Quantitative analysis of Cu and Zn in fluid inclusions using synchrotron radiation X-ray fluorescence

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Fluid inclusions are sub-millimeter-sized hydrothermal solutions trapped in minerals during precipitation of crystals. Various kinds of information carried by fluid inclusions such as concentrations of metals have made it possible to clarify the mechanism of ore formation such as metal transport, fluid cooling, and mineral precipitation. Quantitative analysis of individual fluid inclusion is more useful for making higher resolution model of ore formation than bulk analysis. In recent years, synchrotron radiation X-ray fluorescence (SXRF) has provided an opportunity for micrometer-scale analysis of fluid inclusions, and has achieved good results for qualitative analysis. To improve the quantification of SXRF, several researchers have performed empirical calibration, but SXRF still has significant errors for quantitative analyses. This paper improves the precision of quantitative analysis of fluid inclusions through the consideration of fluid inclusion geometry which is one of the most critical problems remained unsolved in qualitative analyses of fluid inclusions.

In this study, synthetic fluid inclusion technique was introduced to obtain inclusions with known composition. Synthesis of fluid inclusions was carried out on the basis of Bodnar and Sterner (1987). Natural quartz crystals were cut into rod of 4 mm, 4 mm, and 2-3 cm in dimension. The cores heated at 400 degrees in advance were dropped immediately into pure water at ambient temperature to generate fractures. Solutions containing 100-10000 ppm Cu and Zn were loaded into a gold tube with a quartz core and quartz powder. These capsules were loaded into a high P-T autoclave equipped for this study, and held at 500 degrees and 100 MPa for several days. After that, the cores were cut and polished on both sides to prepare sections about a quarter millimeter thick for X-ray irradiation. All the SXRF measurements were performed in Beamline BL-4A at the Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan. This system generates about 5 µm and 5 µm sized microbeam

Analyses gave XRF spectra and 2-dimensional distribution map for Cu and Zn. The integrated intensity from the whole inclusion area of the mapping image and relative intensity, an intensity corrected by irradiation time and inclusion size, from point analysis was compared their correlation coefficient, therefore, the latter was more suitable as a representative intensity data. In the former, difficulty of the decision of inclusion edge probably causes uncertainty. When the incident X-ray passes through an inclusion, it generates primary fluorescent X-ray from dissolved ions. This primary X-ray is expected to generate secondary fluorescent X-ray from dissolved ions. The result suggests that secondary characteristic X-ray does not have a significant effect on relative intensity. Using plots of relative intensity, equations displaying Cu and Zn concentrations of inclusion fluid were determined as a function of inclusion depth and relative intensity. The equations agreed with the value expected by mass absorption coefficients. These results suggest that values are theoretically expected for various host minerals using published mass absorption coefficient and host mineral density. The ratio of the slopes of the correction curves for Cu and Zn was in good agreement with the ratio of florescence cross-section, an element-dependent parameter representing the efficiency of X-ray fluorescence. It suggests that concentrations of inclusion fluid for several elements with at least similar atomic number are predictable by extrapolation using the florescence cross-section.