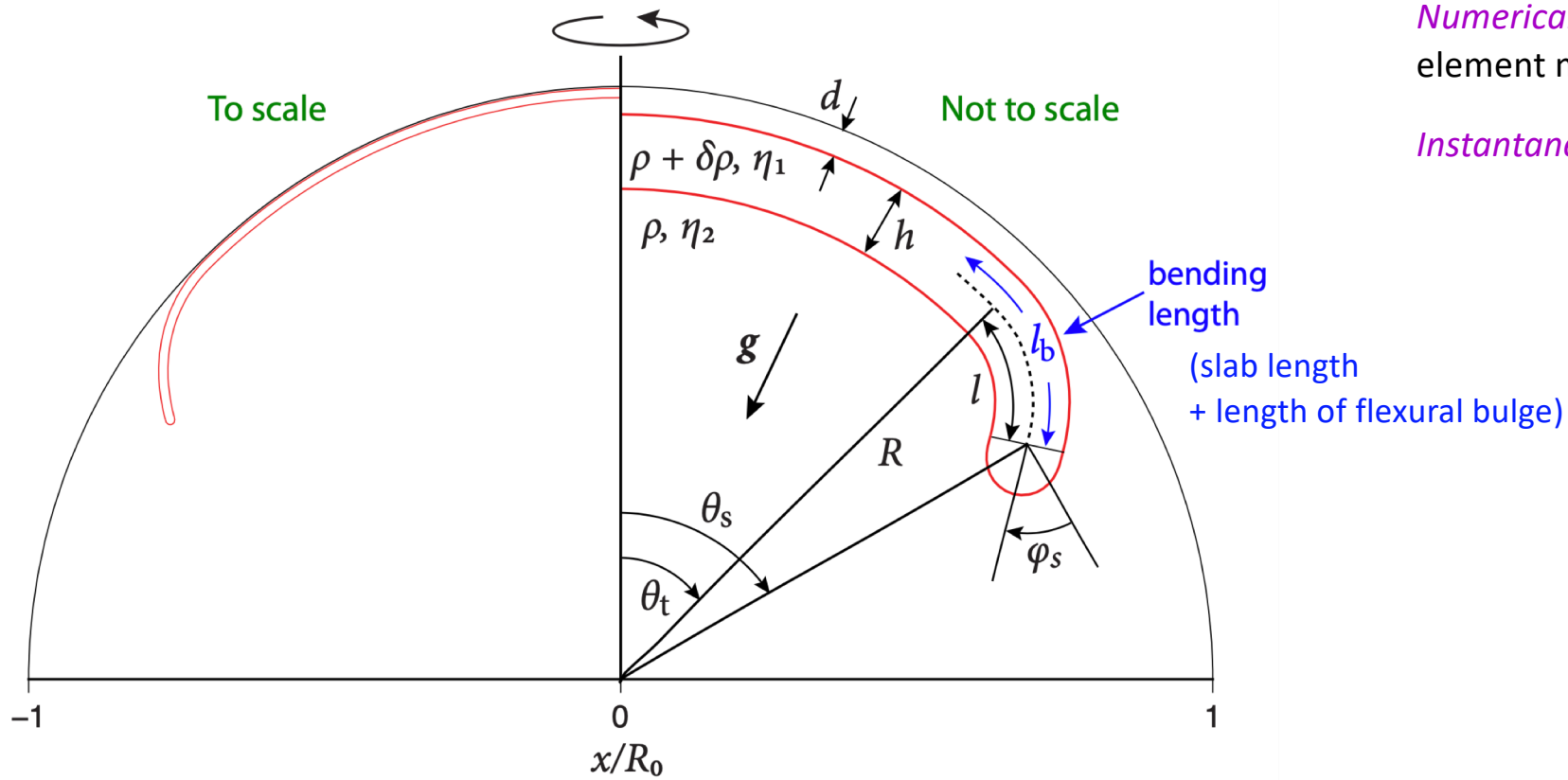
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Courtilot et al. (2003)

