The response of a fractured crystalline reservoir to natural pressure buildup: Experiment results from the Bedretto Lab

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1 Introduction

The BULGG (http://www.bedrettolab.ethz.ch/) is a newly created underground research facility that promotes experiments aimed at understanding processes related to geothermal energy extraction. Currently, 6 boreholes ranging from 200 m to 400 m total length have been drilled in the volume. Three of these boreholes are cemented and permanently instrumented with geophysical sensors. One borehole (MB2) contains a permanent packer installation, and the remaining two (ST1 and ST2) are designated for hydraulic stimulation. During a period of62 days we closed the boreholes at the wellhead and allowed the system to regain its ambient pressure. The total outflow before closing exceeded 120 L/min. When we opened the boreholes again, we monitored the response of the reservoir using all geophysical sensors as well as time-lapse Ground Penetrating Radar (GPR) in ST1. Here, we present some preliminary results from this experiment.

2 Characterization volume

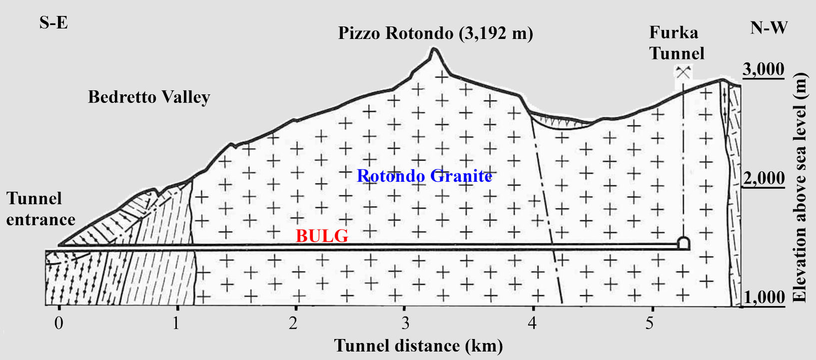


Figure 1. (Top) A geological cross-section of the Bedretto tunnel. The volume surrounding the lab is dominated by the Rotondo granite. Figure modified from Keller and Schneider (1982), Geologie und geotechnik, *Schweizer Ingenieur und Architekt*, 100 (24).

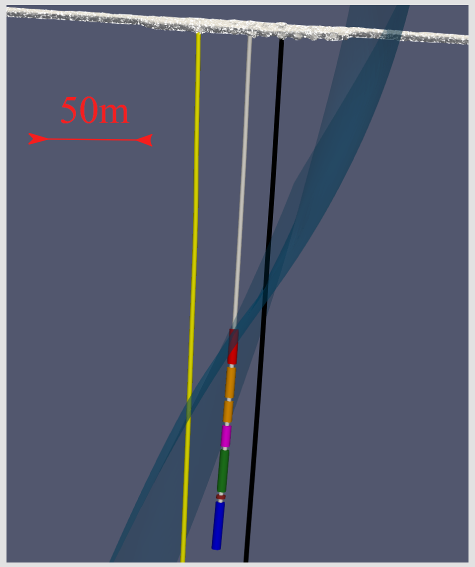


Figure 2. (Left) A model of the first major fault zone that traverses the investigation volume. The fault zone surface (shown here in transparent blue) is constrained in location and orientation from borehole logging data (acoustic and optical televiewer) and a model is created using GemPy (www.gempy.org). The relevant boreholes are also included in the plot: ST2 is shown in yellow, ST1 in black, and MB2 in white, along with the packed off intervals (colors correspond to the pressure curves shown in Figure 3).

