Modeling the thermal structure of plate boundaries with COMSOL Multiphysics (FEMLAB)

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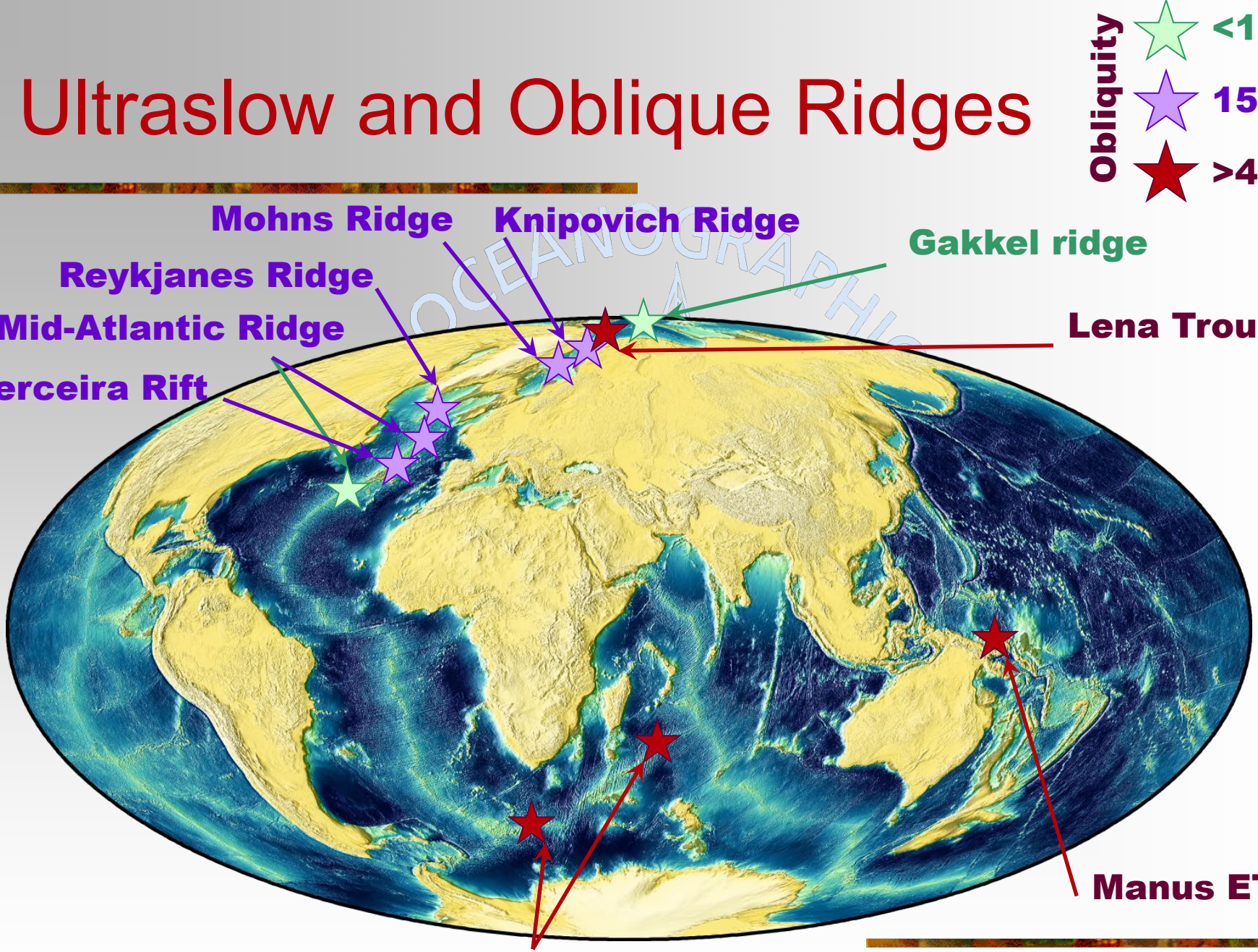
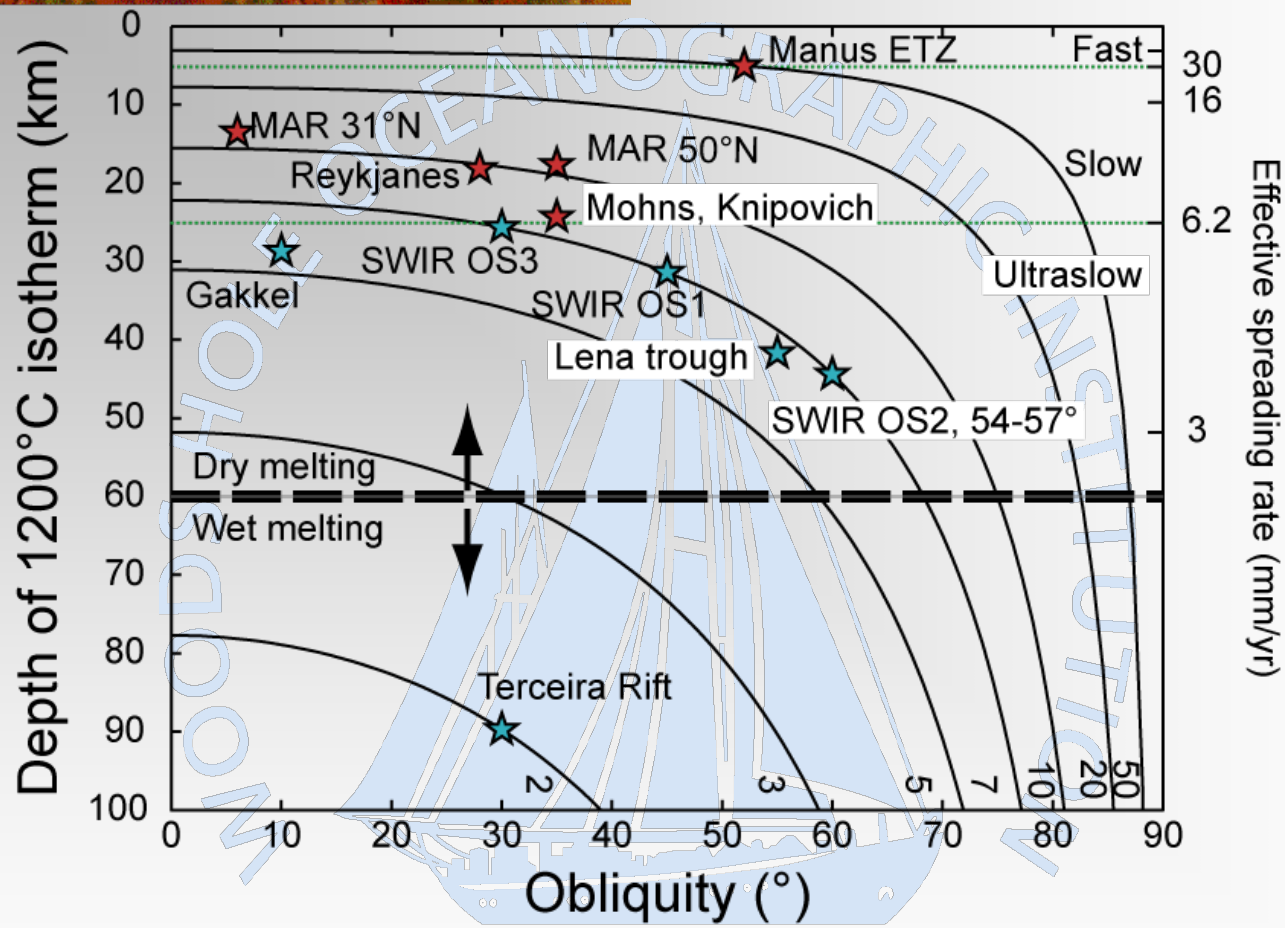
Outline

