Effect of Fe content on Olivine Viscosity at High Pressure and Implication for the Martian Mantle

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Deformation experiments were carried out in the D-DIA at synchrotron beamlines (NSLS X17-B2, APS 6-BM-B, ESRF ID06) on olivine polycrystals with various compositions along the forsterite-fayalite joint. Run *P* and *T* were within 2.5 – 8.0 GPa and 1073 – 1573 K, and strain rate was in the range 0.2 – 14 $\times 10^{-5}$ s^{-1}. Dry specimens with different iron contents, chemically separated from each other by Ni disks, were deformed two by two in order to compare their rheology. A Ni Jacket was used in some experiments to control fO_2. Strain rates and the applied stress were measured in situ by X-ray imaging and diffraction, as described elsewhere [1]. The contrast in effective viscosity between Fe-rich olivine and Fe-poor olivine is much lower at high pressure than observed at low pressure (i.e., 300 MPa, [2]). This observation is partly explained by the different strain-rate sensitivities to stress and pressure variations of olivines with different iron contents, which translate in classical power laws into different stress exponents (*n*) and activation volumes (*V**). By carrying out stress-step and pressure-step experiments, we observed that *n* and *V** increase with Fe content. A consistent increase of the *n* value with olivine Fe content is also observed at low *P* (a review in [3]). Applying these results to the interior of Mars, with an olivine Fe-content (Fe #) estimated to between 25 and 30 %, and assuming reasonable values for mantle stresses, we conclude that the viscosity increases with depth in the Martian upper mantle could be up to a factor of 40 times more than estimated in the Earth. Such a strong increase in viscosity may have critical consequences for Mars' mantle convection mode.

[1] Raterron P. and Merkel S. (2009) *J. Synchrotron Rad.*, *16*, 748-756 ; [2] Zhao Y.-H. et al. (2009) *EPSL*, *287*, 229-240 ; [3] Bollinger C. et al. (2014) *PEPI*, *228*, 211-219.

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