

## Underground Fumaroles: “Excess Heat” Effects in Vein Formation

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### Abstract

We examine the heat extracted from a fractured hydrothermal system following the sudden dilation of fractures in the host rock. This dilation increases the permeability of the system, and veins form along irregular fractures where the opening is localized. For simplicity, we will consider one such vein in this paper. Fluid in the system is assumed to be initially close to vapor saturation and in thermal equilibrium with the surrounding host rock. The rapid opening of the vein leads to approximately isenthalpic vapor separation and causes a pressure drop to propagate through the system. As the two-phase fluid in the fracture system is constrained to the vapor-pressure curve, the depressurization is accompanied by a rapid cooling of the fluid. Fluid flow is also induced from a hydrothermal reservoir toward the dilated discharge vein. The temperature difference between the host rock and the two-phase fluid in the fracture system drives heat from the rock into the fluid. The “excess heat”<sup>1</sup> derived from the host rock in this manner evaporates additional liquid in the two-phase flow, which develops substantially larger vapor fractions than those due only to the rapid initial adiabatic depressurization of the fluid. Such additional vapor separation, therefore, leads to high solute concentrations in the liquid phase and potentially results in faster deposition of minerals in the fracture system and local veins. A model is developed here to describe the minimum “excess heat” transfer (i.e., the worst-case scenario) into the two-phase saturated-liquid/vapor mixture as it is drawn horizontally from the hydrothermal reservoir toward the discharge vein. “Excess heat” effects are shown to be effective within tens to hundreds of meters of actively forming veins and a principal cause of oscillatory banding and lamination fabrics.

This transient heat extraction process applies to a wide range of shallow crustal deposit styles associated with brittle and brittle-ductile deformation. These deposit styles range from epithermal bonanza veins, sea-floor massive sulfide deposits, mesothermal veins in shear zones, to the higher temperature veins and stockworks of hypothermal and porphyry mineralization.