IMPACT OF LONG-TERM THERMAL PULS ON BENTONITE EROSION-RATES IN LABSCALE EXPERIMENTS: INITIAL RESULTS FROM SAMPLES OF THE LOT/ABM EXPERIMENTS

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INTRODUCTION

Due to their advantageous properties (i.e. swelling and sorption), bentonites are used as geotechnical barrier materials in the engineered barrier system (EBS) for radioactive waste disposal in crystalline host rocks [1]. To reduce the spatial footprint of the repository, these systems are being revised for thermal optimization [2]. A key aspect is determining the maximum thermal load at the canister-bentonite and bentonite-host rock interfaces under which bentonite maintains its functionality. Thermal loading affects both swelling [3] and possibly erosion behaviour, potentially compromising long-term integrity of this barrier.

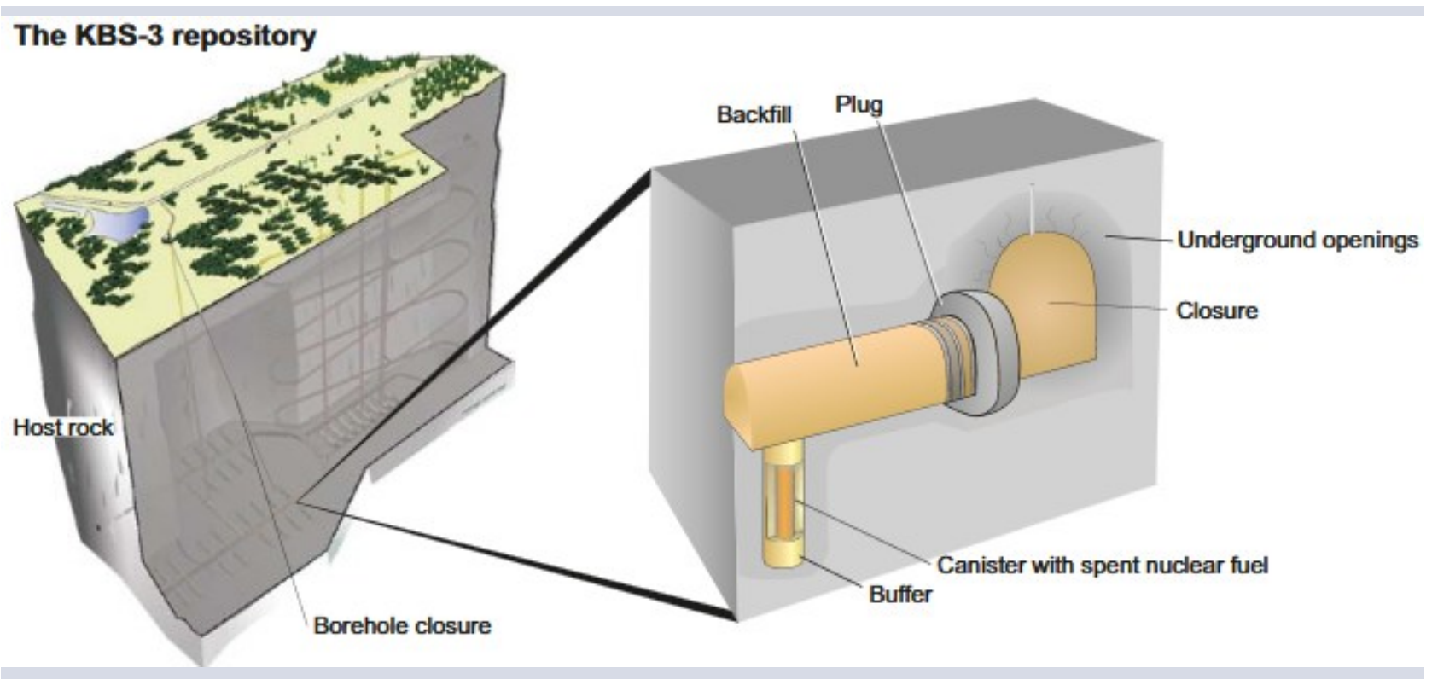


Image 1
Conceptual design of the KBS-3 repository [4]. Swedish/Finnish design for a high-level radioactive waste repository in crystalline host rock with an engineered barrier system (EBS).

