Deep geothermal fluid resources: Energetic use and beyond

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with contributions by

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Section 4.1 – Reservoir Technologies
International Centre for Geothermal Research ICGR

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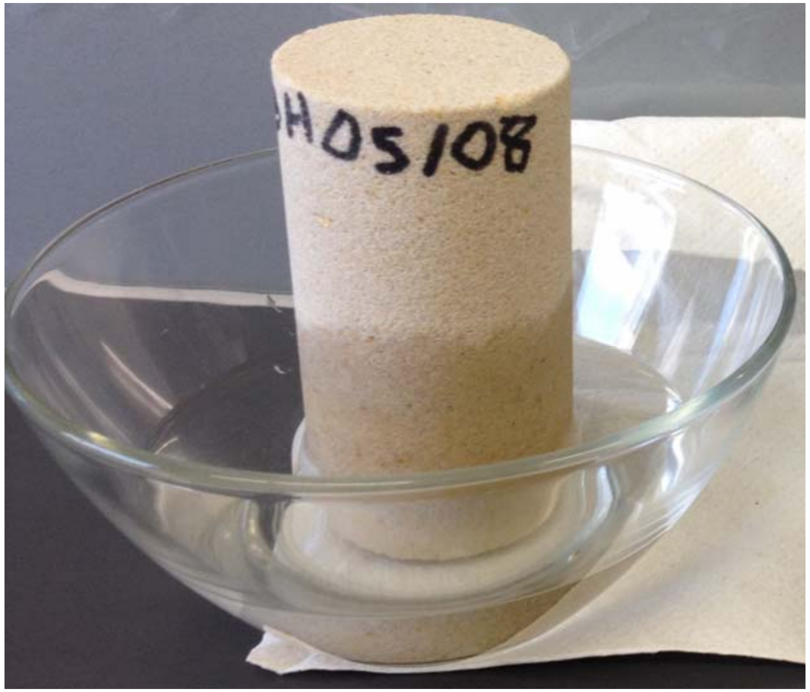
Introduction

