

Geothermal Energy: Risks and benefits of utilizing hot fluids from the deep underground

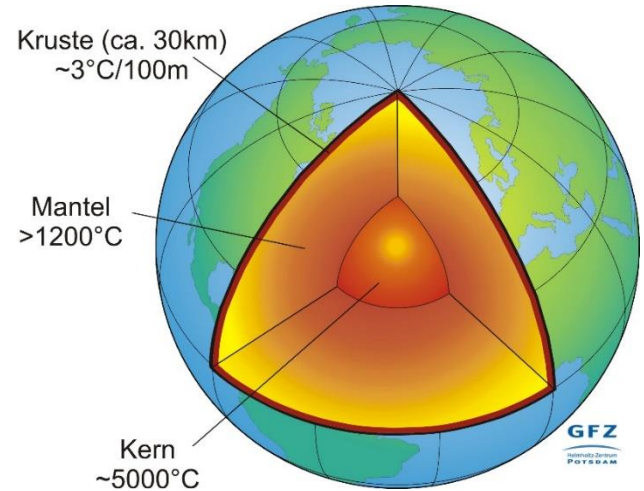


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Overview

- 1) Background on geothermal energy
- 2) Risks of geothermal fluids: scaling and corrosion
- 3) Benefits of geothermal fluids: exploration and raw material mining
- 4) Example: Geothermal research site Groß Schönebeck



Energy transition requires heat transition

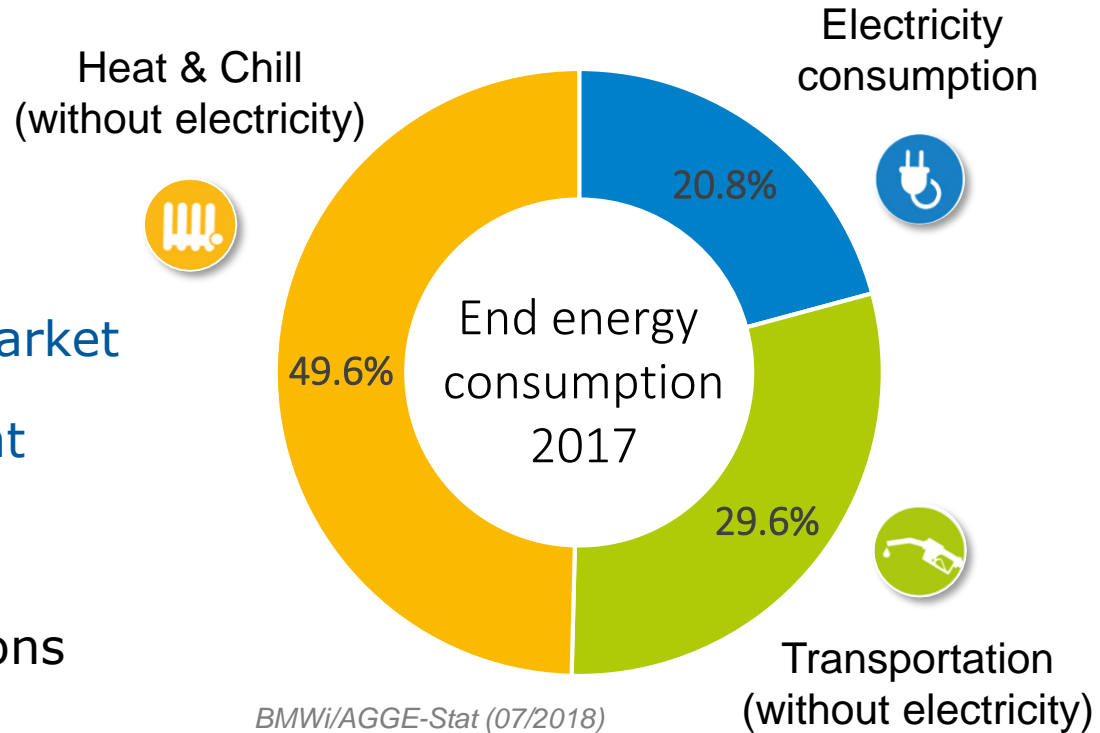
Grand challenges:

- Climate change
- Energy transition

Heat market ~ 2x electricity market

Geothermal – the sleeping giant

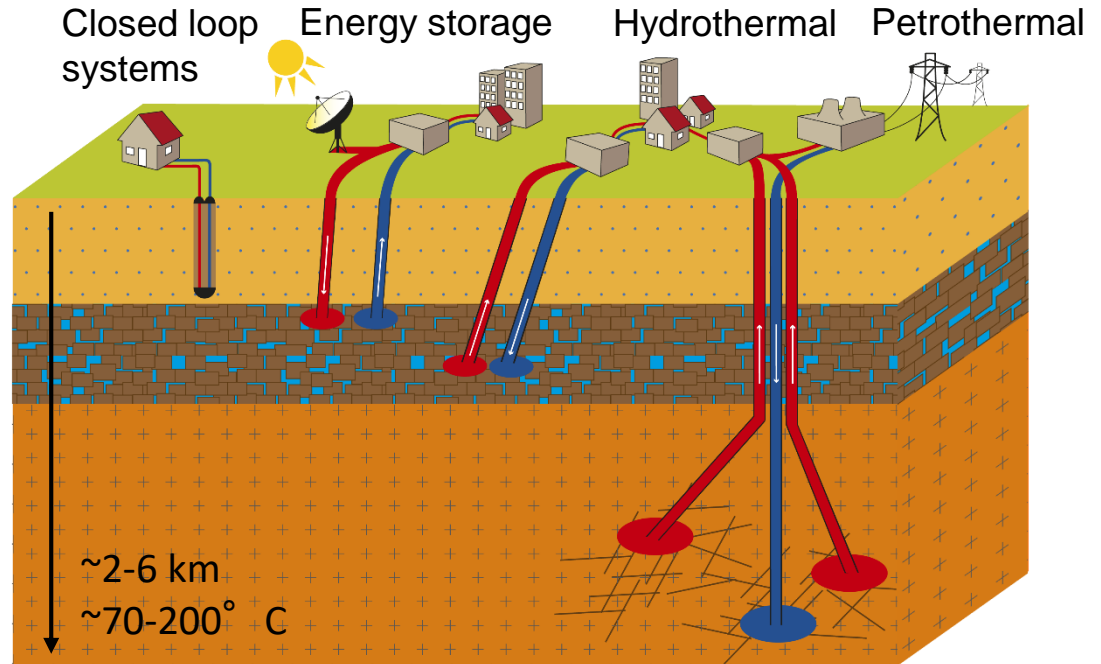
- Huge potential
- Local baseload energy
- Low greenhouse gas emissions



