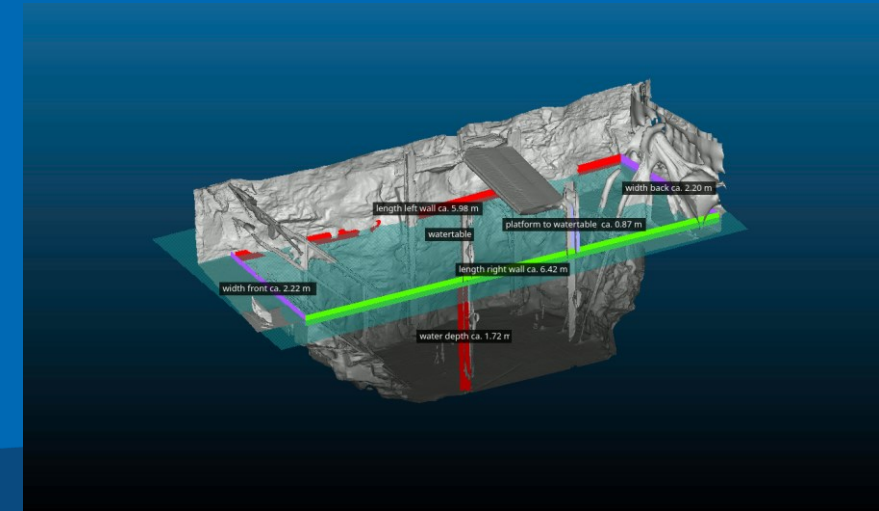


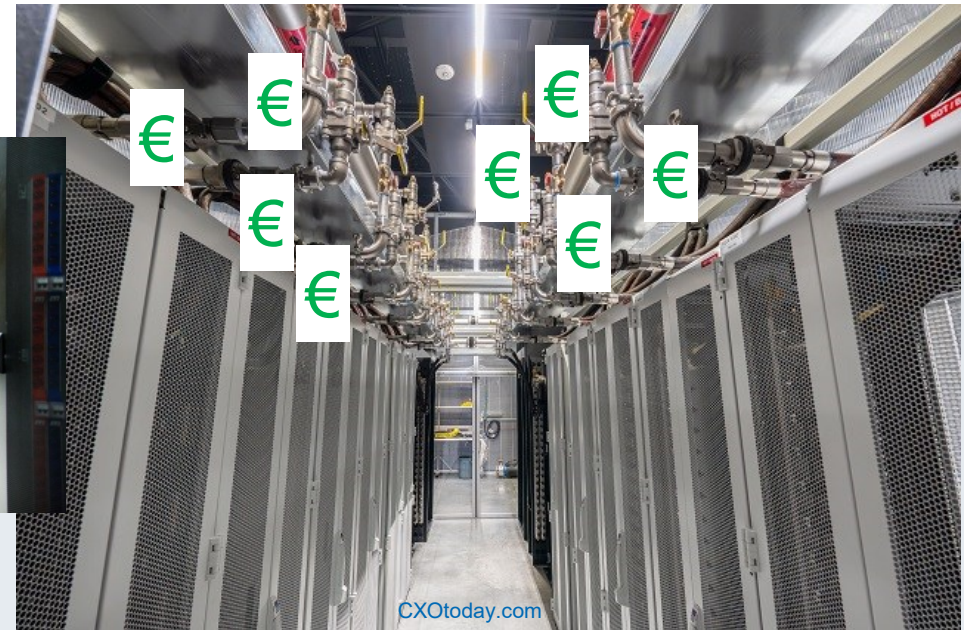
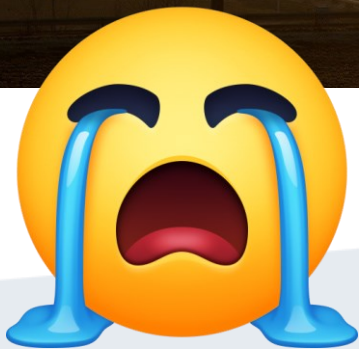
A new life for underground mines: The Reiche Zeche Geo-Lab for in-situ simulation of mine thermal energy storage

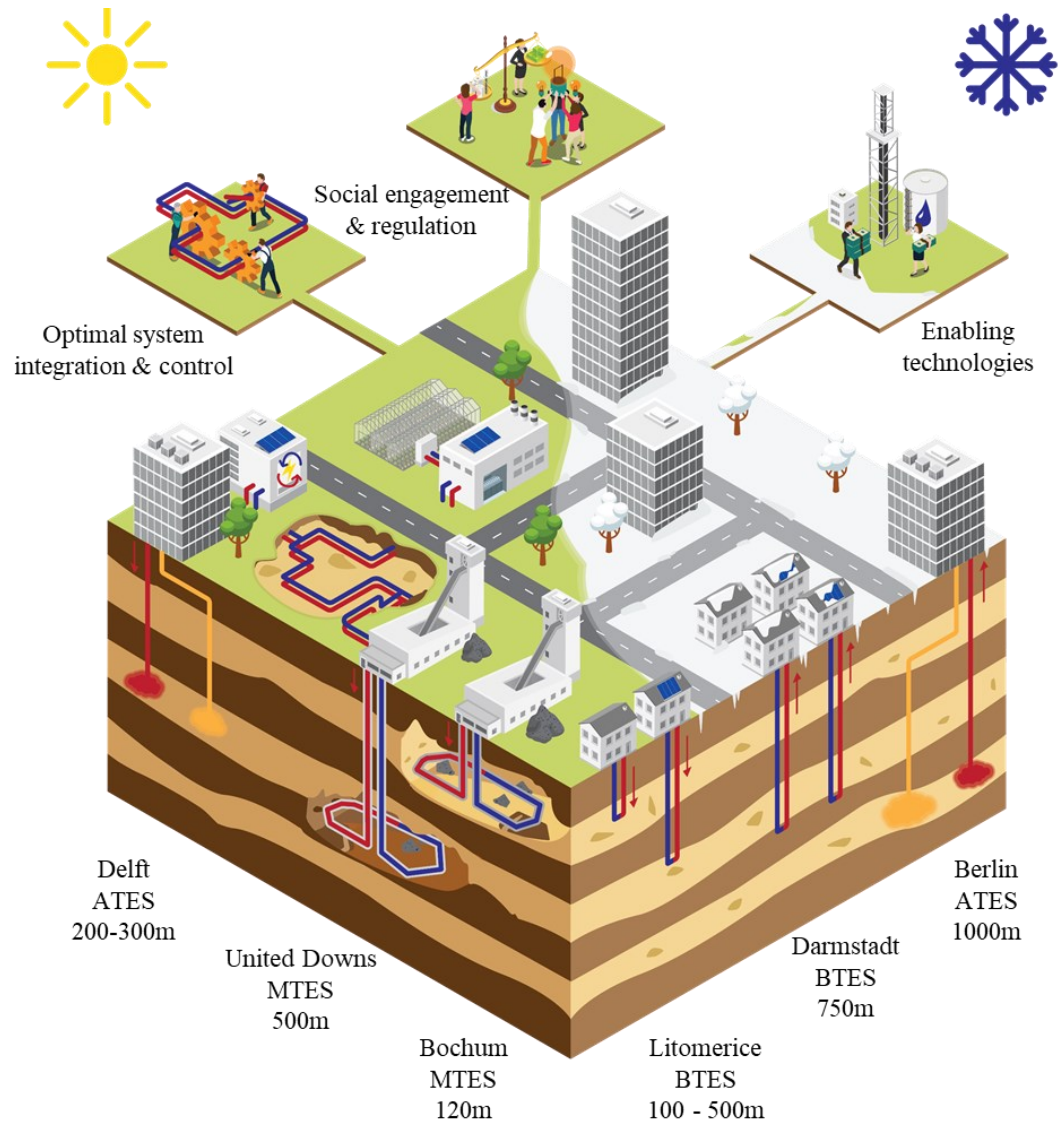
(Nutzung grundwassererfüllter bergbauliche Hohlräume als thermische Energiespeicher)



Alireza Arab, Martin Binder, Lukas Oppelt, Christian Engelmann, Chaofan Chen,
Timm Wunderlich, Tobias Lotter, Christoph Späker, Frank Schenker, Traugott Scheytt

Waste heat? (cold)

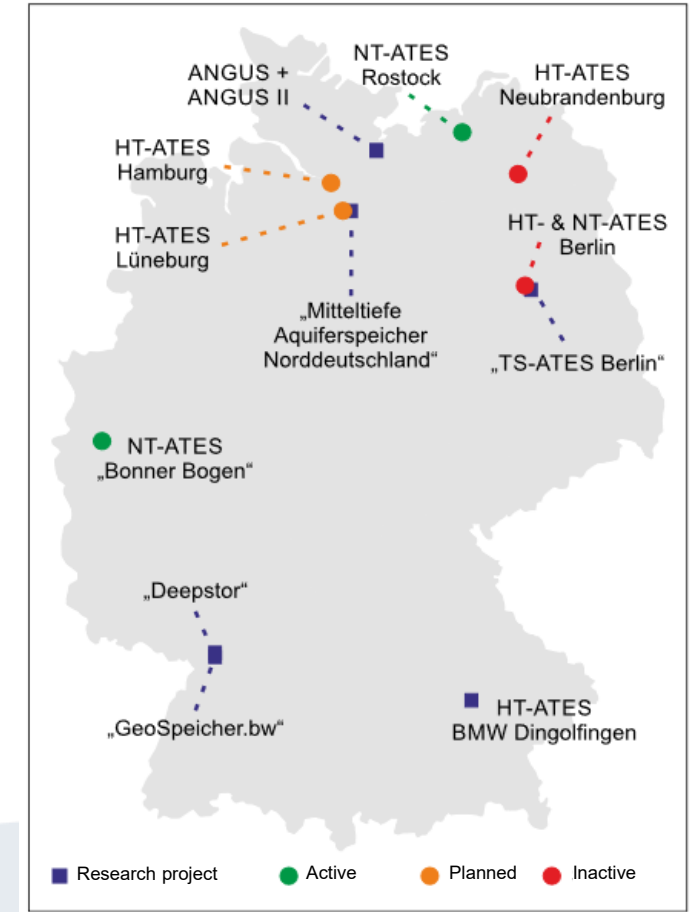
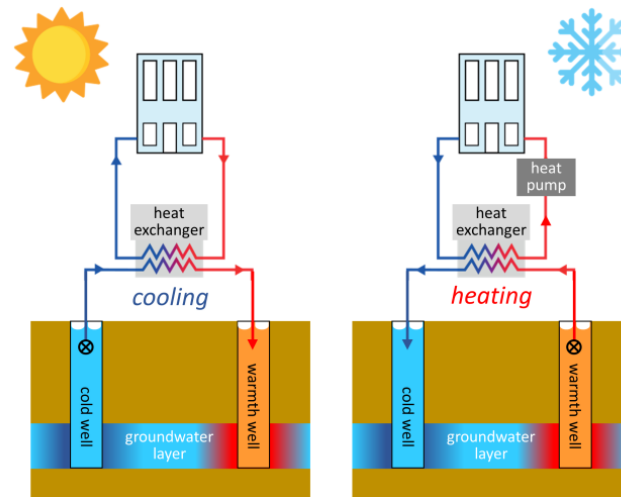




