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Linking postseismic and interseismic deformation along the North Anatolian Fault Zone: The role of transient rheology and low-viscosity shear zones

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Past studies have shown that postseismic deformation following the Izmit-Duzce earthquake sequence results from rapid afterslip in the middle to upper crust and viscoelastic relaxation of the lower crust and upper mantle. Models incorporating a Burger's body rheology for the lower crust and upper mantle, with two characteristic viscosities (2 to 5 $\times 10^{19}$ Pa s and at least 5 $\times 10^{20}$ Pa s), and a characteristic evolution time of about ten years, are consistent with both the later postseismic and the highly localized interseismic deformation. However, for reasonable postseismic strain rates in the lower crust and upper mantle, these parameter values are not consistent with laboratory experiments.

I have developed a new suite of models to assess whether viscous shear zones in the lower crust and upper mantle can also explain both the postseismic and interseismic deformation. These models incorporate narrow (10 to 60 km-wide) channels of relatively low viscosity material embedded in the lower crust and upper mantle, which are modeled with depth-dependent power-law or linear (Maxwell) rheologies. These models are meant to represent the effects of grain size-sensitive flow, with fine-grained material in the NAF shear zone (deforming with a linear rheology) and coarser-grained material (deforming at a low rate via power-law flow) elsewhere in the lower crust and upper mantle (Warren and Hirth, 2006, Mehl and Hirth, 2007).

Models with embedded channels yield deformation which is more stationary throughout the earthquake cycle than that produced by layered models (i.e. with infinitely wide channels). These models also produce differential stresses high enough to allow dislocation creep in the mantle and lower crust outside the channel, for reasonable mineral grain dimensions. However, to explain the near-field surface deformation, time-varying effective viscosity is still required in the channel material. For the required, rapid evolution of the effective viscosity in the channel material to be consistent with available laboratory data on transient creep, strain rates must be very high ($\approx 10^{-11}$ /s). This may suggest rapid relaxation of a network of narrow ultramylonite strands. The temporary reduction in the effective viscosity of the channel material should cause it to deform postseismically in response to total stress, rather than just the coseismic stress change, potentially explaining an increase in the rate of NAFZ-normal extension in the Marmara Sea region following the Izmit earthquake.