Postseismic crustal deformation by viscoelastic relaxation following large earthquakes in the eastern margin of the Japan Sea

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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 the fault and the viscoelastic structure of the medium. Afterslip is a dominant mechanism for postseismic deformation following interplate earthquake to the east of the northeastern Honshu (e.g., Ueda et al., 2001). However, it had not been known what had caused postseismic deformation following large earthquakes to the west of it. We studied the postseismic deformation following three large earthquakes; the 1964 Niigata earthquake, the 1983 Nihonkai-Chubu earthquake, the 1993 Hokkaido Nansei-oki earthquake (Ueda et al., 2003).

2 Method and Data

We utilized GPS, leveling, and tide level data observed for several years after the earthquakes. We identify the principal cause of the deformation from two possibilities; afterslip and viscoelastic relaxation in this study. We assumed a slip on the mainshock fault or its down-dip extension in an elastic half space for afterslip model, and a three-layered viscoelastic structure for viscoelastic model. Thickness and viscosity of the layers are estimated based on the grid search inversion.

3 Results

We find that the three postseismic deformations are well explained by the viscoelastic relaxation model. The estimated viscoelastic structures have an elastic first layer with the thickness of 40-100km and a viscoelastic second layer with the thickness of 50-70km and the viscosity of 4x10^17-4x10^18Pas. On the other hand, it is difficult to explain the postseismic deformations by the afterslip model.

4 Discussions

The depth of the viscoelastic layer roughly coincides with that of low P wave velocity zone beneath the west coast of the northeastern Honshu. 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). Furthermore, the back-arc side of the volcanic front in northern Japan is characterized by high heat flow. 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 feature is far different from that of large earthquakes to the east of the northeastern Honshu. We consider that two factors bring the difference. The one is a difference of viscoelastic structure between the two regions. The Vp structure (Nakajima et al., 2001) and the thermal structure suggest that the viscosity of the uppermost mantle beneath the west coast is lower than that beneath the east coast. Another factor is a difference of frictional properties of the faults. The faults in the eastern margin of the Japan Sea are much younger than the plate boundary of the Pacific plate, so fault gauge probably is not yet well developed as compared to that of the Pacific plate. The dominance of afterslip on the boundary may be attributed to weak coupling of the plate boundary that was brought about through a long history of subduction process.

Since lateral heterogeneity of viscoelastic structure between the west an east brings heterogeneity of stress in the crust, it may affect seismicity and crustal deformation. However, it is difficult to discuss such effects by our simple layered structure model. It will be necessary to consider three-dimensional variation of viscosity to develop a more detailed viscoelastic model.

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