Partial melting and melt migration in planetary bodies

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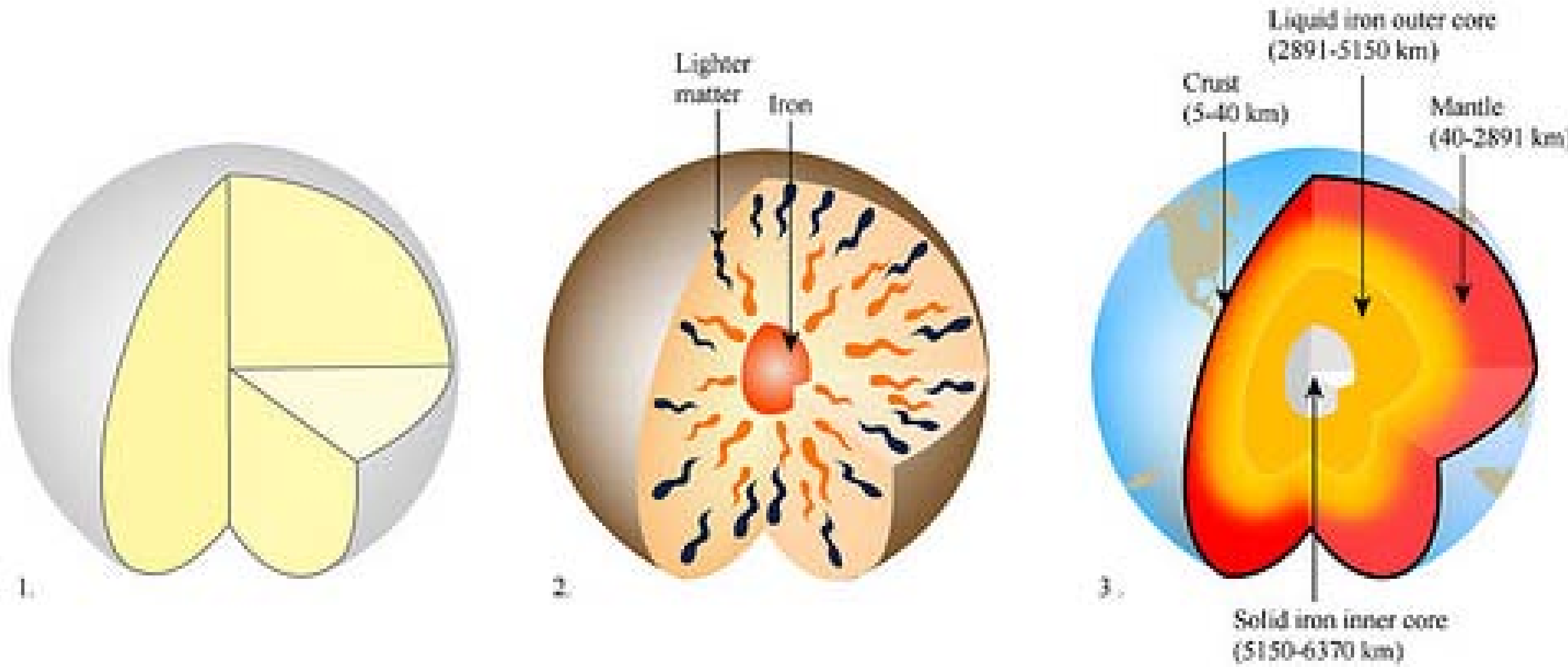
Outline

1. Why melting is planetary science

2. What I do.

3. Where it might be useful.

Planetary differentiation



Physical differentiation: gravity segregation, counter current flow, compaction

Chemical differentiation: phase change, element partitioning

What I do

Processes:

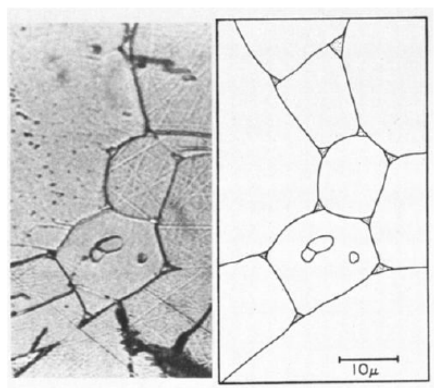
- Porous media/fractures
- Multiphase flow/geomechanics
- Phase behavior/petrology

