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Progress Of The GeoLaB URL Exploration In The Odenwald (Germany): Towards The Final Site Construction Decision

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ABSTRACT

The GeoLaB (Geothermal Laboratory in the Crystalline Basement) project (a Helmholtz initiative) aims to realize an underground geothermal research laboratory in crystalline rocks (i.e., granite). Considerable efforts were and are implemented exploring the area of the Tromm, Odenwald Germany. The Otzberg fault, the occurrence of fractured and permeable granites makes the region very promising for the realization of the underground laboratory. The first exploration stage was completed by means of fieldwork campaigns (rock sampling), two pilot seismic surveys, potential geophysics, hydrogeological measuring-monitoring spots, installation of weather stations. Two wells were drilled: GeoLaB-1 (fully cored) and GeoLaB-2. Mineralogical investigations on outcrop samples confirmed the dominant granitic composition of the Tromm granite with traces of hydrothermal alteration. Important results from the seismic interpretation and a preliminary assessment of the core material indicate a change in the lithology at approximately 410 m depth. Two units named Granitoid 1 (above 410 m showing granitic mineral assemblage with macrocrysts and porphyritic structure) and Granitoid 2 (darker with finer texture featuring calcite-quartz filled veins-fractures) characterize the subsurface of the area. A broad investigation program with geomechanical experiments on the cores, will progressively deliver additional subsurface details of the granite rock bodies, fluid pathways and structural geology features. Once the Tromm site will be confirmed as a location to build the GeoLaB underground laboratory we will be closer to realize a unique research platform to investigate the use of crystalline rocks for geothermal purposes.

1 INTRODUCTION

The working group planning/exploration focuses the activities on the Tromm (Odenwald) exploration following different approaches. From the surface to the subsurface we aim to understand the granitic rock bodies, the fractures, shear zones, alteration and faults (Otzberg fault) in the area. The overall scope is to determine the sustainability of the Tromm location for the realization of the GeoLaB underground research laboratory. By means of several disciplines such as geology, geophysics, drilling, petrology and geochemistry valuable information are being gathered for a better knowledge of the Tromm region.

2 MINERALOGY AND PETROLOGY: INVESTIGATION OF THE OUTCROP ROCKS

The samples were collected based on the accessibility, exposure and alteration of the outcrops in the Tromm area. The samples from the Streitsdöll quarries and the samples from the Tromm village are considered as closer example of the Tromm granite. Rock samples from 4 different locations were investigated by means of XRD and EMP (Deon et al. 2022). One sample will be described, see Figure 1. Further investigations on the core samples from the GeoLaB-1 and cuttings of GeoLaB-2 wells are ongoing.

