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Coseismic thermal-mechanical-chemical processes on the Wenchuan Earthquake fault: constraints from experiments and numerical modeling

J. Chen (1,2), X. Yang (1), and C. J. Spiers (2)

(1) State key Laboratory of Earthquake Dynamics, Institute of Geology, China Earthquake Administration, Beijing, China (J.Chen@uu.nl), (2) HPT Laboratory, Department of Earth Sciences, Utrecht University, Netherlands

We have determined the frictional, transport properties and mineralogical composition of the fault rocks, collected from two exposures along the Longmenshan (Wenchuan Earthquake) Fault Zone, and used the data obtained to numerically model coseismic slip. Friction test at 1.3 m/s were carried out on principal slip surface gouges with 1 mm thickness under normal stress of $\sim$ 1 MPa. Experiments of dry samples revealed a peak friction coefficient of around 0.6 followed by dynamic weakening to steady state value of $\sim$ 0.17. Results for wet samples were characterized by rapid attainment of steady state slip with a very low friction coefficient (0.07 and 0.13), and little or no dynamic weakening. Fluid transport properties were measured on transect fault rock samples, in particular on principal slip surface gouges and nearby rocks, at effective pressure (P_e) cycled in the range of 7 - 165 MPa. The oscillating flow method was applied using water as pore fluid at a mean pressure of 14 MPa, measuring permeability and porosity change at each step change of confining hence effective pressure. Permeability, specific storage and porosity values obtained for the gouge samples at P_e = 165 MPa fell in the range of 7.3 $\times 10^{-22}$to 2.6$\times 10^{-20}$m^2, 1.1$\times 10^{-10}$ to 4.0$\times 10^{-10}$ Pa^{-1} and 9.4 % to 5.9 %, respectively. The surrounding rocks show values up to 4 orders of magnitude, 10 times and 4 times higher than these. The two gouge samples on the principal slip surface consisted of quartz (29%, 66%), dolomite (27%, 7%) as the major minerals, illite (17%, 20.6%) and smectite or I/S mixlayers (8%, 13.4%) as clays.

On basis of these experimental data, numerical modeling of coseismic slip were conducted, considering the real slip history, chemical reactions (i.e. dehydration of smectite, decarbonation of dolomite) and the state dependent thermodynamic properties of the pore fluid, allowing for the formation of SC water and CO_2. The results indicate that (1) thermal pressurization enhanced by chemical reactions played a significant role during the Wenchuan Earthquake; (2) over pressure may have developed in impermeable zone at depth, limiting the temperature increase less than 600 ^{o}C; (3) the two stage slip mode observed at locations such as Beichuan could have been associated with a major decrease (60%) in fault strength after the first stage of slip. We explored a wide range of parameters in order to determine the contribution from different factors and their sensitivity. Over pressuring is possible under conditions of low permeability, rapid reaction kinetics, high abundance of hydrated minerals and/or high slip velocity, as reported in previous studies (i.e. Brantut et al., 2010; Rice, 2006). Especially, the state dependent thermodynamic properties of the fluid played a crucial role. Our results showed that local PT condition within the slip zone can vary over a large range during frictional sliding, and that the pore fluid may even undergo multiple phase changes, from liquid to vapor and or supercritical states with increasing temperature, changing the thermodynamic properties of the mixed fluid phase by up to three orders of magnitude. Such effects may have determining role in EQ dynamics, much more important than previously realized.