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Reconstruction of absolute stress based on a condition of aftershock occurrence

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Absolute crustal stress is essential to understand the earthquake generation process. If focal mechanisms both before and after an earthquake together with the fault slip model of the earthquake are available, the magnitude of absolute stress can be constrained (e.g., Hardebeck and Hauksson, 2001; Wesson and Boyd, 2007; Yang et al., 2013). However the application of those methods is inherently limited, because background seismicity is generally low. In this study, we propose a method to reconstruct an absolute stress field incorporating a condition of aftershock occurrence, which is applicable to areas without enough pre-mainshock focal mechanisms.

We suppose that there are pre-existing weak planes represented by aftershock focal mechanisms. Because these planes were locked before the mainshock but afterwards activated, it is reasonable to expect that the slip-tendency, defined by the ratio of shear to normal stress acting on a given plane (Morris et al., 1996), increases after the occurrence of the mainshock. On the basis of this consideration, we search the best absolute stress field as follows.

(1) We assume a pre-mainshock homogeneous absolute stress field (**B**) in the study area. We then compute a post-mainshock stress field (**A**) at each aftershock location by combining the stress change due to the mainshock and the aforementioned pre-shock stress field.

(2) For the fault plane of each aftershock, we compute a pre- and a post-mainshock slip-tendency ($T_s{}^b$ and $T_s{}^a$, respectively) based on the pre- and post-mainshock stress fields, **B** and **A**, respectively. Regarding the computation of $T_s{}^a$, we adopt the component of stress acting in the slip direction on a fault instead of the shear stress itself. Therefore, $T_s{}^a$can have a negative value.

(3) We compute the summation of $T_s{}^a$ of aftershocks that satisfy the condition of $T_s{}^a > T_s{}^b$. If both nodal planes satisfy the condition, the larger $T_s{}^a$ is used for the summation.

(4) We repeat the procedure (1) to (3) by changing the initial stress field **B**, and search a stress field that has the largest sum of $T_s{}^a$.

Numerical tests of this method work well. It is noted that multiple candidates of stress fields were inferred, if we did not incorporate the condition of $T_s{}^a > T_s{}^b$, suggesting that the condition is important in the situation without pre-mainshock focal mechanisms. We then applied the method to the 2013 M6.3 Awaji Island earthquake. Focal mechanisms of 115 aftershocks were determined from P-wave polarity data as well as body wave amplitude. A finite fault slip model of the mainshock was derived from slip inversion analysis (see Uchide and Ide, 2007) of KiK-net strong-motion data. A preliminary analysis shows that the pre-mainshock stress field is characterized by a reverse-faulting regime with a WSW-ENE oriented maximum compression and the differential stress of 200-300 MPa.

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Keywords: absolute stress field, aftershock, focal mechanism, 2013 Awaji Island earthquake, slip-tendency