Geothermal energy systems

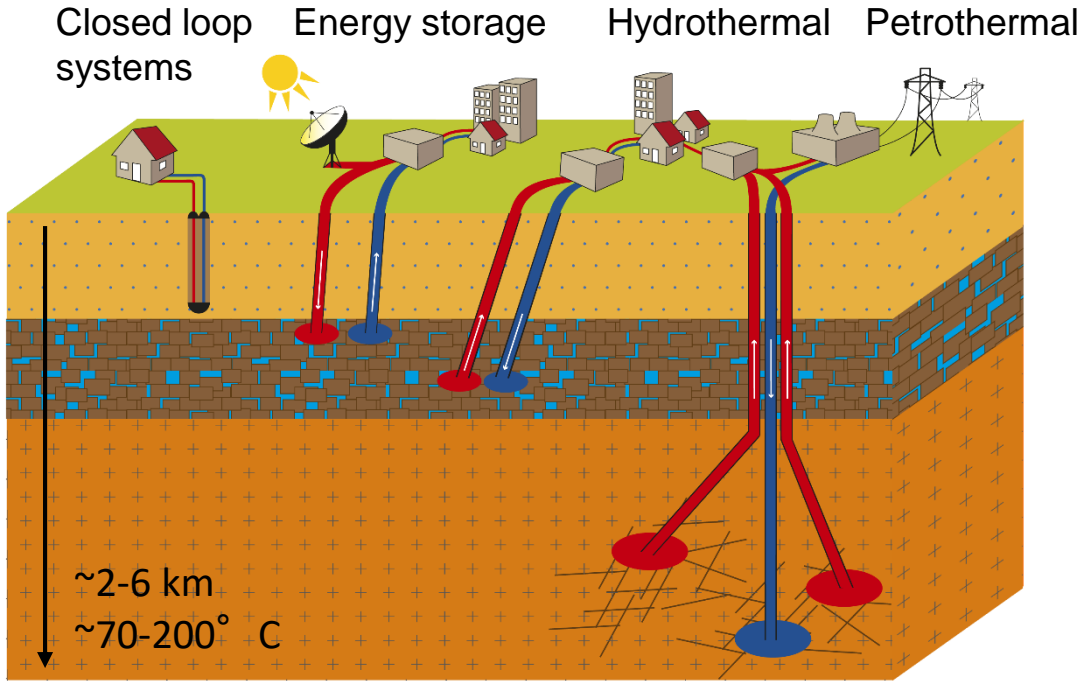


Hot spring: fluid reservoir is connected by faults and fractures to the surface



Geothermal plant: fluid reservoir is connected by wells to the surface

Geothermal fluid



- Transported in the the pores and fractures of the geothermal reservoir
- Heat carrier for energy supply
- Gas and liquid phase of high pressure and temperature
- Often very saline with many chemical components

Geothermal reservoirs in Germany

Nutzung der Tiefen Geothermie in Deutschland
Stand am 2021

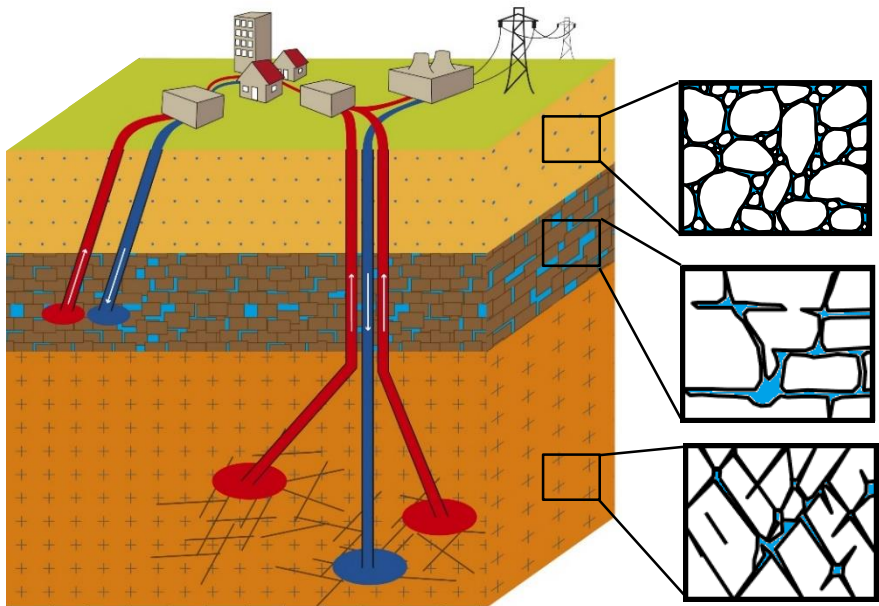
Ansatz der Anlagen nach Art der Strom- und/oder Wärme:
 - in Baden-Württemberg mit Stromerzeugung 28
 - in Bayern mit Stromerzeugung 11
 - in Deutschland keine Anlagen mit Strom- und Wärme
Ansatz der Anlagen nach Art der Strom- und/oder Wärme:
 - in Baden-Württemberg 335,25 MW
 - in Bayern 144,00 MW
Ansatz der Anlagen nach Art der Strom- und/oder Wärme:
 - in Baden-Württemberg 1,00 TWh
 - in Bayern 0,70 TWh
 - in Deutschland 1,70 TWh

