Oceanic Upper Mantle Rheology Constrained From Viscoelastic Postseismic Deformation of the 2012 M_w8.6 Wharton Basin Earthquake

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ABSTRACT

The 2012 M_w8.6 Wharton basin earthquake ruptured multiple planes in an orthogonal conjugate fault system, about 100 km west of the Sumatra subduction zone. It is the largest intra-plate strike-slip event ever recorded. We processed time series of more than fifty continuous GPS stations in the region between the Andaman Islands and southern Sumatra. These GPS stations recorded up to ~30 cm coseismic displacements and up to ~10 cm cumulative postseismic displacements in the two years after the earthquake. The significant postseismic deformation provides a unique opportunity to better constrain the viscosity structure in the Indian Ocean asthenosphere across the subduction slab, to test the contribution of afterslip following the earthquake, and to better understand the interaction between the intra-plate fault system and subduction zone systems. We develop three-dimensional viscoelastic finite element models of the 2012 Sumatra earthquake to study these problems. In our model, we assume that the upper mantle is characterized by a bi-viscous Burgers rheology that is able to describe slow long-term deformation as well as very rapid short-term transient deformation. Our model indicates that a thin weak asthenosphere beneath the oceanic lithosphere is required to produce enough horizontal postseismic displacements and observed subsidence in the forearc. The thickness and steady-state viscosity of the asthenosphere are determined to be on the order of 50-80 km and 2-8 x 10^{18} Pa s, respectively. The steady-state viscosity of the oceanic mantle is determined to be on the order of $5x10^{20}$ - $5x10^{21}$ Pa s.