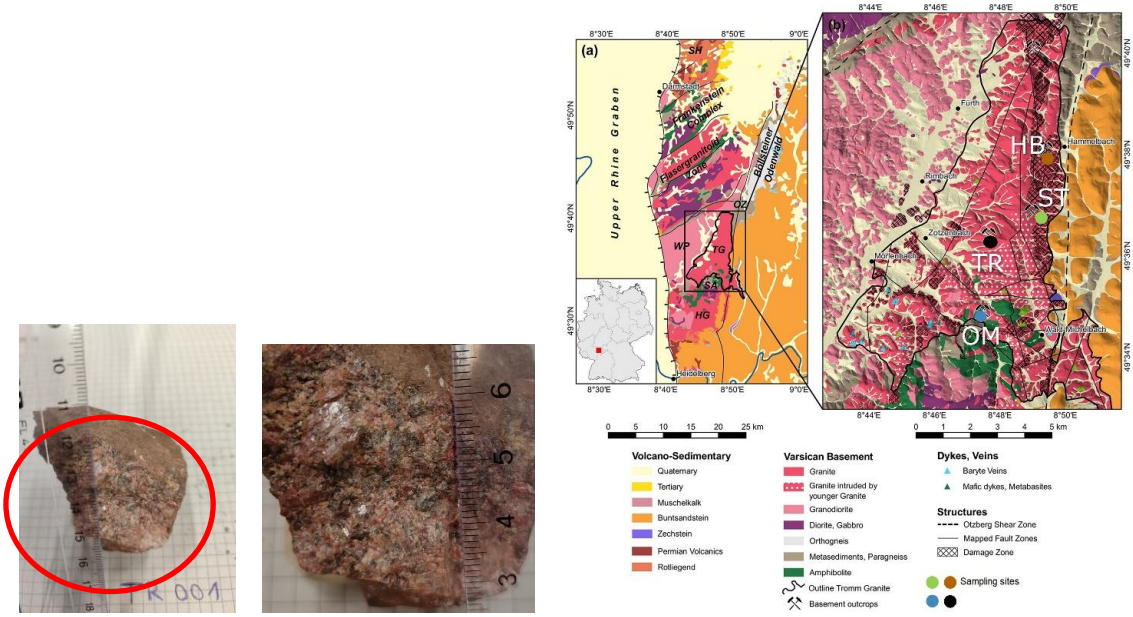


Figure 1. Rock sample collected in the Tromm village, sample Tromm 1. The fresh unaltered surface shows plagioclases, feldspars and micas. Beside the geological map (modified after Frey et. al. 2022) with the sampling sites.

2.1 X-ray powder diffraction XRD

The rock samples (see Figure 1) were crushed to powder and analyzed in order to determine the modal mineral composition following the procedure described in Deon et al. (2022). Scope of this investigation is to get the mineral abundances of the rock samples. The sampling locations are shown in the map modified after Frey et. al. (2022) in Figure 1.

The interpretation of the XRD patterns was performed semi-quantitatively and quantitatively with the Rietveld refinement method. Figure 2 shows an XRD pattern from a typical Tromm granite. Given the paragenesis and the detected mineral concentration the example shown below can be considered as unaltered fresh Tromm granite. The sample was selected because there is no indication of hydrothermal alteration given the mineral composition. Thus, this lithological unit is feasible for the construction of the underground research laboratory. XRD measurements and geochemical measurements are currently being conducted on core samples from the GeoLaB-1 well to have an encompassing overview of the mineralogical and geochemical composition of the 500 m retrieved cores.

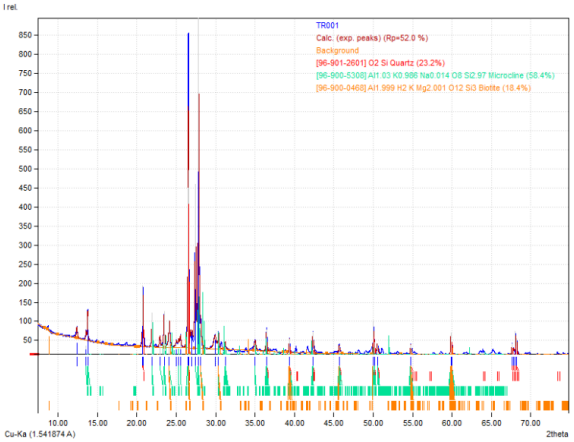


Figure 2. XRD pattern of the sample TR001. The semi-quantitative mineral quantification indicates quartz (main peak 26.4° 2Θ), plagioclase-feldspar (in the interpretation microcline given the best fitting structure 27.8° 2Θ) as dominating mineral species. Micas (main peak 8.9° und 12.3° 2Θ) were detected. The amount of mica might be overestimated given the preferred orientation.

2.2 Electron microprobe

Ultra-polished thin sections were prepared and analyzed at the EMP. Secondary Electron images (Figure 3) confirm the mineral composition detected with XRD (Figure 2). The occurrence of hydrothermal alteration as well as microfractures was observed (Deon et al. 2024). This microscale information should be further investigated in terms of orientation and texture. Moreover, these results are only limited to surface outcrop samples. An extensive analytical program will be implemented on the cores which were recently collected from the GeoLaB-1 well.

