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Effect of pore pressure on the permeability evolution in low porous Indian sandstone

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Permeability evolution of low permeable rocks is of critical importance during the flow of gases in processes like, enhanced reservoir recovery and CO_2 sequestration. Permeability measurement depends on the geometric structure of flow path (hydraulic radius, connectivity, tortuosity), the stress regimes surrounding the rock (isotropic, deviatoric) and the characteristic of the fluid (viscosity, compressibility, pore pressure). For the case of gas permeability within Knudsen diffusion regime ($0.001 < Kn < 0.1$), the effect of slippage is prominently observed.

Laboratory scale permeability experiments on an Indian sandstone having connected porosity ~10%, are performed under hydrostatic condition. Nitrogen gas is selected as pore fluid, to avoid adsorption phenomenon. Transient technique of pore-pressure-pulse decay is used for permeability measurement as it is faster and accurate to measure pressure, than the steady state method. Pore pressures and confining pressures are varied in the study to understand the relative effect of matrix compressibility and fluid compressibility on the permeability. Micro-CT analysis of sample is also performed to quantify the geometric attributes of sample.

Apparent gas permeability ranging from 0.1 to 1 micro-Darcy is obtained from the experiments. The permeability is found to be decreasing with simple effective stress (σ_{ii}-p) for constant pore pressures. But a counter intuitive decrease in permeability with increasing pore-pressure at constant confining pressure is also evident and can be attributed to stress dependent Biot's coefficient (λ). Slippage corrected permeability is further analysed theoretically and numerically to formulate nonlinear permeability evolution equation in the functional form, $f(\sigma_{ii}-\lambda p)$ to support experimental outcomes.