

Experimental study of the behavior of copper and zinc in a boiling hydrothermal system

Ken-ichiro HAYASHI*¹ and Hiroki NAGASEKI²

¹Graduate School of Life and Environmental Sciences,
University of Tsukuba, Tsukuba, Ibaraki 305-8572, Japan

²Graduate School of Science, Tohoku University, Sendai, Miyagi 980-8578, Japan

Introduction

Phase separation of hydrothermal fluid in the deeper parts of magmatic systems may play an important role in the segregation of Cu from hydrothermal fluid in the process of porphyry-type mineralization. Dense hydrothermal vapor can contain significant amounts of Cu, much greater than other heavy metals, whereas hypersaline liquid contains most of the Fe, Zn, and Pb, but concentrations of Cu lower than in the vapor phase. This conclusion is based on microanalysis of coexisting vapor-rich and liquid-rich inclusions [1], and is qualitatively indicated by chalcopyrite daughter crystals in many vapor-rich fluid inclusions. The purpose of the present study is to determine the factors controlling the volatility of heavy metals in boiling hydrothermal fluid under the high temperature and pressure conditions typical of porphyry-style mineralization.

Experimental method

The synthetic fluid inclusion technique was used in this study to allow high temperature and pressure fluids to be sampled without cooling or depressurization. Solutions containing 1500–12000 ppm Cu and Zn with 10–30 wt% NaCl were prepared. The solutions were injected into a Au capsule (3–5 cm long, 6.0 mm outer diameter, 0.2 mm wall thickness) along with elemental sulfur, a quartz core and quartz powder. These capsules were loaded into the autoclave and maintained at the desired temperature and pressure for several days. The cores were cut into slices and polished on both sides to prepare sections of approximately 0.25 mm thick for microscopic observation and X-ray irradiation.

Synchrotron X-ray fluorescence (SXRF) analysis was performed to determine Cu and Zn concentrations in fluid inclusions at BL-4A of the Photon Factory, KEK. Experimentally determined calibration curves between the intensity of fluorescent X-rays and the concentration of Cu and Zn in fluid inclusions [2] were applied for quantitative analyses of individual fluid inclusions.

Result and discussion

A substantial Cu concentration was detected in vapor-rich inclusions, and a considerable enrichment of Zn was

detected in liquid-rich inclusions [3]. It thus appears that Cu preferentially partitions into the vapor phase while Zn partitions into the liquid phase under these experimental conditions. The Cu concentration in the liquid phase and the Zn concentration in the vapor phase were much lower than in the coexisting phases. Therefore, our data suggest that the chemical speciation of Cu under sulfur-rich conditions differs from that under sulfur-free conditions. Figure 1 shows the relationship between the sulfur content of the system and the vapor-liquid distribution constant ($\log K_D = \log(m_{i(\text{vapor})}/m_{i(\text{liquid})})$) of Cu and Zn at 500 °C and 35 MPa. The figure clearly shows that $\log K_D$ for Cu gradually increases with sulfur content particularly at >1 molality S, whereas Zn does not become enriched in the vapor phase with an increase in sulfur, indicating that for Zn, $\log K_D$ is independent of the sulfur content. Our data therefore support the hypothesis that sulfur is responsible for Cu enrichment in the vapor phase [4].

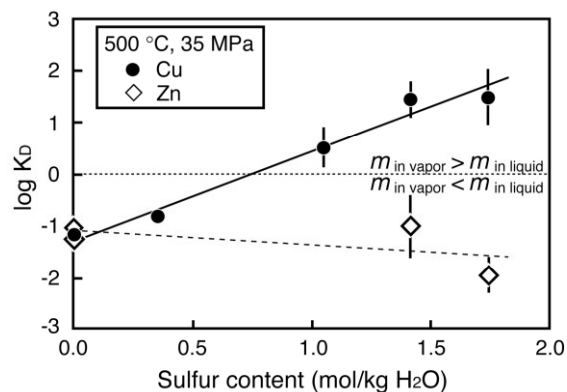


Figure 1. Vapor-liquid distribution constant ($\log K_D$) for Cu and Zn and its dependence on sulfur content at 500 °C and 35 MPa.

References

- [1] T. Ulrich et al., *Nature*, 399, 676 (1999)
- [2] H. Nagaseki et al., *Eur. Jour. Mineral.*, 18, 309 (2006)
- [3] H. Nagaseki and K. Hayashi, *Geology*, 36, 27, (2008)
- [4] C. A. Heinrich et al., *Geology*, 27, 755 (1999)

*khayashi@geol.tsukuba.ac.jp