Zonal Isolation, Drilling and Exploitation of EGS Projects

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Final report according to BNBest-BMBF 98

Joint project: ZoDrEx - Zonal Isolation, Drilling and Exploitation of EGS Projects; Subproject: Stimulation tests in extended boreholes
Funding code: 0324267B

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Content

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1. brief description

The primary objective of the sub-project at RWTH Aachen University was to systematically test, evaluate and demonstrate stimulation procedures in boreholes that were drilled to prototype scale in the Bedretto Rock Laboratory (Switzerland) and were to be equipped with various state-of-the-art, partly zonal, extensions.

The planning phase of the sub-project began immediately after receipt of the approval notice in 2018. Due to delays in the expansion of the rock laboratory and the subsequent restrictions on European travel due to the Corona pandemic, it was not possible to begin work on the site until the second half of 2020.

Jahr	2018				2019				2020				2021			
Quartal	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Task 0								0								
Task 1											1					
Task 2													2			
Task 3																3
Task 4																4
Task 5																5

Meilenstein

Task 0	Übergeordnete Planung und Vorbereitung der Feldversuche
Task 1	Pre-Stimulation Charakterisierung
Task 2	Post-Completion Charakterisierung
Task 3	Stimulationsphase
Task 4	Post-Stimulation Charakterisierung
Task 5	Übergeordneter Task (Analyse, Berichterstattung, Technologietransfer)

Apart from a large number of industrial projects (especially in the oil and gas industry), there are to date only a few small-scale field experiments to better understand stimulation processes with high-spatial-resolution monitoring (Jung, 1989; Martin et al., 1990; Rudquist, 1995; Schweisinger et al., 1997; Cornet et al., 2003; Murdoch et al., 2004, Derode et al., 2013; Guglielmi et al., 2014; 2015; Amann et al. 2017). However, these field tests address in particular the seismic-hydro-mechanical processes associated with high-pressure injections or, in part, the influence of the stimulation process on seismic events and permeability changes, but not technical ways to optimise the wellbore's connection to the reservoir. Demonstration tests of stimulation procedures in boreholes (in crystalline or sedimentary rocks), with different wells developed according to the state of the art, have not been systematically investigated until today, although they are of utmost relevance for the development of geothermal resources for electricity generation from the hot but dense subsurface. This scientific and technical state of the art should be taken up with the ZoDrEx project.

2. In-depth presentation

The most important items of the numerical statement are:

1) Personnel costs (0812) in the amount of € 242,171.39

2) Investments in items over € 410 (0850) in the amount of € 214,826.26

3) Rents and computer costs (0834) totalling € 86,360.00

While the use of personnel is self-explanatory, points 2) and 3) will be explained in more detail below with reference to the specific work packages and results achieved as well as the necessity and appropriateness of the respective use of funds against the background of the project objectives.

The investments of 410 € are mainly for the acquisition of hydraulic test and stimulation equipment and a fibre-optic measuring system for temperature measurement. These were procured contrary to the original planning and in agreement with the project executing agency and operated by the chair's own staff instead of commissioning appropriate service companies to carry out the work.

A total of € 117,032.80 was spent on the procurement of the hydraulic test and stimulation equipment, which already includes the expansion or retrofitting of the injection equipment, which was absolutely necessary due to the sometimes unexpectedly high rock pressures below the Bedretto Gallery. Specifically, this item includes high-pressure pumps and so-called flowboards, i.e. combinations of pressure and flow meters optimised for use in the field, as well as the necessary hardware and software for data acquisition. This equipment, specially designed for the project, made it possible to hydraulically characterise individual intervals of the ST2 borehole and to break up the natural rock formation. The central result of this activity is the statement that no reduction of the formation breakdown pressure could be observed in the borehole sections pre-damaged by the project partner by means of notching and micro turbine drilling, as can be seen in Appendix 1. Due to the presence of natural fractures in many of the specified intervals and the small number of intact reference intervals, it cannot be conclusively stated whether an insufficient degree of pre-damage is the cause in each case. Accordingly, only a need for further research in this question could be identified, which in itself is not initially reflected in a technical publication. As a by-product, so to speak, additional information on the local stress field could be generated through an analysis of the hydraulic data obtained, in particular the closure process of the created or activated openings in the rock, which is of cross-project use for the activities in the Bedretto rock laboratory. These outputs are to be assigned to the work packages 2.1 "Characterisation of boreholes" and 3.4 "Stimulation of intervals" according to the project proposal. It should be noted that due to the large time delays in the project schedule, the hydraulic testing and stimulation was carried out in a combined injection protocol per segment to maximise the time efficiency of the field work.

A sum of 69,526.22 € was spent on the acquisition of a fibre-optic temperature measuring system. This works according to the principle of fibre-optic distributed temperature sensing, FO-DTS for short, and makes it possible to detect inflows of colder formation water along the boreholes. Such effects could be detected for the fracture cluster at 109.5 to 112.5 m in ST1 as well as the single fracture at 179 m in ST2, as known from the acoustic and optical logs (Appendix 2). It should be noted that none of these hydraulically active structures could be clearly identified in the conventional spinnerlog. Since the conception of the measurement system took place at a time when it was not yet foreseeable that both boreholes would be drilled further than the originally advised 300 m for project-wide reasons, the deepest borehole sections could unfortunately not be recorded. Special mention should also be made in this context of the sum of € 11,910.53 spent on the 3D printing of special centralising pieces, which were developed at the Chair in order to be able to insert the fibre-optic measuring cable undamaged into the inclined and, in places, very fissured boreholes and recover it again. The expenses listed are to be assigned to work package 2.1 "Characterisation of the boreholes" according to the project application.

The main share of €70,000 in rent and computer costs was for the financial participation in the two boreholes ST1 and ST2 and their production, as well as for the provision of infrastructure and personnel support on site by Geoenergie Suisse AG. Due to the withdrawal of the company H. Angers und Söhne GmbH from the consortium, the production of the boreholes had to be contracted out by the project coordinator, which led to unplanned additional costs. These could be covered by the omission of standby costs for the drilling equipment after consultation with the project executing agency from the approved budget.

The findings from the project have not yet been published in a scientific journal. Whether this will happen in the future is unclear at the moment.

