



## GeoLaB – Geothermal Laboratory in the crystalline Basement: synergies with research for a nuclear waste repository

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Received: 30 March 2023 – Revised: 19 June 2023 – Accepted: 22 June 2023 – Published: 6 September 2023

**Abstract.** Challenges for geosciences with societal relevance include the use of crystalline geothermal reservoirs for the energy transition as well as final disposal. Crystalline rocks, along with clay and salt, are being considered as host rocks in the ongoing search for a suitable site for a nuclear waste repository in Germany. Currently, there is no existing experience in terms of excavating a repository within crystalline rocks in Germany. In the case of geothermal energy, the greatest potential – as yet untapped – lies in the crystalline basement. New targeted, science-based strategies are the key to harness this energy under safe, sustainable, predictable, and efficient conditions. The research infrastructure GeoLaB (“Geothermal Laboratory in the crystalline Basement”) is the first underground laboratory to be built in Germany for many years and offers unique opportunities for the geoscientific community. In the following, GeoLaB will be described, and the synergies it offers for geothermal research and also for nuclear waste disposal will be elaborated.

GeoLaB aims to scientifically address and overcome the key challenges of deep geothermal exploitation of fractured crystalline reservoirs. To reach these goals of (1) sustainable reservoir technology, (2) wellbore safety, and (3) productivity enhancement in deep crystalline reservoirs, GeoLaB is designed as an underground laboratory consisting of a main gallery starting at the surface, providing access to several subsurface openings. These are typically small caverns in which or from which the planned scientific experiments will be conducted and observed.

The first phase of the project began in January 2023 and will primarily consist of an exploration campaign to identify and characterize a suitable site. The Black Forest and Odenwald are considered suitable locations for the planned underground laboratory related to specific scientific and technical criteria. Here, the rocks of the crystalline basement, which are an important geothermal reservoir in the Upper Rhine Graben, have been lifted up and are thus accessible for science. In the Upper Rhine Graben and Black Forest–Odenwald complex, a good database and a high level of expertise has been built-up over decades by science, the petroleum industry, and geothermal activities.

The technical measures in the development phase until 2029 include intensive monitoring as well as underground mining development and the construction of a control and visitor center above ground. A digital twin of the GeoLaB, named “Virtual GeoLaB”, will accompany the development of the research infrastructure already during the construction phase and support the scientific investigations, including planning, analysis, and documentation, in the operation phase. It is used for visual analysis and data storage and will play an important role in communication with stakeholders, decision-makers, and the public. In its dialog and participation concept, GeoLaB focuses on transparency and offers citizens opportunities for active participation. It takes action

in communication and knowledge transfer as well as education. GeoLaB will be developed as a blueprint for environmentally sound technology developments in the underground, and it will incorporate multiple research perspectives.

With BGE (Bundesgesellschaft für Endlagerung) joining GeoLaB, the exploration and building phases, in particular, have become a mutual effort. From the perspective of safe nuclear waste disposal, several topics of the GeoLaB project are of interest even though the target rock characteristics differ to some extent. The collaboration starts with the planning phase for the underground laboratory. The geophysical exploration together with the required drilling, logging, testing, and monitoring of exploration wells is comparable – to a large extent – regardless of the purpose of the mine. Several topics with relevance to Germany's current nuclear waste disposal site selection process are part of the scientific work within GeoLaB, for instance the characterization and quantification of the subsurface stress regime. Furthermore, regulatory topics and outreach intersect greatly. Finally, the excavation of the mine is of utmost interest from the perspective of nuclear waste disposal. Recent experience of mining in Germany is rare, especially with respect to crystalline rocks.