KIT-INE contribution into WP2: Bentonite Erosion

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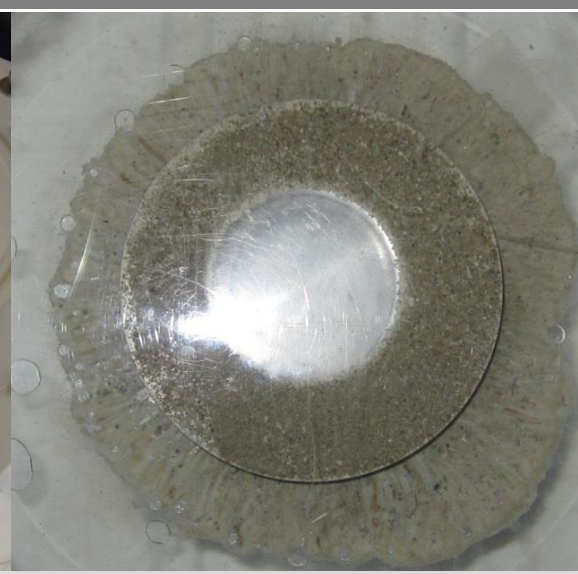
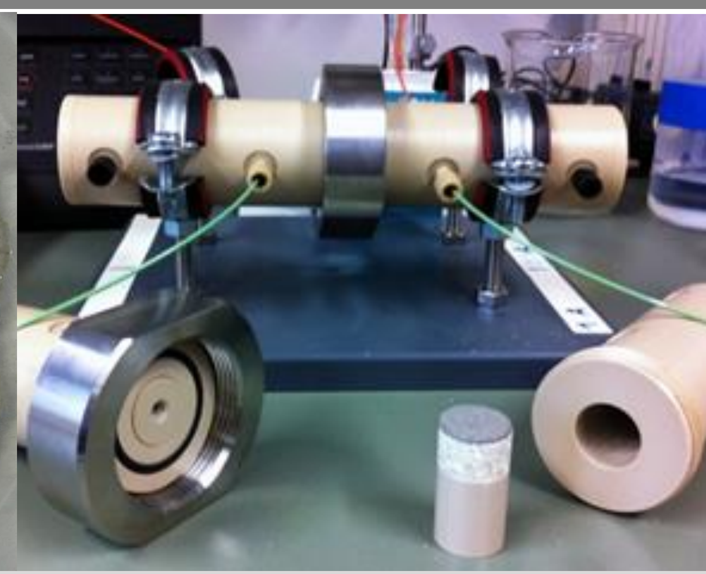


