EGW 2019

7th European Geothermal Workshop
Karlsruhe, 9-10 October 2019

Contribution ID: **97** Type: **Poster**

Numerical modeling of thermal front propagation caused by fluid injection in a fractured reservoir for forecasting thermal-induced seismicity

Wednesday, October 9, 2019 9:00 AM (20 minutes)

In this work, the propagation of a thermal-hydraulic front caused by cold fluid injection is investigated, using a finite element (FE) model. The objective of the work is to simulate the propagation of temperature changes in the subsurface and to quantify the resulting thermally induced stresses. The model is based on a typical setup of a geothermal powerplant in the greater Munich area. In the vicinity of the injection well of the powerplant seismic events occurred five years after commissioning.
The powerplant uses the Malm aquifer as a geothermal reservoir and reinjects cold fluid in the vicinity of a fault zone. In order to approach to the complex reservoirs'hydrogeology and the fault zone characteristics, a mesh generator was created using MATLAB. The generator creates a model based on regular cube-shaped elements, which can be separately parameterized and thus grouped to geological units. Furthermore, the cube's surfaces can be integrated as discrete, two-dimensional elements, which can also be separately parameterized. Thus, a 3D model was created with a reservoir containing a regularly distributed fracture network and fault zone. A scenario analysis was used to investigate the influence of the fault and the fractures on the thermal-hydraulic front propagation.
The results of the simulations show that especially the fracture network can significantly influence the range of the area influenced thermally by fluid injection. The fluid flow within the fault zone can lead to temperature changes in several hundred meters underneath the transition zone from the reservoir to the crystalline basement of several degrees. To quantify the resulting thermo-hydraulic stresses analytical approaches were used. The results show that the thermal-induced stresses exceed the hydraulic induced stresses clearly. In total, the changes of the stresses caused by the fluid injection are ranging in orders of magnitude which can affect a fault's integrity.

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Session Classification: Poster Session

Track Classification: Topic 4: Resource Development