- Thermal structures of ultraslow and Oblique Mid-Ocean Ridges
  - Montési, Behn, and Barry (2005, 2006)
- Formation of the Denali volcanic gap
  - Rondenay, Abers, and Montési (2006)
- Gravity anomalies at ridge-transform intersections
  - Gregg, Lin, Behn, and Montési (2006)
- All these projects use COMSOL Multiphysics, the code formerly known as FEMLAB
- All could use addition of melt migration

Ultraslow and Oblique Ridges



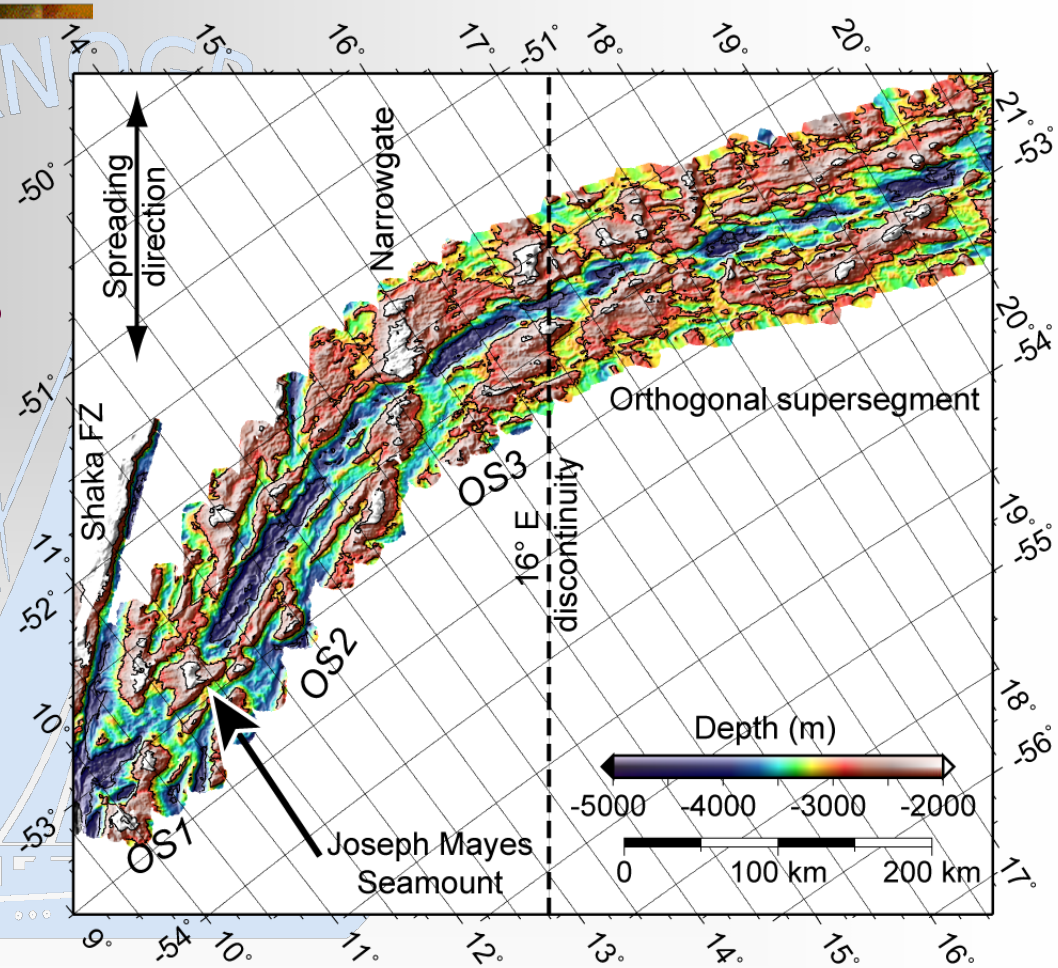
MAR- and SWIR type



- Transition to ultraslow spreading for V_E<~6.25 mm/yr, T_{1200}>25km

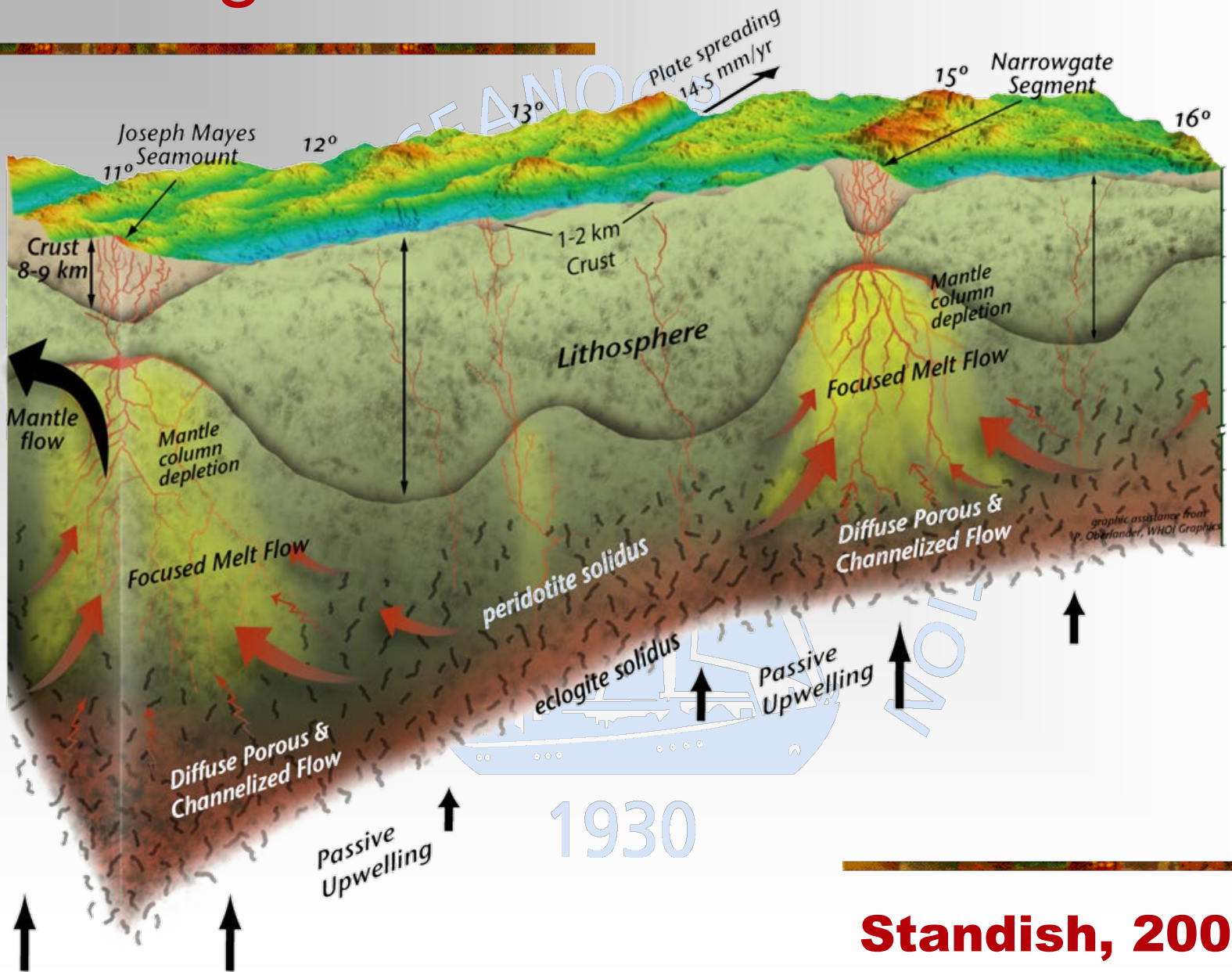
Oblique Supersegment: 9-16°E

- Oblique supersegment
  - Obliquity up to 60°
  - No en-échelon ridges
  - Ridge lined by mantle blocks
  - Punctual volcanic center, separated by 80+km



