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Imaging strain localization in porous limestone by X-ray Computed Tomography and Digital Image Correlation

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The brittle-ductile transition in porous sandstones has now been studied extensively. Microstructural studies combining various techniques on samples deformed in the laboratory documented the development of a wide variety on strain localization patterns and failure modes in overall agreement with the field observations in various sandstone formations. In contrast, there is a paucity of mechanical and microstructural laboratory data on the brittle-ductile transition in porous carbonates, particularly for the high porosity end-members. The question of strain localization is in particular hard to tackle as conventional microstructural analyses cannot as in sandstone be guided by acoustic emission statistics. In this context, X-ray Computed Tomography (CT) imaging provides a promising technique to accurately describe the various failure modes associated with the brittle-ductile transition in porous limestone.

In this study, we focused on a grainstone from the Majella Mountain, central Italy. Detailed field observations performed in this formation by Tondi et al. (2006) have revealed some complex interplay between deformation/compaction bands and stylolites. Our samples of Majella grainstone had a nominal porosity of 31% and were primarily composed of calcite. A series of hydrostatic and conventional triaxial experiments were performed in dry conditions at room temperature, constant strain rate and at confining pressures ranging from 5 to 50 MPa. Several sets of CT images at a resolution of 25 microns were acquired before and after deformation. Digital Image Correlation (DIC) was performed on images of the intact and deformed samples. The full 3D strain tensor field was derived. Results for the two strain invariants corresponding to the volumetric and shear components were obtained for grid steps of 500 and 250 microns.

Our new results showed that deformation was compactant in Majella grainstone over the wide range of pressures investigated. Strain localization was observed in samples deformed triaxially at pressures ranging from 5 to 25 MPa. Compactive shear bands developed at these pressures and the band orientations with respect to the major principal stress decreased with increasing confining pressure.