Underground Thermal Energy Storage (ATES/MTES) in Germany



[<https://www.wur.nl/>]

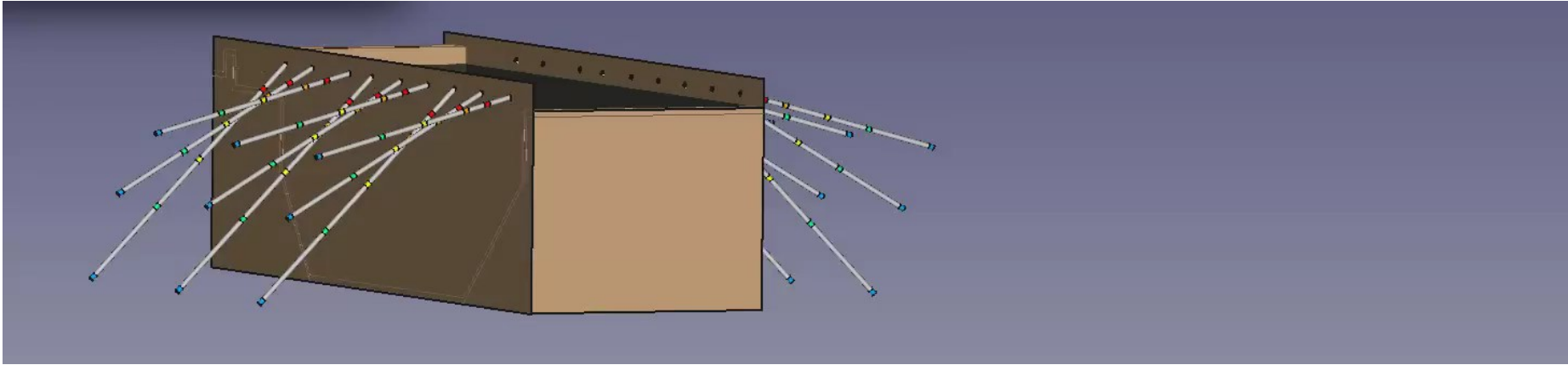


[Fleuchaus, P. et al. 2021]

Rules of the game:

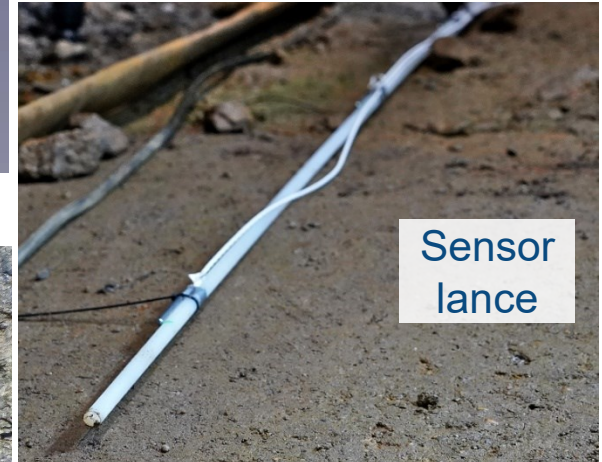
- Reservoir and heat exchanger should remain functional
- Pumps, pipes, equipment, and plants should have a sufficiently long service life
- Sustainable energy storage (long-term, reliable, low-maintenance, cost-effective)

In-Situ laboratory – sensor array installation

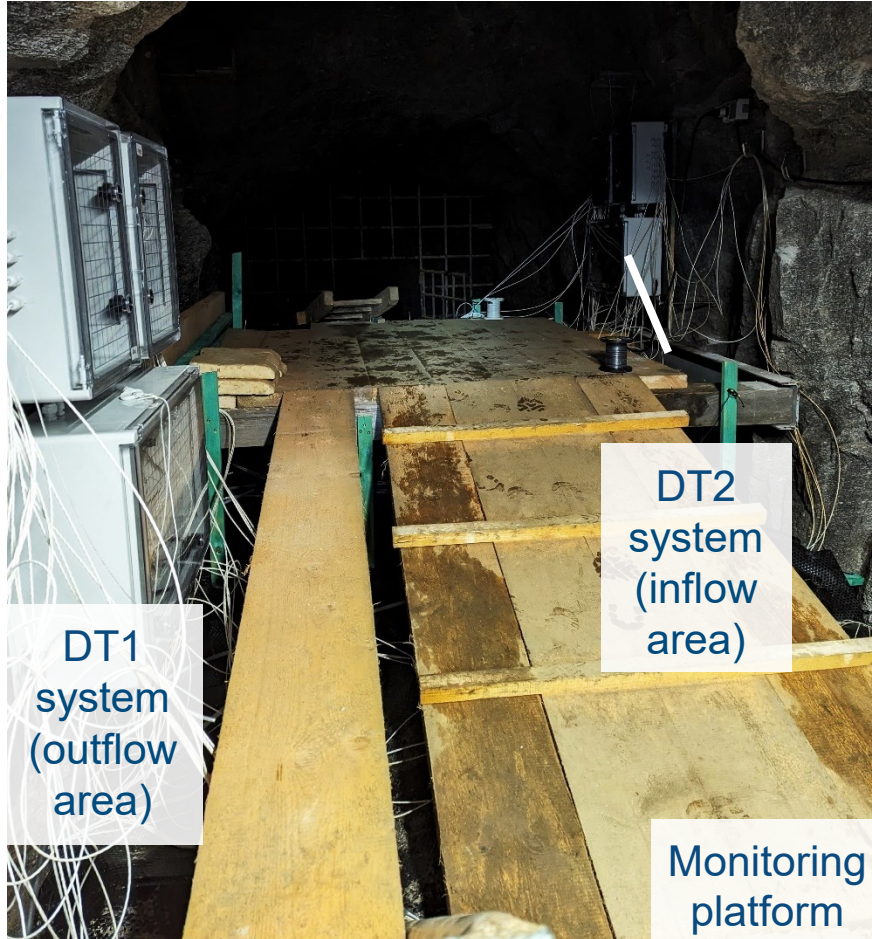


Thermal conductivities
(HotDisk method)
Rock \approx ThermoCement
 $\approx 3.0 \text{ W / (m}\cdot\text{K)}$

In-situ basin in the Reiche Zeche silver mine with 3 m plastic rods and sensors connected to them



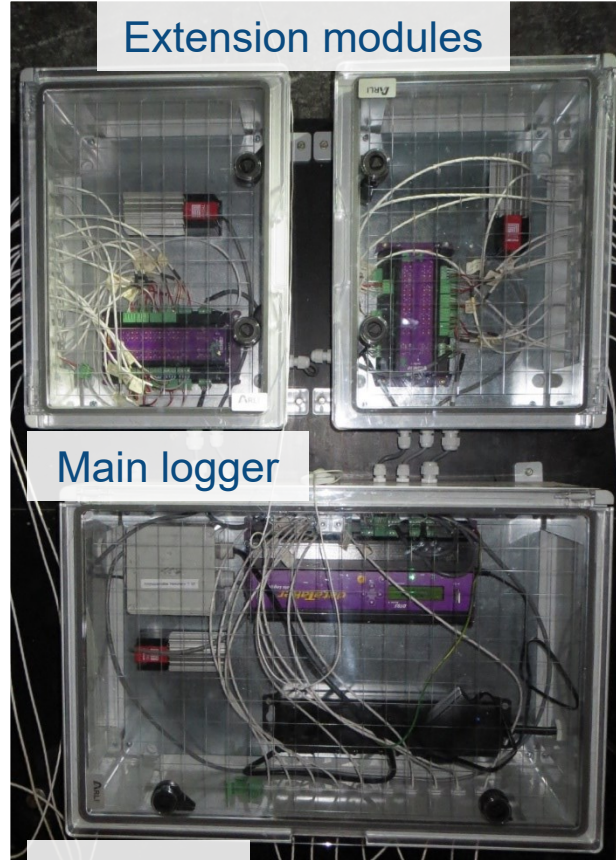
In-Situ laboratory – monitoring platform



DT1 system (outflow area)

DT2 system (inflow area)

