Clay, water, and salt: controls on the permeability of fine-grained sedimentary rocks

IAN C. BOURG[1,2], FRANCISCO F. CARRILLO[3], XINYI SHEN[1], THOMAS R. UNDERWOOD[1]

[1] Department of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey 08544, USA, bourg@princeton.edu

[2] Princeton Environmental Institute, Princeton University, Princeton, New Jersey 08544, USA

[3] Department of Chemical and Biological Engineering, Princeton University, Princeton, New Jersey 08544, USA

Carbon capture and storage (CCS) relies on the ability of buoyant fluids, such as supercritical CO_2, in the subsurface for decades to millennia. A predominant role in this trapping is played by the primary seals or caprocks, laterally extensive low-permeability formations that overlie the storage formations. At most existing or planned CCS sites, the primary seals are fine-grained sedimentary rocks. Predictions of CO_2 storage security require not only site-specific measurements of seal permeability prior to CO_2 injection, but also predictive models of the sensitivity of this permeability to geomechanical and geochemical alteration and to the presence of preferential flow paths such as fractures or faults.

Here, we review existing data on the core-scale permeability of shale and mudstone formations and on the regional-scale permeability of faults. We show that permeability is a function of porosity, mineralogy, and pore fluid chemistry. We provide evidence of a threshold at a clay mineral mass fraction of ~1/3 separates fine-grained rocks with very different properties. We show that the constitutive relations that govern the regional-scale permeability of faults are surprisingly similar to those that control the core-scale permeability of intact fine-grained sedimentary rocks. Finally, we discuss how meso- and nano-scale studies can provide insight into the impact of pore water chemistry on seal permeability.