Geophysical Research Abstracts
Vol. 18, EGU2016-14338, 2016
EGU General Assembly 2016

The physical hydrology of magmatic-hydrothermal systems: High-resolution ^{18}O records of magmatic-meteoric water interaction from the Yankee Lode tin deposit (Mole Granite, Australia)

Szandra Fekete (1), Philipp Weis (1,2), Thomas Driesner (1), Christoph A. Heinrich (1), Lukas Baumgartner (3), and Anne-Sophie Bouvier (3)

(1) ETH Zürich, Institute of Geochemistry and Petrology, Department of Earth Sciences, Zürich, Switzerland (feketeszandra@gmail.com), (2) GFZ German Research Centre for Geosciences, Potsdam, Germany, (3) University of Lausanne, Institute of Earth Sciences, Lausanne, Switzerland

Magmatic-hydrothermal ore deposits are important economic Cu, Au, Mo and Sn resources (Sillitoe, 2010, Kesler, 1994). The ore formation is a result of superimposed enrichment processes and metals can precipitate due to fluid-rock interaction and/or temperature drop caused by convection or mixing with meteoric fluid (Heinrich and Candela 2014).

Microthermometry and LA-ICP MS trace element analyses of fluid inclusions of a well-characterized quartz sample from the Yankee Lode quartz-cassiterite vein deposit (Mole Granite, Australia) suggest that tin precipitation was driven by dilution of hot magmatic water by meteoric fluids (Audétat et al.1998). High resolution in situ oxygen isotope measurements of quartz have the potential to detect changing fluid sources during the evolution of a hydrothermal system. We analyzed the euhedral growth zones of this previously well-studied quartz sample. Growth temperatures are provided by Audétat et al. (1998) and Audétat (1999). Calculated δ^{18}O values of the quartz- and/or cassiterite-precipitating fluid show significant variability through the zoned crystal. The first and second quartz generations (Q1 and Q2) were precipitated from a fluid of magmatic isotopic composition with δ^{18}O values of ~8 – 10 ‰δ^{18}O values of Q3- and tourmaline-precipitating fluids show a transition from magmatic δ^{18}O values of ~ 8 ‰ to ~ -5 ‰The outermost quartz-chlorite-muscovite zone was precipitated from a fluid with a significant meteoric water component reflected by very light δ^{18}O values of about -15 ‰ which is consistent with values found by previous studies (Sun and Eadington, 1987) using conventional O-isotope analysis of veins in the distal halo of the granite intrusion. Intense incursion of meteoric water during Q3 precipitation (light δ^{18}O values) agrees with the main ore formation event, though the first occurrence of cassiterite is linked to Q2 precipitating fluid with magmatic-like isotope signature. This apparent discrepancy can be explained by the presence of a fluid of meteoric origin that was isotopically equilibrated with a hot, but already solidified and fractured granitic intrusion under rock-dominated conditions prior their transfer to the cold ore deposition site (Heinrich, 1990).

Conversely, in porphyry copper systems meteoric fluid incursion has been assumed to participate in formation of peripheral or post-mineralization processes (Bowman et al., 1987; Sillitoe, 2010; Williams-Jones and Migdisov, 2014). However, recent numerical simulations of porphyry copper systems identify a significant role of meteoric fluids for the enrichment process, providing a cooling mechanism for metal-rich fluids expelled from an upper crustal magma chamber (Weis et al. 2012, Weis 2015). Furthermore, new petrographic and fluid inclusion work of ore-mineralized quartz veins (Landtwing et al., 2010; Stefanova et al., 2014) indicates lower (~450°C) than magmatic fluid temperatures for copper precipitation. Given that the Yankee Lode study validated the capability of high resolution, in situ δ^{18}O analysis to trace meteoric water incursion, we will apply this method to hydrothermal quartz samples from two significant porphyry copper deposits (Bingham Canyon, USA and Elatsite, Bulgaria). By this we intend to better constrain a potential role of meteoric water incursion in porphyry copper ore precipitation.

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