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Protracted fabric evolution in olivine: Implications for the relationship among strain, crystallographic fabric, and seismic anisotropy

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Crystallographic fabrics in olivine-rich rocks provide critical information on conditions and mechanisms of deformation as well as seismic properties of Earth's upper mantle. Previous interpretations of fabrics produced in laboratory experiments were complicated by uncertainty as to whether the steady-state fabric was attained. To examine the systematics of the evolution of olivine crystallographic fabrics at high strain, we conducted torsion experiments on olivine aggregates to shear strains of up to $\sim$20. Our results demonstrate that a steady-state fabric is not reached until a shear strain >10, a much higher value than previously thought necessary. Fabrics characterized by girdles of [010] and [001] axes or by clusters of [010] and [001] axes are both observed. Until now, these fabrics were associated with either two different deformation mechanisms or two different sets of deformation conditions. Here we establish that both fabrics are, in fact, part of the same evolutionary process. An eigenvalue analysis allows the fabric shape to be quantitatively correlated with the magnitude of shear strain. Misorientation analysis suggests that the observed fabric evolution results from the competition of the two easiest slip systems in olivine, (010)[100] and (001)[100]. Our results open up the possibility of using olivine crystallographic fabrics or seismic anisotropy to quantitatively evaluate strain histories in both field studies and geophysical investigations of upper-mantle rocks.