Deciphering dynamics of salt crystal formation in porous reservoir rocks – A reactive transport study

Name of supervisors: Dr. Mohammad Nooraiepour, Professor Helge Hellevang
Candidates' background: Geosciences, Physics, Mathematics, Computational fluid mechanics
Number of available projects: 2
Preferred project period: 01.05.2021 – 31.07.2021

Project Outline:

Introduction:

Injection of large volumes of dry or undersaturated (with respect to water) supercritical CO_2 into the geological formation causes evaporation of formation water. As evaporation proceeds, the concentration of the dissolved salts in brine pore fluid increases. Under the thermodynamic conditions of a given storage reservoir, when the salt concentration reaches the solubility limit, it will precipitate out of the aqueous phase, and salt crystals will form in the porous medium. Salt precipitation during subsurface injection of CO_2 into the saline aquifers can alter both reservoir and top seal rocks' properties. While precipitation of salt crystals in the near-wellbore regions and the reservoir units is unfavorable, it may have a positive impact on reducing the permeability of leaking pathways in the fractured caprocks. The permeability of reservoir rock in the near-wellbore regions can be severely reduced because of brine evaporation into the CO_2 stream and the consequent salt precipitation. The near-wellbore salt formation triggers excess pressure build-up and induces a decline in injection efficiency.

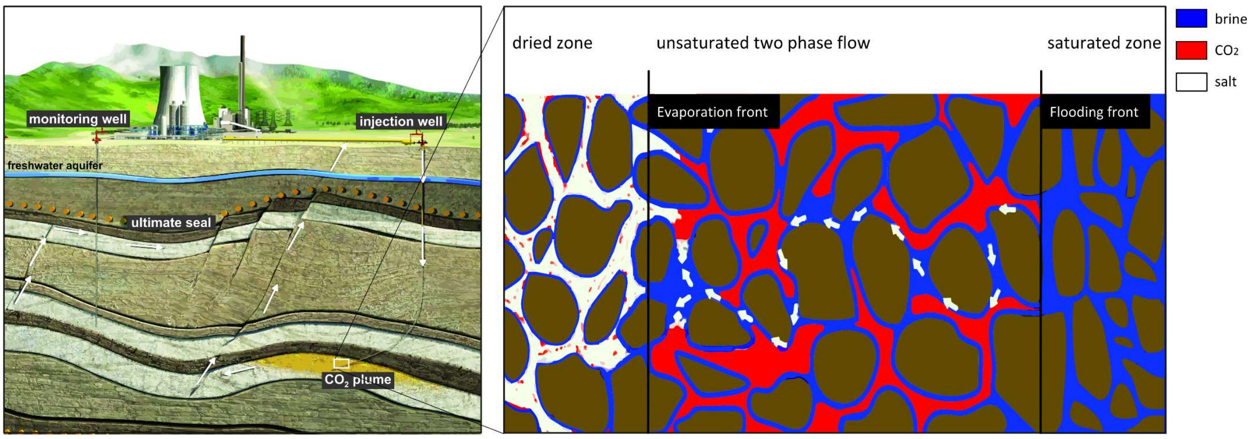

Figure 1. Potential zones and fluid-solid phases in the near-well environment during CO_2 injection in saline aquifers.

Research Objectives:

Identify precipitation pattern, location, and timing of salt crystal accumulations in the porous medium over broad salinity and temperature-pressure conditions relevant to CCS Operations.

Research Scope:

For the experimental part of the project, lab-on-chip investigations on glass-microchips (synthetic porous medium) and geomaterial microfluidics (real reservoir and caprocks) will be conducted to provide insights into the physics and dynamics of salt precipitation at the pore-scale and also to find the possible explanations for the large-scale salt precipitation observed in the field.

For the numerical simulation part of the project, based on the competencies and interests of the candidate, investigations in two different length-scales can be performed: (a) pore- and meso-scale using either Lattice Boltzmann Method (LBM) or Pore Network Modeling (PNM) or (b) large-scale reservoir simulations of subsurface CO_2 injections using open-source MATLAB Reservoir Simulation Toolbox (MRST). Candidates will use our in-house numerical modeling codes for reactive transport processes.

For each part, candidates will have training and responsibilities to develop the necessary tools for carrying out the research (laboratory setup or numerical code), conducting the research to answer open-questions, following the overall objectives, and compiling a report to present the results and discuss findings.

As Figure 2 shows, the interplay between petrophysical, geochemical, and geomechanical parameters influence the injectivity considering the composition of a given rock and fluid system (in-situ and injected). We limit the study's scope to geochemistry (fluid-rock interactions) and petrophysics (fluid flow in porous medium and transport properties) in these two projects.

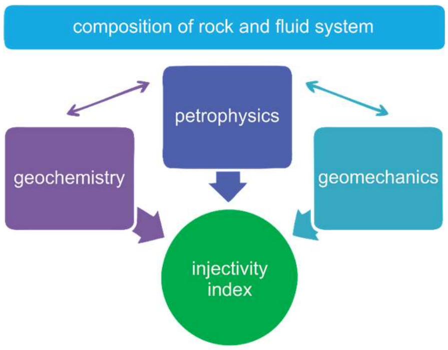

Figure 2. Parameters affecting near-well injectivity during subsurface CO_2 storage, modified from [5]. k: absolute permeability, kr: relative permeability, and μ: viscosity of the injected fluid.

With active participation and supervisors' directions, the candidates will have a unique opportunity to be involved in state-of-the-art research, receive training in experimental and modeling techniques, familiarize themselves with reactive transport studies, and be part of a lively curiosity-driven research group.

In collaboration with supervisors, the candidates will disseminate the project outcome in conference proceedings, if possible, peer-reviewed articles. A research communication platform will also be the Geoscience Basement Talks after the project duration (Fall 2021).

Since 2020, we face many new challenges because of the restrictions imposed by the Covid-19 pandemic. As it may introduce some risks in finding suitable candidates for these two summer projects, we are happy to announce that we are open to review candidates from The Faculty of Mathematics and Natural Sciences (UiO) with suitable background, from the Department of Physics, Mathematics Chemistry, or beyond along with the applicant from the Geosciences. If the Covid-19 pandemic continues and campus restrictions for students go on, as it is today (January 2021), we will modify the project tasks accordingly to allow quality and successful implementation via home office work and active digital supervision.

The project will be an opportunity to start learning and working with state-of-the-art techniques for studying the reactive transport processes relevant not only for CO_2 storage but also for hydrogen storage, geothermal energy, waste disposal, and environmental studies.