Zechstein salt (Germany)

Description: For some years bentonite has been discussed as a material for sealing drifts in repositories in rock salt. The idea is to use dry compacted bentonite for construction of such seals. In the event of water intrusion into the repository bentonite will become saturated. The bentonite will swell and residual open pore space will be reduced resulting in a low permeable barrier. Due to its high flow resistance the bentonite seals represent important barriers for brine inflow into parts of the repository and outflow of contaminated brine out of the repository.

Under highly saline conditions short-term as well as long-term reactions can lead to changes in the sealing properties of bentonite and in particular to alteration of montmorillonite. As a result the swelling pressure of the bentonite can be significantly reduced and the permeability can be increased. On the other hand the convergence process causes further compaction of the bentonite and decrease in permeability. Short-term reactions such as changes in interlayer composition can be investigated in the laboratory. Long-term reactions such as the alteration of montmorillonite to illite and chlorite are beyond the time scales of laboratory tests. Natural analogues can give information about these long-term processes.

Naturally occurring saliferous clays from the Permian Zechstein era, which have been exposed to saturated brines over geological timescales, could be regarded as the final product of the bentonite alteration in highly saline environments. Different kinds of saliferous clays such as red salt pelite, brown-red salt pelite, and grey salt pelite are observed as sedimentary layers on top of salt layers. Pronounced layers of these salt pelites are found for example in the Werra area in the middle of Germany.

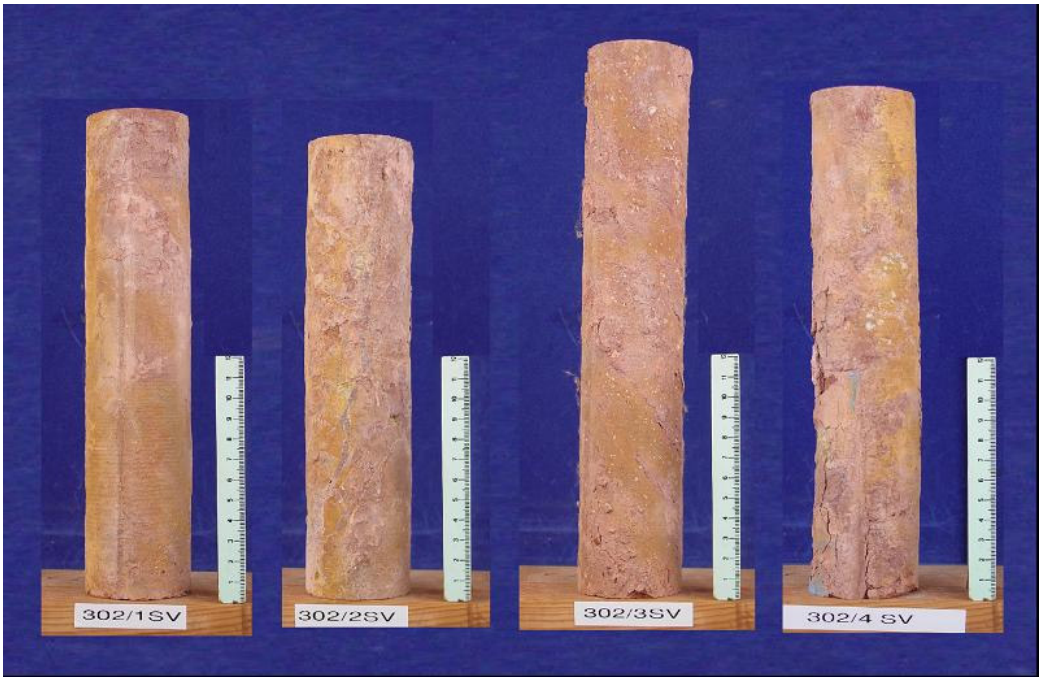

Figure 1: Samples red salt pelite (Sigmundshall)

The dominant minerals of all kinds of salt pelites are quartz, illite and chlorite. In grey salt pelites additionally kaolinite and magnesite are found, whereas in brown-red pellites typically feldspar, magnesite, anhydrite, haematite and halite are also observed.

