GSA DATA REPOSITORY 2014012

"Coseismic graphitization of principal slip zone gouge during the 2008 Mw 7.9 Wenchuan earthquake"

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This file includes text, figures and tables that are divided into three data repository items:

Data repository Item DR1: Summary of experimental conditions

Data repository Item DR2: Description of sample preparation and method of *in-situ* synchrotron X-ray analysis

Data repository Item DR3: Description of starting material compacted to 12 MPa

Data repository Item DR4: Computation of temperature evolution along the principal slip zone formed at 15 MPa

Data Repository Item DR1

Summary of experimental conditions

Table DR1: Experimental condition for seven friction experiments performed on fault gouge layers at room-temperature and room-humidity. Selected friction tests are plotted in Fig.2 in the main text. σ_n: applied normal stress; τ_{ss}: steady-state shear stress; Frictional power density: $\tau_e \cdot V$; Friction work: $\tau_{ss} \cdot d$

Experiment	Grain size (μm)	σ_n (MPa)	τ_{ss} (MPa)	Slip velocity (m/s)	Frictional power density (MW/m^2)	Acceleration/ Deceleration (m/s^2)	Frictional work (MJ/m^2)	Total displacement (m)
s596	< 250	5	1.8	3.2	5.76	6	5.4	3
s597	< 250	10	2.3	3.2	7.36	6	4.6	2
s598	< 250	15	3.6	3	10.80	6	6.3	1.76
s602	< 250	10	2.6	3.2	8.32	6	5.2	2
s604	< 250	5	1.6	3.2	5.12	6	4.8	3
s605	< 250	25	6.7	3.2	21.44	6	13.4	2
s711	< 250	15	3.3	3.2	10.56	6	6.6	2

Data Repository Item DR2

Description of sample preparation and method of *in-situ* synchrotron X-ray analysis

Gouge layers were recovered following the experiments and impregnated in low-viscosity epoxy. Resin experimental products were then sliced with a Leica SP1600 saw machine. The slices of about 150 μm thickness were prepared in perpendicular to the gouge layers and approximately parallel to sub-parallel to the rotary shear direction for the investigation with the synchrotron X-ray analysis.

In-situ X-ray diffraction analysis was performed at the beamline BL01C2 of the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. The synchrotron X-ray radiation was generated from the superconducting wavelength shifted magnet of 5.0 Tesla with ring energy of 1.5 GeV typical ring current of 200 to 120 mA. The X-ray wavelength was 0.5166 Å which was delivered by a double crystal monochromator with two Si(111) crystals. In each typical analysis, the experimental PSZs were confirmed with an aligned infrared ray (Figure DR1). Two dimensional X-ray diffraction patterns were recorded by using a Mar345 imaging plate detector with a pixel size of 100 μm and the typical exposure time of 60 sec. During the data processing, the X-ray diffraction spectra were scaled to a two theta that corresponds to a typical copper source by transferring the wavelength of 0.5166 Å to 1.540 Å (CuKα). The one dimensional XRD profile was converted using FIT2D program of a cake type integration, and selected results are plotted in Fig.4 in the main text.

Figure DR1: Photo of *in-situ* synchrotron X-ray analysis. The cross section of two white lines with a light spot showing the analyzed location (PSZ in our study).

Data Repository Item DR3

Description of starting material compacted to 12 MPa

The bulk pieces of gouge recovered from the WFSD-1 borehole were gently crushed and were sieved to a grain size < 250 μm. To investigate the gouge microstructures that formed during initial compaction in the experiments, we compacted 5 g of room humidity black Longmenshan fault gouge up to 12 MPa normal stress. Compaction of the gouge was conducted between two cylinders of gabbro with external and internal diameters of 50 mm and 30 mm, respectively, so that the entire compacted gouge layer plus gabbro cylinders could be recovered. The fault gouge was from the same batch used in the rotary-shear experiments with a grain size < 250 μm. Both the gouge layers and the gabbro cylinders were saved in epoxy for thin section preparation. We prepared polished thin sections with the same orientation as those for the deformed gouge layers described in the main text (i.e., perpendicular to the gouge layers and parallel to sub-parallel to the rotary shear direction).

