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Relationships between SEM-cathodoluminescence response and trace-element composition of hydrothermal vein quartz

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ABSTRACT

Laser-ablation ICP-MS data of hydrothermal vein quartz with zonation in scanning electron microscope cathodoluminescence reveal two groups of trace elements, one that co-varies in concentration with luminosity and another that remains uniform throughout. Bright luminosity correlates with a high total abundance of trace elements in early quartz, including Al (up to 410 μg/g), Ti (up to 240 μg/g), K (up to 330 μg/g), Li (up to 8 μg/g), Na (up to 36 μg/g), and Fe (up to 20 μg/g). Up to 20 times lower concentrations of these elements are associated with dark luminosity in late quartz. Concentrations of P (~21 μg/g), Ga (~0.3 μg/g), Ge (~1.3 μg/g), Sn (~1.5 μg/g), Cu (~0.3 μg/g), and Ag (~0.1 μg/g) demonstrate no relationship with luminosity. Charge balance cannot be achieved for bright luminescent quartz unless the presence of up to 6 μg/g H^+ (not analyzed by LA-ICPMS) or interstitial Al^{3+} is invoked. Interestingly, the inferred ~6 μg/g H^+ remains constant for quartz containing more than 10 μmol total trace elements and might represent the solubility of H^+ in hydrothermal quartz at temperatures between 450 and 700 °C.

LA-ICPMS results indicate that the fluid chemistry determines the quartz trace-element pattern, which may serve as a monitor for the chemical environment from which quartz crystallized. Ratios of Na/Al and Ti/Al are uniform, whereas K/Al evolves toward lower values with decreasing luminosity. Combined evidence, including quartz vein textures, silica solubility data, and estimates of the temperature of quartz growth, suggest that early quartz crystallized fast but late quartz grew more slowly at 350 to 425 °C. It is speculated that the higher the quartz growth rate is, the more trace elements are incorporated into quartz, besides the temperature dependence known from the literature. Clearly, growth rate, temperature and fluid chemistry are important parameters affecting luminosity; however, their relative importance may vary from case to case.