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Spontaneous dynamic rupture propagation with thermal pressurization: Phase transitions of pore fluid

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We investigate whether or not an increase in pressure and temperature of pore fluid due to thermal pressurization (TP) can cause phase transition of pore water, on the basis of 3-D numerical simulations for spontaneous dynamic ruptures. Mizoguchi et al. (2007) conducted friction experiments and observed a decrease in friction owing to the phase transition of water from liquid to vapor. Although effect of TP has been investigated using numerical simulations (e.g., Urata et al., 2008), the phase transition of pore water controlling TP has never been considered. In this study, we discuss possibility of the phase transition and its effects on dynamic ruptures. Our numerical algorithm is based on the finite-difference method by Kase and Kuge (2001). Pore pressure and temperature are calculated by the formulations of Bizzarri and Cocco (2006), and simply compared to a water phase diagram. Any processes of the phase transitions are not included in our simulations. We put a vertical strike-slip square fault with the length of 6 km. The fault is subjected to external normal and shear stresses. We examine cases when the external stresses are either uniform or depth-dependent. Under the uniform stresses, initial values of stresses, pore pressure, and temperature are uniform and independent of depth, whereas the values increase with depth under the depth-dependent stresses. The values of the uniform stresses correspond to those at a depth of 3 km in the depth-dependent stresses.

Judging from the temperature and pressure of pore water, liquid pore water is likely to change to supercritical water in most part of the fault under the uniform stresses, whether TP works or not. On the other hand, under the depth-dependent stresses, liquid pore water is likely to change to supercritical water in deeper portions than about 2 km. In both cases, TP promotes the transition. The phase transition from liquid to vapor is not likely to occur. According to PROPATH[1)], the transition from liquid phase to supercritical one can cause changes in viscosity, compressibility, and thermal expansion of water, which can affect TP. The changes due to the transition would have two opposite effects on TP; suppressing a rise of pore pressure from temperature increase, and decreasing hydraulic diffusivity. We include the changes due to the transition in numerical simulations of dynamic ruptures and investigate whether or not the phase transition of pore water causes TP to be more effective.

[1)] PROPATH Group, PROPATH : A Program Package for Thermophysical Properties, version 13.1, 2008.