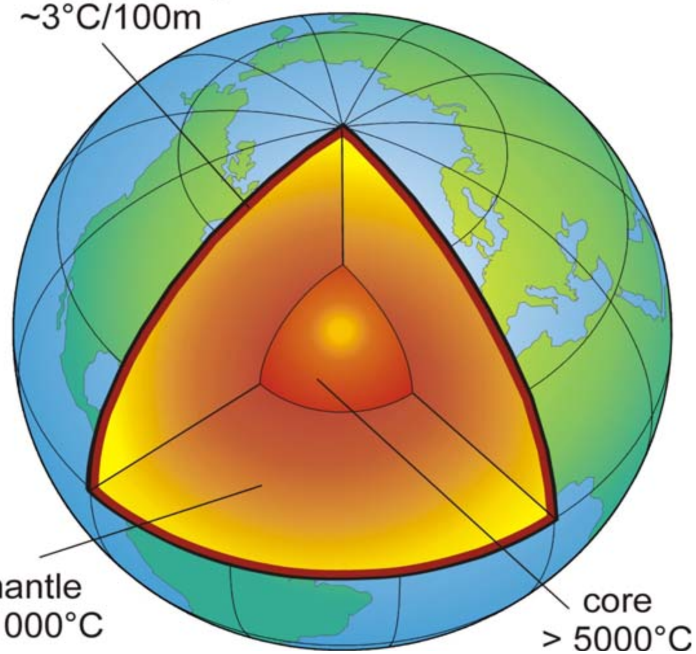
Operational Risks

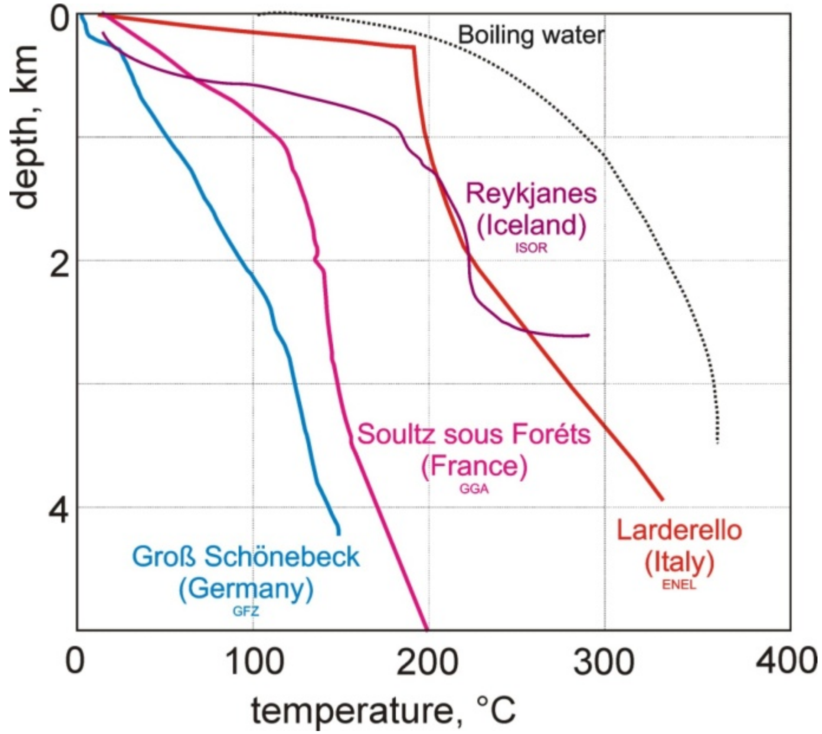
Process Control

Beyond Energy

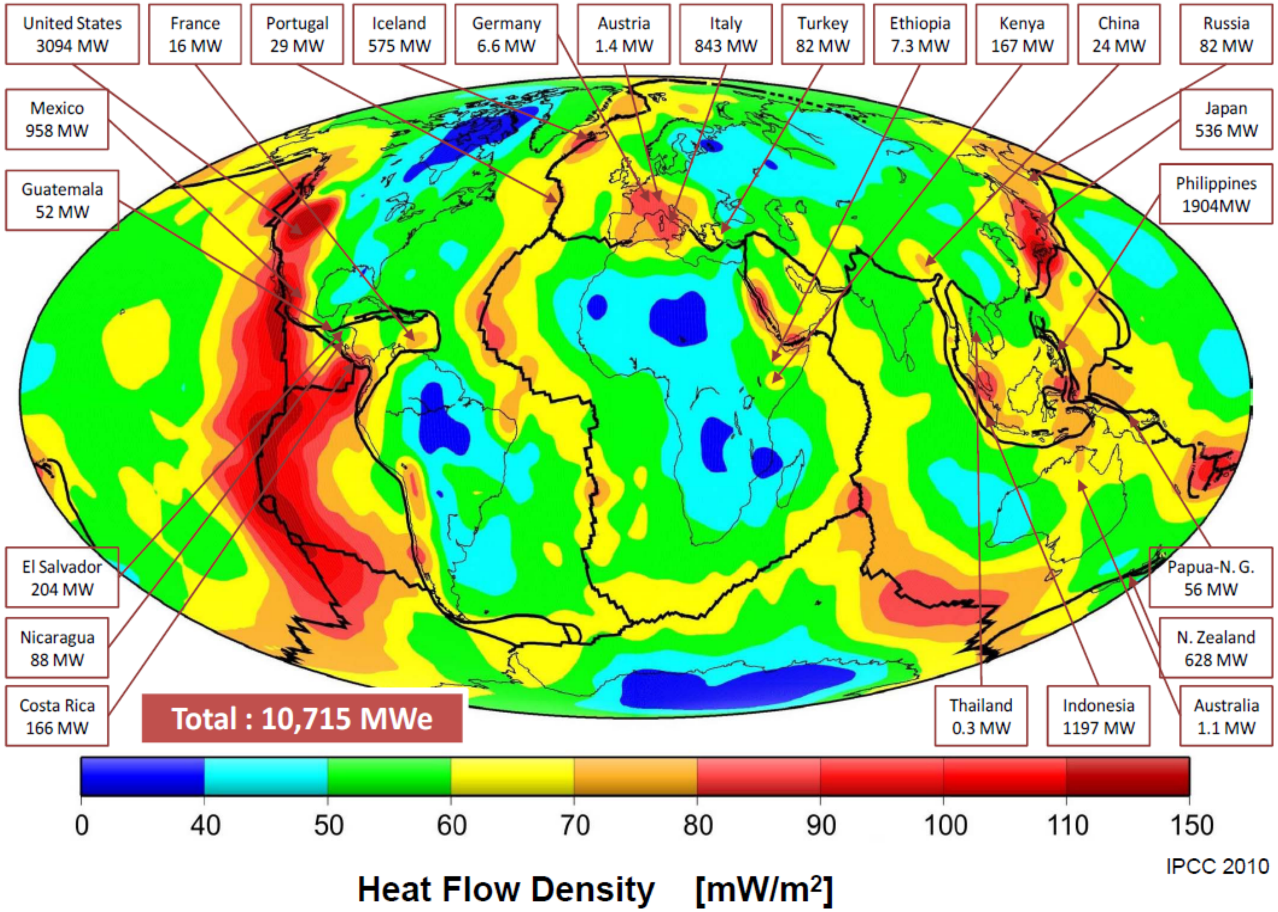


Thermal gradient