Model

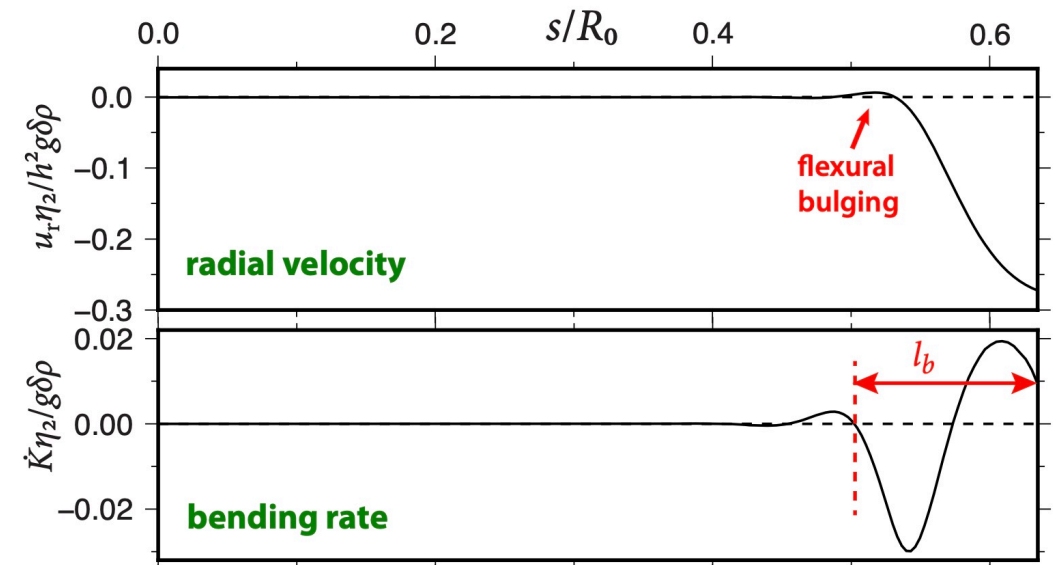
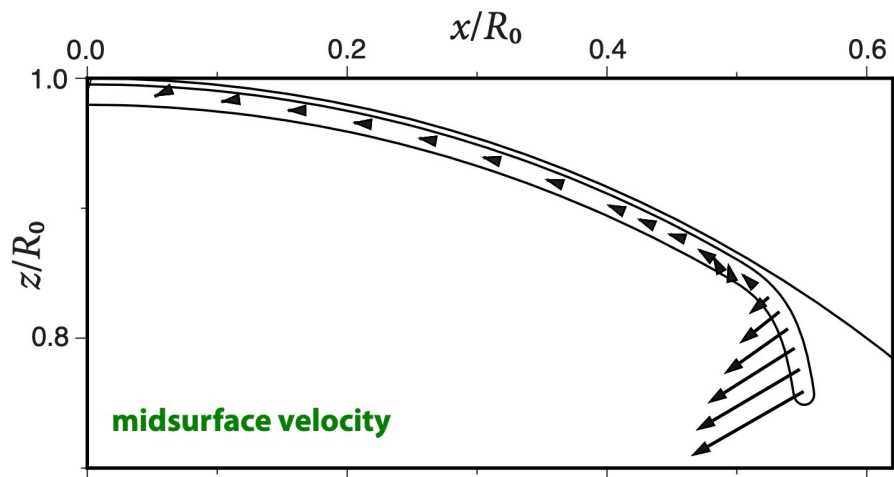
- a dense axisymmetric shell with viscosity η_1 sinking into a planet with viscosity η_2



Numerical method: boundary-element method (BEM)

Instantaneous solutions only

Instantaneous Flow Solution: An Example ($\theta_t = 30^\circ$, $\eta_1/\eta_2 = 100$)



