Reuse of Hydrocarbon Wells for Enhanced Geothermal System Development

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Background

The hydrocarbon industry leaves behind millions of deep wells and the environmental risks of abandonment, while many hydrocarbon basins have temperatures sufficient for geothermal energy extraction. Harnessing this infrastructure and data for the development of Enhanced Geothermal Systems (EGS) is one option for repurposing abandoned or end-of-life hydrocarbon wells. Earlier EGS demonstration projects show that reuse of existing data and infrastructure can significantly reduce both costs and risks. Based on the experience of the EGS pilot site Groß Schönebeck, this study aims to develop an engineering workflow for the reuse of hydrocarbon wells. Procedures for the reuse of hydrocarbon wells have been summarized in order to provide a sound framework and workflow for the assessment of existing conditions which are suitable for the development of EGS in the North German Basin.

1 Identifying the potential of geothermal resource of hydrocarbon basins

The North German Basin (NGB) is part of the Central European Basin System (Figure 1). It reflects a low-enthalpy geothermal setting (Norden et al., 2023). With a temperature gradient of ~30℃/km and a depth of up to 7 km, the NGB has enormous geothermal resources of 2100 EJ (exajoules), consisting of 96% petrothermal systems (2016 EJ), 4% fault zones (84 EJ) and 1% hydrothermal systems (21 EJ) (Jung et al., 2002).

The North German Basin therefore has strong potential for petrothermal energy resources suitable for the development of EGS.

In the TRANSGEO project, the North German Basin is one of the basins investigated for hydrocarbon well reuse demonstration.

