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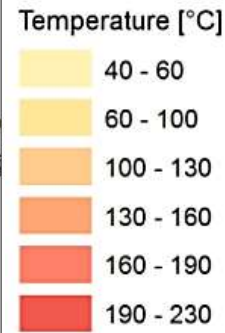
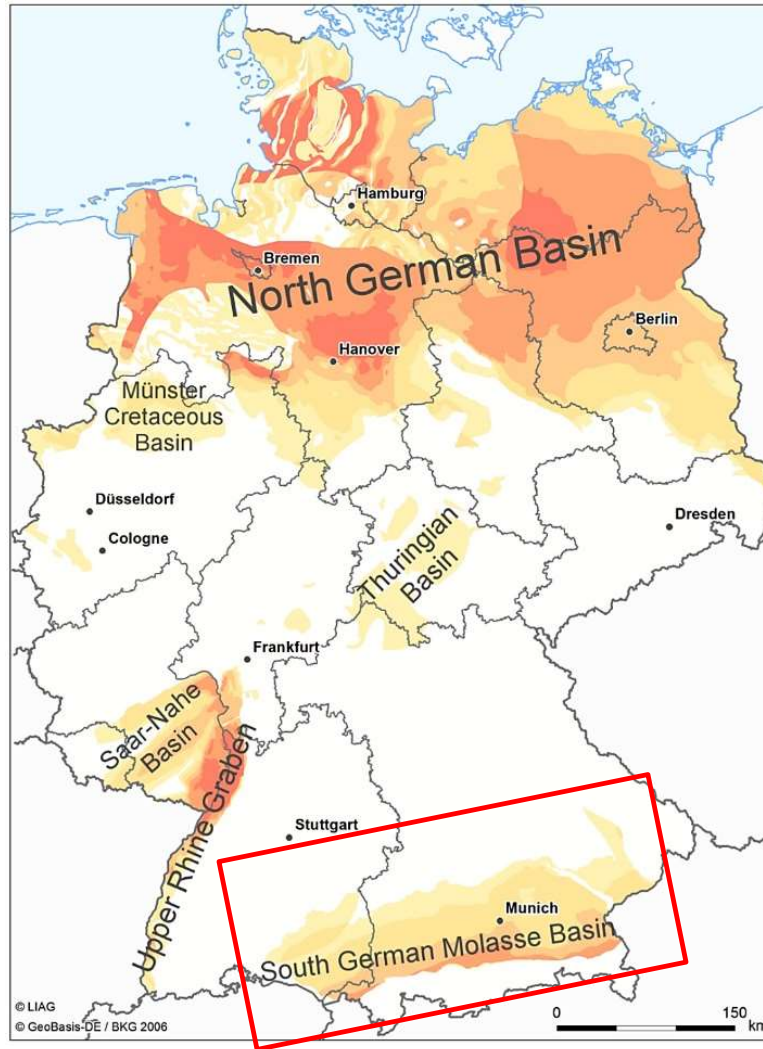


# Preventing calcite precipitation in deep geothermal energy wells and power plants in Southern Germany

Alireza Arab, Broder Merkel, Traugott Scheytt

Groundwater, key to the SDGs international conference  
19 May 2022, Paris, France

