



Investigating the sealing capacity of a seal system in rock salt (DOPAS Project)



Kyra Jantschik

Brussels 2nd and 3rd
November 2015



Content

- Background
- Repository concept in rock salt
- Available core material
- Laboratory investigations
 - Viscous deformation behaviour
 - Mechanical-hydraulic behaviour
 - Chemical-hydraulic behaviour
- Conclusions

Background

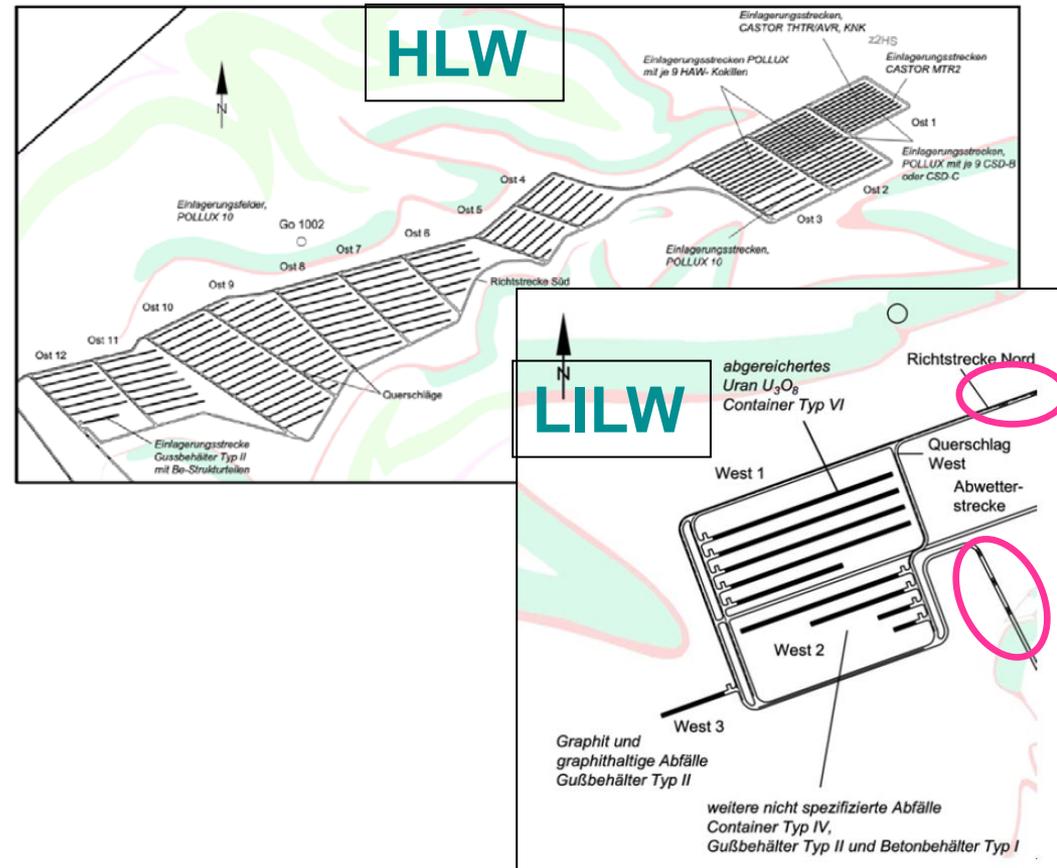
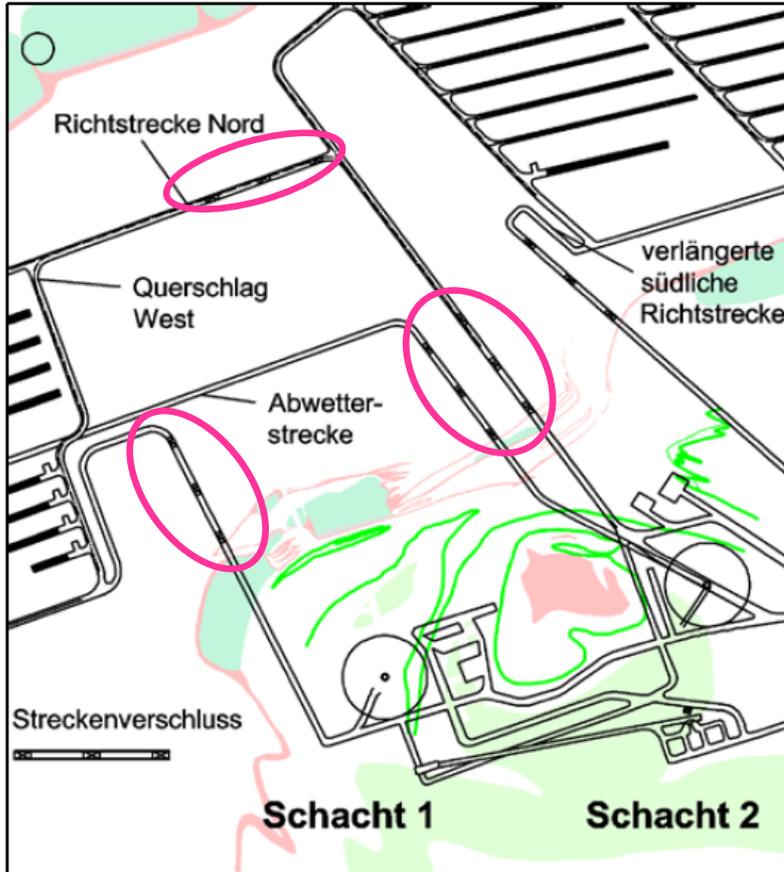
- The German safety requirements for a repository of heat-generating nuclear waste [BMU 2010] comprise several safety principles, the most important ones being:
 - Radionuclides and other contaminants in the waste must be concentrated and contained in a containment-providing rock zone and thus be isolated from the biosphere as long as possible.
 - Waste disposal must ensure that release of radionuclides from the repository enhances only insignificantly the risks resulting from natural radiation exposure
- **A robust barrier system is required to ensure that the safety principles are met!**

