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Fluid flow and reaction fronts: characterization of physical processes at the microscale using SEM analyses

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Fluid migrations are the principal agent for mineral replacement in the upper crust, leading to dramatic changes in the porosity and permeability of rocks over several kilometers. Consequently, a better understanding of the physical parameters leading to mineral replacement is required to better understand and model fluid flow and rock reservoir properties. Large-scale dolostone bodies are one of the best and most debated examples of such fluid-related mineral replacement. These formations received a lot of attention lately, and although genetic mechanics and implications for fluid volume are understood, the mechanisms controlling the formation and propagation of the dolomitization reaction front remain unclear.

This contribution aims at an improvement of the knowledge about how this replacement front propagates over space and time. We study the front sharpness on hand specimen and thin section scale and what the influence of advection versus diffusion of material is on the front development. In addition, we demonstrate how preexisting heterogeneities in the host rock affect the propagation of the reaction front. The rock is normally not homogeneous but contains grain boundaries, fractures and stylolites, and such structures are important on the scale of the front width. Using Scanning Electron Microscopy and Raman Spectroscopy we characterized the reaction front chemistry and morphology in different context.

Specimens of dolomitization fronts, collected from carbonate sequences of the southern Maestrat Basin, Spain and the Southwestern Scottish Highlands suggest that the front thickness is about several mm being relatively sharp. Fluid infiltrated grain boundaries and fractures forming mm-scale transition zone. We study the structure of the reaction zone in detail and discuss implications for fluid diffusion-advection models and mineral replacement. In addition we formulate a numerical model taking into account fluid flow, diffusion and advection of the mobile reactive species, reaction rates, disorder in the location of the potential replacement seeds, and permeability heterogeneities. The goal of this model is to compare the shape of the resulting patterns, notably in terms of thickness, and eventually roughness or fractal dimension.