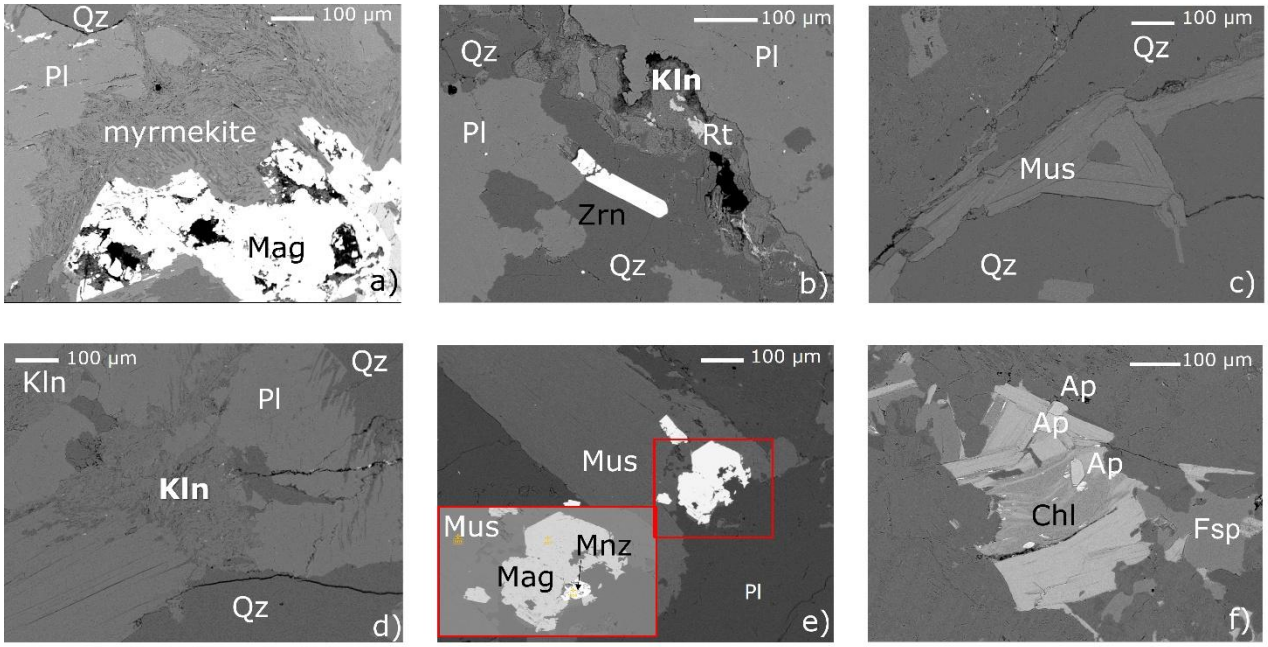


Figure 3. A selection of SE (Secondary Electron) images acquired with the electron microprobe. a) ST001: myrmekite structures, i.e., inclusion of quartz in plagioclase (Pl) indicating tectonic induced metasomatism. The structures follow the magnetite (Mag) rims. b) HB002: well-formed zircon (Zrn) embedded in quartz (Qz). Kaolinite (Kln) occurring in the fracture indicate the occurrence of hydrothermal alteration. Rutile (Rt) is an accessory phase. c) ST002: a triangular muscovite (Mus) embedded in quartz. d) ST002: small kaolinite (Kln) grains likely formed form the alteration of plagioclase (Pl). e) ST002: muscovite (Mus) grain including magnetite (Mag) and monazite (Mnz). The latter offers the possibility to perform in-situ geochemical dating and investigate REEs concentration. f) OM001: Chlorite (Chl) with large apatite (Ap) grains.