Content

- Background
- Repository concept in rock salt
- Available core material
- Laboratory investigations
 - Viscous deformation behaviour
 - Mechanical-hydraulic behaviour
 - Chemical-hydraulic behaviour
- Conclusions

Repository concept in rock salt – sealing materials

Preliminary safety concept for the Gorleben site:



Repository system

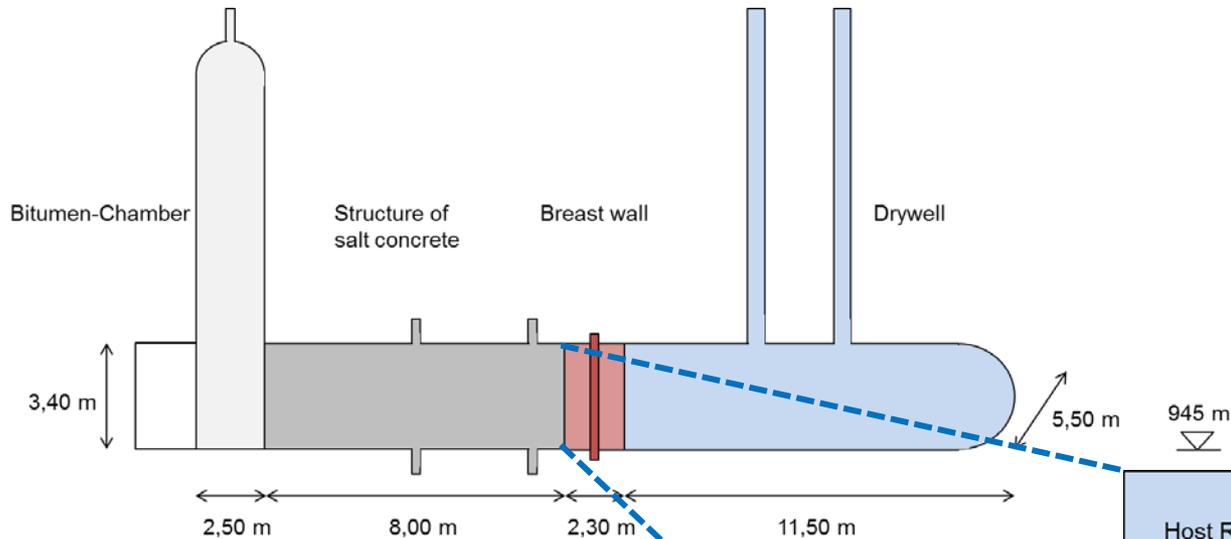
Preliminary Safety Analysis of the Gorleben site

[GRS-290]

Content

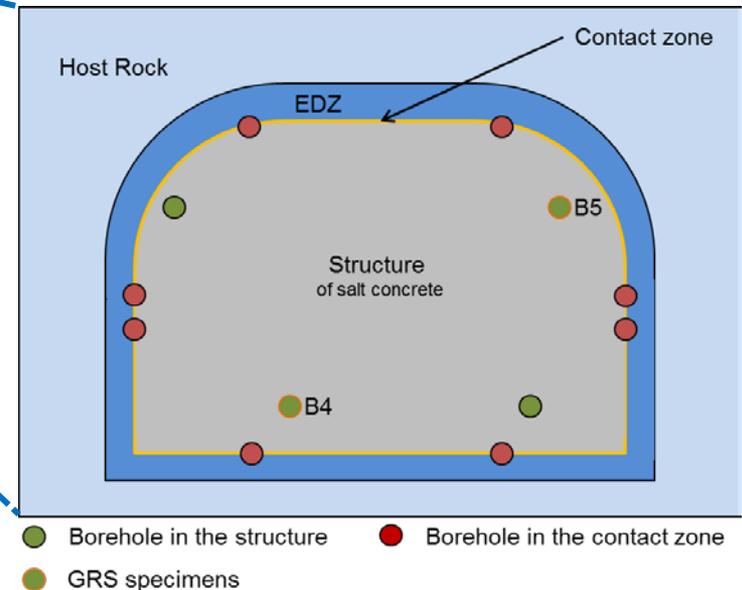
- Background
- Repository concept in rock salt
- **Available core material**
- Laboratory investigations
 - Viscous deformation behaviour
 - Mechanical-hydraulic behaviour
 - Chemical-hydraulic behaviour
- Conclusions

Available core material for laboratory investigations I



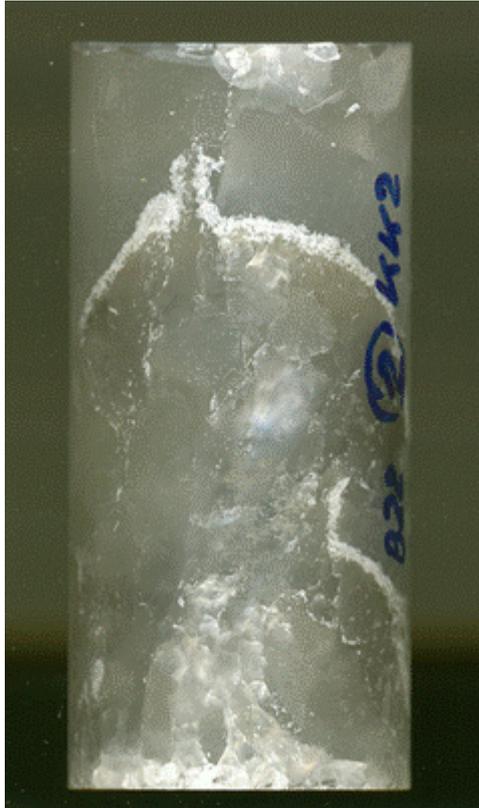
Drift sealing element

- Depth 945m
- Finished in 1992
- Investigated in 2003
- Salt concrete (72% crushed salt, 18% cement, 10% NaCl-brine)
- 8m in length, 5.5m in width, 3.4m in height



