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 × 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 fO₂. 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.


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