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4D porosity evolution during solid-solid replacement reaction in mineral system (KBr, KCl)

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An extensive understanding of the controlling mechanisms of phase transformation is key in geosciences to better predicting the evolution of the physical parameters of rocks (porosity, permeability, and rheology) from centimetre-scale (e.g. fingering in siltstones) to kilometer-scale (e.g. Dolostone geobodies), in both the diagenetic and metamorphic domains. This contribution reports the 4D monitoring of a KBr crystal at different time steps during an experimental, fluid-mediated replacement reaction with KCl. Volumes are reconstructed based on density contrast using non-destructive X-ray Computed Tomography (XCT) at a resolution of 3 microns. A sample of KBr was immersed in a static bath of saturated KCl at room temperature and pressure. 5 scans were performed during the reaction at 5, 10, 20, 35 and 55 minutes, until 50% of the original crystal was replaced. As a control experiment, two samples reacted continuously for 15 and 55 minutes, respectively. Each 3D dataset was reconstructed to visualize and quantify the different mineral phases, the porosity distribution and connectivity, along with the reaction front morphology.

In the case of successive baths, results show that the front morphology evolves from rough with small fingers to flat and thick during the reaction, suggesting a switch between advection and diffusion controlled reactant distribution through time. This switch is also reflected in the mass evolution and the rate of propagation of the replaced zone, being rapid in the first 20 minutes before reaching steady state. The porosity develops perpendicular to the crystal wall, suggesting a self-organization process governed by advection, before connecting laterally. While the reaction changes from advection controlled to diffusion controlled, the direction of the connected pores becomes parallel to the crystal walls. This phenomenon is not observed when the crystal is reacting discontinuously for 55 minutes. In the latter case, self-organization similar to extended fingering is observed, suggesting the advection to diffusion switch is related to the successive stop of reaction progress for scanning. In both cases, when considering only the reacting zone of the crystal, we can estimate the porosity created by Br-Cl substitution at 30%. The evolution of connected porosity distribution helps to understand how fluid flow can migrate in a transforming rock, for example during dolomitisation, a phenomenon extensively observed in sedimentary basins.