Dick, Lin, and Schouten, 2003

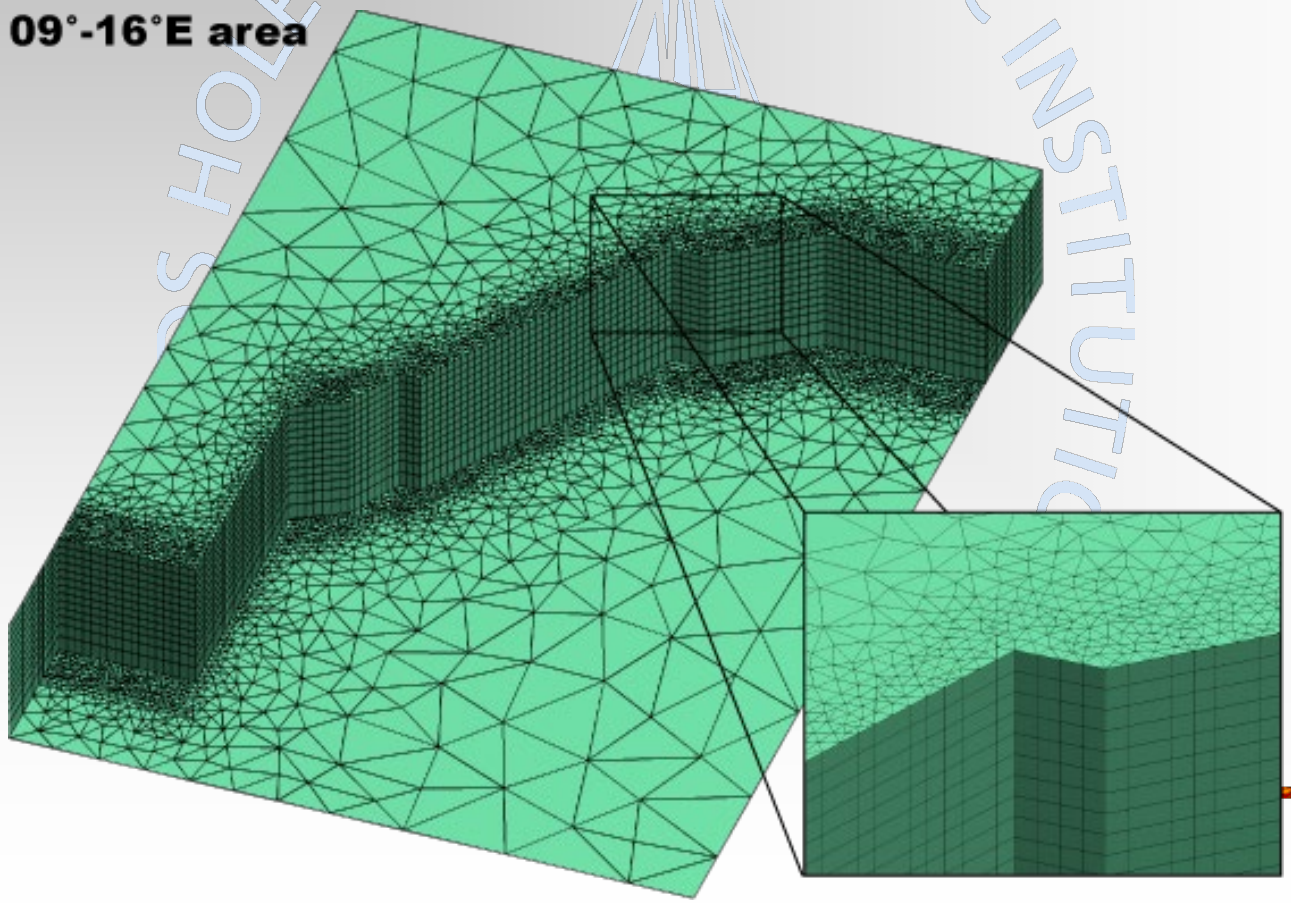
Focusing of enriched melts



Standish, 2005

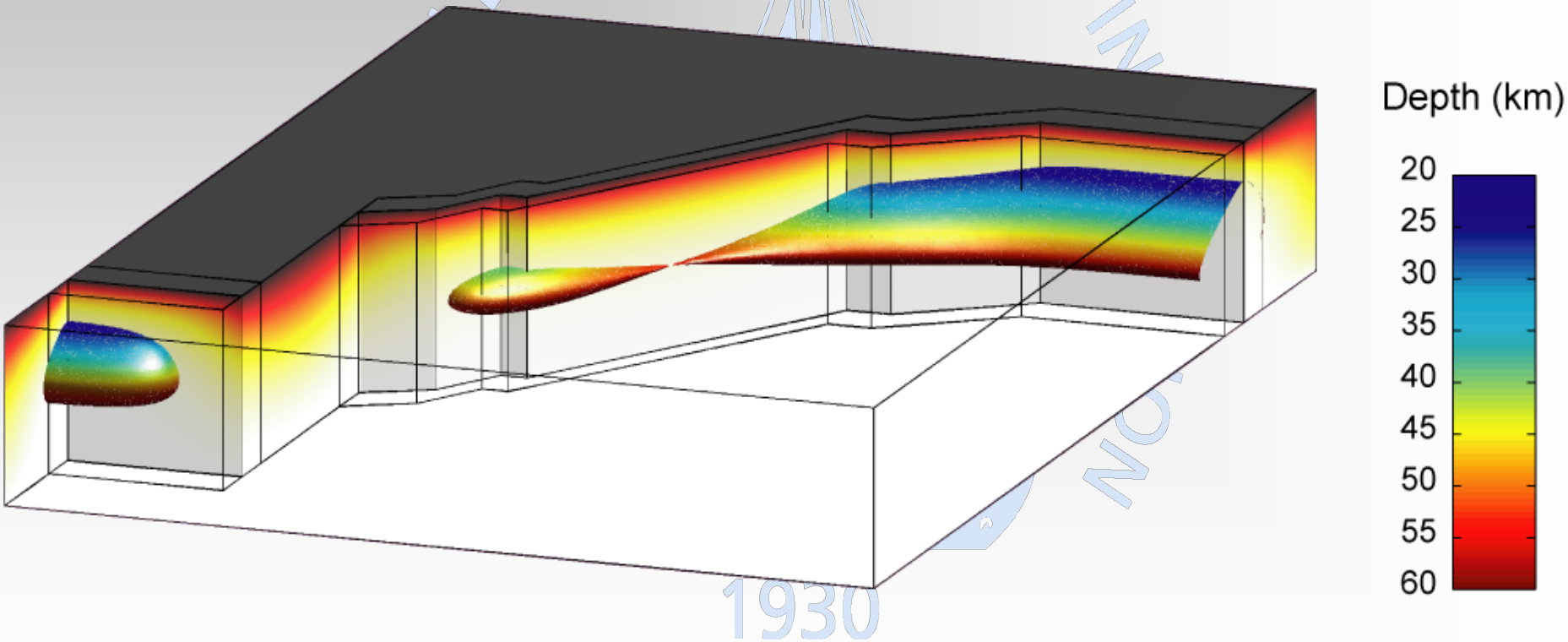
SWIR 09-16°E area

- 500x700x100 km^3 area, 1.6 Million degrees of freedom: requires 12 Gb RAM, 24+ hours



