Instantaneous dehydration of serpentinite during large earthquakes: evidence from high-velocity friction experiments

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Thermal pressurization has been proposed as a major mechanism in weakening the dynamic strength of faults during earthquake slip (e.g., Sibson, 1973; Lachenbruch, 1980; Andrews, 2003; Wibberley and Shimamoto, 2005). A commonly invoked mechanism of thermal pressurization in this regard is a reduction in effective normal stress induced by the sudden increase in pore pressure that arises from the release of fluid by dehydration reactions triggered by frictional heating (Tibi et al., 2002; Meado and Jeanloz, 1991). The results of a recent experimental study suggest that serpentine minerals are dehydrated due to the frictional heating that accompanies earthquakes with large slip (Hirose and Bystricky, 2007). Serpentine is closely associated with transform faults (Christensen, 1972; Francis, 1981; More and Rymer, 2007) and seismogenic faults within subduction zones (Ulmer and Trommsdorff, 1995); indeed, the presence of serpentine minerals is considered to facilitate creep along the San Andreas Fault (More and Rymer, 2007), thereby explaining its low fault strength (Wibberley, 2007). Should serpentine dehydration occur due to frictional heating along seismogenic faults during earthquake slip, a considerable volume of water would be instantaneously released from slip zones rich in serpentine minerals. Thus, rapid serpentine dehydration would induce a sudden increase of fluid pressure that would simultaneously act to reduce the effective normal stress and markedly weaken the dynamic strength of seismogenic faults.

To test this hypothesis, a high-velocity rotary shear test apparatus Japan installed in Shizuoka University was used to conduct uniaxial high-velocity friction (HVF) experiments under conditions of large earthquake slip using natural serpentinite samples from Nagano Prefecture, Japan. This paper describes the results of these experiments, including the instantaneous dehydration of serpentinite caused by frictional heating along the simulated faults.

High-velocity friction experiments on serpentinite under conditions of large earthquake slip produce large volumes of water vapor derived from the frictional-heating-induced dehydration of serpentinite. Experimental results demonstrate that rapid serpentine dehydration led to a pronounced weakening of the simulated fault strength during high-velocity slip. Thus, increased pore pressure resulting from serpentine dehydration may lead to the dynamic weakening of seismogenic faults, thereby facilitating seismic slip during large earthquakes in subduction zones and along intracontinental faults that contain abundant hydrous minerals.