Figure DR2 shows backscattered SEM images of the black gouge layer compacted to 12 MPa normal stress. The gouge layer shows fracturing of quartz grains and numerous polymineralic fragments formed from crushed gouge fragments. The microstructural observations did not show any evidence of grain sorting, localization of deformation, or preferential orientation of grains.

a

b

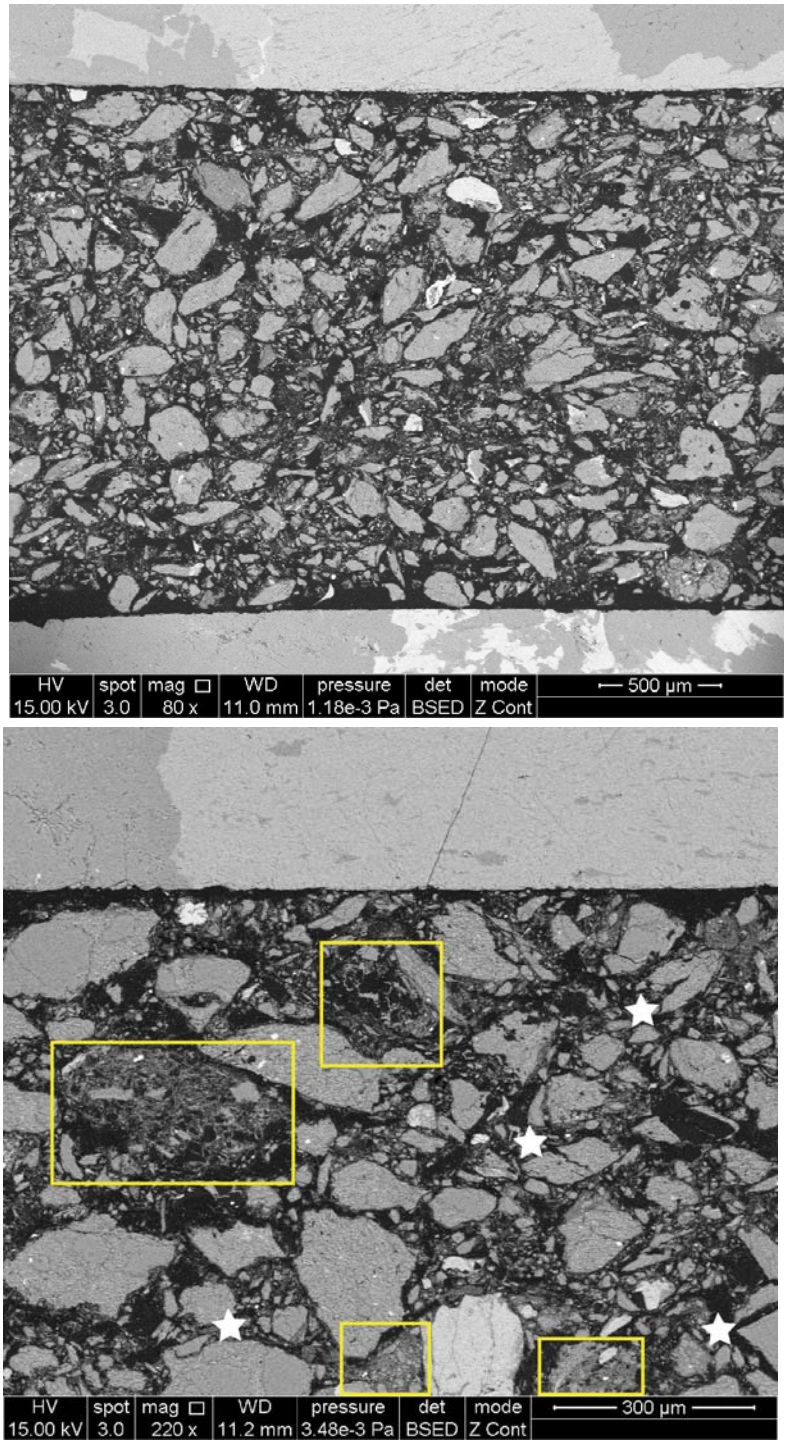

Figure DR2: Microstructures of black gouge compacted to 12 MPa normal stress. a) Low magnification backscattered SEM image showing gouge layer compacted between cylinders of gabbro, b) Backscattered SEM image showing fractured grains within the gouge layer (examples highlighted by white stars) and a few polymineralic fragments and aggregates constituted of gouge fragments (example highlighted with yellow box).

