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Constraining the interactions of magmatic and hydrothermal processes during ore formation in porphyry copper systems with numerical modelling

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The process of metal enrichment to form magmatic-hydrothermal ore deposits is controlled by the interplay of magmas, rocks and fluids within the upper crust. The mechanism of fluid generation in magmas and its release across the magmatic-hydrothermal interface is closely related to the evolution of the magma reservoir, which is affected by conductive and convective cooling. The quantification of these coupled interactions is challenging due to the complexity of the magmatic and hydrothermal processes involved, which depend on nonlinear material properties.

For this study, we have further developed a coupled numerical model that can simultaneously resolve magma and hydrothermal flow by introducing a simplified description of fluid transport within the magma reservoir and subsequent volatile release to the host rock. Our simulations use realistic magma properties derived from published experimental and modelling works and cover different magma compositions and water contents. We show that magma convection at melt-dominated states leads to magma homogenization, delays fluid release and promotes a rapid evolution toward a magma mush state. We show that the onset of magmatic volatile release from a tube flow mush requires high initial water contents to overcome the percolation threshold. In high-crystallinity states, outgassing is taking place by capillary fracturing. After fluid release, the model calculates the evolution of these saline, metal-rich magmatic volatiles within the hydrothermal system overlying the magma reservoir. In the hydrothermal part, the model can capture fluid phase separation, dynamic permeability evolution due to hydraulic fracturing, and interactions with convecting meteoric fluids. The simulations demonstrate that fluid release rates have a direct influence on the efficiency of metal enrichment processes to form magmatic-hydrothermal ore deposits. This presentation will show preliminary simulation results from this newly developed coupled model and will highlight the controls of magmatic processes on the formation of porphyry copper deposits.