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High-resolution zircon petrochronology from the Bingham Canyon porphyry copper deposit: Implications for the lifetime and evolution of upper-crustal magma reservoirs

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Porphyry copper deposits represent the interface between the plutonic and volcanic domains of upper crustal magmatic systems. Focussed fluid extraction from a large magma body results in the concentration of significant economic mineralisation within small sub-volcanic porphyry intrusions. Understanding the role of magmatic processes, including fractional crystallisation, magma mixing, and fluid exsolution, in these upper crustal reservoirs is essential for quantitative models of the formation of these economically valuable deposits. Traditional models include rapid emplacement of upper crustal magma bodies followed by prolonged convective cooling of melt dominated magma chambers that undergo fractional crystallisation until complete solidification [1]. However this is at odds with more recent thermal and geochronological constraints, which imply the necessity of sustained magma input throughout the lifetime of the upper crustal magma chamber in order to prevent solidification of the magma body within several 10,000 years [2]. These studies infer that long-lived upper-crustal reservoirs require incremental assembly by a sustained magma flux and that the melt is stored in a highly-crystalline magma, where mafic underplating or recharge contribute to the extended lifetime of these systems.

In this study we examine the magmatic evolution of the >1400 km3 [3] upper crustal magma reservoir that was responsible for the formation of one of the world's richest porphyry Cu-Mo-Au deposits at Bingham Canyon (USA). We apply a combination of high-precision zircon U-Pb geochronology (CA-ID-TIMS) and zircon LA-ICP-MS geochemistry on four sub-volcanic intrusions that bracket the entire duration of mineralisation. The petrochronologic information obtained from the investigated zircons allows us to critically evaluate the thermal and chemical evolution of the large underlying magma reservoir.

High-precision geochronology reveals protracted zircon crystallisation over several ∼800 ka, far in excess of other investigated magmatic systems associated with hydrothermal porphyry Cu-mineralisation (e.g. [4], [5], [6]). Coherent temporally resolved geochemical trends further indicate that individual porphyry intrusions were successively extracted from a source reservoir that evolved by simple closed-system fractional crystallisation. We infer that progressive fractional crystallization and related episodic fluid exsolution from a homogeneous magma reservoir were the dominant processes resulting in the world class economic mineralisation at Bingham Canyon.

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