Prospects for laboratory studies of dislocation damping

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Olivine [$(Mg,Fe)_2SiO_4$] is the most well studied mineral, representative of the upper mantle of the Earth. Despite this, the various mechanisms that allow for the attenuation of seismic waves in the upper mantle still require additional research. One such mechanism is called dislocation damping. This study aims to systematically investigate the effect of the dislocation density on the propagation of seismic waves in deformed olivine (single and polycrystalline specimens) through forced torsional oscillation (FTO) experiments.

Synthetic polycrystalline olivine was created from a solgel precursor, hotpressed, and deformed under 1300C, 300MPa and up to 19% strain yielding an initial dislocation density of 4.09 ± 0.41 μm^{-2}. It was subsequently sectioned and the resulting pieces were allowed to anneal under controlled atmospheric conditions at different temperatures ($\leq$1450C) and time durations ($\leq$50 hours). The samples were prepared for the SEM via an oxidation-decoration technique, careful polishing and imaging using backscatter electrons (BSE). Montages of high resolution SEM images (8k and $\geq$ 5000 μm^2) were made to estimate the final dislocation density using software such as ImageJ to threshold and count the dislocations and determine their respective lengths which were corrected for. The data fits a second order dislocation annealing rate law with an activation energy of 308 ± 26 kJ mol^{-1}. The obtained relationship predicts no significant dislocation annealing at 1100C, the maximum temperature at which the first attenuation experiment is carried out on for a similar deformed synthetic olivine aggregate.

The data from this FTO run, compared with previous data on the same, undeformed material, did not show any significant enhanced seismic wave attenuation. The internal friction from grain boundary sliding, of the micrometre sized grains, appears to swamp the contribution of dislocation damping. Extrapolation to coarse grained mantle materials is not possible. The project will therefore focus on the deformation of single crystal natural olivines and the seismic wave attenuation measurement thereof. This is backed up by dislocation schmid factor calculations for olivine’s most dominant slip system (010)[100] for a cylindrical specimen in a certain crystallographic orientation. The goal is to allow for the generation and damping of the most favourably oriented dislocations created from either uni-axial or torsional deformation.