Monitoring platform



Extension modules

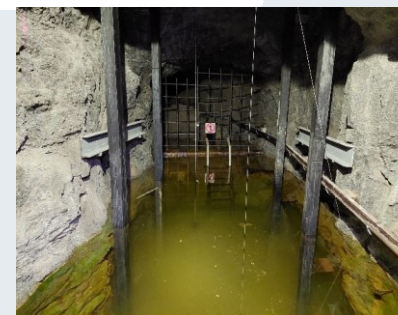
Main logger

Heated cabinets



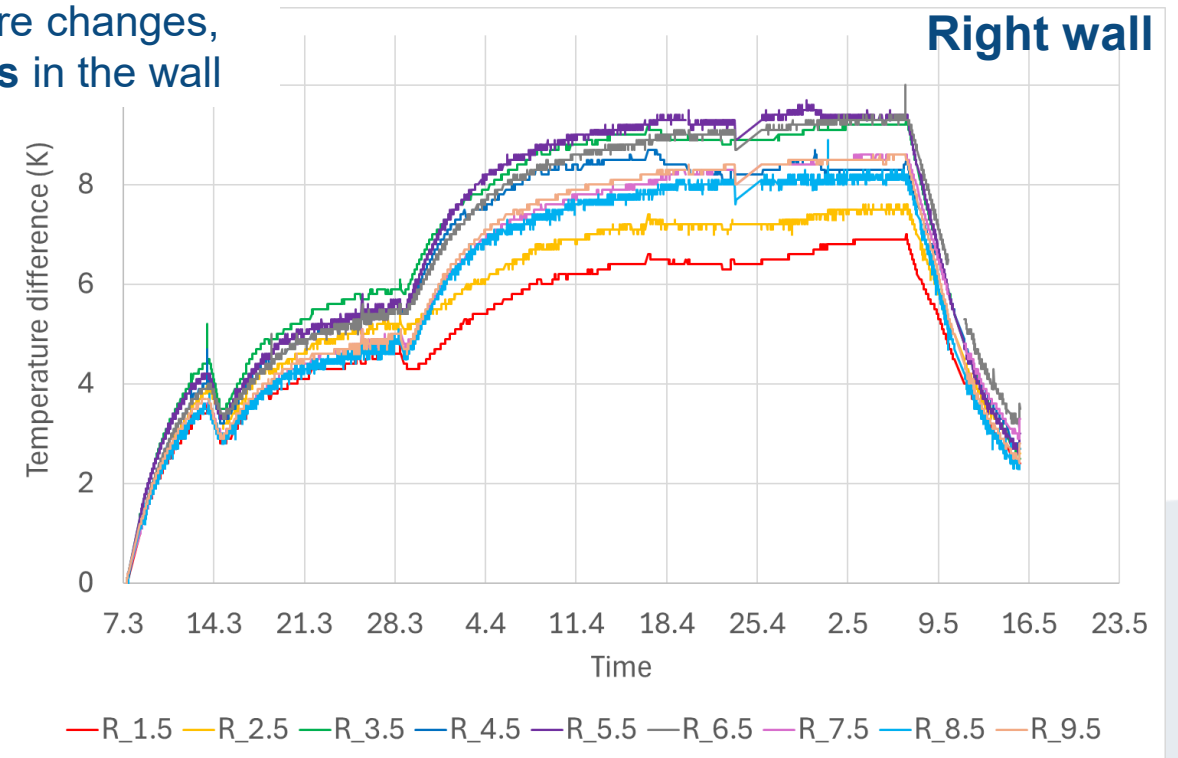
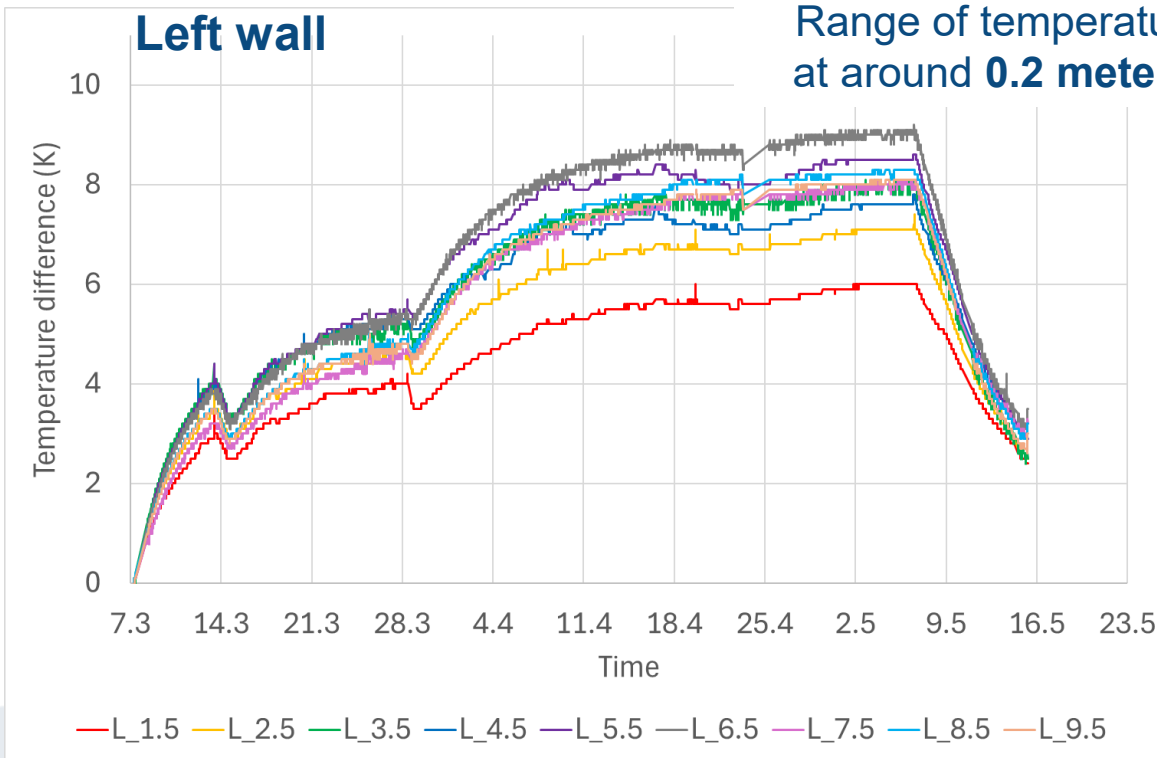
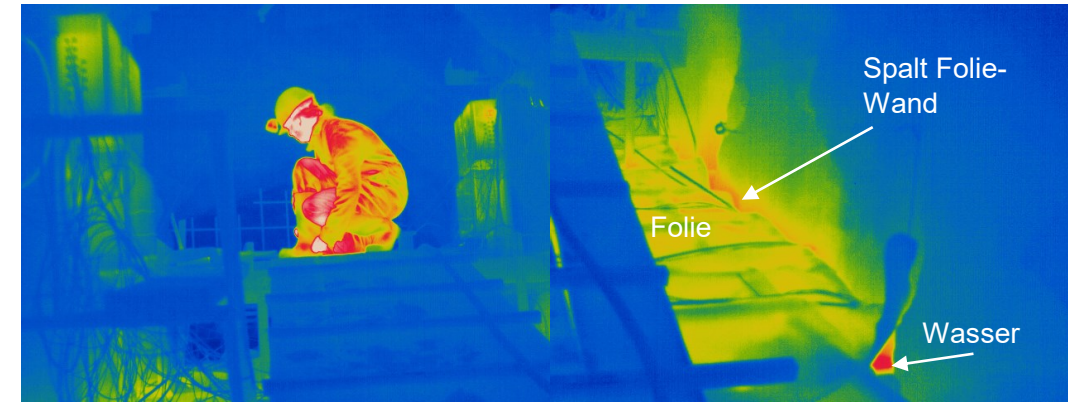
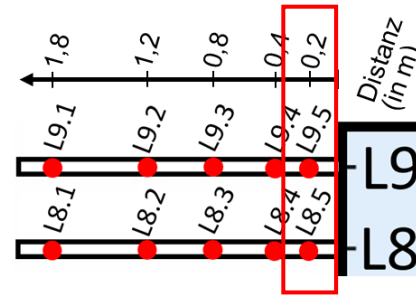
Mobile pH / EC meter

Temperature monitoring equipment (dual system DT1 and DT2); mobile analysis of guiding parameters



