Newsletter 2 (July 2022)

Bedretto Underground Laboratory for Geosciences and Geoenergies

Digging deep – ongoing experiments and construction work at the BedrettoLab

Since our last issue, the VALTER experiments have gained momentum. At the same time, the BedrettoLab was extended to create more space for upcoming research activities.
A dense, high-quality, and reliable monitoring network is at the core of past and future activities at the BedrettoLab. In this newsletter issue, we tell you about the challenges of engineering and closely monitoring the rock. Further, one of our PhD students gives us an insight of a typical day in the lab.
Enjoy reading and learning more about the intensive work at the BedrettoLab. And do not miss to get to know about "Mangia e Cammina", an exciting event including the opportunity to visit the BedrettoLab.

In this newsletter:

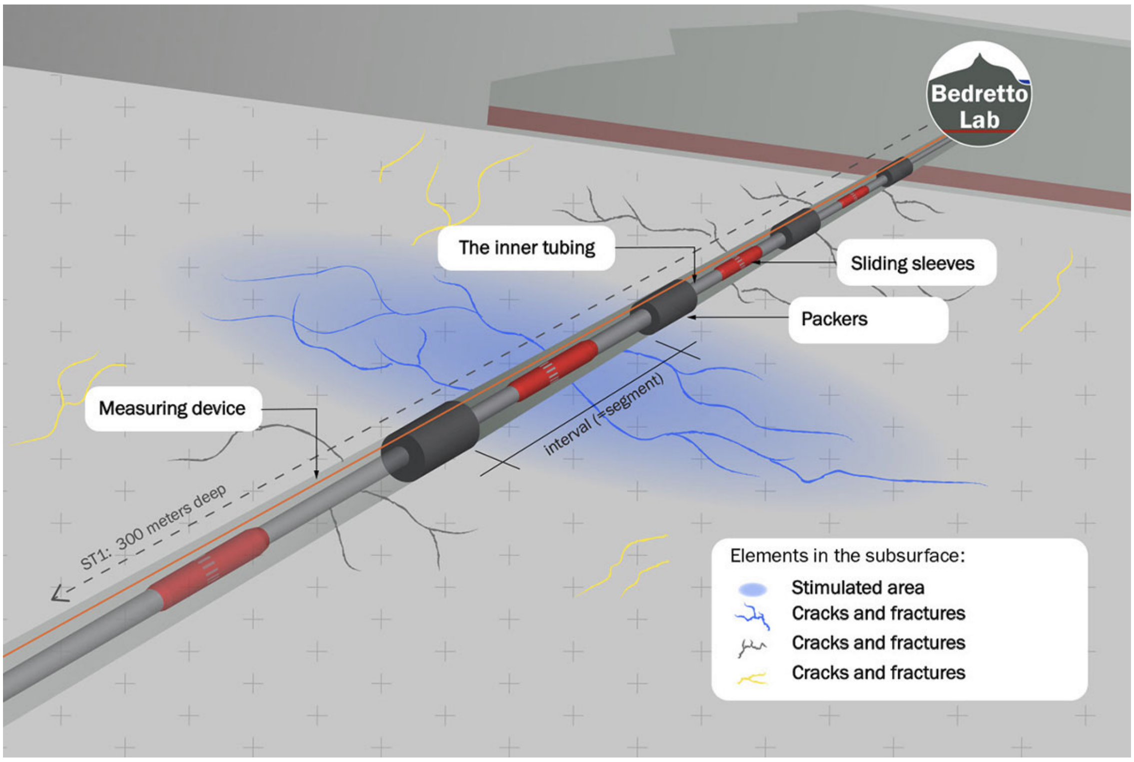
The reservoir engineering phase of the VALTER project has started

After a short break for data analysis and planning, the VALTER team resumed with the stimulations. In this next phase, Phase 2, the actual reservoir engineering phase is taking place. The

two boreholes, namely borehole ST1 and ST2.