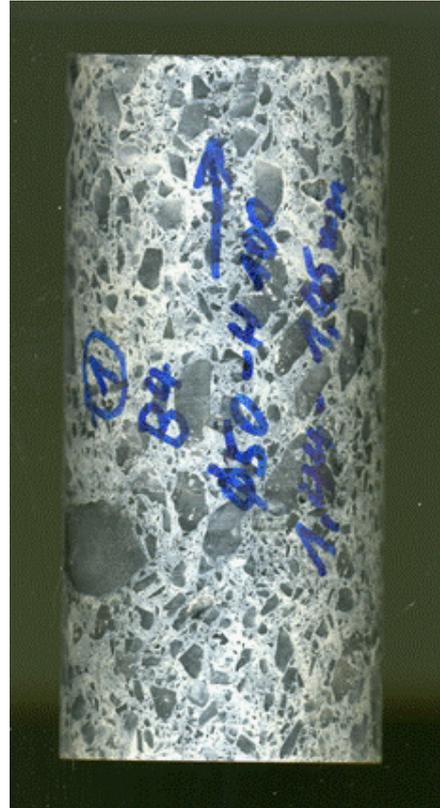
Available core material for laboratory investigations II

Rock salt



Rock salt from the excavation damaged zone (EDZ)

Salt concrete



Cement matrix with crushed salt inclusions and pore structure from an sealing element

Sorelconcrete

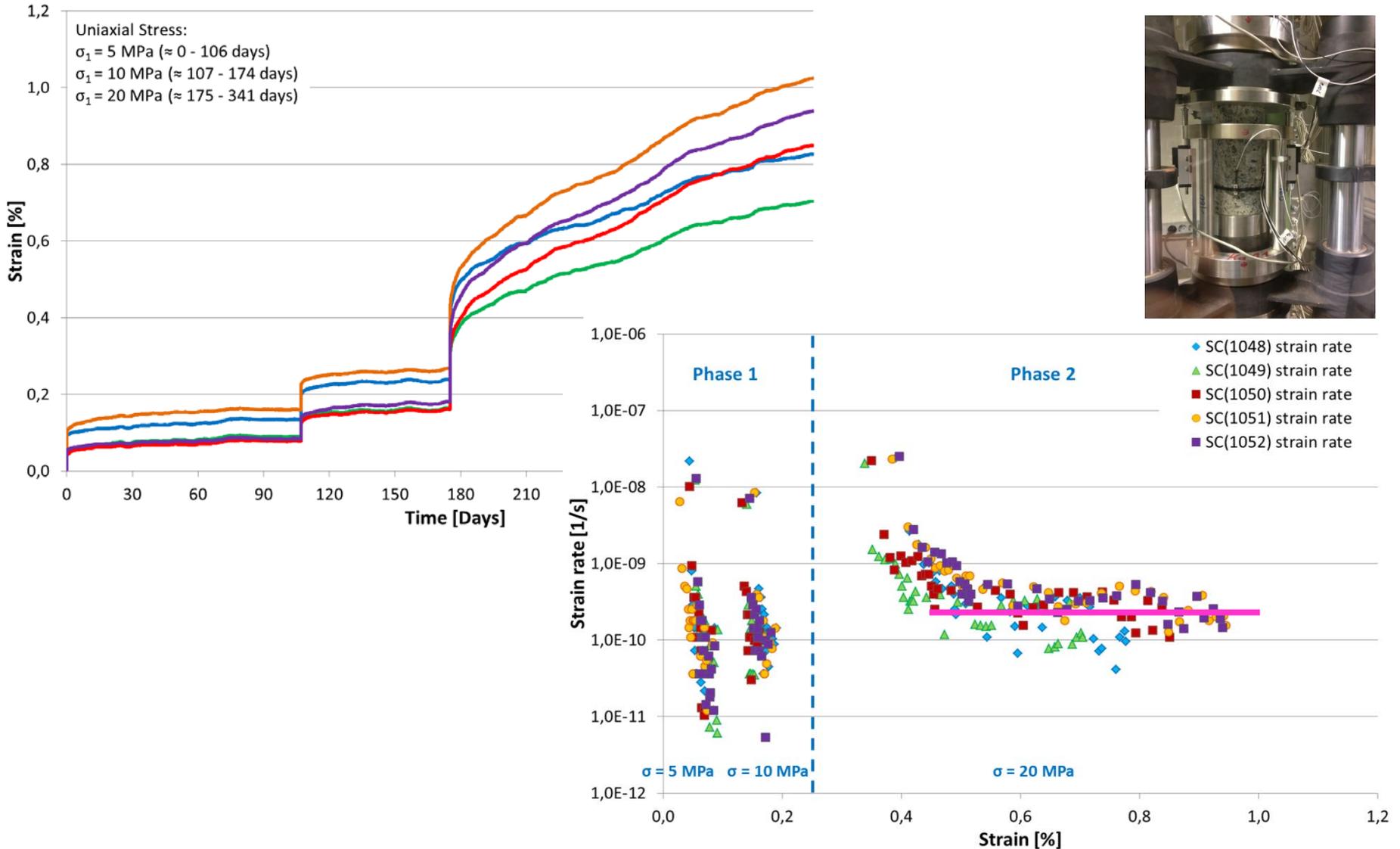


Matrix of magnesium oxide with crushed salt inclusions, produced in GRS laboratory

