Université de Neuchâtel
Centre d'hydrogéologie et géothermie

MSc in Hydrogeology and Geothermics

Thesis topic proposal 2026

Simultaneous observation of flow and thermal lag in rocks-on-a-chip media

Context and objectives

Understanding the coupled propagation of fluid and heat in porous media is important for geothermal systems, where fluid circulation controls heat extraction and thermal breakthrough. While the injected fluid may advance along preferential flow paths, the associated heat signal is expected to spread differently because of thermal diffusion and heat exchange with the solid matrix. Directly observing this mismatch at laboratory scale could provide useful insight into the role of pore structure on coupled flow and heat transport.

The objective of this project is to develop, as a proof-of-concept, a **millifluidic or microfluidic experiment** with a disordered porous-medium analogue. The setup will allow the joint observation of an injected plume with an **optical** camera and a **thermal** camera. Optical images will be used to track the displacement and spreading of the invading fluid, while thermal imaging will be used to characterize the propagation of the heat signal through the medium. By comparing the timing and spatial evolution of the hydraulic and thermal fronts, the project will assess whether their delay and spreading can be related to effective thermal behavior at the pore-network scale. As an optional extension, the study may also investigate how rock analogues covered with **biofilm grown in the chip** modifies flow paths, thermal lag, and the joint propagation of fluid and heat.

Methodology

The project will build on an existing wet-lab and optical imaging facility in the EFM Lab at UNIL already used for controlled millifluidic experiments and plume visualization in disordered porous analogues. The main experimental development will consist in adapting this established setup by integrating a millifluidic device with one thermally transparent side, allowing simultaneous observation of the injected plume with an optical camera and of the associated heat signal with a thermal camera. Initial experiments will focus on controlled injection tests under simple boundary conditions relevant to geothermal transport.

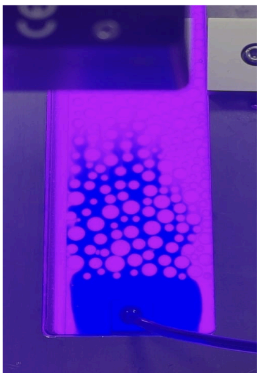
While thermal fronts have previously been visualized in simple quartz cuvettes under well-controlled conditions, such joint observation has not yet been developed in a porous medium analogue. The resulting image sequences will be analyzed to compare hydraulic and thermal front propagation, spreading, and delay, and to assess whether the observed thermal lag can be related to effective transport behavior in the medium.

As an optional extension, a **mature biofilm** may be grown in the chip to investigate its effect on preferential flow, heat propagation, and thermal lag.

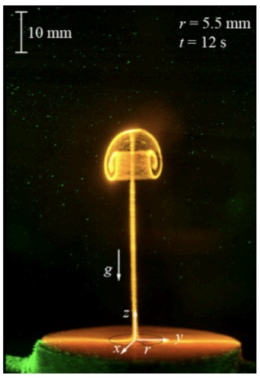
Supervision and collaboration

The project will be supervised by Dr. F. Miele (CHYN, UniNe) and in collaboration with Prof. P. De Anna (UNIL).

a.



b.



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a. Blue-dye tracer's plume invading in a 2D soil analogue lab-scale porous material visualized by optical camera.

b. Visualization of a thermal spreading plume of rhodamine in an empty quartz cuvette (from Kondrashov et al., 2016)