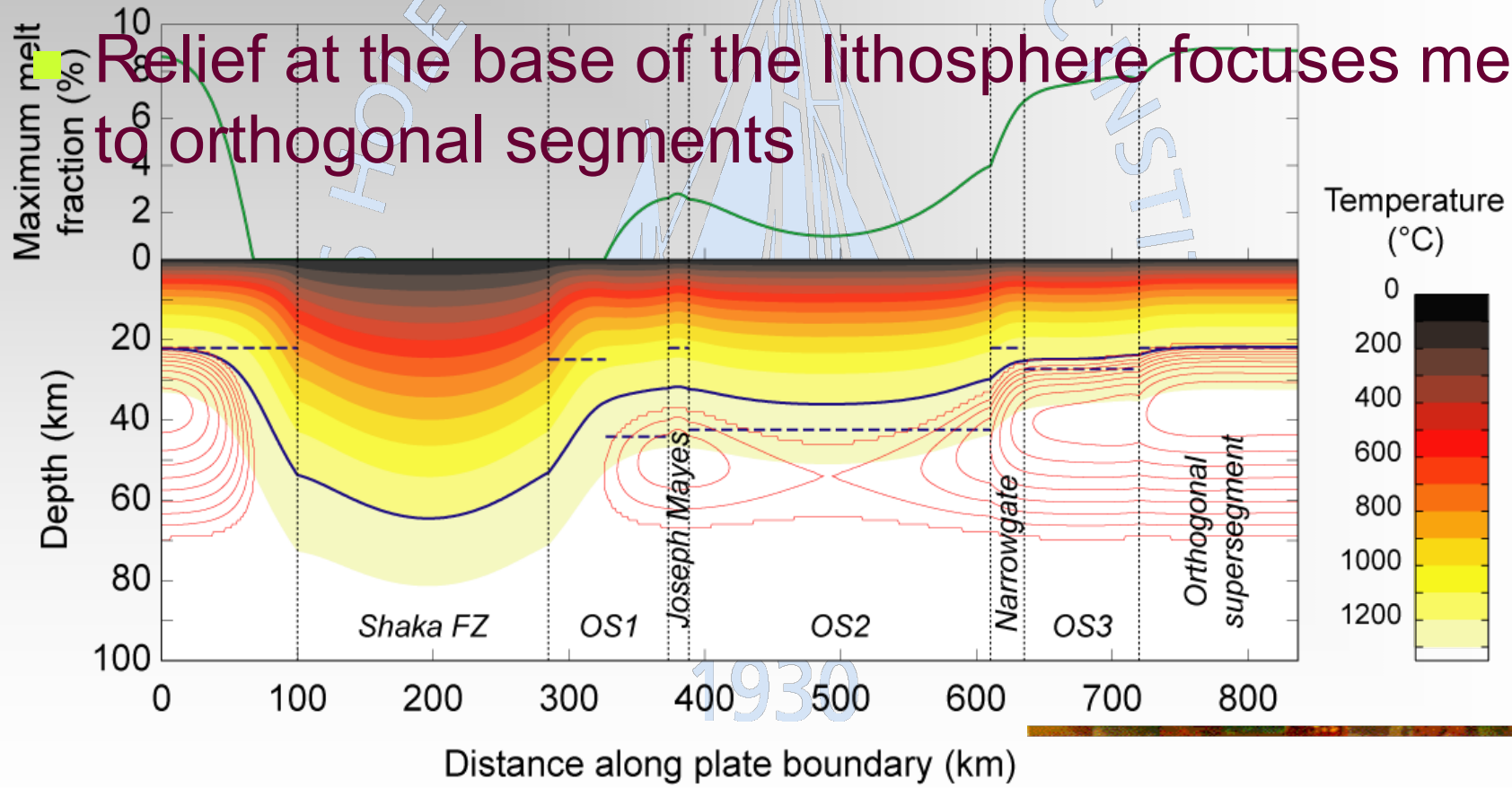
Melt body at 09-16°

- Melt anomaly associated with Joseph Mayes Seamount



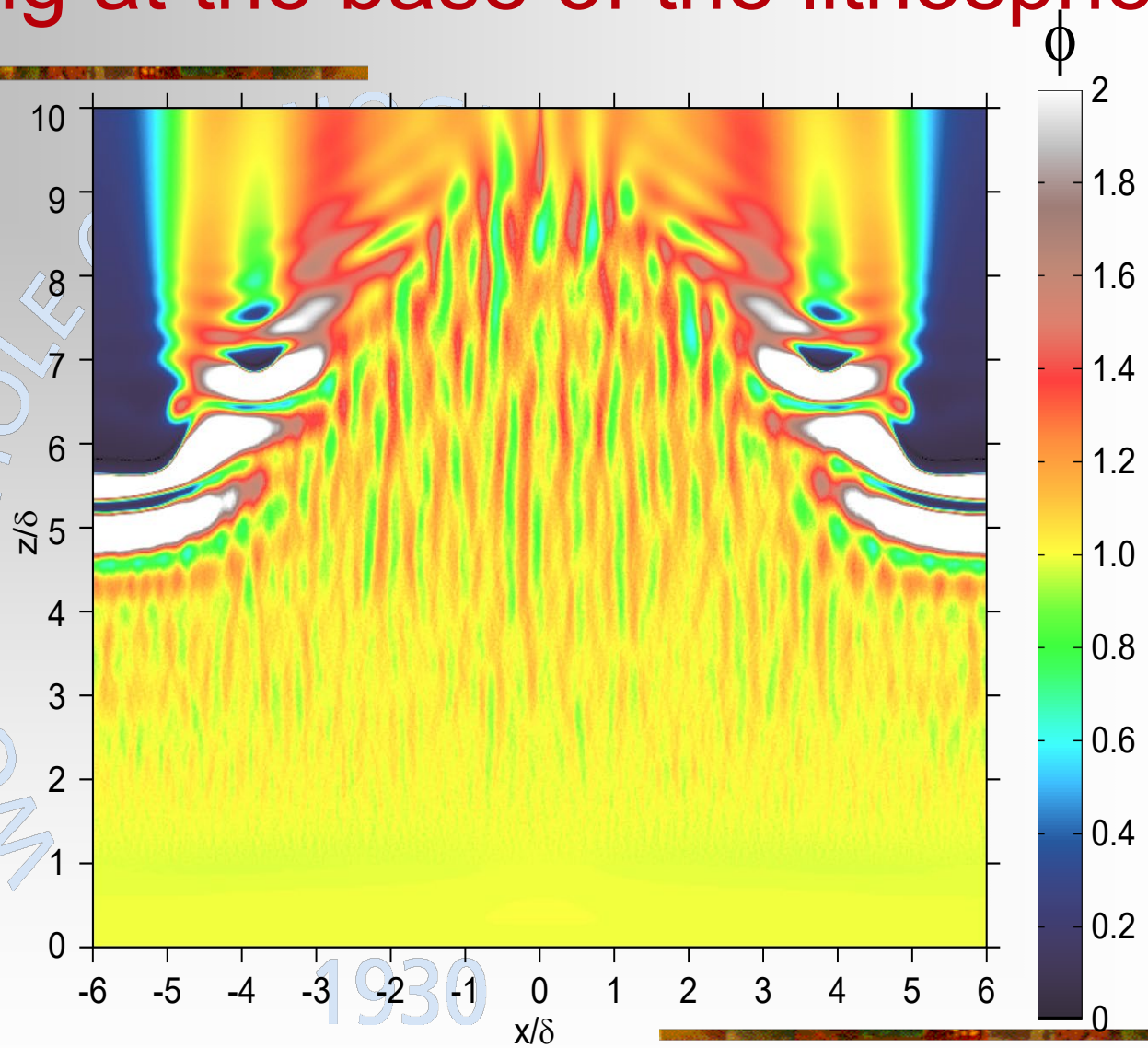
Temperature and melting at 09-16°E

- Segment-to-segment variations OK with 2D analysis, but no segment is truly 2D
- Relief at the base of the lithosphere focuses melt to orthogonal segments