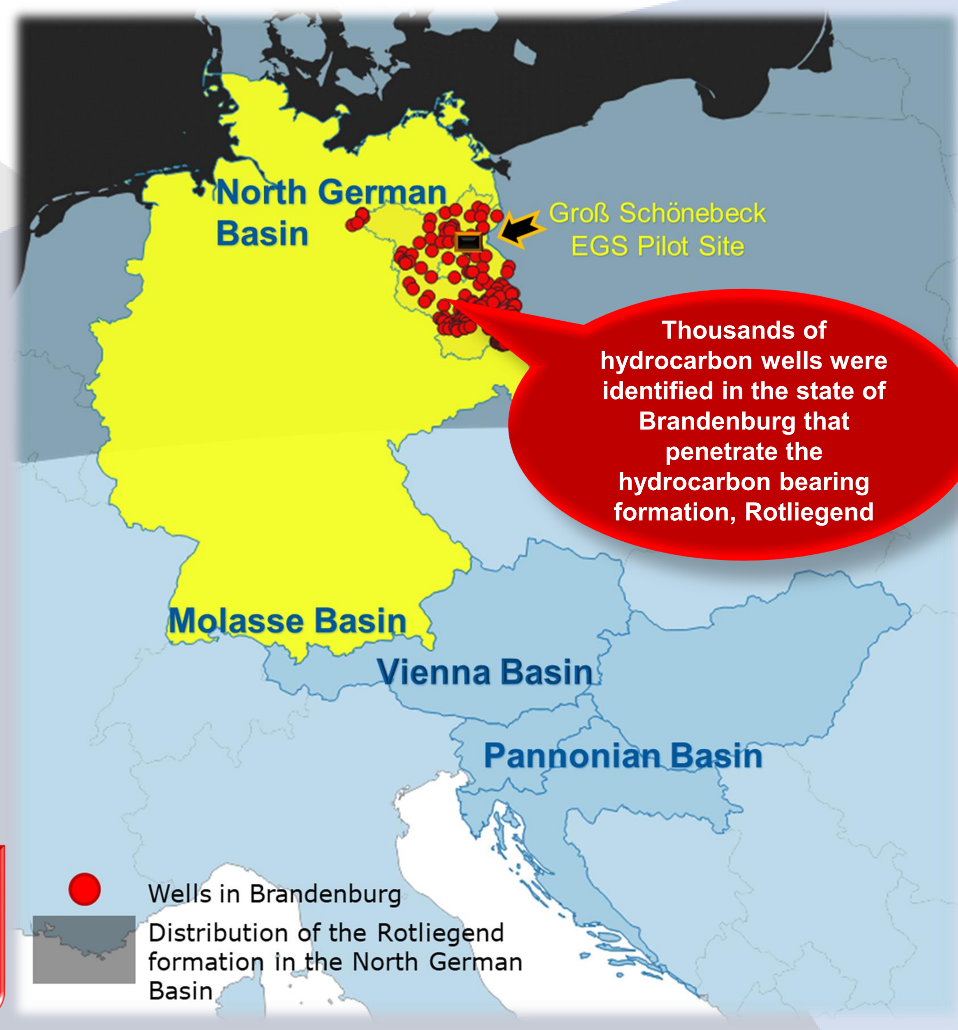

Figure 1. Potential of geothermal resource of hydrocarbon basins

2 Geothermal resource and well integrity assessments at Groß Schönebeck pilot site

E GrSk 3/90, an abandoned gas exploration well drilled in 1990, was re-opened, re-drilled, cleaned and deepened to 4294 m in 2000. A series of logging runs and well tests were then conducted in the borehole for initial assessment of well productivity and integrity.