Attachment 1

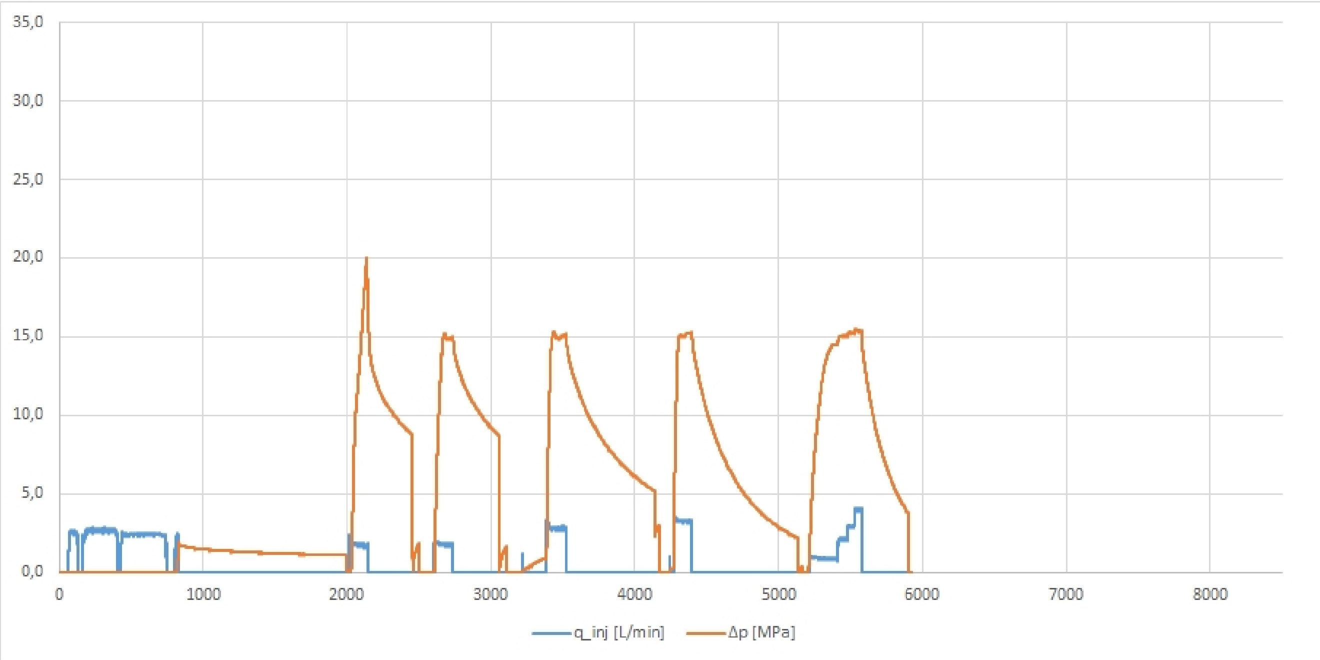

Fig. 1 Hydraulic test in the interval 22.1 - 24.1 m (potentially pre-damaged by notching)

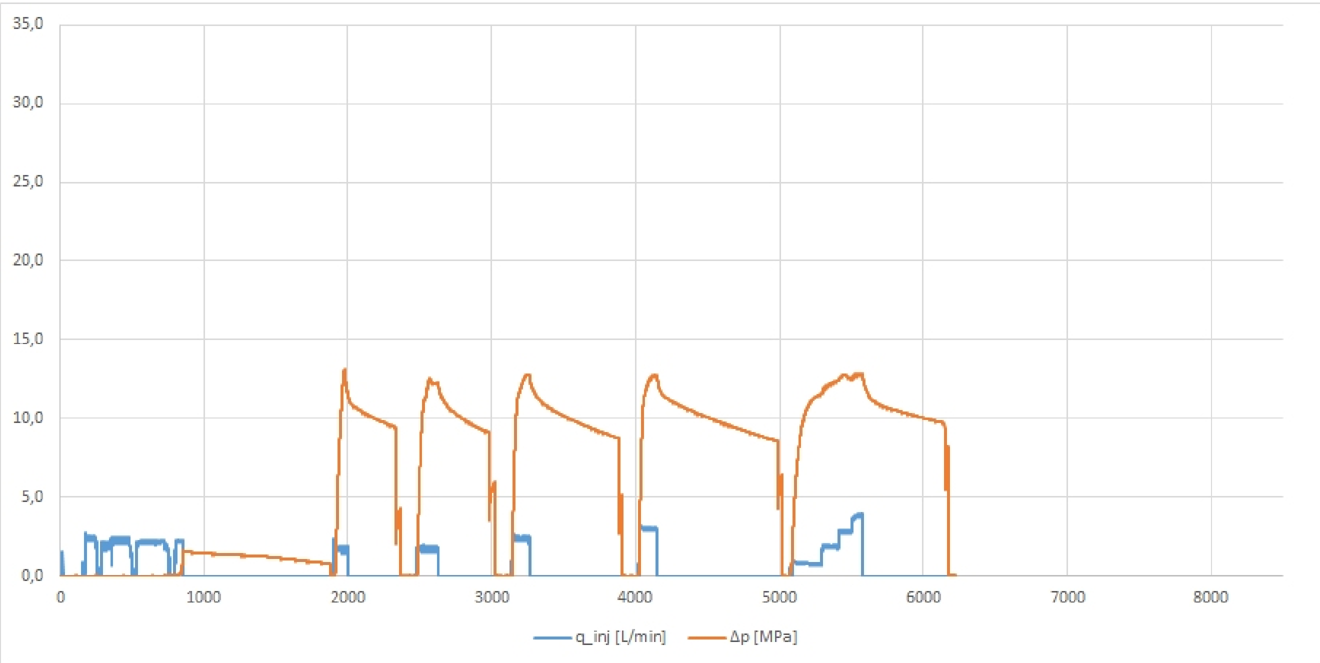

Fig. 2 Hydraulic test in the interval 30.0 - 32.0 m (natural fissuring, no previous damage)

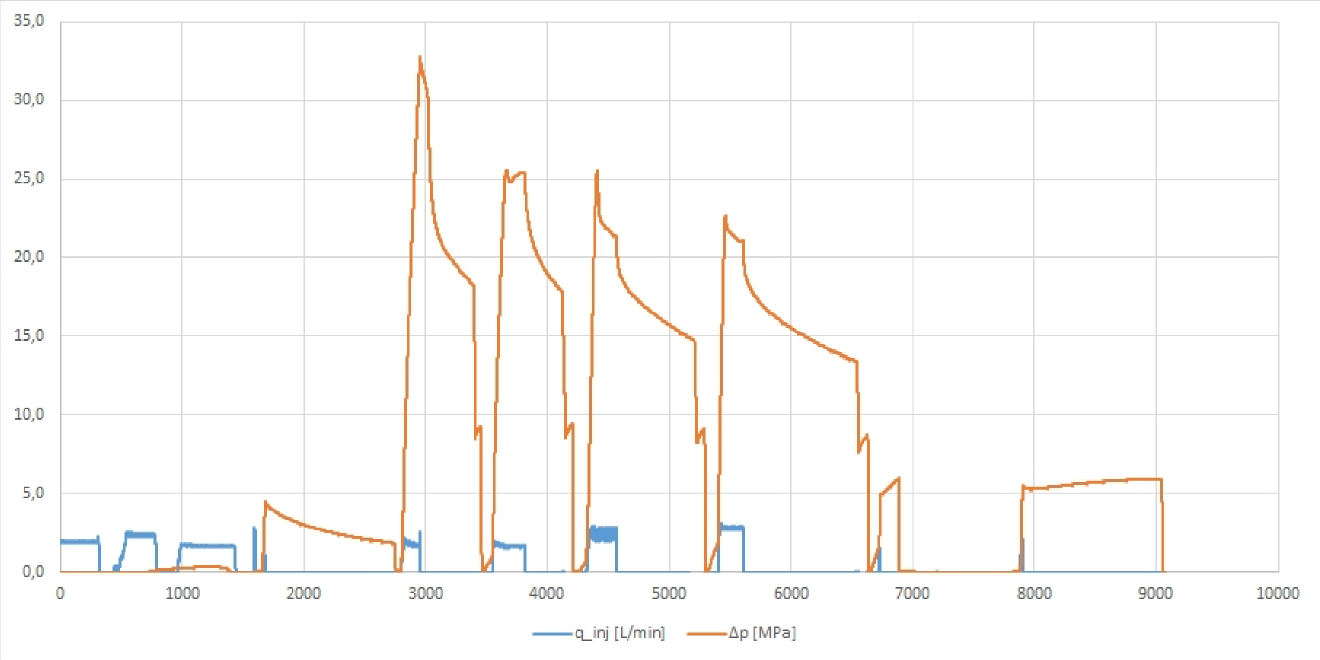

Fig. 3 Hydraulic test in the interval 100.0 - 102.0 m (hardly any natural fissuring, no previous damage)

