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The interplay of non-static permeability and fluid flow as a self-organizing pre-requisite for supercritical geothermal resources

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Heat transport in the Upper Crust is governed by thermal conduction mainly through the solid rock mass and by heat advection with fluids flowing through the pore space. The average system-scale permeability of the rock has a major influence on which of these processes dominates, eventually governing the temperature-profile of natural geothermal systems as an expression of the convecting fluid's specific enthalpy [1,2]. Fluids in high-enthalpy systems typically have specific enthalpies near 1.2-1.5 MJ/kg. Supercritical systems, such as the one tapped at the IDDP-1 well at Krafla, Iceland, may reach enthalpies in the order of 3 MJ/kg [3]. Given that geothermal up-flow is normally considered to represent isenthalpic convection this difference is too large for supercritical resources simply being the feeder zones of high-enthalpy systems. Rather, a hydrologic divide is required that at least partially separates the two regimes from each other. Here, we present new insights into these processes from our recent numerical simulations of magmatic-hydrothermal systems where such a hydrologic divide proved to be crucial to provide a mechanism for metal enrichment to economic grades explaining the formation of porphyry-copper ore shells [4]. The model considers dynamic permeability feedbacks mimicking hydraulic fracturing and the transition from brittle to ductile rock behavior in a geologically reasonable way. Ascending volatiles, expelled from a cooling upper crustal magma chamber, establish a hot fluid plume under near-lithostatic pressures that is surrounded and cooled by convection of colder meteoric fluids. The physical principles, flow rates and permeability and depth ranges of these simulations are identical or comparable to conventional natural and enhanced geothermal systems [5], but temperatures are considerably higher – such as in supercritical geothermal systems. The intimate interplay of dynamic permeability responses to temperature and pressure conditions invoked by fluid flow [4-7] may therefore also be a crucial pre-requisite to describe these unconventional geothermal systems.

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