Timescales of Porphyry Cu Deposit Formation: Insights from Titanium Diffusion in Quartz

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Porphyry dikes and hydrothermal veins from the porphyry Cu-Mo deposit at Butte, Montana contain multiple generations of quartz that are distinct in SEM-cathodoluminescence (CL) images and in Ti concentrations. A comparison of microprobe trace element profiles and maps to SEM-CL images shows that the concentration of Ti in quartz correlates positively with CL brightness (Fig. 1) but Al, K, and Fe do not. After calibrating CL brightness in relation to Ti concentration, we use the brightness gradient between different quartz generations as a proxy for Ti gradients that we model to determine timescales of quartz formation and cooling. Model results indicate that timescales of porphyry magma residence are ~1000s of years and timescales from porphyry quartz phenocryst rim formation to porphyry dike injection and cooling are ~10s of years. Timescales for the formation and cooling of various generations of hydrothermal vein quartz range from 10s to 10,000s of years. These timescales are considerably shorter than the ~1 Myr overall timeframe for each porphyry-style mineralization pulse determined from isotopic studies at Butte, Montana. Simple heat conduction models provide a temporal reference point to compare chemical diffusion timescales, and we find that they support short dike and vein formation timescales. We interpret these relatively short timescales to indicate that the Butte porphyry deposit formed by short-lived episodes of hydrofracturing, dike injection, and vein formation, each with discrete thermal pulses, which repeated over the ~3 Myr lifetime of the deposit.

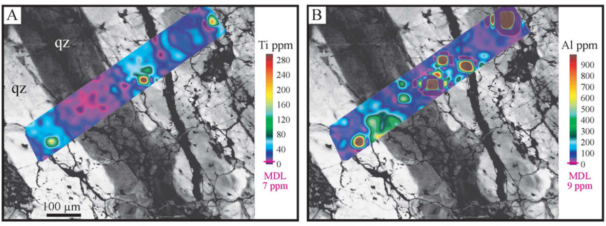

Figure 1. High sensitivity microprobe trace element maps of CL-bright barren quartz vein that is cut by CL-dark veinlets