Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.31193

Dissolved krypton as a tracer during a hydraulically stimulated seismic experiment in Bedretto, Switzerland.

ALEXANDRA K LIGHTFOOT[1], ALBA ZAPPONE[1], MATTHIAS S BRENNWALD[2], ROLF KIPFER[2] AND STEFAN WIEMER[1]

[1]ETH Zürich
[2]Eawag

In hydraulic stimulation experiments, such as those used in seismic and geothermal studies, integrating tracers is essential for revealing fluid transport and evolution within the rock matrix. Although fluorescent dyes and halide salts have traditionally been employed as tracers, dyes can be challenging to manage due to staining and residue issues, while salts often exhibit high background levels that complicate detection and may impact the microbial ecosystem. In contrast, noble gases offer an attractive alternative because their inertness ensures reservoir chemistry and microbial communities are conserved, while emerging advances in analytical techniques now enable their detection with high sensitivity even at low concentrations.

In this study, controlled hydraulic stimulation experiments were conducted at the Bedretto Underground Laboratory for Geosciences and Geoenergy (BULGG) with the aim of triggering a microseismic event with a target magnitude close to zero (M0). The underground laboratory is uniquely located in a previously abandoned 5 km - long tunnel in the Swiss Alps, with an average overburden of 1 km. Boreholes for both hydraulic injection and monitoring are primarily oriented horizontally along the walls of the tunnel. The injection borehole, ST1, underwent an initial high-pressure water injection phase (up to 20 MPa) over several days, triggering the M0 event, while krypton was introduced as a dissolved tracer at the forefront of the injected water parcel.

ST2 - a monitoring borehole with continuous groundwater outflow and located 44 m away from ST1 - was ideal for measuring dissolved gases and tracer breakthrough. A portable mass spectrometer measured dissolved gas concentrations of krypton alongside helium, argon, nitrogen, carbon dioxide, and oxygen at the ST2 outflow. The delayed arrival of krypton relative to the variations in other dissolved gas species suggests that the changes observed at ST2 are mainly due to mobilised stored fluids trapped within the rock volume, triggered by the high-pressure injection. Further, only a small fraction of the fluid injected at ST1 in-fact reaches ST2.

These findings highlight the critical role of tracers in elucidating fluid dynamics in seismic and geothermal studies while demonstrating the effectiveness of applying noble gases as tracers in similar environments.