Geophysical Research Abstracts
Vol. 13, EGU2011-4641-1, 2011
EGU General Assembly 2011

Hydrogeological architecture of a fault zone reconstructed through an outcrop survey: mesoscopic and microscopic observations, multipoint hydrogen gas measurements, particle size distribution analyses and chemical analyses of fault rocks

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Many field studies and observations of faults in outcrops indicate that fault zones are composite structures, comprised of a fault core and bounding damage zones (e.g. Chester at al., 1993). The permeability is closely related to this structural style, as the fault core and the damage zone can act as a barrier and a conduit, respectively (Caine et al., 1996; Evans et al., 1997). Groundwater flow plays an important role in mass transport and nuclide migration. Hence, understanding hydrogeological characteristics of fault zones is one of the major subjects for topical issues such as geological disposal of radioactive waste. Outrcop survey is efficient in understanding a geological setting spatially, while boring is an effective way to obtain quantitative hydrogeological data of a specific area. Here we studied in well-preserved outcrops of a fault zone and reconstructed its permeability sturucture. We newly adopted quick and multipoint H2 gas measurements using a portable gas monitor and a hand drill devised by Shimada et al. (2008), in addition to the detailed description of mesoscopic and microscopic features, particle size distribution analyses and chemical analyses of fault rocks.
The fault zone studied belongs to the Atera Fault in central Japan. It includes a smectite-rich fault core between two clearly distinguishable damage zones of granite cataclasite and welded tuff fault breccia on opposite sides of the fault core. Although the welded tuff fault breccia and the granite cataclasite are pervasively fractured and fragmented, the fault cores display notable fragment/grain size reduction due to intense abrasive wear and comminution. The multipoint H2 gas measurements show that H2 gas emissions collected during 120 to 180 minute sampling periods range from 320 to 446 ppm/min in the granite cataclasite and 61 to 138 ppm/min in the welded tuff fault breccias. However, negligible quantities of H2 gas could be obtained from the fault core. Such H2 gas emission patterns are closely linked to microfracture development in fault rocks.
Particle size distribution analyses of fault rocks indicate that the granite cataclasite tends to be rich in finer particles; it is less cohesive and easy to disaggregate, suggesting that the granite cataclasite has high permeability. According to an XRD analysis, smectite and kaolinite are abundant in the fault core, in contrast to lack of clay minerals in the granite cataclasite. Whole-rock chemical composition of fault rocks analyzed by XRF and ICP-MS shows depletion of elements such as Ca, Na and K due to clay mineral formation in the fault core. Results of the H2 gas measurements, the particle size distribution analyses and the chemical analyses support the inference that the H2 gas probably has migrated in permeable damage zones, mostly by advection with groundwater, and that the more fine grained smectite-rich fault core has the potential to act as a barrier to fluid flow.

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