別紙4

報告番号	※　　　　　　　　　第　　　号

主　論　文　の　要　旨

論文題目

Comprehensive postseismic deformation model of the 2004 Sumatra-Andaman earthquake constrained by GPS data in northern Sumatra
2004年スマトラーアンダマン地震の包括的余効変動モデル～スマトラ北部のGPSデータを用いて～

氏　　名 ENDRA GUNAWAN

論　文　内　容　の　要　旨

On December 26, 2004, the M9.2 Sumatra-Andaman earthquake occurred in the Sundasubduction zone along the north Sumatra, Nicobar and Andaman Islands. This earthquake provides us with a unique opportunity to examine the postseismic deformation using GPS data. The 2004 earthquake is an important event because of various reasons. First, this earthquake is the first M9 class earthquake recorded by modern global seismic and GPS networks (Kanamori, 2006). Using these modern equipment, we can evaluate the deformation associated to this earthquake comprehensively. Second, the 2004 earthquake caused large enough postseismic deformation (e.g. Gahalaut et al., 2008; Satirapod et al., 2008; Paul et al., 2012) and a long enough time has passed after the earthquake, which provide us a great opportunity to distinguish the physical mechanisms of postseismic deformation. Third, there have already been many studies on postseismic deformation with essentially different conclusions. It is important to unravel how different assumptions and different datasets in each study led to different conclusions and to find the most probable interpretation for the observed data. This difference indicates that mechanisms of postseismic deformation are poorly understood.

Continuous GPS data in northern Sumatra clearly show temporal decays reflecting postseismic deformation. It is noticeable that horizontal displacements significantly decreasedwith time, while the vertical component looks almost linear in time.The difference in the temporal changes between horizontal and vertical components implies that multiple physical mechanisms are responsible for the postseismic deformation; we assume that they are viscoelastic relaxation and afterslip. We construct two analysis strategies to investigate the postseismic deformation after the 2004 earthquake. These strategies are (1) Strategy 1to correlate the shorter relaxation time with viscoelastic relaxation, and the longer relaxation time with afterslip, and (2) Strategy 2to correlate the longer relaxation time with viscoelastic relaxation, and the shorter relaxation time with afterslip.

Strategy 1, which was used by previous studies, has fatal problems regarding the vertical displacement data. First, using continuous GPS data in northern Sumatra, the calculated vertical displacements of the viscoelastic relaxation and the afterslip are expected to have similar contribution (in an opposite sense), but only viscoelastic relaxation is effective in the horizontal components. Second, in the vertical component, the viscoelastic relaxation and the afterslip have similar time constant as well as similar amplitude just to cancel out each other. These problems simply indicate that the original assumption of using horizontal displacements to construct a viscoelastic relaxation model was wrong.

In order to apply Strategy 2 to the dataset, a new iterative method to estimate both the viscoelatic structure and afterslip distribution is developed. Starting from the estimation of rheological parameters based on vertical GPS data in northern Sumatra, afterslip and the rheological parameters are estimated one after another until the minimum χ^2 is obtained. By applying this method, we can decompose the postseismic deformation into the contribution of viscoelastic relaxation and that of afterslip.We assume a simple rheological model with an elastic lithosphere overlying aMaxwell viscoelastic substratum, in which the lithosphere thickness and the Maxwell viscosity are the rheological parameters.This strategy isappliedto the GPS data in northern Sumatra with four different coseismic fault models by Kreemer et al. (2006), Banerjee et al. (2007), Fujiiand Satake (2007), and Rhieet al.(2007). We find that the coseismic fault model of Rhie et al. (2007) results in the least χ^2 of 3.86 and that the Maxwell viscoelastic relaxation plus afterslip model successfully explains GPS data in northern Sumatra. The estimated best rheological parameters are the lithospheric thickness of 65±5 km and η_M of 8.0±1.0 x 10^{18} Pa s, which are consistent with various previous studies.For time period between 2005.91~2006.90, the estimated maximum afterslipwas 0.90 m located at 20~40 km depth and the total seismic moment released by afterslip was1.12 x 10^{21} N m (M_w 8.2).During 2005.91~2006.90, theestimated afterslip accounts for only15% of the observed vertical displacement at ACEHin northern Sumatra, and the contributionis only 1% during 2006.90~2007.90. This result clearly explains why the shorter relaxation time is not evident in the observed vertical displacement at continuous GPS sites in northern Sumatra.

In this study, significance of a time-dependent (Burgers) rheology, suggested by previous studies (Pollitz et al., 2006; Panet et al., 2010), is not supported. The current study suggests that the rapid transient signal at the early postseismic stage was caused mainly by afterslip, not by the viscoelastic relaxation. The vertical component in northern Sumatra is a strong evidence for this result.

This study also demonstrates that the rheology model estimated from GPS data in northern Sumatra is applicable to postseismic deformation of the 2004 Sumatra-Andaman earthquake recorded in other regions such as the Andaman Islands and Thailand. The rheology model can reproduce the long-term trends of GPS data in Thailand while the rapid transient signals in the early postseismic stage can be attributed to the afterslip in Andaman and Nicobar region. Also, it is shown that the postseismic deformation in the Andaman region contains significant contribution of viscoelastic relaxation. Seismic moment release by the afterslip from January 2005 to February 2006 estimated in this study is 1.1×10^{21} N m (M_w 7.9), which is 29 % of the previous estimate by Gahalaut et al. (2008). So it should be noted that the interpretation of postseismic deformation is highly sensitive to assumptions.

This study is based on a simplified layered structure model. So the result may be changed if we take 3-dimensional structure including subducted slab into account. Also, the satellite gravity data analyzed in previous studies are not analyzed in the current study. These problems will be solved in the future.

Through this study, a model of the rheological structure and afterslip distribution is constructed for the postseismic deformation of the 2004 Sumatra-Andaman earthquake. This is a comprehensive model in that it can reproduce main features of all the available GPS data in northern Sumatra, Andaman, and Thailand. This study providesunique as well as important insights into the rheological structure of the asthenosphere and postseismic relaxation processes of great earthquakes.