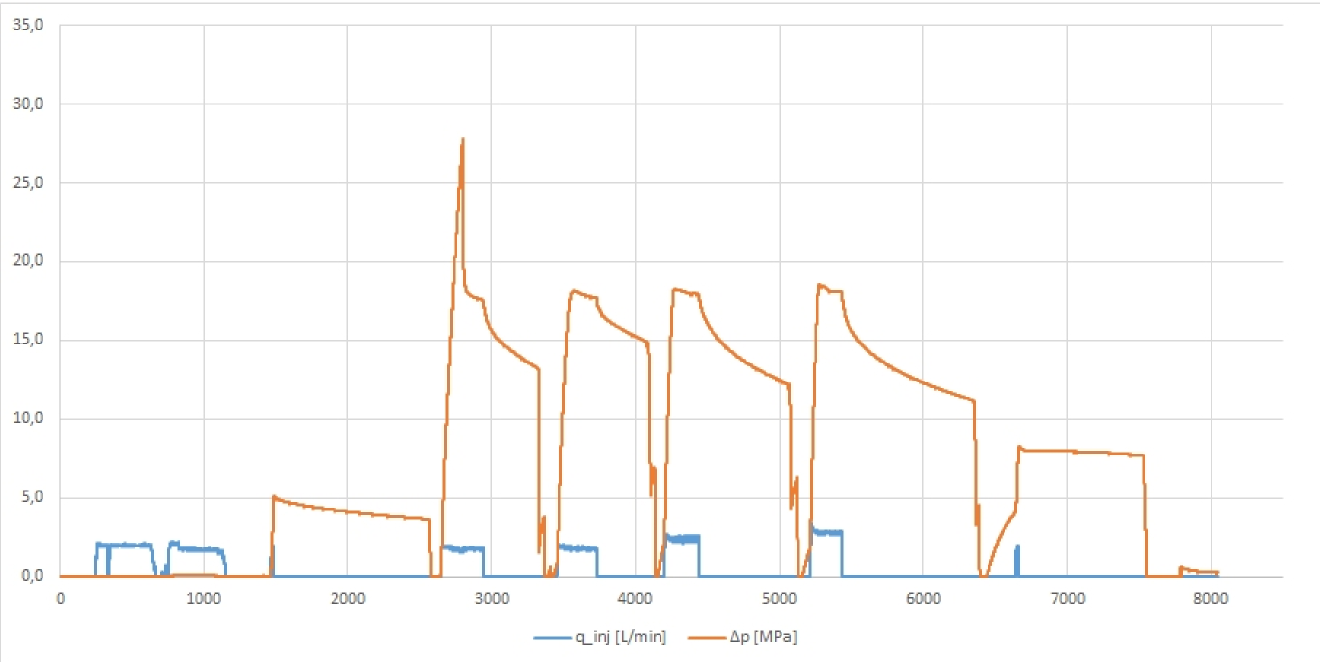

Fig. 4 Hydraulic test in the interval 265.0 - 267.0 m (potentially pre-damaged by micro drilling)

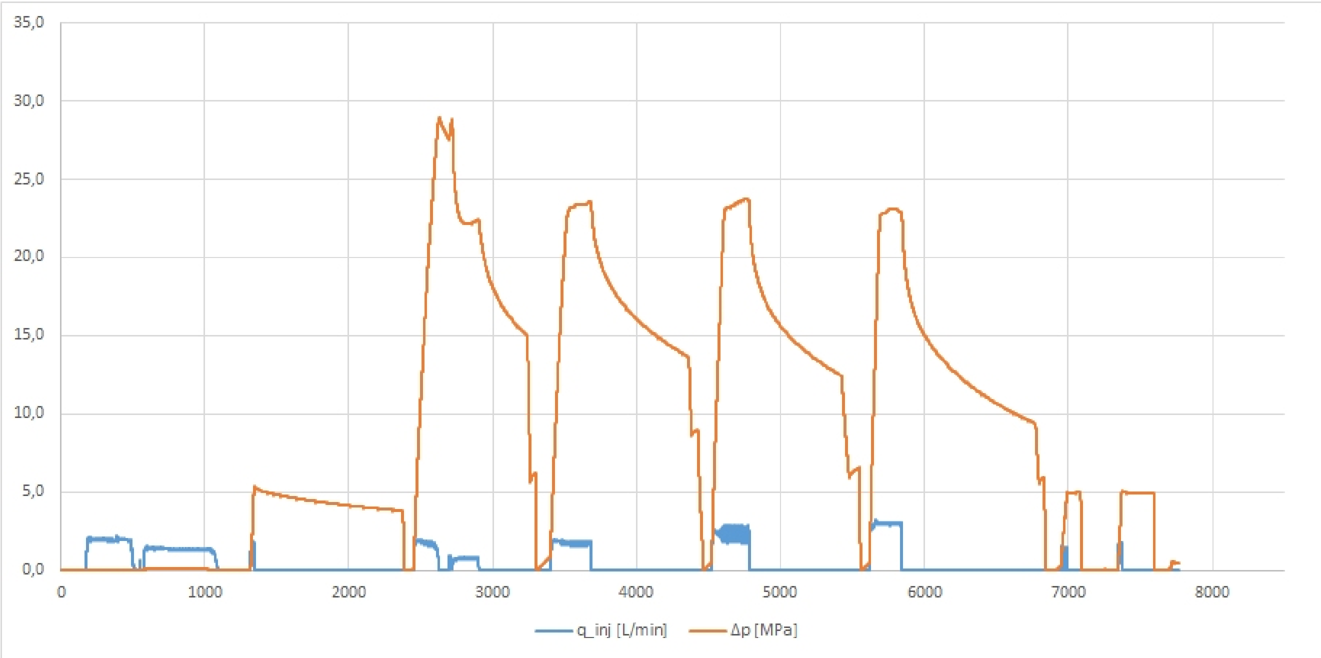

Fig. 6 Hydraulic test in the interval 270.2 - 272.2 m (natural fissuring, no previous damage)