Techniques:

- Mathematical modeling
- Numerical simulation
- Experiments (simple)

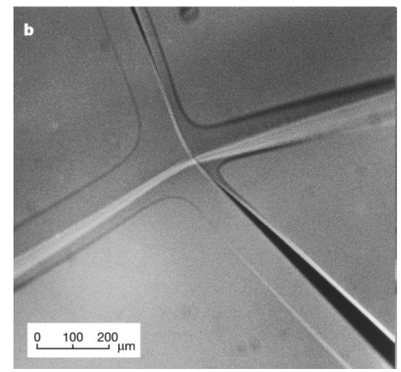
Microscale: porous medium

Peridotite
Earth's mantle



Waff & Bulau 1979
JGR, 84, B11, 6109

H_2O-Ice
glaciers & ice-sheets



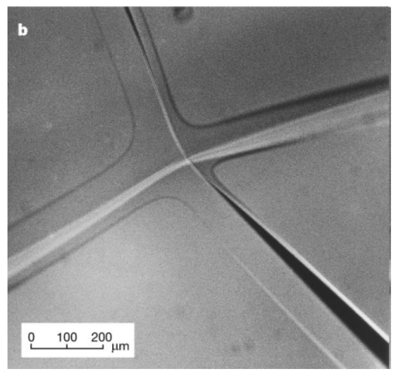
Rempel et al. 2001
Nature, 411, 568-571

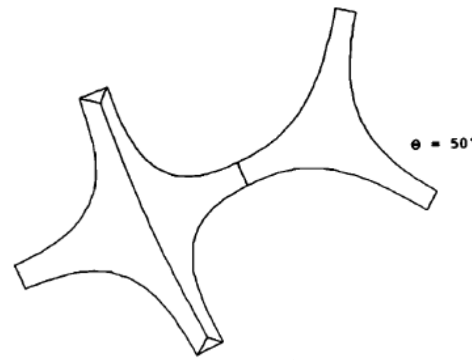
Thin percolating melt films

Real

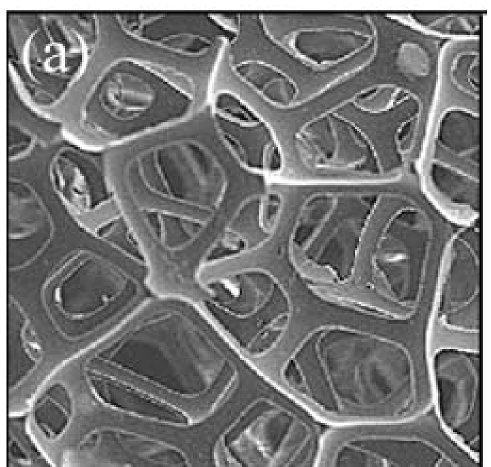
Model

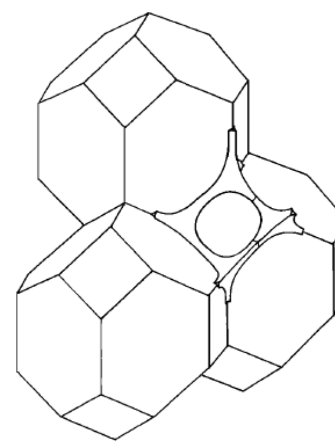
Detail





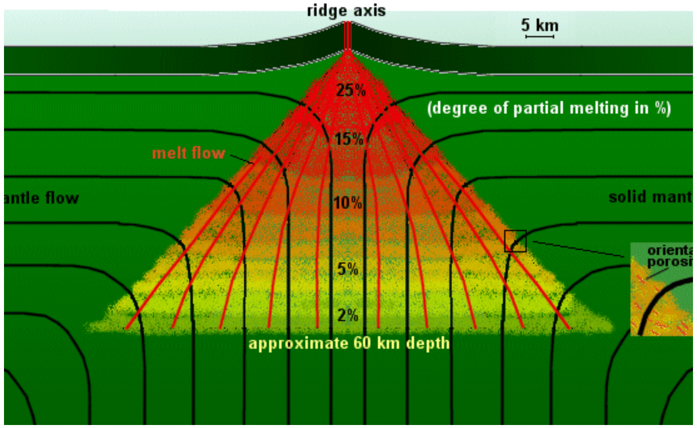
Network





