COTHERM: Modelling fluid-rock interactions in Icelandic geothermal systems

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Mineralogical alteration of reservoir rocks, driven by fluid circulation in natural or enhanced geothermal systems, is likely to influence the long-term performance of geothermal power generation. A key factor is the change of porosity due to dissolution of primary minerals and precipitation of secondary phases. Porosity changes will affect fluid circulation and solute transport, which, in turn, influence mineralogical alteration.

This study is part of the Sinergia COTHERM project (COmbined hydrological, geochemical and geophysical modeling of geotTHERMal systems) that is an integrative research project aimed at improving our understanding of the sub-surface processes in magmatically-driven natural geothermal systems. We model the mineralogical and porosity evolution of Icelandic geothermal systems with 1D and 2D reactive transport models. These geothermal systems are typically high enthalpy systems where a magmatic pluton is located at a few kilometers depth. The shallow plutons increase the geothermal gradient and trigger the circulation of hydrothermal waters with a steam cap forming at shallow depth. We investigate two contrasting geothermal systems: Krafla, for which the water recharge consists of meteoritic water; and Reykjanes, for which the water recharge mainly consists of seawater. The initial rock composition is a fresh basalt.

We use the GEM-Selektor geochemical modeling package [1] for calculation of kinetically controlled mineral equilibria between the rock and the ingression water. We consider basalt minerals dissolution kinetics according to Palandri & Kharaka [2]. Reactive surface areas are assumed to be geometric surface areas, and are corrected using a spherical-particle surface/mass relationship. For secondary minerals, we consider the partial equilibrium assuming that the primary mineral dissolution is slow, and the secondary mineral precipitation is fast. Comparison of our modeling results with the mineralogical assemblages observed in the field by Gudmundsson & Arnorsson [3] and by Icelandic partners of the COTHERM project suggests that the concept of partial equilibrium with instantaneous precipitation of secondary minerals is not sufficient to satisfactorily describe the experimental data. Considering kinetic controls also for secondary minerals appears as indispensable to properly describe the geothermal system evolution using a reactive transport modelling approach [4].

[1] Kulik D.A., Wagner T., Dmytrieva S.V., Kosakowski G., Hingerl F.F., Chudnenko K.V., Berner U., 2013. GEM-Selektor geochemical modeling package: revised algorithm and GEMS3K numerical kernel for coupled simulation codes. Computational Geosciences 17, 1-24. http://gems.web.psi.ch.

[2] Palandri, J.L., Kharaka, Y.K., 2004. A compilation of rate parameters of water-mineral interaction kinetics for application to geochemical modelling. U.S.Geological Survey, Menlo Park, CA, pp. 1-64.

[3] Gudmundsson B.T., Arnorsson S., 2005. Secondary mineral-fluid equilibria in the Krafla and Namafjall geothermal systems, Iceland. Applied Geochememistry 20, 1607-1625.

[4] Kosakowski, G., & Watanabe, N., 2013. OpenGeoSys-Gem: A numerical tool for calculating geochemical and porosity changes in saturated and partially saturated media. Physics and Chemistry of the Earth, Parts A/B/C. doi:10.1016/j.pce.2013.11.008