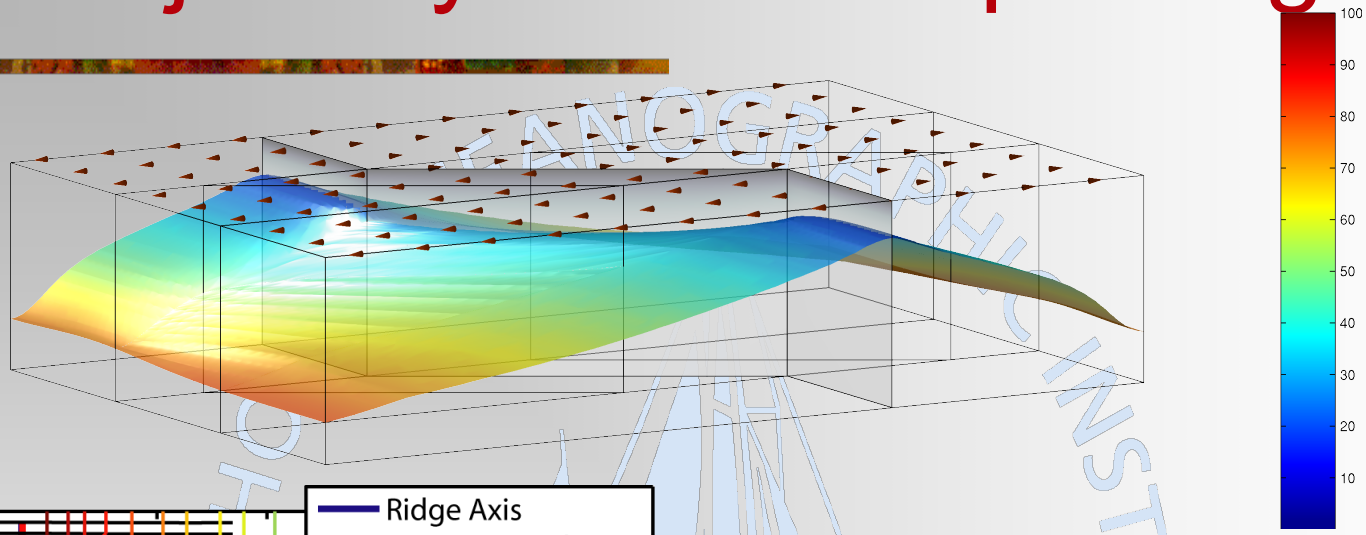
Melt focusing at the base of the lithosphere

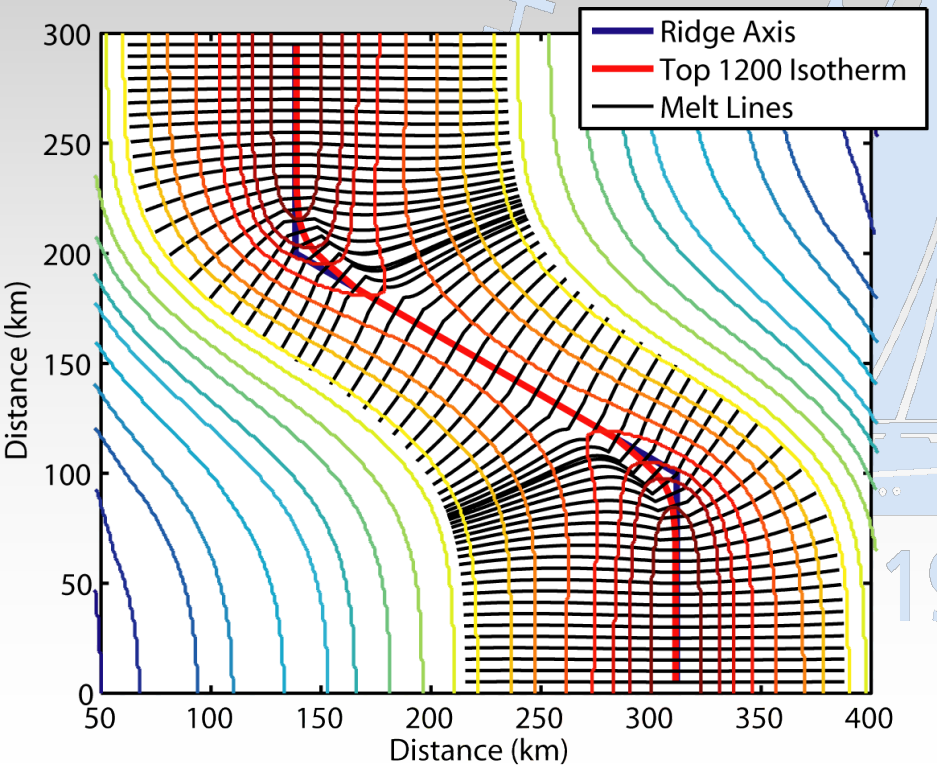
- Include inclined crystallization front
- Original idea by Sparks and Parmentier, 1991
- Effect of melt-rock reaction, proposity-dependent viscosity



