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Modeling of Gas Chimney Formation During Geological Storage

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Fluid-rich chimney-like structures characterized by a high porosity and permeability are widely observed in sedimentary basins. Thus, understanding the mechanisms leading to focused fluid flow is crucial in predicting natural and human-induced fluid leakage, especially in geological sequestration scenarios. Mechanical and reactive porosity waves provide a mechanism predicting spontaneous localization of fluid flow within sedimentary, without relying on predefined flow pathways and fracture structures.
In this study, we have developed a coupled hydro-mechanical model that allow to predict the spontaneous localization and wave-like propagation of porosity anomalies leading to spontaneous formation and evolution of high-permeability channels through lithological boundaries with sharp properties contrasts. The governing equations describe the filtration of pore fluid in deforming viscous-elasto-plastic matrix. The proposed model considers the generation of (de)compaction-driven leakage pathways. We also consider the extension of the model to estimate the effect of reactive fluid flow on leakage pathways formation. Our numerical implementation relies on Matlab prototype and GPU-based code using the CUDA-C programming language to resolve flow localization and channels formation on high resolution solving the coupled hydro-mechanical model at reservoir scales.
Our results provide numerical predictions of fluid-rich chimney formation during geological sequestration for different rheological types of rocks and lithology layers. Results are shown as an application to the Tornerose and the Snøhvit field in the South-West Barents Sea, and seismic imaging is used as a proxy for chimney comparison.

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Primary author: Dr KHAKIMOVA, Lyudmila (University of Lausanne; Skoltech Institute of Science and Technology)

Co-authors: Dr ALKHIMENKOV, Yury (Massachusetts Institute of Technology); Prof. PODLADCHIKOV, Yury (University of Lausanne)

Presenter: Dr KHAKIMOVA, Lyudmila (University of Lausanne; Skoltech Institute of Science and Technology)

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