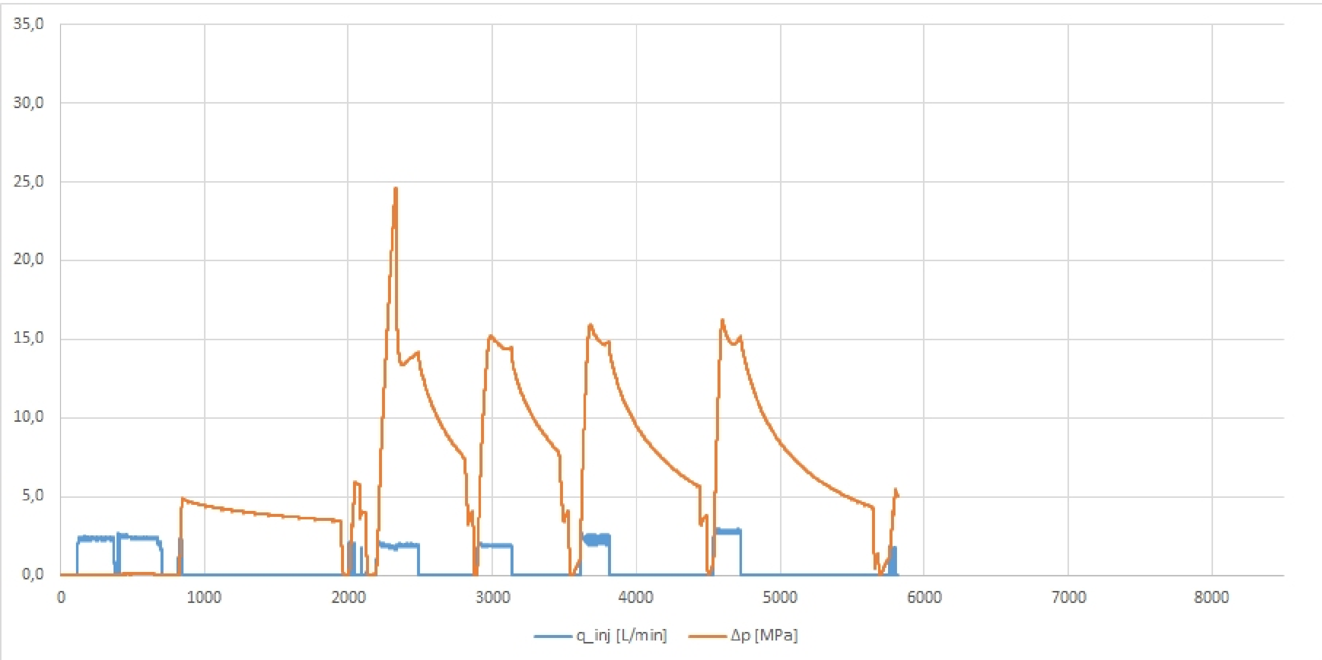

Fig. 5 Hydraulic test in interval 273.2 -275.2 m (potentially pre-damaged by micro drilling)

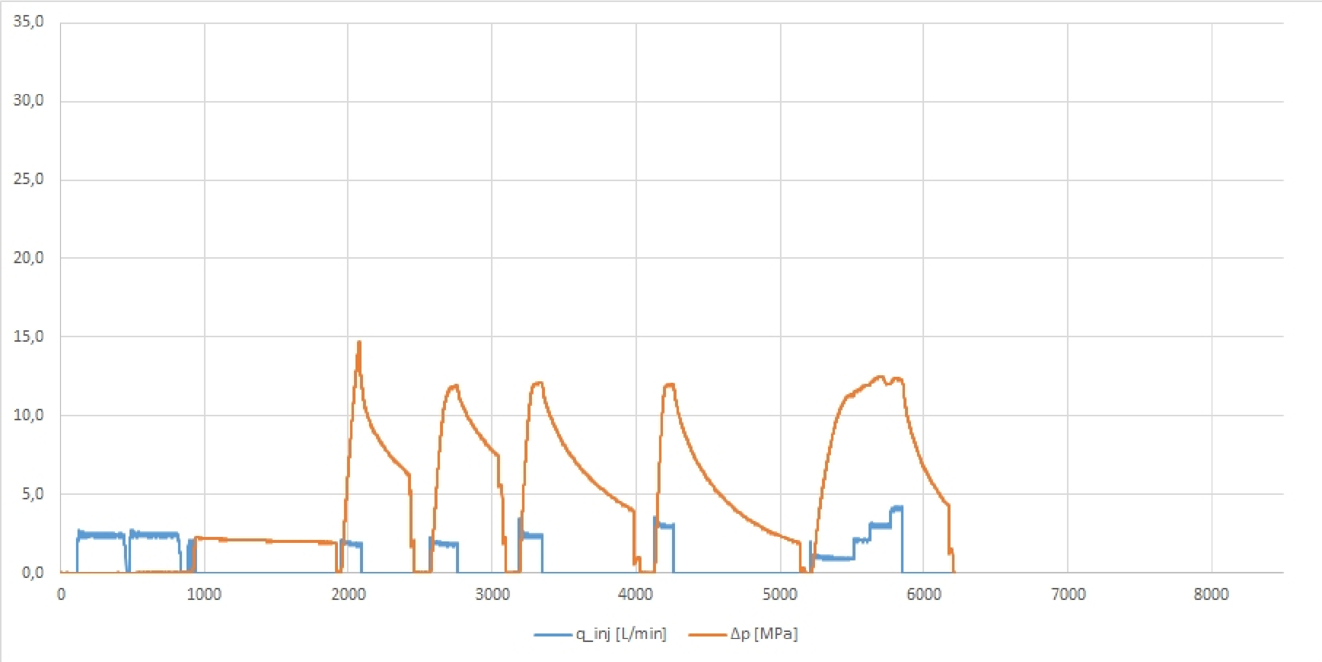

Fig. 8 Hydraulic test in the interval 301.3 - 303.3 m (natural fissuring, no previous damage)

