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A Phenomenological Approach to Simulating LPO Development of Various Olivine Fabrics

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The analysis of seismic anisotropy has become the most conventional tool for characterizing flow in the Earth's upper mantle [1]. Thus, it is crucial for geodynamic models to include predictions of anisotropy so that their relevance for the Earth can be easily evaluated. Rigorous fabric development models, which rely on deforming and rotating a large number of discrete grains, have already been created for the purpose of analyzing flow model [2,3]. However, most lack the flexibility to examine all known fabric types and the results from different methods are not always in agreement with one another [4,5]. Therefore, it is important to have a simpler tool that provides rapid, approximate predictions of mantle fabric and anisotropy for hypothesis testing.

The simplest proxy for anisotropy is provided by the instantaneous flow field. It is acceptable if the strain rate field varies along a particle trajectory more slowly than anisotropy develops [6,7]. More generally, anisotropy may be associated with the finite strain ellipsoid with the a-axis of olivine tending to rotate toward the direction of maximum extension [8,9]. However, various slip systems are activated under different conditions. Therefore, one may expect that for a different fabric type, a different olivine axis will rotate toward the extension direction [10]. We have generalized the calculation of finite strain to produce an ellipsoid associated with the most likely orientation of the a-, b-, and c-axes of olivine, called a fabric ellipsoid. To compute the fabric evolution tensor, we perform an eigen-decomposition of the strain rate tensor, symmetric part of the velocity gradient tensor. We retain the eigenvectors but rearrange the eigenvalues according to he active deformation mechanism. In that way, the fabric ellipsoid evolves in such a way that the desired olivine axes rotate toward the instantaneous maximum elongation and maximum shortening directions. We developed algorithms for each kind of fabric identified by Karato et al. [2008].

We incorporate two additional mechanisms of fabric development: fabric healing and dynamic recrystallization. We simulate fabric healing by averaging the fabric ellipsoid with an isotropic sphere. For recrystallization, we average the developing fabric ellipsoid with an ellipsoid whose principal axes are already oriented along the principle directions of strain rate. The relative contribution of each mechanism can be adjusted. A comparison between model results and naturally and experimentally deformed olivine aggregates shows that fabric healing and recrystallization play a major role in fabric orientation and magnitude. In some cases, especially in natural samples [11], recrystallization and healing play a stronger role than grain rotation.

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