Hydrothermal experiment on quartz hydration: Toward a development of new dating method for natural phenomena

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In the field of archaeology, the diffusion of water into quartz exposed to the natural environment has been proposed as a dating method (quartz hydration dating: QHD) applicable to archaeological artifacts. We examined application of QHD to geologic materials to understand natural phenomena crucial for safety assessment of geological disposal, such as uplift and erosion, faulting, and hydrothermal activity.

In this study, hydrothermal experiments were conducted to understand the degree of the diffusion of water into natural quartz included in an exposed rock body. Intact granite samples (Late Cretaceous Kojaku Granite, central Japan) were mirror polished and immersed in deionized water in an autoclave apparatus. We held the samples in the apparatus at controlled temperatures (150˚C or 250˚C) and controlled pressures (9.8 MPa or 25.5 MPa) for 100 hours. The pressurization was performed by CO_2 gas (pH in the water is 3.2 to 3.6), or N_2 gas. After the experiment, secondary ion intensity of H^+ from the quartz surface in the samples was measured by secondary ion mass spectrometry (SIMS). We estimated thickness of hydration layer based on depth profile of H^+ intensity.

According to the SIMS measurement, clear increase of H^+ concentration within 2 μm depth from the surface was identified in the experiment at 250˚C and 25.5 MPa. The H^+ concentration increased more in the case of the pressurization by CO_2 gas than by N_2 gas. Based on Ericson et al. (2004, J. Archaeol. Sci.), diffusion coefficient on water uptake of quartz was calculated from the depth profile of H^+ concentration by fitting with complementary error function. The calculated diffusion coefficient was consistent with values from archaeological artifacts and synthetic crystals reported by previous studies. Development of hydration layer of maximum thickness several μm in quartz is possible for a ten thousand year, according to the estimation from diffusion coefficient at ambient temperature calculated by extrapolation based on the Arrhenius equation. Thus, the QHD can be promising as a new tool to understand natural phenomena.

In contrast, no clear increase of H^+ concentration was identified in the experiment at 150˚C. According to the estimation from diffusion coefficient at 150˚C calculated by extrapolation based on the Arrhenius equation, this infers that the hydration layer was too thin to detect by SIMS.

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