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MineATES - Unraveling operational challenges and failures in mine thermal energy storage

Alireza Arab, Martin Binder, Christian Engelmann, Traugott Scheytt (**HYDGEO**)

Lukas Oppelt, Tim Wunderlich, Thomas Grab (**THERMO**)

Chaofan Chen, Thomas Nagel (**BOMECH**)

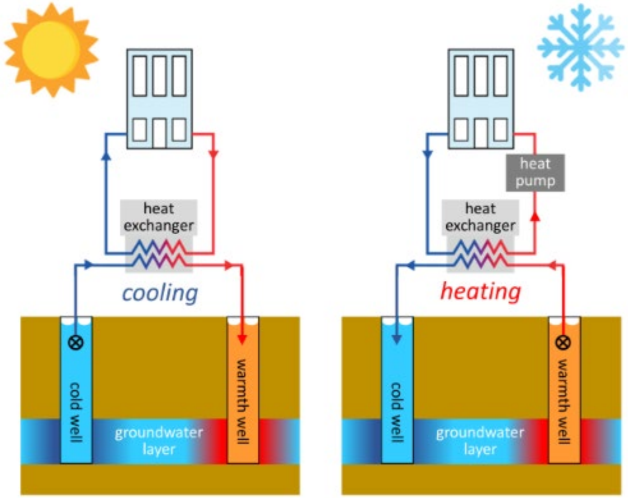
Patrick Heinrich, Mareike Bleidießel, Thomas Wenzel

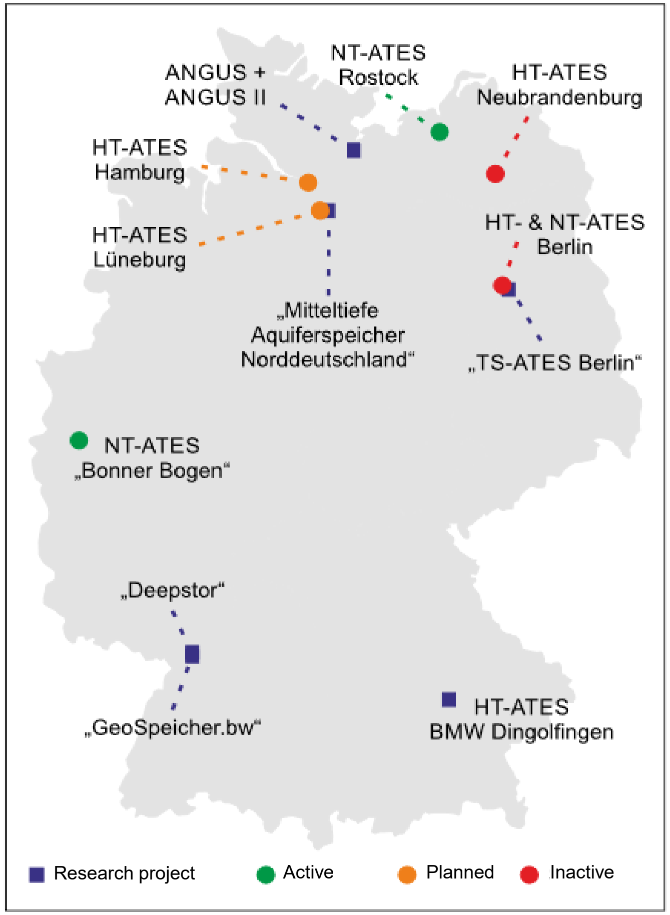
Julia Mitzscherling, Jens Kallmeyer, Dirk Wagner

Dr. Alireza Arab | TU Bergakademie Freiberg | Hydrogeology and Hydrochemistry | Tel: 03731 / 39-2436 | araba@geo.tu-freiberg.de

Aquifer Thermal Energy Storage (ATES) in Germany

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





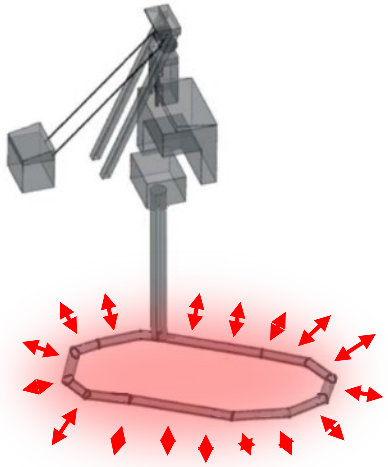
[Fleuchaus, P. et al. 2021]

Rules of the game:

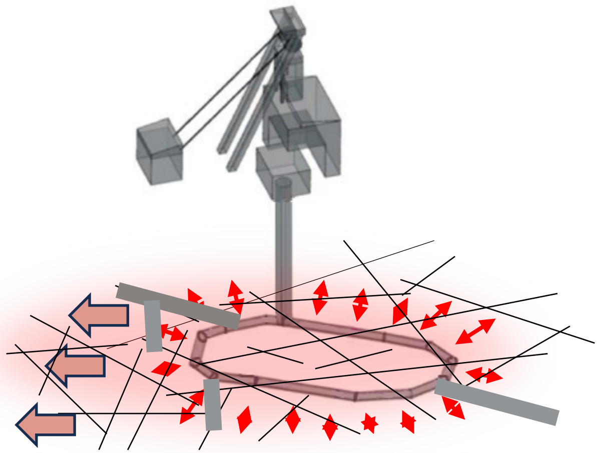
- Reservoir and heat exchanger should remain functional
- Pumps, pipes, equipment, and plants should have a sufficiently long service life
- Sustainable energy storage (long-term, reliable, low-maintenance, cost-effective)

Mine Thermal Energy Storage (MTES)

