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# Dislocation Damping and Anisotropic Seismic-wave Attenuation in the Earth's Upper Mantle

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Seismic anisotropy, attributed to olivine lattice preferred orientation, suggests that tectonic deformation in the Earth's shallow upper mantle involves dislocation creep. Reversible glide of dislocations, generated by the prevailing/fossil tectonic stress, may result in anelastic relaxation that contributes to the reduction of seismic wave speeds and associated attenuation. To test this hypothesis, pure polycrystalline olivine specimens were synthesised by isostatic hot-pressing of synthetic powders of Fo90 composition. The hot-pressed material is dense (< 1% porosity), fine-grained, essentially dry and melt-free olivine. Other, more coarse-grained material was prepared in the same way from crushed natural (San Carlos) olivine. These contrasting materials provided the opportunity to distinguish between the influences of grain size, dislocation density and minor impurities. Selected specimens were deformed by dislocation creep either in compression or torsion and characterised for dislocation density via oxidative decoration and backscattered electron imaging. The shear modulus and associated strain-energy dissipation in both hot-pressed and pre-deformed specimens were measured at seismic frequencies and low strain amplitudes under conditions of simultaneous high pressure and temperature with torsional forced-oscillation methods. On the basis of a prior study of dislocation recovery, a maximum temperature of 1100C was chosen to allow sustained forced-oscillation testing under conditions of relatively stable dislocation microstructure. The high-temperature dissipation background, attributed in undeformed fine-grained materials to grain-boundary sliding, and the associated partial relaxation of the shear modulus, are systematically enhanced in the pre-deformed materials – suggesting a role for the dislocations introduced during the prior deformation. The enhancement is systematically greater for prior torsional deformation than for prior deformation in compression. This observation is consistent with the prediction from a simple model of resolved shear stress that dislocations generated by prior torsional deformation are more favourably oriented for glide during the subsequent torsional oscillation measurements. Such dislocation damping is expected to become more significant relative to grainsize-sensitive effects for the larger grain sizes of the Earth's mantle. Moreover, it is predicted that dislocation damping in the Earth's mantle will be anisotropic – being greatest for those shear-wave propagation directions and polarisations with shear stress aligned with the prevailing/fossil tectonic stress.