Legende

- in Betrieb
- in Betrieb mit Stromerzeugung
- in Bau
- in Bau mit Stromerzeugung
- Planung
- in Planung Strom und/oder Wärme
- Thermalbad / Heilquelle
- Ansatz Thermalbäder / Heilquelle

Plan: 0 Braunkohle-Lagerung
 PL: 0 Kohle-Lagerung
 T: 0 Tertiäre Thermalwasserlagerung
 T: 0 Tertiäre Thermalwasserlagerung
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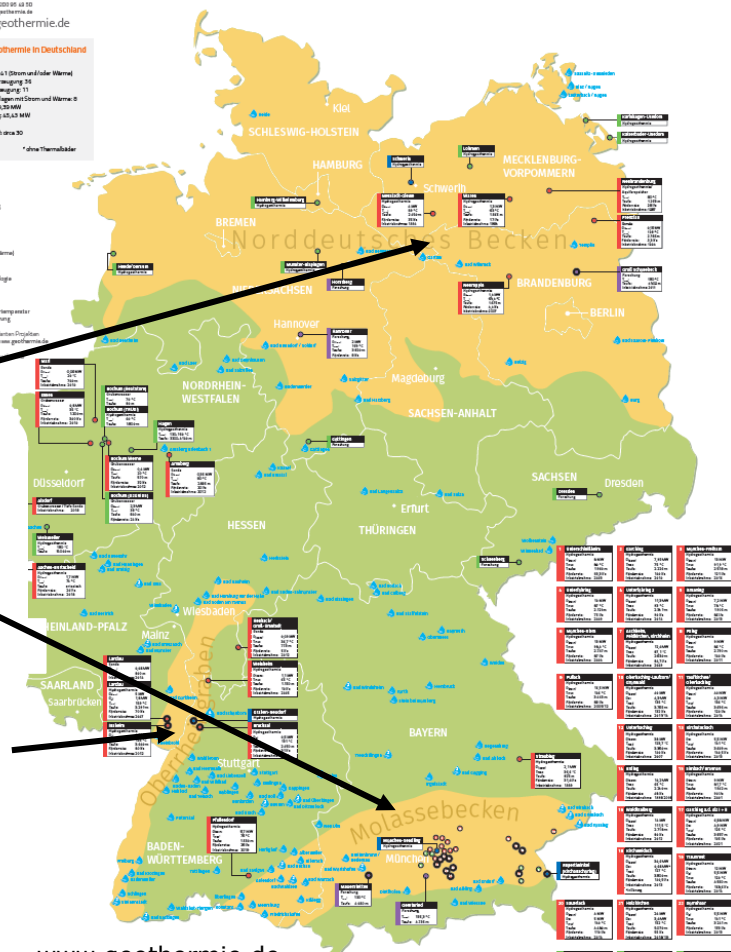
Hydrothermal Petrothermal



Pores

Karst

Fractures



Risks: Chemical reactions during geothermal activities

Change of pressure
→ degassing

Change of temperature
→ Change of mineral solubility

Interaction with new materials
→ Reaction between fluid and new material

Mixing of Fluids from different reservoirs

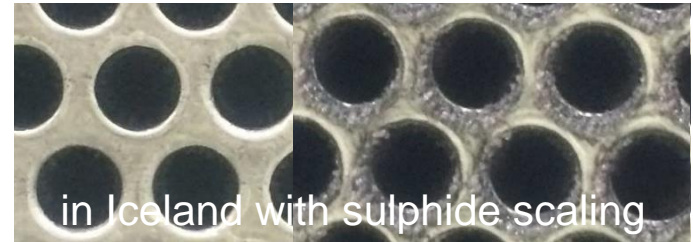
Scaling (mineral precipitation) and corrosion

Scaling

Scale formation depends on:

- Temperature
 - Pressure
 - Chemical components
 - Concentrations
 - pH- and Eh
 - Interaction with surrounding material (rock or power plant)
 - Kinetics of crystal formation
 - Crystal seed (surface, microorganisms)
- } change during fluid production and re-injection

Heat exchanger:
strong T- decrease

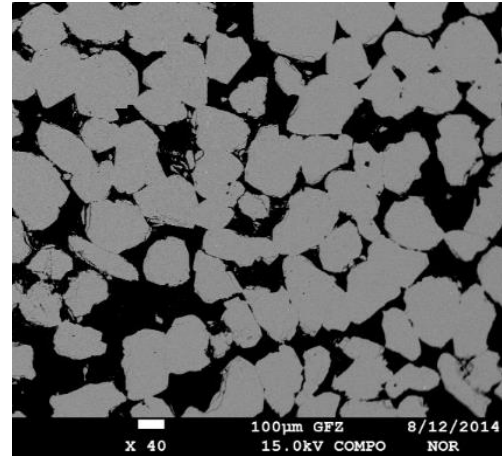


Scaling in the reservoir

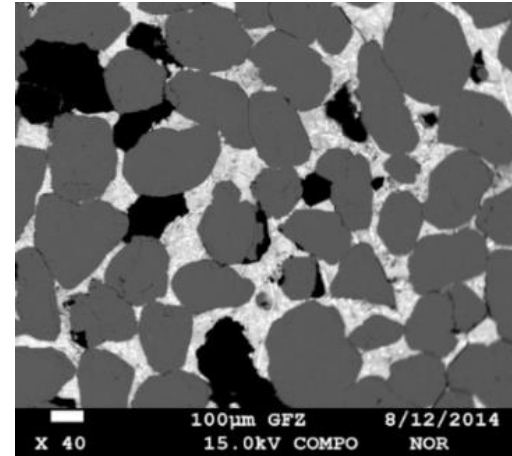
Precipitation in pores and fractures of the rock decrease permeability (reservoir damage)

