EEIG
Route de Kutzenhausen
F-67250 Soultz

Short Note on

Strategy Planning

for the Stimulating of GPK4

Technical Note

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1 Aim

Design of an advantageous injection strategy for GPK4, to improve the borehole wall transmissibility in the deep part of the open hole (OH) section.

2 Method

Numerical HEX-B tool (see TN XXX) to predict the pressure development in the OH-section with respect to the near-borehole microseismicity, accounting for technically controllable parameters as flow rate, injection temperature and fluid density.

3 Input-model

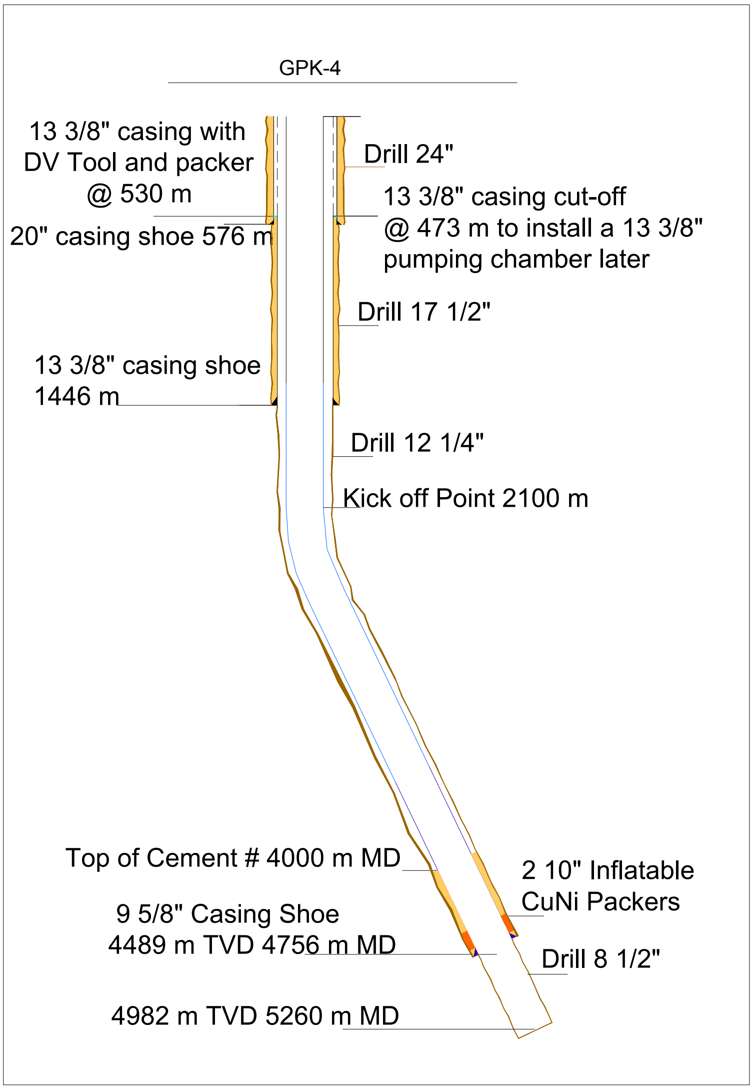

Figure 1: Model design

4 Flow log

Table 1 shows the fracture-frequency in the OH section of GPK4, which has been determined from UBI logging. We assume, that a flow log would indicate fluid losses into the rock matrix with identical percentage as the fracture-frequency. Consequently, the flow rate along the borehole is then determined.

Table 1: Fracture-frequency from the UBI log in GPK4 in the OH section zone and corresponding flow rate percentage

Depth-interval	Fracture-frequency	Fracture-frequency %	Flow-rate %
until 4800 m	0	0.0	100.0
4800 - 4900 m	7	17.1	82.9
4900 - 5000 m	10	24.4	58.5
5000 - 5100 m	7	17.1	41.5
5100 - 5200 m	11	26.8	14.6
5200 - 5300 m	6	14.6	0.0
Total	41	100.0	

5 Minimum failure pressure

Another assumption of the present analysis concerns the validity of GPK4 failure pressures for near-borehole seismic events. The GPK3 measurements are taken to be generally valid for the rock mass at 4000-5000 m in Soultz and allow to convert the GPK3 data into depth-pressure couples for GPK4, correcting for the trajectories of both boreholes.

