Influence of fault activity to hydration thickness of quartz: Application of SIMS analysis

*Masakazu Niwa[1], Koji Shimada[1]

1. Japan Atomic Energy Agency

Occurrence of recent activity of faults is often evaluated based on displacements of young subsurface sediments covering the faults. However, this evaluation is not applicable for faults that occur where young subsurface sediments are not found. Faulting in brittle regimes often results in the development of fault gouge along a slip plane. In addition, the formation of hydrous silica gel has been proposed as one of indicators of paleo-earthquakes within the rock record (Faber et al., 2014). Analysis for silica hydration along faults as well as structural, mineralogical and geochemical analyses of a fault gouge may assist in reconstructing the history of fault activity, and also contribute to identification of recent faulting.
Hydration thickness measurement of silica glass has been applied for dating for archeological artifacts such as a stone figure and axe made from obsidian (Katsui and Kondo, 1967; Stevenson et al., 1989). Hydration thickness of volcanic glass estimated from refractive index analysis using optical microscopy has positive correlation with its sedimatation age (Yamashita and Danhara, 1995; Ikuta et al., 2016). Hydration rate of volcanic glass is about 1 μm/1,000 yr, depending on sedimentary environment. In contrast, hydration rate of quartz is too slow; diffusion coefficient values of quartz and glass at ambient temperatures are about 10^{-21} and 10^{-17} cm^2/s, respectively (Ericson et al., 2004). However, examinations of natural fault mirror surfaces and experimental studies for siliceous rocks have suggested that silica gel lubrication could cause coseismic weakening (Hayashi and Tsutsumi, 2010; Kirkpatrick et al., 2013). Near-surface faulting possibly facilitates a growth of quartz hydration.
In this study, we examined the relationship between development of quartz hydration and fault activity. The hydration thickness was estimated by secondary ion mass spectrometry (SIMS), Physical electronics PHI 6650 or PHI ADEPT 1010 housed at Foundation for Promotion of Material Science and Technology of Japan. Cesium ion was used as primary ion, and depth profile of secondary ion intensities of hydrogen, silicon, oxygen and aluminum ion was obtained for a 10 μm depth from a sample surface. Hydrogen ion concentration was calculated from normalization using a quartz standard sample. Primary accelerated voltage was 5.0 kV, and analyzed area was approximately 20 μm $\times$20 μm.
We analyzed chert samples from the Franciscan Complex in California and Mino Belt in central Japan. We compared depth profiles of hydrogen ion concentration between (1) mirror surfaces along fault plane, (2) natural, flat surfaces without fault slip, and (3) inside of the samples exposed by cutting and polishing. The analysis suggests that hydrogen ion concentration from the mirror surfaces to >1 μm depth increases severalfold compared to inside of the samples, while the natural surfaces without fault slip have no clear concentration change for depth. This study shows that the SIMS analysis could be applicable for the estimation of hydration thickness of quartz along faults as well as the measurement of obsidian hydration thickness (Liritzis and Laskaris, 2009). The tests for still more samples should be further studies to examine geochronological application for fault activity.

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