→ **Reduced injectivity and productivity**

Sandstone sample before and after a flow-through experiment



SEM picture:
pores intact



SEM picture:
clogged pores

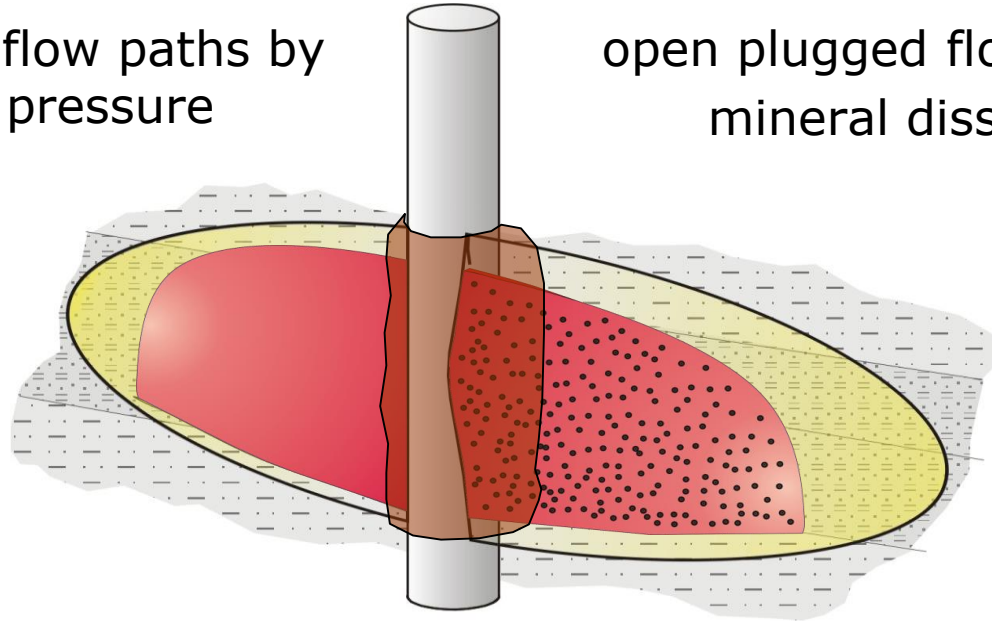
Remediation of scaling in the reservoir

Hydraulic stimulation

open plugged flow paths by hydraulic pressure

Acid stimulation

open plugged flow paths by mineral dissolution



Scaling: Silica (SiO_2)

Formation:

Precipitation due to temperature reduction

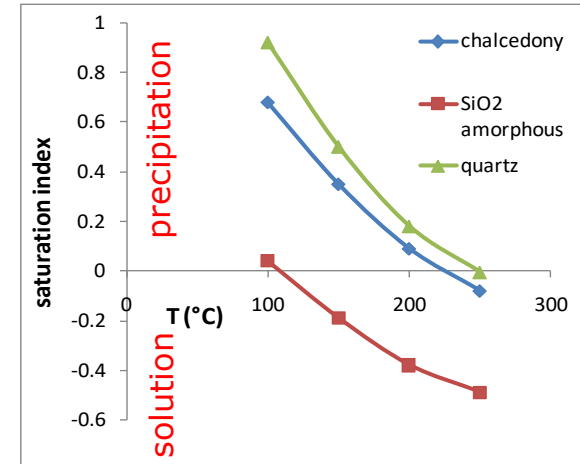
Examples:

High temperature fields in Indonesia, Iceland, New Zealand often in injection lines and wells

Prevention:

Add inhibitors, controlled precipitation in ponds or crystalizer tanks

Phreeqc calculated temperature dependent SiO_2 saturation indices (400 mg/L Si)



Scaling: Carbonates (CaCO_3)

Formation:

Precipitation due to degassing upon pressure release (shift of the carbonic acid equilibrium)

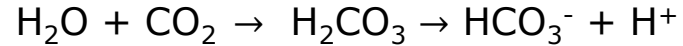
Examples:

Malm carbonates (Molasse Basin);
Volcanic gas-rich reservoirs: Soultz (France), Landau (Germany)

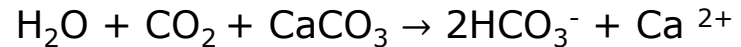
Prevention:

Maintain pressure above bubble point (avoid CO_2 degassing), add inhibitors to keep Ca in solution, add acid...

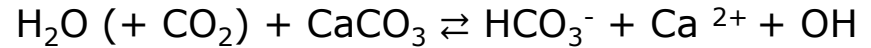
Dissolution of CO_2 in water:



Dissolution of calcite:



Degassing \rightarrow Shift of the equilibrium:



Scaling: Copper (Cu), Magnetite (Fe_3O_4)

Formation:

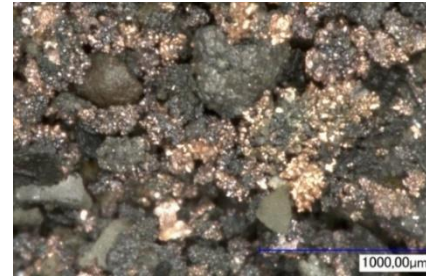
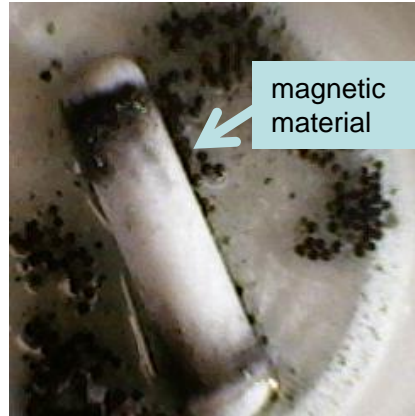
Electrochemical reaction, e.g. with the carbon steel casing

Example:

Groß Schönebeck
Combined corrosion and scaling reaction

Prevention:

Deploy alternative materials (e.g., composite or clad casings)



Corrosion: Casing

Formation

Corrosion is a process, which converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulfide → gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment.