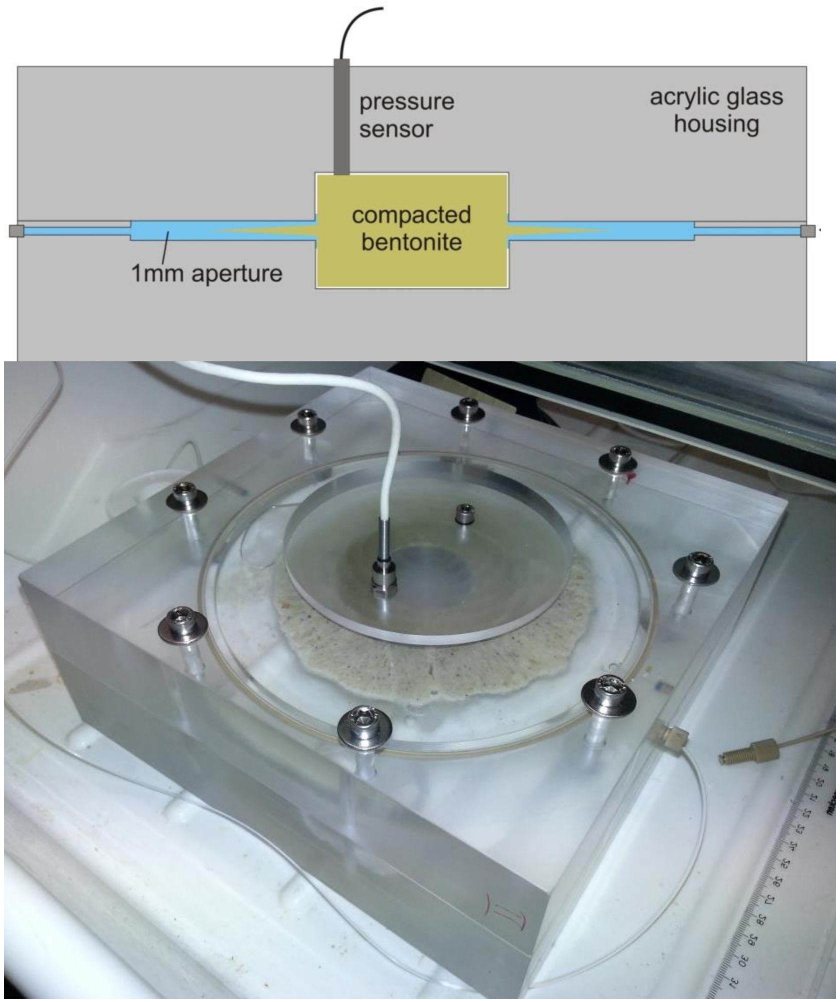


Outline

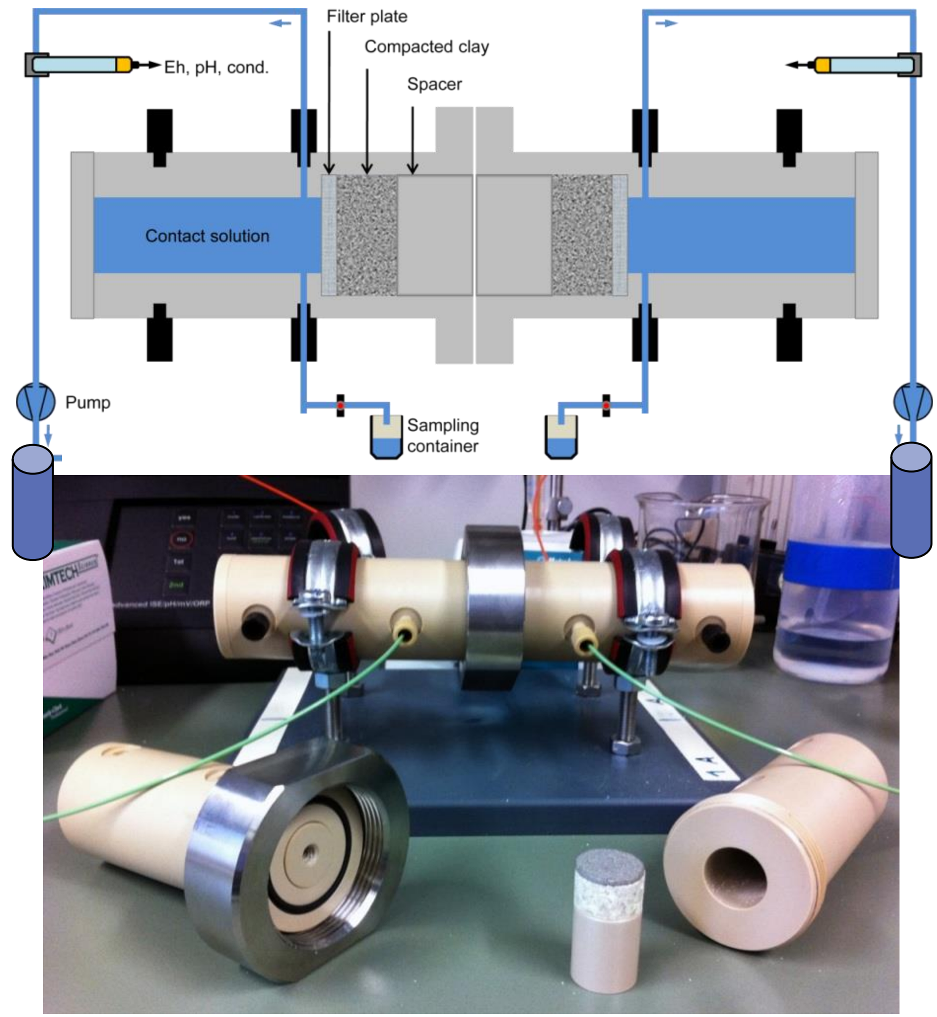
- Summary of the bentonite erosion experiments conducted at INE during the last three years concerning:
  - Erosion cell parameters
  - Characteristics of bentonite clay samples
  - Groundwater chemistry and flow velocity
  - Clay-groundwater interactions and colloid mobility controlling processes