Data Repository Item DR4

Computation of temperature evolution along the principal slip zone formed at 15 MPa

We assume that heat generated by shearing was accommodated along the principal slip zone once formed. We utilize the 1 D equation (Carslaw and Jaeger, 1959):

$$\Delta T(t) = \frac{1}{\rho \cdot C \cdot \sqrt{k\pi}} \cdot \int_0^t \frac{1}{2} \cdot \frac{\tau(t') \cdot V(t') - \emptyset(t')}{\sqrt{t-t'}} dt'$$

where ρ =2400 kg m^{-3} is mass density, kappa = 10^{-6} m^2/ s is thermal diffusivity and c = 1250 J/kg °K is heat capacity. Delta T is the temperature rise in °K. The available heat rate per unit surface at any given time is the frictional power tau(t)V(t) minus the heat sink rate phi(t).

The heat sink phi(t) is computed based on the theory of Sulem and Famin (2009), and Brantut et al. (2011), using an Arrhenious law for the reaction kinetics of dehydration with dm/dt = alpha (1-n(t)) ρ A Exp[-Ea/(R T(t))]:

where dm/dt is the amount of mass undergoing dehydration per unit volume per unit time. For simplicity, we assume a single dehydration mechanism where R = 8.31 J /K mol is the gas constant, Ea = $196 \cdot 10^3$ J /mol is the activation energy and A = $9.57 \cdot 10^8$/s is the pre-exponential factor (we used these values based on Saikia et al. (2002)). n(t) is the proportion of hydrated material which has undergone dehydration at time t and alpha is the initial fraction of hydrated material in the bulk rock; here we assume alpha~0.3 (given the proportion of hydrated minerals in the bulk rock) and that the whole thickness (3mm) is involved. Further, we assume that decarbonation absorbs a latent heat of dehyration L = $3190 \cdot 10^3$ J /kg (Sulem and Famin, 2009). Figure DR3 shows the solution to this equation for the experiment s598 at 3 m/s and 15 MPa, and red curve is omitting heat sinks (i.e., phi=0).

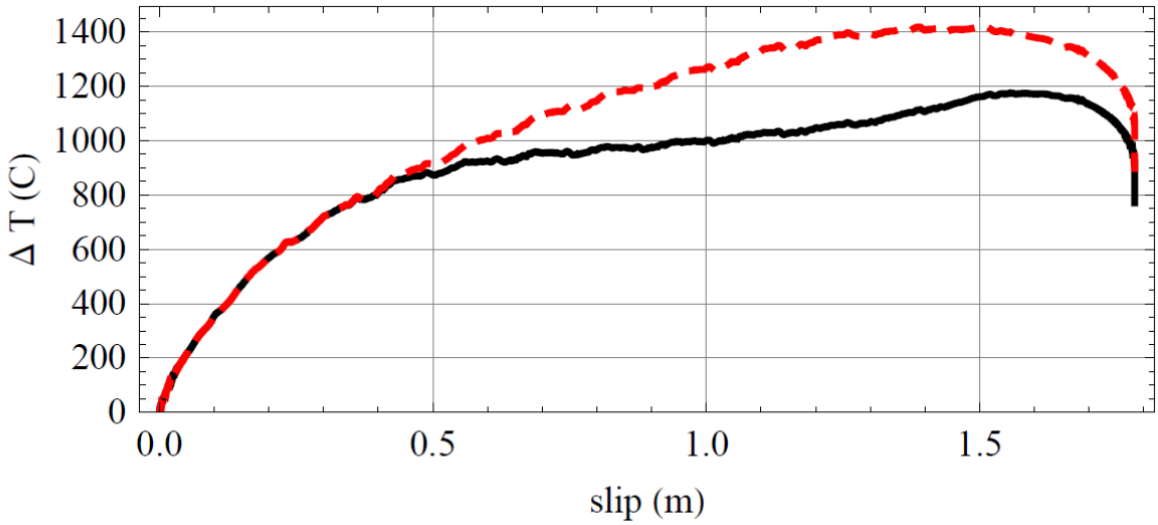

Figure DR3: Temperature calculated using the 1 D heat diffusion equation. Temperature evolution on the PSZ during the experiment s598 (see Fig.2A in manuscript).

References Cited in Data Repository

Carslaw, H. S., and Jaeger, J. C., 1959, Conduction of heat in solids, Oxford, Oxford University Press, 510 p.

Saikia, N., Sengupta, P., Gogoi, P. K., and Borthakur, P. C.,2002, Kinetics of dehydroxylation of kaolin in presence of oil field effluent treatment plant sludge: Applied Clay Science, v. 22, p. 93-102.