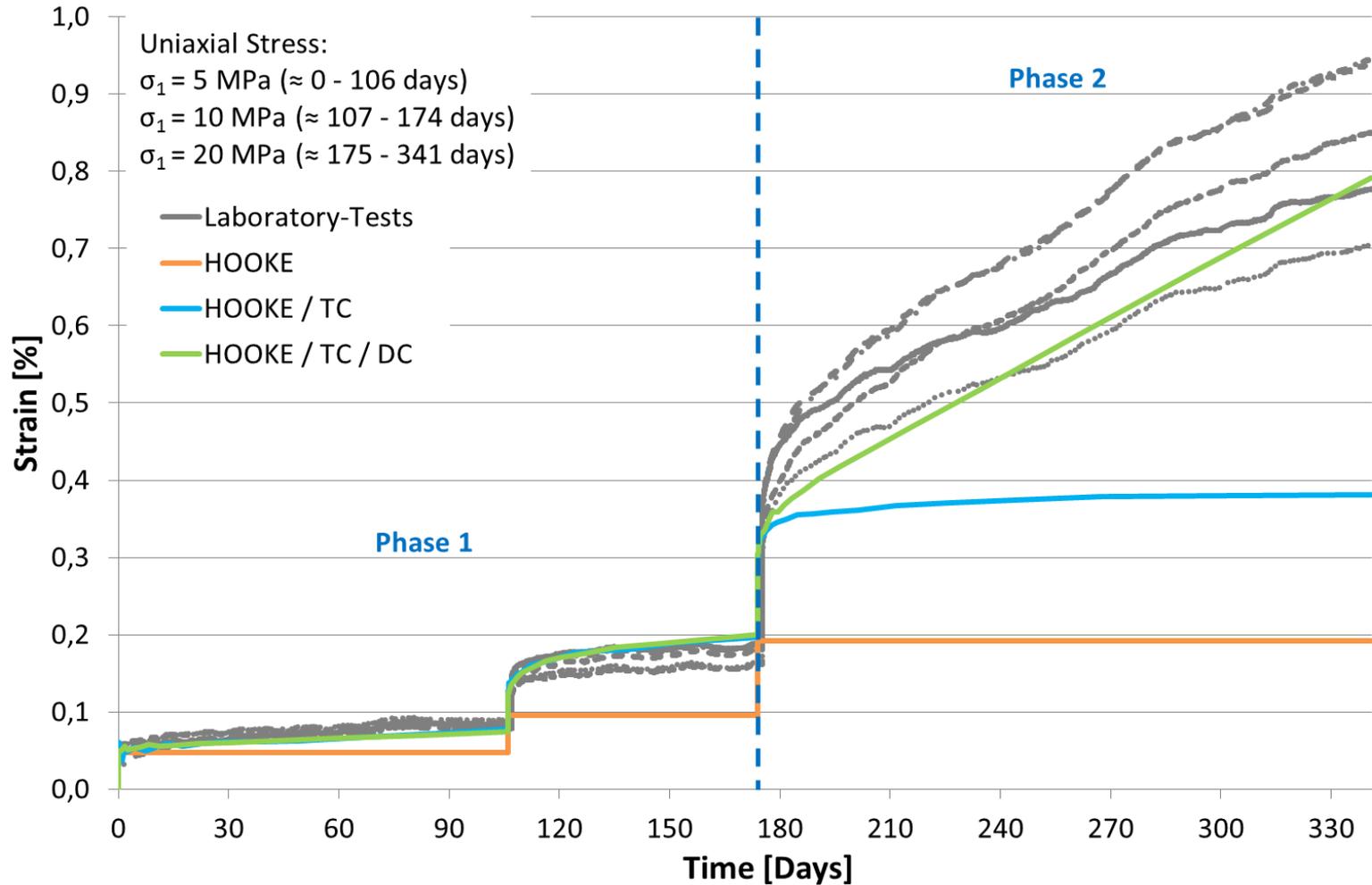
Content

- Background
- Repository concept in rock salt
- Available core material
- **Laboratory investigations**
 - Viscous deformation behaviour
 - Mechanical-hydraulic behaviour
 - Chemical-hydraulic behaviour
- Conclusions

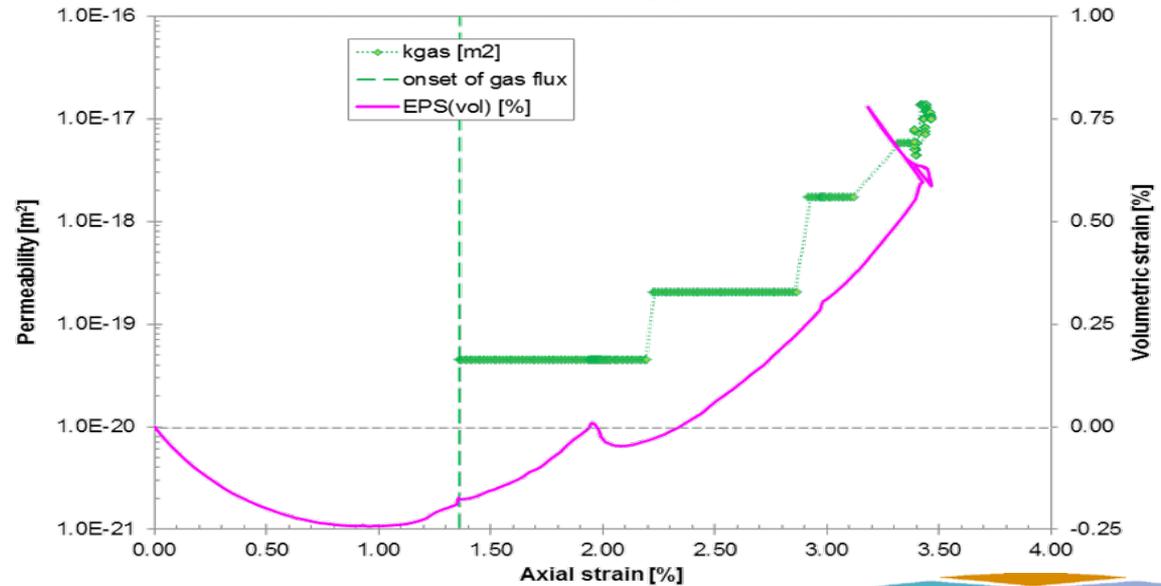
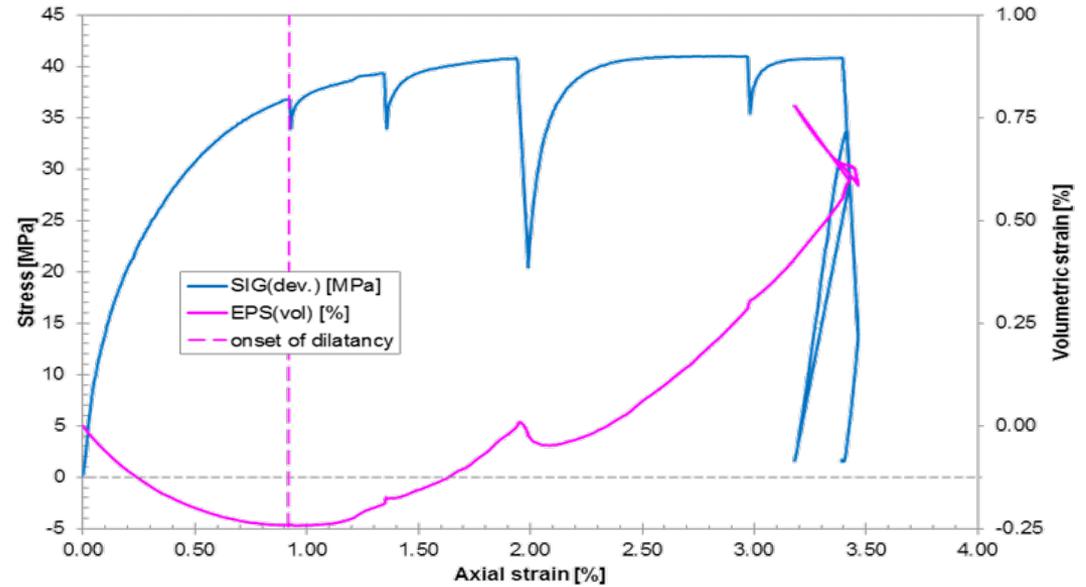
Viscous deformation behavior of salt concrete



