Geophysical Research Abstracts
Vol. 17, EGU2015-11744, 2015
EGU General Assembly 2015
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Numerical modeling of the impact of temperature on the behavior of minerals in the Soultz-sous-Forêts enhanced geothermal system

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Operation of the enhanced geothermal system (EGS) requires to re-inject fluid, after heat exchange at the surface to the energy production, into the geothermal reservoir. This cold re-injected fluid can cause a strong disequilibrium with the fluid and granitic rock within the geothermal reservoir and then implies the possible dissolution/precipitation of minerals. The hydrothermal alterations include the transformation of plagioclase, biotite and K-feldspar and the precipitation of various secondary minerals. The major sealing phases observed in the main fracture zones are quartz, calcite, and clay minerals. These mineralogical transformations may modify the porosity, permeability and fluid pathways of the geothermal reservoir. In the Soultz-sous-Forêts EGS (Alsace, France), the hydraulic connection between the injection well and the production well is quite poor. Therefore, understanding the impact of changes in temperature, which are caused by the re-injected fluid, on the behavior of minerals (especially for the main newly-formed minerals such as quartz, calcite and clay minerals) is a critical preliminary step for the long-term prediction of their evolution. The approach used in the present work is typically based on a geochemical code, called THERMA, which enables to calculate the changes in equilibrium constants of all primary and secondary minerals and aqueous species as a function of temperature. Our model accounted for a wide range of different mineral groups in order to make sure a large freedom for the numerical calculations. The modeling results showed that when the temperature of geothermal reservoir is cooled down, quartz, calcite, illites, galena and pyrite have tendency towards equilibrium state, which indicates that they are precipitated under the geothermal conditions. In contrast, other minerals including plagioclase, K-feldspar and biotite remained unsaturated. These behaviors of minerals were further illustrated by the Khorzinsky stability diagrams, which are based on the activities of different species such as H4SiO4, Ca2+, Mg2+, and Al3+ and take into account partial CO_2 pressure,. The modeling results further suggested that we should pay a special attention to the main minerals (e.g., quartz, calcite and illites) when studying the changes in porosity and permeability of the geothermal reservoir. This study was preparing a simulation of water-rock interaction processes related to these temperature conditions.