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Application of 2D and 3D Digital Image Correlation on CO_2-like altered carbonate

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In order to provide mechanical constitutive laws for reservoir monitoring during CO_2 long term storage, we studied the mechanical properties of Lavoux limestone before and after a homogeneous alteration following the protocol of acid treatments defined by Egermann et al, (2006). The mechanical data have been analysed at the light of systematic microstructural investigations.

Firstly, the alteration impact on the evolution of flow properties related to microstructural changes was studied at successive levels of alteration by classical petrophysical measurements of porosity and permeability (including NMR, mercury porosimetry and laser diffraction) and by observations of microstructures on thin sections and by SEM. Secondly, the mechanical properties of the samples were investigated by classical (macroscopic) triaxial and uniaxial tests and are discussed in terms of the structural modifications. The macroscopic tests indicate that the alteration weakens the material, according to the observed decrease of elastic moduli and Uniaxial Compressive Strengths, from 29MPa to 19MPa after 6 cycles of acid treatments.

The study is further complemented by 2D full (mechanical) field measurements, thanks to Digital Image Correlation (DIC) performed on images acquired during the uniaxial tests. This technique allows for continuous quantitative micro-mechanical monitoring in terms of deformation history and localisation processes during compression. This technique was applied on both intact and altered materials and at different scales of observation: (i) cm-sized samples were compressed in a classical load frame and optically imaged, (ii) mm-sized samples were loaded with a miniaturized compression rig implemented within a Scanning Electron Microscope. At last, 3D full field measurements were performed by 3D-DIC on mm-sized samples, which were compressed “in-situ” an X-ray microtomograph thanks to a miniaturized triaxial cell allowing for confining pressures of up to 15 MPa.

At the macroscale and for the intact samples, a diffuse accommodation of the deformation is observed during the pseudo elastic regime, followed by sudden failure propagation after the peak stress. Conversely, the altered samples exhibit much more localized and pronounced deformation levels.
At the SEM scale for the intact samples, but closure of the porosity, failure precursors and localized deformation were not observed. In opposition, the altered samples showed early opening of microcracks at the grain junctions. Finally, at the μ-tomograph resolution (5μm/voxel) and in triaxial conditions, we observed for intact samples at macro and micro scales similar behaviour as for optical and SEM characterization. At 5 MPa of confining pressure the altered samples avoid brittle failure and a few shear bands are visible. As previously inferred from 2D-DIC, we observed strong and early localization of deformation, but the limited resolution of the μ-tomograph did not allow to clearly evidence microcracks.

The DIC results suggest that besides the overall increase of porosity, the dissolution processes enhance the local heterogeneities of the porous network, which phenomenon further increases the weakening of the materials.