SAMPLES

Three samples from the Äspö Hard Rock Laboratory were analysed to evaluate the effects of prolonged elevated thermal load on the erosion behaviour of bentonite:

Sample	Origin	Runtime	Thermal Load
MX-80 Wyoming-type bentonite	LOT S2; Block 18	20 a	500 W (max. T. 95 °C)
MX-80 Wyoming-type bentonite	ABM 45:5; Block 8	5 a	340 W (max. T. 55 °C) and 1800 W (max. T. 250 °C) for the last year
FEBEX bentonite	ABM 45:5; Block 25	5 a	340 W (max. T. 55 °C) and 1800 W (max. T. 250 °C) for the last year

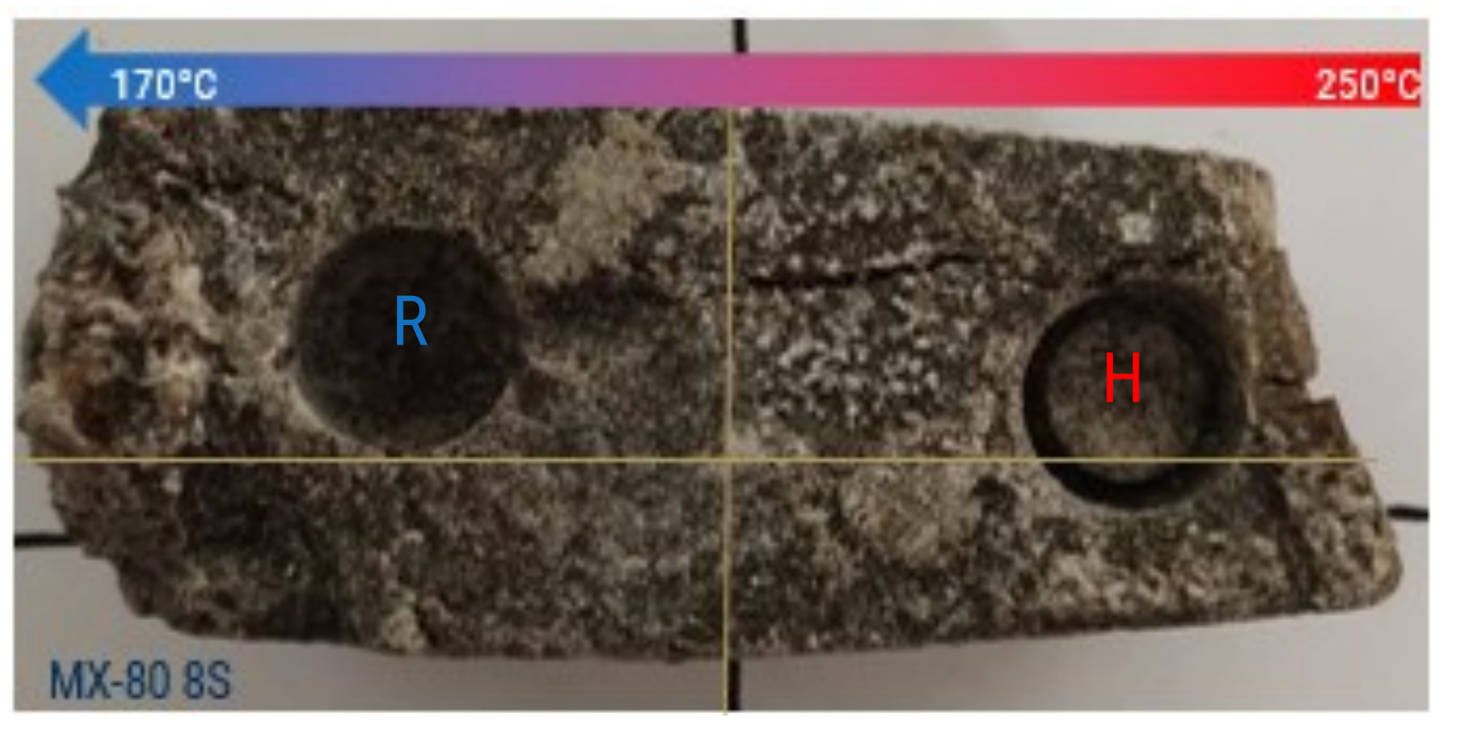


Image 2
Sample block of thermally treated MX-80-8S (ABM 45:5) bentonite with drill holes from plug extraction. Horizontal brown line showing cut for reserve sample. Vertical line cut for distinction in sample R left side and H right side

- **R** denominates samples nearer to the **rock-interface** (cold)
- **H** denominates samples nearer to the **heater-interface** (hot)

EXPERIMENTAL SETUP

Erosion experiment in artificial fracture cell:

- Bentonite plugs: 13 mm diameter, 5 mm height
- 1 mm aperture parallel plate artificial fracture (PMMA)
- 50 µL/min flow rate
- Low-ionic strength (0.2 mM) Grimsel Groundwater (GTS)

Image 3
Lab-scale erosion experiment setup in PMMA parallel-plate artificial fracture cells of 1 mm aperture and Ø 85 mm

Preparation for ATR-FTIR:

- Grinding sample to <63 µm in agate mortar
- Homo-ionisation of 10 g sample in 1 L 10M NaCl solution
- Washing and size-fractionation into <50 nm; 50-200 nm;

