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Compaction driven flow and caprock sealing integrity

Viktoriya Yarushina (1), Roman Makhnenko (2), Yuri Podladchikov (3), and Ludovic Raess (3)

(1) Deptartment of Environmental Analysis, Institute for Energy Technology, Kjeller, Norway, (2) Department of Civil & Environmental Engineering, University of Illinois at Urbana-Champaign, 205 North Mathews Ave, Urbana, IL, USA, (3) Institute of Earth Sciences, University of Lausanne, Geopolis UNIL-Mouline, Lausanne, Switzerland

Geological carbon capture and storage (CCS) is an emerging technology that is designed to mitigate the impact of human activities on the global warming. In order to get public acceptance of this technology, one needs to guarantee its safety for the environment and population. Potential leakage of CO_2 from underground storage sites is one of the risks associated with CCS. Clay-rich rocks are considered as a good caprock candidate due to their ability to effectively relax stresses and extremely tight pore network. Reservoirs are often heterogeneous and contain low-permeable clay lenses that might reduce storage capacity and injectivity. We study the impact of viscoelastic deformation and strongly nonlinear stress-dependent permeability of these materials on their role as flow barriers from experimental and modelling perspective. We report poroviscoelastic and flow parameters of representative caprock and intra-reservoir flow barrier material. Our calculations based on experimental measurements show that compaction/dilation driven flow in viscoelastic rocks gives rise to solitary porosity waves forming flow channels often imaged as seismic chimneys. Such channels can propagate with a speed on the order of through intra-reservoir clay lenses leaving behind high permeability flow pathways that can be further utilized by injected CO_2. The diameter of a channel depends on the bulk viscosity and permeability of the rock as well as fluid viscosity and might vary from mm scale up to tens of meters. This might have a positive effect on injectivity and storage capacity due to elimination of minor reservoir compartmentalization and thus, pressure build up. At the same time, porosity waves may question the reservoir integrity by creating pathways for fluid leakage in the originally very low-permeable caprock.