Erosion cell parameter

Artificial fracture cell



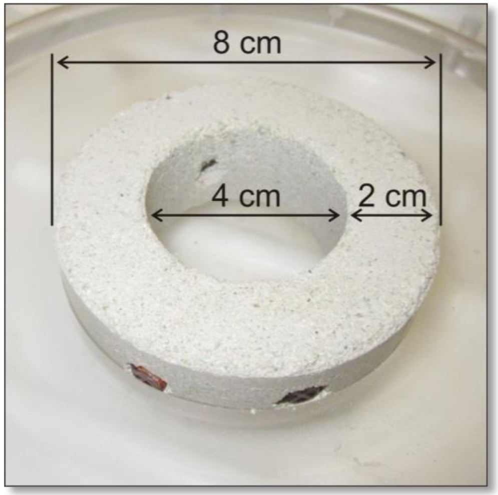
Twin side reactor



Artificial fracture cell - Bentonite sample

- Natural compacted Febex bentonite
  - 92% montmorillonite
  - 2% quartz
  - 2% plagioclase

- 1.65 Mg/m^3 dry density
- 98 mL sample volume



- Erosion takes place on a ring of 1mm height around the sample which is contacted with the water bearing fracture (initial contact area: $2.6 \cdot 10^{-4}$ m^2)
- Experiments are performed without presaturation

Twin side reactor - Bentonite sample

- Compacted MX80 (Volclay)
    - Purified Na-exchanged
    - Purified Ca-exchanged
    - Purified Na/Ca mixture (50/50)
    - Natural MX80 clay
- All experiments in duplicates
- 1.6 Mg/m^3 dry density
- 3.1 mL sample volume

Groundwater chemistry and flow velocity

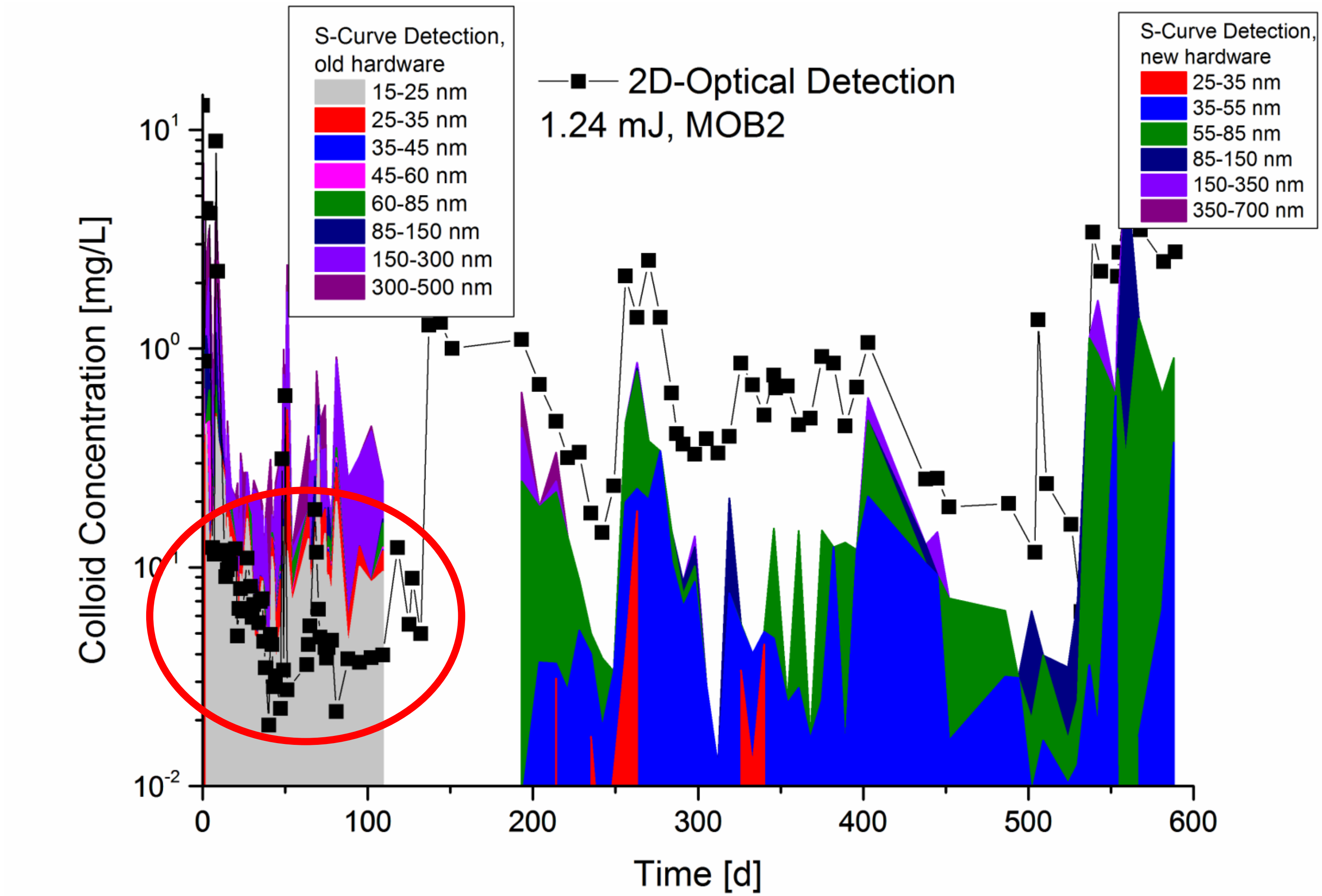
Erosion experiments at KIT-INE are focussed on natural groundwater systems

