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Olivine texture evolution under simple deformation: Comparing different numerical methods for calculating LPO and anisotropic viscosity

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The development of olivine texture, or lattice preferred orientation (LPO), has been implemented in many numerical modelling tools to predict seismic anisotropy, which places constraints on mantle dynamics. However, a few recent studies have linked olivine texture development to its mechanical anisotropy, which in turn can affect deformation rates and also the resulting texture. To study the effect of anisotropic viscosity (AV) and LPO evolution in geodynamics processes, it is important to know the role of AV and LPO and the differences between the numerical methods that calculate them.

The modified director method parameterizes the olivine LPO formation as relative rotation rates along the slip systems that participate in the rotation of olivine grains due to finite deformation. When it is coupled with a micromechanical model for olivine AV, it allows the anisotropic texture to modify the viscosity. We compare the olivine textures predicted by the modified director method both with and without a coupled micromechanical model and textures predicted by the D-Rex LPO evolution model. To do this, we recalculate the texture observed in simple 3D models such as a shear box model and two other well-understood models: a corner flow model and a subduction model.

In general, we observed that the D-Rex models predict a stronger anisotropic texture compared to the texture predicted by the modified director method both with and without the micromechanical model, in agreement with previous studies. When including the micromechanical model, the anisotropic texture changes the observed strain rates, which allows for a slightly faster texture evolution that is more similar to the D-Rex predictions than it is to those produced by the modified director method alone. We found that even for the simplest settings there is an increase of 10~15% in strain rate during deformation until a strain of 2.5. When shearing the asthenosphere over ~10 Myr, such anisotropy could modify the effective viscosity of the mantle,causing an up to 40% increase in plate velocity for the same applied stress. The anisotropy can also induce deformation in planes other than the initial shear plane, which can change the direction of the primary deformation.

Our ultimate goal is to understand the role of AV and LPO evolution in geodynamic processes by looking at deformation paths predicted by geodynamic models in ASPECTWith this initial test, we will gain a basic understanding of olivine AV behavior and LPO evolution under different deformation settings calculated with different numerical methods, which we will carry onto our next step of implementing anisotropic viscosity of olivine in 3D into ASPECT.