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Upper mantle rheology of Sea of Japan inferred from postseismic displacements of the Tohoku earthquake

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The 2011 Great Tohoku earthquake struck the Pacific coast of northern Honshu, Japan almost two years ago. It generated huge co- and postseismic crustal displacements and deformations in the near-field zone. However, the western part of the far-field zone represented by the Korean Peninsula, northeastern China and the south of the Russian Far East were also being affected by coseismic offsets and have still been demonstrating appreciable postseismic movements. It is obvious that the nature of these deformations is connected not only with the earthquake source geometry and processes but also with Sea of Japan and northeast Asia lithosphere and upper mantle structure and rheology. In this study we determine and analyze the far-field postseismic crustal displacements and deformations induced by the 2011 Great Tohoku earthquake using different GPS data sources in the south of the Russian Far East and Kunashir Island (IGS data, continuously and periodically observed regional geodynamic GNSS networks and other GNSS observations applicable for this study). The maximum value of first-year postseismic displacements exceeded 30 mm in the continent, which is about 60% of the appropriate coseismic offset value. In contrast to the continental stations, the postseismic displacement on Kunashir Island located northward from the rupture has already exceeded its coseismic offset (about 10 mm) more than twice. To explain the observed postseismic displacements we adopted the viscoelastic relaxation mechanism and constructed the lithosphere-upper mantle model consisting of elastic lithosphere layer of 50 km thick and two viscoelastic layers of 200 and 265 km thick with Maxwell rheology. We varied the viscosity of the upper viscoelastic layer from 10^17 to 10^19 Pa s to fit the calculated postseismic deformations to their observed values. Our approach gives the astenosphere viscosity of 5-10∗10^17 Pa s which is relatively low with respect to previous estimates. However, the recent study of Kogan et al., 2011 devoted to determination of the mechanism of postseismic deformation triggered by the 2006-2007 great Kuril earthquakes presented a similar viscosity value. The obtained astenosphere viscosity value allows us to adequately explain the far-field postseismic displacements in our GNSS network but fails to explain the first 50 days after the mainshock. Thus, a question about wide variability and time dependency of Japan Sea and northeast Asia upper mantle viscosity should be carefully investigated in the nearest future.

キーワード: lithosphere-upper mantle model, the far-field postseismic crustal displacements, GNSS observations, The 2011 Great Tohoku earthquake, astenosphere viscosity
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