Geophysical Research Abstracts
Vol. 20, EGU2018-3386, 2018
EGU General Assembly 2018

Permeability of porous limestone: effect of stress and effective stress law

Patrick Baud (1), Fanbao Meng (2,3), Hongkui Ge (3), and Teng-fong Wong (2)

(1) EOST Strasbourg, France (patrick.baud@unistra.fr), (2) Earth System Science Programme, Faculty of Science, The Chinese University of Hong Kong, Hong Kong, (3) The Unconventional Natural Gas Institute, China University of Petroleum-Beijing, China

A fundamental understanding of tectonic deformation and fluid flow in carbonate formation is of importance in many crustal processes. Laboratory studies have shown that although the phenomenology of low-temperature brittle-ductile transition in porous carbonate and clastic rocks are qualitatively similar, fundamentally different micromechanical processes are operative in the two different rock types. Most porous rock data are for sandstones, which typically show, under high confinement, a significant reduction of permeability with the onset of shear-enhanced compaction. Similar investigations of permeability evolution in porous carbonate rocks are limited. In this study, we investigated the evolution of permeability and its effective stress behaviour in relation to inelastic deformation and failure mode in Indiana and Purbeck limestones with porosities of 18% and 13%, respectively. Hydrostatic and triaxial compression tests were conducted on both rocks at room temperature on water-saturated samples at pore pressure of 5 MPa and confining pressures up to 90 MPa. Permeability was measured using the steady-state flow technique at different stages of deformation.

For Indiana limestone, under hydrostatic loading pore collapse initiated at an effective pressure of 55 MPa, beyond which an accelerated reduction of permeability was observed. At confinements of 35 MPa and above, a permeability reduction (by up to a factor 3) was observed beyond the onset of shear-enhanced compaction. In the brittle regime, at a confinement of 15 MPa and below, permeability continued to decrease beyond the onset of dilatancy, with a negative correlation between porosity and permeability changes. Purbeck limestone showed similar evolution of permeability through the brittle-ductile transition. Permeability variations in both limestones are significantly smaller than variations previously reported in porous sandstones of comparable porosities.

Microstructural, mercury porosimetry and NMR data showed that pore size distribution in both Indiana and Purbeck limestones is bimodal, with significant proportions of macropores and micropores. The effective stress behaviour of a limestone with dual porosity is different from the prediction for a microscopically homogeneous assemblage, in that its effective stress coefficients for permeability and porosity change may attain values significantly larger than 1. Indeed this was confirmed by our new data in samples that had not been inelastically deformed. We also investigated the behaviour in samples deformed beyond the yield point in hydrostatic and triaxial conditions. Our new data consistently showed effective stress coefficients for both permeability and porosity change with values less than 1. Thus the effective stress behaviour in an inelastically compacted sample is fundamentally different, with attributes akin to that of a microscopically homogeneous assemblage. This is likely related to compaction from pervasive collapse of macropores, which would effectively homogenize the initially bimodal pore size distribution.