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Numerical modelling of hydraulic and thermal processes in the deep heat reservoir of the EGS test site Soultz-sous-Forêts, France

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A tracer test was performed in 2005 within the European Enhanced-Geothermal-System research project at Soultz-sous-Forêts in France to study the hydraulic system. This test is used to calibrate a model for predictive simulations of the long-term heat extraction of the reservoir using the finite element code SHEMAT (Clauser 2003).

The Enhanced-Geothermal-System in Soultz-sous-Forêts comprises three wells, which are aligned in North-South direction: GPK3 in the centre is the injection well, GPK2 and GPK4 are the production wells located in 600 m distance from the injection well. They reach a depth of approximately 5000 m where temperature reaches 200 ˚C are measured. Granite is the dominating rock type within the heat reservoir. Based on the concept of Gérard (2006), the 2D model comprises four structural units: two nearly vertically dipping fracture families (1); a highly altered fracture between GPK3 and GPK4 (2); mechanically stimulated zones around the wells (3). A direct hydraulic connection between the three wells is assumed by a single conductive fracture (4).

Results of the simulations demonstrate a varying impact of the structural units on the breakthrough curve. The fracture families do not influence significantly the tracer breakthrough. Depending on its conductivity, the highly altered fracture between GPK3 and GPK4 leads to drainage of the tracer or it acts as a barrier for the tracer. As a result, the concentration detected at GPK4 is reduced in both cases. The mechanically stimulated zones around the wells are responsible for the characteristic tailing of the tracer breakthrough. The single conductive fracture between the wells is required for the early tracer arrival times at the discharge wells.

A parameter study was performed to determine the significance of the hydraulic parameters porosity and permeability within the different structural zones. The parameters were varied separately for each structural unit. Then, and the result was compared with the reference simulation. A reduction of porosity in the single conductive fracture, for instance, yields an earlier arrival of the tracer breakthrough and a higher maximum concentration. Increase of porosity in the stimulated zones around the wells yields a lower peak concentration, while it does not affect the time of the tracer breakthrough.

Based on the results of the parameter study the model which fits the data best was chosen for a long-term simulation of 20 years of heat extraction. The direct hydraulic connection between GPK3 and GPK2 causes an early decrease in temperature in GPK2. With pumping rates identical to the hydraulic test, the average temperature begins to decrease after one year and decreases to temperatures of 170 ˚C after two years. The decrease in temperature slows down after two years and reaches values of 130 ˚C after 20 years. The cold injected water reaches the discharge wells too quickly to be heated up sufficiently on its way. Models with enlarged thicknesses of the reservoir show a delayed onset of temperature decrease.

With decreasing temperatures, the efficiency of the geothermal power plant also decreases. The long-term simulation with pumping rates equal to the hydraulic test yields a thermal power of 9 MW during the first year and of 4.6 MW after 20 years. Within the assumptions of this model, an improved thermal yield of the heat reservoir requires a longer flow path of the injected cold water in the heat reservoir at depth.

Clauser C (2003) Numerical Simulation of Reactive Flow in Hot Aquifers - SHEMAT and Processing SHEMAT. Springer Verlag, Heidelberg.

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