A Multi-phase Heat Transfer Model Of Cooling Lava

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INTRODUCTION: We have constructed two COMSOL models: a simple heat pipe model in wet (boiling) sediment and a more complex model of a cooling basaltic sill in wet (cool) sediment. 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.

Figure 1. Basaltic sill (Priest Rapids Basalt, 14.5 m.a.) intruded into soft, wet sediments beneath Miocene Clarkia Lake, Idaho

COMPUTATIONAL METHODS in COMSOL: 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 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.

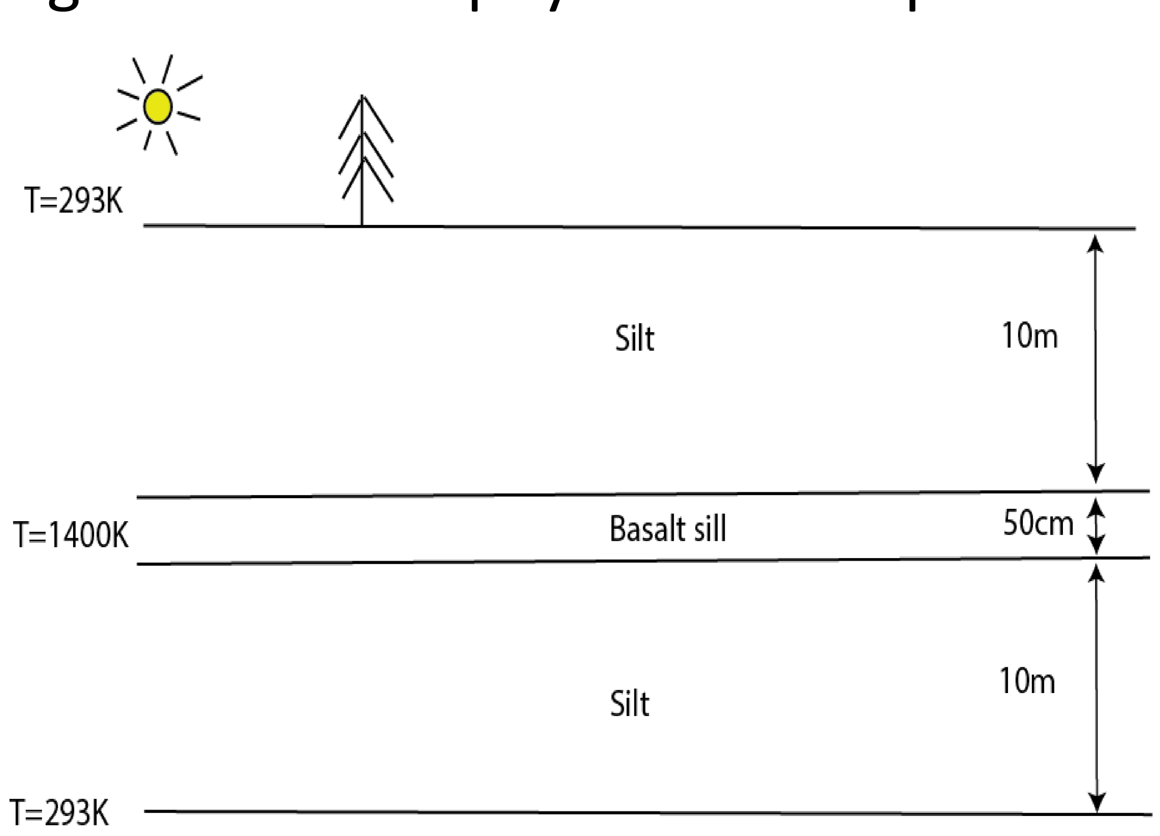

Figure 2. Sketch of modeled sill

The model has been set up within COMSOL as a 1-D time-varying heat-transfer problem, using the "heat transfer in solids" module, along with a "domain ODE" for the crystallization.

RESULTS:
COMSOL: Either no heat pipe develops at all, or we see violent shocks within heat pipe area. We surmise these effects are most likely due to varying CP, K and rho as a function of temperature

C#: Smooth transitions develop between the heat pipe area and other areas.