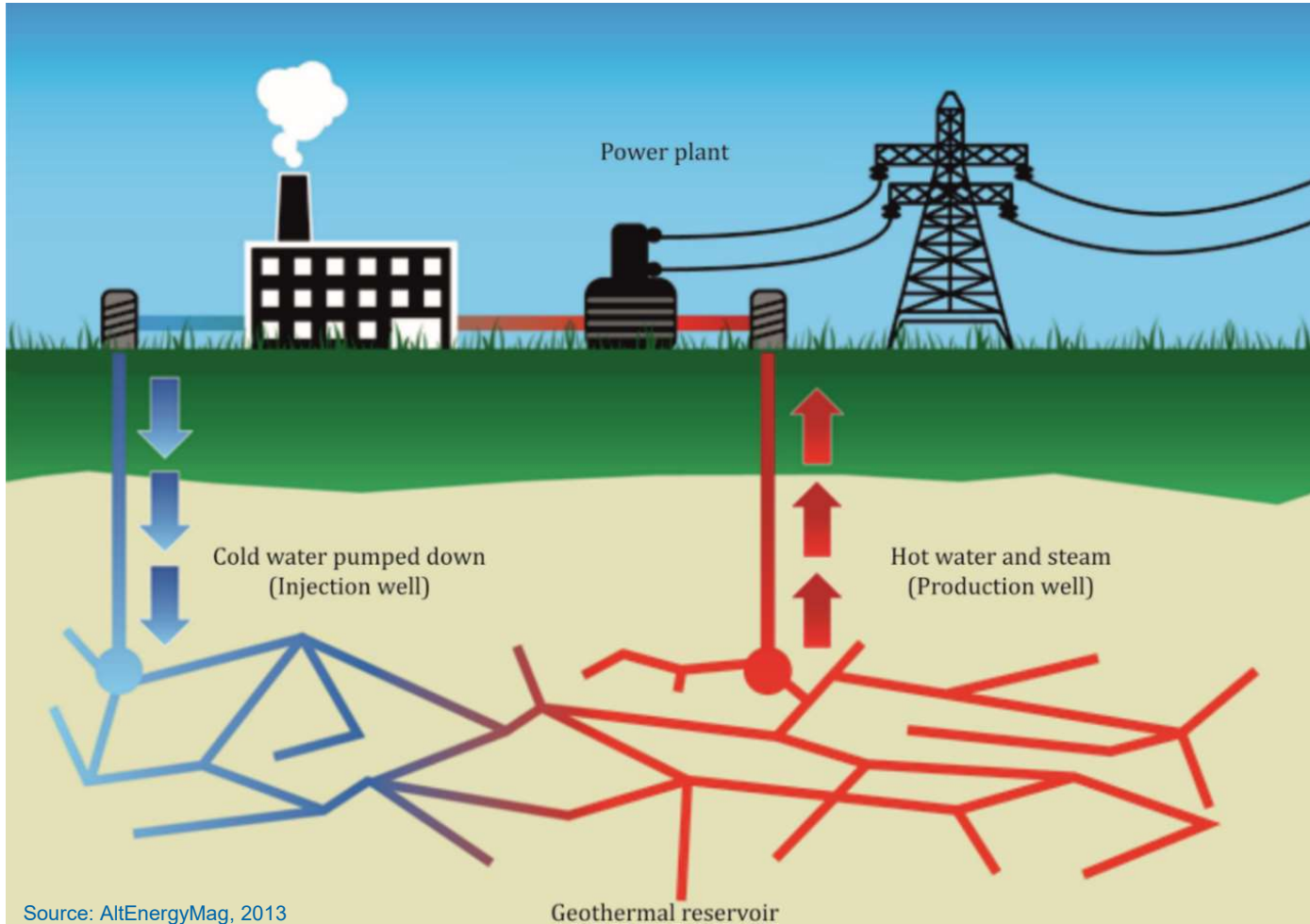
# Region of interest



## Malm-Aquifer

Introduction - Methods and Results - Conclusions and Outlook

# Geothermal doublet system



# Scaling in a geothermal well



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

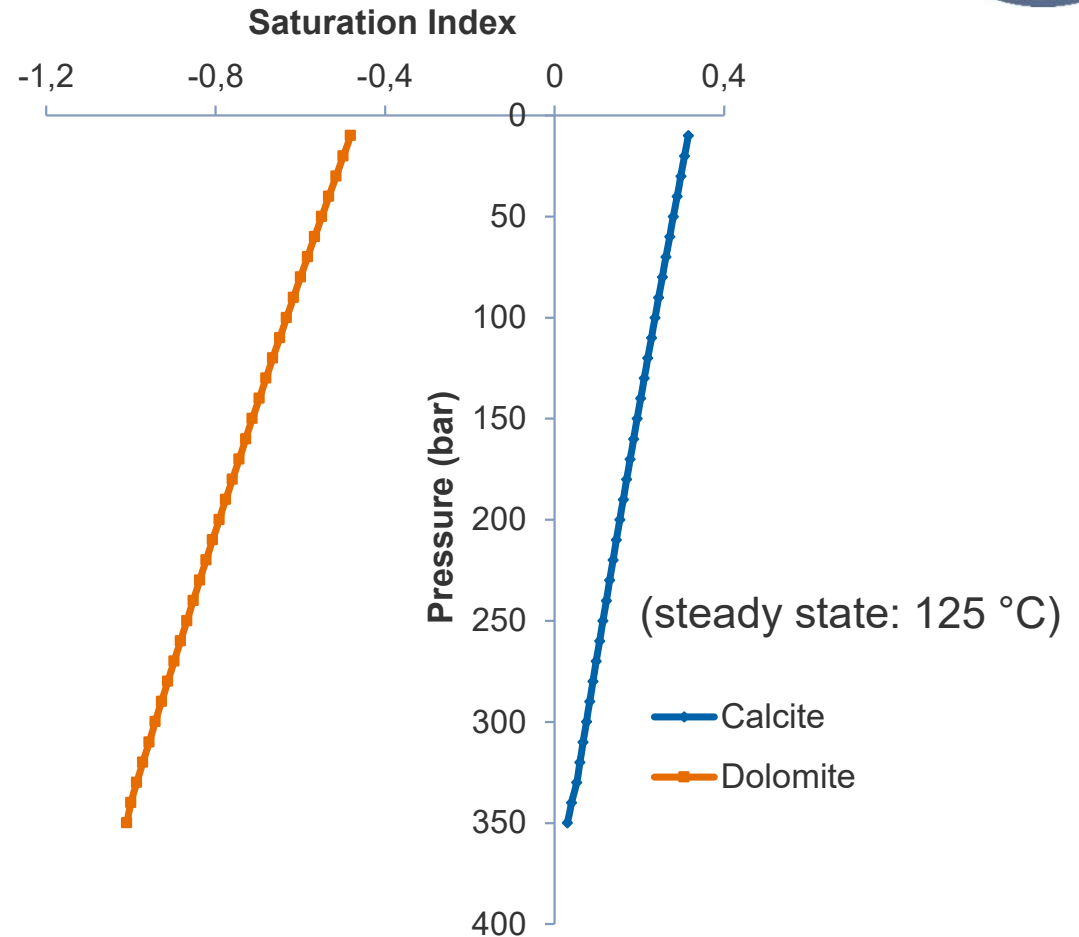
IAP: ion activity product  
 K: solubility product calcite (25 °C)

Carbonates ≠ pure calcite

But:

Precipitation is kinetically controlled

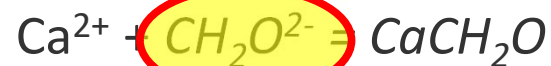
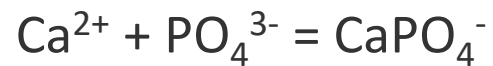
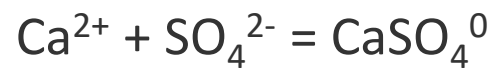
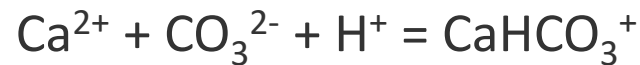
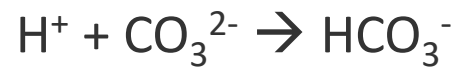
Solution and precipitation can be different