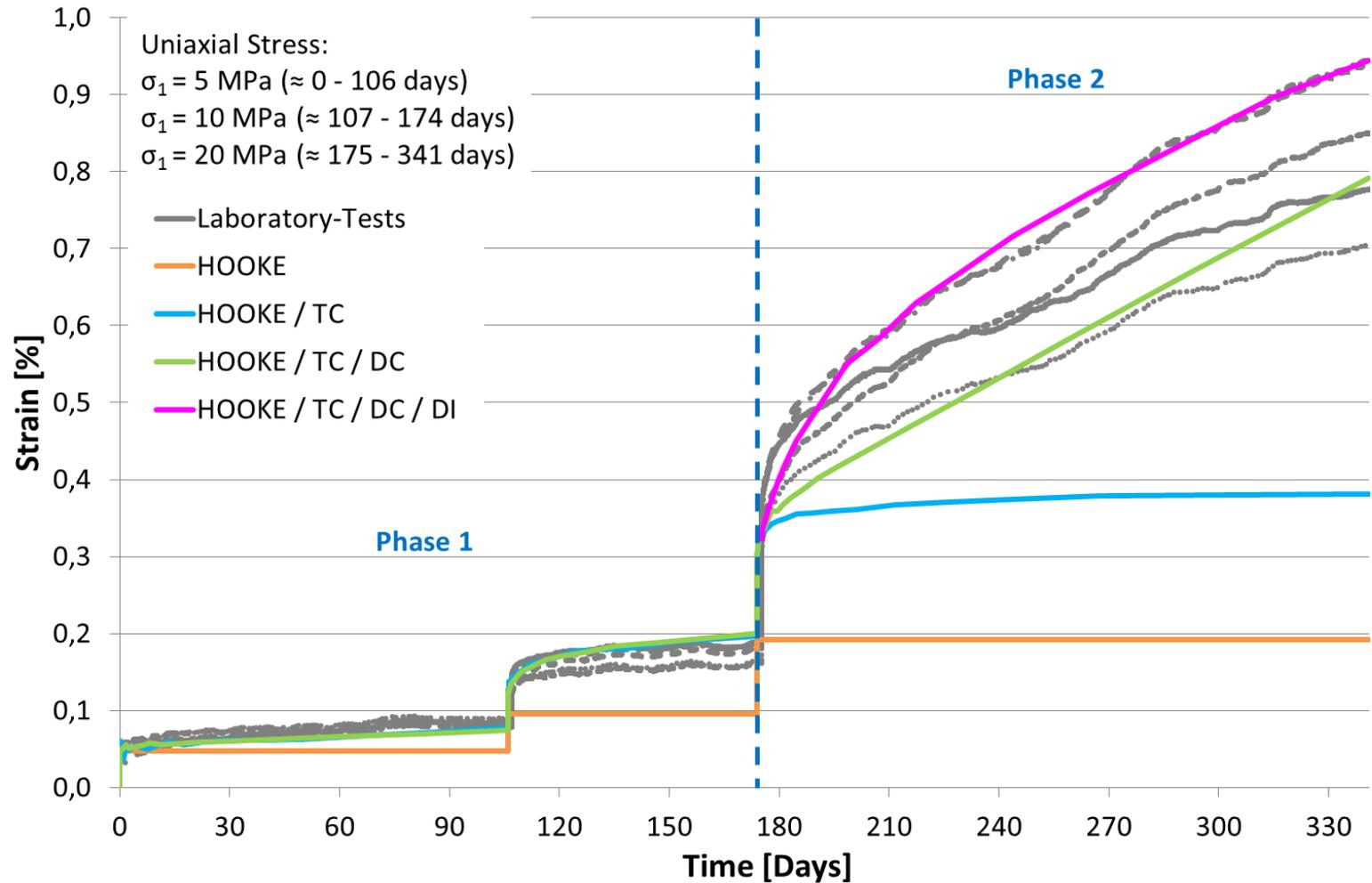
Physical modelling versus laboratory tests I



