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Revisit of the mechanism of the postseismic deformation associated with the 1993 Hokkaido-Nansei-Oki earthquake

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1. Introduction

Continuous GPS observation of GEONET from October 1994 shows that GPS sites in southwestern Hokkaido are moving westward relative to those in northern Hokkaido and that GPS sites around Uchiuara Bay are uplifted. This uplift is concordant with a result of leveling between Otaru and Suttsu showing 3cm of uplift in Suttsu relative to Otaru for five years following the 1993 Hokkaido-Nansei-Oki earthquake. These deformation are considered as postseismic deformation of the 1993 Hokkaido-Nansei-Oki earthquake. Viscoelastic relaxation in the upper mantle and afterslip are proposed as mechanisms of the observed postseismic deformation (e.g. Nishimura, 2000; Ito, 2000; Fukuda et al., 2001; Ueda et al., 2002). Ueda et al.(2002) suggest that the observed deformation is explained by the viscoelastic relaxation model with a Maxwell viscoelastic layer whose viscosity is 4*10^18 Pa s in depth of 40-85km. In this study, we first present temporal change of postseismic deformation observed by GPS and a result of leveling on Okushiri island. And then we present our interpretation of mechanisms of the observed deformation.

2. Vertical deformation on Okushiri Island and temporal change of the observed deformation

We found rate of westward displacement at GPS sites in southwestern Hokkaido decreased year by year. For example, rate of the westward displacement at Sedana station relative to Mashike station was 2.3 cm/yr for a year from April 1995 and was 1.7, 1.3, and 1.0 cm/yr for each year from April 1996 to March 1999, respectively. The average rate from April 1999 to March 2002 is 0.9 cm/yr. However, temporal change of vertical deformation is not so significant.

Leveling on Okushiri Island shows that the northeastern part of the island is subsided by ~3cm relative to the southwestern part for three years following the earthquake. It suggests tilting of the island toward northeast. The direction of the postseismic tilting is different from those of both the coseismic one and the long-term one based on marine terraces in Quaternary.

3. Estimation of viscoelastic structure and afterslip

We used four kinds of data, that is, (1) Horizontal displacement observed by GPS, (2) Vertical displacement observed by GPS, (3) Vertical displacement between Otaru and Suttsu observed by leveling, and (4) Vertical displacement on Okushiri Island observed by leveling and considered viscoelastic relaxation or afterslip as the mechanism of the observed deformation. We adopted the coseismic fault model by Tanioka et al.(1995) and calculated synthetic postseismic deformation due to viscoelastic relaxation with the method of Pollitz(1997). The observed vertical deformation on Okushiri Island is completely different from the calculated one with viscoelastic model and favors the afterslip model on a deep segment of the coseismic fault. The afterslip model is preferable if we use all datasets and data weighting based on observation uncertainties because the displacement on Okushiri Island is large. However, uplift around Uchiura Bay requires the viscoelastic relaxation in the upper mantle. We applied a model with an elastic plate overlying a viscoelastic half-space to the dataset excluding Okushiri Island. The elastic thickness is estimated to be 32+-12km with the half-space viscosity of 2.5*10^18+-0.4 Pa s. The elastic thickness is approximately equal to the local crustal thickness. We apply more complex viscoelastic structures including Ueda et al(2002)'s model to fit the observed deformation and do not find the residual is significantly smaller than the simple two-layers model. Assuming the viscoelastic model described above is the main mechanism of the postseismic deformation, we need afterslip on an east-dipping fault just beneath Okushiri Island to explain the observed vertical deformation on the island.