## How can the problem be solved?



### Keep SI < 0 ?



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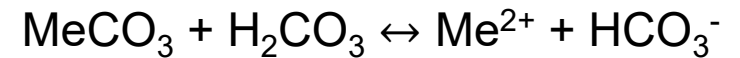
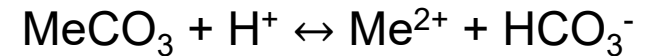
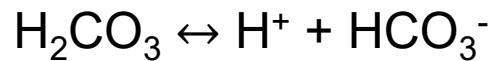
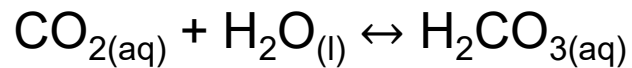
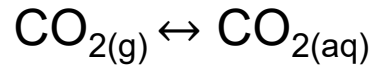
Using CO<sub>2</sub>

LERWTG Project

Using inhibitors

EvA-M project

## Using carbon dioxide



Feldspar carbonation, chemical  
and physical changes

Effects of  $\text{CO}_2$  on rocks, casings, pipes, pumps under reservoir conditions

Research measures:

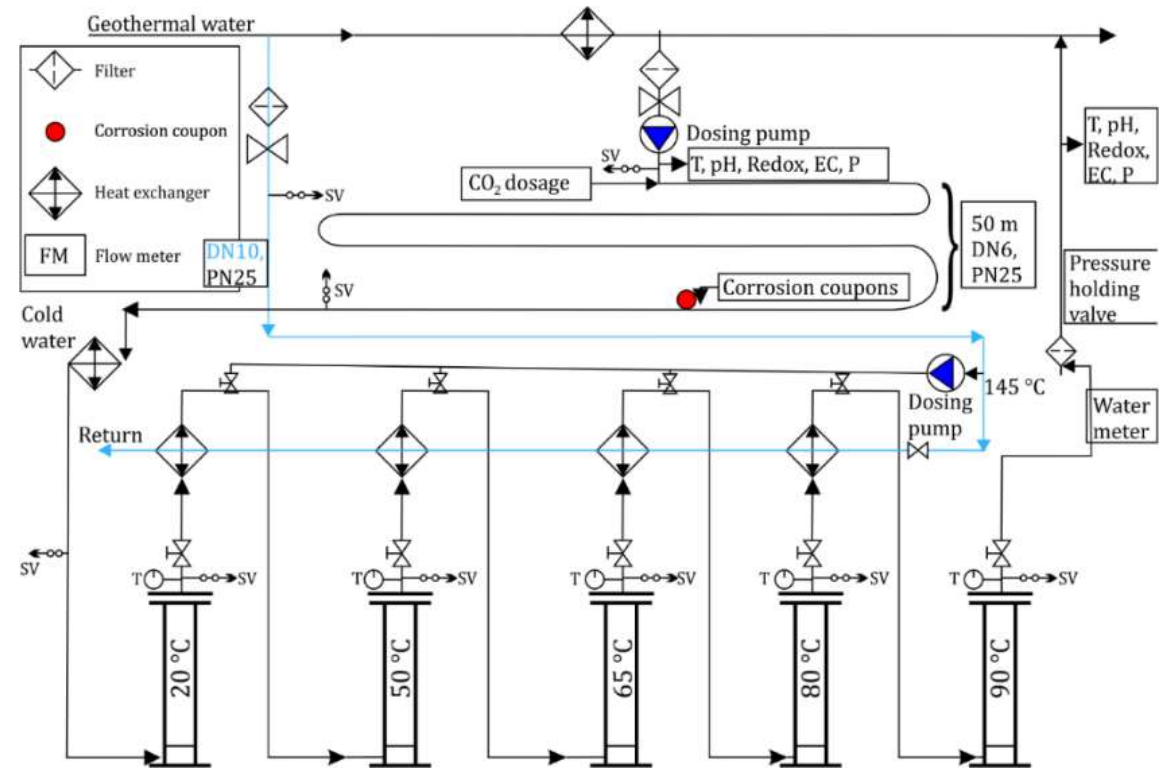
Bypass system

High pressure temperature autoclave tests

Modeling



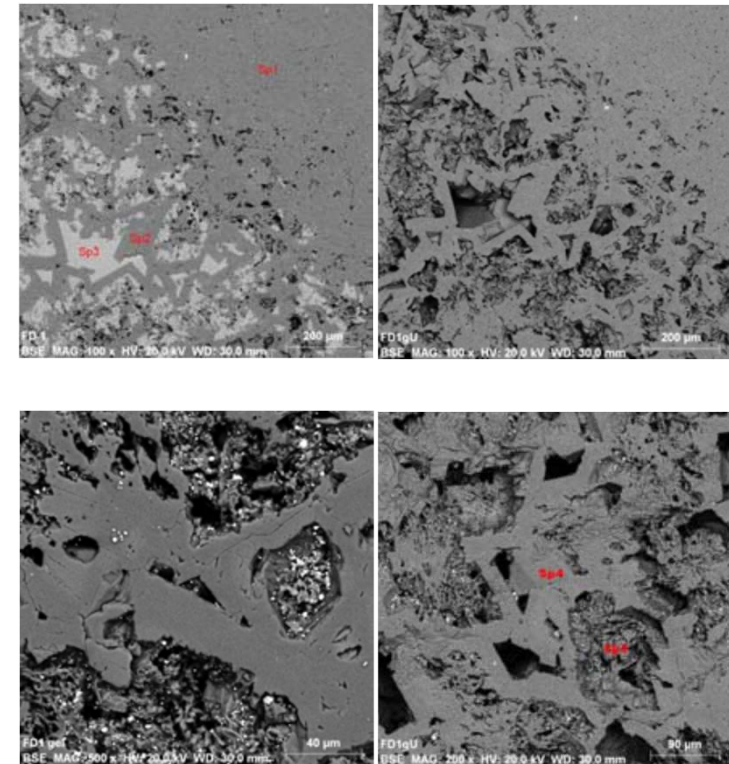
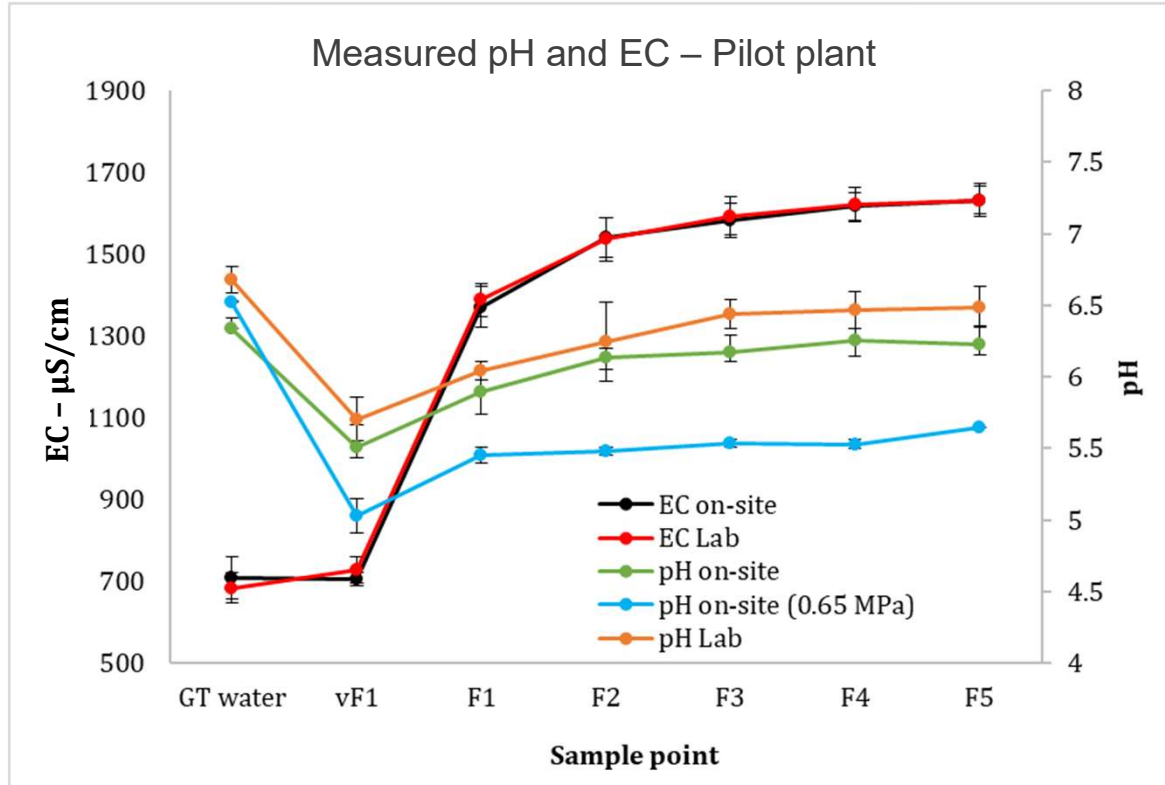
# On-site pilot plant (bypass system)



**On-site:** Temperature, pressure, pH-conductivity, redox potential, oxygen conc.

**Weekly Sampling:** Major anions and cations, DIC, DOC (analyzed in the lab)

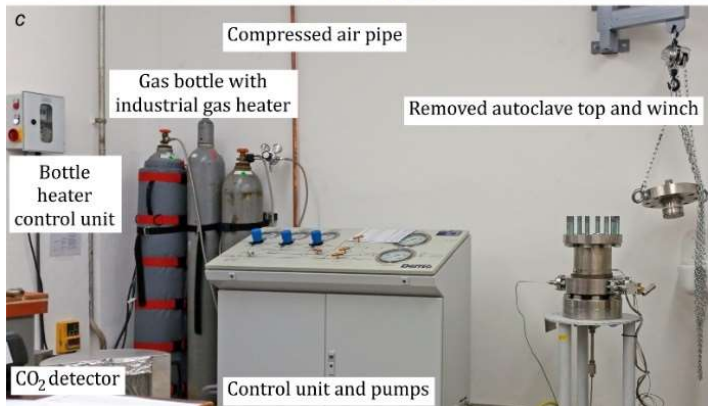
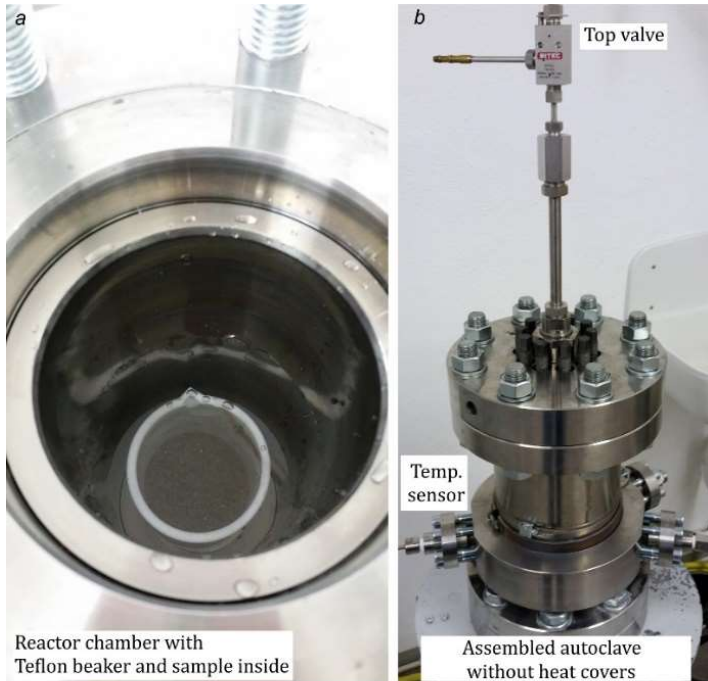
# On-site pilot plant (bypass system)



tot. rock= 1375 kg, avg. 150 mg/L rock => **58 kg (4.2%)** rock dissolved in 6 months