	Artificial fracture cell	Twin side reactor
	Natural GGW	Synthetic GGW
pH	9.6 ± 0.2	8.4 ± 0.2
IS	$1.2 \cdot 10^{-4}$ M	$1.3 \cdot 10^{-4}$ M
Na^{+}	$6.9 \cdot 10^{-4}$ M	$1.2 \cdot 10^{-3}$ M
Ca^{2+}	$1.4 \cdot 10^{-4}$ M	$5.0 \cdot 10^{-5}$ M
F^{-}	$6.1 \cdot 10^{-5}$ M	$1.0 \cdot 10^{-4}$ M
Cl^{-}	$1.6 \cdot 10^{-4}$ M	$7.4 \cdot 10^{-5}$ M
SO_4^{2-}	$6.1 \cdot 10^{-5}$ M	$4.0 \cdot 10^{-5}$ M
HCO_3^{-}	$2.9 \cdot 10^{-4}$ M	$1.0 \cdot 10^{-3}$ M
Flow velocity	50 µL/min (≈ $8 \cdot 10^{-6}$ m/s)	3 µL/min (≈ $2.3 \cdot 10^{-4}$ m/s)

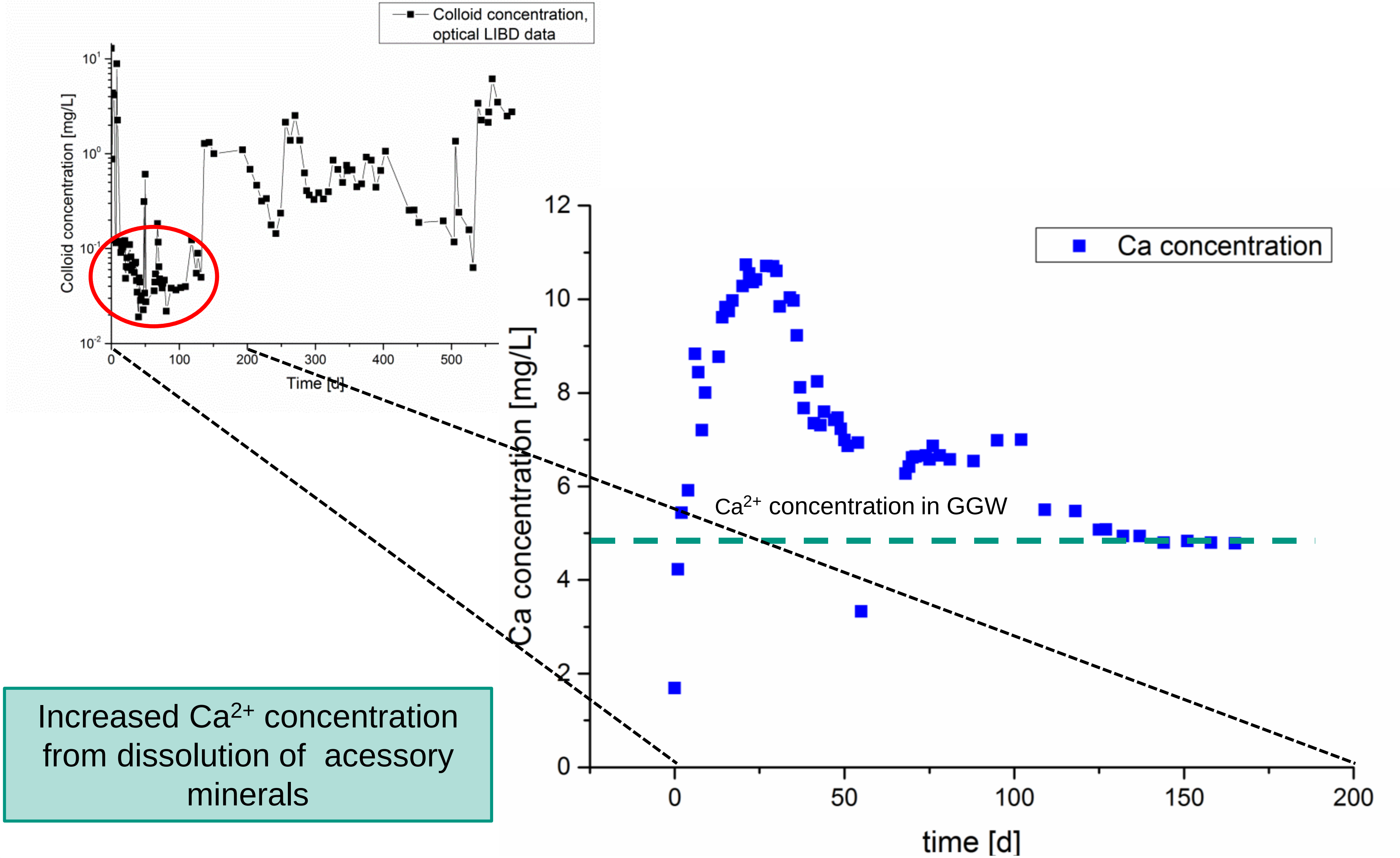
Synthesis of issues: Erosion (WP2)

Issue	Safety case position at start of BELBaR	Outcomes sort for final State-of-art report
Clay – Groundwater interactions	Changes in bentonite porewater solute concentrations can be modelled. The related rates assumed to be limited by the availability of different porewater solutes. Mass loss rate assumed to have hydrodynamic contribution. The buffer and the groundwater never reach a true equilibrium.	A validated argumentation for (the conditions for) maximum clay mass loss rate to be used in safety case (cross-WP effort). Summary of how these processes should be integrated in the safety case.