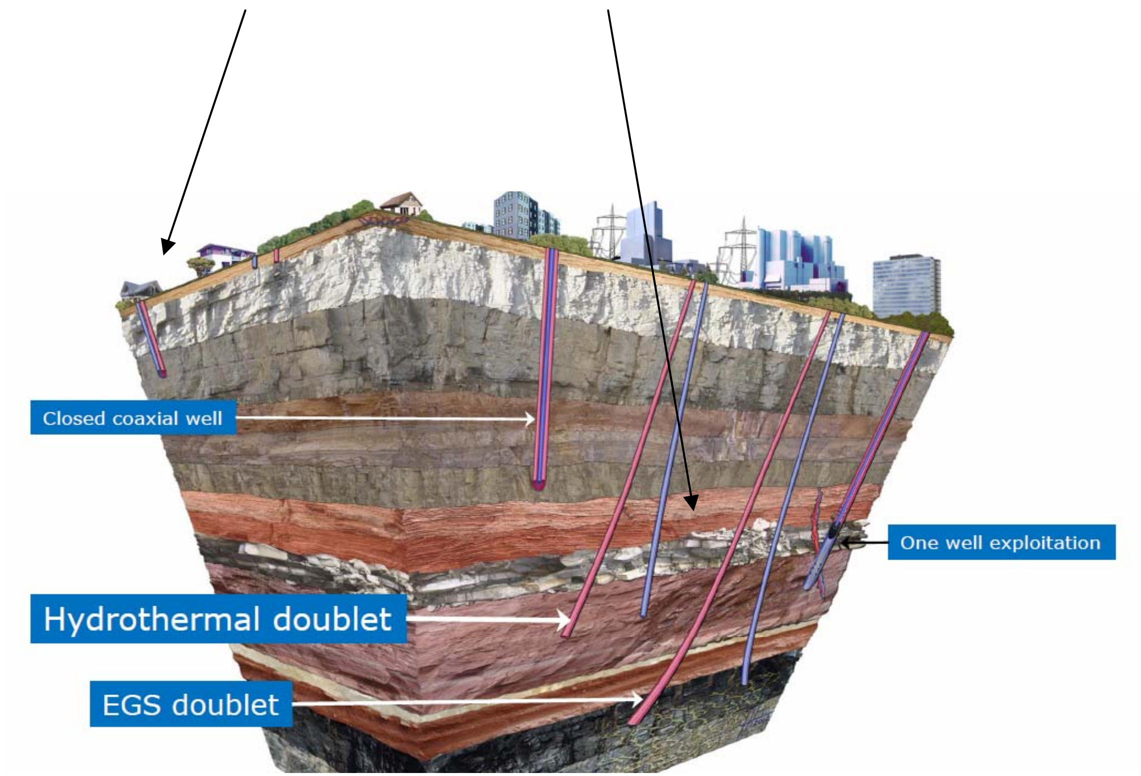




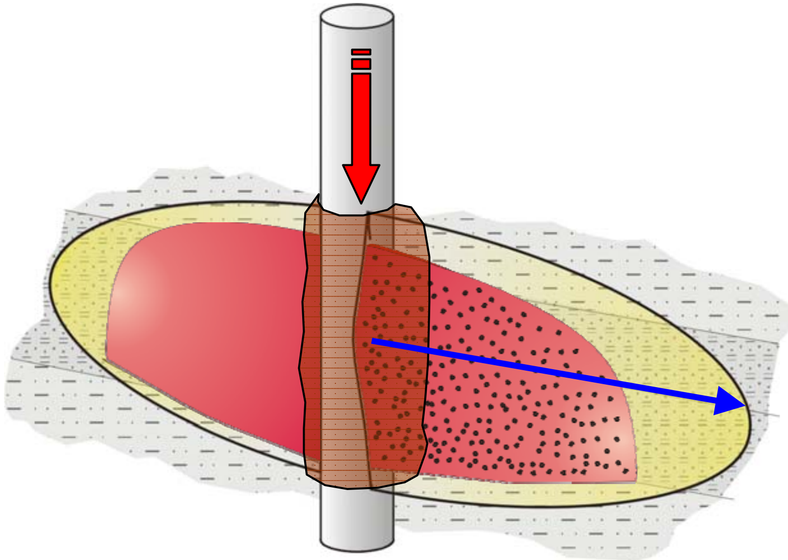
Installed capacity



Shallow and *Deep* Geothermal Energy

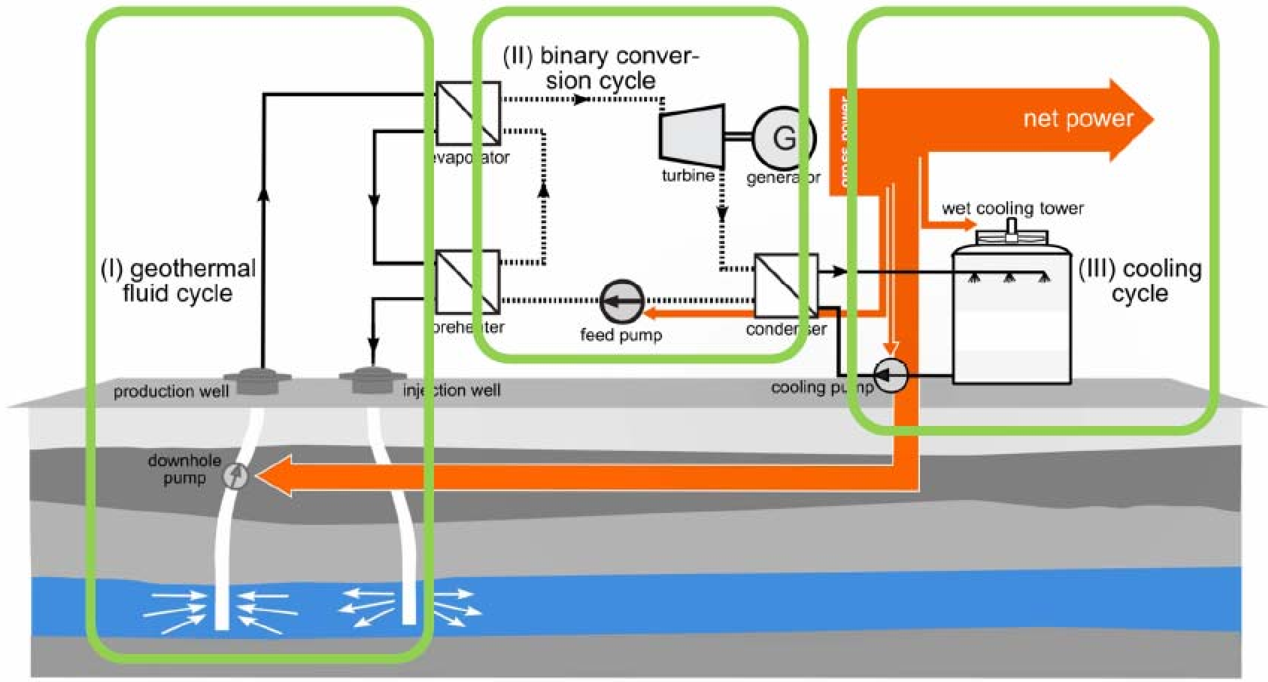


Enhanced Geothermal Systems (EGS)



