Water Does Not Influence the Plasticity of Olivine at Low Temperatures

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Small concentrations of intracrystalline water (in the form of H+ ions) have a major effect on the strength of olivine at asthenospheric temperatures. However, the role of water is comparatively poorly studied at lower temperatures relevant to the lithosphere. In addition, the microphysical processes by which hydrous defects affect deformation of olivine are not well understood, with several models having been suggested to explain the weakening observed at high temperatures with increased concentrations of intracrystalline water. The predictions of these models are in agreement at the high temperatures at which the majority of experiments have been performed, but the differences in underlying physical assumptions lead to significant divergence in predicted strength at low temperatures. In this study, we examined the effect of water on the yield strength of olivine during low-temperature plasticity using room-temperature Berkovich nanoindentation. Experiments were conducted on a single crystal of San Carlos olivine initially hydrated in a multianvil apparatus, resulting in a water concentration of 1600 ppm H/Si. After indentation tests, this sample was dehydrated such that the water content was reduced to 700 ppm H/Si, after which further indentation tests were performed. Additional tests were conducted on dry, untreated San Carlos olivine. The presence of 1600 ppm H/Si in olivine led to a slight reduction in the measured Youngs modulus relative to olivine with 700 ppm H/Si, consistent with previous experimental results regarding the effect of water on elasticity of olivine. However, hardness and yield stress were not distinguishable between the two sets of tests. In addition, the hardness and yield stress of wet (7001600 ppm H/Si) and dry (40 ppm H/Si) crystals were not significantly different among indents performed in similar crystallographic directions. These observations suggest that water content does not affect the strength of olivine when diffusive processes are inhibited. Thus, intracrystalline water may not play a role in olivine deformation at low homologous temperatures, such as on cold frictional faults or in flexing oceanic lithosphere. We additionally infer that the manner by which water leads to weakening at asthenospheric temperatures is through its influence on diffusivity.

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