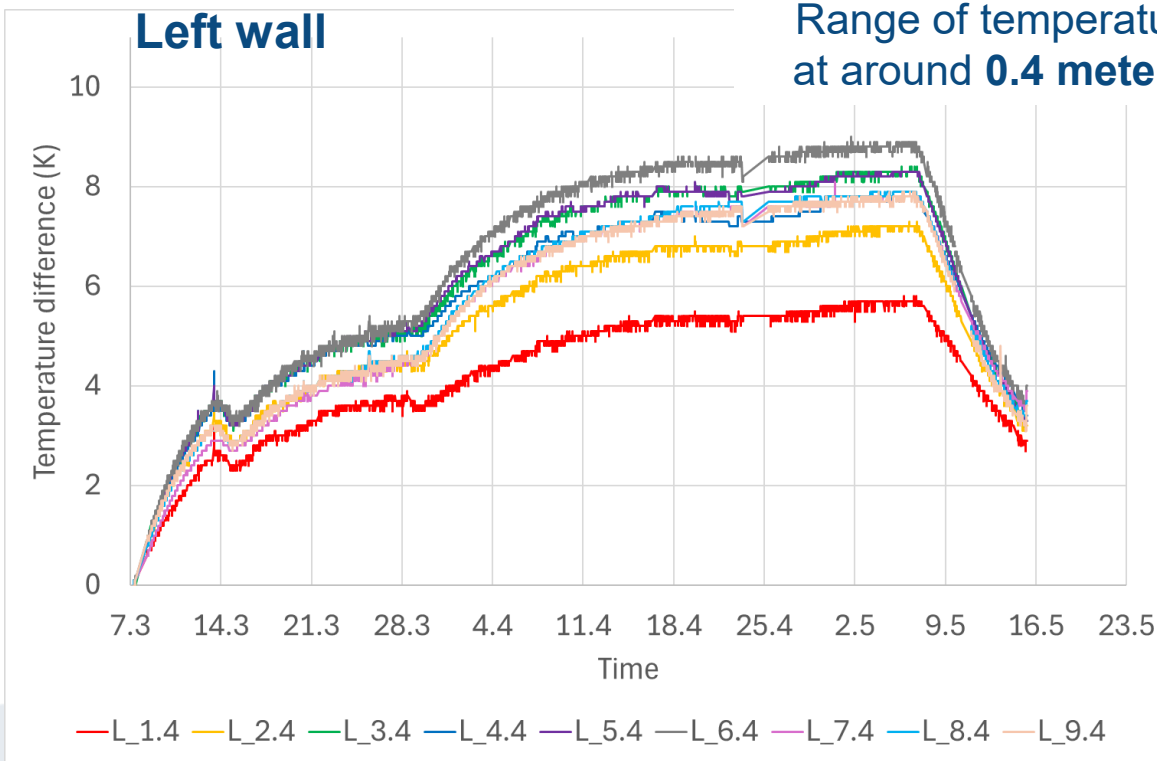
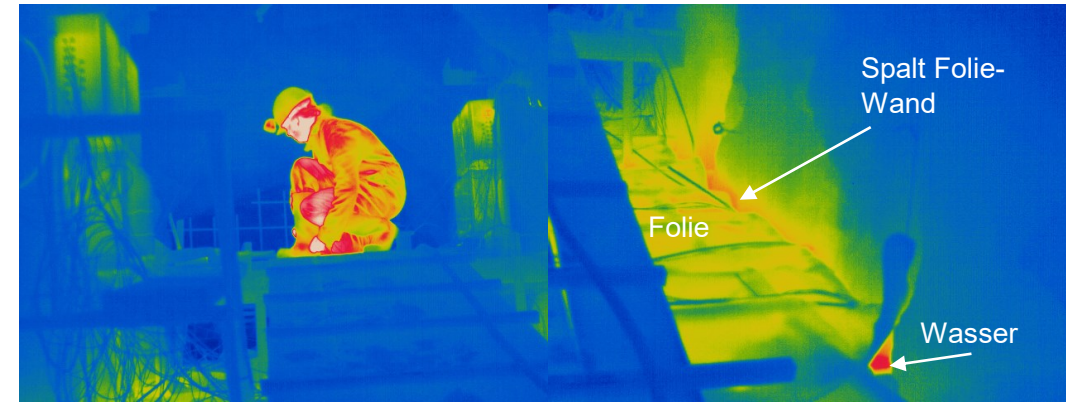
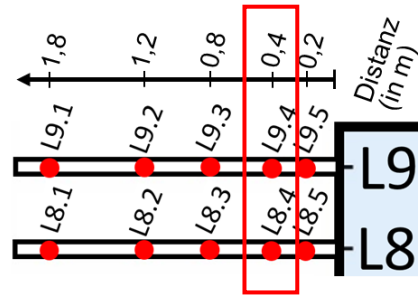
In-Situ laboratory – temperature sensing

- Heat transport into rock was observed on all sensors.
- Numerical model to be used to quantify recovery efficiency.

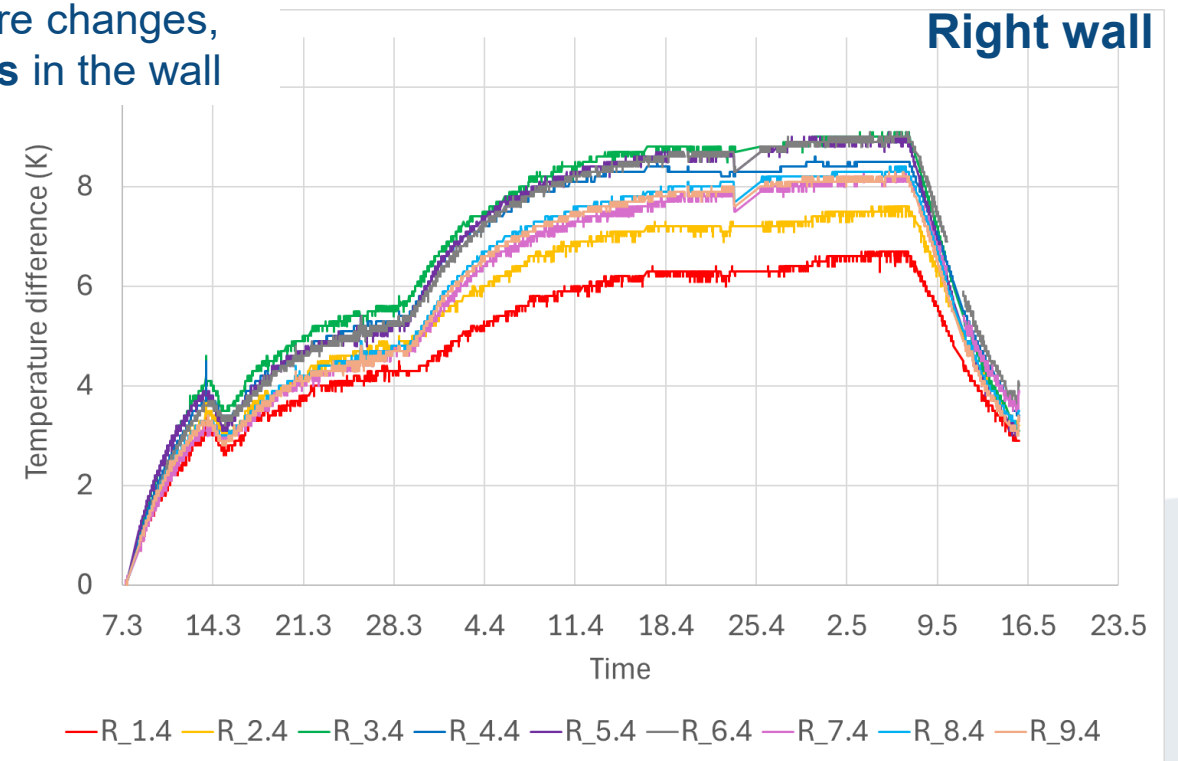


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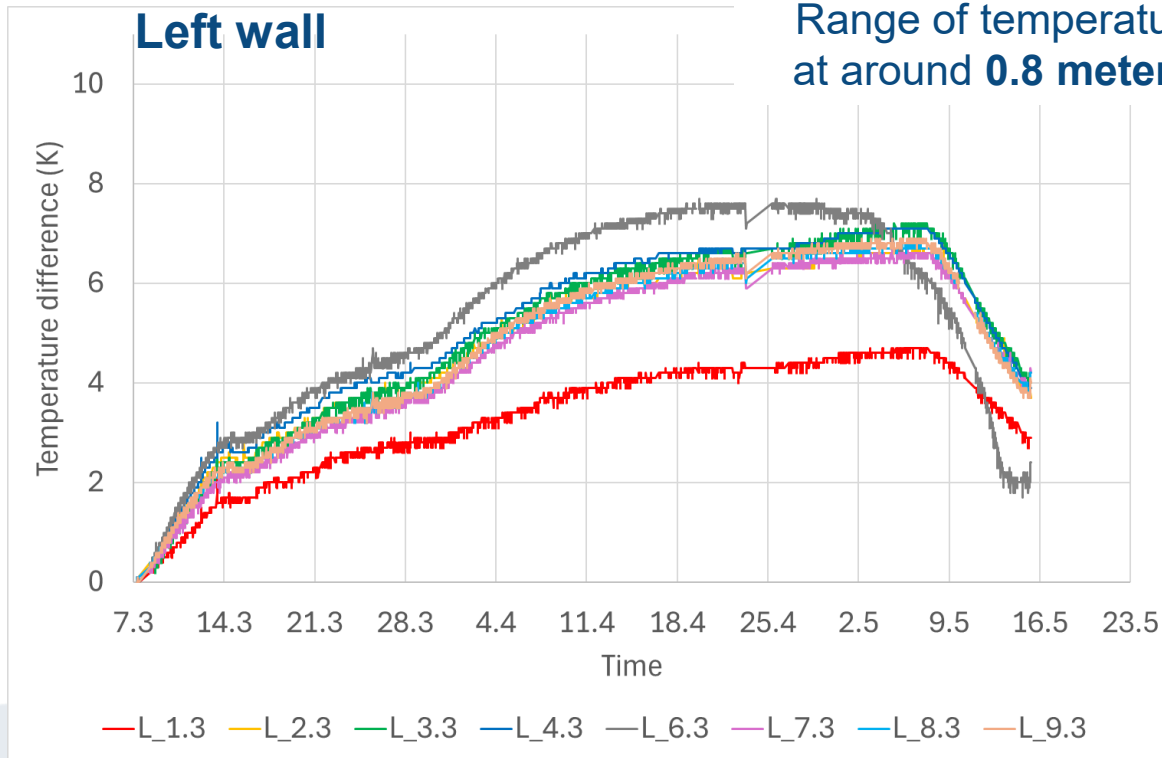
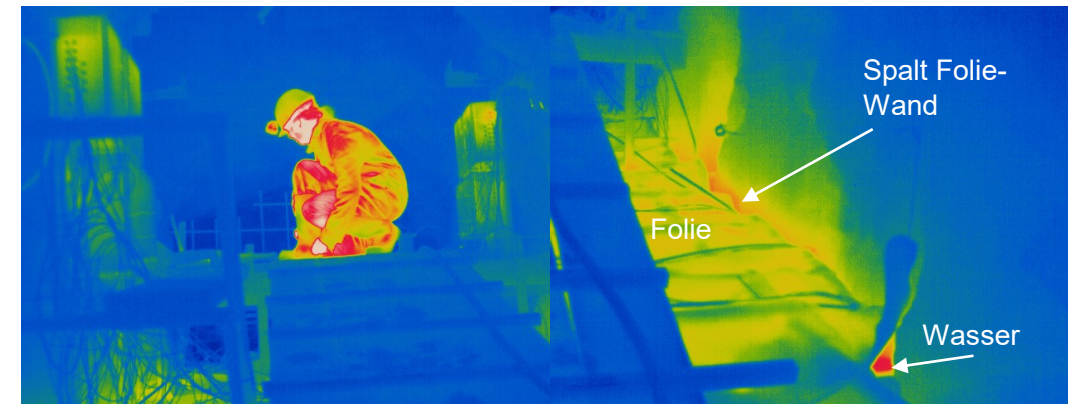
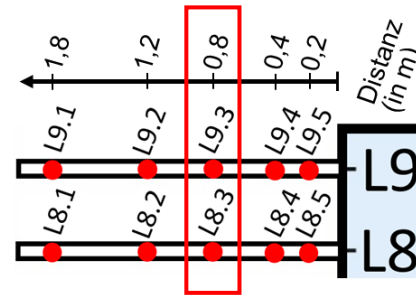


