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Lattice Preferred Orientation (LPO) evolution in dynamically recrystallizing olivine polycrystals: a numerical approach

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Understanding the development of lattice preferred orientation (LPO) during plastic deformation of olivine rocks is crucial to interpreting some of the geophysical anisotropies inferred in the upper mantle rocks (e.g. seismic, thermal, mechanical or electrical conductivity anisotropies). The elastic anisotropic behaviour of olivine determines that seismic waves propagate with velocities depending on the propagation direction and induces a seismic anisotropy of compression and shear waves. The relationship between LPO development during olivine deformation and seismic anisotropy has been examined both experimentally and numerically. These results have shown that the observed fast seismic direction tends to be parallel to the flow direction, and therefore, can be used to constraint large scale models of mantle's convective flow.

In addition to plastic deformation by dislocation creep, the thermal activated processes of dynamic recrystallisation (i.e. nucleation, grain boundary migration, recovery) can occur. Microstructure evolution during dynamic recrystallisation is governed by a series of concurrent but also competing processes. While deformation tends to reduce the grain size due to the introduction of dislocations and subgrain formation, grain boundary migration leads to an increase of grain size and reduction of crystalline imperfections. The balance between these processes controls the microstructure evolution (e.g. grain size and shape, grain and subgrain boundaries, etc) and LPO development, and hence the anisotropic response of rock volumes.

This study extends previous work by numerically simulating the effects on LPO development of the thermally activated processes of dynamic recrystallisation (i.e. nucleation and grain boundary migration). The microstructure evolution of a two-dimensional olivine polycrystalline aggregate is explicitly simulated using a full-field approach based on coupling of crystal plasticity and recrystallization. We concentrate our analysis on two extremes cases: where only dislocation glide is allowed and where crystal plasticity is combined with grain boundary migration. Numerical results suggest that the coupling of orientation-dependent grain boundary migration with lattice rotations due to dislocation glide can produce LPO that are significantly different from dislocation glide alone, and can lead to cases where fast seismic direction is not parallel to the flow direction.