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Thermal Decomposition as a Coseismic Fault Zone Process

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Frictional heating at high slip rates and large displacements characteristic of seismic slip appears to induce specific physico-chemical processes which cannot be operated in fault zones slid at low slip rates. Identification and understanding of the processes would be critical for improving our knowledge on seismic faulting, because products of the processes may be possible indicators of past seismic motion in natural fault zones and coseismic fault strength seems to be directly related to them. The processes which have been reproduced well in laboratory experiments are (1) frictional melting of silicate rocks [e.g., Spray, 1987, JSG; Tsutsumi and Shimamoto, 1997, GRL; Hirose and Shimamoto, 2005, JGR], (2) tribochemical reaction in silica-rich rocks at a wet condition (silica gelation) [Goldsby and Tullis, 2002, GRL], (3) thermal decomposition of carbonates [Han et al., 2007, Science; Han et al., 2007, Geology] and hydrous minerals [Hirose and Bystricky, 2007, GRL; Brantut et al., 2007, Eos Trans.]. Thermal pressurization in wet and effectively undrained fault rocks could also be an important process [e.g., Sibson, 1973, Nature; Lachenbruch, 1980, JGR; Wibberley and Shimamoto, 2005, Nature; Noda and Shimamoto, 2005, BSSA], although it has not been explored by high-velocity friction experiments yet. Also, studies on fluid phase changes during seismic slip and its effect on fault strength [Mizoguchi et al., 2007, GRL] and on the development of fault microstructures [Boutareaud et al., 2008, GRL] has just been started.

In this contribution, thermal decomposition of carbonates will be focused, and mechanical data and observational results from high-velocity friction tests on carbonates will be presented first: (1) dynamic fault strength drops dramatically to less than 0.1 in terms of friction coefficient during sliding at seismic slip rates and the strength drop is associated with thermal decomposition of carbonates into ultra-fine particles (a few tens of nanometers in diameter) and CO_2, (2) high-velocity frictional behavior is characterized by strong velocity- and slip-weakening, (3) slip is localized in the quickly formed gouge layer into a quite narrow zone of a few tens of micron in thickness with increasing fault displacement, and (4) sliding surface temperature becomes lower following the friction drop. Then, it will be discussed on the topics such as (1) possible weakening mechanism(s) which may operate in simulated and natural carbonate faults, (2) seismic slip record in carbonate-bearing fault zones by showing an example of siderite decomposition and (3) experimentally derived parameters such as slip weakening distance and fracture energy by comparing them with seismologically determined values, (4) strong (almost exponential) velocity-weakening behavior observed not only in steady-state friction and but also in non-steady-state friction while slip-rate is changing.

Thermal decomposition, which is identified in laboratory tests and also inferred from natural fault zones, may be an important coseismic fault zone process, and together with thermal pressurization, frictional melting and other processes mentioned above seems to indicate that thermal processes prevail in fault zones and control dynamic friction significantly at seismic slip-rates.

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