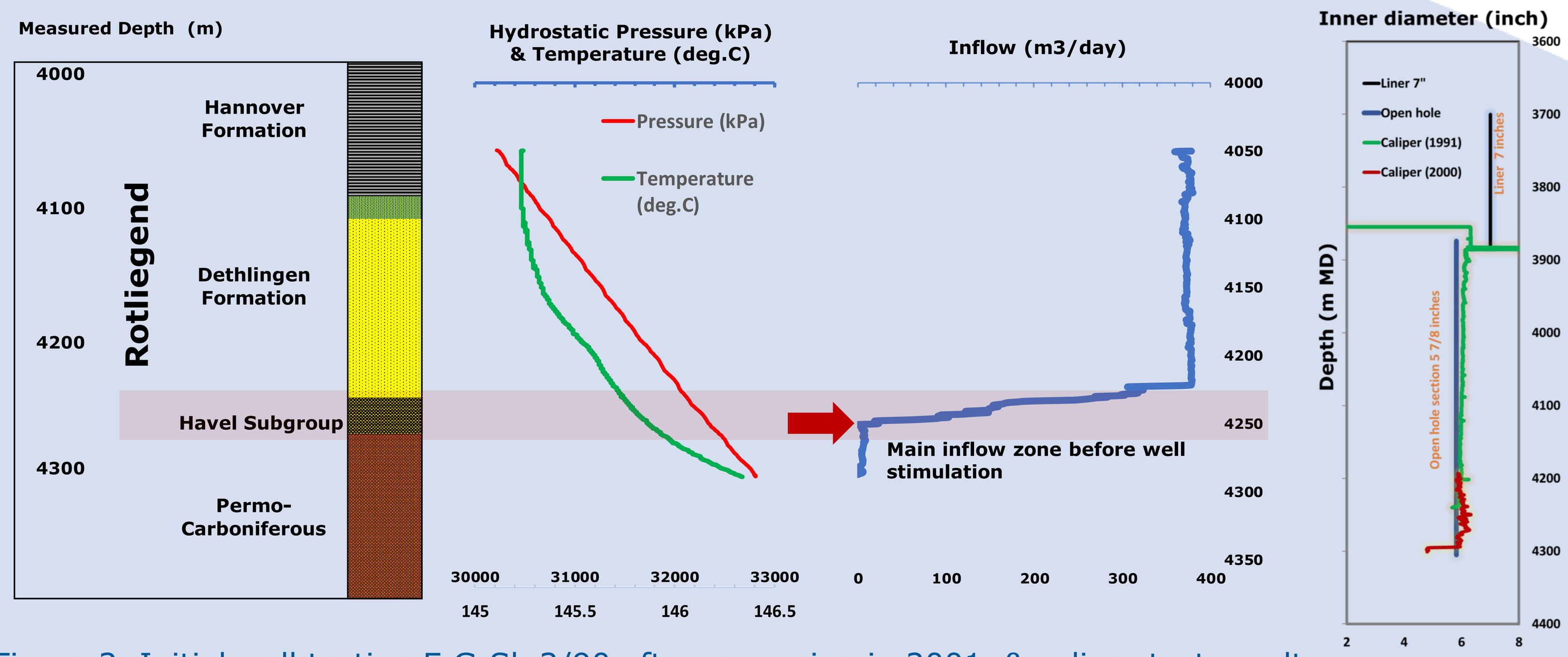

Figure 2. Initial well testing E GrSk 3/90 after reopening in 2001 & caliper test results

The initial condition of E GrSk 3/90 (Figure 2) shows that the bottom hole temperature is about 146 ℃ and the inflow of the reservoir fluid from the lower part of the Rotliegend formation, Havel subgroup formation is about 375 m3/day. The rest of the Rotliegend formation has no flow. The inflow is not sufficient for geothermal production. EGS technology is therefore the best option for developing Groß Schönebeck.

3 Well workover and matrix-dominated EGS development concept at the pilot site Groß Schönebeck (2000 – 2010)

Workover workflow after re-opening E GrSk 3/90 (injection well)