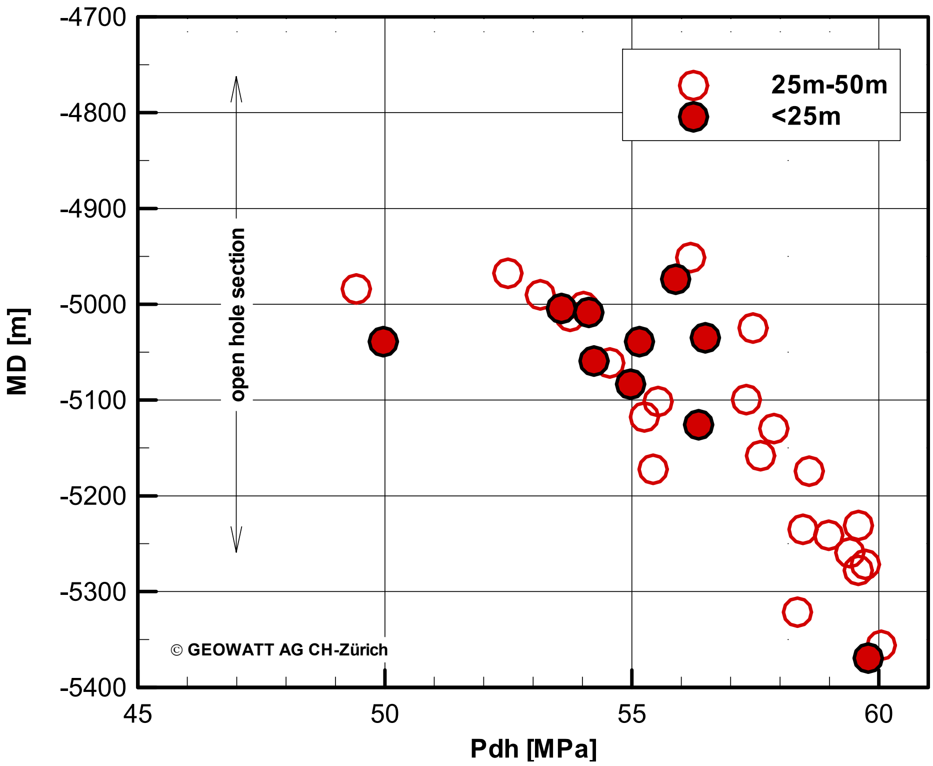

Figure 2: predicted minimum failure pressure in the OH section of GPK4, with respect to the near-borehole microseismic events (horizontal distance to the borehole < 25 m and 25-50 m) during the first 24 hours of the GPK3 stimulation test 03may27

6 Numerical Simulation

The objective of the massive injection test is to stimulate the largest possible number of deep fractures at the earliest moment. A first stimulation of the deepest fractures implies to quickly increase the hydraulic pressure at the bottom of GPK4, and to achieve a high pressure gradient in the OH section.

The pressure gradient can be increased by initially injecting brine under careful, low-rate injection. The applied pressure in the borehole needs to remain under the minimal failure pressure level (red points in Figure 2). Once the brine has reached the bottom, the flow rate can be increased to stimulate the fractures.

The numerical simulation determined the following parameter:

- Maximal initial flow rate by a given injectivity in the OH section, to be used to remain under the minimal failure pressure level.
- Necessary NaCl-quantity (→ time) to reach the bottom of the borehole by given flow rate and injectivity.

Given Parameters:

- Constant injection-temperature of 22 °C
- Injectivity in the open hole section of 0.2 respectively 0.4 l/s/MPa
- Initial temperature profile: calculated from the one of GPK3.
- Initial NaCl-molality profile: linear increase from 0 mol/Kg at the surface to 1.8 mol/Kg (correspond to 1060 Kg/m^3) at 5260 m depth.

7 Results

The given initial state in the borehole of temperature and NaCl-molality results in an initial pressure state (Figure 3: pressure profile at $t=t_0$). During the brine injection (NaCl-molality = 6) the minimum failure pressure has not to be exceeded. Depending in the OH injectivities the maximum flow rate is 0.5 l/s at OH injectivity of I_A=0.2 l/s/MPa and 1.0 l/s for OH injectivities of I_B=0.4 l/s/MPa. These low flow rates would increase the bottom hole pressure by ~2.5 MPa (time t_1). With the assumed injectivity profile (Table 1) the brine takes 460'000 s (I_A) or respectively 230'000 s (I_B) to reach the bottom hole (Figure 3: identical pressure profiles for both, I_A and I_B at $t=t_2$). With the brine injection the pressure decreases at the casing shoe (z=-4700m) by 1 MPa, and correspondingly, the pressure gradient will increase along the OH section.

