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Hydrothermal alteration of kimberlite by convective flows of external water

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Kimberlite volcanism involves the emplacement of olivine-rich volcaniclastic deposits into volcanic vents or pipes. Kimberlite deposits are typically pervasively serpentinised as a result of the reaction of olivine and water within a temperature range of 130–400 °C or less. We present a model for the influx of ground water into hot kimberlite deposits coupled with progressive cooling and serpentisation.

In order to simulate cooling of a kimberlite body by external water influx, we have used a modified version of the filtration code MUFITS (www.mufits.imec.msu.ru). The code is developed for simulation of multiphase multicomponent flows in porous media in a wide range of pressures and temperatures, including sub-critical and supercritical conditions. It solves mass conservation laws for individual components (water and a proxy component, not participating in serpentinisation) together with energy equation for the system as a whole including the solid rock matrix, and Darcy transport equations for different phases. Two modifications of the code were implemented: Serpentinisation of the olivine leads to a decrease in the density of the rock matrix and filling pore spaces resulting in significant decrease in porosity and permeability; latent heat of serpentinisation is accounted for in the energy equation.

The simulation results indicate that large-pressure gradients cause influx and heating of water within the pipe with horizontal convergent flow in the host rock and along pipe margins, and upward flow within the pipe centre. Complete serpentisation is predicted for wide ranges of permeability of the host rocks and kimberlite deposits. For typical pipe dimensions, cooling times are centuries to a few millennia. Excess volume of serpentine results in filling of pore spaces, eventually inhibiting fluid flow. Fresh olivine is preserved in lithofacies with initial low porosity, and at the base of the pipe where deeper-level host rocks have low permeability, and the pipe is narrower leading to faster cooling.

We also present recent investigations on spatial instability of serpentinisation process, which results in formation of extended bodies with increased serpentinite content. The relations between the spatial and time scales of the instability are determined.

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