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Modeling fault development and mountain building along the Backbone range, NE Japan

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In northeastern Japan, many intraplate earthquakes occur on preexisting normal faults that are reactivated as reverse faults during shortening deformation (Sato, 1994). Stress-concentration processes, caused by the presence of heterogeneous rheological structures, are important for the reactivation of particular faults. It is acknowledged that the presence of aqueous fluids weakens the crustal rock beneath the Ou Backbone range to a greater extent than that in the surrounding area; this leads to shortening deformation in the lower crust beneath the range, which in turn induces the development of faults in the upper crust (e.g., Hasegawa et al., 2003). Okada et al. (2010) found a distinct low-velocity region below the focal area of the 2008 Iwate-Miyagi inland earthquake and suggested that the crustal fluids were related to the occurrence of this earthquake. A crustal thermal structure also affects the generation process of inland earthquakes. Yoshida et al. (2005) pointed out that crustal thermal structures have been affected by intensive magma intrusions to form large magma storages beneath the late Miocene to Pliocene calderas. To model fault development and mountain building in northeastern Japan, we need to consider crustal thermal structures, the presence of aqueous fluids, and preexisting weak faults.

We model fault development and mountain building all over northeastern Japan by considering viscoelasticity and elastoplasticity using a finite element code (Shibazaki et al., 2008). Recently, dense geothermal observations were carried out using Hi-net boreholes (Matsumoto, 2007). As a first step, we consider a geothermal structure based on Hi-net geothermal observations (Matsumoto, 2007) and the geothermal gradient data provided by Tanaka et al. (2004). On the basis of the rheological model developed by Muto (2010), we consider power-law creep for three layers: the upper crust (wet quartzite), the lower crust (wet anorthite), and the uppermost mantle (wet olivine). We also set the frictional angle to 15 degree. By giving an E-W contraction velocity of 0.2 cm/year, we examine the manner in which faults develop and mountain building occurs. Numerical results show that east- and west-dipping reverse faults develop in the high thermal gradient regions, and mountains that correspond to the Ou Backbone range are built up. In some areas, simulated fault geometry is not consistent with the observed fault geometry. For example, the strain concentration zone in the northern Miyagi prefecture cannot be reproduced in the model. To model the strain concentration zone in this region, the effects of water on the model of crustal deformation should be taken into account. We report the numerical results considering the non-uniform distribution of water fugacity and frictional strength.

Keywords: modeling, Ou Backbone range, mountain building, fault development, thermal structure, rheology