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Mass transport in a fault zone: effects of fracturing and host rock lithology

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Fault zone development has the potential to impact regional groundwater flow (e.g. Caine et al., 1996, Geology). Groundwater flow plays an important role in mass transport and nuclide migration. Thus understanding mass transport along fault zones is one of the major subjects for topical issues such as geological disposal of radioactive waste. Here we analyzed whole-rock chemical composition of fault rocks from well-studied outcrops of the Atera Fault in central Japan, using XRF and ICP-MS, to elucidate chemical composition changes associated with fault activities.

The fault zone studied includes a smectite-rich fault core between two clearly distinguishable damage zones of cataclasite of the Naegi-Agematsu Granite and fault breccia of the Nohi Rhyolite on opposite sides of the fault core (Niwa et al., 2009, Island Arc). Black fragments of mafic volcanic rocks are included in the fault core. The fragments, derived from the Ueno Basalts of 1.5 Ma, are characteristically coated with carbonates.

On the basis of the whole-rock chemical composition analyses, we identified the concentration of heavy rare earth elements (HREE) and U in the fault core. Intense brecciation and subsequent fragment size reduction due to fault fracturing increase surface area and enhance potential for water-rock interaction and clay mineral formation (e.g. Wintsch et al., 1995, JGR). In addition, the radical reaction on new fracture surfaces during brecciation of silicate minerals generates hydrogen ions, which may facilitate further chemical reaction of fluids with silicate minerals to form clay minerals (Kameda et al., 2003, GRL). Assuming that the concentration of HREE and U in the fault core was caused by fault activities, sorption on clay minerals could be one of the dominant concentration mechanisms. The sorption reaction is mainly controlled by ion-exchange and/or complexation on mineral surfaces. In the case of ion-exchange reaction, light REEs (LREE) are more selectively-sorbed in 2:1 clay mineral such as smectite than HREE, because LREE have smaller hydrated radii than HREE (Otani et al., 2005, Resour. Geol.). On the other hand, REE tends to form complexes with carbonates, hydroxides or organic matters. These complexes are more stable for HREE than LREE (Shikazono et al., 2006, Resour. Geol.). It is possible for HREE to concentrate in the fault core together with the carbonate coated with the black fragments. Although REE and U is also concentrated by the sorption on iron oxide or iron hydroxide (Akagawa et al., 2004, J. Geol. Soc. Jpn.), these elements in the studied outcrop seems to be less correlated with composition changes of Fe.

The REE and U concentrations is also influenced by the dissolution and/or precipitation of minerals including these elements. The Naegi-Agematsu Granite is rich in radioactive minerals such as zircon and monazite (Ishihara and Wu, 2001, Bull. Geol. Surv. Jpn.), however, compositions of HREE and U in the fault rocks are less correlated with those of Zr and P. Thus their concentration could not be caused by the distribution of radioactive minerals. Moreover, there has a low likelihood of simple HREE precipitation in the fault core, because they are precipitated only in lower pH than LREE except tetravalent cerium. Th/U-Ce/U plots show that the fault core is under a reductive environment (poor in Ce and rich in U). The fault core shows sulfur concentration, as well as carbonate concentration in the fragments of mafic volcanic rocks. It is possible that uranium dissolved in groundwater could be migrated as complex ions binding to carbonate or sulfate ions, and precipitated in the reductive fault core (Kobayashi, 1989, Mining Geol.).

As discussed above, heterogeneity of host rock lithology presented as mixing of fragments of mafic volcanic rocks in the fault core has a great influence on the concentrations of specific elements, through surface complexation of HREE and uranium precipitation in the reductive environment.

Keywords: fault zone, mass transport, rare earth element, clay mineral, carbonate