Université de Neuchâtel
Centre d'hydrogéologie et géothermie

MSc in Hydrogeology and Geothermics

Thesis topic proposal 2026

Long-term permeability decline in fractured media due to colloidal deposition and clogging

Context and objectives

Fluid flow in fractured rock is central to geothermal systems, where fractures often provide the main hydraulic pathways while the surrounding rock matrix contributes to storage and mass exchange. Although stimulations initially enhance permeability, long-term operation can lead to a progressive decline in transmissivity. One major cause of this decline is clogging within fractures.

Clogging may result from fine particles and debris produced by rock alteration, thermo-mechanical damage, or remobilization of pre-existing material, as well as from secondary mineral precipitation triggered by changes in temperature, pressure, or fluid composition, which progressively reduces fracture aperture and connectivity.

The objective of the project is to investigate the **long-term effect of clogging on permeability decline in fractured media**, with emphasis on geothermal applications. The work will first review the main sources of clogging, including fines formation, debris transport, and mineral precipitation, and their potential role in fracture sealing. It will then explore how these mechanisms can be represented numerically within a **Discrete Fracture Network (DFN)** framework. Publicly available digital rock and fractured-media datasets (Digital Porous Media) will be screened as potential sources of realistic geometries for the modeling work. Laboratory scale rock-on-a-chip can also be 3D printed for lab scale permeability tests.

The final aim is to identify the key controls governing long-term permeability loss in fractured media and to evaluate under which conditions clogging can significantly alter hydraulic performance.

Methodology

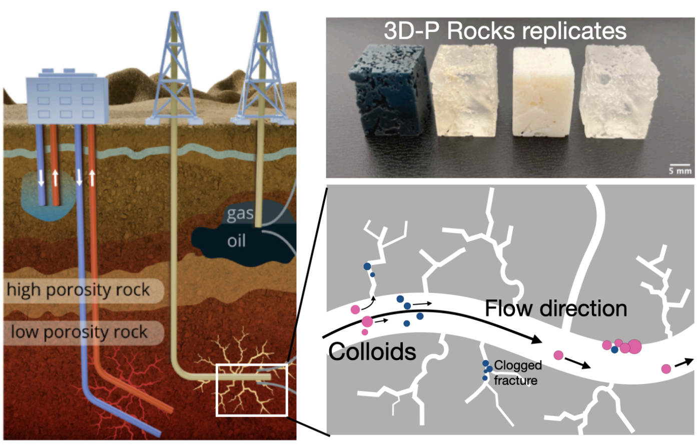
The project will start with a review of clogging processes in fractured media, with emphasis on fines, debris transport, and mineral precipitation in geothermal systems. Public digital rock and fractured-media datasets will then be screened to identify realistic geometries for modeling. The numerical framework will be based on a **DFN** coupled with a **dual porosity** representation of the rock matrix.

Simplified laws will be used to describe progressive transmissivity reduction caused by particle deposition and/or precipitation. Sensitivity analyses will assess the role of fracture geometry, aperture distribution, matrix exchange, and clogging kinetics on long-term permeability decline.

As an optional, laboratory-scale flow experiments may be considered using a 3D-printed fractured rock analogue, continuous injection of colloids, and permeability decline monitored with pressure sensors.

Supervision and collaboration

The project will be supervised by Dr. F. Miele (CHYN, UniNe) and in collaboration with Prof. V. Morales (University of California, Davis). **Contact :** filippo.miele@epfl.ch.



Conceptual framework of fracture clogging induced by accumulation of colloidal particles. (Adapted from Farber et al. 2025). Example of 3D-Printed rock-on-a-chip (Patino and Miele et al., 2025)