In reality: it is an open, reactive system



Heat conduction into rock and storage in the rock → more storage space available, but also potential losses



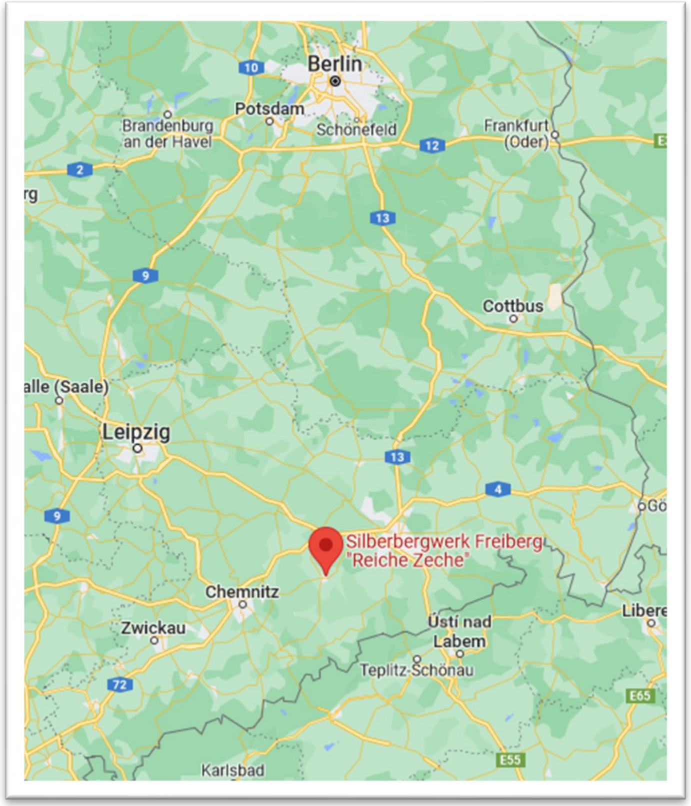
Heat convection with water flow (e.g., via fractures or leaking seals etc.) → potential losses

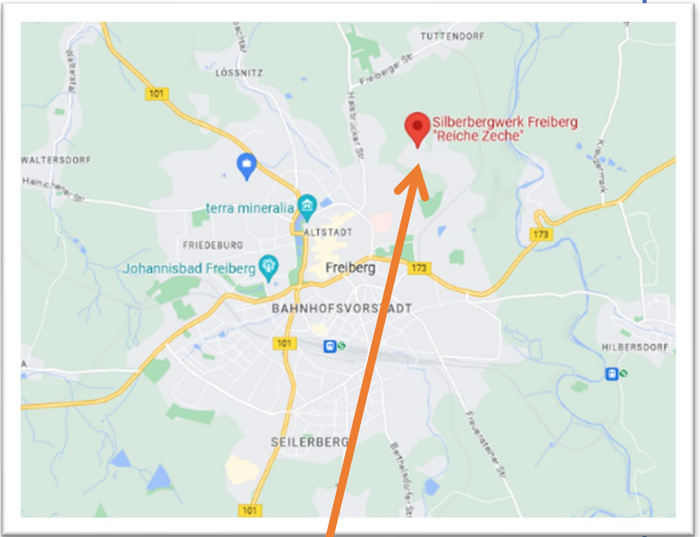
Basic concept of MTES [modified after Bundesverband Geothermie] and challenges

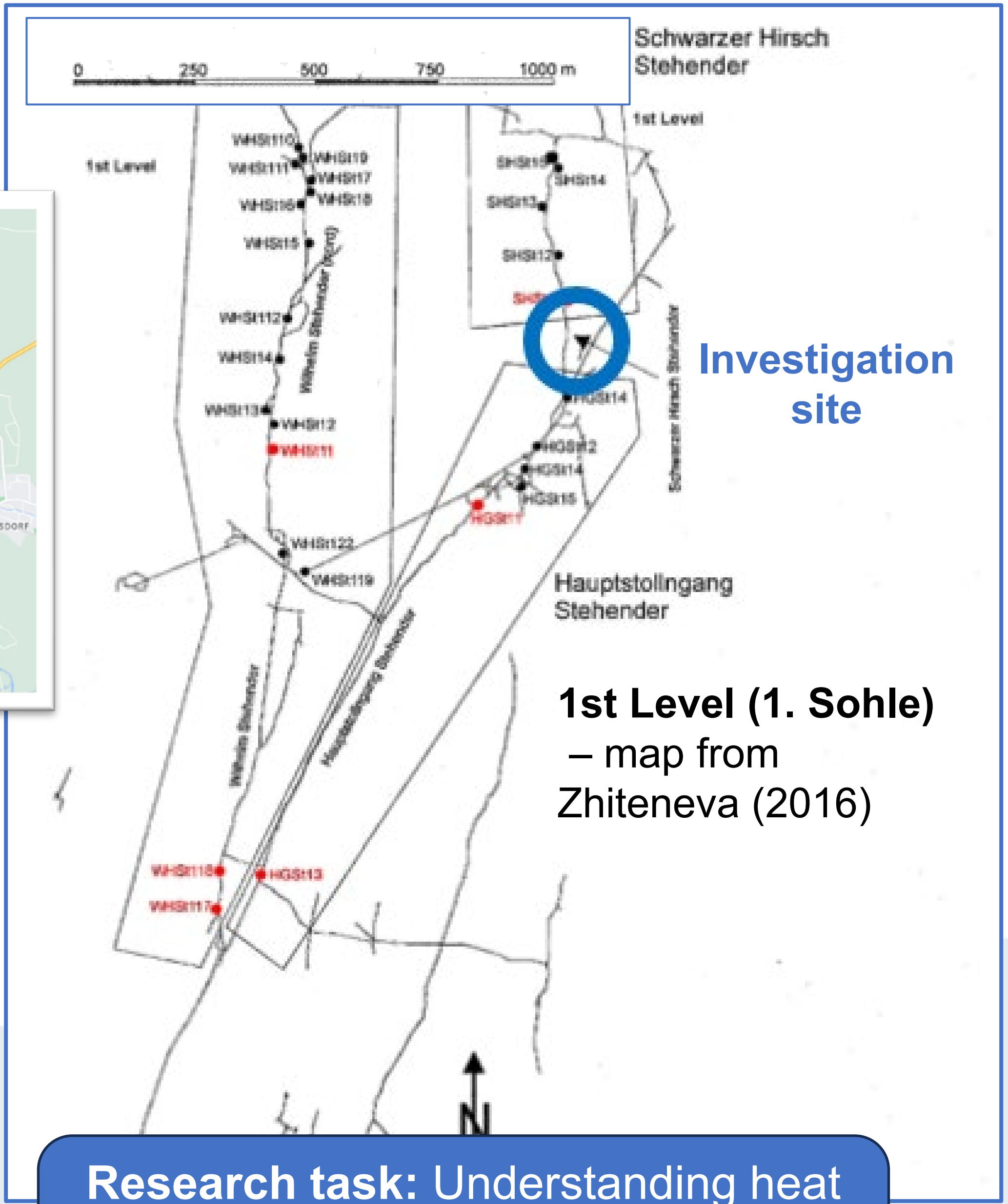
Where do the dangers lurk?

