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Postseismic crustal deformation by viscoelastic relaxation following the 1983 Nihonkai-Chubu earthquake

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1. Introduction

Postseismic crustal deformation following a large earthquake is generally explained by afterslip on the fault plane or viscoelastic relaxation of the coseismic stress change. Modeling of the postseismic deformation can provide important constraints for frictional properties of fault and the viscoelastic structure of the medium.

We found that the postseismic deformation after the 1993 Hokkaido Nansei-oki and 1964 Niigata earthquakes can be explained by viscoelastic relaxation in the uppermost mantle, but not by afterslip (Ueda et al., 2001). Although small postseismic crustal deformation also followed the 1983 Nihonkai-Chubu earthquake (Miura et al., 1990), the mechanism of the deformation has not been clarified yet. We identify the principal cause of the deformation from two possibilities; afterslip and viscoelastic relaxation in this study.

2. Postseismic deformation

We investigate the leveling data obtained by the Geographical Survey Institute after the Nihonkai-Chubu earthquake. The vertical deformation data show that small uplift of about 3 cm occurred in about three years after the earthquake near the Japan Sea coast in northern Honshu. Along the same route, subsidence and uplift occurred at the occurrence of the earthquake and before the earthquake, respectively. These are explained by coseismic slip on the fault and preseismic slip on its down-dip extension, respectively (Tada, 1983). The preseismic uplift having a maximum along the coast showed a tilt to the east. This feature contrasts with the postseismic uplift that showed a dome-like shape with a peak at about 40 km to the east of the coast.

3. Modeling of the postseismic deformation

We use the postseismic vertical deformation data in about three years after the Nihonkai-Chubu earthquake. A viscoelastic deformation is synthesized to explain the postseismic data by the method of Matsu'ura et al. (1981) with a three-layered viscoelastic structure. Thickness and viscosity of the layers are estimated by trial and error. In consequence, we find that the postseismic deformation is well explained by the viscoelastic relaxation model. The best-fit viscoelastic structure consists of the elastic first layer of 50 km in thickness, the viscoelastic second layer of 45 km in thickness and 6*10**18 Pas in viscosity, and the elastic half space.

On the other hand, an afterslip on the mainshock fault and its down-dip extension, if it occurred, must bring about a similar deformation pattern as the co- or pre-seismic deformation. The postseismic deformation is quite different from this pattern and cannot be explained by the afterslip model. We judge that the viscoelastic relaxation of the uppermost mantle is the primary cause of the postseismic deformation following the Nihonkai-Chubu earthquake.

4. Discussion and Conclusion

The depth of upper bound of the viscoelastic layer roughly coincides with that of low P wave velocity zone near the focal area of the earthquake (Nakajima et al., 2001). Iwamori and Zhao (2000) state that the low velocity anomaly is caused by partial melt of mantle with transportation of H2O. The presence of the partial melt and H2O lower the viscosity of the mantle (Cooper and Kohlstedt, 1984; Karato et al., 1986). Thus we speculate that the low viscosity is mainly originated from high temperature, and the presence of partial melt and H2O.

We find that three large earthquakes in the eastern margin of Japan Sea and the 1896 Riku-u earthquake have a common feature; their postseismic deformations were mainly caused by viscoelastic relaxation. The back-arc side of the volcanic front in northern Japan is characterized by high heat flow. Therefore the presence of low viscosity substance beneath the back-arc side is most probably a principal factor of the common mechanism of viscoelastic relaxation.

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