Hydraulic Stimulation

Geothermal Energy Systems



Geothermal Energy in Germany

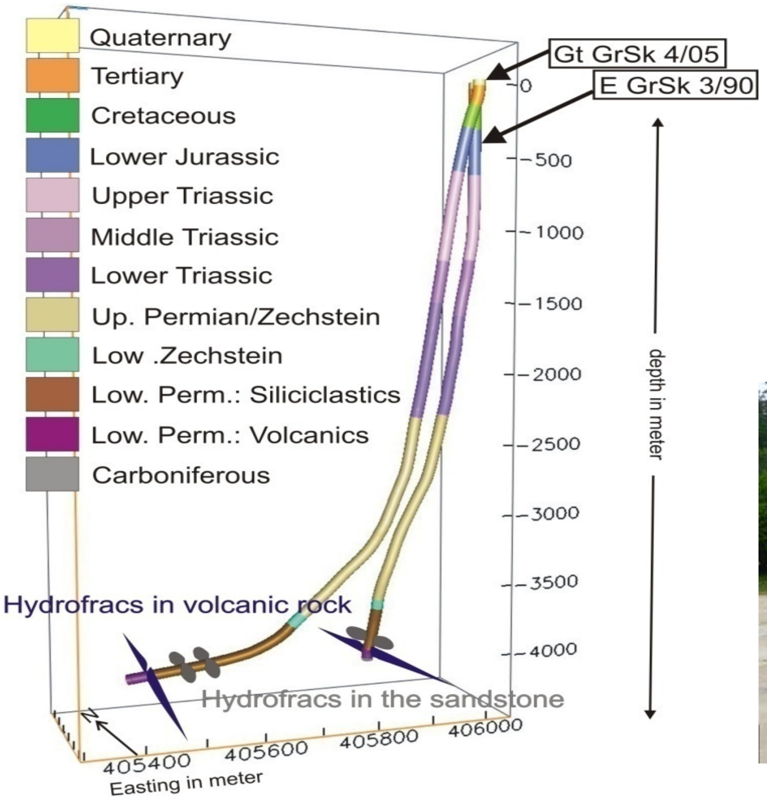
- in NG-Basin from sandstone reservoirs (mesozoic / paleozoic)

- in Molasse-Basin from carbonate reservoirs (Malm-Karst)

- in Upper-Rhine Graben from various reservoirs (sedimentary / crystalline)

Geothermal Research Platform

Groß Schönebeck



Doublet in North German Basin (NGB)

Fluid-production from Sandstones / Volcanites

P ≈ 450 bar / T ≈ 150°C

Fluid Composition / Liquid

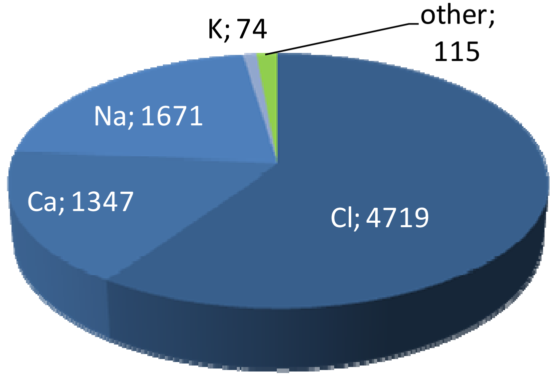
Main components

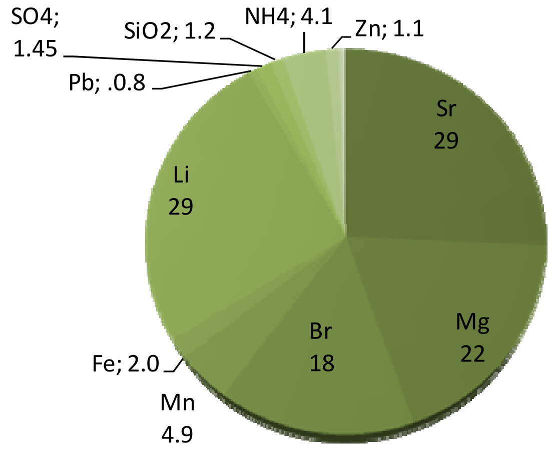
- sodium chloride (NaCl)
- calcium chloride ($CaCl_2$)

Variability

- ratio of the main components
- presence / amount of trace elements

Physical and chemical properties of geothermal fluids can differ significantly from those of pure water





Example: Groß Schönebeck fluid (mM/L)

TDS = 265 g/L

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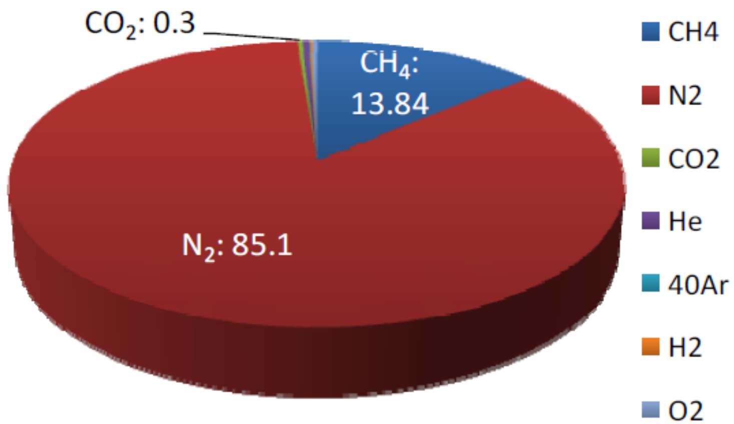
Fluid Composition / Gas