Montési, Kelemen and Spiegelman (still) in preparation

Melt trajectory at an oblique segment

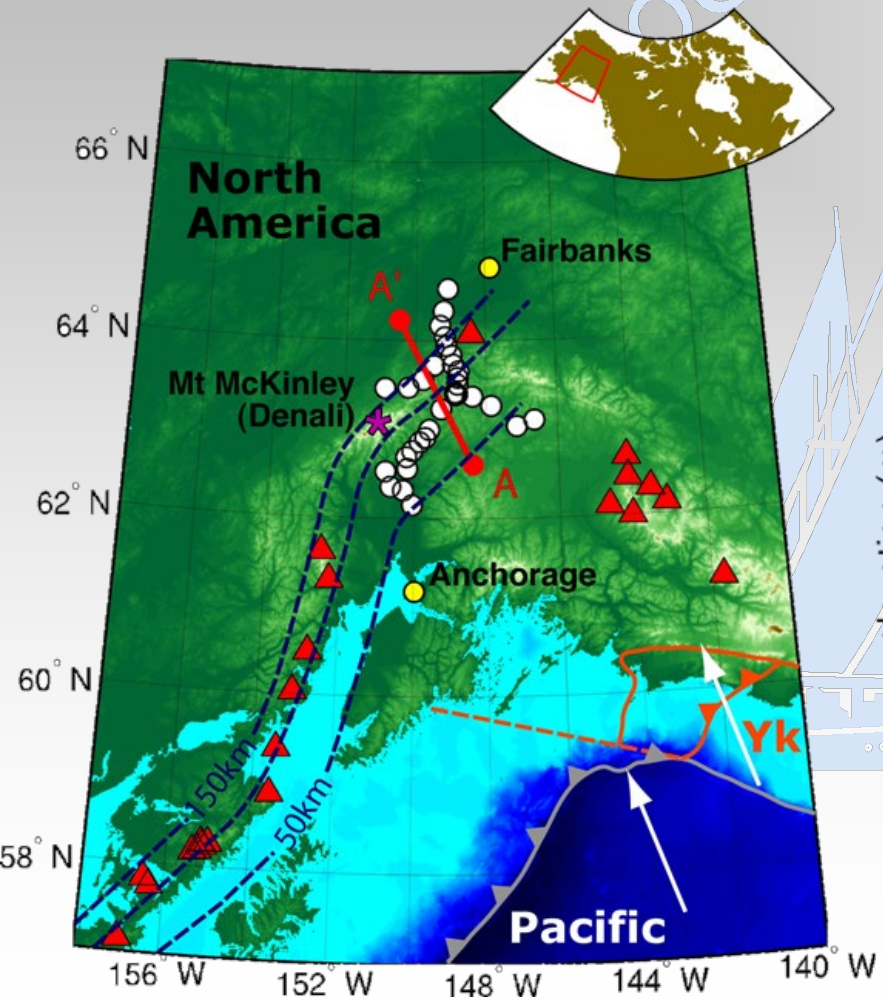


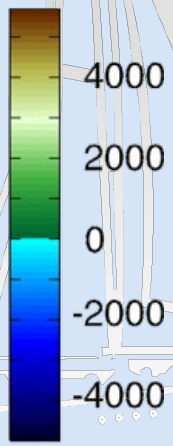


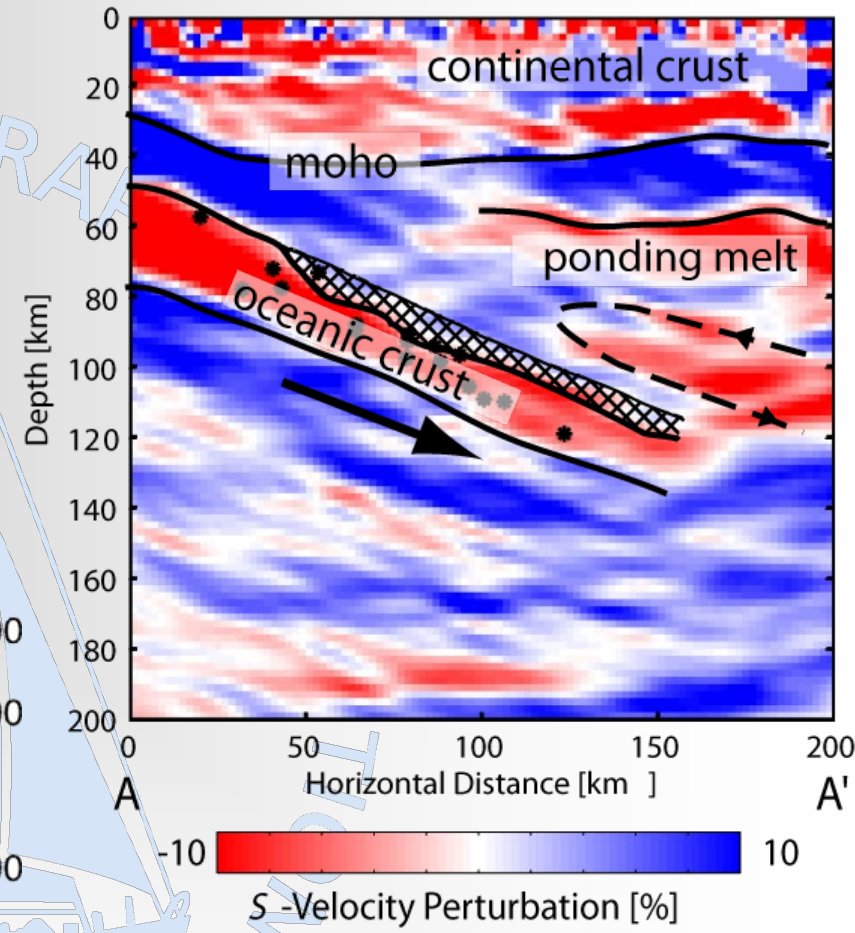
- Generic oblique segment
- Follows 1200° isotherm
- Focusing at outside corner
- Offset of melt collection zone and imposed ridge axis

