Mineral Reactions in Lower Freshwater Molasse Sandstones During High-Temperature Aquifer Thermal Energy Storage

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heatstore GEOTHERMICA UNIVERSITÄT BERN

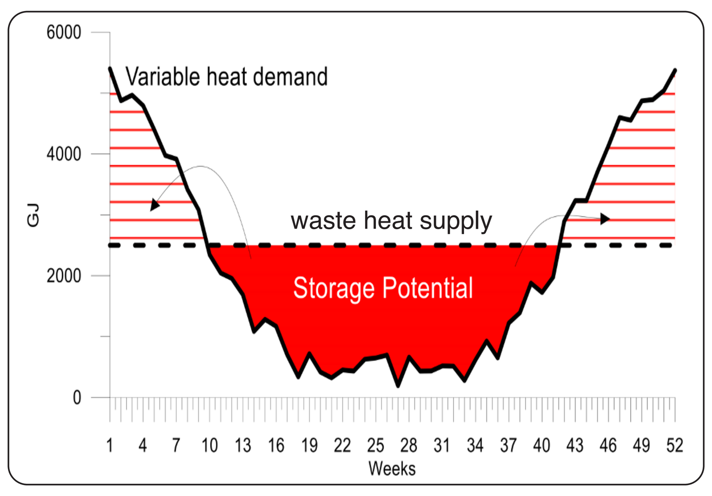
Background

Industrial processes produce surplus heat! [1]

Demand for heat is seasonal

Excess energy produced in summer needs to be stored for use in winter months

Aquifer thermal energy storage (ATES)
=
Using porous lithologies with little/no groundwater flow to store warm water produced in summer within the geosphere for use in winter [3]



LT-ATES= Low Temperature Aquifer Thermal Energy Storage.

>2500 Operational world-wide

HT-ATES = High Temperature Aquifer Thermal Energy Storage.

5 operational world-wide [3]

HT-ATES = Hard to implement

Why?

Geochemical issues & site information

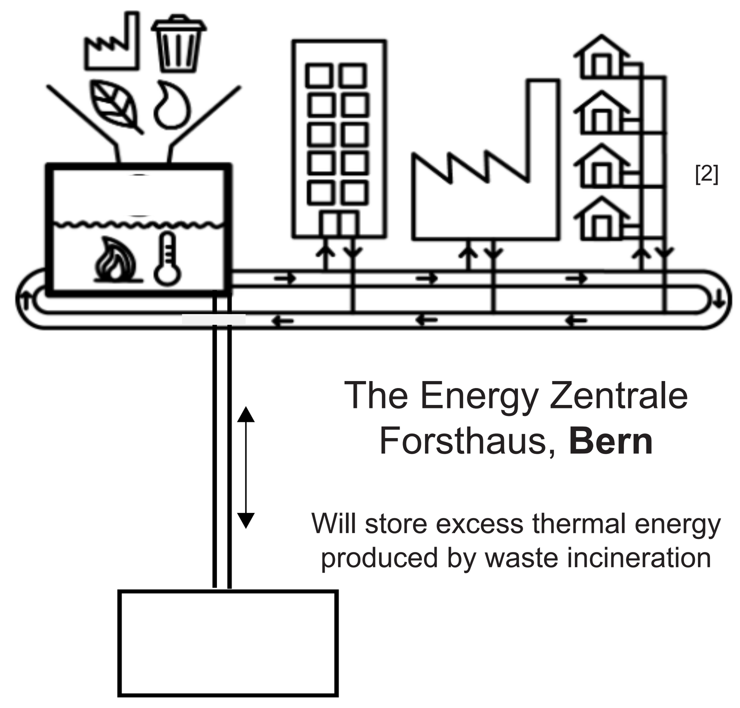
All issues lead to decreased efficiency of the operation and increased **cost**

In surface installations

- Corrosion damage
- Scaling & clogging [5]
- Reduction of fluid flow [3]
- Turbulence.

In reservoir

- Mineral dissolution [4]
- Collapse of pore network
- Clogging of the pore network
- Mobilization of fines