Artificial fracture set-up - Colloid release

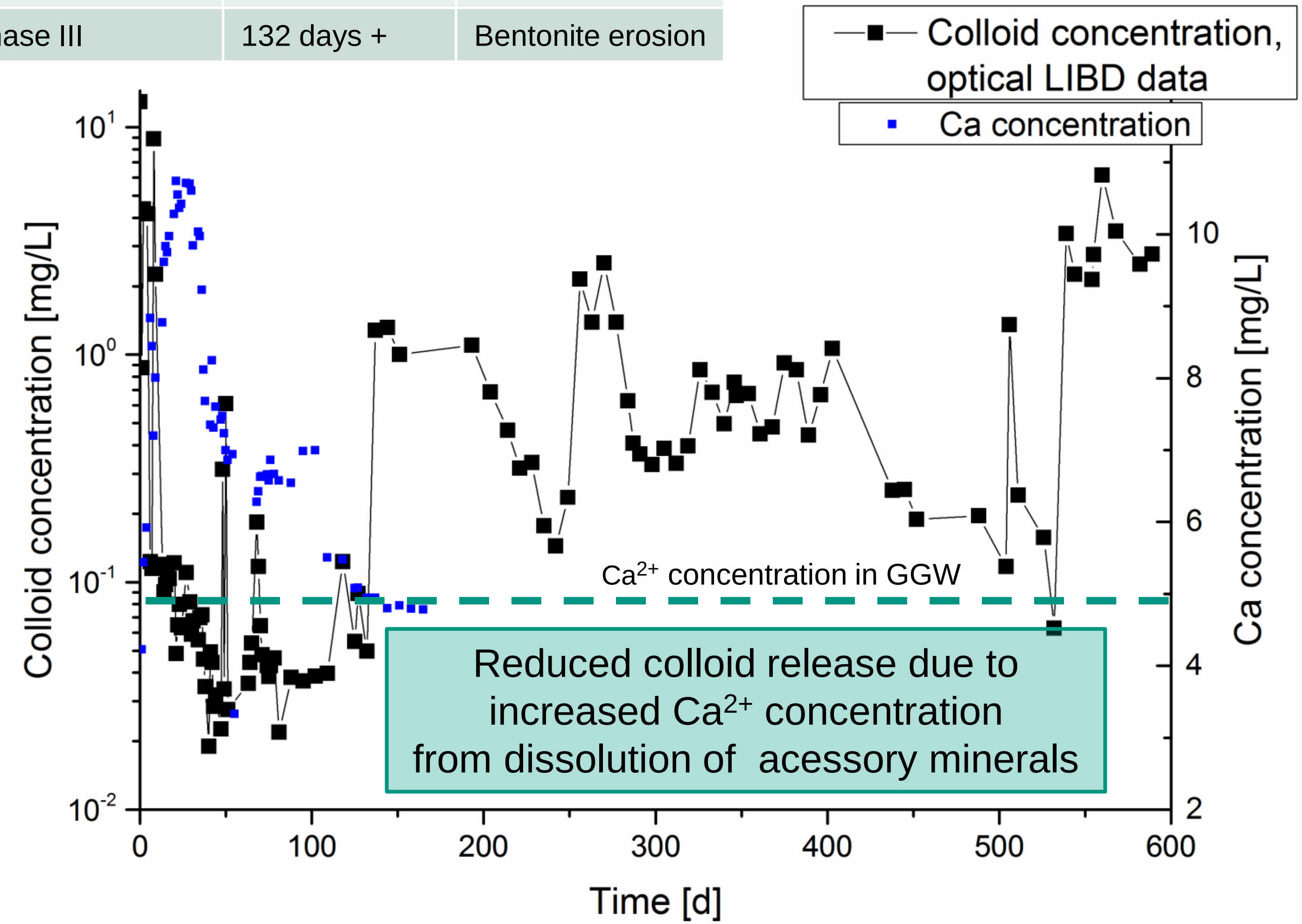


Artificial fracture set-up - Calcium concentration



Increased Ca^{2+} concentration from dissolution of acessory minerals

Experiment phase	Timespan	Process
Phase I	0 – 12 days	Washing
Phase II	13 – 132 days	Dissolution
Phase III	132 days +	Bentonite erosion