Barry et al., 2005

Denali volcanic gap



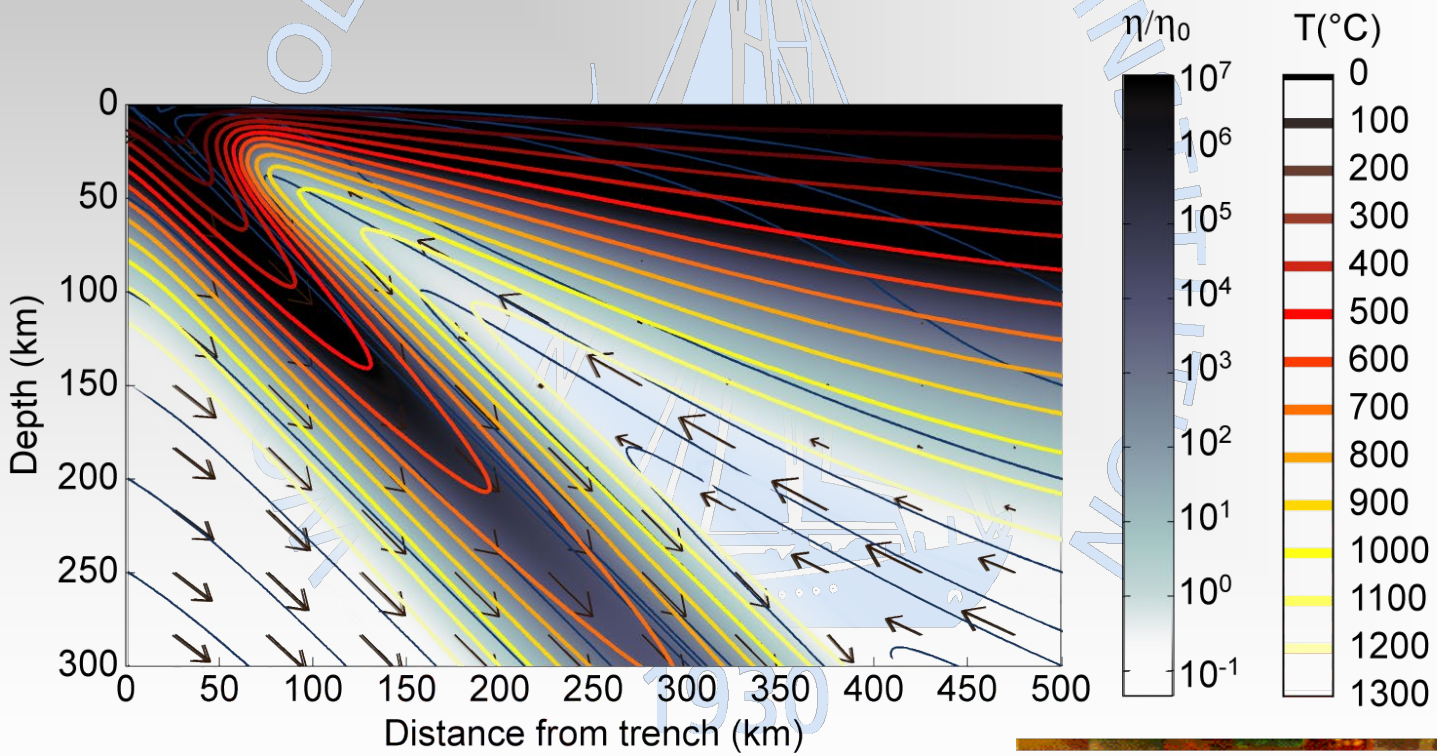




Rondenay, Abers, and Montési, 2006

Thermal structure

- Temperature-dependent viscosity
- Focusing at the base of the lithosphere towards the arc
- Corner flow enhances heat flow takes ~100Ma to erode llithosphere
- No “hot pinch zone” in Denali gap because of Yakutat underplating



Rondenay, Abers, and Montési, 2006

What about COMSOL Multiphysics?

- The code formerly known as FEMLAB
- Pro: Easy to use
  - Predefined applications (fluid, solids, heat, steady-state, transient, poroelasticity, ALE mode)
  - GUI and scripting modes
  - Custom PDEs, ODEs
  - Easily coupled with MATLAB
  - Good performance at subduction benchmark (Mark Behn)
- Cons: Restricted development
  - No parallelization (SMM in next version), use 64 bits for large models
  - Limited quad meshes, adaptative remeshing, dislocations
  - Commercial: need to pay, difficult to influence development

Thank You

The End