Gas components in geothermal fluids:

N_2, CO_2, He, CH_4, H_2S, H_2, (O_2)

gas	problem
CH_4	green house gas
CO_2	carbonate scale formation when degassing (shift of the equilibrium)
H_2S	corrosive, smell, toxic
H_2	corrosive

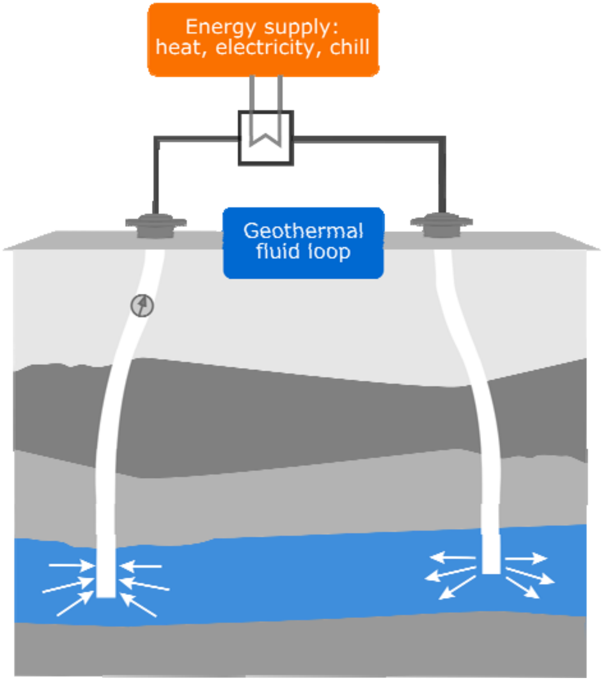
production well: 2003-2009



Example: Groß Schönebeck fluid (vol%)