When increasing flow rate the pressure profiles would develop nearly parallel for constant injectivities. However, already at flow rates of 2.5 (I_A) and 5.0 (I_B) l/s the critical pressure in the rock would be surpassed along the total of the OH section (Figure 3: pressure profiles at $t=t_3$). Therefore, for the given low injectivity it can be expected first stimulation effects can be expected already at very moderate flow rates.

Figure 4 and Figure 5 resume the considered injection history for the two injectivities.

8 Conclusion

The injection of saline brine will result in a 1 MPa pressure reduction at the casing shoe. At constant injectivity, an increase of flow rate will result in a near-linear increase of the pressure profile. Note, the first injectivity increase in a given fracture zone along the OH section can have a strong influence on this forecast. With first flow logs and injectivity measurements in hand a more sophisticated prognosis can be provided.

According to this analysis, the required stimulation pressure difference increases with depth. Therefore, the chances for the stimulation of deeper fracture clusters will increase with a sudden pressure "shock". Low injection flow rates have the potential to stimulate just upper depth ranges. It needs to be kept in mind that this statement also applies to low-rate pre-stimulation injection tests.

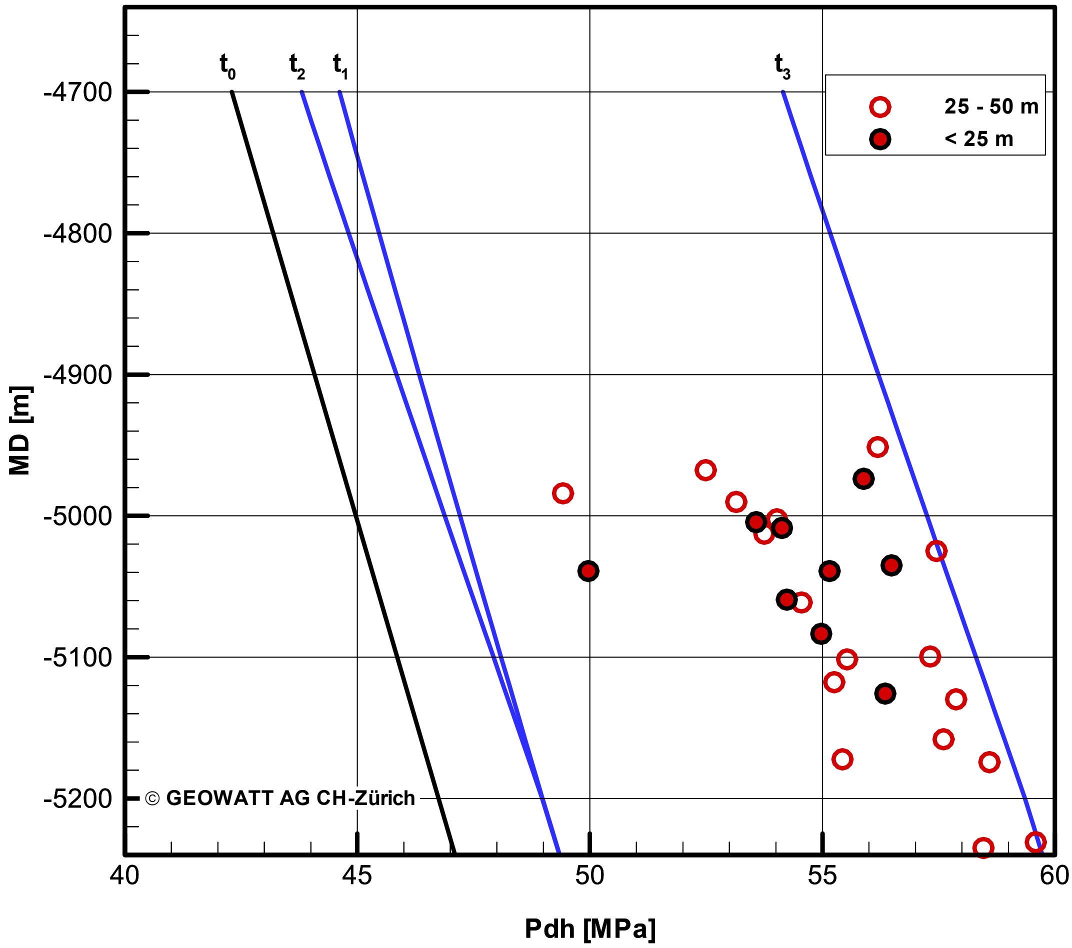

Figure 3: Pressure trend in the OH section. t_0 correspond to the initial state (Q = 0 l/s), t_1 to the state at the beginning of brine injection (Q = 0.5 respectively 1.0 l/s). By t_2 the brine has reached the bottom hole. At t_3 an increase of flow rate is assumed (see text).

