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Microcracks induced during dilatancy and compaction in a porous oolithic carbonate rock

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Reservoir rocks can undergo irreversible deformation (dilatancy or compaction) as a result of a change in effective stress during production of hydrocarbon or during CO_2 storage; and whether deformation occurs in conjunction with dilatation or compaction, it has important implications on fluid transport processes. In this study, we investigated the mechanical behavior of the Chauvigny limestone. This porous limestone is one of the rocks, which constitutes the Dogger, a deep saline aquifer, one of the favorable geological reservoirs for CO_2 storage in France. This limestone is an oolithic one and is characterized by a dual porosity: a micro-porosity (inside the ooliths) of $\sim$13% and a macro-porosity of $\sim$4%. The total porosity is $\sim$17%.

Previous studies performed on limestone, even the ones with very low porosity like Carrara marble, show at room temperature, a transition with increasing pressure from brittle regime to catalastic flow. Two mechanisms are involved during failure of limestone: cracking, and crystal plasticity, which can be activated at room temperature.

To investigate the brittle-ductile transition in this porous limestone, we performed 8 conventional triaxial experiments, at confining pressure in the range of 5-100 MPa, at room temperature and at a constant strain rate of $2.10^{-4}s^{-1}$. In addition, the evolutions of elastic wave velocities were measured periodically with loading. The elastic wave velocities are affected by two competing mechanisms: porosity reduction -which increases the velocities-, and cracking -which decreases the velocities-. However the elastic wave velocities are much more sensitive to cracking than to porosity reduction.

Our results show that diltatant (nucleation and propagation of cracks) and compaction micro-mechanisms (plastic pore collapse) compete. Two limit cases can be distinguished. During hydrostatic compression, the inelastic volumetric strain seems to be mainly associated with plastic pore collapse, whereas for the triaxial experiments at confining pressure < 30 MPa, the inelastic volumetric strain seems to be mainly associated with the development of shear-induced cracks. For the triaxial experiments at confining pressure > 30 MPa, we are able to distinguish a first critical stress state where plastic pore collapse occurs, and a second stress state where shear-induced cracks are initiated.

Reference:

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