Range of temperature changes, at around **0.4 meters** in the wall

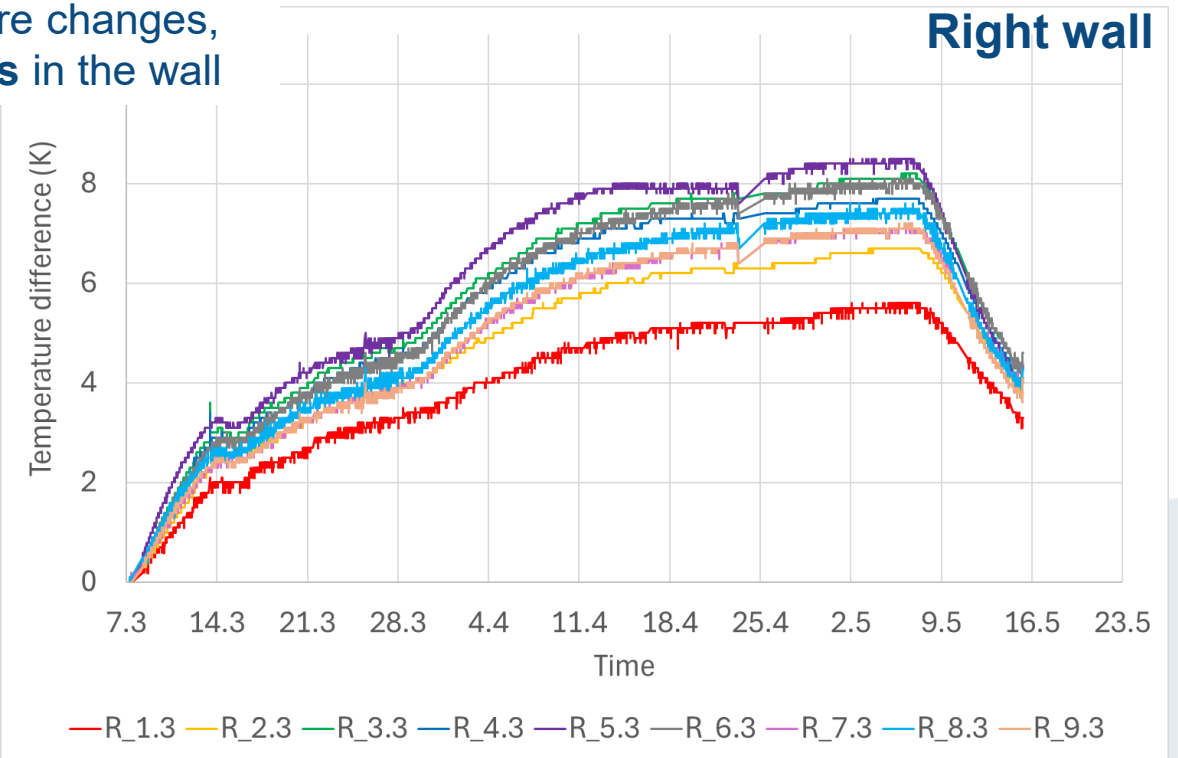


In-Situ laboratory – temperature sensing

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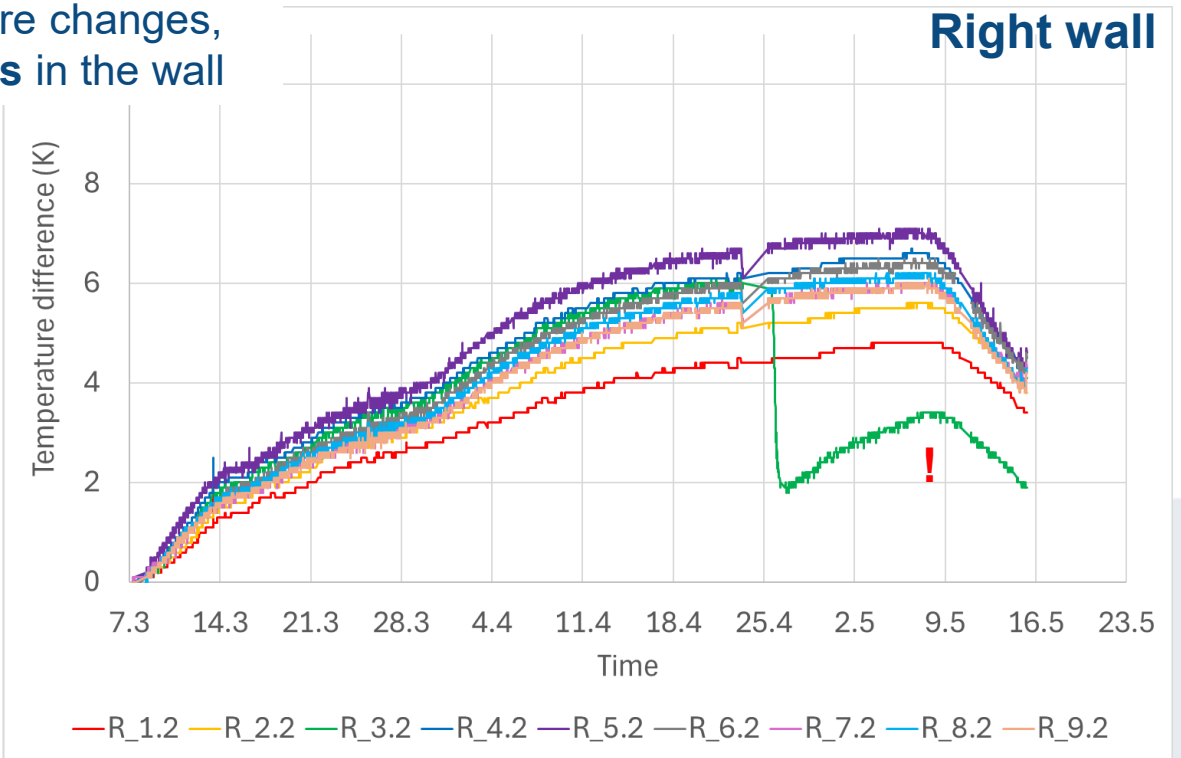
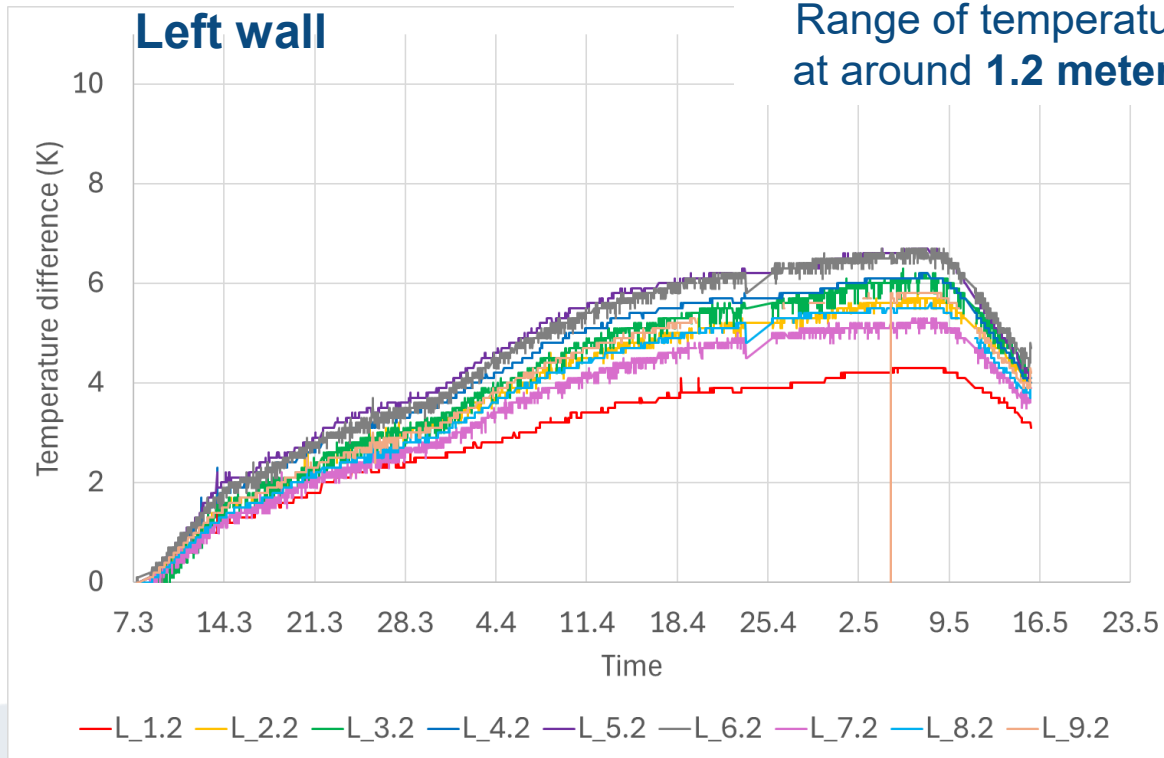
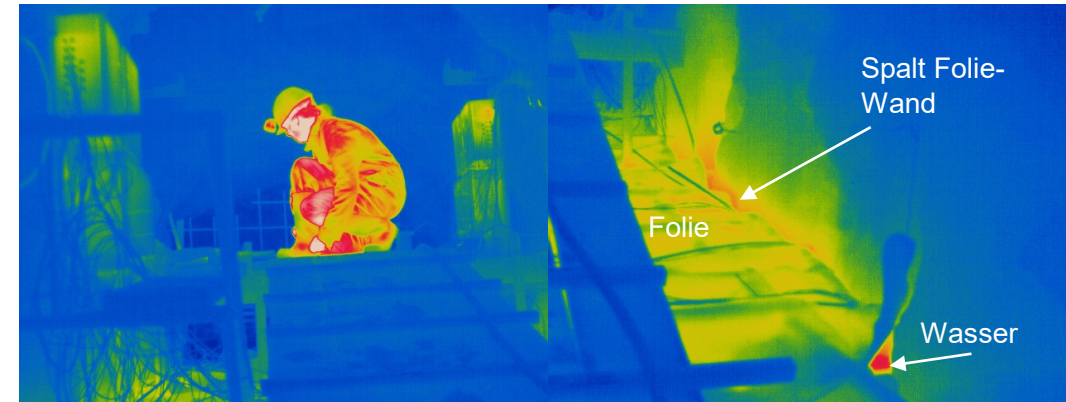
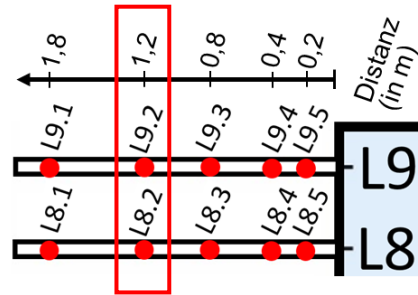