The VALTER team started to carry out hydraulic stimulations of four intervals in mid-June and will resume the stimulations in September 2022. In the past phase of the **VALTER project**, which is part of the **Bedretto Reservoir Project**, the intervals (=borehole segments) in borehole ST1 had been stimulated according to a stimulation protocol with consistent and predefined injection protocols. Based on the data from Phase 1, the fracture systems linked to the different borehole intervals were characterized and the most promising segments selected for Phase 2.

In Phase 2, approximately four intervals that turned out to be most suitable for connecting the boreholes ST1 and ST2 are going to be further enhanced. By stimulating an interval over a period of up to 48 hours, the water creates new small fractures in the rock and ideally connects the boreholes ST1 and ST2. The distance between the boreholes ST1 and ST2 is 35 meters. High-precision temperature sensors will be installed in borehole ST2. If the connection is successful, this will result in subtle changes in the temperatures measured in borehole ST2.

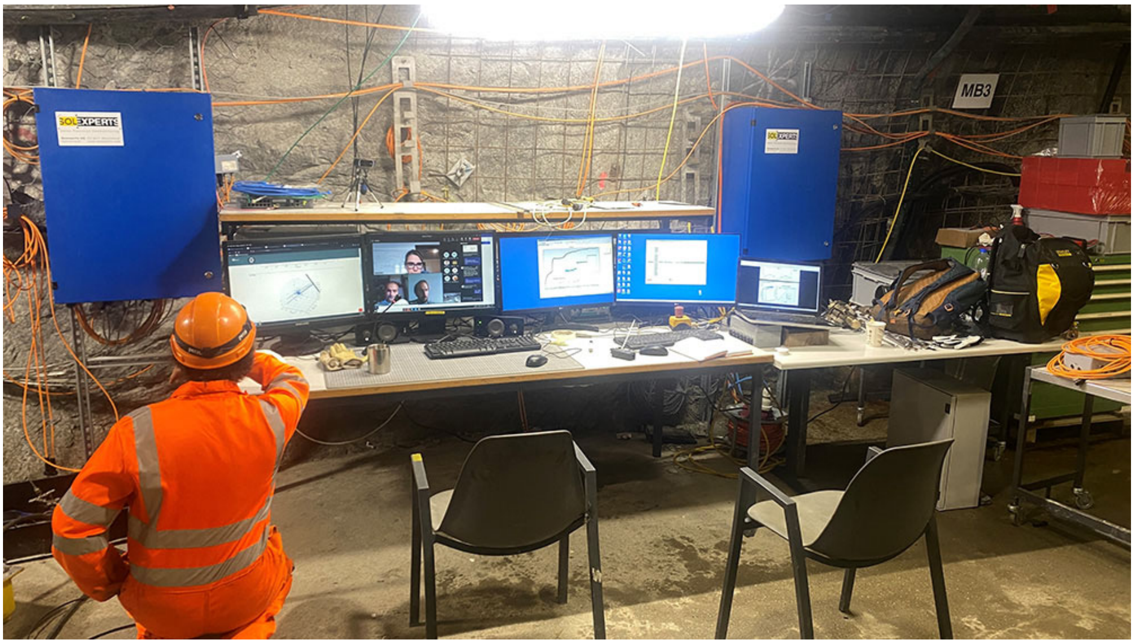


The water flows through the cracks (blue area) as a result of the stimulations in borehole ST1 flows to the next borehole, ST2. © BedrettoLab, 2022

Hydraulic stimulations (injection of water under pressure) will enhance transmissivity through both seismic and aseismic deformation. Transmissivity is an indicator of the amount of water fractures can transmit. While more than 99% of the hydraulic energy is released without creating seismic events (aseismically), through creeping processes, we expect that again numerous tiny earthquakes will accompany the stimulation. Seismologists call earthquakes in the magnitude range -4 to -2 nanoseism.

magnitudes of -6, so called picoseism. During the Phase 2 stimulations the team plans to record again numerous pico- and nanoseismic events that are not only needed to create the reservoir but also represent a rich source of information on the reservoir evolution. The largest event observed during the Phase 1 stimulations was a magnitude -3. In Phase 2 slightly higher magnitudes are expected to be observed, as more water is injected.

