An implication to the cut-off depth of aftershocks around the fault zone of the 2000 Western Tottori earthquake

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Depth-distributions of the aftershocks of the 2000 Western earthquake are accurately determined [Chiba et al., 2003]. The data show that the cut-off depth of aftershocks located at the southern part of the main fault is nearly 13 km. The cut-off depth could be interpreted from a view point of the brittle-plastic transition of granitic rock. Renshaw and Schulson (2001) have proposed the model of brittle-plastic transition, based on the crack propagation model with the creep dislocation process at crack tips. Sliding along the primary crack generates a stress concentration at the end of the sliding segment. This stress concentration results in a region around the sliding segment tip where the stress exceeds the yield stress of the material, resulting in inelastic deformation. If the applied strain rate is high or temperature is low enough, creep deformation will not have sufficient time to relax the stress concentration and a secondary crack will initiate. Secondary cracks do not initiate at lower strain rates or high temperatures because the stress concentration is relaxed by creep. The creep relaxation is governed by a power-law relationship. Their model prediction for the brittle-plastic transition is consistent with data from a variety of crystalline materials, including granite. Based on this model, there is a critical length of the primary crack which is determined by strain rate and temperature. If the primary crack length is less than a critical length, the crack could not propagate.

As one interpretation, we applied this model to the cut-off depth of aftershocks in the 2000 Western Tottori earthquake, assuming that the crust is wet and there are many existing cracks of which length vary with the scale. At the constant strain rate of 10^(-15) /s, the critical length depends on the temperature and the critical stress intensity factor, using the power-law creep law of wet granite (Hansen and Carter, 1982). Here, we focus on the cut-off depth of the earthquake. The cut-off depth is suggested to correspond to the temperature of 350C by previous studies. If the critical stress intensity factor does not depend on the scale of the primary crack is calculated to be around 50 m. In short, the primary crack of which length is less than 50 m could not nucleate by itself at temperature of 350C. If the earthquake occurs by growth of the primary crack, this indicates that the earthquake of magnitude less than about 2 does not occur around the cut-off depth. However, it is found from the depth distributions of aftershocks that the earthquakes of magnitude less than 2 indeed occurs around the cut-off depth, and there is no clear dependency of the cut-off depth of earthquakes on the magnitude at the ranges of magnitudes from 0.5 to 3 as mentioned above. These suggest that the crust is not wet, or the critical stress intensity factor (~ fracture energy) depend on the scale of the primary crack.