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A numerical approach to quantify volume and surface changes at the pore scale during CO2 sequestration from synchrotron microtomographies

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Synchrotron microtomography is a non-destructive 3D-characterisation technique providing a three-dimensional mapping of μ, the linear X-ray absorption coefficient. Absorption of X-rays is a function of several physical parameters, mainly the local density and the atomic number of the intersected material. When the considered sample is composed of several materials having dissimilar μ values, it is possible, by segmentation, to transform the μ mapping into a 3D image of the distribution of the different constitutive materials. Furthermore, microtomography being non-destructive, it is possible to modify the sample between two acquisitions and to follow the subsequent evolution in 3D within the sample and with an unrivalled precision. In the first part we present the main steps of the numerical process going from the data acquired on the tomography beamline (from 4 to 13 Gbytes per scan) to a series of 3D images representing a sample at the different stages of its evolution: 1) The raw data filtering permitting a significant reduction of various artefacts generated by wrong pixels on the CCD camera, by X photons emitted by the environment (hot spots) and by non-linear response of some pixels (ring artefacts), 2) the 3D reconstruction from the projections, 3) the 3D filtering to improve the signal over noise ratio, 4) the storage reduction transforming the 3D data coded in real (32 bits) to 3D data coded in bytes, 5) the 3D registration of the different 3D images to put them in the same system of coordinates, and 6) the segmentation of the 3D images to assign a material to each voxel. 3D registration is a requirement since the sample is moved from the acquisition setup for reactive percolation. Consequently, the 3D images are only roughly aligned. To be able to make differences between images at different times, a very precise 3D registration procedure is required. We propose an approach using the interface between the sample and the coating of sealing resin as an invariant throughout the experiment.

The dissolution of a porous limestone core during CO2-enriched water injection has been followed by microtomography with a spatial resolution of 4.91 m. Pressure drop between the sample input and output has been measured during the experiment and the fluid at the output regularly sampled for chemical characterisation. Two processes were successively involved in the rapid permeability increase of the sample. First, the microcrystalline phase was partially dissolved, associated to displacement of mineral particles. Second, the sparitic phase dissolved, accompanied by a decrease of the pore wall roughness and an increase of the pore connectivity. Changes in volume and fluid/solid interface have been characterised by image analysis. An estimate of the effective reactive surface is obtained. This example illustrates the possibilities offered by computed microtomography to make a step in the understanding of multi-scale coupled reactive transport processes in porous media. This work is a part of the projects PICOR and PICOREF. Percolation experiments have been performed by ISTEEM (Montpellier) and ESRF is acknowledged for synchrotron beam time at ID19.