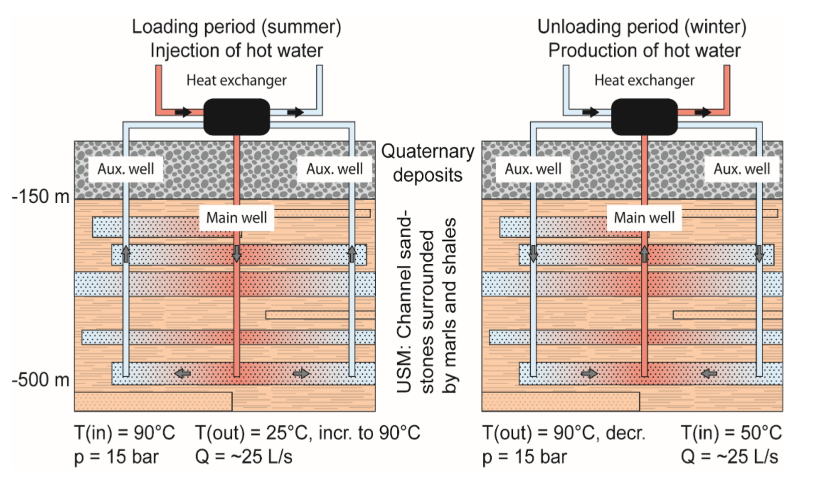


The Energy Zentrale Forsthaus, **Bern**

Will store excess thermal energy produced by waste incineration

13 GW/yr → 1500 X [1]

System parameters & materials used



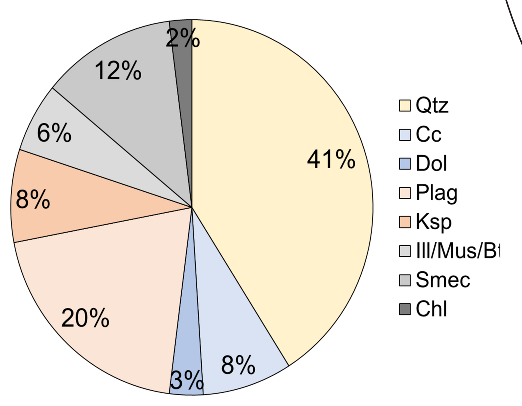
Porewater Chemistry

Na-HCO3 type

Ion	Concentration mg/L
Ca^{2+}	25.5
Mg^{2+}	19.7
Na^{+}	75.7
K^{+}	2.80
Cl^{-}	30.8
$SO4^{2-}$	22.5
$HCO3^{-}$	308

Reservoir Lithology

- Medium-course grained meanderbelt sandstone
- Porosity= 18%



[1]

Aims

- Determine composition of artificial USM groundwater in equilibrium with USM sst. at 20, 60 and 90 °C
- Determine mineral reactions controlling (changes in) fluid chemistry
- Check if tabulated reaction rates describe experiments

Approach

Rock fragments + artificial pore water

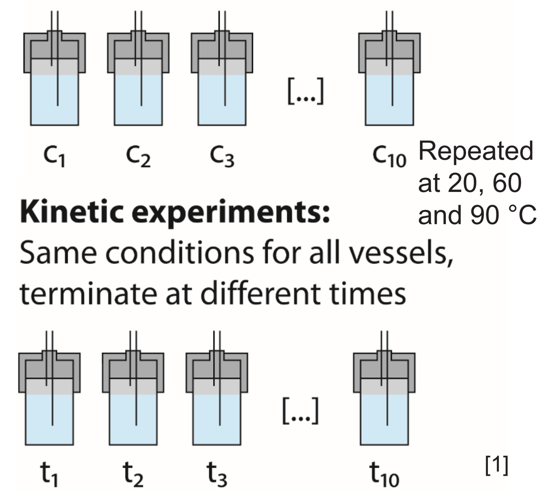
Placed in rotary oven at desired temperature for 3

Comparing water composition before and after to identify mineral reactions

Methodology

Screening experiments: Different conditions for all vessels, open at the same time

Kinetic experiments: Same conditions for all vessels, terminate at different times



Determine composition of APW after 3 month reaction with reservoir rock

Determine the composition of ions in solution (using IC, ICP-OES, C-Analyser and Titration) before and after the 3 month reaction. Determine net gain/loss of each ion