Macroscale: creep and compaction

mantle flow



temperate glaciers

10^{19} - 10^{24} Pa s

10^{13} Pa s

modeled by a (non-linear) viscous rheology

Water ~10^{-3} Pa s

Darcy-Stokes Flow

fluid conservation: $$\frac{\partial \phi}{\partial t} + \nabla \cdot \left(\phi v_f\right) = \Gamma$$

incompressible: $$\nabla \cdot \left[\left(1-\phi\right) v_s + \phi v_f\right] = 0$$

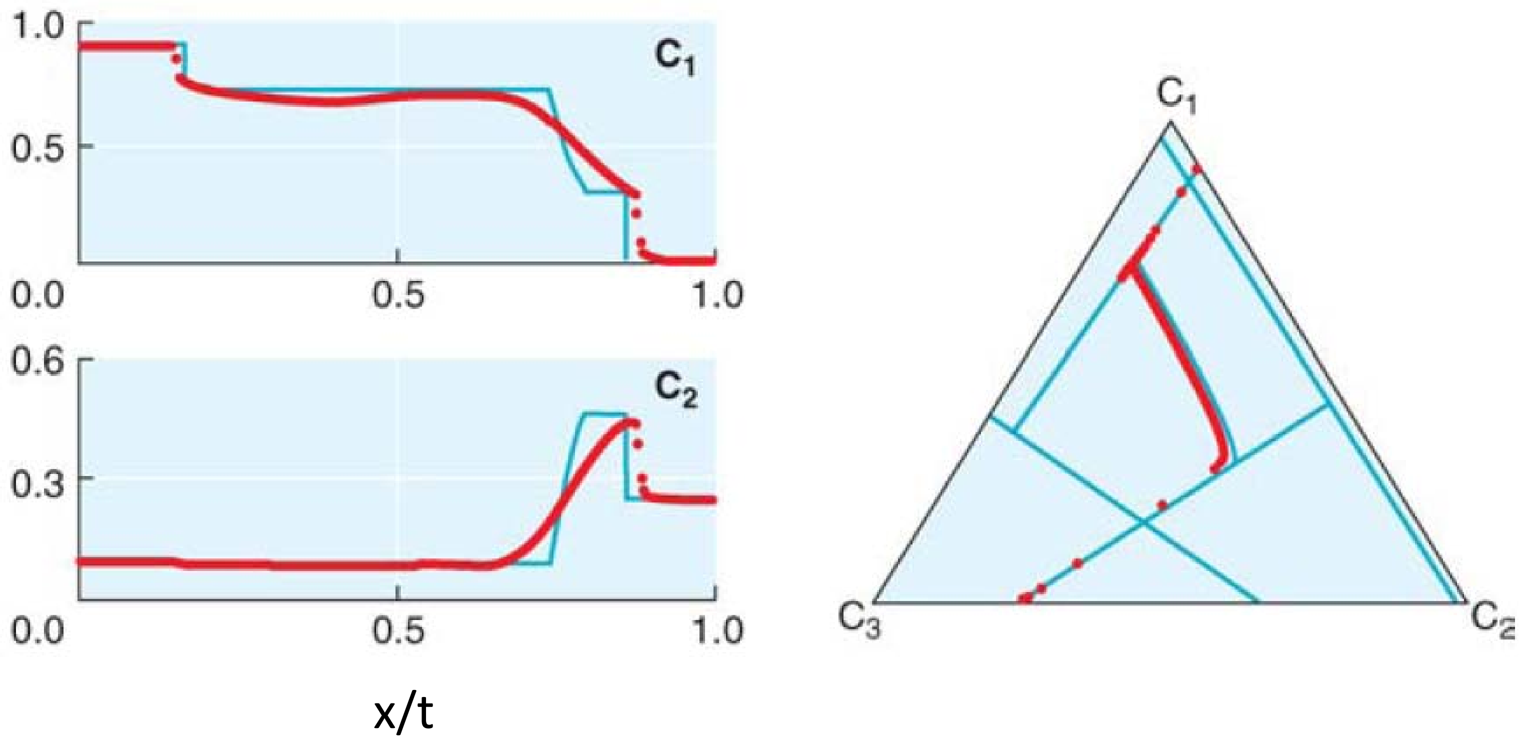
total moment. cons.: $$\nabla \cdot \left[\left(1-\phi\right)\sigma_s + \phi \sigma_f\right] + \left(1-\phi\right)\rho_s + \phi \rho_f = 0$$