To make sure that the operations are safe, the injection is halted and bleed off initiated as soon as predefined safety thresholds in magnitude or vibration are reached. Besides that, the seismologists of the VALTER team are monitoring the stimulations continuously and watch out for unusual developments. Between the stimulations, a period of around three to four weeks is needed for data analysis. With this final phase, the scientists expect to gain insights into safe reservoir engineering on a scale that is meaningful for real-world applications, such as the geothermal project planned in Haute Sorne.



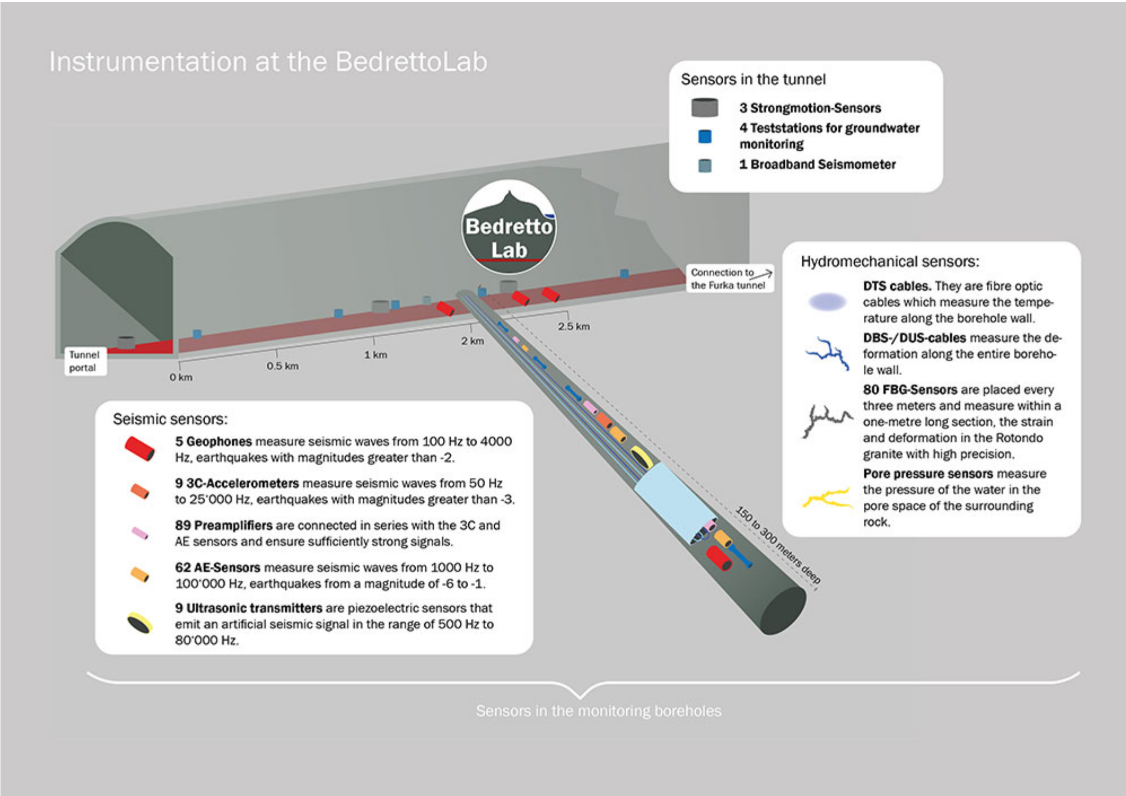
Shift work: During the stimulations some team members work on site to monitor the equipment and instruments in the tunnel. Others work remotely to monitor the different data flows. © BedrettoLab, 2022

In the heart of the rock: the monitoring system of the BedrettoLab

It is deeply hidden in the rock and yet one of the most important things about the lab: the monitoring system and its sensors. Dr. Katrin Plenkers and Dr. Anne Obermann explain what is behind this and why the monitoring system is such a crucial part of the BedrettoLab.