Example

The total annual cost of corrosion in the oil and gas production industry is estimated to be \$1.372 billion*



<https://www.nace.org/Corrosion-Central/Industries/Oil--Gas-Production/>

Prevention

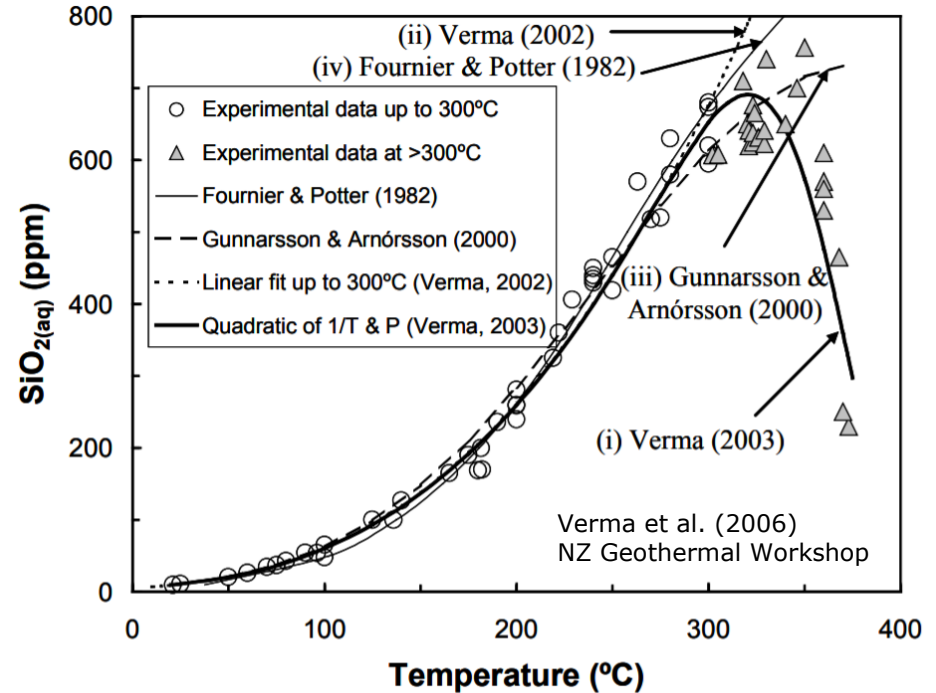
Fluid-specific material selection, new casing materials, new coating materials, avoid O_2 , remove H_2S

Benefit: Geothermal resource exploration

Example

SiO₂ Geothermometer

The clear dependency of SiO₂ solubility from temperature can be used to calculate the reservoir temperature of the geothermal fluid



Benefit: Co-production of resources

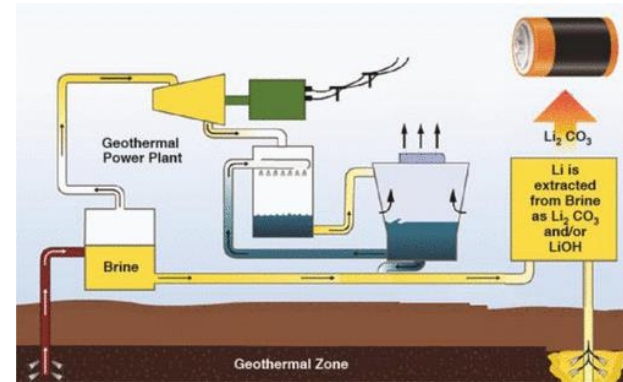
Traditional raw material extraction (Mining)



- Environmental damage
- Large CO₂ release

Example Lithium

Raw material extraction from thermal water



- Low land use, no chemicals, no mining waste
- Almost no CO₂ release

“Lithium Rush” from thermal water

- **Germany:** Upper Rhine Valley (Geothermal plants Insheim, Bruchsal) → Vulcan Energy Resources Ltd. + Pfalzwerke Geofuture GmbH; EnBW
- **United Kingdom:** Cornish Lithium + Geothermal Engineering Limited
- **California, USA:** Salton Sea

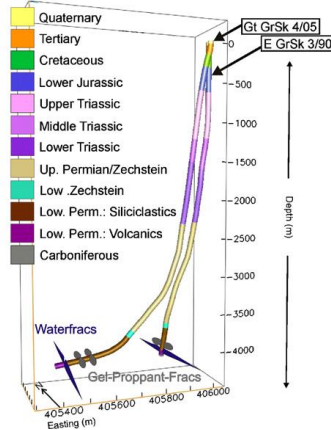
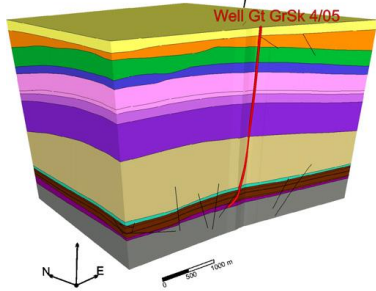
Ionexchange process:
Pilot-scale lithium extraction system (Lilac, Oakland)