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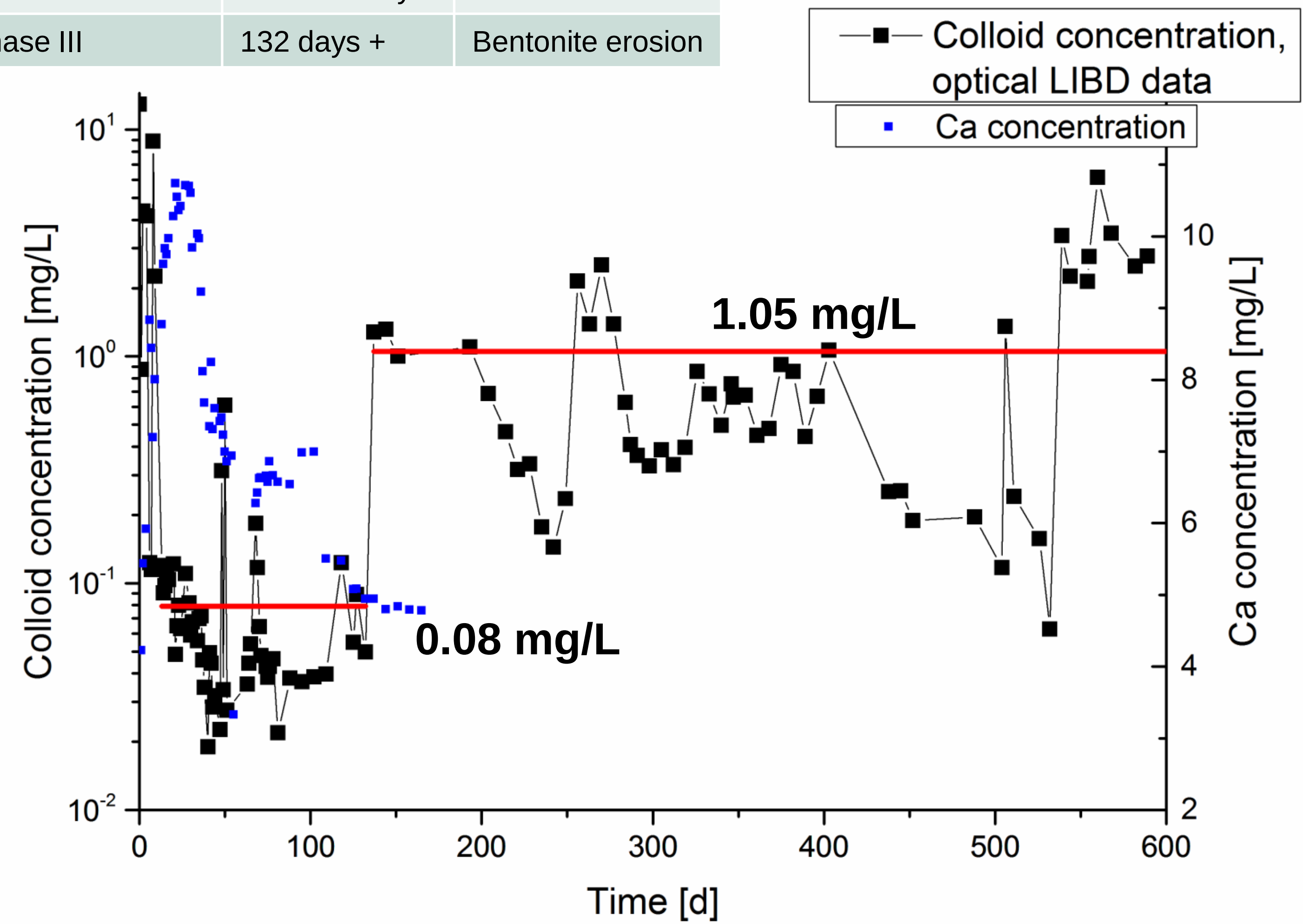

Artificial fracture set-up - Colloid release rates

- 36 mg bentonite colloids have been released from the artificial fracture set-up during 600 days
  - **0.7 mg** released in dissolution phase
  - **35.3 mg** released in erosion phase
- Colloid release rates are calculated as a function of the initial contact area between bentonite sample and groundwater
- Contact area
  - Sample diameter: 80 mm
  - Fracture height: 1 mm
  - → **$2.6 \cdot 10^{-4}$ m^2**

Dissolution Phase: **$R_D = 8.3$ g/(a*m^2)**

Bentonite Erosion Phase: **$R_{BE} = 109.9$ g/(a*m^2)**

Synthesis of issues: Erosion (WP2)

Issue	Safety case position at start of BELBaR	Outcomes sort for final State-of-art report
Characteristics of Bentonite clay	Divalent cations have not been studied that systematically. Should the existence and quantitative effect of divalent cations be argued, the importance of this outstanding uncertainty would reduce.	The role of divalent cations (WP2 and WP4). The stability of different bentonites (WP4) 6

