Geophysical Research Abstracts
Vol. 19, EGU2017-13086, 2017
EGU General Assembly 2017

Grain-scale deformation in granular materials: time-lapse XCT-imaging of a deforming reservoir sandstone

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Relating macroscopic deformation of granular media to grain-scale processes, such as grain fracturing, has been a focus of many studies. Understanding these processes is key for predicting surface subsidence and induced seismicity caused by hydrocarbon depletion, the hydraulic fracturing response of geothermal reservoirs, and post-seismic crustal deformation. With the development of state-of-the-art techniques, such as time-lapse X-ray tomography imaging during triaxial deformation, new avenues to investigate the operating mechanisms have opened up.

As a first step to understanding grain-scale deformation processes, we performed a deformation experiment on highly porous sandstone, obtained from a depleting gas reservoir, using a novel small-scale triaxial deformation apparatus coupled to high-resolution 4D X-ray tomography, available at the European Synchrotron Radiation Facility (ESRF, Grenoble) and Université Grenoble Alpes. This state-of-the-art apparatus allows for 3D time-lapse imaging of samples, while deforming at pressure, temperature and fluid flow conditions relevant for geological reservoirs.

We performed our experiment at relevant in-situ reservoir conditions (T = 100˚C, 10 MPa pore pressure, 40 MPa effective confining pressure). Axial stress was increased step-wise until failure occurred, while continuously imaging deformation. This enables us to monitor progressive grain failure, and strain localisation, during deformation in real-time. Though the vast amount of data obtained from even a single test poses challenges for data analysis, this presentation will address the first results obtained from this experiment.