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Quantification of heat mining in the Malm aquifer of the Bavarian Molasse Basin

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Geothermal energy is a key technology for the transition from fossil ressources to renewable energy. The Bavarian Molasse Basin offers unique geological and hydrogeological conditions for district heating and heat and power generation. With 15 plants operating and another dozen in construction or planning, exploration is highly successful. However, detailed knowledge about the processes occuring in the aquifer which is crucial to run geothermal facilities efficiently and economically, still is scarce.

After more than 10 years of operation there is a good record of the hydraulics and the hydrochemistry at the production well, including numerous data from pump failures and the development of precipitates. The injection well and its surrounding, however, is usually a black box which is not readily accessible. Here, not even the temperatures in the immediate vicinity have been measured. Nevertheless, the performance of the aquifer near the injection well controls the long-term operation of the geothermal system.

Thanks to an extension of the Pullach geothermal facility with a third well in 2011 there was a unique opportunity to produce water from a former injection well after 5 years of operation. Since the start of the production from this well in 2012, we collected an extensive data set of hydraulic, thermal and hydrochemical data.

Within the first two years after reverting the flow direction and at a production rate of 20 L/s, which is significantly lower than the injection rate of up to 35 L/s, the temperature at the well head increased with a rate of 10 K/a. These temperatures were compared with predictions from the initial heat mining model, which was then refined. From the data it was immediately obvious that a homogeneous treatment of the Malm aquifer is not applicable. Instead a heterogeneous flow regime has to be assumed to account for the fast initial increase of the temperatures which is caused by a higher effective exchange area. The results suggest that the regeneration time of the cooled reservoir in this setting is not too much longer than the injection period. Heat energy is primarily supplied by the water drawn to the well and heat conduction in low flow zones. This has to be taken into account when designing future facilities with more wells.