Upper Mantle Rheology From Postseismic Deformation of the 2013 M_w 8.3 Okhotsk Earthquake

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The upper mantle rheology at depths within a few hundred kilometers has been well studied through shallow great megathrust earthquakes. However, understanding of the mantle rheology at greater depths, such as in the vicinity of the transition zone, has been limited by the lack of direct or indirect measurements. The largest well-recorded deep earthquake with magnitude M*w* 8.3 occurred within the subducting Pacific plate at ~600 km depth beneath the Okhotsk Sea on May 24, 2013. Twenty-seven continuous GPS stations in this region recorded coseismic displacements of up to 15 mm in the horizontal direction and up to 20 mm in the vertical direction. Within three years after the earthquake seventeen continuous GPS stations underwent transient westward motion of up to 8 mm/yr and vertical motion of up to 10 mm/yr. The geodetically delineated postseismic crustal deformation thus provides a unique opportunity to study the three dimensional heterogeneity of the mantle rheology and properties of the subducting slab at great depths. We have developed three-dimensional viscoelastic finite element models of the 2013 Okhotsk earthquake to explore these questions. Our initial model includes elastic continental and oceanic lithosphere, an elastic subducting slab, a viscoelastic continental upper mantle and a viscoelastic oceanic upper mantle. We assume that the upper mantle is characterized by a bi-viscous Burgers rheology. For simplicity, we assume that the transient Kelvin viscosity is one order of magnitude lower than that of the steady-state Maxwell viscosity. Our preliminary models indicate that the viscosity of the upper mantle at depths 410-660 km is at the same order of the upper mantle at shallower depths. Viscosity at greater depths is at least 10^{22} Pa s. The subducting slab may be still elastic at depths >410 km or be viscoelastic with a viscosity no less than 10^{22} Pa s.

Keywords: Upper mantle rheology, Postseismic deformation, Finite element method, Subduction zone, Numerical modeling, Burgers rheology

