Effect of thermal pressurization on earthquake rupture propagation

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Sibson [1973] explained the scarcity of pseutotachylyte by the interaction of frictional heat and fluid flow. Excess pore pressure generated by frictional heating sustains normal stress on a fault plane, which results in a reduction of fault strangth. This process is called thermal pressurization. Several mathematical models on this process were proposed [Lachenbruch, 1980, Mase and Smith, 1987], and recently hydraulic properties of fault zones were reported which were essentially important in this process [for example Wibberly 2002, Noda and Shimamoto 2003]. Noda and Shimamoto [2003] measured hydraulic properties of natural fault gouge samples picked up from an outcrop of the Hanaore fault, Central Japan under high confining pressure. Clayey fault gouge of the Hanaore fault has permeability of around 10^-18[m^2] at 80MPa effective pressure and storage capacity of 5*10^-11[/Pa] assuming the medium is rigid. They also estimated the effect of thermal pressurization by solving numerically the mathematical model by Lachenbruch [1980] using measured hydraulic parameters, and revealed that Dc, weakening distance of a fault, ranges from tens of centimeters to one meter depending on depth, relatine velocity, and width of deformation zone, which agrees very well with seismically determined ones [Ide, and Takeo, 1997, Mikumo, et al., 2003, Mikumo, and Yagi, 2003]. In their calculation, constant relative velocity is assumed, and in order to discuss dynamic rupture processes such as earthquakes it is improtant to put this constitutive relation into dynamic rupture propagation calculation.

Assuming a crack-like solution, because relative velocity at the crack tip is infinitely large, pore pressure rises abruptly at the initiation of the faulure. Andrews [2002] indicated that this abrupt pore pressure rise becomes increasingly larger as the ruptured area grows, and it is not negligible after the rupture propagated more than 300m for hydraulic diffusivity of 0.2[m^2/s]. He also pointed out that this effect accelerates the rupture propagation. This result implies strongly that the efficiency of thermal pressurization determines whether an initially small rupture propgates further and causes a large earthquake or not.

In this work, dynamic ruputure propagation was simulated using measured hydraulic parameters of the Hanaore fault zone based on fluid flow mathematical model by Lachenbruch [1980], and 3D TNS (Traction at Split Node) method [Andrews, 1973, Day, 1977, Archuleta and Day, 1980, Andrews, 1999]. Rupture propagation was calculated for vrious width of deformation zone under the condition of 3km depth, 0.6 static frictional coefficient, 0.4 dynamic frictional coefficient, and 0.42 initial shear traction ratio to the normal stress, after the rupture was forced to propagate up to 180m radius at 80% of S wave velocity. In the case that the deformation zone was 5cm width, the rupture didn't propagate further, while in the case of 1cm, it propagated at increasing rupture velocity. Although effects of deformation, such as time dependent concentration of deformation and dilatancy or compaction at the initiation of deformation were neglected in this calculation, width of deformation affects the behavior of the fault dramatically.