Estimation of the Fault Constitutive Parameter A*sigma from Stress Step and Seismicity Change Induced by a Large Earthquake

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1. Introduction

In late years researches to relate a change of stress to seismic activity are advancing (e.g. Toda et al., 2002) and tend to use the model of Dieterich (1994) that is basing on the rate- and state- dependent friction law for the physical basis. According to this model we can predict a seismic rate change caused by a stress change, and inversely we can also infer a stress change by observing a earthquake rate change (e.g. Dieterich et al., 2000; Toda and Matsumura, 2004). Therefore this model is promising in the point of view that we may become to know a stress change in many locations where seismicity data are available. However, in order to get reliable results, it is important to estimate parameters concerning the model appropriately. In this study, we introduce a way of estimating one of the fault constitutive parameters, A*sigma, by using the step change of stress and seismicity response that are induced by a large earthquake.

2. Method

According to Dieterich (1994), a step change of Coulomb failure stress, dS, causes a seismicity rate change expressed by the simple equation:

$$R / r = \exp (dS / A^*\mathrm{sigma})$$

where r and R are earthquake occurrence rates immediately before and just after the stress change, respectively, A is fault constitutive parameter and sigma is normal stress (less pore fluid pressure). This equation shows that we can estimate A*sigma if we know the values of dS and R/r. Here we do not treat the parameters A and sigma separately, but consider them as one parameter A*sigma in the form of a product. We estimate dS by evaluating a stress change calculated for a fault model of a large earthquake, and estimate r as an average seismicity rate before a large earthquake. R is evaluated by applying the modified Omori formula for the seismicity rate just after a large earthquake.

3. Data

When we select the target area to apply the method, we consider the following conditions: the fault model of a large earthquake is well determined, the seismicity rate change is clearly recognized, the area is far enough from a large earthquake not to be effected by a slip inhomogeneity of the earthquake, and the rate change tend to follow the Omori formula. Consequently we try to apply the method to two areas of Ishikari mountains in Hokkaido, Japan, where Takahashi et al. (2004) and others reported that the seismicity changed in relation to the 2003 Tokachi-oki earthquake (M8.0). We use the JMA catalog data with magnitude larger than or equal to 0.5 and depth shallower than 25km during the period from January 2003 through January 2005. The source fault model of the 2003 Tokachi-oki earthquake we adopted is the single fault plane model estimated by GSI (2004) using geodetic data. We assume two fault models for the earthquakes in analyzed area as receivers of a stress change, that is, vertical right-lateral fault models with strikes of N70E and N170E.

4. Result

The values of A*sigma we have obtained are 0.015~0.017 MPa for the receiver fault model with strike of N70E and 0.008~0.009 for that with strike of N170E. This shows the estimated values are varying widely depending on the receiver fault models. These values are a little smaller than 0.035 MPa obtained by Toda et al. (1998) for the region associated with the 1995 Hyogoken-nambu earthquake. One possible reason for this is that the values obtained in this study are for a limited small area where seismic activation is remarkable whereas that of Toda et al. is an averaged one for widely distributed areas.

References: Toda et al.,2002,Nature,419,58-61; Dieterich,1994,JGR,2601-2618; Dieterich et al.,2000,Nature,408,457-460; Toda and Matsumura,2004,EPSU spring meeting; Takahashi and Kasahara,2004,JISIN,115-130; Geographical Survey Institute,2004, Report of CCEP,71,26; Hashimoto and Tada,1988,JISIN,29-38.