Reconciling geodetic observations of time-dependent deformation around faults with their geologic slip rates: Dynamic models of the North Anatolian and San Andreas Faults

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We often explain rapid postseismic deformation following large earthquakes in terms of rapid afterslip on and below the rupture, followed by relaxation of viscoelastic mantle and/or lower crust with a modest effective viscosity. In the case of the North Anatolian Fault Zone (NAFZ), however, the lithosphere that yields such deformation must also produce interseismic deformation that is highly localized around the fault, insensitive to time in the earthquake cycle, and (somewhat) consistent with the geologic slip rate. This is made clear by the kinematic block model of Reilinger et al. (2006), in which active faults must slip at close to their geologic rates, with shallow (16 to 20 km) locking depths, to fit the current GPS velocity field in the eastern Mediterranean region. Since modest mantle or lower crust viscosities are inconsistent with highly localized strain around the NAFZ (e.g., Savage and Prescott, 1978), the effective viscosity must increase interseismically. This could be acheived either by a nonlinear or transient viscoelastic rheology. We investigate both possibilities using numerical models of both the NAFZ earthquake cycle and (in more detail) postseismic deformation following the Izmit earthquake. Our new postseismic deformation models are calibrated to a GPS dataset spanning the first five years after the Izmit earthquake (Ergintav et al., 2006).

We confirm that immediately after the 1999 Izmit, Turkey earthquake, stable frictional slip with a very small velocity-strengthening parameter (A-B = 0.5 MPa) likely occured along the NAFZ in the middle to upper crust (Hearn et al., 2002). Within months, relaxation of transient upper mantle and/or lower crust with an initial, effective viscosity of 2 to 5 times 10^19 Pa s took over as the principal cause of the accelerated postseismic deformation. Earthquake cycle models show that the effective viscosity must increase by a factor of ten or more over the next few decades to explain the observed interseismic deformation (similar to the analytical results of Hetland, 2005). Using the earthquake cycle model, we investigate whether clustering of large earthquakes along the NAFZ

might account for the fact that the NAFZ's GPS slip rate is somewhat higher than its geologic slip rate (e.g., Reilinger et al., 2006), and whether results of the latest paleoseismic studies are consistent with this idea.

A similar model could be applied to the southern California lithosphere around the creeping section of the San Andreas Fault Zone (SAFZ) and the Carrizo Plain (where the SAFZ geometry is fairly simple). Dynamic models of this part of the SAFZ already incorporate both aseismic fault zone creep and viscoelastic relaxation (e.g., Li and Rice, 1986; Johnson and Segall, 2004). I will present new dynamic models of deformation around the creeping section of the SAFZ, and (attempt to) stimulate discussion as to whether transient rheology, earthquake clustering, or other effects are required to reconcile geodetic deformation data with geologic estimates of the SAFZ slip rate.

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