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Cathodoluminescence properties of quartz eyes from porphyry-type deposits: Implications for the origin of quartz

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Abstract

Hyperspectral cathodoluminescence (CL) mapping, combined with electron probe microanalysis (EPMA) and Fourier transform infrared spectroscopy, was used for the reconstruction of crystallization conditions of quartz from porphyry environments. Quartz eyes from the two porphyry deposits Rio Blanco (Chile) and Climax (U.S.A.) were studied. Three peaks are found to be responsible for the total CL emission: 1.93, 2.05, and 2.72 eV. The first two peaks are assigned to O-M (with M being an alkali ion) and oxygen vacancies, respectively. The 2.72 eV peak shows a linear correlation with the Ti concentration determined by EPMA point measurements. In addition, a negative correlation between the 1.93 eV emission and the Al concentration was observed.

Quartz grains often form clusters in which adjacent grains show identical CL patterns, indicating that they crystallized attached to each other and were not disturbed later. Quartz cores display sector zoning and enrichment in Li, OH, and sometimes Al, which points to rapid crystallization from an extremely evolved melt. Quartz rims show high Ti, and low Li and OH contents, indicating crystallization from a less evolved melt either at higher temperatures or at higher titanium activities. The Al and Ti distribution patterns are frequently not correlated and both show uneven distribution indicating fast growth from inhomogeneous melts. Only Ti displays sharp transitions and fine oscillatory zoning, which can be explained by the higher mobility of Al in the quartz lattice.

The quartz eyes crystallized after magma emplacement under non-equilibrium conditions. It is likely that the crystallization occurred from the melt enriched in Al, Li, and OH and probably other metals and/or volatiles on the brink of fluid exsolution. Subsequent fluid exsolution brought about disequilibrium to the system, resulting in dissolution of quartz and redistribution of elements between the melt and the fluid. The OH, Li, and other alkali metals and volatiles partitioned into the fluid, whereas Ti and Al remained in the melt. Resorption of quartz caused by the fluid exsolution continued until equilibrium was reached again, after which crystallization of quartz rims began from the water-, alkali-, and volatile-poor melt with higher Ti activity. Further accumulation of Al and Ti in the residual melt led to crystallization of extremely Al- and Ti-rich quartz.

Keywords: Cathodoluminescence of quartz, trace elements, lattice defects, porphyry-type deposits