Determine mineral reactions taking place by replicating on PHREEQC

Build up a model of reaction components that replicate the observed results

On going

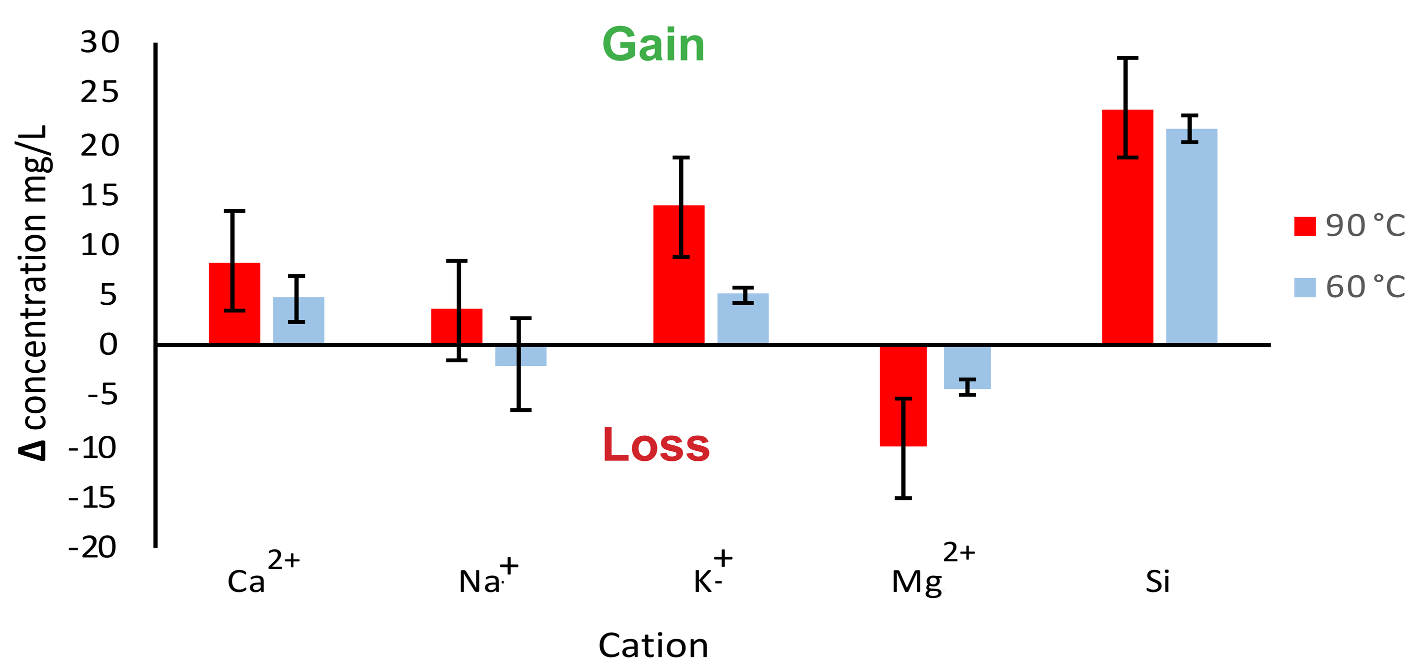
Fit evolution f(time) by including dissolution and precipitation rates for reactions

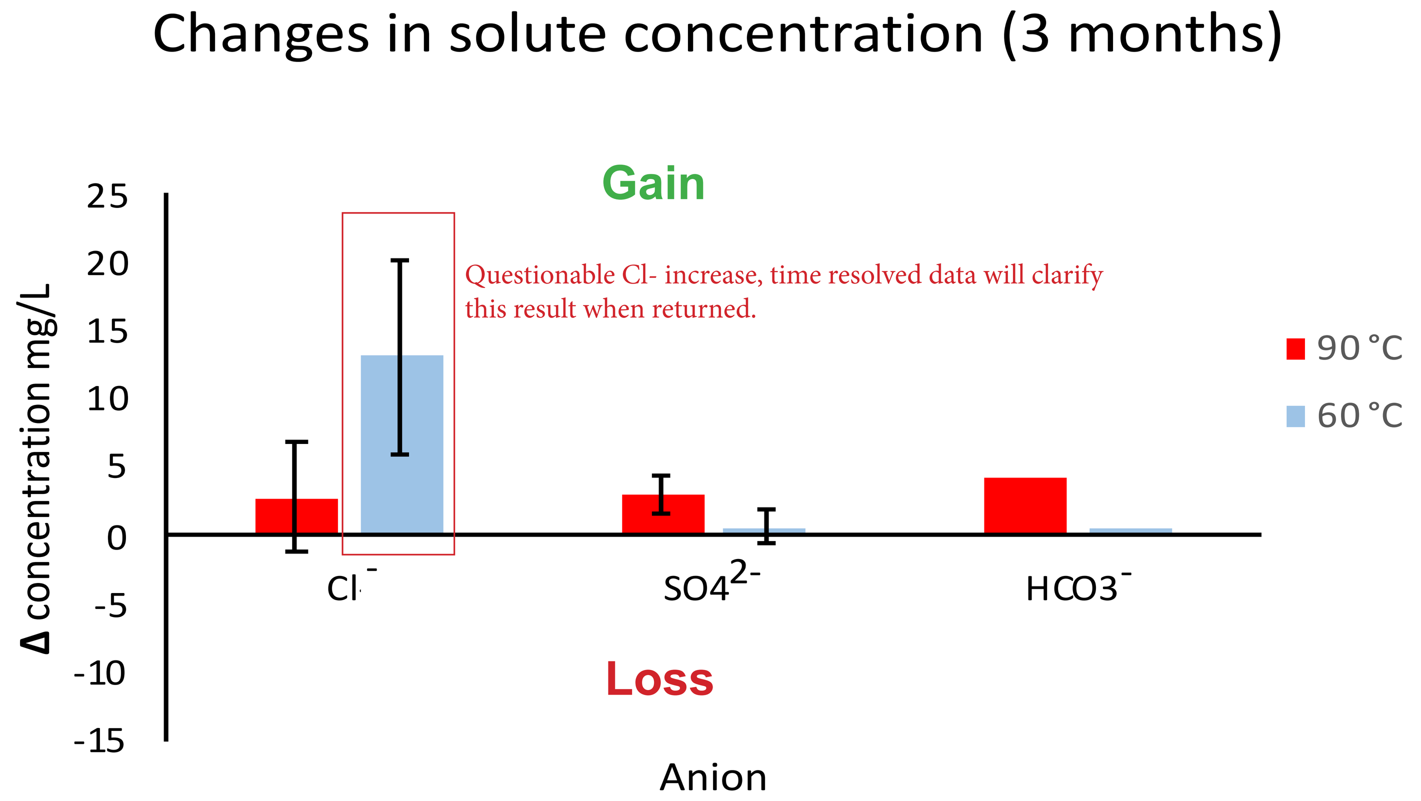
Can replicate the system with PHREEQC = Can replicate system with thermodynamics