RESULTS

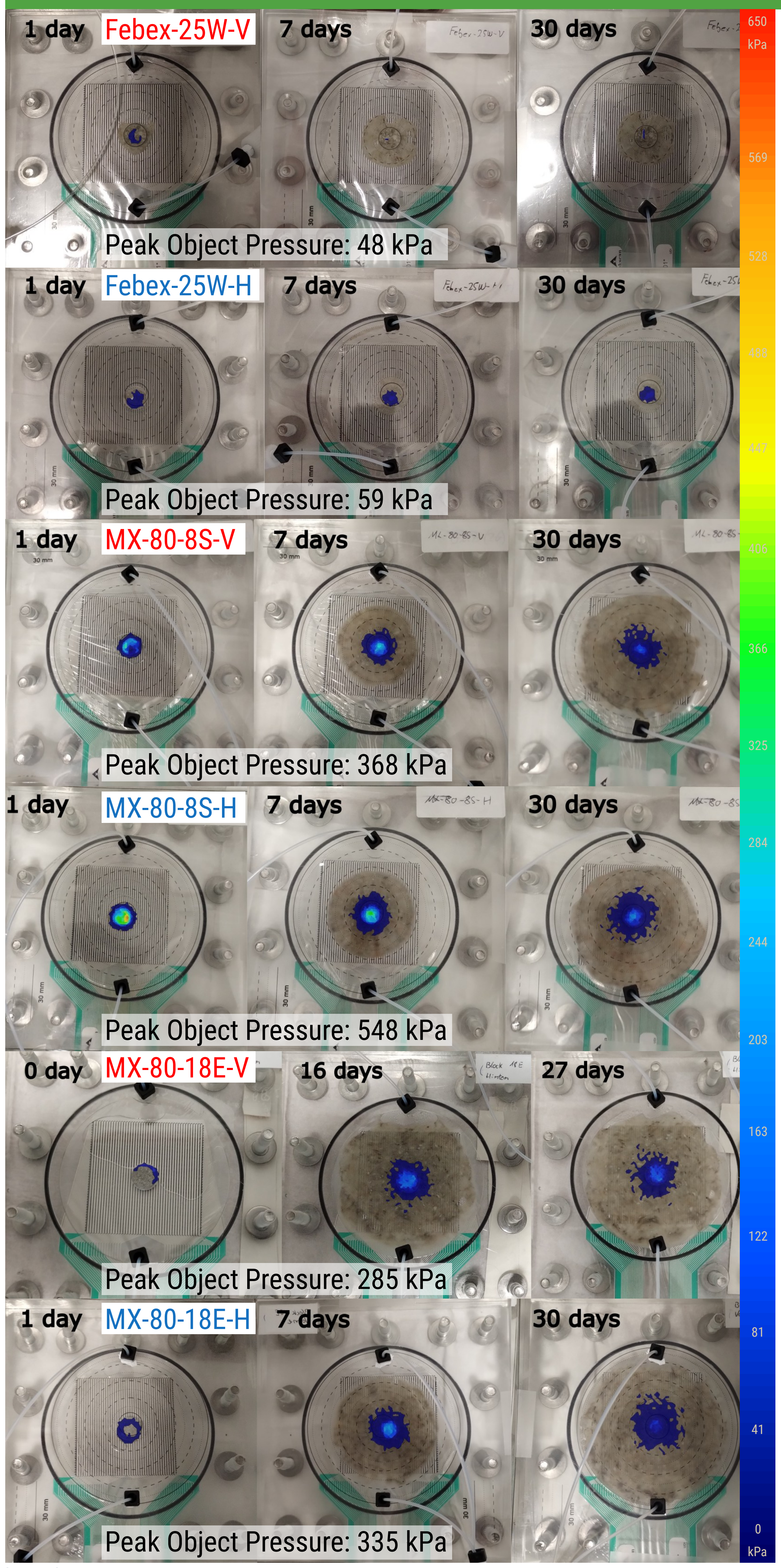