Thermal Loop

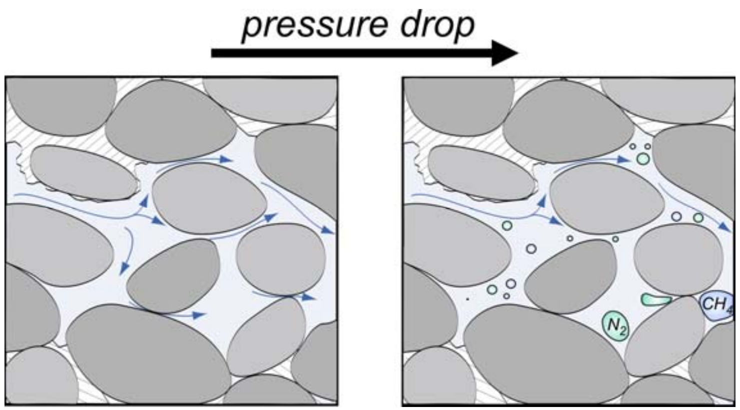
1.5 MPa / 140°C → 1.5 MPa / 70°C

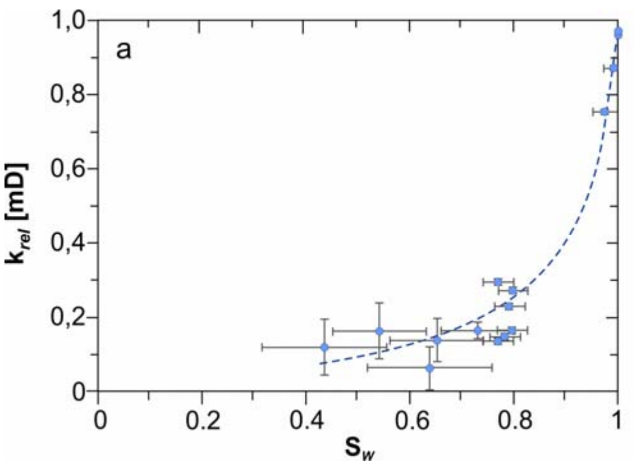


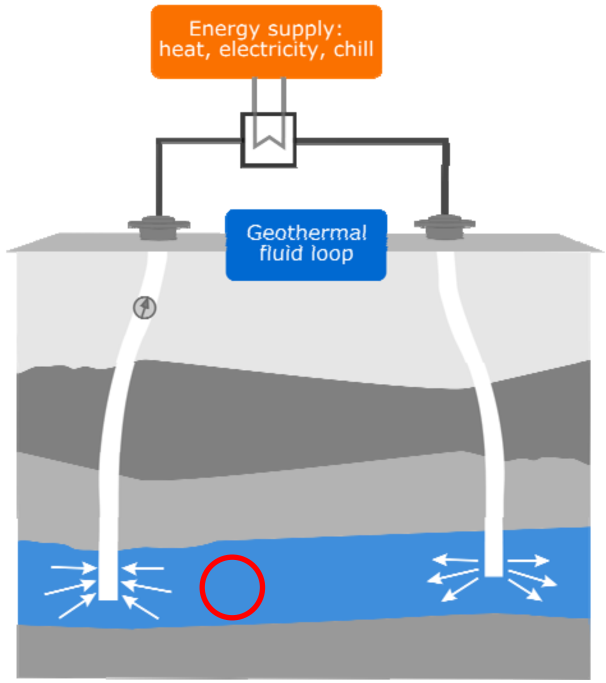
45 MPa / 150°C ← 50 MPa / 80°C

Two-Phase Flow

$$q = \frac{\dot{V}}{A} = -\frac{k}{\eta}\nabla p$$



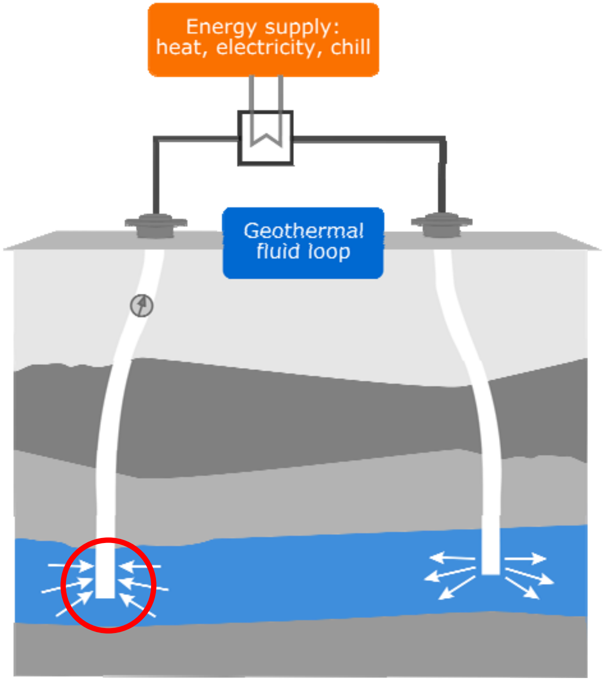




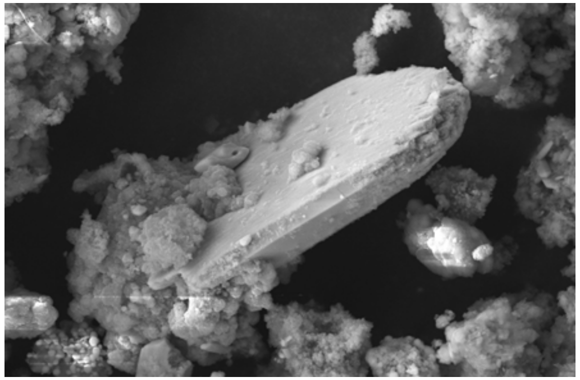
Redox Reactions

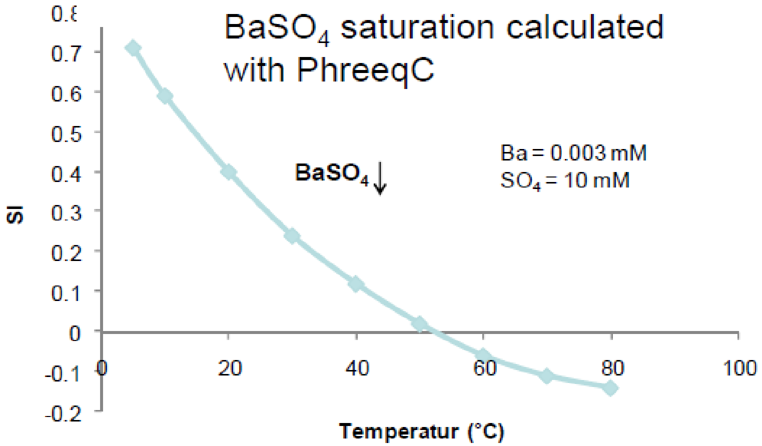
Cu^{2+} + $2e^-$ → **Cu_0** (Reduktion)

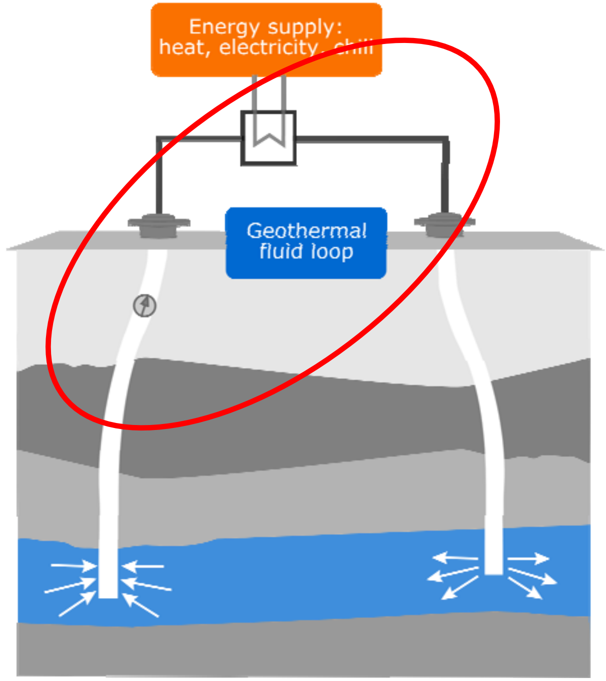
Fe_0 → Fe^{2+} + $2e^-$ (Oxidation)