Three Forces Acting on a Slab: Scaling Analysis

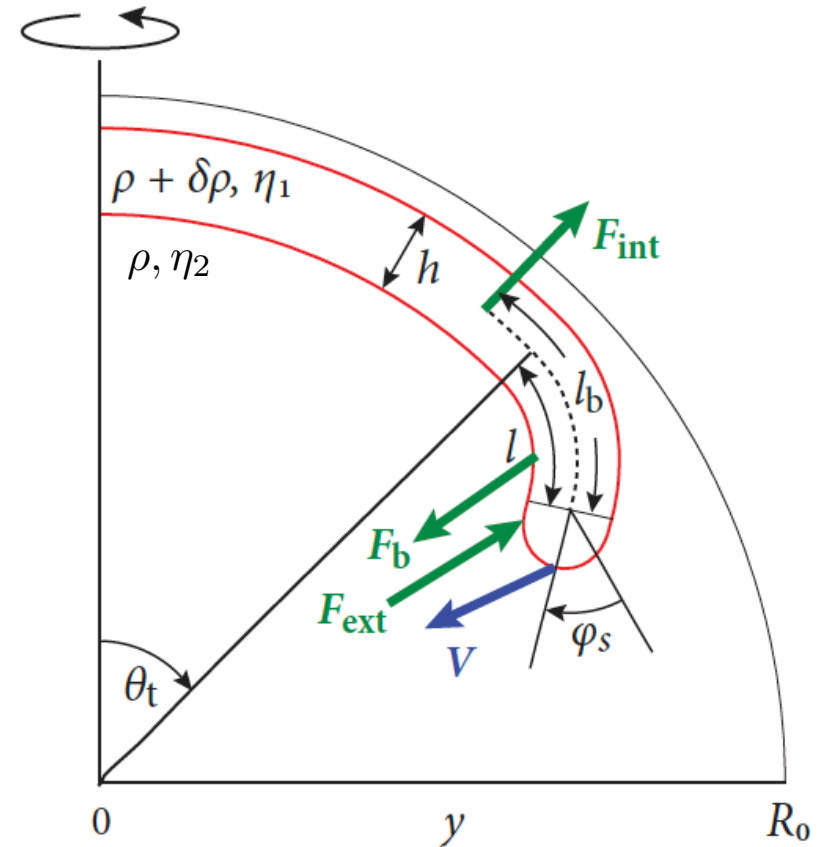
(Negative) buoyancy: $F_b \sim lhg\delta\rho$

External force (drag): $F_{\text{ext}} \sim \eta_2 V$ ($V = \text{slab sinking speed}$)

Internal resistance to bending (from thin-shell theory)

$$F_{\text{int}} \sim \eta_2 V f_1 \left(\frac{\eta_1 h^3}{\eta_2 l_b^3}, \frac{l_b}{R_0} \cot \theta_t \right)$$

flexural stiffness St dynamical sphericity number Σ_D



Dynamical vs. Geometrical Sphericity

Dynamical sphericity number: $\Sigma_D = \frac{l_b}{R_0} \cot \theta_t$

Geometrical sphericity number: $\Sigma_G = \theta_t$

Implications:

1. Dynamical sphericity is greater for small plates (“sphericity paradox”)
2. Geometrical sphericity is greater for large plates;
3. Sphericity is important at *all* scales in the dynamics of subduction

This hemisphere has...