Geothermal research site Groß Schönebeck: History

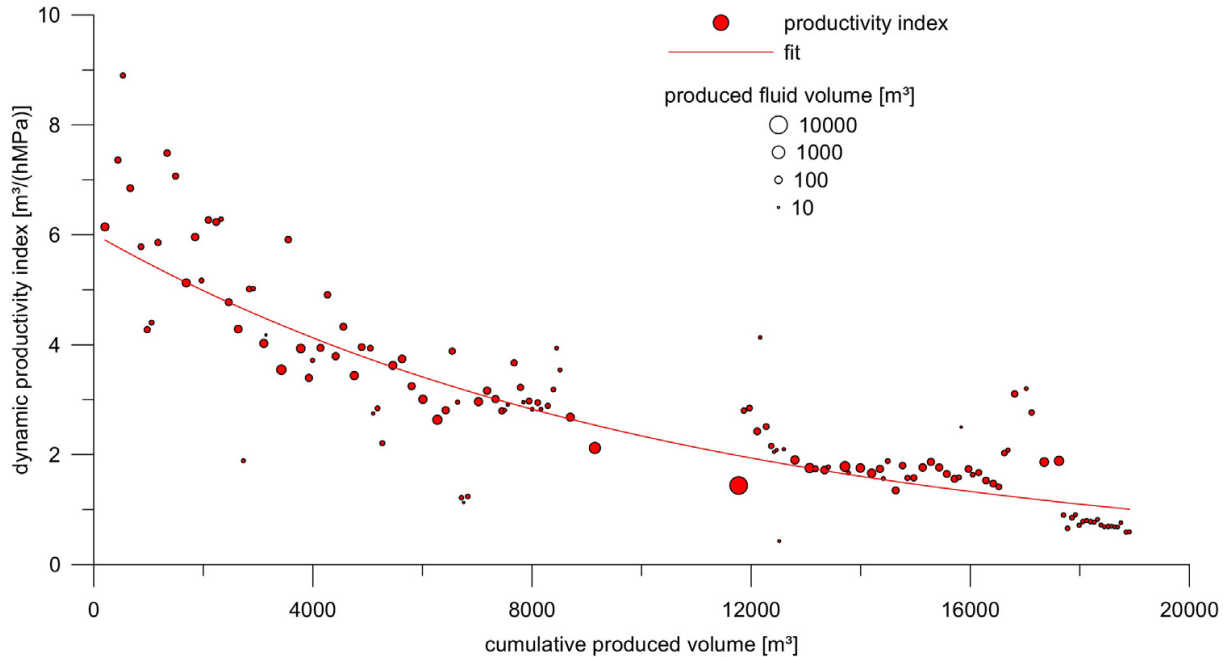


Geothermal research field
Groß Schönebeck



- 2001-2003: Re-opening of gas exploration well GrSk 3/90
 - Deepening of GrSk 3
 - Stimulation of GrSk 3
- 2006-2007: Drilling of well GrSk 4/05
 - Stimulation of GrSk 4
- 2011-2013: Hydraulic tests
 - Stable injectivity
 - Productivity decline
- 2016-2019: Preparation of fracture dominated site development concept
 - 3D Seismics

Geothermal research site Groß Schönebeck: Productivity decline



Geothermal research site Groß Schönebeck: Countermeasures

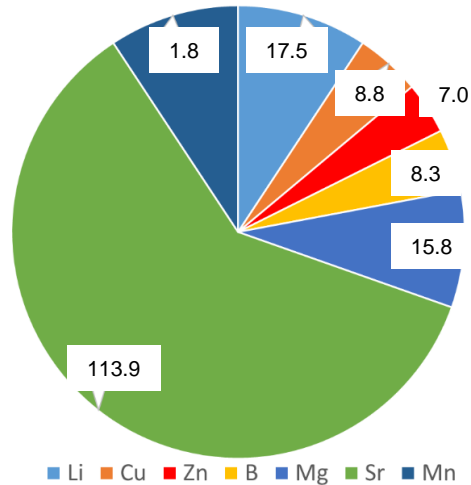
Process	Counter actions
Sedimentation of Baryt in borehole	<ul style="list-style-type: none">• Use of commercial inhibitors
Copper scaling clogging near wellbore area	<ul style="list-style-type: none">• Use of cladde pipes to avoid electrochemical reaction• Extraction of copper at the surface
Damage of induced fractures due to excessive pressure reduction	<ul style="list-style-type: none">• Analysis of fracture sustainability in laboratory• Less pressure reduction during production
Two-phase flow due to degassing reduces relative permeability of water	<ul style="list-style-type: none">• Modelling shows no relevant influence• Free gas was not confirmed• Less pressure reduction during production
Limited reservoir volume due to impermeable faults	<ul style="list-style-type: none">• 3D Seismics showed no indication of impermeable faults

Geothermal research site Groß Schönebeck: Resource extraction potential

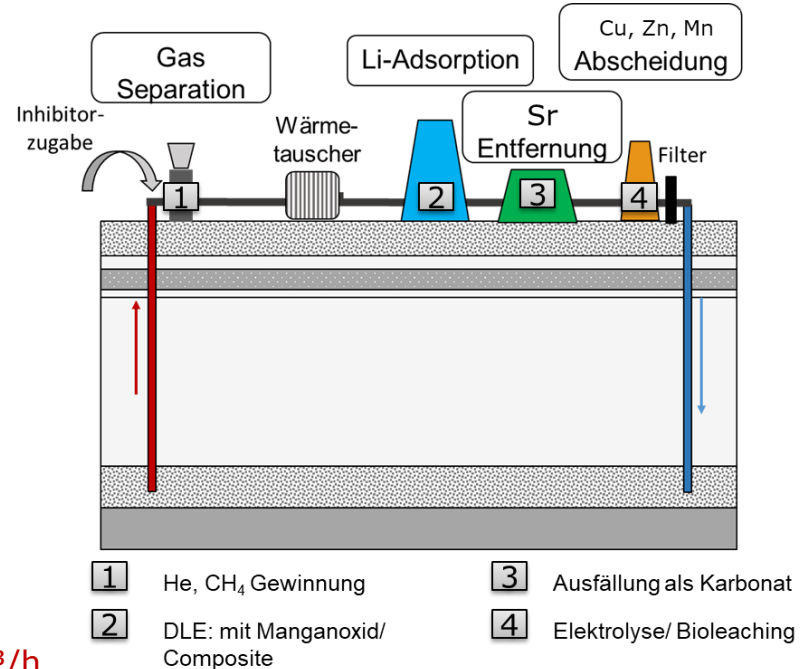
Concentration of strategic relevant elements in the Groß Schönebeck fluid