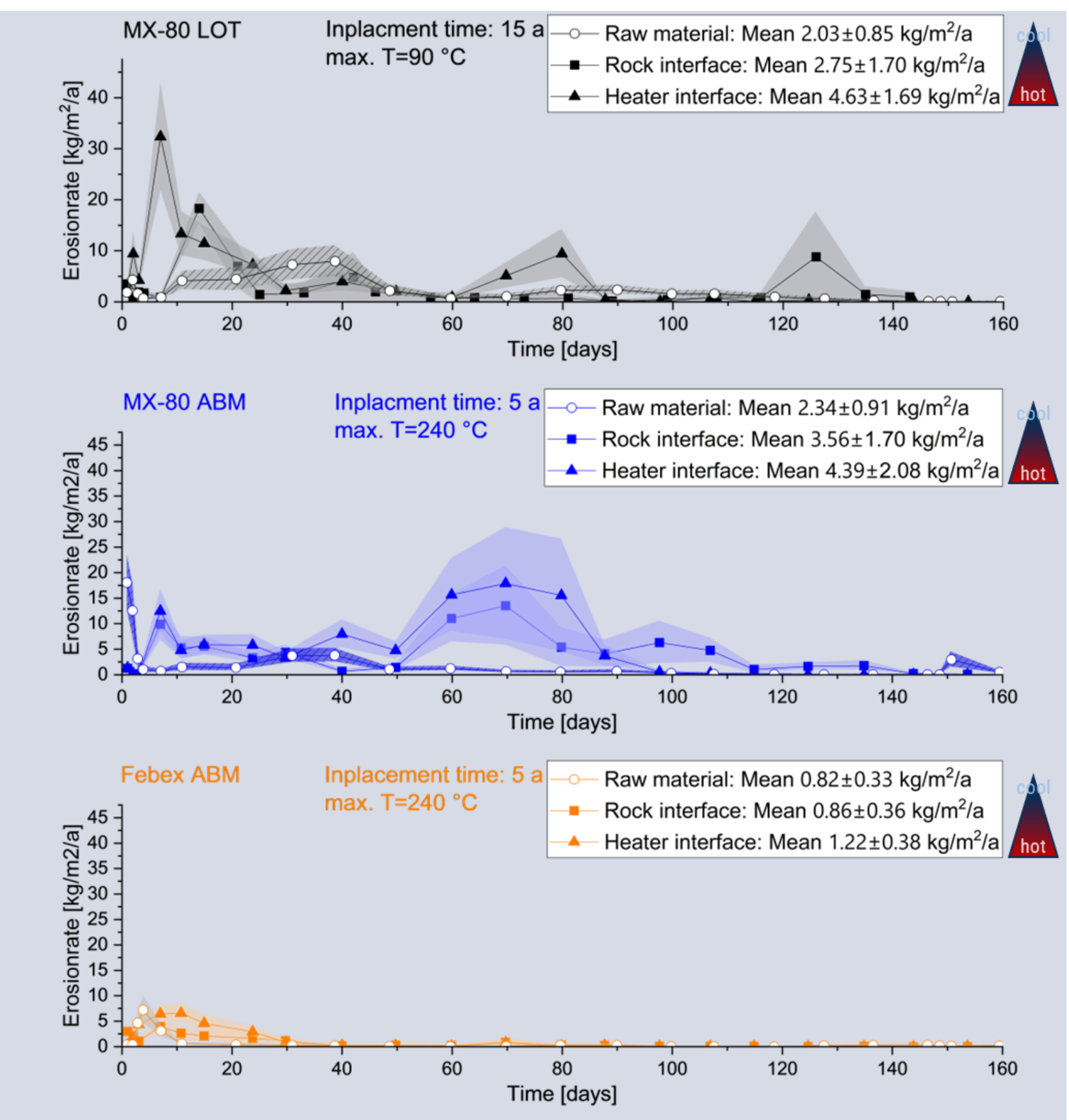