- Slime formation (formation of biofilm, "biofouling")
- Clogging of wells, deterioration of pathways
- Clogging of filter gravel, sieves, strainers, pumps
- Corrosion (especially heat exchangers)
- Calcification / sintering of plants and pipes
- Aluminum deposits
- Combination of several above mentioned processes

In-situ real laboratory station at Reiche Zeche (Freiberg, Saxony)







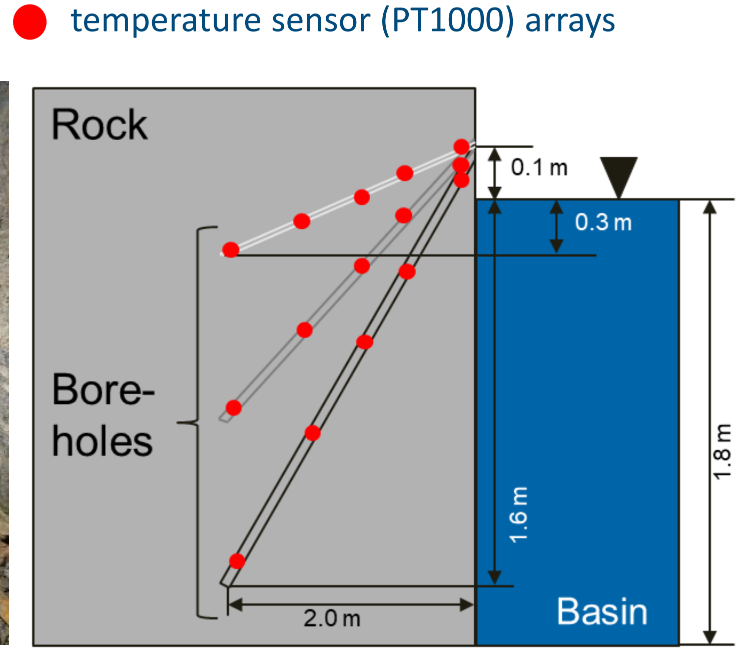
Investigation site

1st Level (1. Sohle) – map from Zhiteneva (2016)

Position and 1st level map of the Reiche Zeche Silver Mine

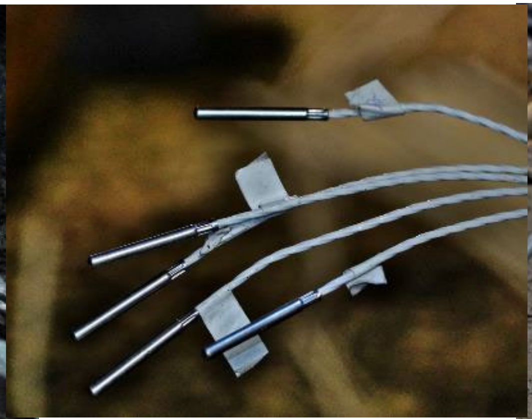
Research task: Understanding heat transport and reactions during TES cycles in an underground mine

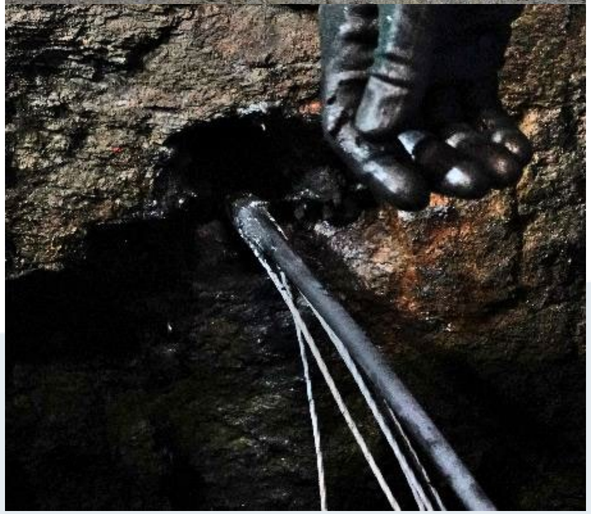
In-situ real laboratory:
temperature monitoring in 21 boreholes