# Autoclaves



# Batch experiment results

Before



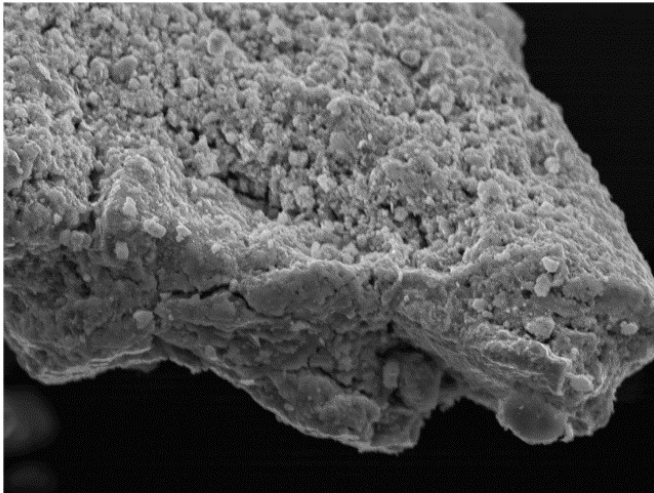
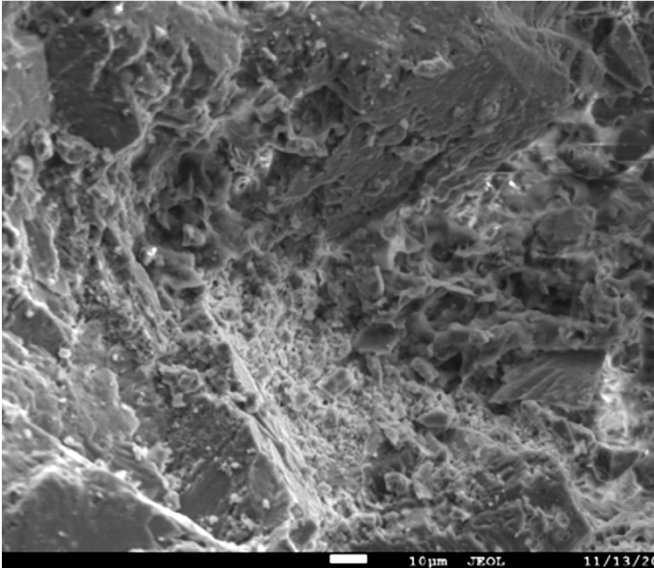
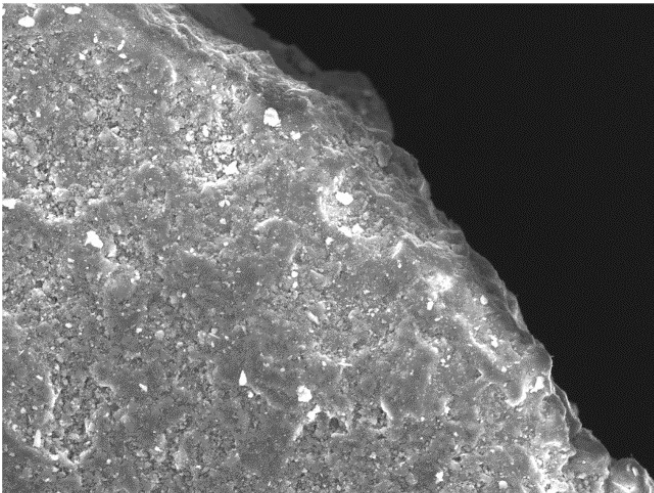
After