Range of temperature changes, at around **0.8 meters** in the wall



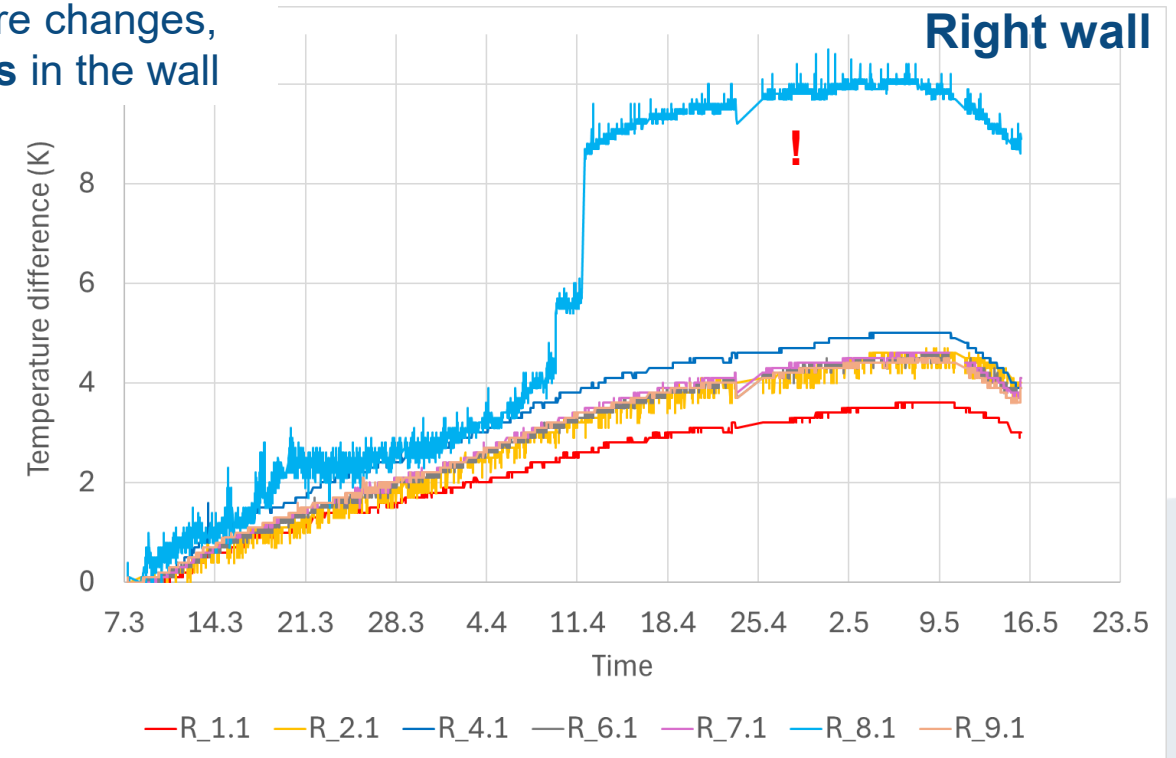
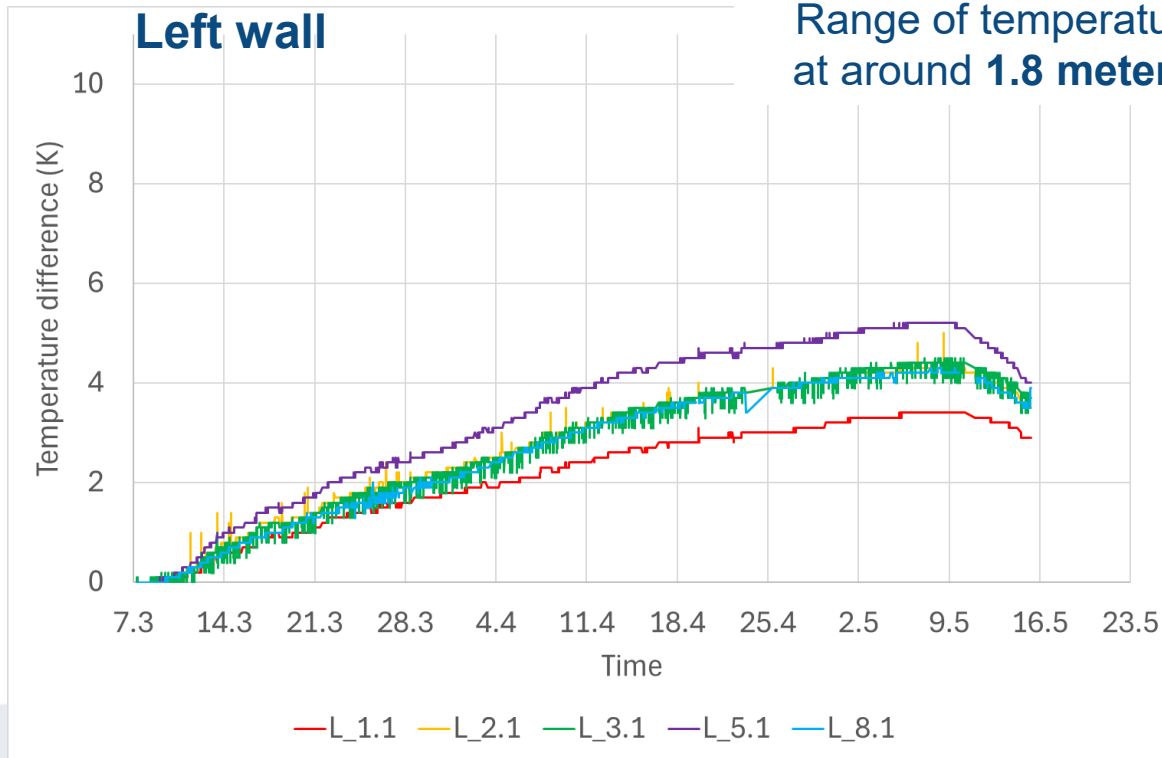
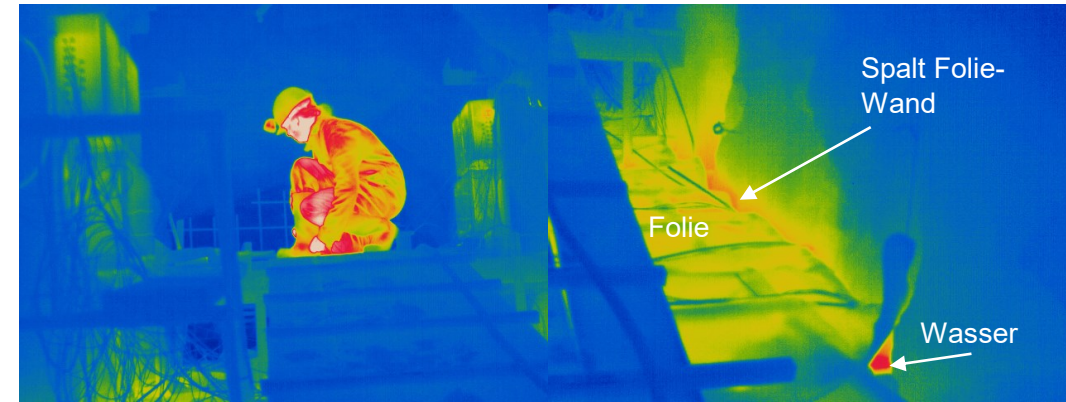
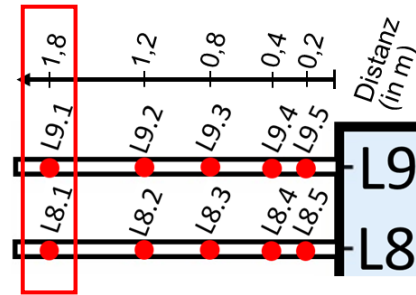
In-Situ laboratory – temperature sensing

