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2008 年?川地震を起こした龍門山断層の内部構造と高速摩擦実験
Internal structure and high-velocity friction studies on the Longmenshan fault that caused the 2008 Wenchuan earthquake

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A challenge in fault and earthquake studies is whether a recent well-instrumented earthquake can be reproduced or not based on measured frictional properties of fault zones that caused the earthquake. In collaboration with Institute of Geology, China Earthquake Administration, the author has studied internal structures of Beichuan fault zone at a large outcrop in Hongkou, Sichuan Province. This fault is the major fault in the Longmenshan fault system that ruptured for more than 250 km during Wenchuan earthquake, and the vertical offset at near Hongkou outcrop is 4 to 5 m. Fault zone consists of clayey fault gouge of about 1 m in width and of fault breccia zones of 30-40 m in width on the hanging-wall side. Slip zone during Wenchuan earthquake was 10-20 mm, but overlapping striations indicate that localization of slip to an even narrower zone of a few to several millimetres occur during seismic fault motion. Graphite was found close to the coseismic fault and it might have formed during seismic fault motion. Fault gouge contains illite and chlorite, but not smectite. Black gouge found in fault core in WFSD-1 (Wenchuan Earthquake Fault Scientific Drilling Project) was not found on the Hongkou outcrop.

High-velocity friction experiments were conducted on fault gouge from this outcrop to understand the dynamic weakening processes of the fault during Wenchuan earthquake. Experiments were done on gouge of about 1 mm in thickness between a pair of solid cylindrical specimens of Belfast gabbro of about 25 mm in diameter under dry conditions, using a rotary-shear high-velocity frictional testing machine at Kochi Core Center of JAMSTEC and a rotary-shear low-to-high-velocity friction apparatus at Hiroshima University. Frictional coefficient decreases from around 0.6-0.8 at slow slip rates to 0.1 to 0.2 at high slip rates. An exponential slip-weakening was confirmed and empirical relationships for the slip-weakening distance and for steady-state frictional coefficient were determined as functions of normal stress and slip rate. A very small temperature anomaly detected WFSD-1 hole at a likely coseismic fault at a depth of 590 m suggests that frictional coefficient during the Wenchuan earthquake was far smaller than 0.1 (Mori et al, 2010). Present experiments reproduced duplex-like structures and shear bands as observed in fault zones in Hongkou outcrop. But any mineralogical changes was not recognized in the samples and present experiments could not reproduce fault rocks similar to the black gouge recognized in WFSD-1 hole. Experiments at normal stresses of at least 10 MPa, corresponding to the depth of the coseismic fault in the drill hole, are needed in the future to reproduce intrafault processes at depths. This requires a new specimen assembly that can prevent gouge leakage at high normal stresses.

Fault motion during an earthquake does not occur at a constant slip rate; it undergoes initial acceleration to the maximum slip rate, and then it decelerates and stops during an earthquake. The servo-motor of the low to high-velocity apparatus was controlled electronically to produce linear accelerating/decelerating slip history and a slip history characterized by regularized Yoffe function (rapid initial acceleration followed by nearly exponential deceleration). Better control of servo-motor has made it possible to conduct friction experiments with complex slip histories. Frictional behaviors of Longmenshan fault gouge are characterized by peak friction, nearly linear slip-weakening and final strength recovery. Slower deceleration causes more pronounced strength recovery which can act as brake to fault motion to promote pulse-like rupture propagation during an earthquake. A modified empirical law of Sone and Shimamoto (2009) describes observed behaviors for variable slip histories reasonably well, using parameters determined in constant slip-rate tests.

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