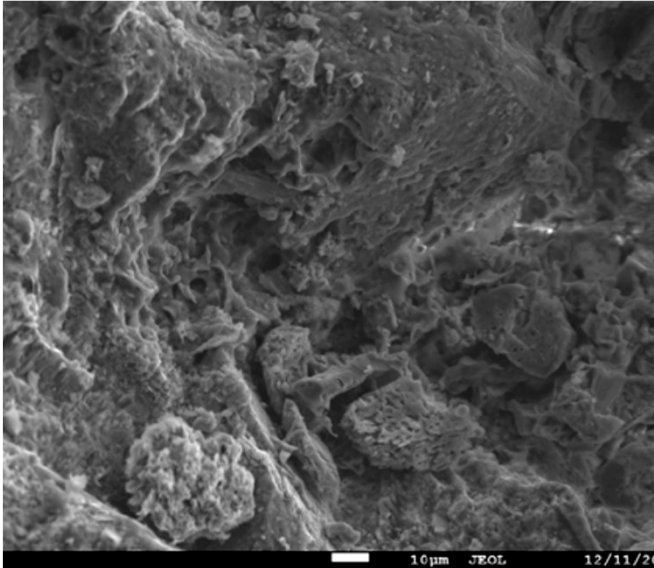


# Batch experiment results

Before

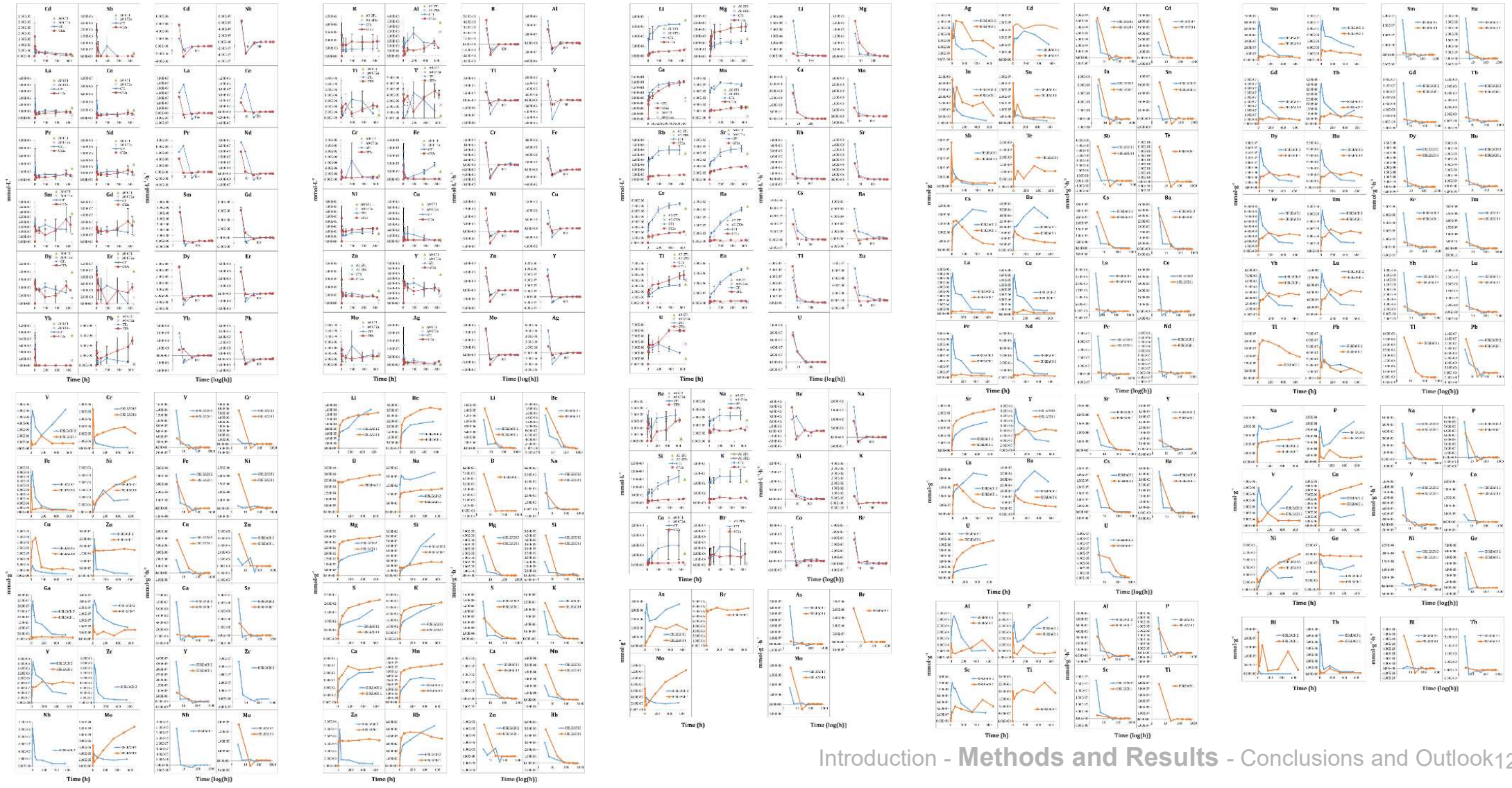


After





# Kinetic experiments





# Kinetic experiments

## Type I

Rapid increase, steady increase

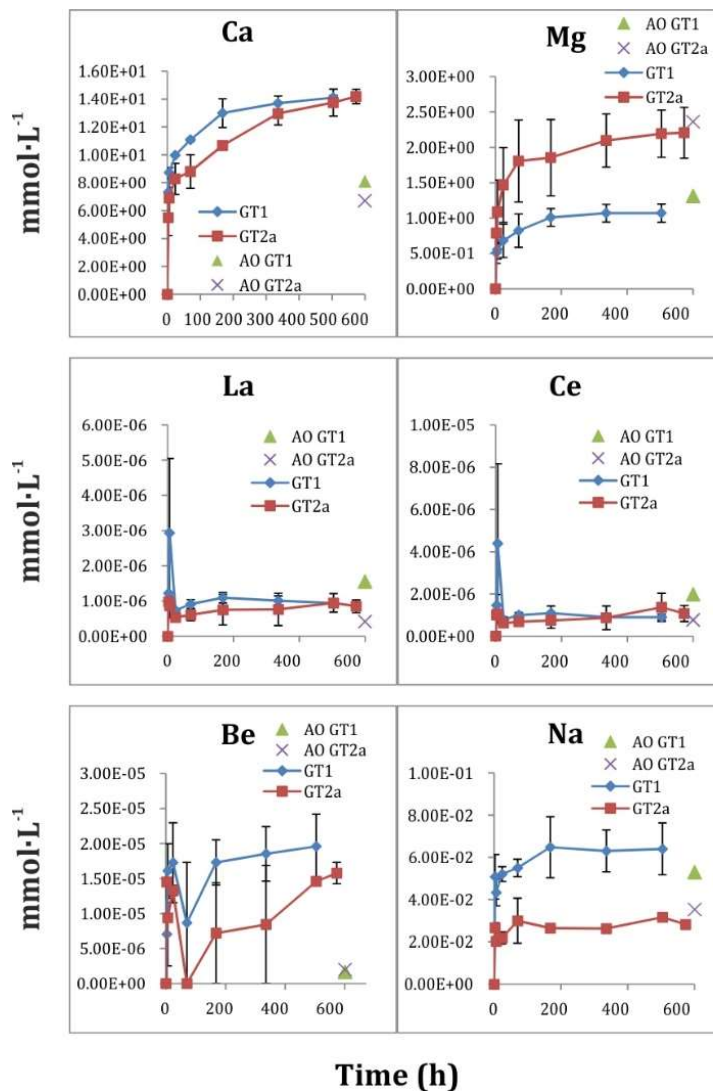
## Type IIA

Rapid increase, then decrease, fluctuating

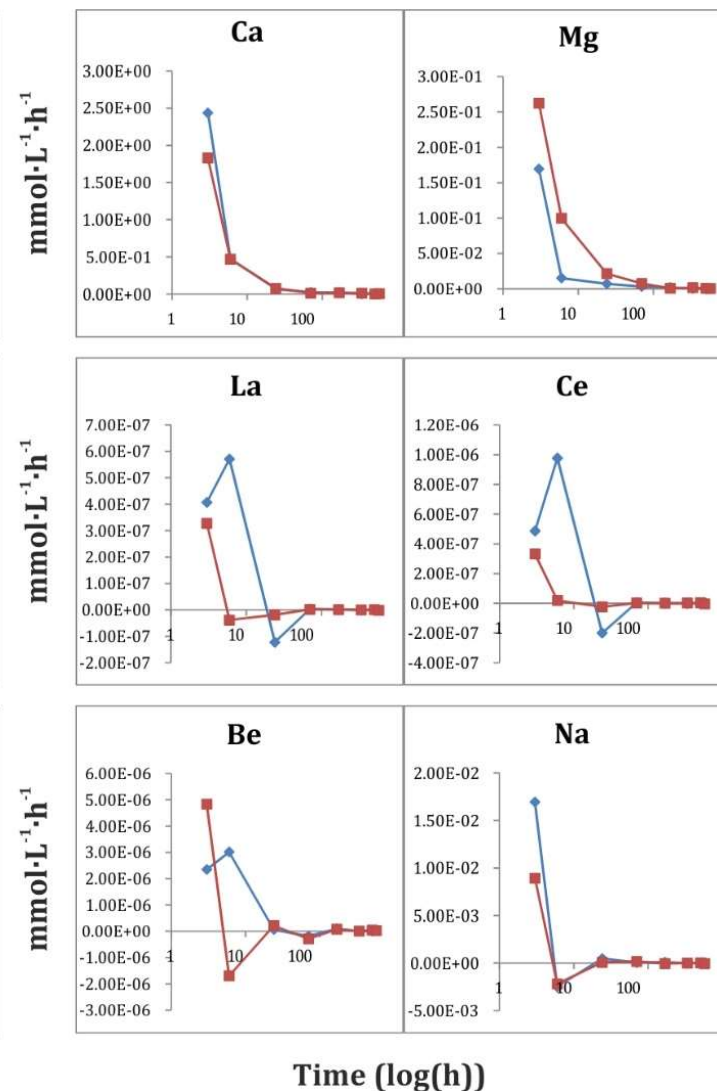
## Type IIB

Rapid increase, rapid decrease, increase again

concentration vs. time