Cannot replicate the system with PHREEQC= more complex: Transition to PFLOTRAN

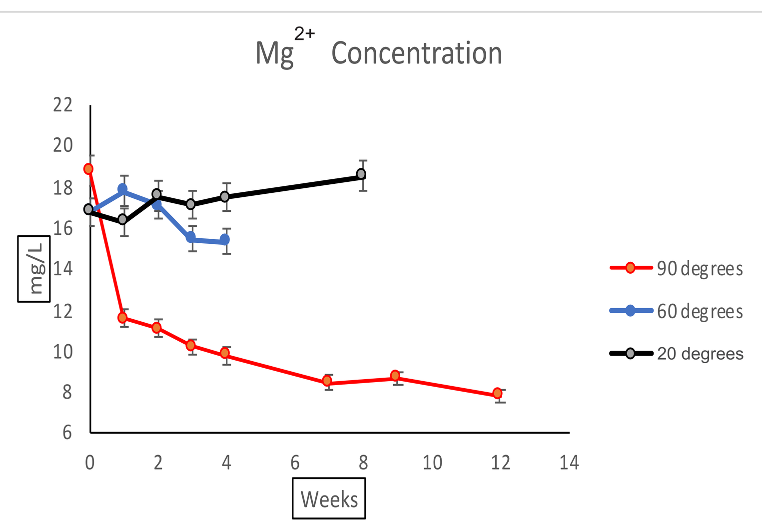
Results

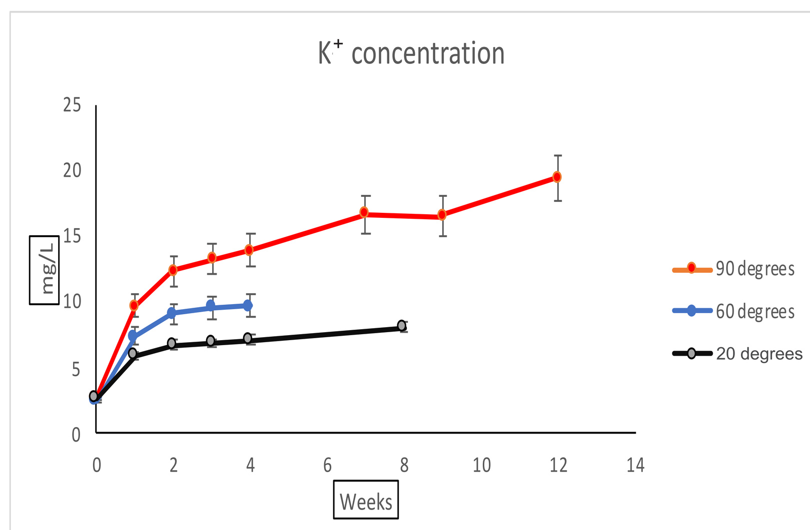
Composition of pore fluid after 3 months reaction time with reservoir rock (screening experiments)





Examples of individual ions- Tracing the evolution of fluid composition over 3 months (kinetic experiments)





Gain loss of major ions (left) provide the basis for back-modelling the reactions. Concentration over time (above) allows identification of equilibrium conditions

References: [1] D.vdH et al 2020, Pre-study of the Forsthaus Geospeicher heat storage and utilisation project: Geological and geochemical aspects, [2]Project Celcius, 2017. accessed: 26.02.2021https://project.celsiuscity.eu/district-heating-and-cooling/. [3] Fleuchaus et al. (2018) [4] Griffioen & Appelo (1993). appl geochem [5] Perlinger et al. (1987). Water Resour. Res.

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