Image 4
Swelling and pressure of thermally treated bentonite in artificial fracture cells. The image shows the evolution of pressure and the swelling front over time.

Data on erosion experiments

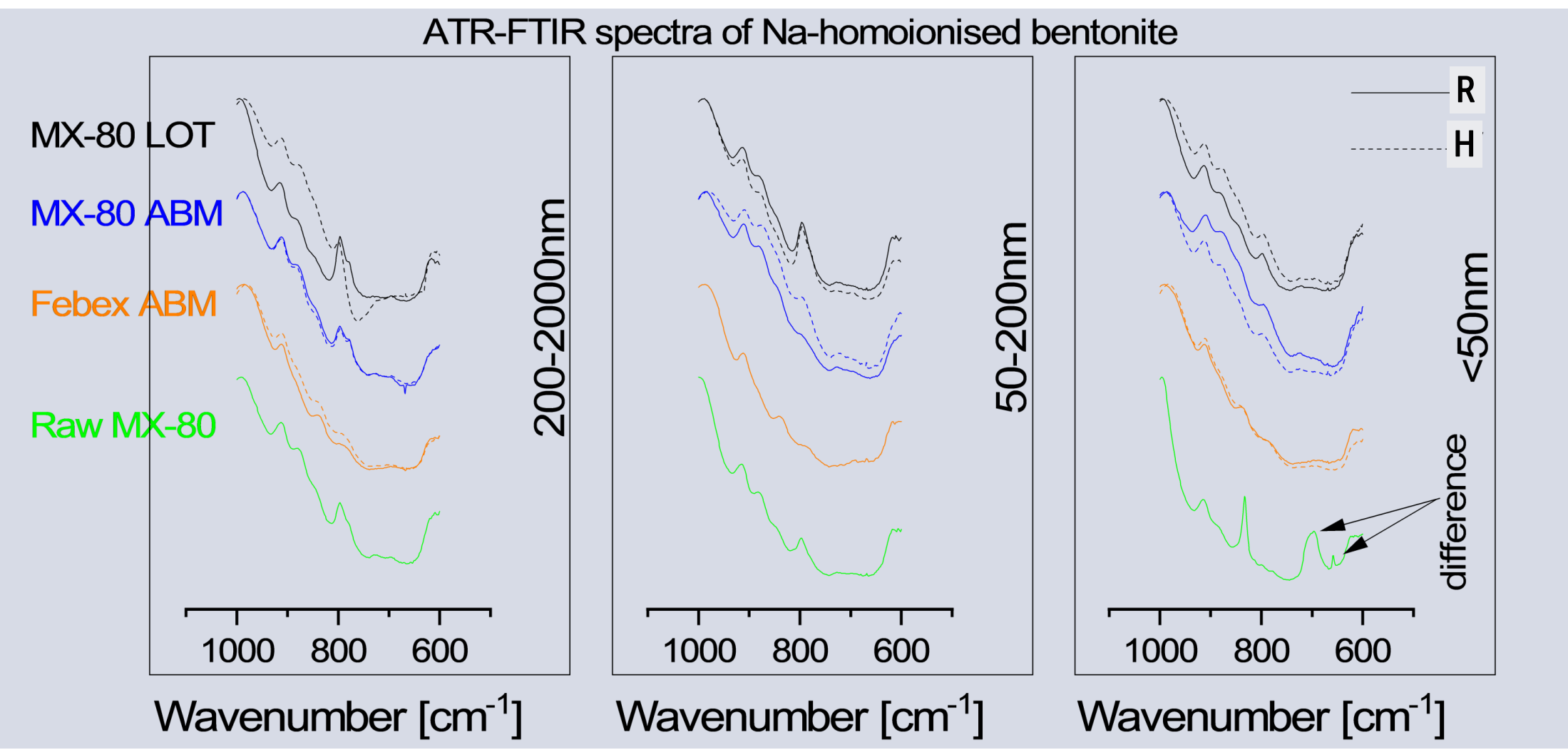
Particle data measured with NTA (NS300 Malvern)

- Median size mobilized between 125 nm – 340 nm



Graph 1
Comparison of erosion between thermally loaded samples, subdivided into regions near the heater interface and near the rock interface, and raw (non-thermally loaded) bentonite from the same batch as the thermally loaded samples.

- Thermally loaded bentonite has **higher mean erosion rates** than the raw bentonite
- **Initial high erosion** regime during **initial swelling** and gel formation. After forming of a **stable gel** expansion front **low erosion regime**.



Graph 2
ATR-FTIR–Spectra of Na-homoionised bentonite of different size fractions. Max-normalised data. Constant offset by bentonite block sample

