EGU2020-11951
https://doi.org/10.5194/egusphere-egu2020-11951
EGU General Assembly 2020

Constraints on the rheology of the mid- to lower continental crust from geodetic studies of the earthquake deformation cycle

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In this presentation I will review geodetic constraints on the rheology of the mid- to lower continental crust from observations and models of all phases of the earthquake deformation cycle. I will focus on observations of slow interseismic strain accumulation and rapid postseismic strain transients, both of which result primarily from deformation in the mid- to lower crust. I will argue that, with a few exceptions, interseismic strain is focused in zones around faults with widths that are compatible with strain at depth being focused on a fault or distributed in a shear zone up to ~3 x the seismogenic layer thickness. I will show that for the North Anatolian Fault, the strain accumulation rate appears to be approximately constant for the entire earthquake cycle, once the postseismic transient has decayed. This is consistent with observations at other fault where geodetic measurements were made prior to major earthquakes; the broad agreement between geological and geodetic estimates of slip rate is also consistent with interseismic strain accumulation rates being relatively time invariant. Time-invariant interseismic strain accumulation rates require a relatively strong mid- to lower crust, where relaxation times are equal to or greater than the average earthquake revisit time. Postseismic deformation transients are commonly observed following most earthquakes, but they are interpreted using a variety of very different deformation mechanisms. By compiling all observations of postseismic deformation we show that the largest transient postseismic velocities decay following a simple t^{-1} power-law, analogous to Omori's law for aftershock decay. This is consistent with frictional afterslip and/or power-law creep in a narrow shear zone. This model of a weak shear zone embedded within a stronger substrate can explain most observations of the earthquake deformation cycle. Exceptions to this simple model might occur in locations where the lower crust is weaker, perhaps due to the presence of partial melt. Geological constraints on rheology are critical for making further progress in understanding the earthquake deformation cycle – geological models for the mid- to lower crust can be tested by comparing geodetic observations with geologically-realistic earthquake cycle models.