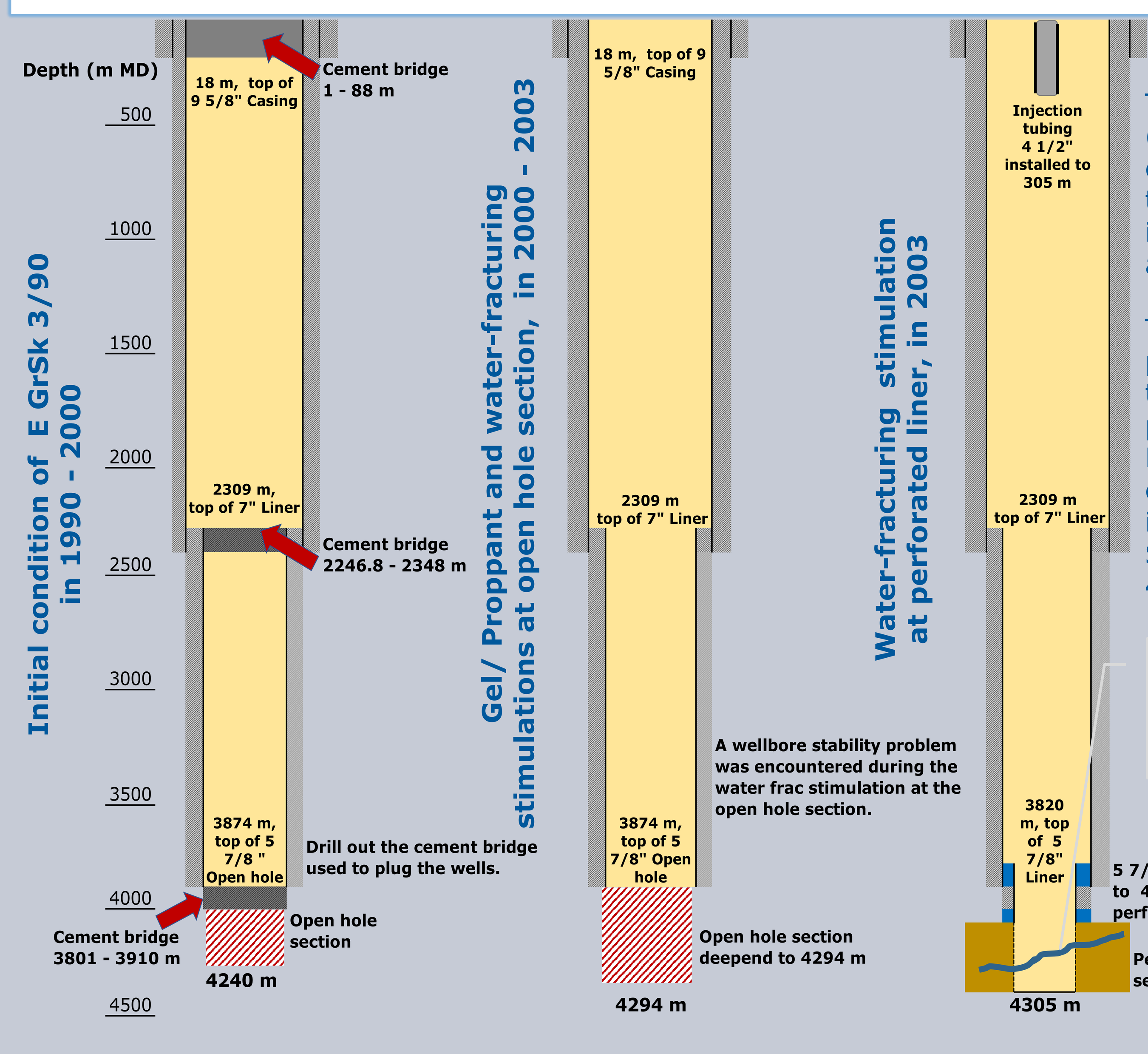

Figure 3. Development of injection well completions & stimulation treatments

Points of Groß Schönebeck doublet wellbore configuration

The well path geometry as shown in (Figure 4) of Gt GrSk 4/05 was determined based on the hydraulic-thermal modelling of E GrSk 3/90 incorporating regional structure analysis.

The design of the wellbore spacing provides a low risk of system thermal short-circuit within the projected thirty-year operation life. For this reason, the bottom-hole distance between production and injection wells at the Gross Schönebeck EGS pilot site was set at 472 m (Huenges et al., 2007).

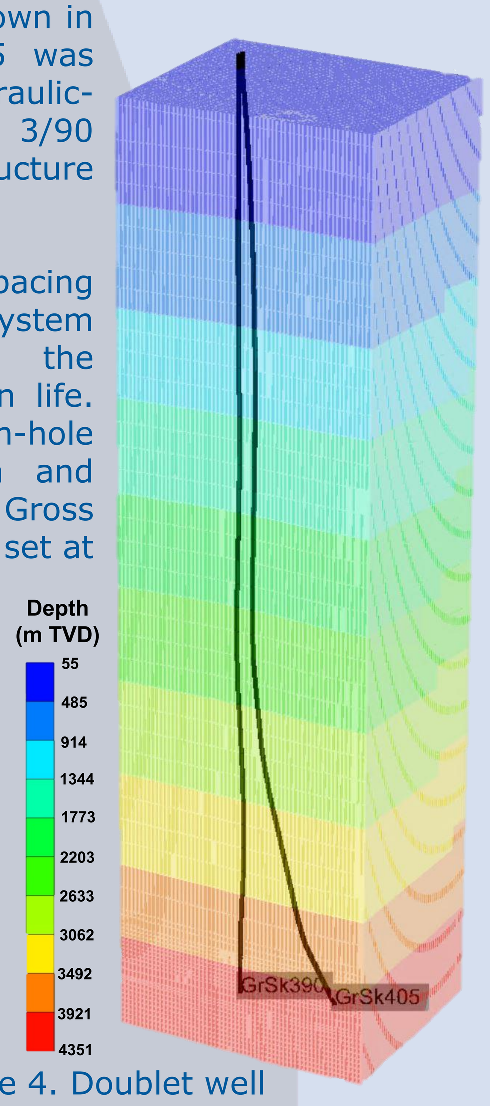

Figure 4. Doublet well configuration

Drilling new well Gt GrSk 4/05 in 2006 (production well)

