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Reactive transport modeling of the interaction between water and a cementitious grout in a fracture

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Grouting of water-conducting fractures with low-alkali cement is foreseen by Posiva (Finnish nuclear waste management agency) for the potential future repository for high-level nuclear waste in Finland (ONKALO). A possible consequence of the interaction between groundwater and grout is the formation of high-pH solutions which will be able to react with the host rock (gneisses) and alter its mineralogy and porosity.

A reactive transport modeling study of this possible alteration has been started following the recommendations from Posiva. First, the hydration of the low-alkali cement has been modeled, using results from the literature [1,2] as a guide. The hydrated cement is characterized by the absence of portlandite and the presence of a C-S-H gel with a Ca/Si ratio about 0.8 after tens of years (Ca/Si is about 1.7 in Ordinary Portland Cement). Afterwards, a one-dimensional system simulating the contact between a grouted section of a fracture and the gneiss has been studied. Diffusion is the only solute transport mechanism in this case. The results from the simulations show a very fast (days to weeks) sealing of porosity at the rock-grout interface. The precipitation of C-S-H, and also ettringite in some cases, is responsible for this fast sealing of porosity. The mixing by diffusion of a high-pH Ca-rich solution from the grout and a Si-rich solution from the rock (plagioclase dissolution) causes this precipitation.

Finally, new calculations have simulated the interaction between flowing water and grout and the alteration of the host rock as this alkaline water flows beyond the grouted section of the fracture. The calculations include the hydration and simultaneous leaching of the grout through diffusive exchange between the porewater in the grout and the flowing water in the fracture. The formation of an alkaline plume is extremely limited when the low-pH grout is used. And even when using a grout with a lower silica fume content the extent and magnitude of the alkaline plume are rather minor. These results are in qualitative agreement with monitoring at ONKALO.

[1] Lothenbach B., Wieland E. (2009) Chemical evolution of cementitious materials. In: NEA Workshop, 17-20 Nov. 2009, Brussels, Belgium. [2] Lothenbach B., Matschei T. (2009) Thermodynamic modelling: hydration modelling. In: The Fred Glasser Cement Science Symposium, 17-19 June, Aberdeen, Scotland, UK.