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Evidence of phase nucleation during olivine diffusion creep: a new perspective for mantle strain localisation

Jacques Précigout (1) and Holger Stünitz (1,2)

(1) Institut des Sciences de la Terre d'Orléans (ISTO), Université d'Orléans UMR/CNRS 7327, Orléans, France (jacques.precigout@univ-orleans.fr), (2) Department of Geology, University of Tromso, Tromso, Norway

Mantle strain localisation is of great importance for lithosphere dynamics, but the cause for this phenomenon remains very elusive, particularly in conditions of the strong and ductile uppermost mantle. In these latter, grain size reduction leading to diffusion creep in olivine is believed to be one of the best candidates to account for strain localisation. However, the mechanisms of grain size reduction in this regime are still poorly understood. Here we show the results of Griggs-type experiments that document grain size reduction and material weakening during wet olivine diffusion creep at 900 °C and 1.2 GPa. While occurring for both, mono-phase and two-phase aggregates, grain size reduction is coeval with strain localisation and local phase mixing in olivine–pyroxene aggregates. Based on evidence of fluid inclusions and cracks filled with a fine-grained phase mixture, we conclude that grain size reduces as a result of fluid-assisted nucleation. Cavitation induced by grain boundary sliding (creep cavitation) can be inferred, and may play a critical role for olivine grain size reduction. Amongst their implications for rock rheology in general, our findings highlight a key process for strain localisation in the ductile uppermost mantle.

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