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Numerical modelling and simulation of fluid infiltration, heat transport and healing of microcracks during magma-driven hydraulic fracturing

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Excellent outcrops in Dronning Maud Land, Antarctica, provide unique insight into the mode and extent of fluid infiltration into metamorphic and plutonic rocks in the middle crust. CO_2- H_2O-dominated fluids are liberated from pegmatitic veins and give rise to alteration halos. In the alteration halos, the conspicuous change in colour is correlated with hydration mineral reactions and high density of microcracks in quartz and feldspar exceeding that observed in the unaltered host rock by an order of magnitude. The field relations indicate that the veins originated as melt driven hydraulic fractures, sealed by pegmatite and aplite crystallising from volatile-rich melts, with the alteration halo being the wake of the process zone formed at the tip of the propagating fractures. The fluid infiltration and healing time scales are investigated using a numerical model which takes into account the combined effects of fluid flow, heat transfer and temperature dependent healing rates. We assume that the damage zone is a porous medium with low permeability. The porosity is assumed to be independent of pore pressure, but reduces with time according to a strongly temperature dependent healing process. Initially, the damage zone is assumed homogenous with porosity of 5% and permeability of 10^{16} m^2 and all the fluid is located in the magmatic vein-fill. We use a one-dimensional dynamic model, where the fluid as well as heat is transported through the host rock perpendicular to the interface between the magma and host rock. We find that the fluid infiltration into the damage zone is rapid and that the fluid flow contributes significantly to the heat transport through the host rock. With pressure difference of 300 MPa, the fluid is able to infiltrate a region of 0.25 m depth

in one minute and one meter within 15 minutes. Assuming an initial temperature on the magma of 700 ˚C and a host rock temperature of 300 ˚C, the heat will be transported 0.07 m in one minute and 0.2 m within 15 minutes. The healing time scale is generally longer than that of the fluid infiltration, and the microcracks heal after fluid infiltration is completed. However the healing processes are strongly temperature dependent and the healing time increases significantly with the distance to the central vein. By considering microcracks with initial aperture of 1 μm, we find that these cracks may be completely healed within one hour close to the central vein and by up to a year at large distances. For larger apertures, e.g. of 3 μm, the healing time scales up to typically one day close to the central vein and tens of years at large distances.