stress tensors: $$\sigma_s = -p_s I + \eta_s \left(\nabla v_s + \nabla^T v_s - \tfrac{2}{3} \nabla \cdot v_s I\right)$$

Darcy's law: $$\phi\left(v_f - v_s\right) = \frac{k(\phi)}{\mu}\left(-\nabla p_l + \rho_l g\right)$$

bulk viscosity: $$p_s - p_l = -\zeta(\phi) \nabla \cdot v_s$$

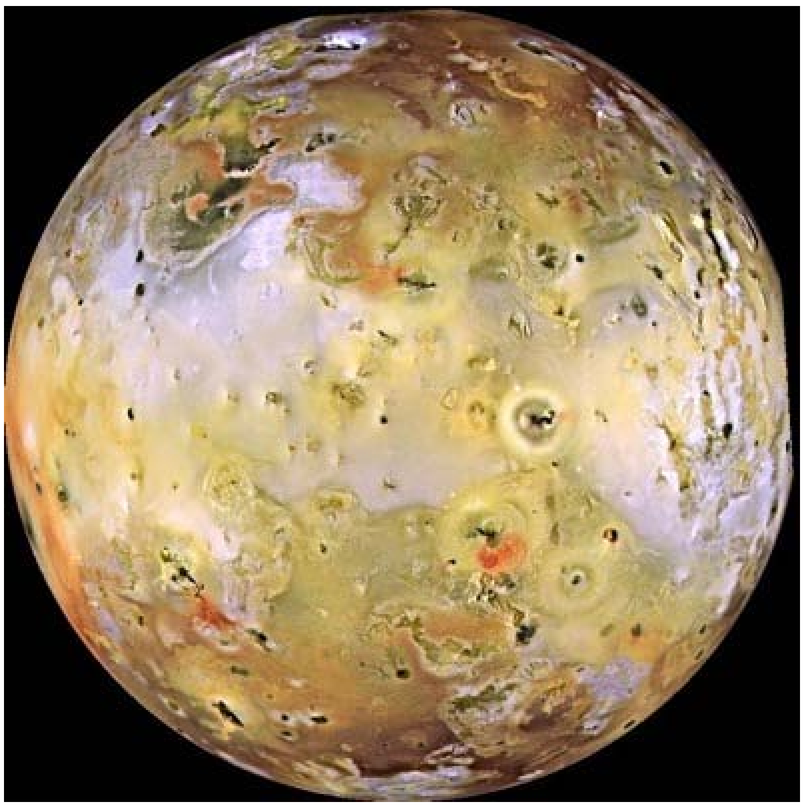
Transport with thermodynamics



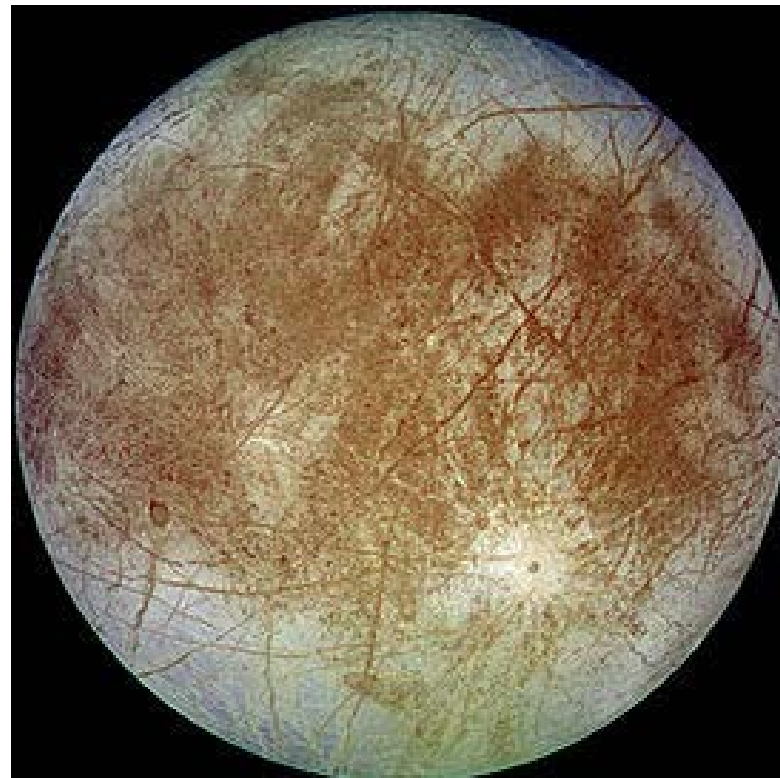
Melting problems in planetary science

Tidal heating

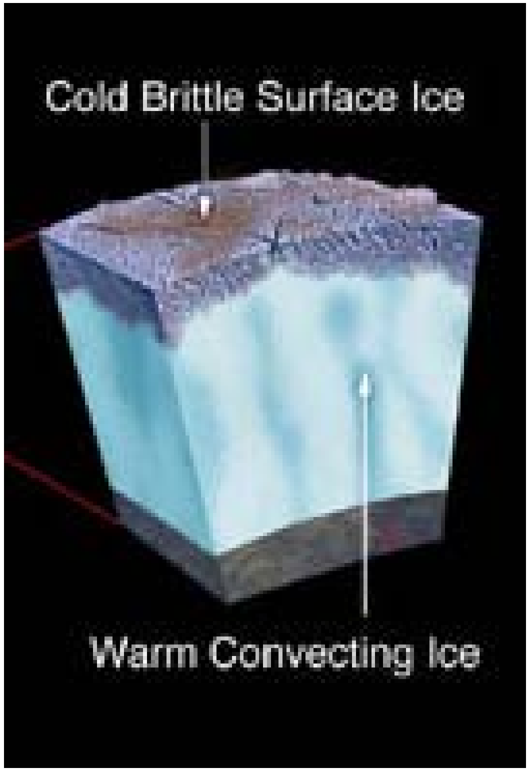
