Thermodynamic and kinetic modeling of mineralogical evolution in the Soultz-sous-Forêts geothermal system: insights into the reaction pathways

Viet Van Ngo, Yann Lucas, Alain Clément, and Bertrand Fritz

Université de Strasbourg/EOST, CNRS, Laboratoire d'Hydrologie et Géochimie de Strasbourg, 1 rue Blessig, F-67084 Strasbourg Cedex,France

Email adresses: Viet V. Ngo (vvngo@unistra.fr); Yann Lucas (ylucas@unistra.fr); Alain Clément (aclement@unistra.fr); Bertrand Fritz (bfritz@unistra.fr)

The energy production from hot fractured rocks has been investigated at the Soultz-sous-Forêts EGS (Alsace, France) from nearly three decades. Three wells have been drilled up to the depth of about 5000 m in which two wells are served as the fluid production and the third as a fluid re-injection. The circulation of geothermal fluids through the fractured reservoir leads to a strong chemical nonequilibrium of the solid and aqueous phases, which potentially cause changes in porosity, permeability, and flow pathways of the geothermal reservoir. Numerous experimental and modeling studies (e.g., Dubois et al., 2000; Baldeyrou et al., 2003; Ledésert et al., 2009; Fritz et al., 2010; Ledésert et al., 2010) carried out within the framework of the Soultz-sous-Forêts system have reported that quartz, calcite and illites are formed as the major secondary phases in the main fractures. Some contributions among the above publications further indicated that calcite plays an important role in the reduction of permeability of the fractured zones and illites are considered as a characteristic product of the hydrothermal vein alteration. Therefore, it is important to predict the evolution of minerals (especially for quartz, calcite, and illites), which may potentially modify the transport properties of the geothermal reservoir (e.g., Ledésert et al., 2009; Fritz et al., 2010). Understanding the changes in mineralogy in the fractured zones is also useful to choose the reagents in order to improve the permeability of the geothermal reservoir via the chemical stimulation. The overall objectives of the current study are to (i) investigate the long-term evolution of mineralogy in the geothermal Soultz-sous-Forêts Enhanced Geothermal System (EGS), (ii) establish the relationship between different mineral groups, (iii) study the reaction pathways, and (iv) compare the thermodynamic and kinetic approaches.

The numerical calculations carried out using the KINDIS numerical code were realized with the thermodynamic and kinetic approaches that only differ in that the precipitation of the main minerals including quartz, calcite, and illites was treated thermodynamically and kinetically. The two approaches have other identical factors such as: all primary minerals are dissolved kinetically; other secondary minerals are formed at equilibrium. The modeling results showed that reaction pathways predicted by two approaches were slightly different. The difference was clearly indicated by the precipitation amount of quartz, calcite and illites, as well as the formation patterns of these minerals. Moreover, the difference in reaction pathways was also demonstrated by the activity diagrams, which presented th@unistra.fre relationship of various mineral groups. Altogether, the system stability fell in the stability zones of the main minerals such as calcite, illites. These findings highlighted the importance of the minerals like quartz, calcite, and illites. Our work further suggested that the kinetic approach would be more appropriate for the coupled thermo-hydro-chemical model in order to predict the long term evolution of the geothermal reservoir. This method can be applied with a great benefit to other geothermal reservoirs for a better understanding of the mineralogy evolution.

References: Balderyou et al., Comptes Rendus Geoscience 335(4), 371-380; Dubois et al., Earth and Planetary Science 331(4), 303-309; Fritz et al., Comptes Rendus Geoscience 342(7–8), 653-667; Ledésert et al., Comptes Rendus Geoscience 342(7–8), 607-615; Ledésert et al., Journal of Volcanology and Geothermal Research 181(1–2), 106-114.