element release rate

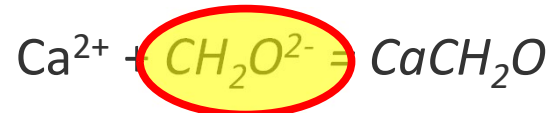
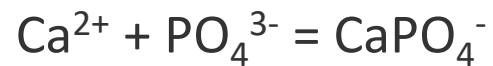
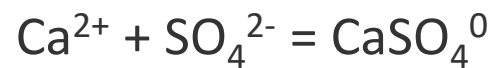
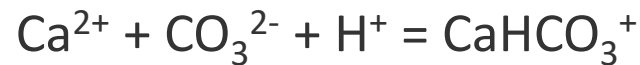
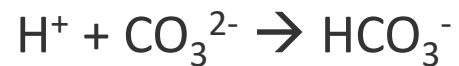
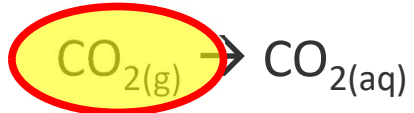




# How can the problem be solved?



**Keep SI < 0 ?**



.....

**Using CO<sub>2</sub>**

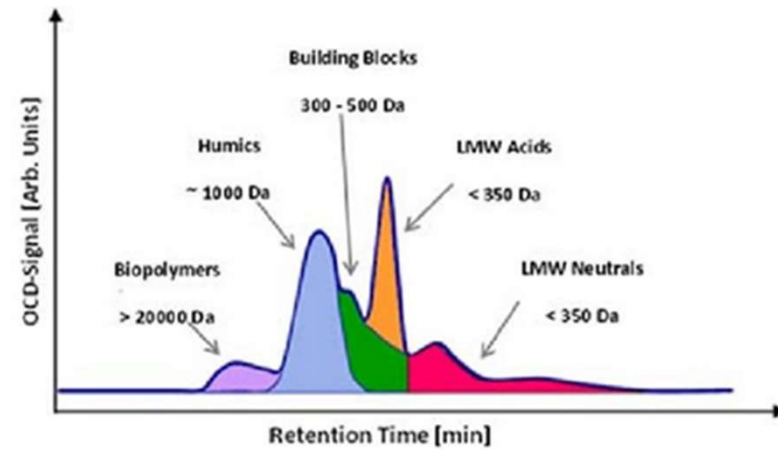
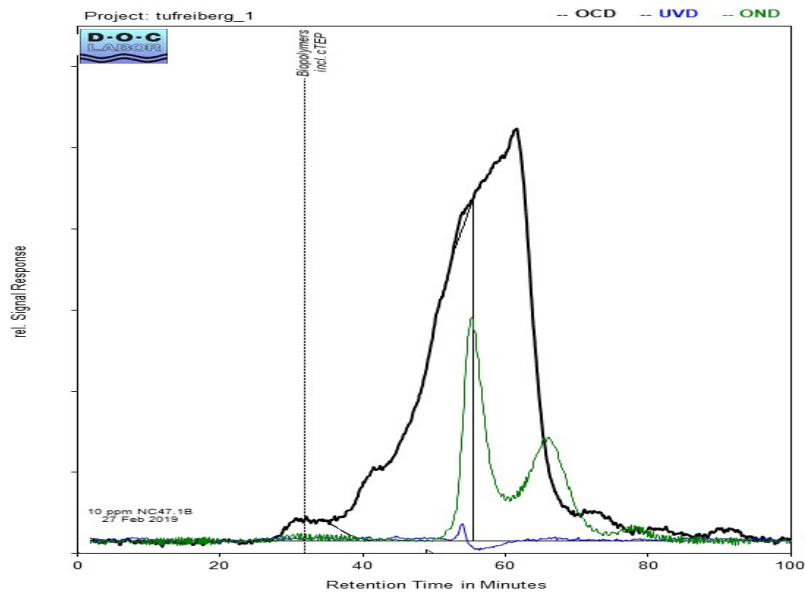
LERWTG Project