Many sensors in the lab are custom made. What makes monitoring in the Bedretto experiments challenging?

are working deep under the mountain in boreholes that are up to 400 metres long. The sensors must withstand water and high pressures, while remaining small enough to fit into the boreholes. Often, existing sensors do not fulfil these conditions. In addition, after installing the sensors, we must seal the boreholes fully, to reach (near to) intact rock conditions for the experiments. We therefore cement the boreholes in a special procedure. This means that the sensors remain in the boreholes and can no longer be taken out.
The multi-disciplinary monitoring system we developed integrates sensors for seismology, geomechanics and applied geophysics. Each part is tailored to withstand the rough conditions. An installation and guidance system is reducing the risks during installation, for example that the monitoring equipment does not get stuck before it has reached its final position.



The sensor network in the monitoring boreholes. © BedrettoLab, 2022

How did you approach this and what challenges did you encounter?

Katrin: The development and the installation of the sensors was only possible, because we collaborated with highly specialized and experienced companies from Switzerland, Germany, Poland, Italy, South Africa and the UK. The biggest challenge was the short time span we had for the development. I am very grateful for the dedication of the companies and the effort they put into the implementation. The development was done jointly, which means that many devices were developed by several companies together to integrate the different experiences. Logistically this was challenging, because the realization fell into the first Covid-19 lockdown. For the cementation procedure, we worked with Dr. Andreas Reinicke, a sealing expert from Nagra.

Anne: We were very relieved that the work of the past years paid off and that we succeeded in running a smooth first stimulation with hundreds of pico-seismic events recorded on our system and registering clear data from the fibre optic cables. We are now optimizing in particular the acquisition systems and are very enthusiastically looking forward to work with the data and acquire even more in the upcoming measurement campaigns.

Let us look into the future: What are you planning next and what challenges do you expect?

Anne: We have learnt substantially from the first instrumented boreholes and the kick-off the stimulation campaign. The next big project around the corner is FEAR, where we need an even denser, more sensitive network to detect also the tiniest picoseismic events. A major challenge here is to protect the acquisition system as good as possible from any potential noise sources (electronic or mechanic). Also, the calibration of the Acoustic Emission Sensors is causing us headaches, however, but I am optimistic that we are on a good way to solving it.

Short Bio Anne Obermann:
I am a Senior Scientist at the Swiss Seismological Service at ETH (SED), leading the seismology group at the BedrettoLab and the Interferometry & Imaging group at SED. Besides my interest for the underground and induced seismicity, my main field of expertise is within coda wave interferometry.

Short Bio Katrin Plenkers:
I am a geophysicist specialized on measurements in underground experiments. In Bedretto I worked as the lab manager for monitoring systems and leader of the underground seismology group. Im now working as a Senior Scientist at Gesellschaft für Geophysik und Materialprüfung (GMuG) mbH.
My main field of expertise is the recording of picoseismicity, i.e. the recording and analysis of small fractures in underground experiments or in structural health monitoring.