3 Results

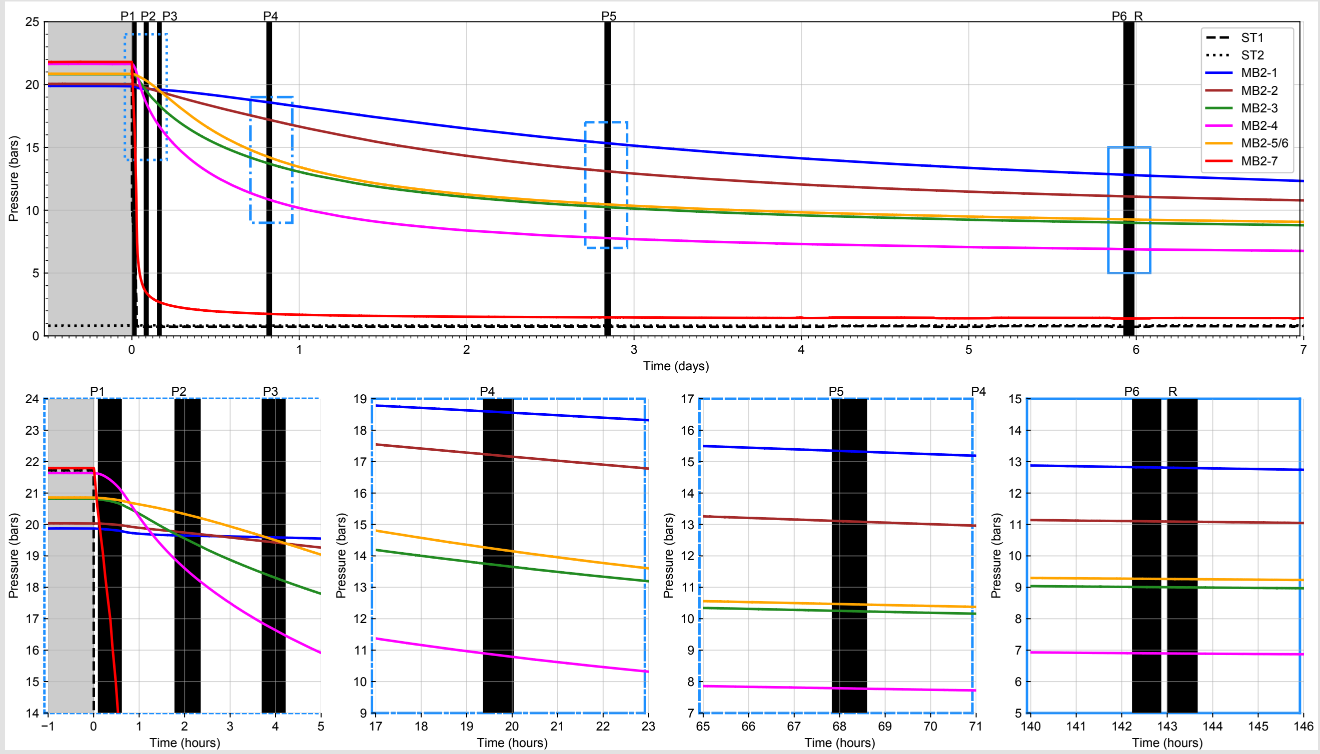
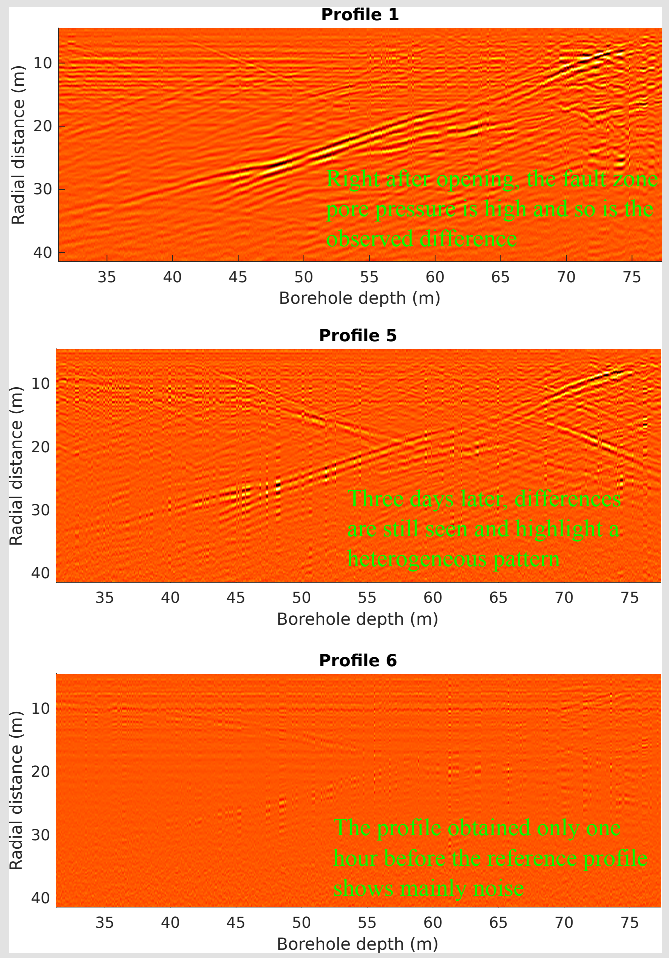


Figure 3. (Top) Pressure evolution during the depressurization phase of the experiment. The pressure curves for the packed off intervals in MB2 are shown (see also Figure 2) are shown, as wel las the pressure in ST1 and ST2. This phase corresponds to the opening of ST1 (time 0 days). The black vertical bars indicate the times at which repeated GPR measurements were taken. Each measurement (profile) takes about 30 minutes. The last profile (7) is used as a reference for difference imaging (see next 2 figures).



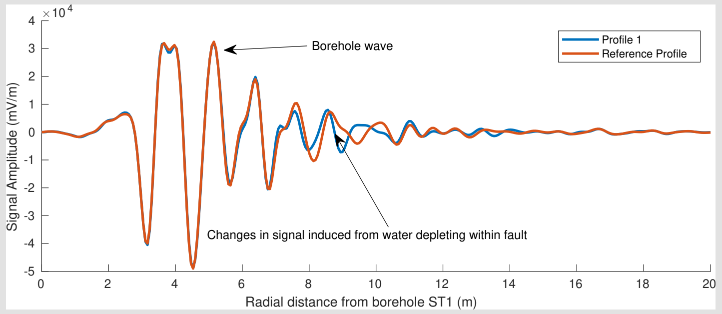


Figure 4. (Left) GPR emits an electromagnetic field and detects the reflected signal. In this geologic setting, reflections occur mainly from water-granite contrasts. At each location along the borehole a single trace is measured, as seen in this figure. By subtracting earlier traces from the reference, we can highlight changes in the medium that correspond, in this case, to changes in permeability.

Figure 5. (Top) When looking at changes in the reflected EM field along the borehole, we can detect how different structures react to the depressurization In the example above, we show how a large fault zone (the one shown in Figure 2) depletes over time. Three profiles are compared to the reference: Profile 1, 5 and 6 (their corresponding times are shown in Figure 3). Surprisingly, the fault zone depletes much slower than the observed pressure drop.

4 Discussion and Outlook

The hydro-geologic response at the BULGG is dominated by a few very hydraulically conductive faults. These faults, often observed to traverse several hundreds of meters (as the example presented here) can have highly heterogeneous properties. During this experiment we observed the depletion of a fault during the depressurization phase with the use of GPR. The results suggest that the flow within the fault occurs over the scale of several days, while the observed pressure drops to (almost) atmospheric within minutes of opening the borehole. The results give an insight into the interplay between pore pressure, permeability and flow for fractured crystalline reservoirs.

5 Acknowledgements

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