European Mineralogical Conference
Vol. 1, EMC2012-718, 2012
European Mineralogical Conference 2012

Numerical Modelling of Ore-Forming Magmatic-Hydrothermal Systems

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Magmatic-hydrothermal systems can form major ore deposit in both oceanic and continental settings. Convection of seawater at mid-ocean ridge hydrothermal systems is driven by basaltic magma lenses and can be referred to as modern analogues of massive sulphide deposits. Magmatism at subduction-related continental settings is more felsic and many ore deposits - like porphyry copper and epithermal gold - are related to ascending metal-bearing magmatic fluids released from crystallizing hydrous magma chambers in the crust. Numerical modelling shows that the implementation of real non-linear fluid properties and transient feedbacks with rock mechanics are key to explain some first-order controls on the hydrology of magmatic systems. The salinities of seawater and magmatic fluids extend the pressure-temperature field of two- or three-phase coexistence of vapour, liquid and solid halite to significantly higher pressures and temperatures as compared to pure water, and many magmatic-hydrothermal systems like porphyry-type ore deposits have dense quartz-vein networks formed by hydrofracturing of the rock. We therefore developed a magmatic-hydrothermal simulator that can combine an accurate model of saltwater and a transient fluid-pressure- and temperature-dependent permeability model with a numerical transport scheme that can handle the expulsion of magmatic fluids. Generic simulations of hydrothermal convection at mid-ocean ridges show the role of fluid properties in self-organizing upflow zones resembling black smoker fields and in causing salinity variations of vent fluids. Generic simulations of continental volcanic settings show the role of fluid and rock properties in stabilizing fluid flow at conditions favourable for metal enrichment to economic grades in the porphyry and epithermal environments.