

Colloid nature of bentonite: Erosion in dilute groundwater

Magnus Hedström

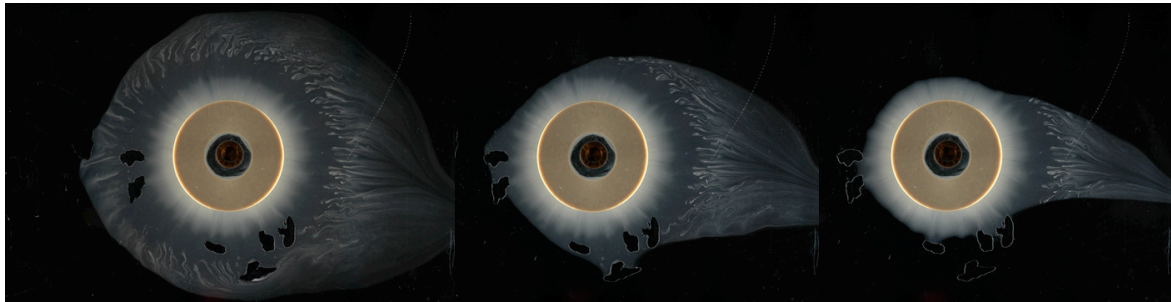


Figure 1 Top view of Na-montmorillonite in artificial fracture illustrating erosion of the sol phase.

In the Swedish KBS-3 concept for a geological deep storage of spent nuclear fuel, bentonite of high montmorillonite content is proposed to serve as a buffer surrounding copper canisters containing the spent fuel. Montmorillonite has high affinity for water which results in the build-up of a swelling pressure when bentonite, in contact with external water, is placed in a confined volume. At fractures intersecting the deposition hole the bentonite is not restricted but can continue to swell until a steady state is reached. Under present day Swedish groundwater conditions the swelling into fractures will be limited because the montmorillonite at the swelling front will coagulate. However, at the end of a glaciation one cannot exclude that glacial meltwater of low ionic strength will permeate the bedrock. This could cause erosion of the bentonite, due to colloidal sol formation at the swelling front (Figure 1).

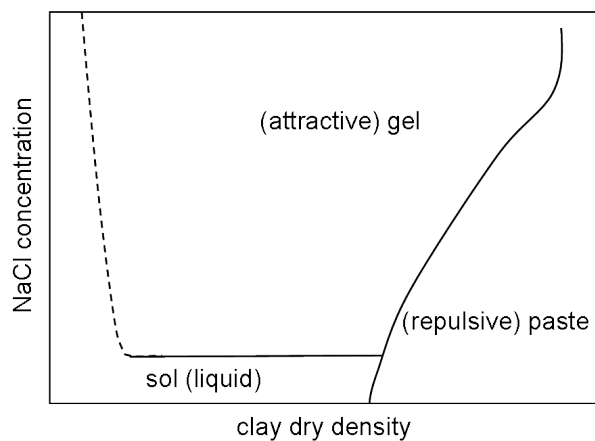


Figure 2. Schematic state/phase diagram of Na-montmorillonite.

To truly assess the extent of this type buffer erosion and the effect on the repository safety, a model that accounts for the physical processes involved is needed. So far, all modelling attempts have failed to properly describe the system, especially at the paste/sol or the paste/gel border (Figure 2). The models used have either been too simplified, physically wrong or a combination of both.

We have instead decided that before modelling can be undertaken, a more detailed understanding of the montmorillonite phase behaviour is needed. For a number of sodium montmorillonites the actual phase borders have been mapped out and they follow the schematic in Figure 2. The clay in the buffer as well as backfill can be characterized as a paste. If the swelling paste is in contact with sufficiently high salinity groundwater it will turn

into a gel at the swelling front. We are investigating the nature of such gels: for example, the strength of the attractive forces keeping the gel together is vital for judging if the gels can withstand flow. One method towards this end is rotating vane rheometry, which we employ to measure yield strength of the gels. The current knowledge suggests that when a gel is formed, erosion will be negligible.

For the erosion scenario, the paste to sol transition is the process that may lead to a problem. How easily the clay is transported with a flow is related to the viscosity of the sol phase. We have over the years conducted numerous viscosity measurements and this work is continuing. We are also using other means to determine the paste/sol border and that information will be crucial for formulating a theory for the swelling and erosion process. The dynamics of this process is explored using artificial fractures made from poly(methyl methacrylate). In these experiments, compacted montmorillonite/bentonite is allowed to swell into the fracture and the swelling and erosion are studied as a function of water chemistry, flow rate and fracture aperture (Figure 3).

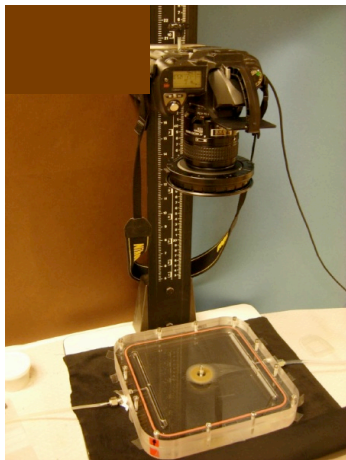


Figure 3 Artificial fracture set-up for investigating erosion of bentonite under dilute water conditions.

Currently, Claytech is a partner in the EU Euratom FP7 project BELBaR (Bentonite Erosion: effects on the Long term performance of the engineered Barrier and Radionuclide transport) www.belbar.eu, where we are actively participating in two work packages, WP2 focussing on the erosion process and WP4 aiming at understanding bentonite colloid stability.

References:

- Birgersson M., Börgesson L., Hedström M., Karnland O. and Nilsson U. 2009. Bentonite erosion – Final report. SKB Technical Report, TR-09-34, SKB Stockholm. www.skb.se
- Karnland, O., Birgersson, M., Hedström, M., 2011. Selectivity coefficients for sodium/calcium exchange in highly compacted bentonite, *Phys. Chem. Earth* 36, 1554-1558.
- Hedström M., and Karnland O. 2011. Ca/Na selectivity coefficients from the Poisson-Boltzmann theory, *Phys. Chem. Earth* 36, 1559-1563.
- Hedström M., Birgersson M., Nilsson U., Karnland, O. 2011. Role of cation mixing in the sol formation of Ca/Na-montmorillonite, *Phys. Chem. Earth* 36, 1564-1571.
- Birgersson, M., Hedström, M., Karnland, O. 2011. Sol formation ability of Ca/Na-montmorillonite at low ionic strength, *Phys. Chem. Earth* 36, 1572-1579.
- Hansen E., Hedström M., Schatz T., Červinka R., Gondolli J., Friedrich F., Rinderknecht F., 2014 Progress report on erosion processes under flowing water conditions www.belbar.eu