Io

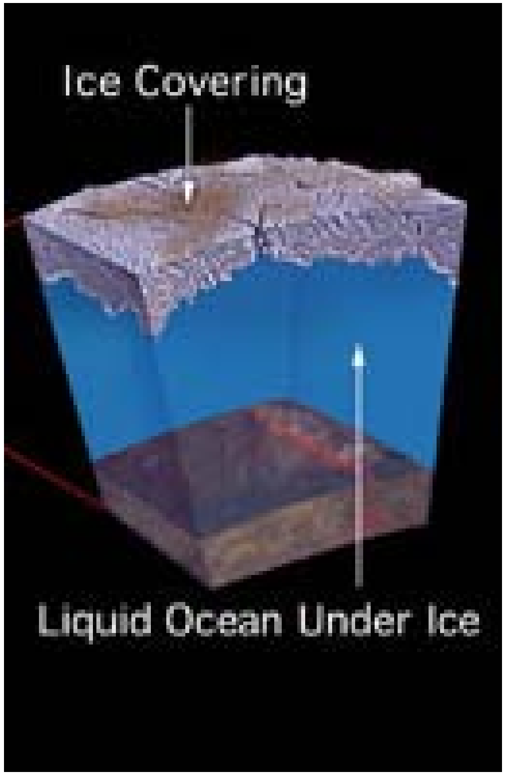


Europa

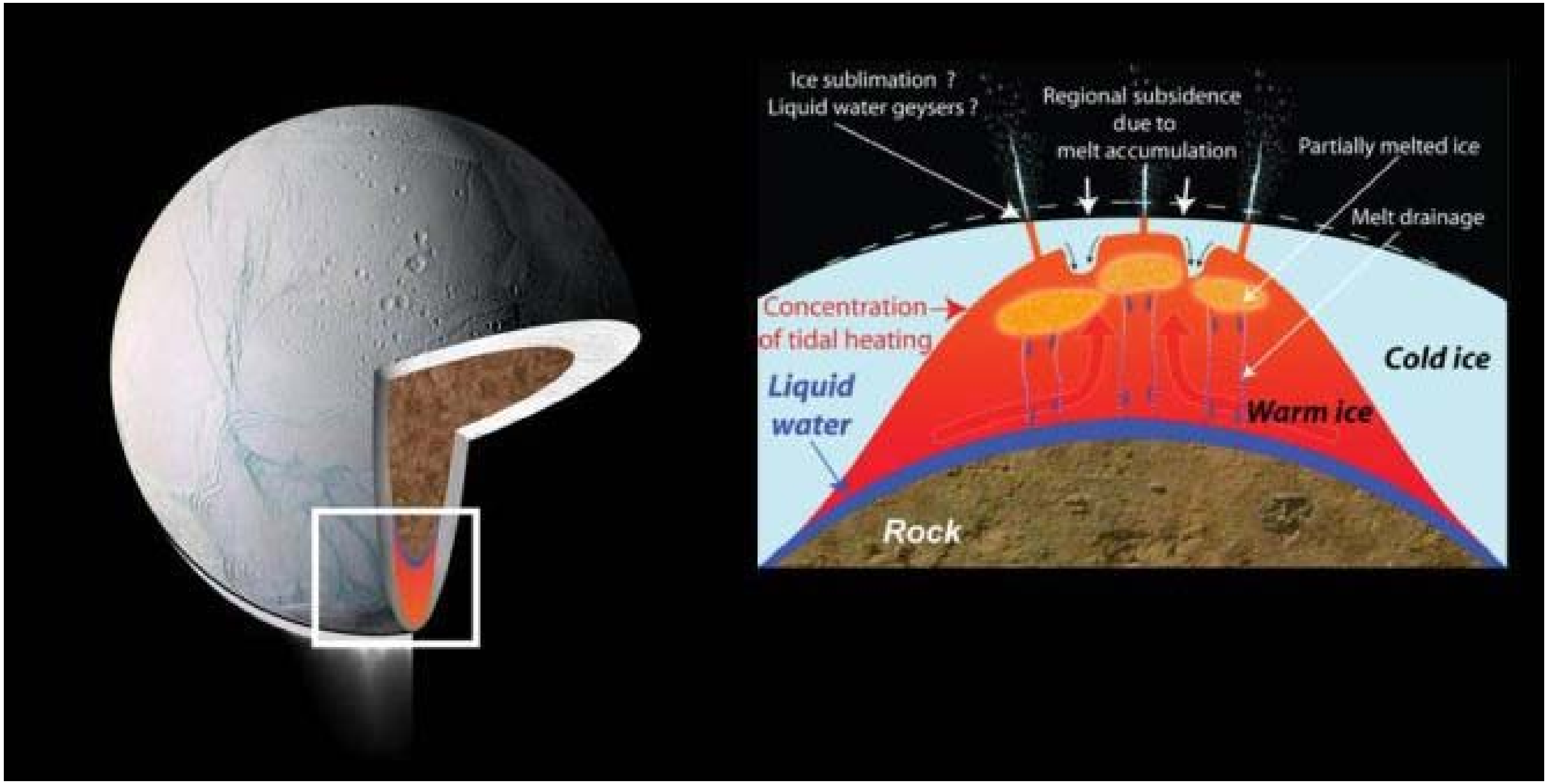


Conceptual models





Partial melting on Enceladus



Interested? Let’s talk.

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