<u>Injectivity in OH section = 0.2 l/s/MPa</u>

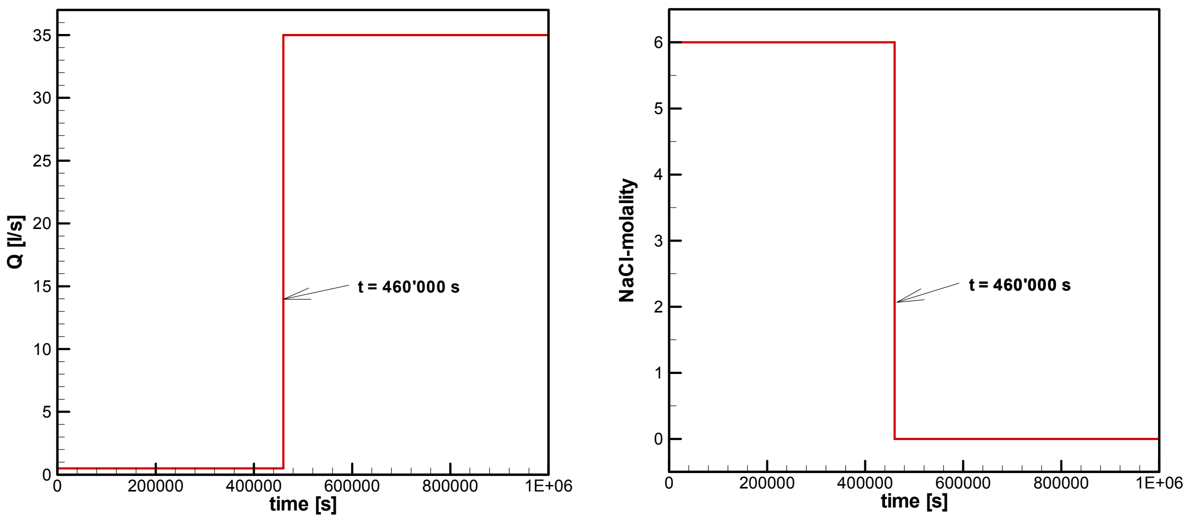

Figure 4: Injection strategy for an injectivity in the OH section of 0.2 l/s/MPa

<u>Injectivity in OH section = 0.4 l/s/MPa</u>

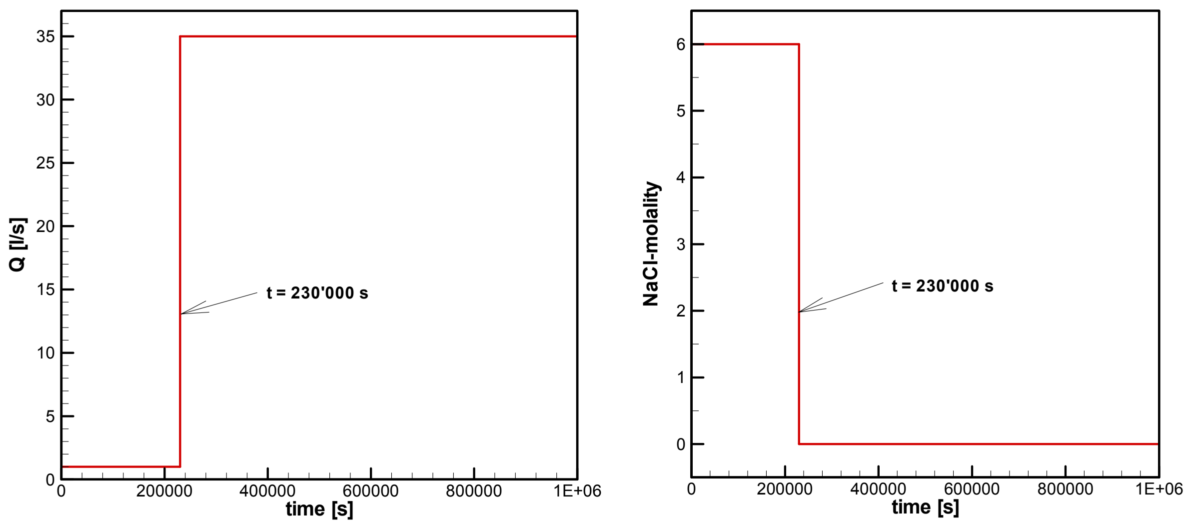

Figure 5: Injection strategy for an injectivity in the OH section of 0.4 l/s/MPa