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

IAN C. BOURG[1]

[1]Department of Civil and Environmental Engineering (CEE) and Princeton Environmental Institute (PEI), Princeton University, Princeton NJ 08544, USA; bourg@princeton.edu

Carbon capture and storage (CCS) relies on the ability of geologic formations to trap 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 [1].

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 that a threshold at a clay mineral mass fraction $X_{clay} \sim 1/3$ separates fine-grained rocks with very different properties [2]. 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 [1]. Finally, we discuss how meso- and nano-scale studies can provide insight into the impact of pore water chemistry on seal permeability [3].

[1] Bourg I.C., Beckingham L.E., DePaolo D.J. The nanoscale basis of CO_2 trapping for geologic storage. *Environmental Science and Technology* 49:10265 (2015). [2] Bourg I.C. Sealing shales versus brittle shales: A sharp threshold in the material properties and energy technology uses of fine-grained sedimentary rocks. *Environmental Science and Technology Letters* 2:255 (2015). [3] Bourg I.C. Clay, water, and salt: controls on the permeability of fine-grained sedimentary rocks. *Accounts of Chemical Research*, in preparation.