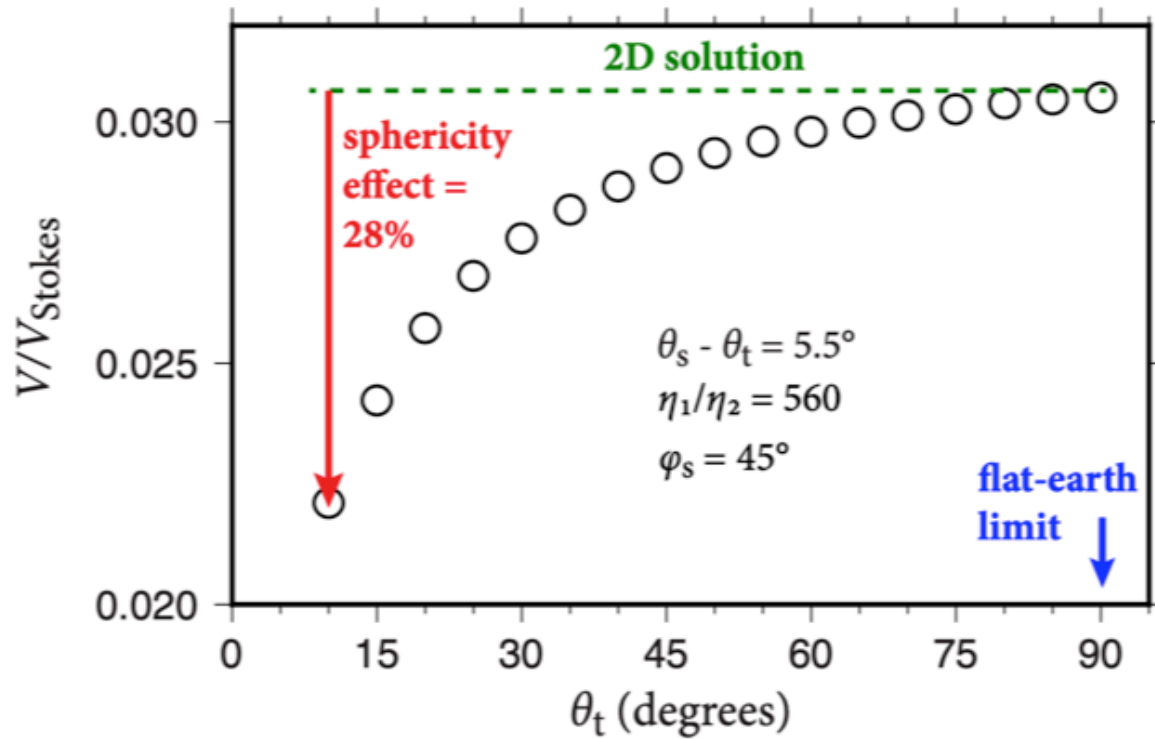
(a) Greater geometrical sphericity

(b) Smaller dynamical sphericity

... than this cap.