Physical modelling versus laboratory tests II



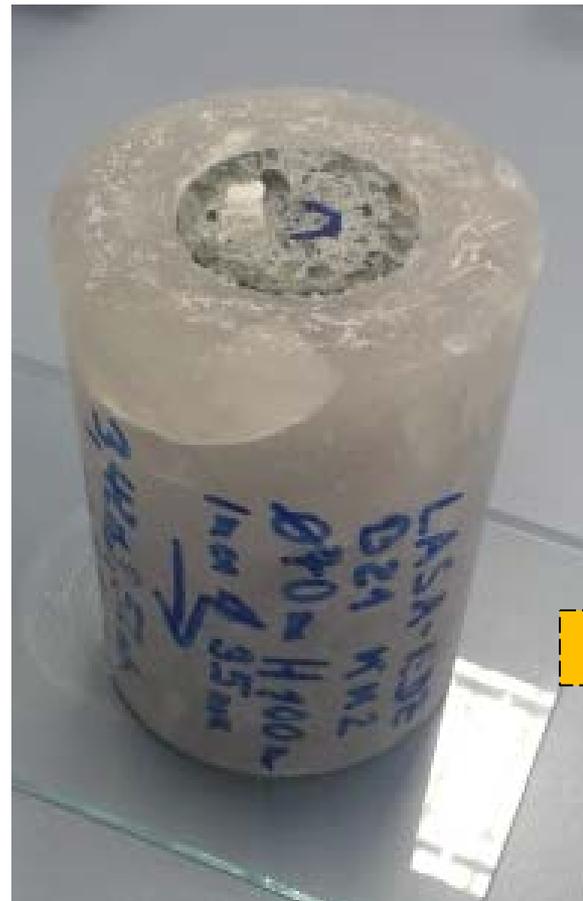
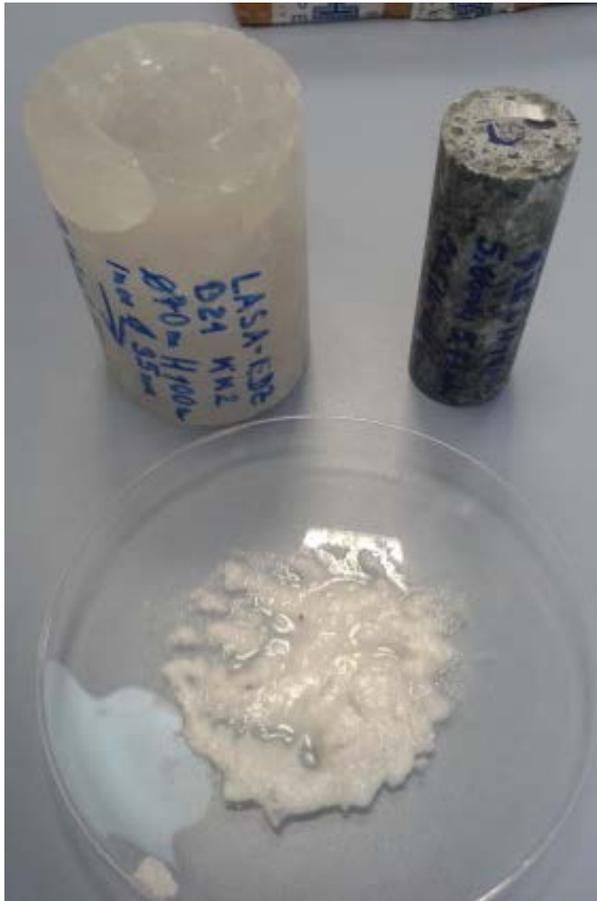
Physical modelling versus laboratory tests III



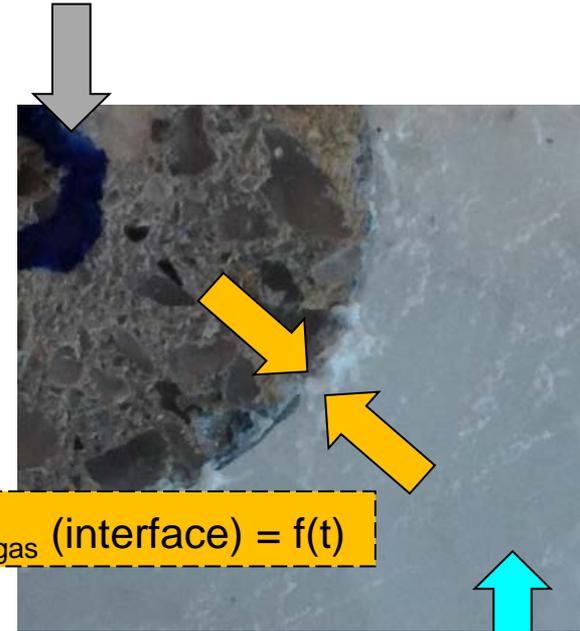
Content

- Background
- Repository concept in rock salt
- Available core material
- **Laboratory investigations**
 - Viscous deformation behaviour
 - **Mechanical-hydraulic behaviour**
 - Chemical-hydraulic behaviour
- Conclusions

Hydraulic sealing capacity of combined samples



$$k_{\text{gas}} (\text{concrete}) < 1.E-18 \text{ m}^2$$



$$k_{\text{gas}} (\text{interface}) = f(t)$$

$$k_{\text{gas}} (\text{EDZ}) < 1.E-22 \text{ m}^2$$

Hollow salt cylinder, salt concrete core and salt slurry

Complete combined sample

Permeability to NaCl-brine of combined samples as a function of time – *preliminary data*



Now brine had been changed from a non corrosive to a corrosive brine: an **increase of permeability** is expected in the next weeks

