**Using Short-Term Postseismic Displacements to Infer the Long-Term Tectonic Environment of the Upper Mantle at an Active Plate Boundary**

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**Abstract**

Postseismic surface displacements are associated with viscoelastic relaxation of the hot lower crust and/or upper mantle in response to sudden coseismic loading. The spatial and temporal characteristics of these displacements tell us something about the tectonic environment (temperature, pressure, background strain rate, water content, creep mechanism) within which postseismic flow occurs. In order to understand how to interpret postseismic observations in terms of the tectonic environment, however, the constitutive relationship utilized to relate strain rates to coseismic stress changes must also take into account a weak initial transient phase of flow. Here we develop a flow law that combines the influences of tectonic environment and a transient phase and apply it to understand the nature of the upper mantle beneath the Eastern California Shear Zone in southern California following the 1999 M7.1 Hector Mine earthquake. This is accomplished using a finite element model of the relaxation process constrained by surface displacement time-series recorded by 55 continuous GPS stations for 7 years following the earthquake. Results suggest that postseismic flow following this earthquake occurs below a depth of ~50 km and is controlled by dislocation creep of wet olivine. Significant diffusion creep is ruled out, as it would require a grain size (3.5 mm) much smaller than what is compatible (~1 cm) with inferred mantle conditions at these depths. Model results suggest an initial transient phase of flow that lasts ~2 years and is ~10 times weaker than subsequent steady-state flow, in general agreement with laboratory observations. The observed postseismic response is best explained as occurring within a relatively hot upper mantle (e.g., 1300° C at only 50 km depth) and a long-term background mantle strain rate of ~0.1 μstrain/yr, consistent with the observed surface strain rate. Long-term background shear stresses at the top of the mantle are ~4 MPa, then drop with depth to a minimum of 0.1-0.2 MPa at 70 km depth before increasing slowly with depth due to increasing pressure. This corresponds with a background viscosity of $10^{21}$ Pa s within a thin mantle lid that drops to ~$5\times10^{19}$ Pa s within the underlying asthenosphere. The earthquake is shown to have induced an immediate order of magnitude drop in viscosity within the upper mantle, which recovers to background levels within a few years. This study shows the utility of using short-term postseismic observations to infer long-term mantle conditions that are not readily observable by other means.