Oversaturation

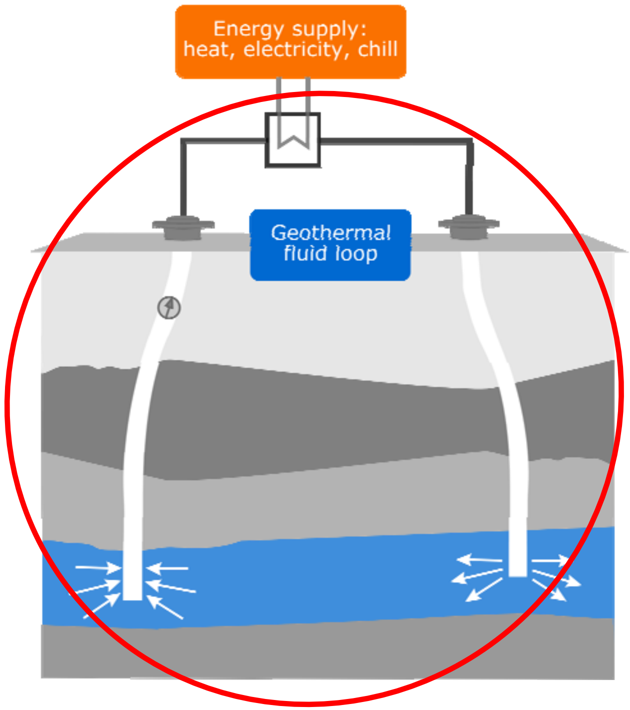




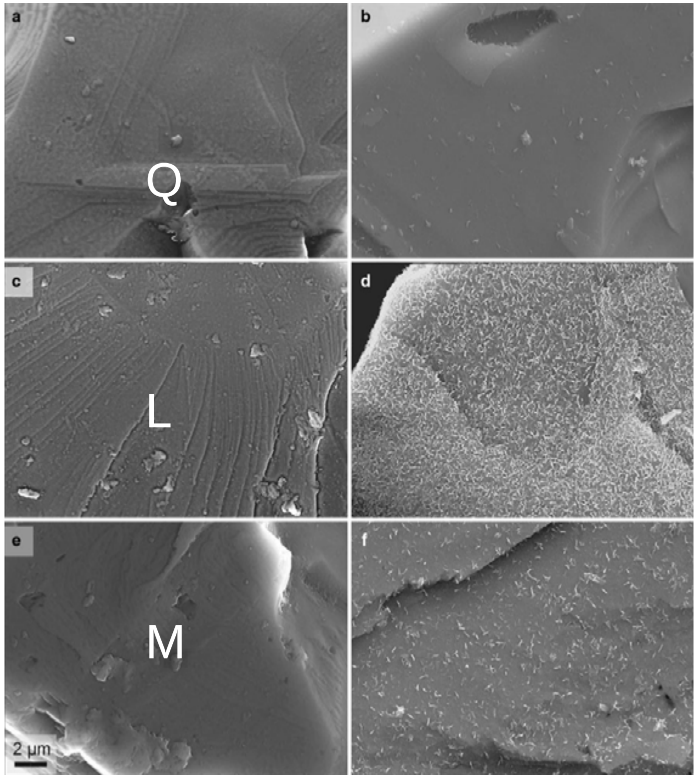


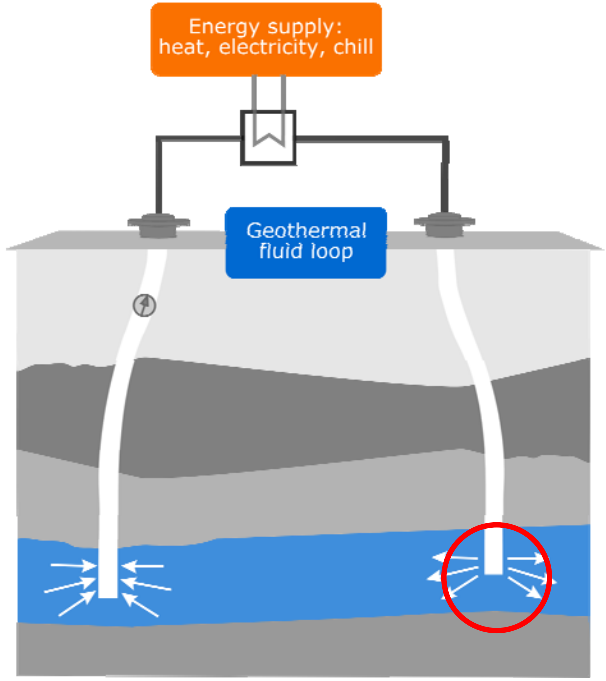
Corrosion

© BAM

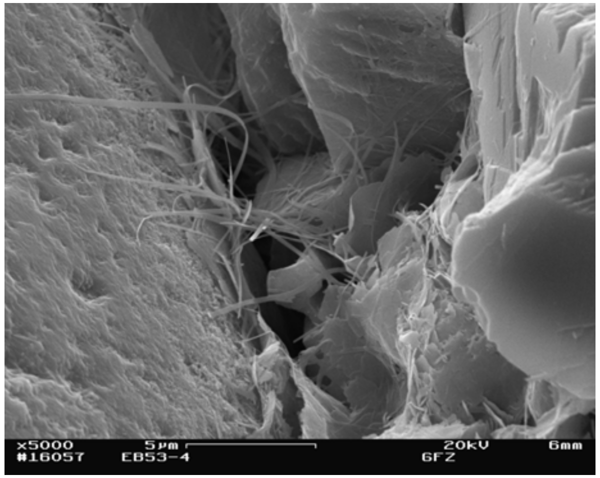


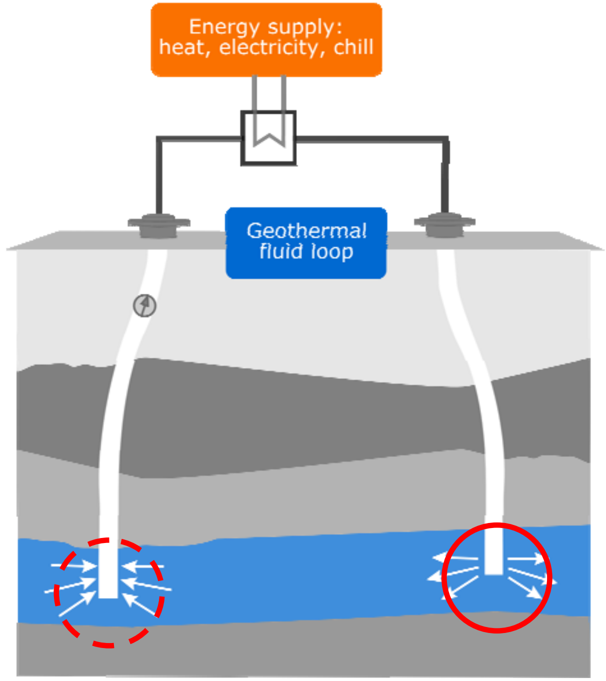
Dissolution-Precipitation Reactions





Particle Transport





1. Requirement: know your fluid, rock and materials *properties*

2. Requirement: understand interaction *processes*

Goal: avoid / handle risks interfering with overall system functionality

- two-phase flow:	- keep draw down low
- redox reactions:	- select appropriate materials
- oversaturation:	- keep temperature high - use *inhibitors*
- corrosion:	- select appropriate materials - active / passive *protection*
- dissolution-precipitation reactions:	- keep temperature high
- particle transport:	- keep flow-rate below threshold - filter fluid before injection - avoid injection of incompatible fluids

Scaling Inhibitors

- Chemical substance added to the geothermal fluid:

  Phosphonates

  Polymers (e.g. Polycarboxylate)

  Acids (e.g. HCl for calcite)

- Designed for specific types of scales (e.g., sulfates, carbonates)

Corrosion Protection

Active:	1) Cathodic protection:	with sacrificial anodes (Mg, Zn)
	2) Corrosion inhibitors:	remove dissolved oxygen from the fluid
Passive:	1) Metallic:	Zn, Ni, Cr / e.g. hot-galvanization
	2) Organic:	resins, thermoplastics, rubber, polymers
	3) Mixed organic-metallic:	zinc coating + organic layer (duplex method)

- Depending on location, geothermal fluids contain a plethora of dissolved elements and compounds.