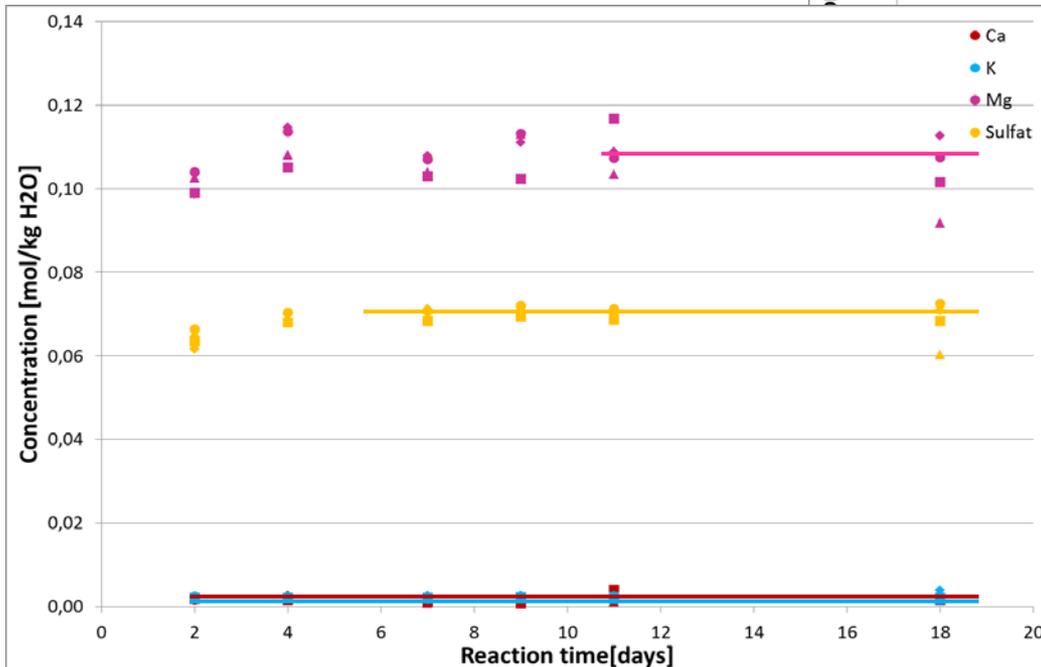
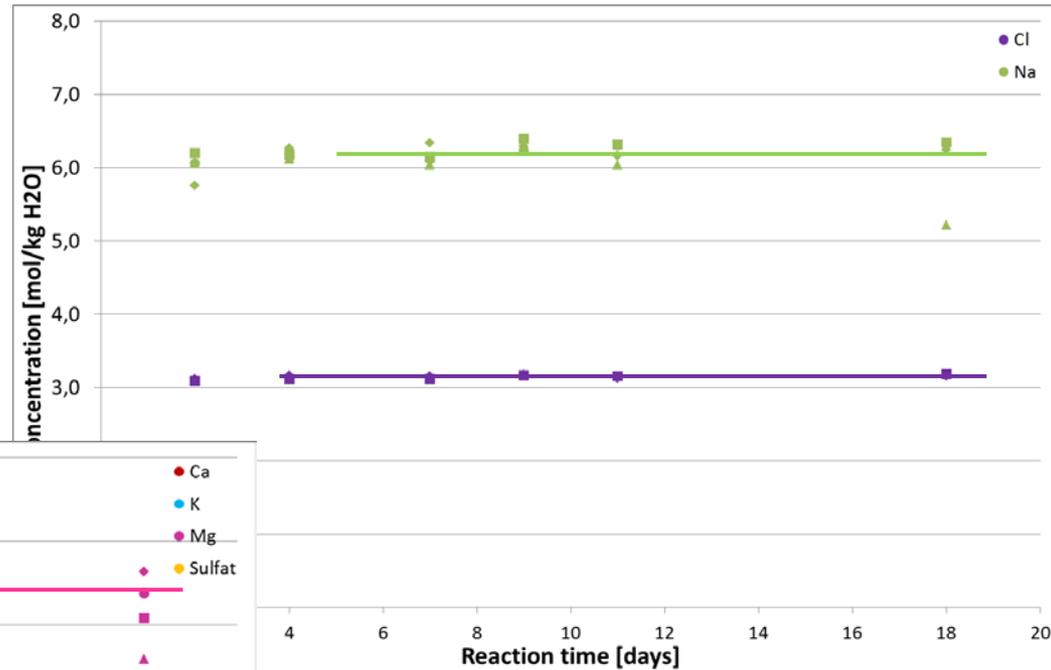
Increase of confining stress (1 to 5 MPa)

Content

- Background
- Repository concept in rock salt
- Available core material
- **Laboratory investigations**
 - Viscous deformation behaviour
 - Mechanical-hydraulic behaviour
 - **Chemical-hydraulic behaviour**
- Conclusions

Batch experiments with sored concrete

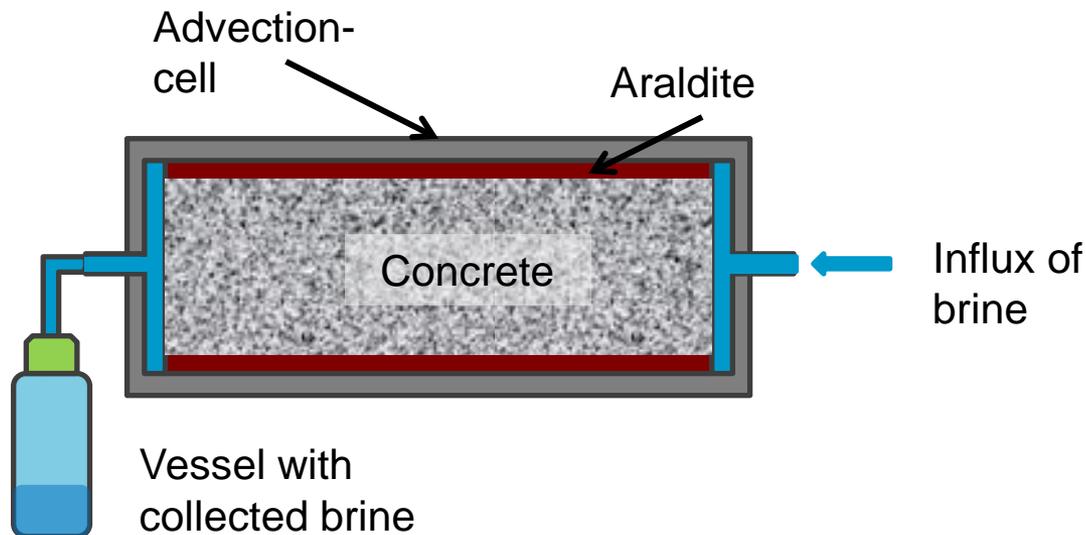
Batch experiments aim to determine the time for equilibration between concrete and (corrosive) solution



Batch experiments in GRS laboratory

Advection experiments with sored concrete I

- Advections experiments aim for investigation the corrosion as result of advective brine flow.