Element	mg/L
Sr	1300
Mn	200
Li	200
B	95
Zn	75
Cu	100

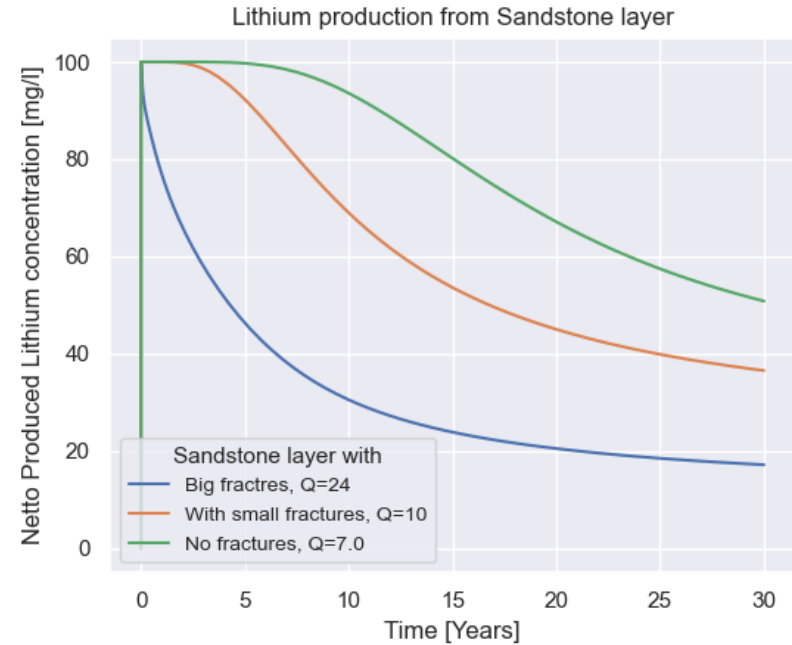
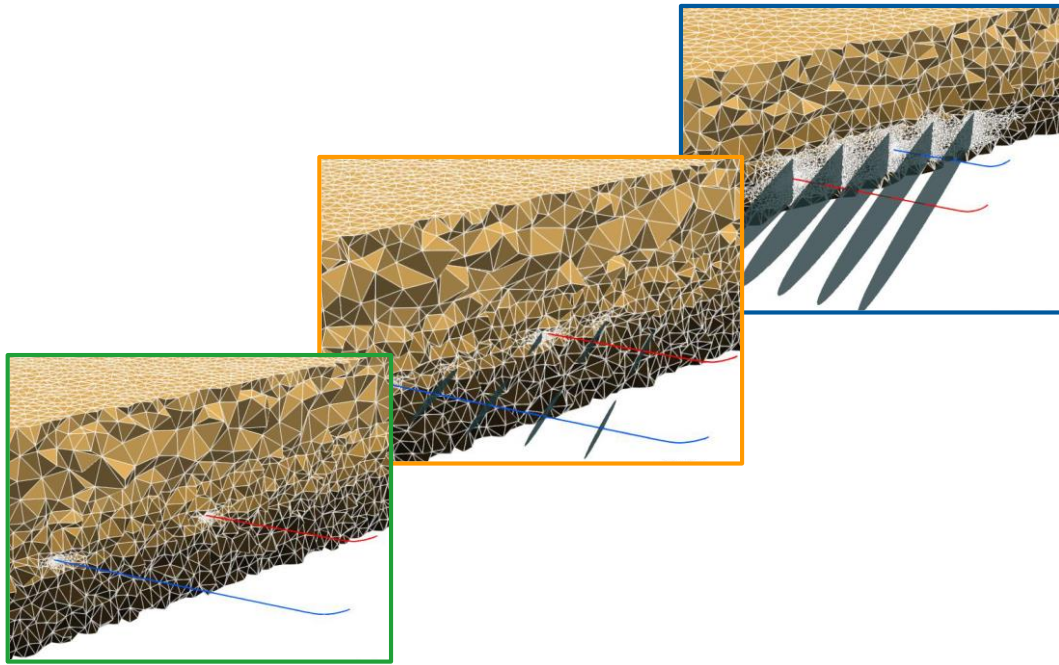
Yearly production (tons) with a production rate of 10 m³/h



