THE EFFECT OF LARGE MELT FRACTION ON THE DEFORMATION BEHAVIOR OF PERIDOTITE: IMPLICATIONS FOR THE RHEOLOGY OF IO'S MANTLE. T. Scott and D. L. Kohlstedt, Dept of Geology and Geophysics, University of Minnesota, 310 Pillsbury Dr, Minneapolis, MN 55455; scot0039@umn.edu, dlkohl@umn.edu

Introduction: One key constraint needed for refinement of the interior geochemical and geodynamic models of Io is the viscosity of the convecting partially-molten silicate mantle. To date, laboratory studies of partially molten mantle rocks have reached melt fractions up to ~0.12, a value much smaller than thought to be appropriate for the asthenosphere of Io where the degree of partial melting may be 0.15 – 0.40 or higher [1,2,3,4]. Therefore, we have performed a series of high temperature, triaxial compressive creep experiments on dry synthetic peridotites in a gas medium apparatus at a confining pressure of 300 MPa and temperatures from 1473 to 1573 K in order to understand the influence of large amounts of melt ($0.15 < \varphi < 0.40$) on the rheological behavior of partially molten rocks.

Experimental Procedure: Mechanical mixtures of crushed and dried San Carlos olivine powder (1-10 μm) plus MORB (~8 μm) were isostatically hot pressed at 1523 K and 300 MPa for 4 h. A portion of each hot-pressed sample is retained for microstructural analysis, including determination of the grain size at the start of the deformation experiment, with the remainder machined down to a cylinder with approximately a 2:1 ratio of length to diameter (~ 16 x 8 mm). These cylinders are then inserted into a nickel sleeve for deformation under controlled fO_2 conditions. The applied load vs. displacement rate is measured in each experiment, which is then converted to stress (σ) vs. strain rate ($\dot{\varepsilon}$).

Experimental Results: Analysis of stress vs. strain rate data (see figure 1) from a sample containing $\varphi \approx 0.25$ MORB with a grain size $d \approx 9$ μm deformed at 1500 and 1523 K and differential stresses of ~1 MPa in the diffusional creep regime (stress exponent $n = 1$) yields a viscosity of 5×10^{15} Pa-s when scaled to 1mm grains.

Discussion: Microstructural analysis indicates that after hot pressing the melt is homogeneously distributed between grain-size and larger melt pockets at triple junctions and smaller pockets at two, three and four grain junctions, with many grains completely surrounded by melt (see figure 2). Extrapolation to the conditions of Io's mantle, or other environments can be made by using a flow law of the form

$$\eta \equiv \frac{\sigma}{\dot{\varepsilon}} = A * d^3 * \exp(-\alpha\varphi) * \exp(Q/RT) \qquad [1]$$

where η is the rock viscosity, A is a pre-exponential term which includes oxygen fugacity, d is the grain size, α is the melt fraction factor (α has been deter-

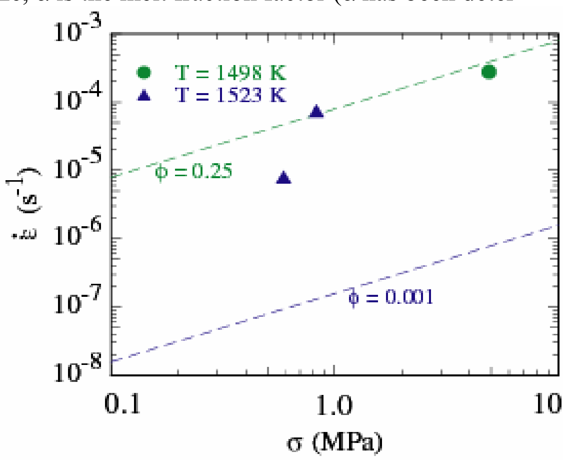

Figure 1: Plot of stress (σ) vs. strain rate ($\dot{\varepsilon}$) for a sample with olivine + 25 vol% MORB deformed in compression at 1498 and 1523 K. The data has been normalized to 1498 K. The dashed lines indicate the prediction of the published flow law, equation 1, for both $\varphi = 0.25$ and $\varphi = 0.001$ (melt free), for the sample grain size $d = 9$ μm.

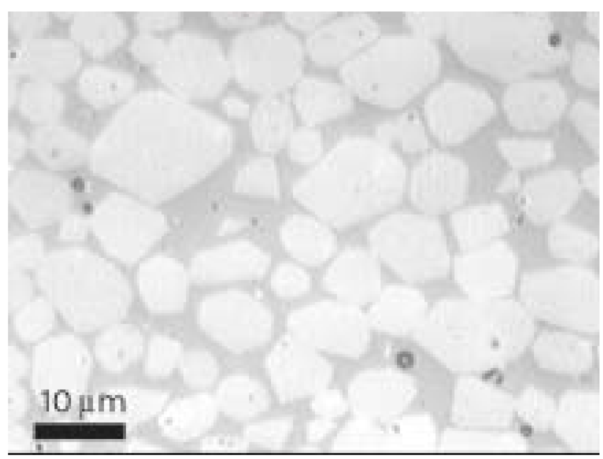

Figure 2: Reflected light micrograph of an olivine + 25 vol% MORB sample deformed in compression from top and bottom. The light grey grains are the olivine while the darker grey is the quenched liquid MORB. The small dark circles are pores.

mined experimentally to be -25 for dry peridotites - its value depends on conditions such as water content, etc), φ is the volume fraction of melt, Q is the activation energy, R the universal gas constant, and T the absolute temperature [5]. Use of this equation assumes the strain rate varies linearly with stress (i.e., viscosity is independent of stress), and that my samples are deforming in the diffusion creep regime, which is reasonable given the low differential stresses and high strain rates.

The viscosity value of $5x10^{15}$ Pa-s is a nearly identical to the value predicted by a flow law reported for dry peridotite, where viscosity $\eta \propto \exp(-25\varphi)$. This viscosity value can be compared to published results from numerical models with viscosity values of 10^{17} Pa-s for a homogeneous convecting mantle and 10^8 – 10^{12} Pa-s for a thin convecting asthenosphere [2,6]. Hence, additional experiments on partially molten mantle rocks with relatively high φ are required to constrain the dynamic properties of Io's mantle. New viscosity data can either help quantify the degree of partial melting for a given model imposed viscosity or, alternatively, allow for a specific viscosity to be selected and, in conjunction with the models, suggest a representative composition for the silicate mantle.

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