3. SEISMIC SURVEY

The Tromm Granite is a potential site of the GeoLaB Underground Rock Laboratory which is planned to provide an experimental platform for in-situ research in the context of the petrothermal use of geothermal energy. According to the current state of knowledge, the Tromm Granite is more or less unfaulted, with an increasingly faulted and fissured transition (“damage zone”) at its Eastern margin while approaching the Otzberg Fault Zone. This setup would be ideal for an underground gallery in the unfaulted Tromm Pluton, providing access to highly permeable rock units enabling experiments investigating high flow rates in such permeable rocks. The field survey consisted of two perpendicular vibro-seismic profiles, one short profile (~1.6 km) in North-South direction, one longer profile (~4.3 km) in East-West direction (Figure 4). Additional autonomous seismic stations were deployed at a lateral distance to these profiles in order to achieve additional 3D-coverage for a tomographic imaging of the region. A map overview of the survey is given in Figure 4. The western part of the East-West acquisition profile is covering the potential location of the GeoLaB underground gallery, and the central and eastern parts of that profile are crossing the transition zone from the presumably unfaulted Tromm Pluton into the fissured eastern margin of the Pluton. The Otzberg Fault Zone is located within the eastern end of the E-W acquisition profile. The main task of this seismic survey is to provide data for an initial imaging of this transition from the Tromm Granite towards the Otzberg Fault Zone. This initial site characterization will also provide valuable baseline information for a more detailed 3D seismic investigation which is foreseen to be acquired for planning the GeoLaB underground gallery, once the decision has been made to build this gallery at the Odenwald (Tromm) site. A second survey was recently conducted in the area.

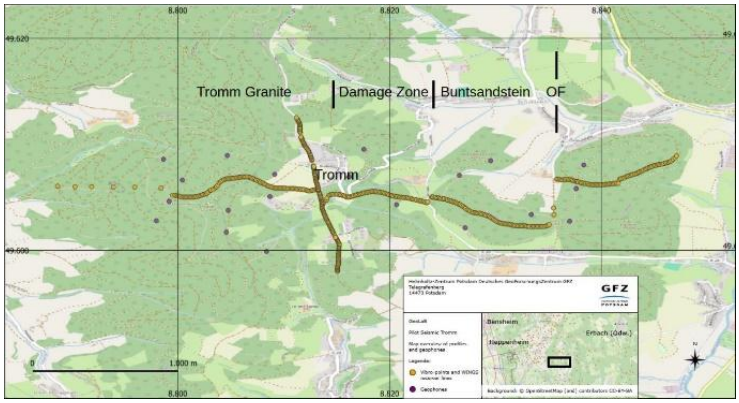


Figure 4. Map overview of seismic profiles and additional geophone positions of the pilot seismic survey. The main geological units covered by the seismic profiles are indicated (Tromm Granite, Damage Zone, Buntsandstein, Otzberg Fault (OF)).

4. POTENTIAL GEOPHYSICS

As part of the preparatory work for the GeoLaB underground research laboratory, an integrated geophysical survey was conducted in the Tromm license area (Odenwald, Germany) between October 2024 and February 2025. The survey focused on evaluating the structural and hydraulic properties of the crystalline basement and adjacent units to support site selection and the design of the experimental infrastructure. Three complementary methods were applied: gravimetry, electrical resistivity tomography (ERT) with induced polarization (IP), and geomagnetic profiling. A total of 357 gravity points were acquired to delineate subsurface density contrasts, while 15.4 km of ERT profiles were recorded in a dipole–dipole configuration to detect resistivity anomalies and zones of charge accumulation. Magnetic field measurements along the same lines were used to identify lithological contacts and possible hydrothermal alteration. The combined dataset revealed several zones of geophysical interest, particularly where low gravity, low resistivity, and moderate chargeability values coincide. Zone A was identified as a central hub of potential fault intersections, with indications of reduced density and structural permeability. Zone B, located in the eastern part of the area, aligns with a major lithological boundary and shows evidence of clay-rich or fractured formations, while Zone C suggests a northwest-trending fault system in the western part. These interpretations remain preliminary, and further validation is planned in Phase 2. Future work will focus on optimized, high-resolution geophysical surveys in the most prospective areas. This targeted approach is expected to refine the geological model and reduce uncertainties in support of GeoLaB infrastructure development.

5. SUMMARY AND OUTLOOK

The samples of Streitsdöll (ST) reveal pegmatitic structures with large k-feldspar grains (up to 1 cm). These structures and geochemical features (SiO_2 excess) will be further investigated. A complete set of analyses along with geomechanical experiments on the cores from the GeoLab-1 well will provide a comparison of the petrology and geochemistry of the surface samples (Deon et al. 2025). Further geophysical surveys will be conducted to gain more knowledge about the subsurface, in order to select the Tromm Odenwald as the site to build the GeoLaB underground research laboratory.

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