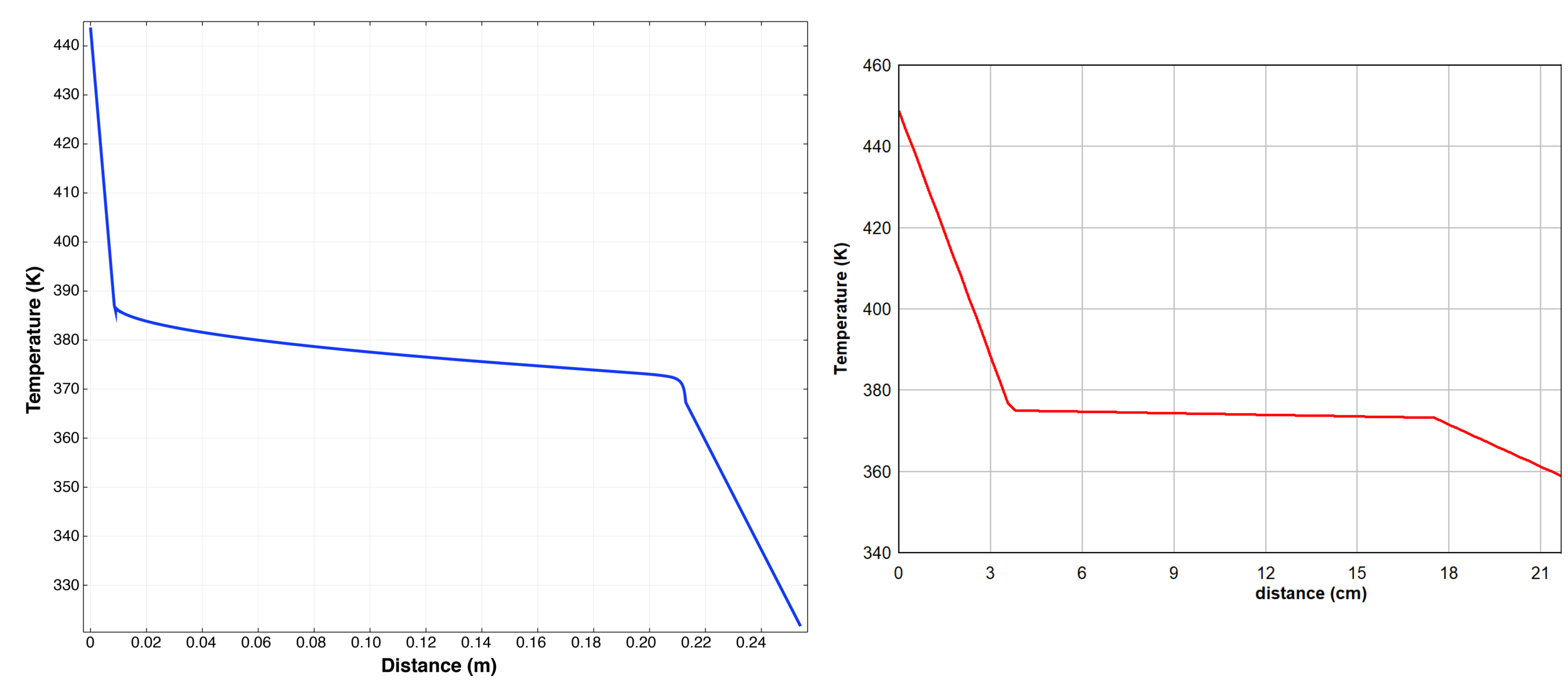

Figure 3. Simple heat pipe model. Panel a) COMSOL and b) C# model. Note the much shorter (and experimentally supported) heat pipe length in b). Both runs were for identical conditions.