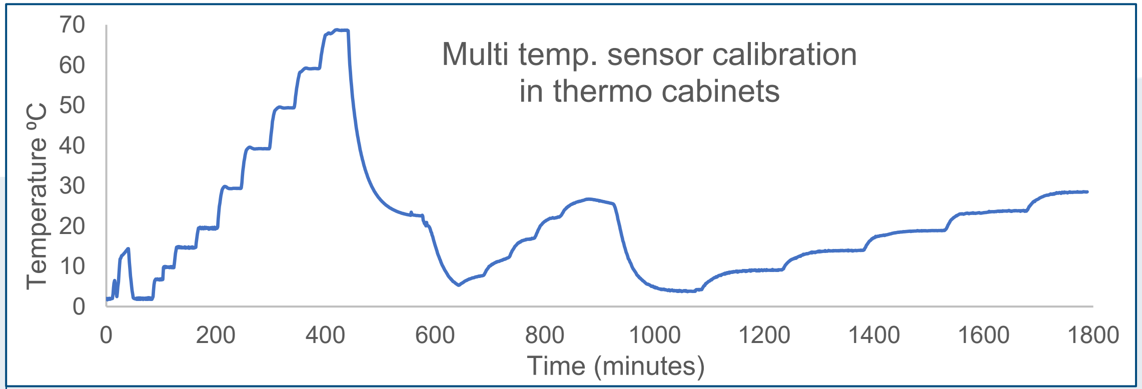
In-situ basin in the Reiche Zeche silver mine
with 3 m plastic rods and sensors connected to them