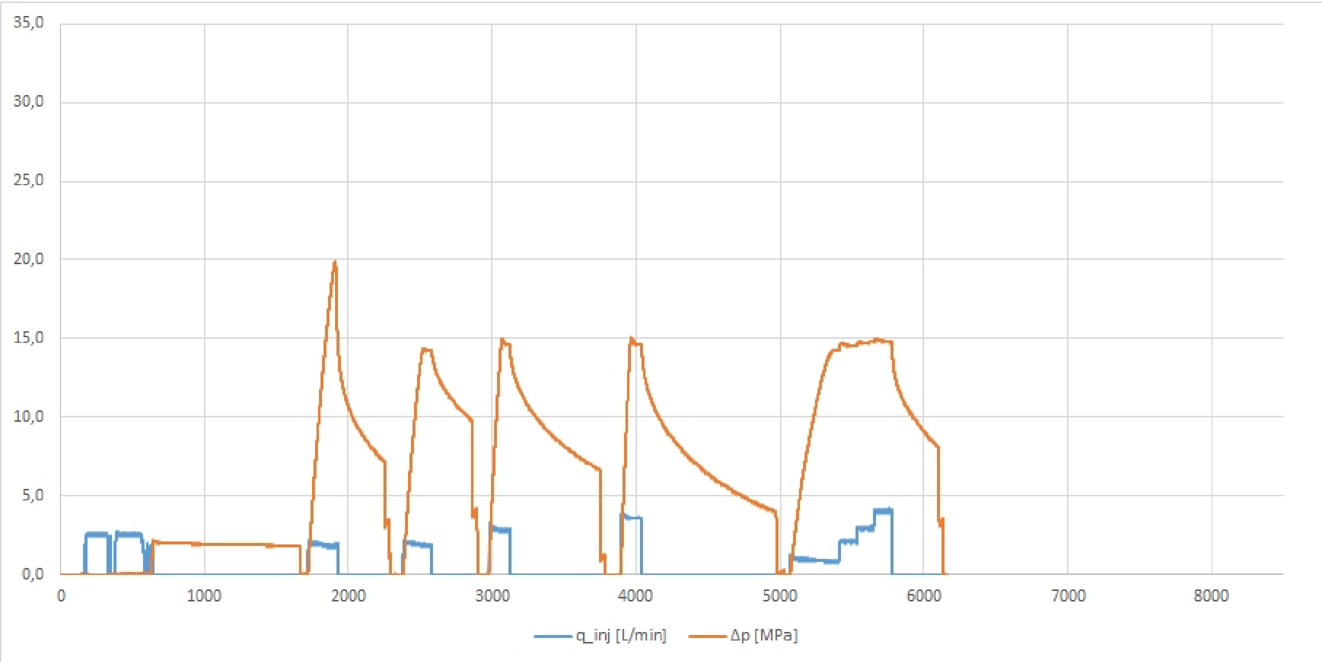

Fig. 7 Hydraulic test in the interval 306.7 - 308.7 m (potentially pre-damaged by notching)

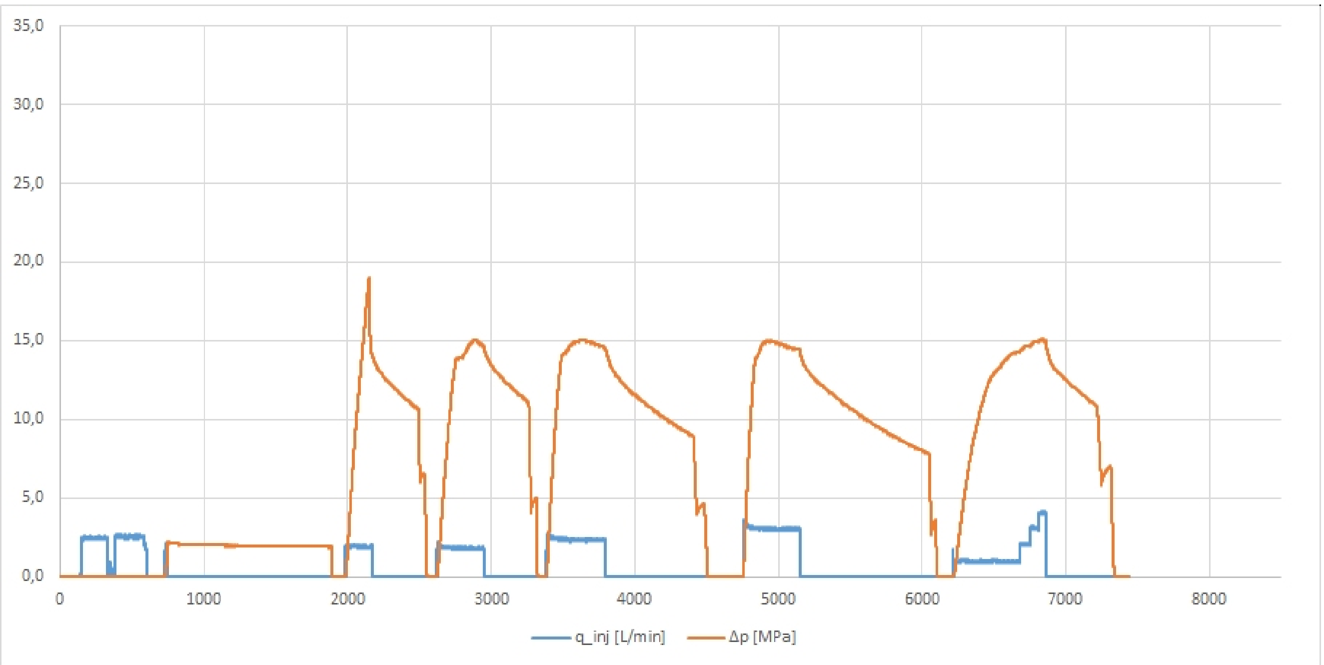

Fig. 10 Hydraulic test in the interval 309.5 - 311.5 m (potentially pre-damaged by notching)

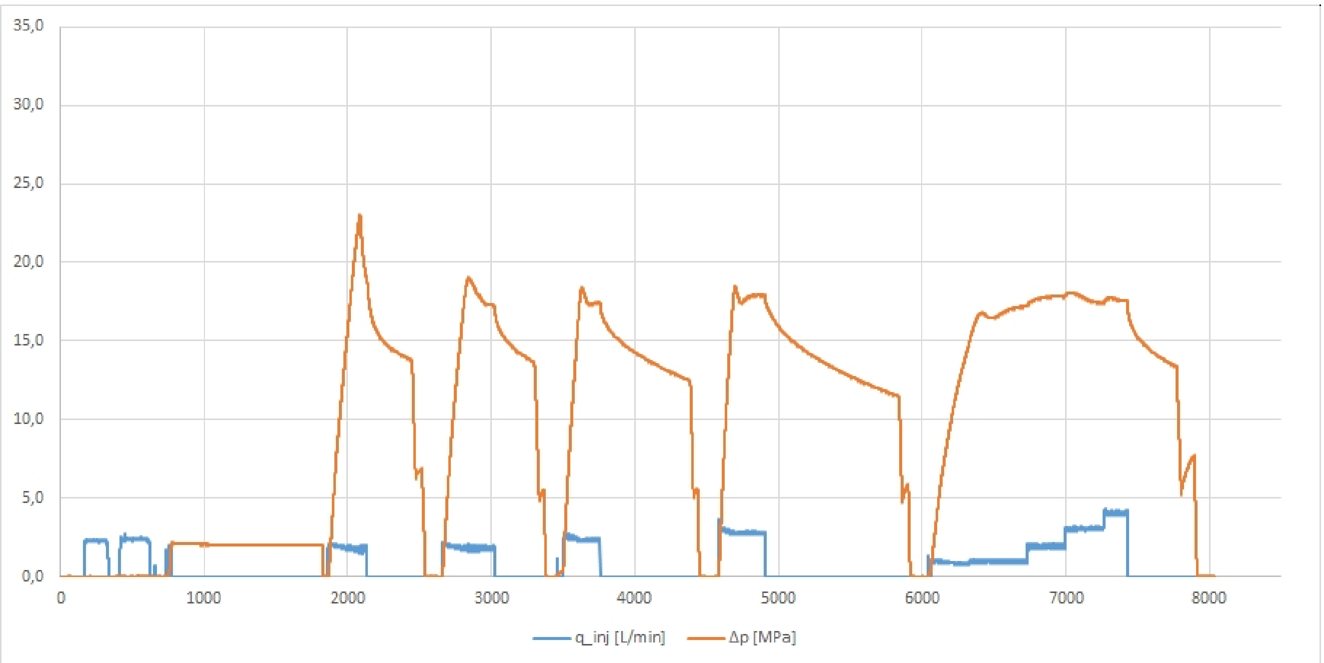

Fig. 9 Hydraulic test in interval 314.8 - 316.8 m (potentially pre-damaged by notching)