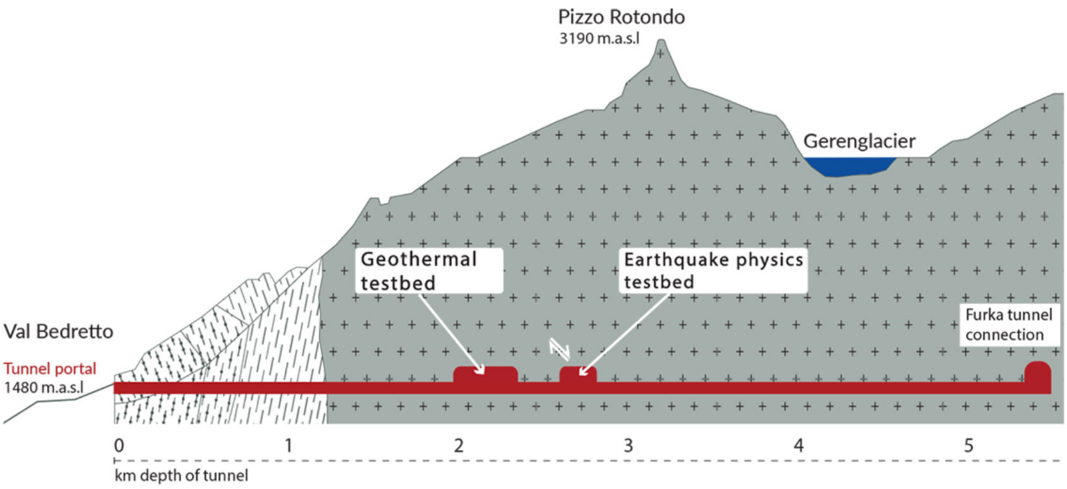
The installation of the monitoring network. © BedrettoLab, 2022

A unique earthquake physics laboratory in the BedrettoLab for the FEAR project

Construction work for the new earthquake physics testbed © BedrettoLab, 2022

Besides some intensive research going on in the BedrettoLab, the tunnel has ventilation are being installed. One of the major upcoming research projects for which the extension is put in place is the FEAR project.

FEAR stands for Fault Activation and Earthquake Rupture. The core idea of FEAR is to gain an understanding on how earthquakes start and stop by modifying stress on faults and using water injections to induce small non-damaging earthquakes up to magnitude 1. A dense instrumentation network will give an up-close view of processes on the fault before, during, and after the earthquake rupture. Findings from FEAR will improve the understanding of the physics of earthquake rupture, contribute to pushing forward the limits on earthquake predictability, and advance the state-of-the-art in safe use of geoenergy.



Cross section of the Bedretto tunnel © BedrettoLab, 2022

The Bedretto tunnel offers a perfect base for the FEAR experiments. About 2.5 kilometres into the tunnel, the researchers have identified a natural fault system which – as laboratory studies show – has hosted earthquakes in the past. The detailed experimental design, the optimization of the locations of boreholes, and a side tunnel to facilitate closer access to the fault, are currently in development.

From the close vantage point afforded by the planned side tunnel, a dense multidisciplinary monitoring system will be installed to observe processes on the target fault and its immediate surrounding, before, during and after inducing an earthquake. The system is designed to detect micro-quakes in the magnitude range -5 to 1, and will provide very high frequency recordings of seismic waves which cannot be recorded with standard instruments.

The first FEAR-related experiments are currently underway, using the VALTER reservoir as the testbed. Further preliminary experiments are planned for early 2023.

The project is carried out by a consortium of scientists from the ETH Zürich in Switzerland, the Rheinisch-Westfälische Technische Hochschule Aachen with a Synergy Grant.

Calculating the chaos of seismic waves – a day in BedrettoLab of PhD student Kathrin Behnen

I am a PhD student working at the BedrettoLab on the anisotropy (see explanations below) of seismic waves. In the last few months, I spent several days at BedrettoLab taking measurements that are part of my PhD project as well as Claire Epiney's Master's thesis. In my doctoral thesis, I focus on the seismic anisotropy as well as its spatial and temporal variation on both, the lab and the field scale. I will contribute to improve the geological and geophysical characterization of the reservoir and the understanding of ongoing seismo-hydraulic processes during geothermal operations.