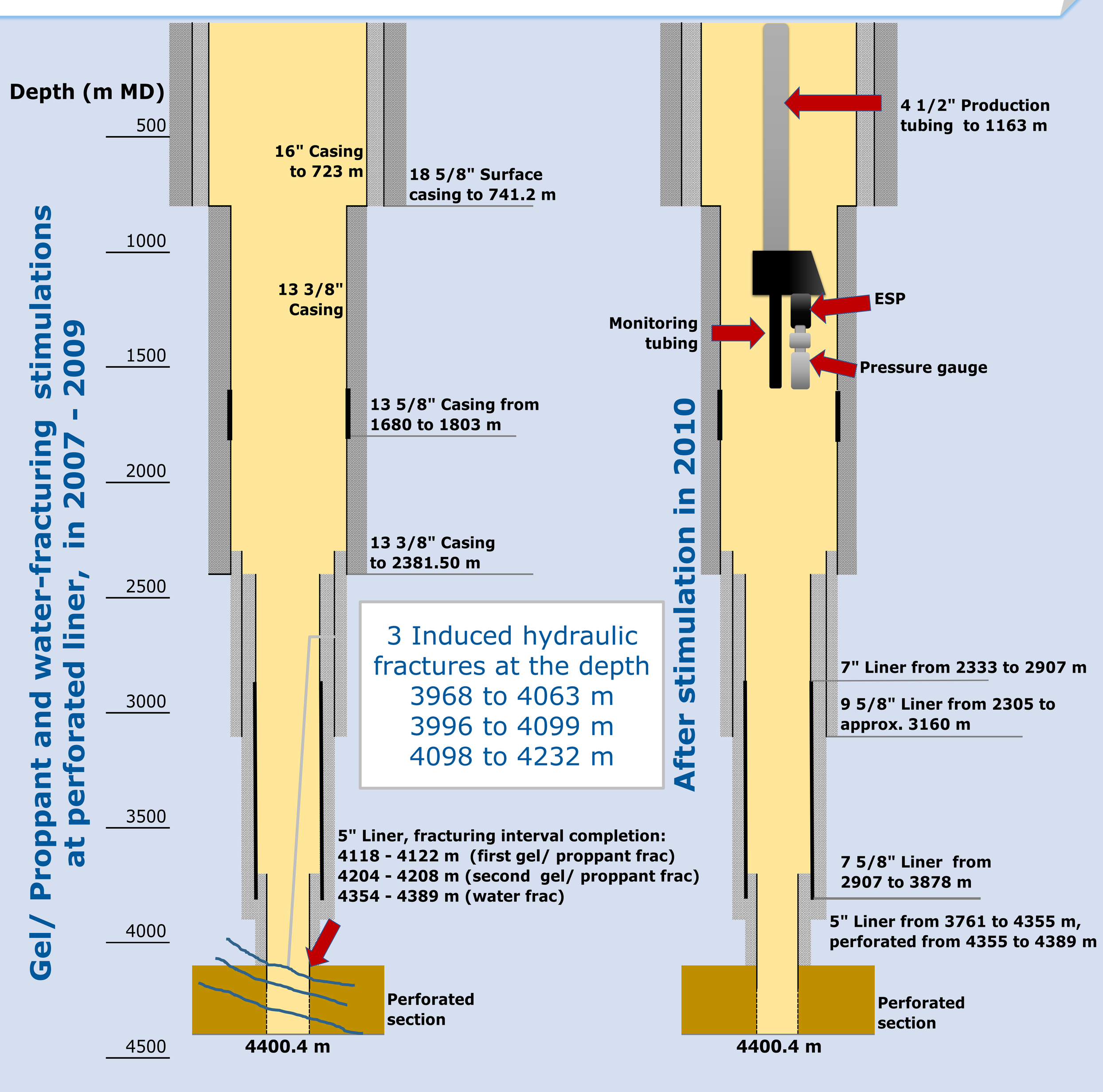

Figure 5. Development of production well completions & stimulation treatments

4 Reservoir model validation using numerical simulation

In this study, the past multi-stage fracturing treatments to develop a matrix-dominated EGS were modelled using the commercial finite difference reservoir simulator CMG STARS. The model was constructed using previous rock and fracture parameterization. Hydraulic test data was used for history matching. The calibrated model will be used for forward modeling studies to demonstrate a state-of-the-art multi-stage stimulation concept with two horizontal wells based on the Groß Schönebeck EGS pilot site that can be extended over the whole North German Basin.

