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Amphibolitization of mafic crust: mechanisms and timescales

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Fluid–rock interactions play a key role in the formation, evolution and recycling of the Earth's crust. For fluids to infiltrate rocks and enable and sustain fluid-mediated mineral transformations, fluid pathways are required. Timescales of fluid-mediated rock transformations cover a wide range from several million years to several month in various geological settings. In this study, we examined the underlying mechanisms and timescales of amphibolitization of mafic crust. For this purpose we performed a detailed mineralogical, petrophysical and thermodynamic analysis of a dry, essentially "non-porous" gabbro that was hydrated and transformed into an amphibolite under amphibolite-facies conditions. The amphibolitization process was triggered by fluid infiltration through a newly opened N–S striking fracture network and allowed the fluid to pervasively infiltrate the rock. Thermodynamic modelling and petrological data show that the transition from gabbro to amphibolite was accompanied by densification and related porosity formation. The modes and compositions of minerals within partly-amphibolitized rocks indicate that besides the uptake of H_2O, no significant mass exchanges were necessary for this transformation, at least on the thin-section scale. Once the gabbro was almost entirely amphibolitized, its mineral content and mineral chemistry no longer changed, so the progress of amphibolitization progress was controlled by fluid availability. To estimate the duration of the amphibolitization we set up a reactive transport model based on local equilibrium thermodynamics, mass balance and Darcy flow, which addresses the mineralogical and petrophysical changes of the rock along the sampled profile at constant ambient amphibolite-facies P–T conditions. Starting from a non-porous rock, the model calculated reaction-induced porosity, permeability, and fluid pressure evolution based on the local bulk composition and the evolving mineral paragenesis. We reproduced the extend of the reaction front by adjusting fitting parameters such as, initial fluid pressure, permeability or fluid viscosity. We repeated these calculations for different reaction front widths we measured in the outcrop to obtain a time estimate of the hydration process that resulted in the amphibolitization of the gabbroic crust.