Core-scale characterization of hydraulic and poroelastic properties using oscillating pore pressure method

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Abstract

Accurate characterization of hydraulic and poroelastic rock properties is crucial for successful management of groundwater, petroleum resources and subsurface contaminant remediation. The oscillating pore pressure method is a popular laboratory technique for permeability and specic storage measurements of rock samples. We present an improvement of the oscillating pore pressure method by simultaneously measuring hydraulic and poroelastic properties of rocks. Measurements were carried out for four conventional reservoir rock quality samples at oscillation frequencies of 0.025–1 Hz and effective pressures of 3.5–62 MPa. Interpreted permeability values decreased with increasing effective pressure and increased sharply above a frequency range of 0.3–0.4 Hz. We established that hydraulically measured storage capacities are overestimated by an order of magnitude when compared to elastically derived ones. Biot coecient was estimated both from pore pressure and strain measurements, and comparison of two data sets reveals high uncertainty of the hydraulic specic storage measurements. We documented grain crushing and pore collapse in a dolostone sample, observed as a permanent and drastic decrease of permeability and bulk modulus. We validated our method by detecting irreversible microstructural changes independently by hydraulic, elastic, X-ray microtomography (CT) and nuclear magnetic resonance (NMR) measurements. We further developed a novel data processing approach that utilizes a broad, multifrequency range of data which are inverted for permeability. We re- process published data and demonstrate that our methodology outperforms traditional data reduction techniques, as our inversion results show a better t to pressure trends. To better understand the effect of frequency on phase and amplitude data and to verify our inversion approach we numerically simulate oscillating pore pressure experiments. We document a strong deviation of experimentally obtained phase data starting at 0.3 Hz oscillation frequency. Our method can be used for robust determination of permeability and rapid prediction of experimental results using numerical simulation, ultimately improving experimental permeability measurements.