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Quantifying chemical and petrophysical alterations in porous materials by CO$_{2}$ using HRXCT

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Geological sequestration of CO_2 is a transitional solution to reduce the concentration of greenhouse gases in the atmosphere pending sufficient renewable energy alternatives. CO_2 can also be used as raw product for industrial processes whereby CO_2 is sequesterd and new materials are formed. Carbonation can be used to stabilize mineral waste or even be transformed into innovative materials. Understanding the mineral-CO_2 interactions is essential in the advances of the carbonation process and the upscaling of geological storage. Accurately translating chemical data from reactor experiments and petrophysical data of reservoir rocks to a model for reactive transport is often a challenging step. This is mainly due to the complexity of the used reservoir rocks in the experiments, resulting in a model that cannot be univocally calibrated or even validated.

This research starts from a clear, verifiable design, in order to unravel the processes that occur when a CO_2-enriched fluid reacts with different mineral phases in porous media. To comprehend the chemical properties and the kinetics of the reactions, individual minerals are exposed to a CO_2-enriched fluid in batch reactors. To analyze the physico-chemical changes (the "diagenesis" of the rock), artificial porous rocks are created from these individual minerals with controllable petrophysical parameters (for example: porosity, permeability, reactive surface, composition) using 3D fiber deposition or other techniques. By using 3D fiber deposition, a homogenous rectangular structure is made, which is ideal for up scaling and modeling of reactive processes. These homogenous artificial rocks are then exposed to a CO_2-enriched fluid in batch and flow through reactors and analyzed using traditional methods and High Resolution X-ray Computed Tomography (HRXCT). HRXCT is a nondestructive technique that allows a complete characterization of the artificial rocks in 3D up to sub-micron resolution (400 nm). The 3D images from the HRXCT are then used as a verification basis for reactive transport models through porous media. Furthermore, because of the nondestructive nature of the technique, the changes (dissolution/precipitation) in the artificial samples due to the exposure to a CO_2-enriched fluid, are analyzed on the same sample and the mineral-CO_2 interactions can be quantified through time. By combining these experimental results on the same samples through time with the models for reactive transport through porous media, the models can be validated and eventually calibrated. This will later on help to understand more complex experiments on real reservoir materials and will allow the optimization of the carbonation processes for the stabilization of mineral waste and the production of innovative building materials.