

Fundamental experiments of mechanochemical water-rock interactions: Fluid chemistry and the implication for seismic fault zones

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Faults on the surface infiltrate surface water into the crust and have a key role of fluid circulation in the crust. At the same time, the faults are weak fracture zones that are movable in response to the stress condition on them, yielding earthquakes in some cases. The fluid penetration in the fracture zone leads into fluid-rock interaction with pulverization process, resulting in the change of the chemical and physical properties of the fault zone materials. One of the examples is the formation of submicron size of low strength materials such as amorphous and clays which seem to be formed by alteration reactions (Evans and Chester, 1995). The fault that is composed of such secondary minerals is considered to become mechanically weaker (Wintsch et al., 1995; Tanaka et al., 2001). The alteration reactions proceed depending on hydrogen ion activity. Thus pH of the fluids that penetrate into the fault zones is an important parameter for the fluid-rock interactions. In order to understand the fluid chemistry during water-rock interactions with pulverization process, we performed batch-style crushing experiments of single crystals and granites with pure water (pH 7) at the ambient temperature and pressure.

Experiments were performed using a ball mill made of alumina ceramic and a shaker at room temperature and pressure. Single crystals of quartz, alkali-feldspar, biotite and Oshima granite were used as a starting material and crushed between mesh sizes 0.15 and 0.512 mm. 5 g samples were combined with 15 g of pure water (pH 7). After the crushing procedure, the fluid was separated into a polyethylene tube, centrifuged and measured pH, cation and anion concentrations, and BET surface area.

pH values decrease for the experiments of quartz single crystal with increasing crushing times, while the other single crystal and granite experiments show the pH increases. Cation and anion concentrations generally increase with increasing the shaking durations. BET surface area linearly increase with increasing the experimental duration time for all the crushing experiments.

The possible mechanism of the H⁺ generation for the quartz crushing experiments is the dissociation of surface silanols, which are stronger acid than monosilicic acid and generated from reactions between water molecules and the siloxane bonds after the reconstruction process or from reactions between water and the homolytic and hetelolytic disconnections of quartz (Saruwatari et al., in press). In the case of crushing experiments of other minerals and granite, the mechanism of pH increase is most likely explained by the cation exchange at the mineral surface, suggesting that the fluid after the pulverization process due to fault movements will probably become basic. Thus, we can propose that the fluid chemistry in fault zone may be cycling between acidic and basic related with the seismic cycle. The fault at the surface will be penetrated by the meteoric water which supply hydrogen ions and oxygen gas into the fault zone, inducing the alteration process and the formation of clay minerals (Wintsch et al., 1995; Tanaka et al., 2001). At this time, the fault environment will be acidified and the bottom of the acidified zone may gradually change into the deeper depth of fault zone, leading the strength of fault zone weaker and the depth of weak zone down. During co- and post-seismic period, the fluid will become basic and change the fault zone into basic environment, precipitating the secondary minerals from probably over-saturated fluid, sealing the damage zone and recovering the fault strength. Then the fault will be again acidified by meteoric water toward the weakening of the fault.

Evans and Chester (1995) *J Geophys Res*, 100,13007-13020, Saruwatari et al. (in press) *Phys Chem Min*, Tanaka et al. (2001) *Island Arc* 10, 381-391, Wintsch et al. (1995) *J Geophys Res*, 100, 13021-13032