In-situ real laboratory: Temperature monitoring

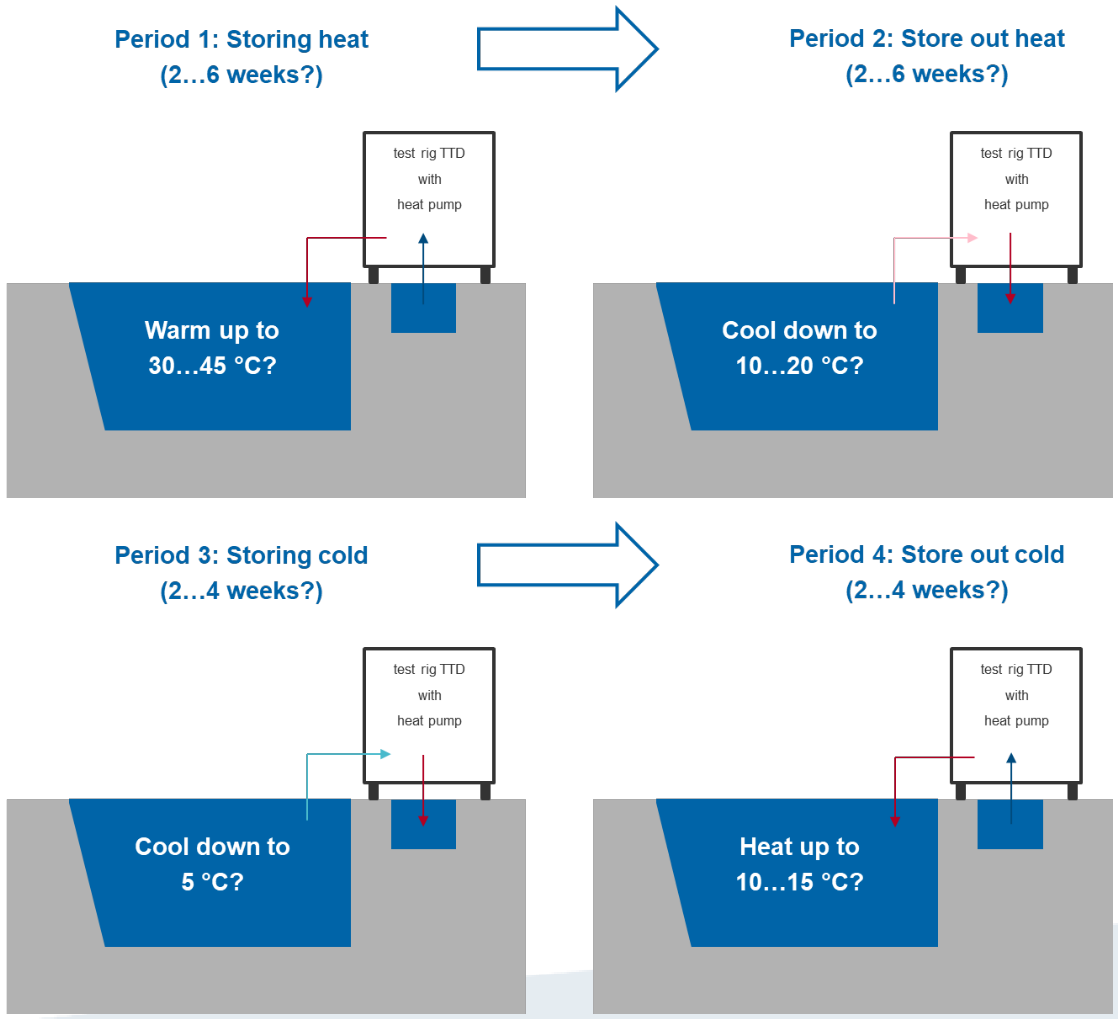


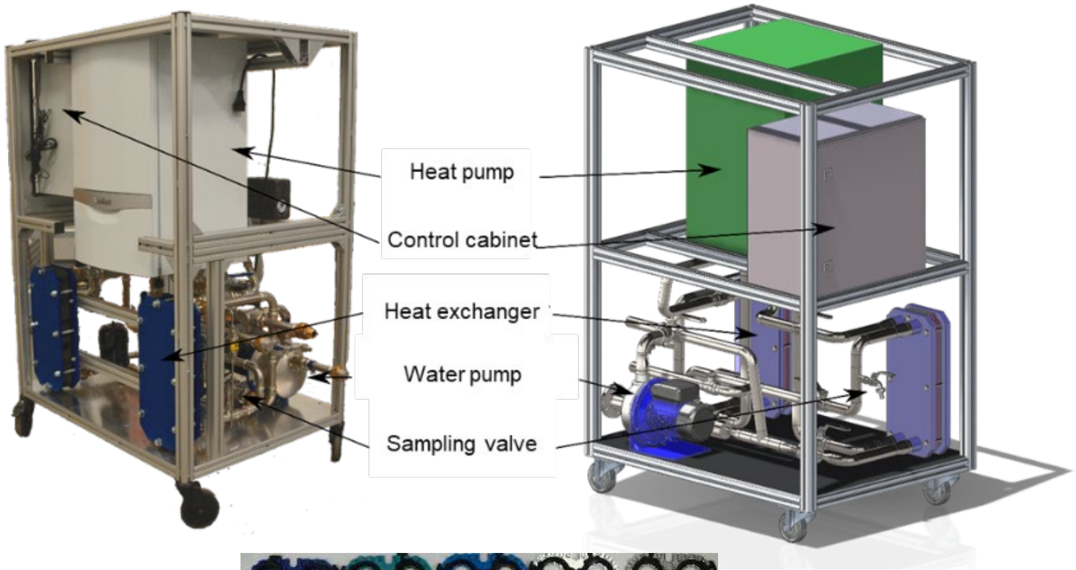


PT1000 sensors and
sensor rod installation
with thermocement



In-situ real laboratory station: Heat and cold storage cycles





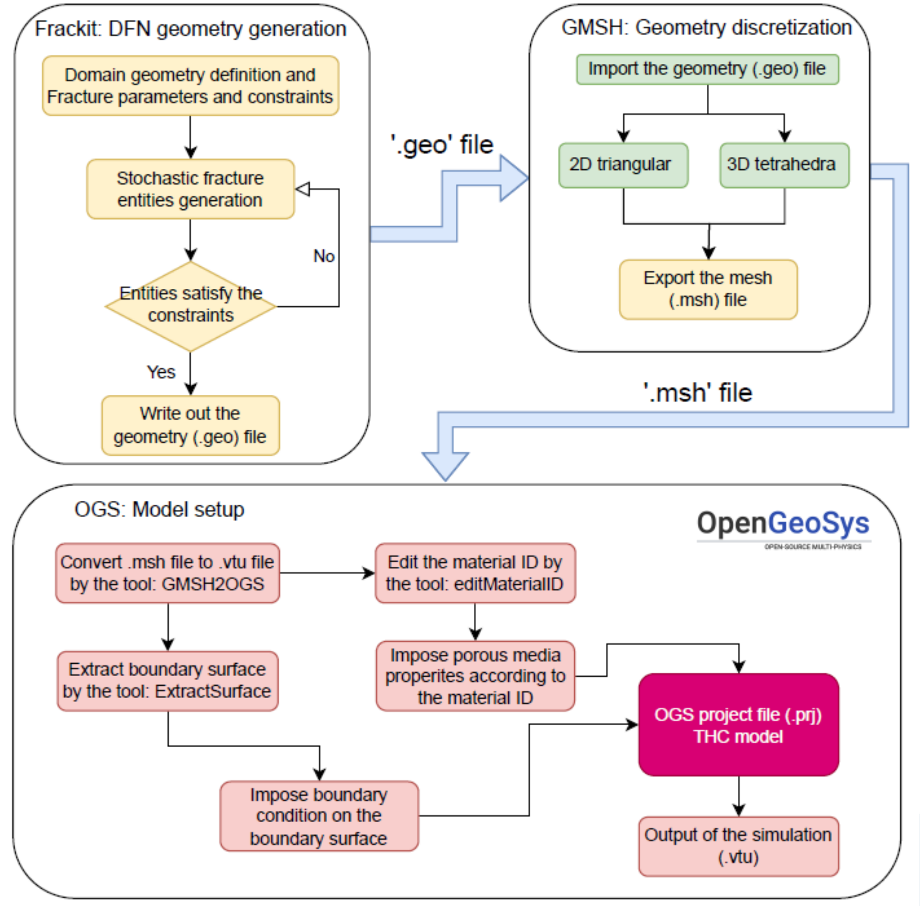
Heat exchangers with different coatings

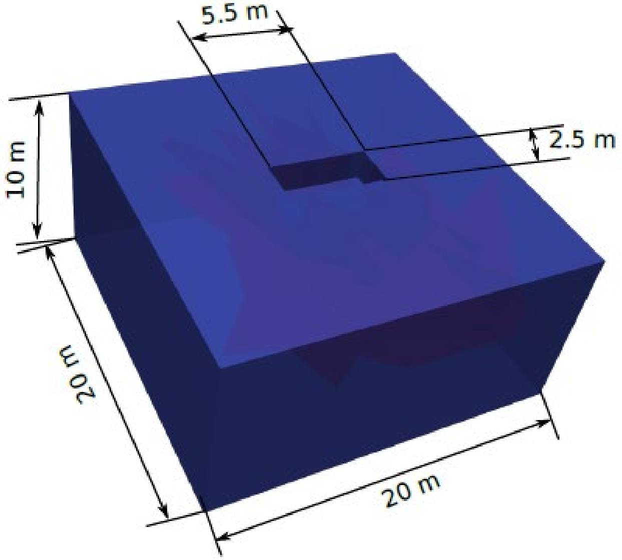
Basin Storage capacity: 640 kWh
Max heating: 4.2 kW