- These may constitute an economic value if:
  1) their concentration is sufficiently high, and
  2) appropriate techniques exist to separate them either from the fluid or a precipitate.
- Substances of interest are, e.g.:

  Silica, *Lithium, Copper* and *Rare Earth Elements* (REE) in the liquid phase and *Helium* in the gas phase.

Example: GrSk-Fluid

SiO_2	72 mg/L
Li	200 mg/L
Cu	10 mg/L (?)
He	> 20 NL/m^3

Example 1: Silica

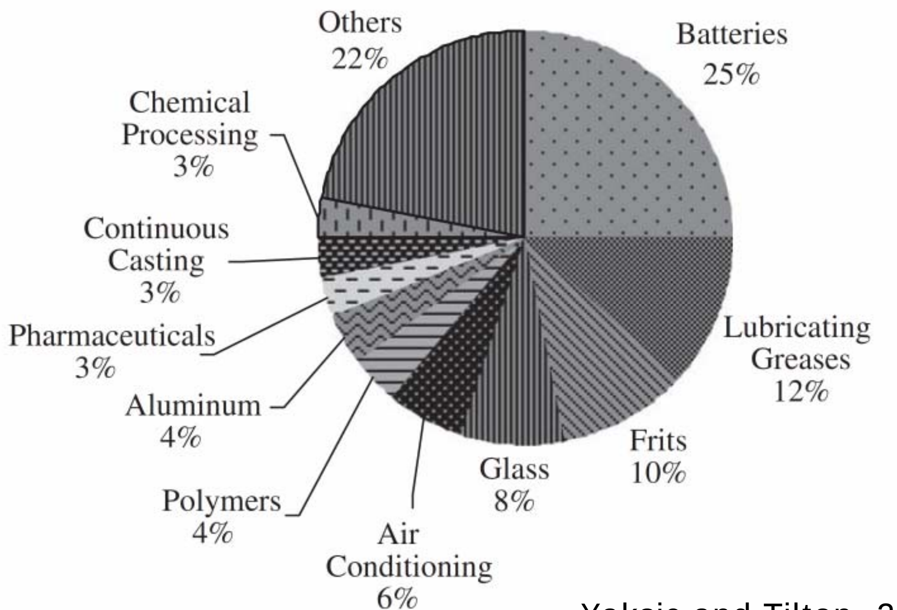
- Mainly of interest for high enthalpy geothermal systems, e.g. Indonesia
- Various industrial applications:
  - fillers (e.g. paper, paint, plastics, rubber)
  - abrasives (e.g. sandpaper)
  - polishing (e.g. silicon wafers)
  - desiccants (e.g. food)
  - feedstock (e.g. semiconductors, catalysts)
- Price between 1–7 US$/kg depending on application
- Processing technology:
  - producing silica sol from colloidal silica

Lahendong, Indonesia

- Dominant sources to date:
  - from ores / minerals, e.g. $LiAl[Si_2O_6]$
  - from salt lakes, e.g. LiCl

Rob Lavinsky, iRocks.com

- Various industrial applications:
  - batteries! (8000 t in 2015)
- Price ca. 5 US$/kg for Li_2CO_3
- Processing technology:
  - solvent extraction
  - co-precipitation with AlOH
  - HMnO ion-sieve adsorbent
  - Li ion-sieve adsorbent



Yaksic and Tilton, 2009

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Example 2: Lithium

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Thank you very much
for your attention

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