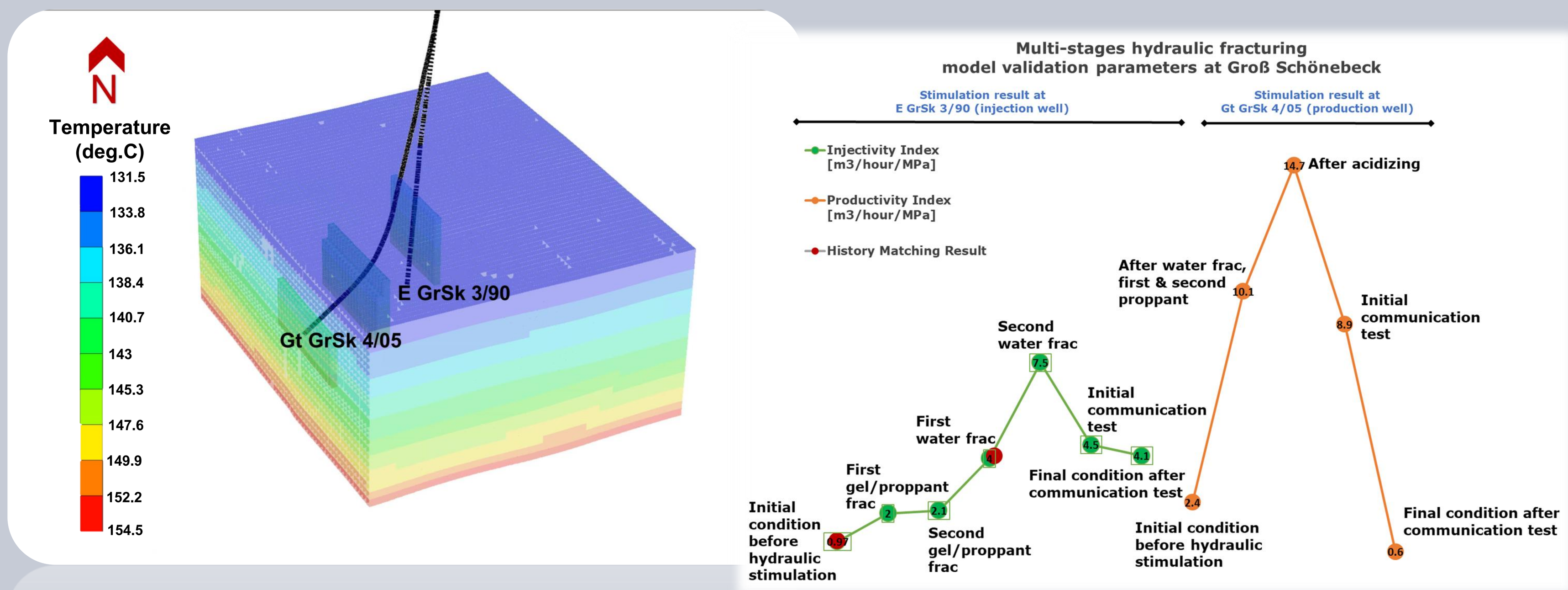

Figure 6. Multi-stage fracturing model setup & validation parameters at Groß Schönebeck

5 Summary and Outlook

(1) The engineering workflow of EGS development, based on the experience of the Groß Schönebeck EGS pilot site, can be summarized as follows:

Geothermal resource identification, well evaluation, re-opening of the well, well testing, reservoir simulation to develop a field development scenario, well modification or rehabilitation, hydraulic stimulation.

(2) Further work will focus on the optimization of the EGS development concept using the validated numerical model and on the feasibility of reusing hydrocarbon wells for EGS development in the North German Basin, the South German Molasse Basin, the Vienna Basin and the Pannonian Basin.

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