Pore structure change by nanoscale particle fracturing in the fault gouge of the Shirako fault in the Miura-Boso accretionary prism

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Fault gouges are thought to be formed by fracturing of minerals and fluid-rock interactions associated with shallow fault movement (Marone and Scholz, 1989; Sibson, 1977; Vroljik and van der Pluijm, 1999). Since clay minerals formed by these processes control the frictional property and permeability of faults (Warr and Cox, 2001), clarifying the clay species and their fabric in fault gouge is important for understanding faulting mechanisms. In this study, we focus on the Shirako Fault in the upper Miocene to lower Pliocene Miura-Boso accretionary complex, and aim to clarify the developmental process of fault gouge by analyzing nano-scale pore structure using gas adsorption/desorption method. Based on vitrinite reflectance measurements and clay mineral analysis, the Shirako fault is considered to be a fault that underwent seismogenic slip in the shallow part of the subduction zone (Hamada, 2013; Kameda et al., 2013; Mausmoto et al., 2018).
Gas adsorption/desorption measurements were performed on the fault gouge samples, which were gently ground and passed through a <425 μm test sieve. Before the measurements, the samples were degassed at 200°C for 12 hours to remove water and gas molecules adsorbed on the surface. The measurements were performed under liquid nitrogen temperature conditions. The Brunauer-Emmett-Teller (BET) theory was applied to the adsorption isotherms obtained from the measurements to calculate the BET specific surface area. In addition, the internal microstructure of the fault gouge was observed by X-ray CT on the untreated samples.
Experimental results showed an increase in BET specific surface area in the fault gouge compared to the host rock, as well as an increase in nanopores smaller than 10 nm. To investigate the cause of these results, CT images were used to analyze the particle size of clasts composed mainly of quartz and feldspar, but no significant differences were found between the fault gouge and the host rock. Therefore, the increase in BET specific surface area cannot be explained by microscale particle fracturing, suggesting that nanoscale clay particle fracturing may have occurred. Therefore, we further performed a Newmod-based XRD pattern simulation using the XRD patterns of the fault gouge and host rock reported in a previous study. The results show that decreasing the number of illite-smectite mixed-layer mineral stacking can reproduce the changes in the XRD patterns specific to fault gouge. These results suggest that clast fracturing during fault movement on the Shirako Fault was less significant, but rather that nanoscale pores were formed by crushing and exfoliation of clay minerals such as illite-smectite mixed layer minerals. When high-velocity coseismic slip occurred on the Shirako Fault, selective deformation of clay particles may have suppressed energy dissipation and promoted fault slip.

Keywords: fault gouge, pore structure, Shirako fault