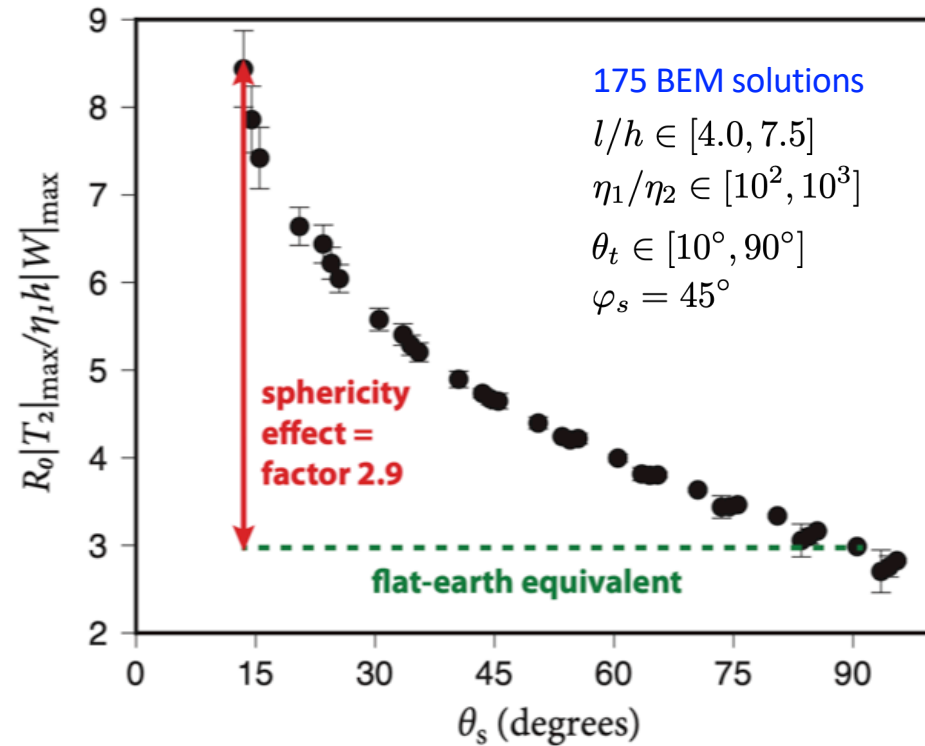


Effect of Sphericity on the Sinking Speed V



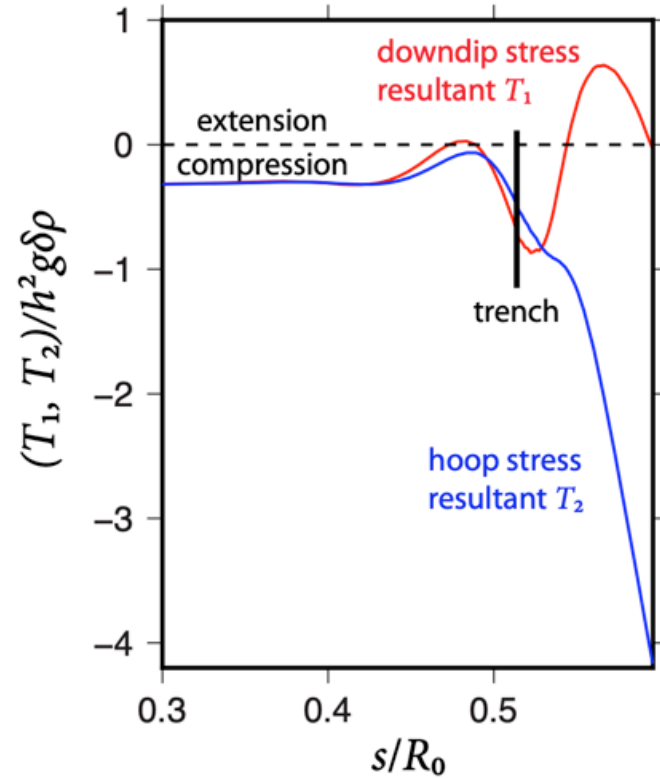
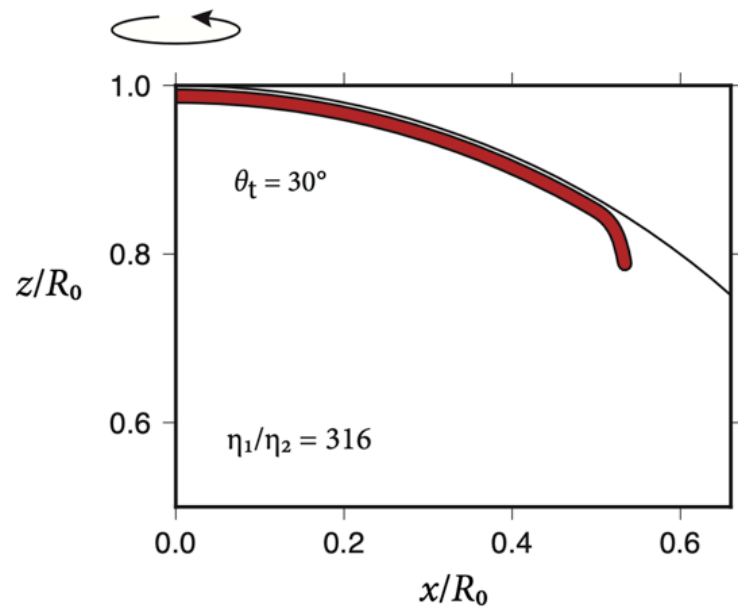
Sphericity reduces V by a few tens of percent for small plates

Universal Scaling of the Maximum Hoop Stress Resultant T_2



Sphericity increases T_2 by a factor ≈ 3 for small plates

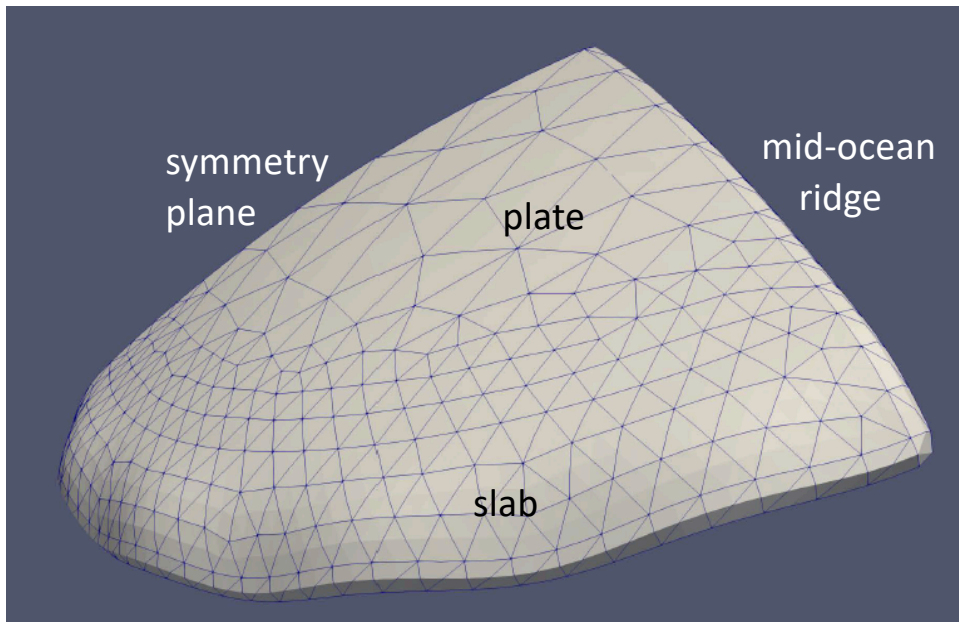
Hoop Stress vs. Dwindip Stress



Stress in most of the slab is dominated by the hoop stress component

Three-Dimensional Model (in progress)

Bird's-eye view of the shell



Cross-section along a meridian

