Evaluation of coseismic physicochemical processes in fault zones based on geochemical analyses of fault rocks

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Trace element and isotope compositions of rocks record processes associated with their petrogenesis and later modifications. Interactions with fluids and melts are major factors to control chemical characteristics of the rocks. Geochemical analyses of rocks thus can be useful means for understanding nature of such fluid- and melt-related interactions, constituting essential part of broad physicochemical processes occurring in the earth’s interior. Here I focus on an attempt to evaluate coseismic physicochemical processes in fault zones based on rock geochemistry.
Frictional heating in a fault zone during earthquake slip affects the slip behavior itself. Increased temperature on a fault can induce dynamic fault weakening by processes such as pressurization of interstitial fluid by thermal expansion, known as thermal pressurization, and melt lubrication. Recent studies revealed that trace element and isotope analyses of fault rocks combined with geological, mineralogical, structural, and geophysical observations are useful for elucidating such slip weakening processes.
In the Chelungpu fault in Taiwan, which slipped during the 1999 Mw 7.6 Chi-Chi earthquake, the slip-zone rocks showed clear geochemical anomalies, including decreases of Li, Rb, Cs and 87Sr/86Sr and an increase of Sr relative to adjacent host sedimentary rocks (Ishikawa et al., 2008). Model calculations revealed that these anomalies were produced by coseismic fluid-rock interactions at >350°C, which may have caused a dynamic decrease of friction along the fault through thermal pressurization. Ancient slip zone rocks from a major reverse fault in the Boso Emi accretionary complex at 1–2 km depth (Hamada et al., 2011) and from a decollement of the Kodiak accretionary complex at seismogenic depth (Yamaguchi et al., 2014) showed similar evidence for coseismic fluid-rock interactions at high temperatures. The 87Sr/86Sr ratios of the Kodiak slip zone rocks also revealed involvement of fluids derived from subducted oceanic crust during the earthquake slip. Recent high-velocity frictional experiments under wet condition demonstrated that detectable fluid-inducted geochemical anomaly can be produced by a single earthquake event (Tanikawa et al., 2015). For the slip zone rocks from the Shimanto accretionary complex in Kure area, which represent rocks of ancient megaspray fault at 2.5–5.5 km depth, geochemical signals derived from high-temperature fluids overlap with those from melting, indicating coseismic fluid-rock interactions followed by disequilibrium frictional melting (Honda et al., 2011). These results demonstrate that geochemical characteristics of the fault rocks are useful indicators of such physicochemical events. However, further studies are required especially for fault system developed within basaltic crust, for which geochemical characteristics of fault rocks have been poorly understood.
Refs: Ishikawa et al. (2008) Nature Geosci. 1, 679-683; Hamada et al. (2011) JGR 116, B01302; Yamaguchi et al. (2014) EPS 66:58; Tanikawa et al. (2015) GRL 42, 10.1002/2015GL063195; Honda et al. (2011) GRL 38, L06310.

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