As the measurements in the tunnel usually take quite long time, I travel to Airolo the evening before to get to Bedretto the next day as early as possible. Usually, we are several people working together. Our trip to the BedrettoLab starts in Airolo with shopping at the supermarket, where we take catering for the whole day in the tunnel. After arriving at the barrack, we take a cup of coffee, put on the security clothes and then prepare and pack all the instruments needed for our experiments. Of course, we already have a precise plan of what we want to do in the lab, as we don't want to lose time by having to go back and forth. Typically, I need the sparker and the hydrophones for Claire's and my thesis. The sparker is placed in a borehole where it induces electrical impulses, which then create pressure waves propagating through the rock. These seismic waves are then measured by the hydrophones in another borehole.

PhD student Kathrin Behnen (right) and Kai Bröker (left) installing the sparker in the borehole.

The instruments are quite heavy and include long cables on top, so we put them on one of our Lokis to transport them in the tunnel. If there is some space left on the loki, I go with it as well. If not, I take a bike or walk to the lab. Once arrived, we start to install our instruments by placing them in the boreholes in the depth of some tens of meters. We start with tests immediately after. Often, the instruments don't work as expected right away. As they are placed in the depth of the boreholes, it is very likely that for example the cable of the sparker is bent somewhere and therefore cannot transmit the voltage. It is very typical that such things happen. But within our team, we usually find a solution quite

Our special bikes offer a shorter and more fun passage to the lab. © BedrettoLab, 2022

As soon as the instruments work smoothly, we can start with the measurements. In general, we try to be as efficient as possible and take a few measurement series that take four to six hours. Also, we do measurement series on several subsequent days to gather as much data as possible. At my office in Zurich, I will need the data to analyze differences in the velocities of the waves in dependence of the direction of the raypath. Sometimes I eat my lunch on the side of working, sometimes we gather for lunch in our container.

energy.

The PhD students of the BedrettoLab at work. © BedrettoLab, 2022

After finishing the measurements, the instruments must be deinstalled and taken back to the Barack by the loki. Once, the instruments are tucked away, my last duty is to fill out a short online protocol of our activities in the tunnel. All in all, I often spend up to ten hours in the lab.

Although the days in the BedrettoLab are long and exhausting, I enjoy working

Finally, working on real data representing the true nature of the rock volume makes the theoretical modelling much more exciting.

The anisotropy of seismic waves
Anisotropy generally refers to the directionality of a property or process. In seismology, it describes the directional dependency of the velocity of a wave.
When a rock has a preferred orientation of the grains or fractures, they influence the velocity of the waves is influenced by that.
The waves travel with different velocities depending on their direction of propagation with respect to these features. A seismic wave usually travels faster along the foliation of fractures and slower perpendicular to it. Thus, by analyzing the seismic anisotropy in a rock, important information about its structure can be derived.

The BedrettoLab in the media

- **RAI News: Futuro24: Svizzera, nel cuore della montagna per produrre e studiare i terremoti** (24.05.2022, in Italian)
- **RSI: Viaggio al centro della terra** (06.03.2022, in Italian)

The shooting of Il giardino di Albert (RSI) in February 2022. © BedrettoLab, 2022

Upcoming event

On Sunday, August 7, the event "**Mangia e Cammina**" will take place.

For this occasion, the BedrettoLab will offer guided tours as well as many additional activities in front of the tunnel. We are looking forward to welcome again many visitors again, after a two years break due to Covid restrictions: https://www.mangiaecamminasuglialpi.ch/bedretto-lab/
For the whole event (including the BedrettoLab) a ticket is required. It can be purchaised **here**.

In the Bedretto Underground Laboratory for Geosciences and Geoenergies, ETH Zurich studies in close collaboration with national and international partners techniques and procedures for a safe, efficient, and sustainable use of geothermal heat and questions related to earthquake physics.
The Bedretto Lab is financed by the Werner Siemens Foundation, ETH Zurich and the Swiss National Science Foundation.