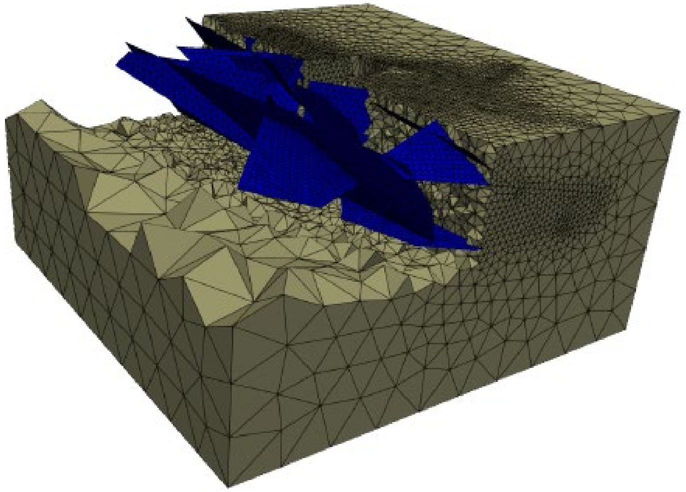
DBI Gruppe

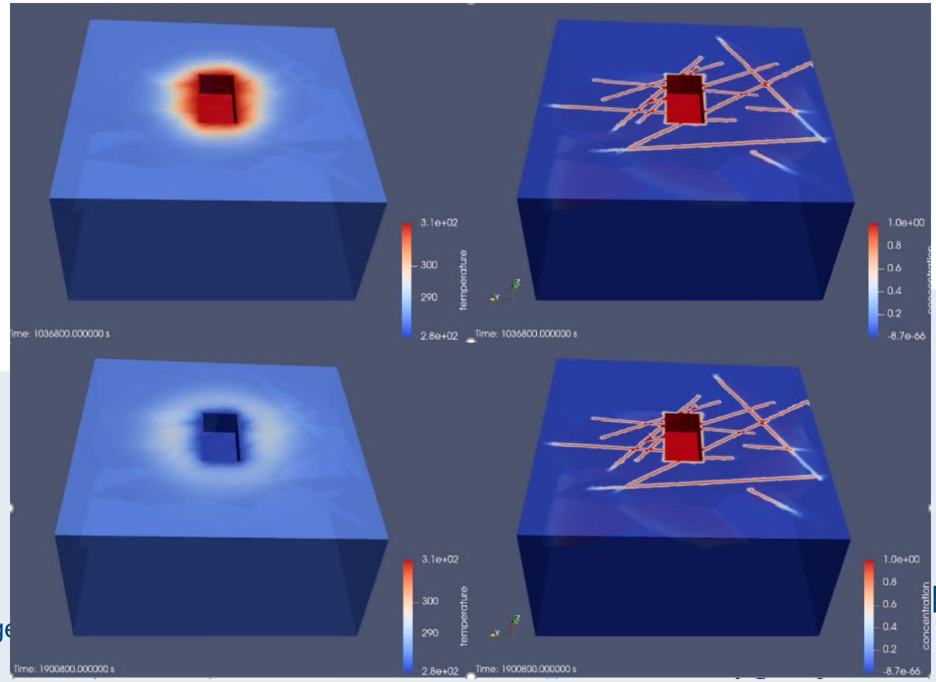
Modeling 3D HTC processes in discrete fracture networks

Modeling workflow in MineATES









Mine water

Parameter	Value incl. unit
Temperature	11.6°C
pH (water)	**2.6**
Redox potential	340 mV (U_{mess}) 556 mV (Eh) → oxidizing
O_2 - dissoved	9.56 mg/l (93.5%)
Electrical conductivity	1081 µS/cm
Turbitity	1.32 FNU
Ammonia/N	0.11 mg/L
SiO_2	**36.5 mg/l**