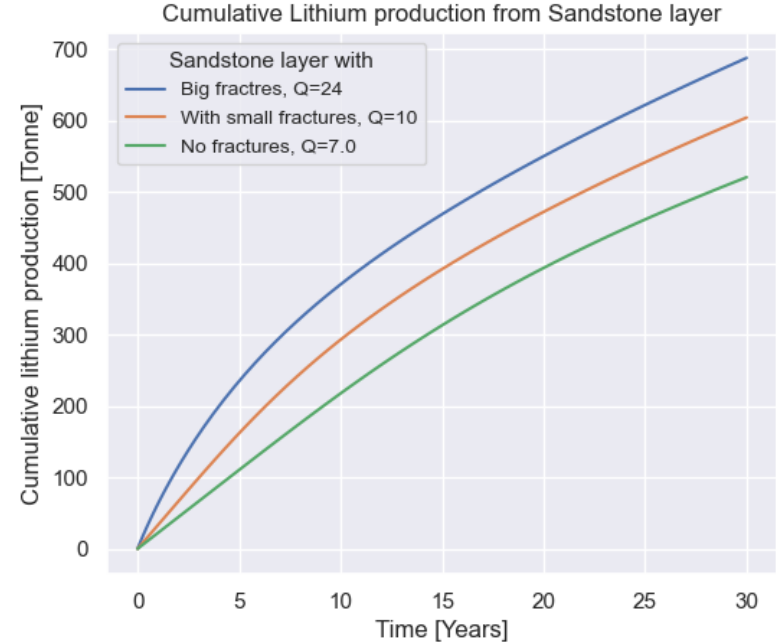
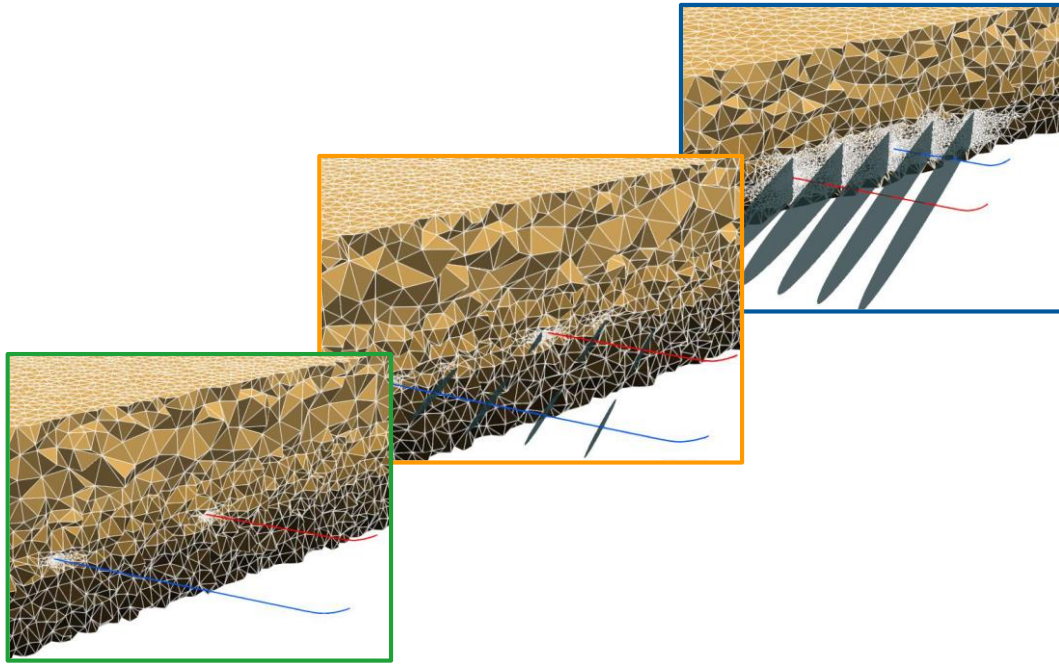
Note: Typical production rates are >180 m³/h



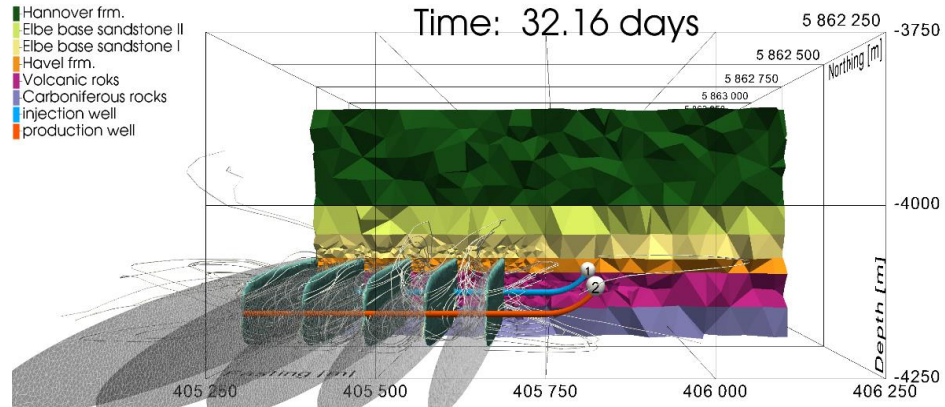
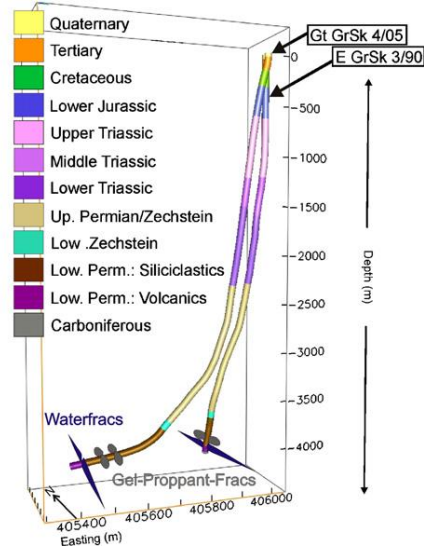
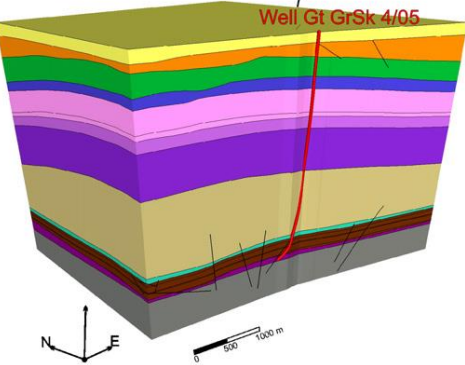
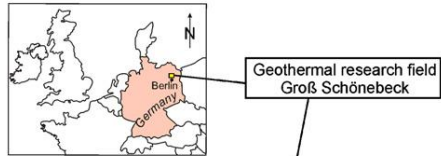
Geothermal research site Groß Schönebeck: Resource extraction potential



Geothermal research site Groß Schönebeck: Resource extraction potential



Future of Groß Schönebeck: Fracture-dominated system for electricity, heat and metal extraction



Risks and benefits of utilizing deep fluids