**Using inhibitors**

EvA-M project

# Inhibitor NC47.1B

- NC47.1B biodegradable polycarboxylate
- Molar mass, number and property of functional groups?
- Surfactant: lowering the interfacial tension between 2 phases
- LC-OCD Analysis



LC=liquid chromatography

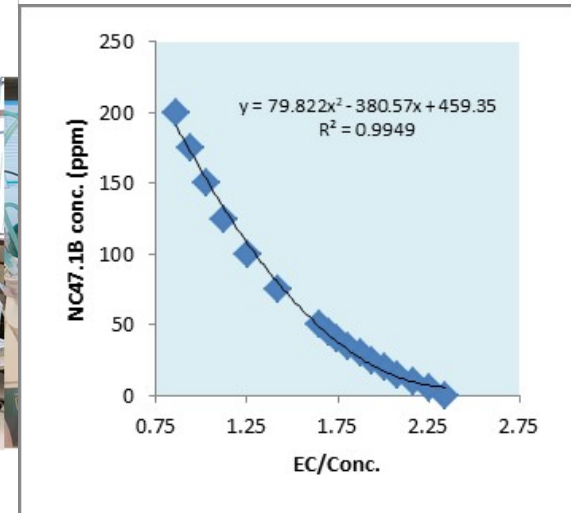
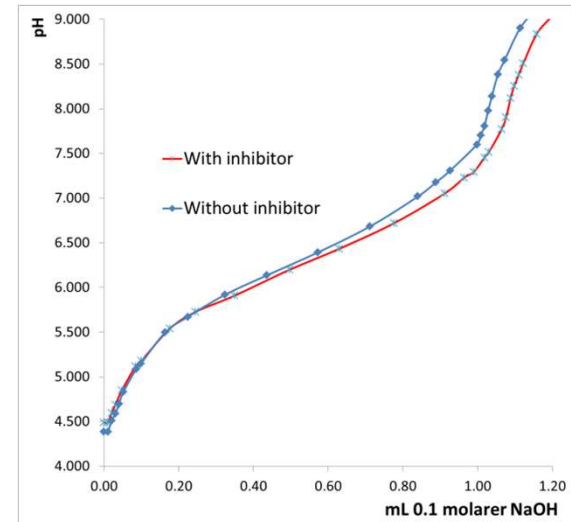
OCD= Organic Carbon Detection

# On-site pilot plant (bypass system)



# Inhibitor characterization: complexation of $\text{Ca}^{2+}$

- Determining complexation constants
- IC and ICP-MS can not differentiate between  $\text{Ca}^{2+}$  and complexed calcium
- Titrations  $\text{CaCl}_2$  solution with NC47.1B: determination of EC and pH (cations and anions)
- LC-OCD analysis of NC47.1B







## Conclusions and outlook

Prevent precipitation in geothermal production  
maintaining and enhancing pathways / permeability

Above ground energy production is not interrupted

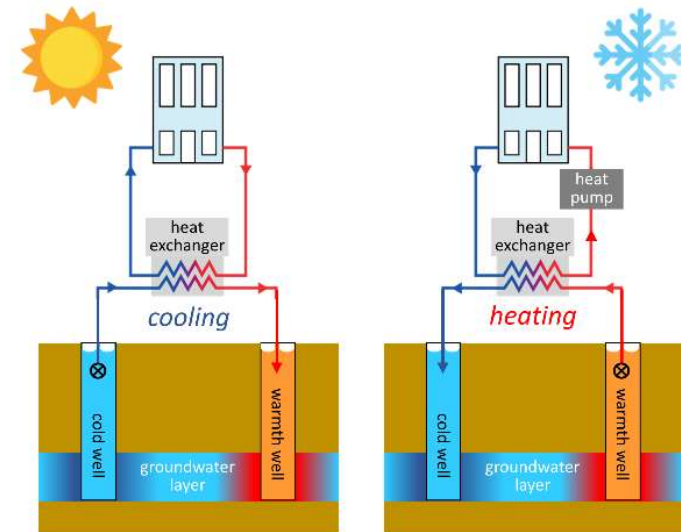
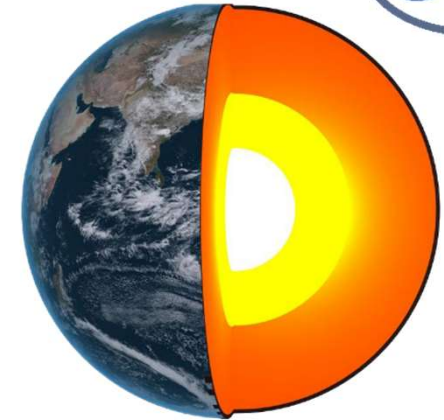
Natural rocks provide better thermodynamic and kinetic data

Sorption, formation of secondary minerals, passivation of reactive surfaces, presence of inhibiting ions

Accurate input data → accurate models

Gained experience is used in Aquifer Thermal Energy Storage (ATES)

→ UnClog-ATES







Thank you.

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