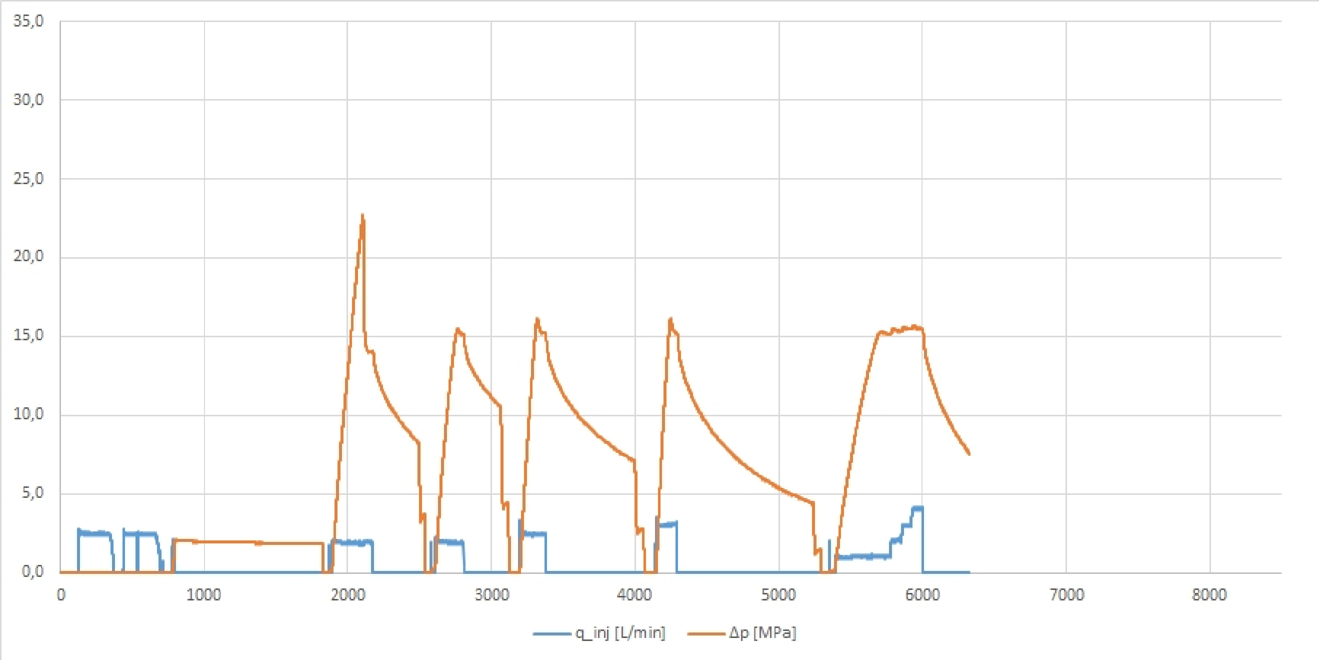

Fig. 11 Hydraulic test in the interval 341.1 - 343.1 m (potentially pre-damaged by micro drilling)

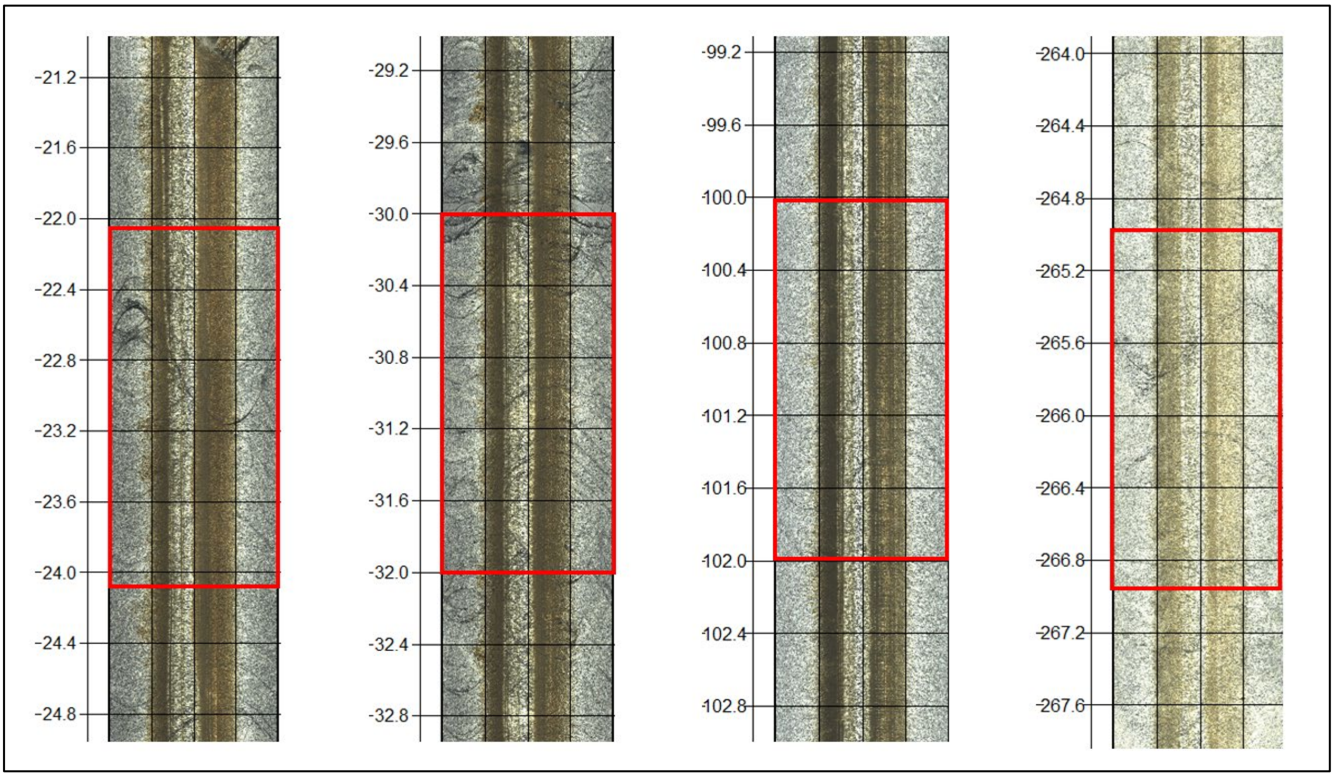

Fig. 12 Optical televiewer images of the intervals below 22.1 m, 32.0 m, 100.0 m and 265.0 m

