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Rheologic effects of crystal preferred orientation in upper mantle flow near plate boundaries

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Observations of anisotropy provide insight into upper mantle processes. Flow-induced mineral alignment provides a link between mantle deformation patterns and seismic anisotropy. Our study focuses on the rheologic effects of crystal preferred orientation (CPO), which develops during mantle flow, in order to assess whether corresponding anisotropic viscosity could significantly impact the pattern of flow. We employ a coupled nonlinear numerical method to link CPO and the flow model via a local viscosity tensor field that quantifies the stress/strain-rate response of a textured mineral aggregate. For a given flow field, the CPO is computed along streamlines using a self-consistent texture model and is then used to update the viscosity tensor field. The new viscosity tensor field defines the local properties for the next flow computation. This iteration produces a coupled nonlinear model for which seismic signatures can be predicted.

Results thus far confirm that CPO can impact flow pattern by altering rheology in directionally-dependent ways, particularly in regions of high flow gradient. Multiple iterations run for an initial, linear stress/strain-rate case (power law exponent n=1) converge to a flow field and CPO distribution that are modestly different from the reference, scalar viscosity case. Upwelling rates directly below the spreading axis are slightly reduced and flow is focused somewhat toward the axis. Predicted seismic anisotropy differences are modest. P-wave anisotropy is a few percent greater in the flow 'corner', near the spreading axis, below the lithosphere and extending 40-100 km off axis. Predicted S-wave splitting differences would be below seafloor measurement limits. Calculations with non-linear stress/strain-rate relation, which is more realistic for olivine, indicate that effects are stronger than for the linear case. For n=2-3, the distribution and strength of CPO for the first iteration are greater than for n=1, although the fast seismic axis directions are similar. The greatest difference in CPO for the nonlinear cases develop at the flow 'corner' at depths of 10-30 km and 20-100 km off-axis. J index values up to 10% greater than the linear case are predicted near the lithosphere base in that region. Viscosity tensor components are notably altered in the nonlinear cases. Iterations between the texture and flow calculations for the non-linear cases are underway this winter; results will be reported in the presentation.