Constraining the crystallization rate of large quartz crystals in the Stewart pegmatite from trace-element disequilibria

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Understanding the kinetics and chemistry of pegmatite crystallization is important for understanding element enrichment processes and ore formation. One way to probe these kinetics is to develop a crystal growth speedometer. This work develops a trace-element based crystal growth speedometer and applies it to the growth of quartz in the Stewart pegmatite, a gem and Li-bearing pegmatite located in the Pala mining district of Southern California (USA).

We analyzed quartz crystals (1-5 cm) from miarolitic cavities within the core and lower part of the hanging wall of the pegmatite body. Quartz presents itself as both massive aggregates and large subhedral to euhedral crystals. Depending on their location within the pegmatite, these crystals record different conditions of crystallization. By understanding the kinetics of the quartz growth, the general crystallization history of the pegmatite can be determined.

Trace element profiles of slowly diffusing elements in the quartz can be used to ascertain crystal growth rate. The enrichment of the trace element in the crystal depends on the element's crystal/melt equilibrium partition coefficient, the growth rate of the crystal, and the diffusivity of the element in the melt. From this, we can estimate crystal growth rate. If the chemical boundary layer in the melt ahead of the growing crystal reaches steady state quickly relative to crystal growth, then enrichments above equilibrium can be used to determine growth rate. If the chemical boundary layer in the melt is not at steady state, then the enrichments for an incompatible element are minimum bounds on growth rate.

The quartz crystals show significant trace element enrichments (Al, Mg, Ca, Ti, and others), particularly for Al, which exceeds 2500 ppm at the rim compared to 67 ppm in the core for one crystal. If the boundary layer is at steady state, the zonation implies that the crystal growth rate accelerated from 2.5±2 cm/yr at the core to 25±17 cm/yr at the rim. Alternatively, if the boundary layer is not at steady state, these are minimum bounds on crystal growth rates. Based on these growth rates, these quartz crystals could have grown in ~20 days, which suggests that even the largest crystals in the pegmatite may have grown within ~150 days.