Twin side reactor - *[Si, Al, Fe, Mg] evolution*

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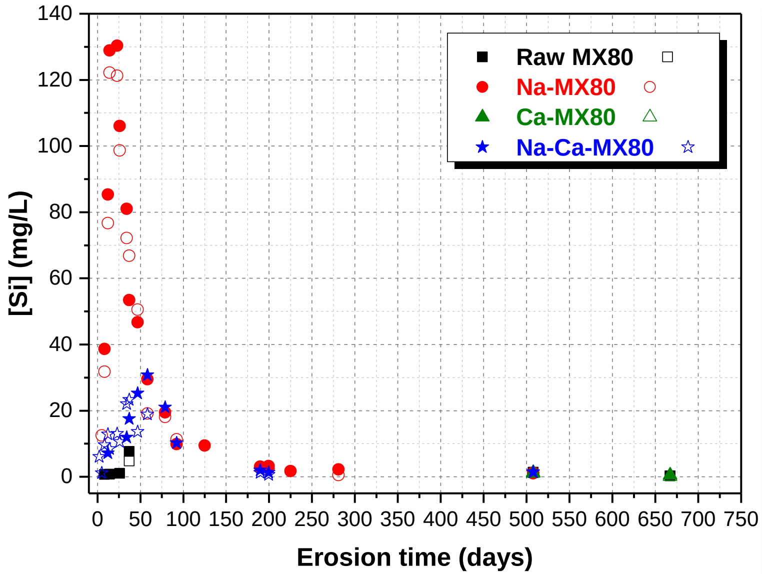

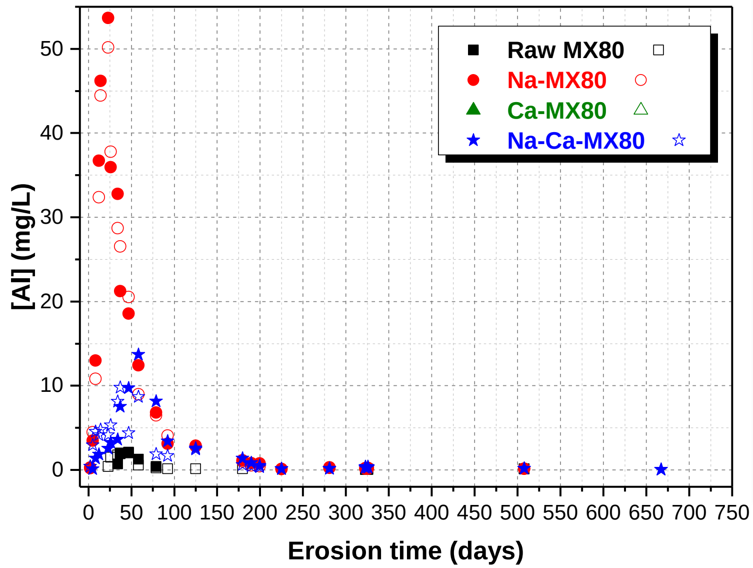

- ✓ ***Experiments are very reproducible***
- ✓ ***Eroded material identified as MX80 colloids from the [Si]/[Al] and [Al/Mg] ratios***
- ✓ ***Pronounced effect of the cation-exchange process:***
  Ca-MX80 no erosion or <<<< raw << Na-Ca-MX80 <<<Na-MX80
- ✓ ***If effective, colloids production maximum after ~ 25 days up to ~ 500 mg/L***
- ✓ ***Decrease of production and level off after 6 months***

0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750

Erosion time (days)

Summary

- KIT-INE's research on bentonite erosion focussed on the behaviour of different bentonite samples under almost natural conditions (water chemistry/flow-velocity)

- The interlayer cation composition has a strong impact on bentonite erosion rates:

Ca-MX80 << raw MX80 < Na-Ca-MX80 <<Na-MX80

- Bentonite erosion on natural samples can be devided in three phases:

1. **Washing of loose particles**
2. **Dissolution of accessory minerals (R_D = 8.3 g/(a*m^2))**
3. **Bentonite erosion (R_{BE} = 109.9 g/(a*m^2))**