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Increase of productivity in the Riehen geothermal system (Switzerland): Tracer test and reservoir model

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The geothermal system in Riehen is in operation since 1994 and produces 65°C thermal water from the Upper Muschelkalk at a depth of 1547 m with a production rate of 18 l/s. It is used to feed the district heating system of Riehen (Switzerland) and Stetten (Germany) and supplies a thermal energy of 26'000 MWh per year to 202 consumers. With the project "Riehen Plus" it is planned to increase the production rate to 23 l/s.
The aim of this study is to investigate possible consequences of the increase in productivity to the geothermal system. Thus, a detailed 3D geological model has been built and verified using gravity data. From Nov/2009 to Dec/2010 a tracer test has been carried out to investigate the return of injected water in the production well.
Riehen is located at the Eastern boundary of the Upper Rhine valley with SSW-NNE-striking boundary faults. The development of the Upper Rhine graben in the Oligocene caused the formation of many small tectonic units. It is assumed that the sediments with the geothermally relevant Upper Muschelkalk in this area are highly fractured.
The 3D model aims to reproduce the major fracture systems which are expected to be represented by the fault zones to the depth of the reservoir. It is based on seismic lines, surface geology and borehole data. Geochemical analyses, however, indicate that a contribution from deeper circulation cannot be excluded. Therefore, gravity has been used to investigate the structures below the Muschelkalk. After reducing the regional trend from the Bouguer anomaly using a Butterworth filter with a wavelength of 50 km, strong gradients in the residuals have been observed in the area of the reservoir. These changes are attributed to different structures in the shallow and deep subsurface. In the strongly fractured zone of the Rheinfelder fault a decrease in density is observed probably caused by the increase of porosity through fracturation. An E-W striking Permo-Carboniferous trough is observed in the southern part of the modeled area, indicated by a negative anomaly and a positive anomaly is probably due to differences in the granitic basement itself.
An earlier pumping test and numerical thermo-hydraulic simulation have shown that the tectonic block on which the reservoir is located can be assumed to be semi-open, i.e. there is a strong circulation within the tectonic unit, but communication with a more regional system to the N and the S is most likely. As conservative tracer 10 kg Uranine has been injected into the injection well in order to investigate a possible connection between the producer and injector. The tracer could not be recovered at all in the period of the experiment. Laboratory experiments, however, confirm that Uranine can be used as conservative tracer in this environment. Thus, the zero recovery of the tracer may indicate a large scale circulation system, as suggested also in the pumping test.
The joint interpretation of tracer test and 3D geological system favors the interpretation of a semi-regional system possibly with an additional lateral fault between the producer and injector inhibiting the circulation between the two.