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In-Situ laboratory – temperature sensing

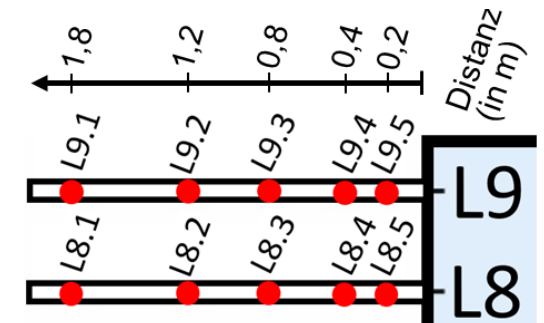
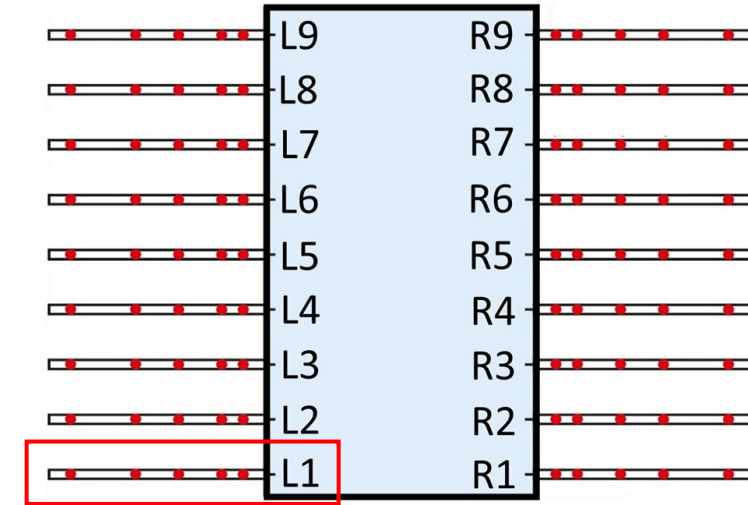
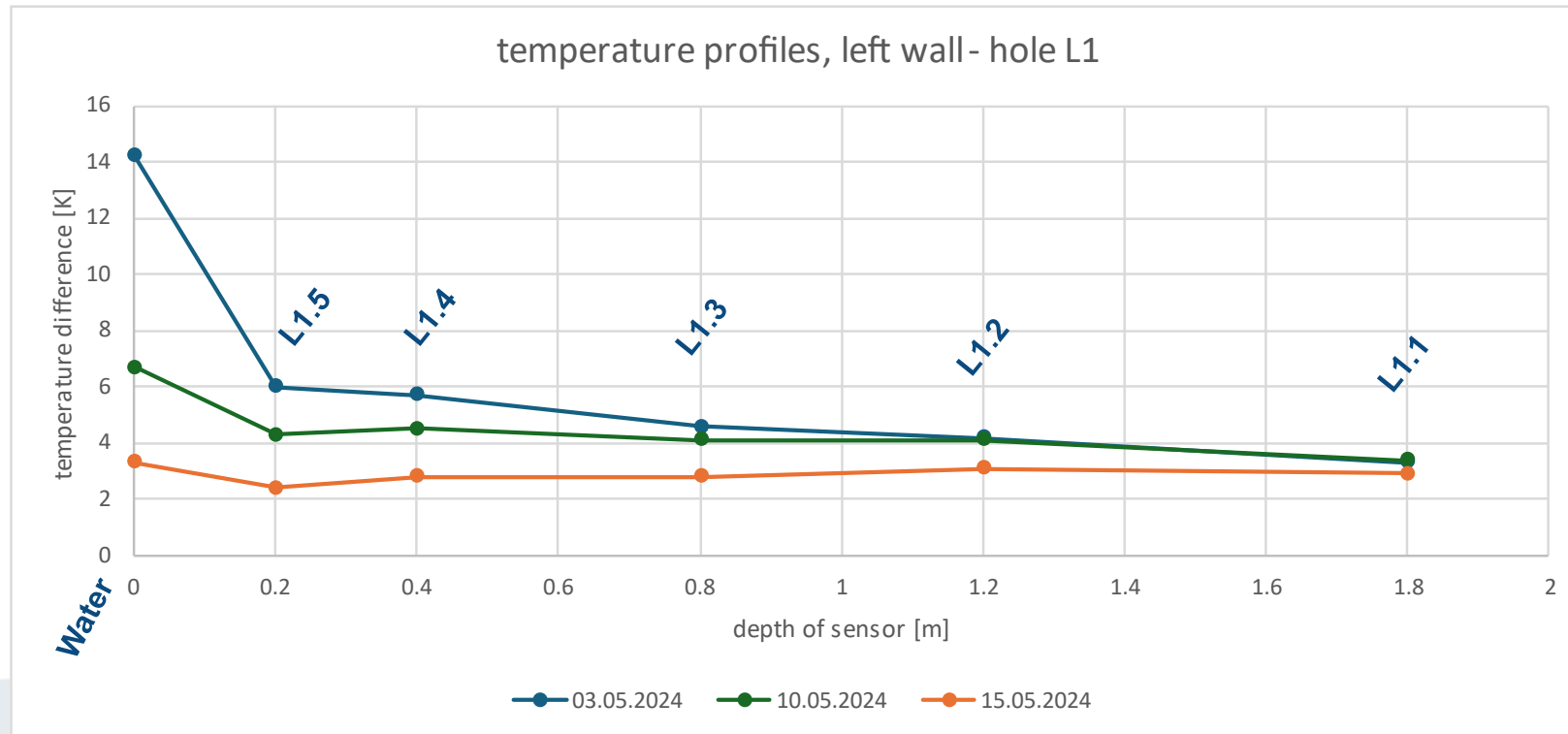
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In-Situ laboratory – temperature sensing

- Heat transport into rock was observed on all sensors.
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Left wall



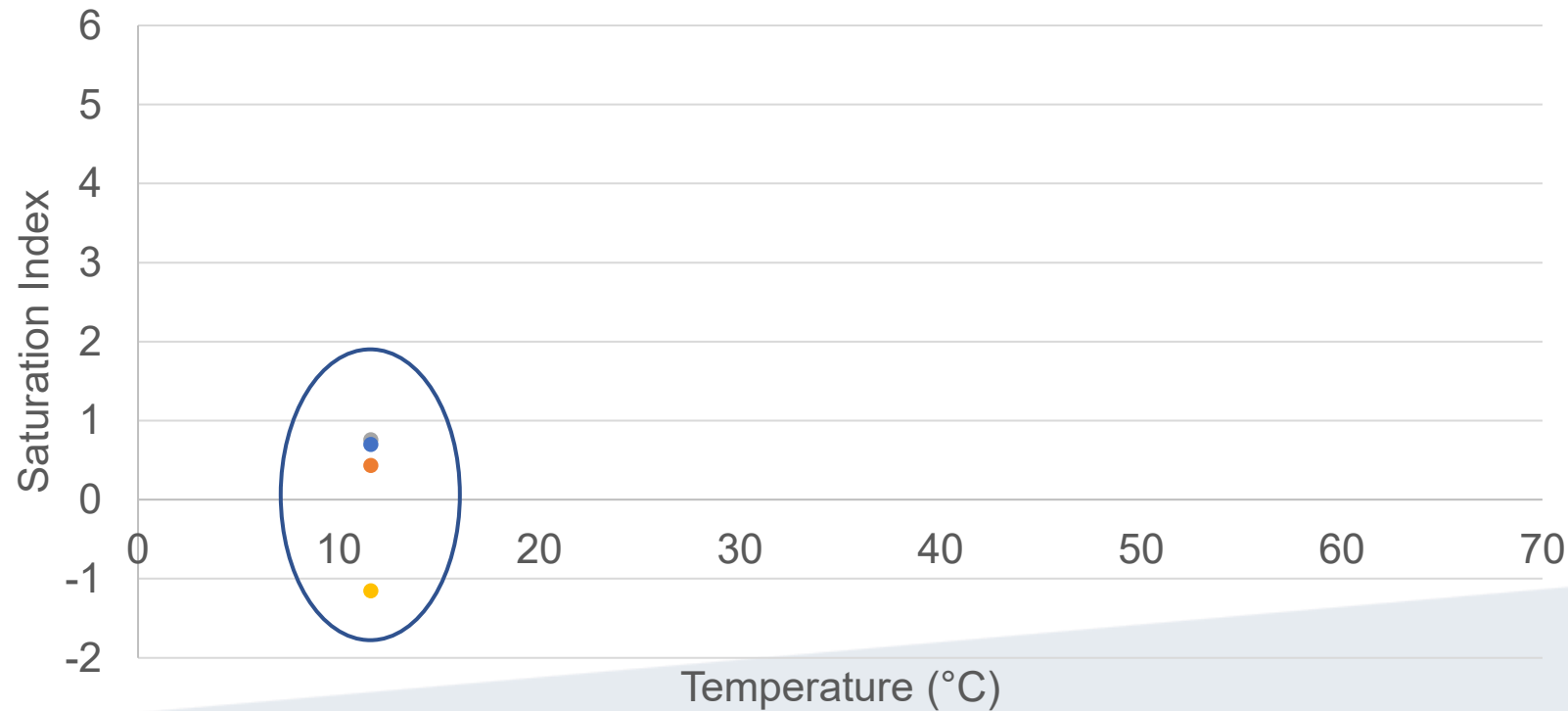
Mine water

Freiberg Gneiss: quartz, plagioclase, potash feldspar, biotite, and muscovite



Sister project

Mineral dissolution/precipitation



- Goethite
- Hematite
- Lepidocrocite
- Quartz
- Pyrolusite (MnO2)