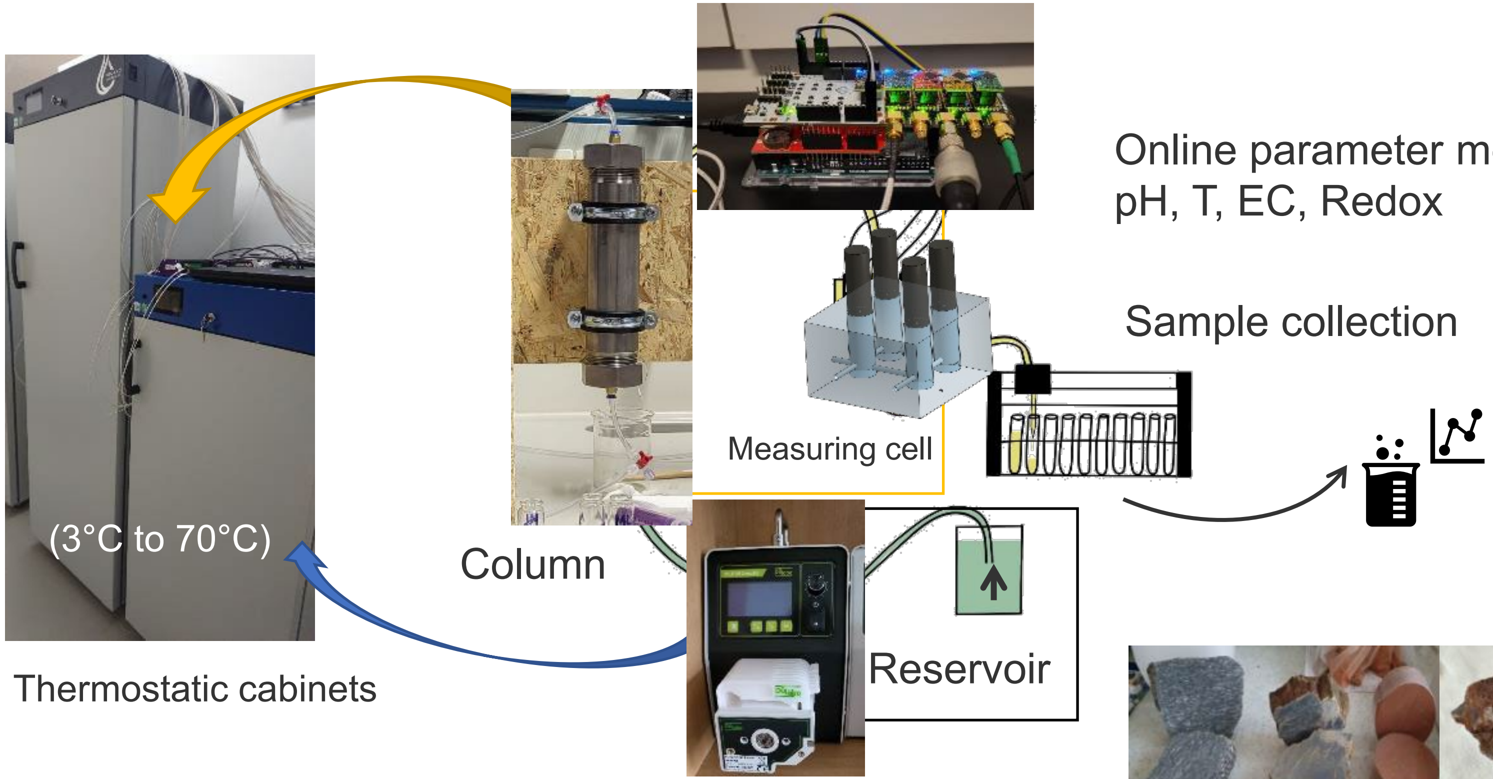
Cations	(mg/L)
Na^+	11.6
NH_4^+	0.18
Mn^{2+}	15.0
K^+	14.0

Cations	(mg/L)
Fe^{2+} (total)	0.39 (2.88)
Mg^{2+}	25.4
Ca^{2+}	78.5

Anions	(mg/L)
F^-	2.07
Cl^-	16.3
NO_3^-	0.96
SO_4^{2-}	**552**

Precipitation waters flowing for long times through weathered areas with sulfides and residual ores.

Laboratory simulations of TES cycles



Simplified experimental concept

Sister project

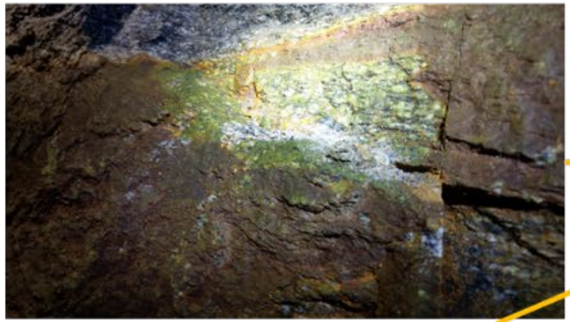
Geomicrobiology

Sampling Nov 2022

Biofilm Links (BF-L)

Biofilm rechts (BF-R)

Grüne Ablagerung (G)



Rote Ablagerung (R) Tiefes Gestein (T1) + (T2)

Grüne Ablagerung rechts (GR)

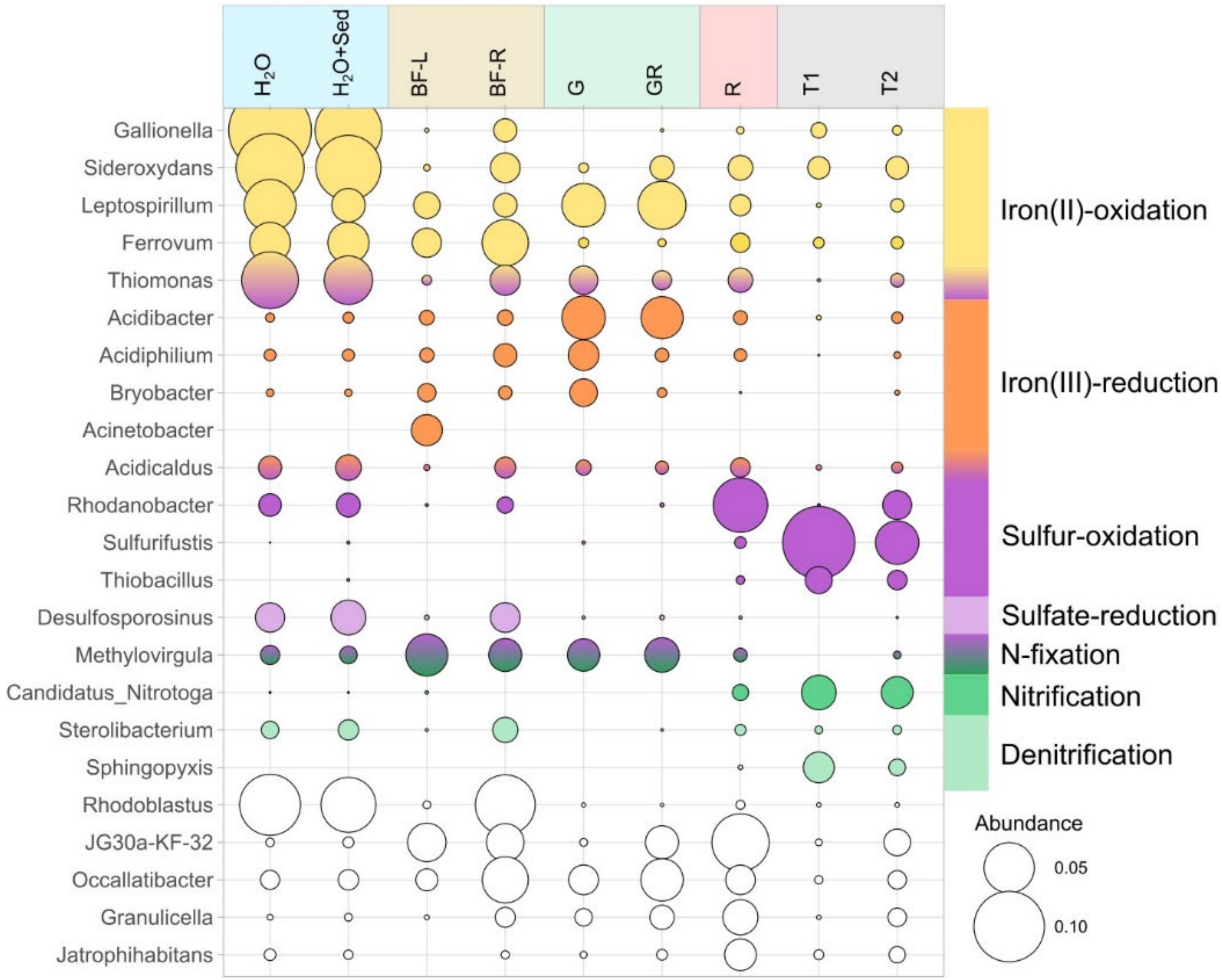
Community composition and potential functions

