English Summary

Intrusion of magma into the Earth's crust is associated with significant thermal perturbations, release of aqeuous fluids and formation of hydrothermal system. In order to better understand the feedback relationships between fluid flow, thermal evolution and permeability variations, we have modeled conductive and advective cooling of a shallow-crustal pluton using the SHEMAT software. Our model represents a two-dimensional cross section through the lithosphere with homogeneous material properties, whebery the heat and mass conservation equations are solved by finite difference method. We first calculate the stable lithospheric geotherm by emplying constant basal thermal flow of 40 mW m^{-2} and a constant surface temperature. Subsequently, we consider a rectangular magmatic intrusion emplaced at 5-10 km depth, which forms a contact aureole by conductive cooling. With time, a mushroom-like shape of the contact aureole is predicted. Inclusion of aqueous fluid flow into the model causes only a small alteration of thermal evolution mainly because the permeability is low and the fluid mass is negligible due to very low density under hydrothermal conditions. In addition to thermal effects, we have explored variations in hydraulic head in order to address the ensuing effects on the flow velocity. The hydraulic head is a function of pressure and buoancy effects caused by the density of the fluid. Increasing the hydraulic potential from 1000 to 5000 m does not lead to appreciable changes in Darcy velocity, a consequence of its dependence on the gradient of the hydraulic head rather than on its absolute value. Changing the surface boundary condition from the free flow to no flow, that is, an impermeable surface boundary has very important consequences for the magnitude of hydraulic head and its temporal variations. Consequently, the vector field of the Darcy velocity evolves differently – the intrusion has only a minor impact on it. Using the constant fluid density, the mass of percolating fluid changes, which has observable effects on the hydraulic head and the Darcy velocity. The impact of the intrusion is again very small, hydraulic head shows significantly smaller range of values than in the other models and Darcy velocity is consequently about an order smaller than in the other models. Finally, we have explored the effects of changing porosity within and outside the intrusion due to fracture formation or thermal and rheological collapse in the aureole. However, the variations are small due to a comparably small magnitude of the integrated fluid flux. Our set of numerical simulations is applicable to cooling and fluid flow in the vicinity of shallow-crustal plutons. We demonstrate that (i) thermal perturbations have dramatic effect on the fluid density. Depending on the rock permeability and fluid flow boundary conditions, hydraulic head around the cooling intrusion varies appreciably in space and time, and (ii) the efficiency of heat advection is linked to the total mass of percolating fluid. Low-density fluids are much less efficient in altering the thermal evolution than the high-density ones.