MARGINS Theoretical and Experiment Institute: Inside the Subduction Factory

The Rheology of the Mantle Wedge (Outline)

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Introduction

1. Show geodynamic model of an arc to introduce importance of mantle viscosity on flow in the wedge (forming link to Chris s talk).

   i. introduce viscous deformation mechanisms.
   ii. introduce importance of temperature, pressure and grain size.
   iii. introduce effects of water and melt fraction.

2. Comment on the importance of rheology on melt migration processes. Porous flow requires both permeability and compaction of the matrix (introduce possibility that melt migration can be controlled by either permeability or rheology)

3. Introduce problem that melt needs to get from the melting region through the lithosphere to the base of the volcanic arc. Introduce the concept of a transition from porous flow to focussed flow of melt in conduits or dikes.

Introduction to Deformation Mechanisms (compliment/review material covered by Karato as necessary)

1. Introduce philosophy of lab experiments and describe flow laws and viscosity

2. Show data for dislocation creep of olivine aggregates and extrapolation to upper mantle conditions (comment on the difference in stress, stress dependent viscosity)

3. Show effect of temperature on dislocation creep ($100^{o}C$ = order of magnitude in strain rate-viscosity)

4. Show transition to diffusion creep in the laboratory (emphasize effect of grain size), show extrapolation in grain size to upper mantle conditions (factor of 2.15 in grain size = order of magnitude in strain rate/viscosity).

5. Briefly review constraints on the effect of pressure on viscosity in the dislocation and diffusion creep regimes (probably covered by Karato).

6. Emphasize importance of stress and grain size for determining dominant deformation mechanism.

Role of Melt on the Rheology of the Mantle Wedge

1. Introduce concepts on the influence of melt on rheology

2. Review Cooper and Kohlstedt model to illustrate these concepts

3. Show data on the effect of melt on strain rate/viscosity in the diffusion creep regime

4. Show microstructure emphasizing melt topology.

5. Show effect of melt on strain rate in the dislocation creep regime.

6. Introduce possibility of a decrease in viscosity as a result of a transition to grain boundary sliding in the presence of melt

7. Illustrate effects of melt on grain size/grain growth: Melt inhibits grain growth thus the onset of melting can result in a decrease in grain size leading to both a decrease in viscosity and permeability

8. Comment on the possibility that the presence of melt may be all that is required for the transition to GBS (owing to relaxation of grain-scale strain compatibility constraints)

9. Introduce compaction experiments of Viskupic et al. (2000) to discuss constraints on Bulk Viscosity versus Shear Viscosity . Compare effect of melt in compaction experiments to that determined in distortional strain experiments. Comment on the role of differential stress on melt topology.

10. Conclude with simplified plot showing exponential relationship between melt fraction and viscosity

Role of Water on Viscosity (Review or add material depending on what Karato says)

1. Illustrate influence of water on viscosity in both the dislocation and diffusion creep regimes

2. Show solubility of water as a function of pressure to illustrates maximum possible viscosity reduction caused by the presence of water.

3. Discuss trade-off in the effects of melt and water caused by partitioning of water into melt phase.

Putting it all together (First cut on Rheology of the Wedge)

1. Extrapolation of flow laws to Wedge conditions to give constraint on magnitude of viscosity. Comment on how water content of arc magmas can be used as a constraint on the water content in the wedge.

Complications

1. Introduce the possibility that melt promotes brittle behavior of the aggregate through a decrease in the effective pressure

2. Introduce concept of dilatancy hardening in partially molten rocks using data on granitic systems

3. Show data on the rheology of olivine+melt system with different melt viscosities (comment on the role of grain-scale permeability) to constrain possible effects of melt pressure on physical properties.

4. Discuss influence of deformation on melt topology

5. Introduce concepts of the transition to dike-like behavior (when does melt move in a dike rather than by porous flow? A GOOD QUESTION FOR DISCUSSION), emphasize role of permeability

Constraints on permeability

1. Constraints from Melt topology (e.g., von Bargen and Waff, Faul)

2. Constraints from analog system (e.g., Wark and Watson)

3. Constraints from compaction experiments (e.g, Viskupic)

4. Effects of deformation (melt topology) and second phases (e.g., pyroxenes)

Independent Constraints on Wedge Rheology (Points to introduce for discussion and provide link to Glenn s, Doug s and Charlie s talks)

1. Effect of rheology on seismic velocity (attenuation)

2. Seismic anisotropy (role of melt and lattic-preferred orientation of olivine)

3. Geochemistry/Petrology: Where do melts equilibrate?, how fast do they get out?, where does the water come from?