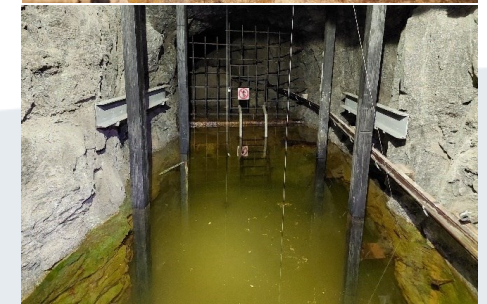
$$SI = \log\left(\frac{IAP}{K}\right)$$

IAP: ion activity product

K: solubility product (25 °C)

SI > 0 precipitation

SI < 0 dissolution



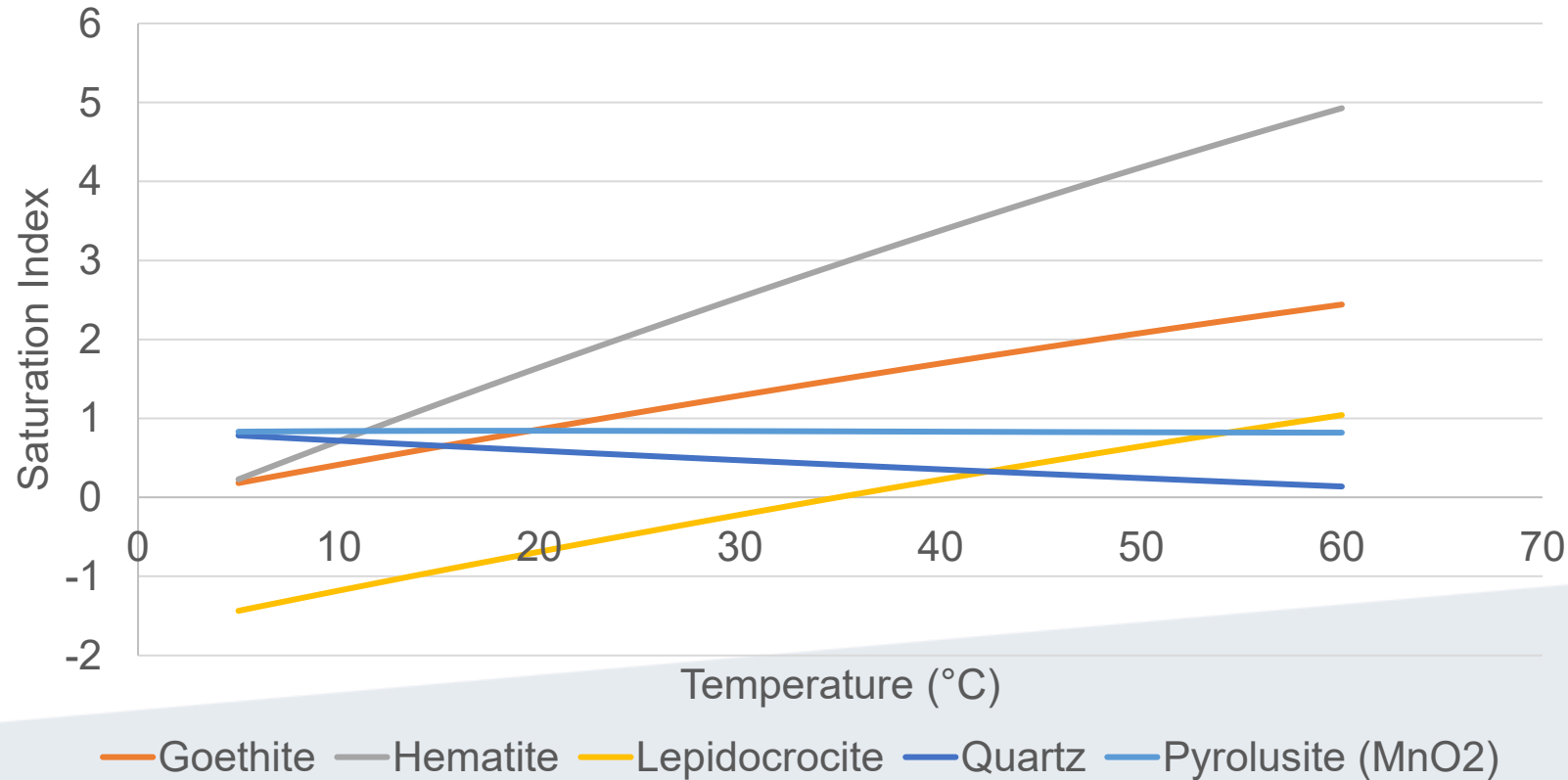
Mine water

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Sister project

Mineral dissolution/precipitation



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IAP: ion activity product
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SI > 0 precipitation
SI < 0 dissolution

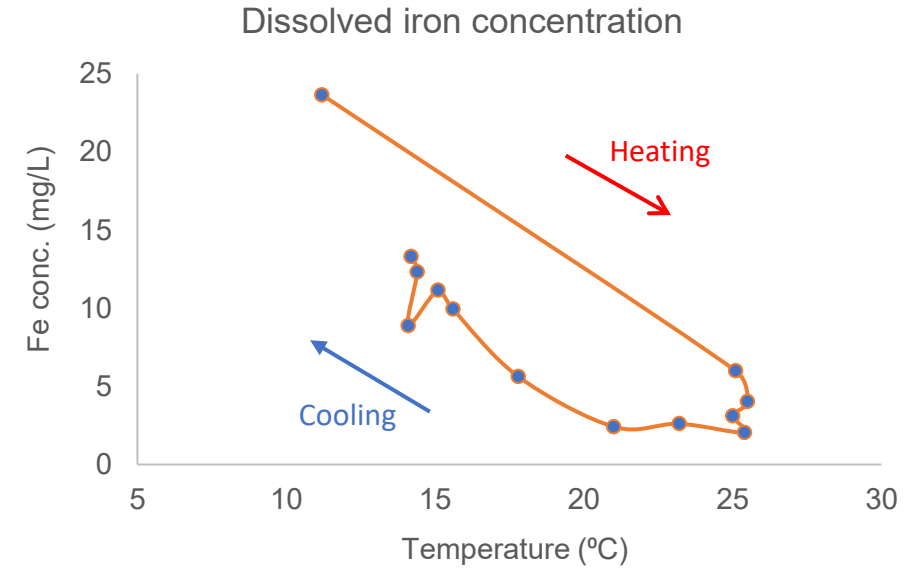
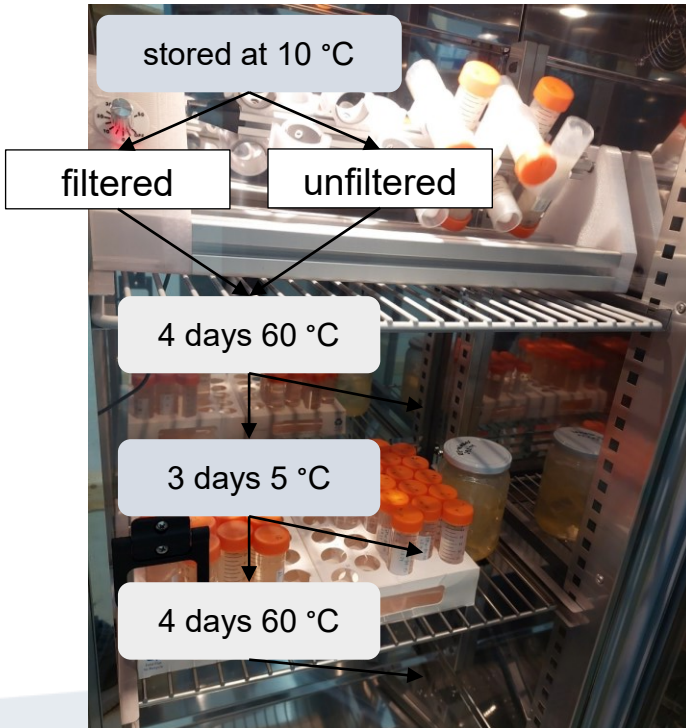
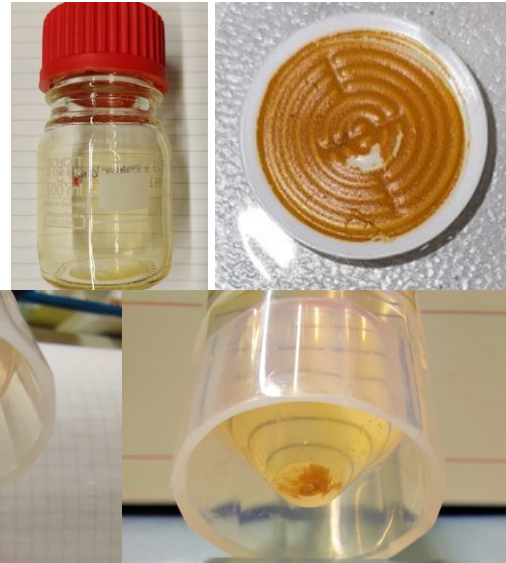


Mine water

- Determine how much iron precipitates and in which form
- How to “UnClog” !



Sister project



Lab experiment	Fe
Mine water 11 °C	22.37 (mg/L)
Heated up	2.01 (mg/L) (avg.)
20 cubic meter - prec. (Sludge 70:30)	0.66 Kg (1.53 Kg)

In-Situ MTES	Fe
Mine water 11 °C	22.65 (mg/L)
Heated up	2.42 (mg/L)
20 cubic meter - prec. (Sludge 70:30)	0.65 Kg (1.52 Kg)