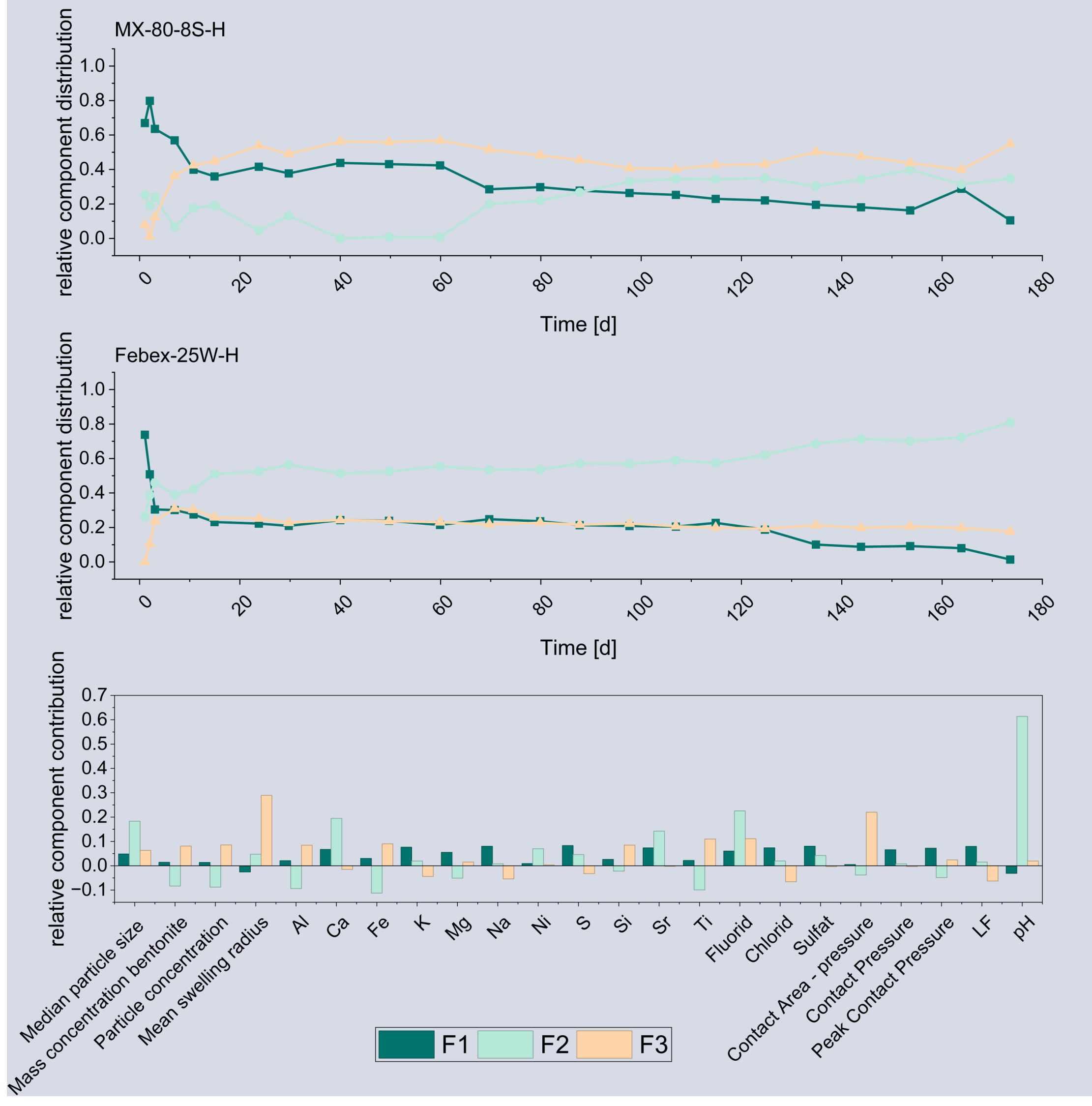
- **Mineralogical** comparison of raw and thermally loaded material show a distinct **alteration only in the <50 nm fraction** in the 696 cm^{-1} and 658 cm^{-1} band

Matrix Factorization [5] semi-non-negative constrained

■ F1: **Cation exchange dynamics and pressure**: Initially strong impact and decreasing over time. Higher impact in MX-80

■ F2: Fingerprint of the **Influent water** with higher pH and **decrease in erosion** with steady increase over time in Febex. Increase after 60 days in MX-80 starting to surpass F1.

■ F3: Fingerprint of **Swelling and erosion**—initially rapid rise during initial swelling and than steady low decline with decreasing erosion. Lower impact in Febex



Graph 3
Three-component Semi-Non-negative Matrix Factorization of erosion data, major element data, physicochemical data, and swelling data.

TAKE HOME MESSAGE

- Long Term thermal load **increases erosion** of Bentonite material **along the thermal gradient.**
- Mean **erosion** rates **under 6.5 kg/m²/a** deemed safe for 1 mm fractures by Posiva [6], **with the highest for the MX-80-18E-V** (4.6 ± 1.7 kg/m²/a at a runtime of 174 days)
- **Febex** (Mg-Ca bentonite) samples show the **lowest erosion** rates but also **lowest swelling** pressure (especially close to the heater)

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