Most abundant microbial genera

related to

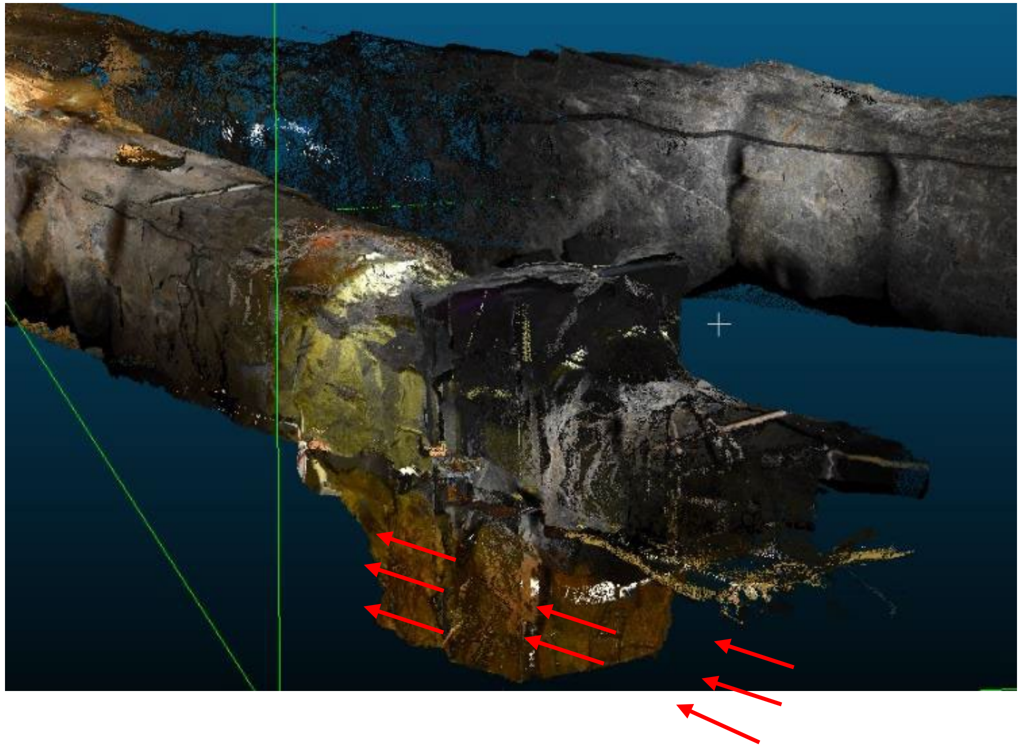
- Iron cycling
- Sulfur cycling
- Nitrogen cycling

-> in acid mine drainage iron and sulphur oxidation are predominant processes



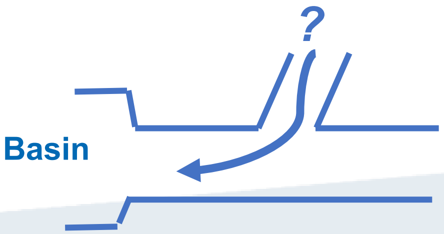
Dr. Alireza Arab

Inflow, rate, outflow?



3D model of the basin and assumed inflow area
[„Markscheidewesen“, TU Bergakademie Freiberg]

Side shaft (> 60° angle;
> 25 m long;
not accessible)



Side view

Tracer tests are planned to find hydraulic connections and estimate flow velocities.

Summary

- Despite large demand for energy storage, potential of aquifer and mine TES is not exploited
- Main reasons:
    - ATES / MTES requires extensive preliminary work and prior knowledge of geologic structure and energy use
    - Hydrogeochemical interactions as well as microbiological activities make sustainable management difficult
- Use of abandoned mines has certain advantages: known location, high probability of discovery, known composition of rock and water, direct access
- Natural rocks and natural settings provide realistic understanding (answer to open questions)
- Challenges: e.g. humidity, low pH -> corrosion and malfunction of devices