

Experimental report

03/10/2026

Proposal: 1-07-22

Council: 4/2023

Title: Coupled Neutron and X-ray Imaging of Reactive-Mixing in Porous Rocks

Research area: Physics

This proposal is a new proposal

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Samples: Bentheim sandstone rock sample

Instrument	Requested days	Allocated days	From	To
NEXT	4	2	16/11/2023	18/11/2023

Abstract:

Fluid mixing in porous media is a fundamental process that controls the subsurface chemical reactions and plays a critical role in many natural processes. The porosity evolution through time as a result of precipitation creates a challenge to quantify the mixing behavior. In this work, we will perform a series of experiments by injecting miscible fluids into samples of sandstone rock that induce a chemical reaction leading to the precipitation of minerals. Neutron imaging allows tracking of the flow inside the rock and X-ray imaging illuminates the regions where mineral precipitation occurs. The outcome of this experiment is to quantify the sensitivity of flow velocity distribution and mixing efficiency to the evolving porosity.

Final Report: Experiment 1-07-22

The project “Coupled Neutron and X-ray Imaging of Reactive-Mixing in Porous Rocks”, 1-07-22 (2 days of beamtime), was successful. The study aimed to investigate how reactive transport processes modify fluid flow and mixing in porous rocks through mineral precipitation, using combined neutron and X-ray imaging techniques. The experiments were conducted as planned and generated a unique dataset that enabled direct observation of the coupling between fluid transport, mineral precipitation, and evolving pore structures.

As part of the project, we conducted two mineral carbonation experiments in basalt, during which calcium and carbonate-rich fluids mixed and reacted inside a basaltic rock matrix and induced carbonate mineral precipitation. The experiments were monitored using time-resolved neutron and X-ray imaging, allowing us to quantify the spatial and temporal evolution of fluid mixing that led to carbon mineralization.

The scientific outcomes of the project have been disseminated through a peer-reviewed publication by a PhD student (Shafabakhsh et al., *Water Resources Research*, 2025) who successfully defended his PhD thesis in 2025. The publication presents the experimental methodology, imaging results, and quantitative analysis of mineral carbonation and reactive transport in porous basalt. The study demonstrates the capability of combined neutron and X-ray imaging to investigate subsurface carbon storage processes at the pore scale and contributes to a better understanding of geological carbon sequestration mechanisms.

References

Shafabakhsh, P., Cordonnier, B., Le Borgne, T., Mathiesen, J., Linga, G., Pluymakers, A., Kaestner, A., Tengattini, A., Renard, F. (2025). Coupling neutron and X-ray imaging of fluid mixing and precipitation in rocks: Challenges and opportunities, *Water Resources Research*, 61, e2025WR041911.

Shafabakhsh, P. 2025. Imaging and Numerical Modeling of Fluid Mixing in Rocks with Evolving Porosity. PhD thesis defended March 5, 2025, at the University of Oslo, Norway.