G007-005 Room: C409 Time: May 30 10:12-10:30

Frictional healing of quartz gouge due to solution-transfer -at only 200C. Part 1: Experimental Results.

Masao Nakatani[1]

[1] ERI

Summary of experimental results

Side-hold-slide tests with a layer of simulated quartz gouge have demonstrated that a mechanism of pronounced time-dependent healing occurs that is restricted to hydrothermal conditions. This healing (referred to as hydrothermal healing) occurs at moderate temperatures (100-200C), realistic for the seismogenic depths, and is accompanied by erasure by subsequent slip, a requirement for the earthquake instability. Up to 1 mm of slip was necessary for the slip-weakening of hydrothermal healing, contrasting to the short critical displacement (~10 microns) associated with the healing mechanism typically seen in room temperature experiments [e.g., Dieterich 1972] referred to as Dieterich-type healing.

The hydrothermal healing does not occur when hot steam was used as pore fluid, showing that a solution-transfer mechanism is the underlying process. Concurrent monitoring of pore fluid chemistry has shown that the healing occurs in silica saturated aqueous pore fluid, showing that the mechanism does not require net dissolution. Also, it has been confirmed that the healing is not due to dilatancy hardening.

The time dependence of this hydrothermal healing was logarithmic with a cut-off time much longer than that of Dieterich-type healing. (Dieterich-type healing did not occur in the present experiments probably because of insufficient shear localization in the gouge layer.) The cut-off time of hydrothermal healing strongly scaled with temperature (~48000 s at 100C, ~1200 s at 100C) following an Arrhenius relationship. The time-dependent increment of static frictional coefficient due to hydrothermal healing was about 0.01-0.014 per an e-fold increase of hold time, about twice larger than the typical value for Dieterich-type healing.

Implication

Time-dependent healing mechanism is a cornerstone of rate and state friction law. Most experiments were done at room temperature, and the associated healing mechanism seems to be of Dieterich-type. Although various healing mechanisms other than Dieterich-type have already been observed experimentally, most of them were either at very high temperature (e.g., solution-transfer of quartz at 636C [Frederich and Evans, 1992], sintering of dry feldspar at 500-900C [Nakatani, 1997]) or on analogue material (e.g., solution-transfer of NaCl [Bos and Spiers, 2001]). However, the present experiment has shown even moderate (and realistic to seismogenic depths) hydrothermal conditions activate a different healing mechanism with a pronounced magnitude. This suggests that upgrading our knowledge of friction for hydrothermal conditions may be indeed necessary.

Technical specs of the experiment

Apparatus: tri-ax with argon confining medium (at LDEO rock mech. lab.). Sample: crushed natural quartz (grain dia. less than 63 microns). Initial layer thickness ~3 mm. Loading block: 37.5 saw-cut stainless steel with 0.38 mm deep triangular grooves. Jacket: FEP (inner) and lead (outer). Effective normal stress: ~100 MPa. Slip velocity: 13 microns/s. Slip displacement: up to 12 mm. Shear stress during hold: 85% of dynamic friction for most experiments. Pore pressure: 10 MPa for most experiments. Temperature: 25, 100, 150, 200C.