Functional principle of an advection-cell

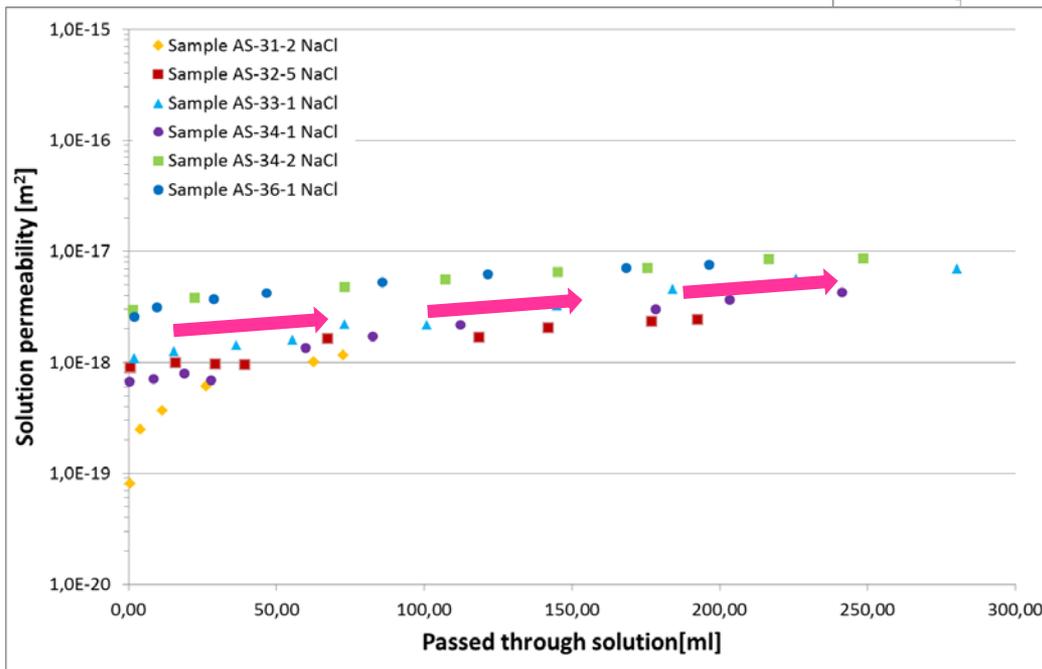
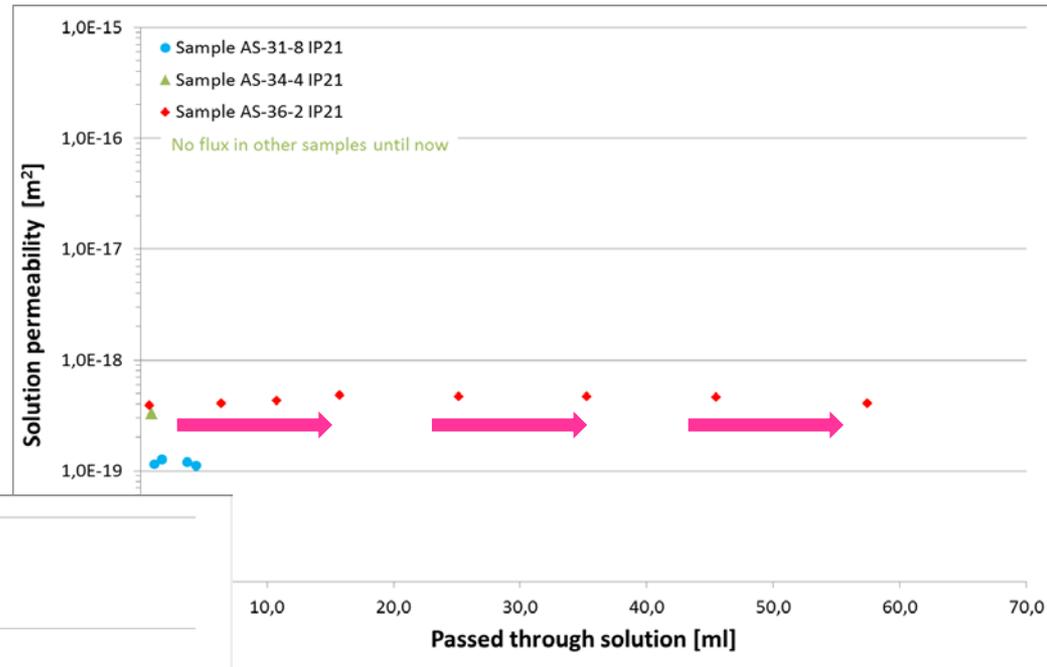


Advections experiments in GRS laboratory

Advection experiments with sorel concrete II

Advection experiments with sorelconcrete and IP21-solution →

- No or very small permeability to brine; permeability stays constant



← Advection experiments with sorel-concrete and NaCl-solution

- Increase of permeability to brine in all samples

Conclusions

Viscous deformation behaviour

- Creep behaviour of salt concrete in lab
 - Creep behaviour of salt concrete is different to the creep behaviour of pure rock salt.
 - Creep behaviour derived from lower load levels is different to the creep behaviour at higher loads. It can be assumed, that structural changes in salt concrete during increasing the axial load may be occurred. \Rightarrow damage of cement boundaries
- Deficits in modelling
 - Model describes the deformation behaviour of salt concrete only by parameter fitting - structure changes could not be considered.
 - Changing material behaviour in the third load level may only be considered by changing parameters of the Viscoplasticity model

Conclusions

Mechanical-hydraulic behaviour

- With an intact seal element, a confining stress of 5 MPa is, however, not sufficient to prevent brine flow along the seal. At a pressure of 10 MPa in the presence of brine, contact seam and EDZ starts to close. Time depending reduction in overall permeability at levels of $10^{-16} - 10^{-18} \text{ m}^2$.

Chemical-hydraulic behaviour

- Equilibrium between powdered concrete and brine is reached after a couple of days.
- Sorelconcrete in contact to NaCl-brine develops nearly direct an increase of permeability. Permeability increases over one magnitude in contact to NaCl-brine while there is no change in permeability in contact to Mg-rich brine in the same time.



Acknowledgements

- O. Czaikowski, H.C. Moog, K. Wieczorek
- The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013 under Grant Agreement no 323273, the DOPAS Project
- Federal Ministry for Economics and Energy (BMWi), represented by the Project Management Agency Karlsruhe (PTKA-WTE), contract no. 02E11132 / 02E11122 / 02E11324
- More information can be found on the DOPAS website:
www.posiva.fi/en/dopas



Federal Ministry
of Economics
and Energy



www.posiva.fi/en/dopas

