Heterogeneous rheology structure estimated by the postseismic deformation following the 2011 Tohoku-Oki earthquake (M_w9.0)

*Yoshiaki Ito[1,2], Satoshi Miura[2], Jun Muto[2], Yusaku Ohta[2], Takeshi Iinuma[3], James Daniel Paul Moore[4]

1. Mitsubishi Space Software Co., Ltd., 2. Graduate School of Science, Tohoku University, 3. Japan Agency for Marine-Earth Science and Technology, 4. Nanyang Technological University

The 2011 Tohoku-Oki earthquake (M_w9.0) was the largest earthquake ever recorded in Japan and triggered substantial and long-lived postseismic deformation. We investigate the characteristics of the postseismic deformation based on the across-arc dense GNSS network running between Iwaki and Niigata cities (Ban-Etsu line) operated by the Geospatial Information Authority of Japan (GSI) and Tohoku University. Using the network, estimated the heterogeneous viscoelastic structure to reproduce the observed 5-year-displacements and their time series. It is revealed that both local subsidence during the first 2 years and gradient changes in all displacement components during latter 3 years occurred around the volcanic front (VF). To evaluate the time series of postseismic deformation, we normalized the horizontal scalar displacements by the total displacements in 5 years to define “relaxation rate.” Picking up the date when the relaxation rate reaches every 0.1 interval from 0 to 1, we obtain “relaxation rate profile (RRP).” The RRP shows that the relaxation rates are generally high and low in the fore-arc and back-arc regions, respectively, together with the relatively higher rate 350 to 400 km apart from the trench. We employed the integral method called Unicycle (Lambert and Barbot, 2016; Barbot et al., 2017) to conduct a three-dimensional modeling of the postseismic deformation considering the afterslip and viscoelastic relaxation. The former is governed by the rate-strengthening friction approximation (Barbot et al., 2009) and the latter is based on power-law Burgers model (Masuti et al., 2016). The viscoelastic parameters were optimized by means of a grid search with minimizing RMS (root mean square). The optimum viscoelastic structure has a low viscosity zone (LVZ) beneath VF and the “cold nose (CN)” region from the trench to around VF, and is consistent with the resistivity structure estimated by Uyeshima et al. (2016) and with the spatial extent of CN deduced by Freed et al. (2017). The model reproduced the overall characteristics of the displacement and the RRP, while the detailed characteristics such as flat pattern 350 to 400 km apart from the trench cannot be replicated. Varying the LVZ’s extent and viscosity, we obtained a better model with the LVZ at 25-55 km in depths to fit the observed characteristics, but more considerations are necessary. However, our best model for the Ban-Etsu line cannot be applicable to a northern across-arc profile, Naruko line of Muto et al. (2016), implying the along-arc heterogeneity of viscoelastic structure. Then, we examined the along-arc heterogeneous CN models, a better model with small extent of the CN in the northern area and the spot-like LVZ beneath the active volcanoes is estimated. The final model explains the observed displacements and also the areal strain distribution (Miura et al., 2014). This suggests the importance of considering not only across-arc but also along-arc heterogeneous viscoelastic structure to explain the observed postseismic deformation of the Tohoku-oki earthquake.

Keywords: postseismic deformation, Tohoku-oki earthquake