A Multi-phase Heat Transfer Model of Cooling Lava

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Abstract

Field observations suggest that two-phase "heat-pipe" processes are active around magmatic intrusions. We are numerically testing the viability of this process around a volcanic sill, embedded in wet sediment. The model focuses on the heat transported by water in the vapor and liquid states as it moves through the pores of the silt. The heat-pipe is simulated by parameterizing the experimental results of Udell (1983,1985) into a thermal conductivity enhancement as the sediment is heated above the boiling point. The sill is composed of vesicular basalt. The "effective" thermal conductivity of the basalt is computed by combining the ordinary conductivity of the avesicular portion together with radiative fluxes across the vesicles. Crystallization within the basaltic sill (an inescapable consequence of a low cooling rate and high temperature) is modeled as well, since the associated phase change has thermophysical consequences.

The model has been set up within the COMSOL Multiphysics® software as a 1-D time-varying heat-transfer problem, using the "heat transfer in solids" module, along with a "domain ODE" for the crystallization. We have not used any models from the Application Libraries. Because the initial COMSOL® simulations did not converge onto physically plausible results, we also solved the problem using a home-grown finite-volume model written in C++. Those results appear more reasonable and we continue to investigate how we can achieve similar results with COMSOL®.