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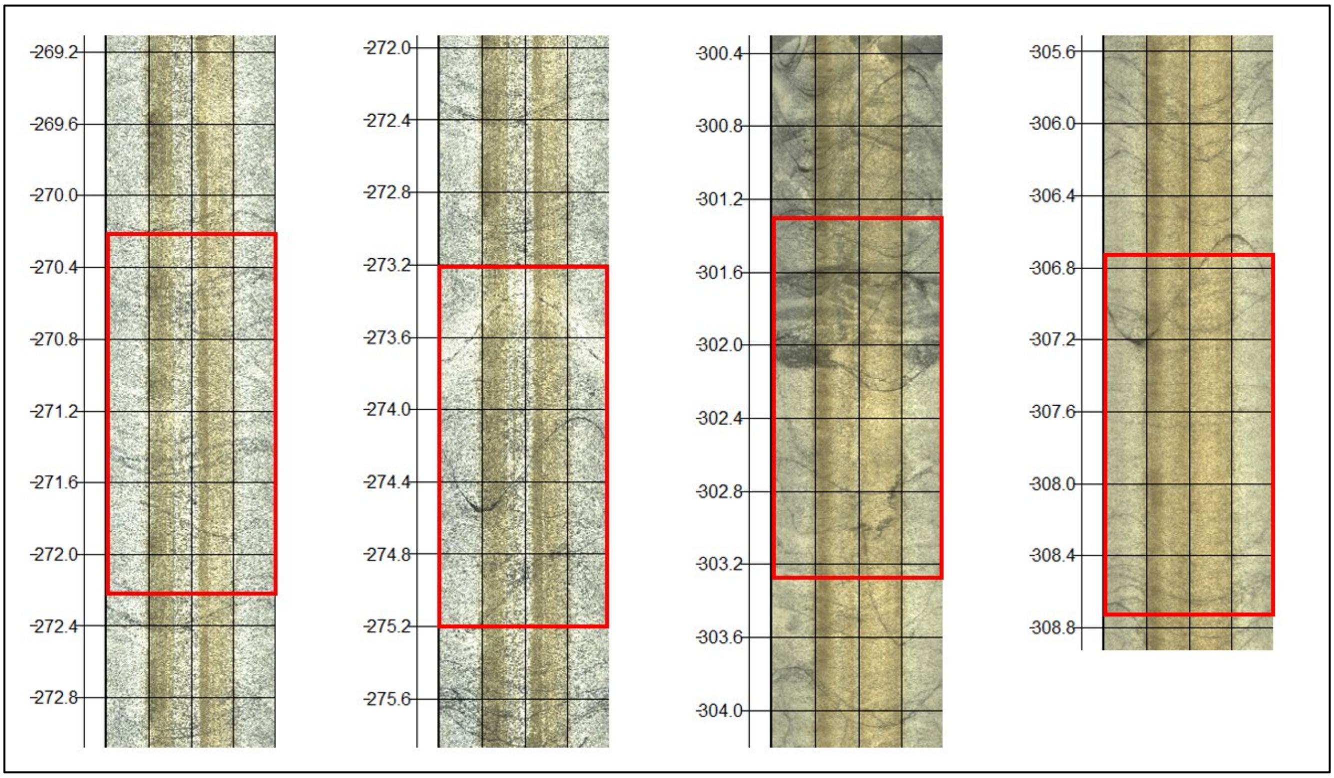

Abb. 14 Optical televiewer images of the intervals below 270.2 m, 273.2 m, 301.3 m and 306.7 m

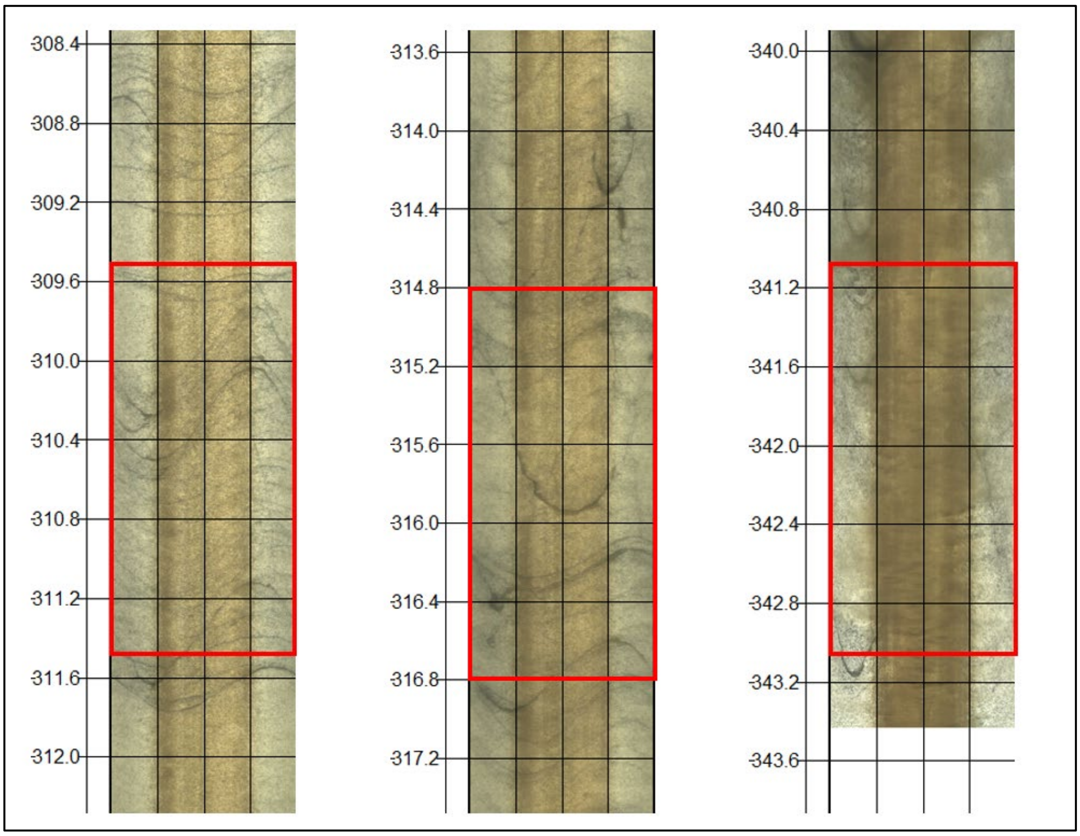

Abb. 13 Optical televiewer images of the intervals below 309.5 m, 314.8 m and 341.1 m

