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Evolution of the Magmatic System Associated with a Supergiant Porphyry Cu Deposit from Trace Element Profiles in Zircons

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Magmatic systems associated with supergiant porphyry Cu deposits (PCDs) undergo a multi-million-year maturation in the deep continental crust as suggested by their increasing Sr/Y, La/Yb, and Eu/Eu* values through time. This evolution is recorded also by zircon, the most used mineral to infer magma fertility in porphyry Cu systems due to its resistance to hydrothermal alteration. Nonetheless, zircon analyses are almost always limited to one or two spots and miss conveying information on changing magmatic conditions during crystallization. This information is valuable to better understand the evolution of the mineralizing magmatic system and can be obtained through detailed core-to-rim profiles.

Here we report nanoSims trace element (Eu, Gd, Ce, Ti, U) profiles in 48 zircons from 8 samples of pre- to syn-mineralization magmatic rocks associated with the supergiant Llurimagua PCD (Ecuador). The 48 zircons span a range of ages between ~23 and ~6.3 Ma. Mineralization occurs at the end of this magmatic cycle, as is typical of supergiant PCDs, between ~7.28 and ~6.22 Ma, based on molybdenite Re-Os ages.

We have quantified Eu/Gd (proxy for Eu/Eu*) zoning by calculating linear slopes in the [Eu/Gd]-[core-to-rim distance] space. Zircons between ~23 and ~17 Ma display flat Eu/Gd slopes (-0.014 to +0.017), whereas after ~17 Ma they start to have increasingly negative Eu/Gd slopes culminating at ~8.5 Ma (-0.043). After ~8.5 Ma Ma Eu/Gd slopes rapidly increase, becoming strongly positive (Eu/Gd increasing towards the rim) up to +0.093 at ~6.3. Eu/Gd values in the cores display a specular opposite trend. We interpret these coupled trends as the result of zircon crystallization from a magma that has evolved at increasingly deeper levels between ~23 and ~8.5 Ma and of subsequent zircon crystallization from a magma fractionating abundant plagioclase and degassing SO_2 at shallow level, which ultimately produced the mineralization.