Geophysical Research Abstracts
Vol. 17, EGU2015-10503, 2015
EGU General Assembly 2015


# Permeability in fractured rocks from deep geothermal boreholes in the Upper Rhine Graben

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The thermal regime of the Upper Rhine Graben (URG) is characterized by a series of geothermal anomalies on its French part near Soultz-sous-Forêts, Rittershoffen and in the surrounding area of Strasbourg. Sedimentary formations of these areas host oil field widely exploited in the past which exhibit exceptionally high temperature gradients. Thus, geothermal anomalies are superimposed to the oil fields which are interpreted as natural brine advection occurring inside a nearly vertical multi-scale fracture system cross-cutting both deep-seated Triassic sediments and Paleozoic crystalline basement. The sediments-basement interface is therefore very challenging for geothermal industry because most of the geothermal resource is trapped there within natural fractures. Several deep geothermal projects exploit local geothermal energy to use the heat or produce electricity and thus target permeable fractured rocks at this interface.
In 1980, a geothermal exploration well was drilled close to Strasbourg down to the Permian sediments at 3220 m depth. Bottom hole temperature was estimated to 148°C but the natural flow rate was too low for an economic profitability (<7 L/s). Petrophysics and reservoir investigations based on core analysis revealed a low matrix porosity with fracture zones spatially isolated and sealed in the sandstone formations. Any stimulation operation was planned and the project was abandoned.
The Soultz-sous-Forêts project, initiated in 1986, explored during more than 30 years the experimental geothermal site by drilling five boreholes, three of which extend to 5 km depth. They identified a temperature of 200° C at 5 km depth in the granitic basement but with a variable flow rate. Hydraulic and chemical stimulation operations were applied in order to increase the initial low permeability by reactivating and dissolving sealed fractures in basement. The productivity was considerably improved and allows geothermal exploitation at 165° C and 20 L/s. Recent studies revealed the occurrences of permeable fractures in the limestones of Muschelkalk and the sandstones of Buntsandstein also.
For the ongoing project at Rittershoffen, two deep boreholes, drilled down to 2.7 km depth target a reservoir in the sandstones of Buntsandstein and in the granitic basement interface. The thermal, hydraulic and chemical stimulations of the first well lead the project to an economic profitability with a temperature of 170° C and an industrial flow rate of 70 L/s.
The deep sedimentary cover and the top of the granitic basement are the main target of the geothermal project in the URG. Permeability of fractured rocks after drilling operations or stimulation operations demonstrates the viability of French industrial deep geothermal projects in the URG was also confirmed by several geothermal projects in Germany that target the similar sediments-basement interface (Landau and Insheim) or the deep Triassic sediments (Bruchsal and Brühl). In France, future geothermal projects are planned in particular in Strasbourg suburb to exploit the permeability of deep-seated fractured sediment-basement interface.