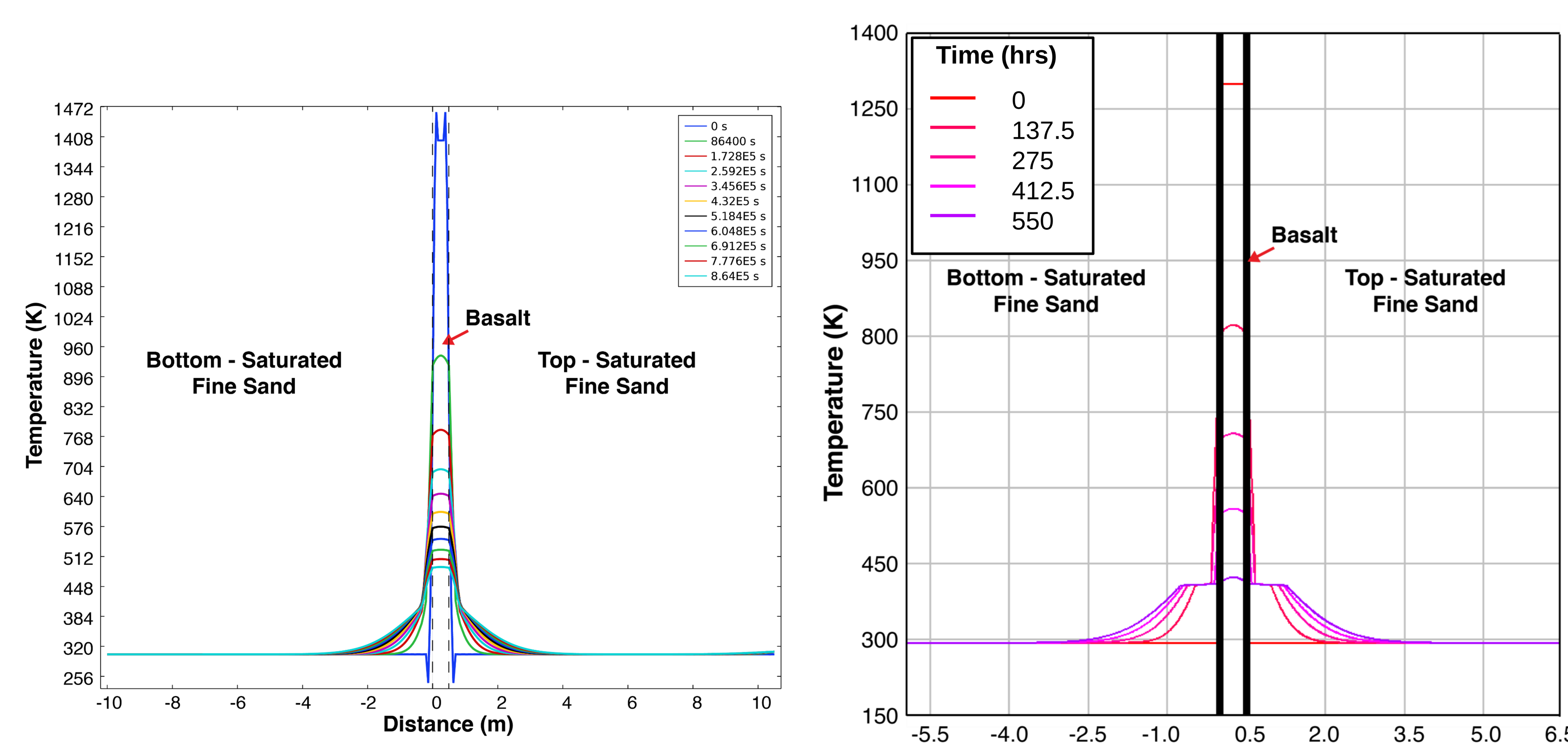

Figure 4. Lava cooling model. Panel a) COMSOL and b) C# model. In a) no heat pipe developed. The results in b) show the development of a heat pipe and are supported by Udell's results. Both runs were for identical conditions.

CONCLUSIONS: Because the initial COMSOL runs 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.

REFERENCES:

1. Udell, K.S., Heat Transfer in Porous Media Heated From Above With Evaporation, Condensation, and Capillary Effects, J. Heat Transfer 105(3), 485-492 (1983).
2. Udell, K.S., Heat transfer in porous media considering phase change and capillarity - The heat pipe effect, International Journal of Heat and Mass Transfer, Vol. 28, 485-495, (1985).