Attachment 2

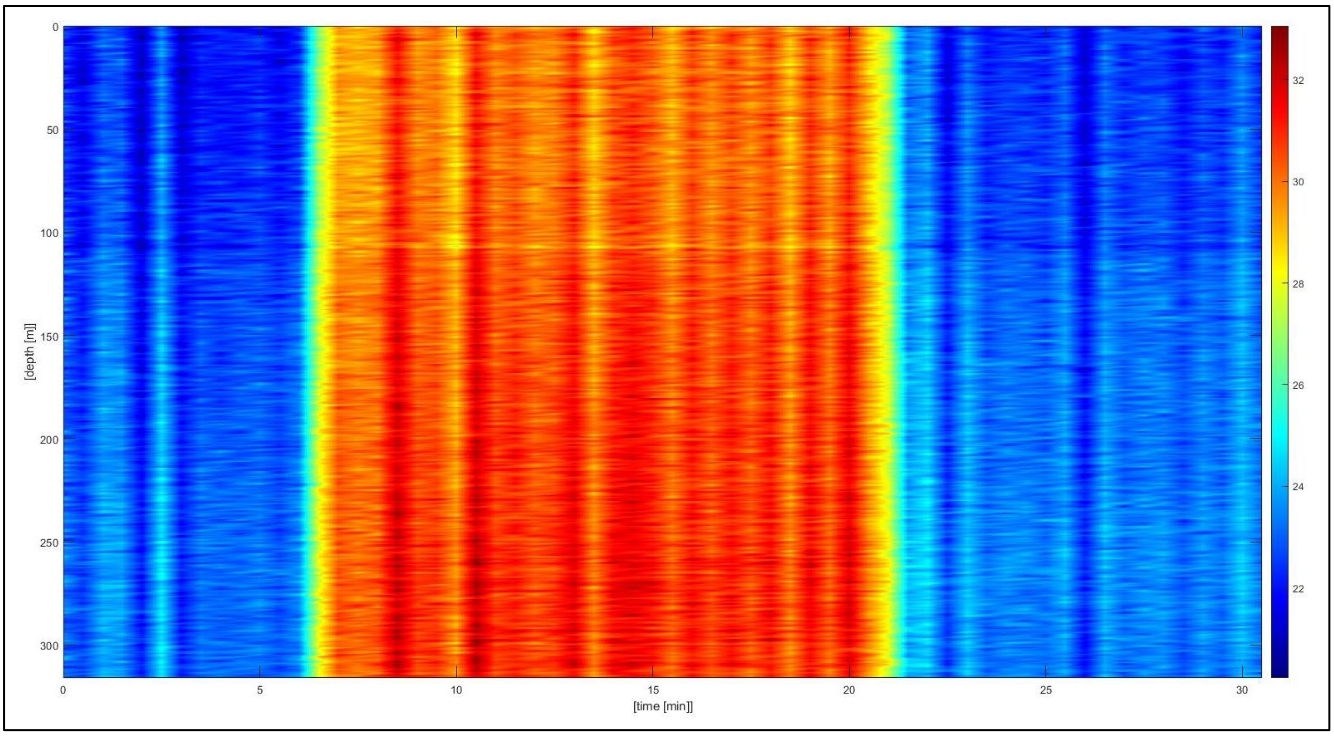

Fig. 15 FO-DTS logging in borehole ST1 with heating phase from minute 6 to 21; hydraulically active fracture coulter at 109.5 to 112.5 m

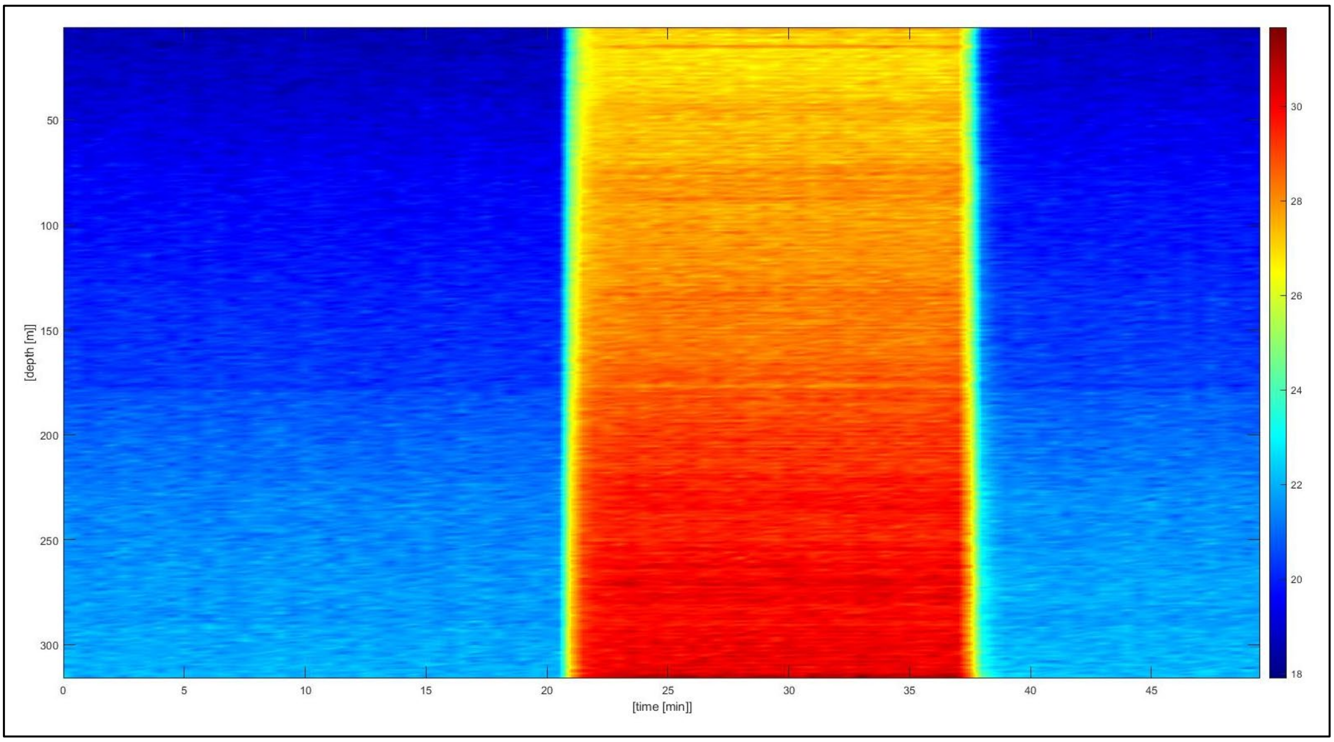

Fig. 16 FO-DTS logging in borehole ST2 with heating phase from minute 21 to 37; hydraulically active single fracture at approx. 179 m

Attachment 3

Success control report

The contribution of the presented results to the funding policy objectives consists primarily in pointing out the need for further research in the field of pre-damage of the rock mass by notching and micro-drilling. As secondary results, knowledge was gained about the application possibilities of FO-DTS systems for the identification of hydraulically active structures in boreholes and information about the stress field in the area of the Bedretto Gallery. Furthermore, valuable practical experience was gained in working in inclined boreholes with partly fissured borehole walls, as this poses special challenges to the work with logging equipment and especially fibre-optic measurement systems.

The Chair of Engineering and Hydrogeology at RWTH Aachen University has not applied for any patents or other comparable property rights in connection with Zodrex.

The work carried out has mostly led to solutions, but has been limited in places by the considerable time delay as well as the measures ordered in the wake of the Covid-19 pandemic, especially with regard to travel.

The timetable was met thanks to the approved extension of the term and the expenses were lower than originally estimated due to said restrictions in the terrain activity.