From considering the initial conditions, the diagenesis of red and brown-red salt pelites is more comparable to the process occurring in the repository. The diagenesis of these pelite sediments starts with detrital input of argillaceous material into basins, where salt deposition took place, i.e. montmorillonite is introduced into a saline environment, as it is planned to be done in the

repository. One important difference to the bentonite in the repository is that the montmorillonite is not compacted at this initial state. The grey salt pelites are built by the sedimentation of clay material occurring directly within the marine, saline basin accompanied by re-dissolution of soluble salt components.

In order to predict the properties of sealing materials, relevant parameters of natural salt pelites have been measured and compared to laboratory results from bentonite, which has been exposed to brines for short times. These are shown in Table 1. Most of the values stem from a limited number of samples from grey pelite from Sollstedt and red pelite from Bleicherode.

Table 1: Comparison of parameters from natural salt pelites and laboratory bentonite exposed to brines

Parameter	Bentonite after saturation with brine	Salt pelite (final state)
Dry density [g/cm^3]	1.5 to 1.7	1.9 to 2.2
Hydraulic conductivity [m/s]	$5 \cdot 10^{-10}$ to $5 \cdot 10^{-11}$	$3 \cdot 10^{-11}$ to 10^{-12}
Swelling pressure [MPa]	0.4 to 1.4	<0.4
Deformation behaviour	Plastic	Plasticity decreased Elasticity increased
Elastic modulus [GPa]	0.4 to 4	30 to 50
Angle of internal friction [°]	10 to 15	37

Most important parameter for PA is the hydraulic conductivity, which is of course influenced by the dry density and the swelling pressure. Due to alteration of montmorillonite into illite / chlorite the swelling pressure of the salt pelites becomes significantly reduced. Nevertheless, the hydraulic conductivity of the naturally occurring salt pelites is about one order of magnitude lower than the hydraulic conductivity of the "fresh" bentonites, because the final density of salt pelites is higher than the starting bentonite density in the sealing element. This gives a strong indication that the alteration product of bentonites, which have been exposed to saturated brines for very long times, still have very good sealing properties.

However, there is no information about the temporal development of the hydraulic and mechanical properties during the alteration process over the time scale of hundreds to ten thousands of years. This time scale is important for PA, because in a case of brine intrusion via anhydrite high radionuclide release out of the repository may occur during this time scale, i.e. the flow resistance of the drifts has to be known for this period.

More work is necessary to gain numerical information and data about the bentonite alteration processes. Firstly the number of samples investigated has to be increased to develop a robust database. The study should be focussed on brown-red and red salt pelites, because their diagenesis is more similar to the bentonite alteration in the repository than that of the grey pelites. In order to get information about the changes of bentonite hydraulic properties with time accompanying modelling work is needed, which has to include the convergence process.

Relevance: Near-field, Mechanical integrity of barriers (Corrosion – chemical alteration), Buffer/Backfill (Bentonite)..

Position(s) in the matrix tables: The study illustrates the processes physical integrity and chemical integrity of bentonite / clay in the near-field matrix table.

Limitations: The study is limited to the behaviour of bentonite in a rock salt formation (saturated brines). Only the final products of the alteration process are available. The study does not give information about the behaviour of the bentonite seal during the alteration process, which is of course important for performance assessment.

Quantitative information: Quantitative information is not yet available from this study.

Uncertainties: This work is mainly based on literature data. Data on hydraulic conductivity and swelling pressure have been determined only for a very limited number of samples from red and grey salt pelites. A higher number of samples need to be systematically investigated.

Time-scale: The time-scale addressed by the study is geological (>2Ma).

PA/safety case applications: There have been no applications in PA so far. The most recent safety assessment has been carried out for the Morsleben repository with non-heat generating low and intermediate level waste. In this repository no bentonite seals are used.
The last overall performance assessment for a repository with radioactive waste in a rock salt formation was finalized in 1991. At that time bentonite was not considered as a sealing material for drifts. Nowadays, bentonite material is regarded as one option for sealing drifts in a repository in a rock salt formation. Therefore, it might play a role in future assessments.

Communication applications: None known

References:

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Added value comments: No

Potential follow-up work: Currently there is no decision about follow up work.

Keywords: sealing, bentonite, salt, brine, alteration

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