DESTRESS

Demonstration of soft stimulation treatments of geothermal reservoirs

Soultz soft stimulations Dr Albert Genter ESG

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Objective & Outline

- ***How to improve hydraulically a low injection well by chemical treatments on an operating geothermal plant?***

Outline

- Soultz site presentation including the geothermal concept evolution
- Brief Soultz history about stimulation
- Geothermal site on-going activity
  - Geothermal and electricity production during exploitation
  - GPK-4 well characterization: Injectivity index, well integrity, minerals to dissolve, …
- Conclusion and perspectives

Soultz site overview

Location

- Geothermal anomaly in the Upper Rhine Graben (URG)
- Crystalline reservoirs: deep-seated fractured granite

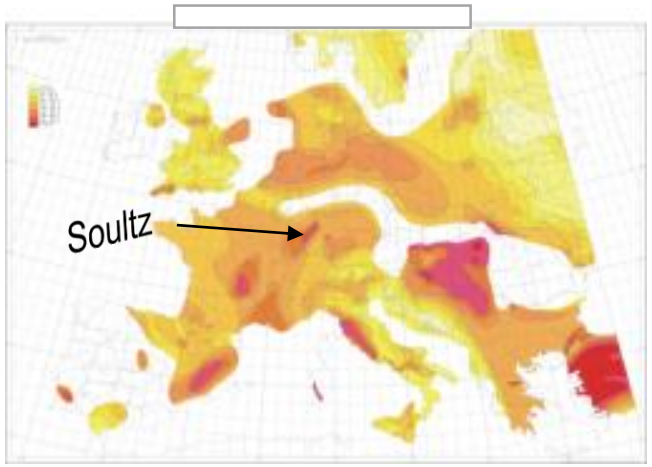
Technology

- 3 deep geothermal wells: 200°C @ 5 km depth
- 1st binary geothermal plant in France (Owner GEIE, Operator ESG)
- Organic Rankine Cycle (ORC) technology: 1.7 MWe gross power
- New plant built on 2016 using old geothermal wells
- Down-hole submersible pump: Long Shaft Pump (LSP)

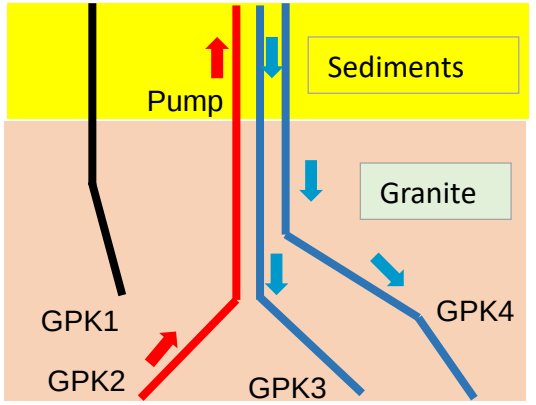
Feed-in tariff from 2010

- Geothermal electricity about 210 € per MWh
- No heat application on site

Down-hole Pump



ORC plant

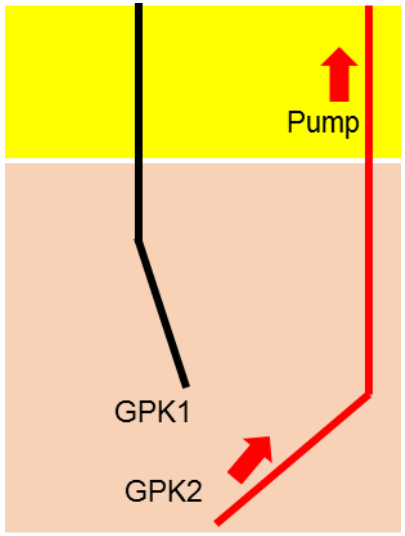


Soultz geothermal plant: two loops

A first geothermal loop connected to a second one, Organic Ranking Cycle (ORC) for electricity production

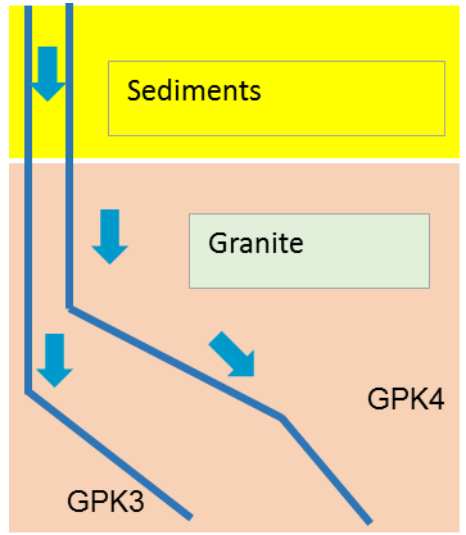
Line Shaft Pump (LSP)
Setting depth: 350 m
Power consumption: 160 kW
Oil lubricated LSP
Wellhead pressure: 22.5 bar

The plant has an installed gross capacity of 1.7 MWe, and a annual baseload factor > 90%



150°C

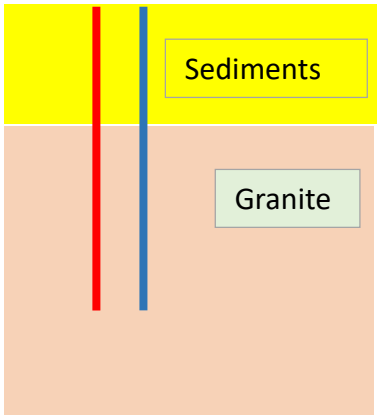
70°C



Na-Ca-Cl fluid with a TDS of about 100 g/L and a Gas Liquid Ratio of 1 (86% CO_2)

Concepts

Hot Dry Rock



Hydraulic fracturing

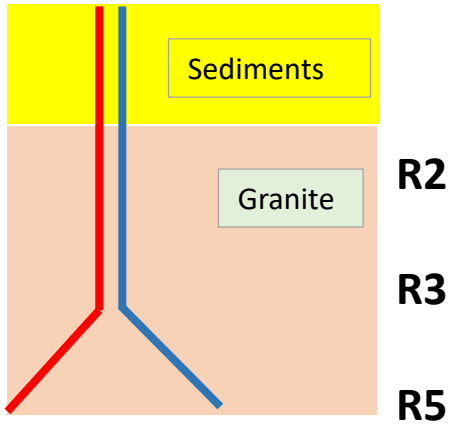
Water injection
Hard rocks

Induced seismic cloud

correlated to permeability

Artificial heat exchanger

Enhanced Geothermal System



Hydraulic stimulation

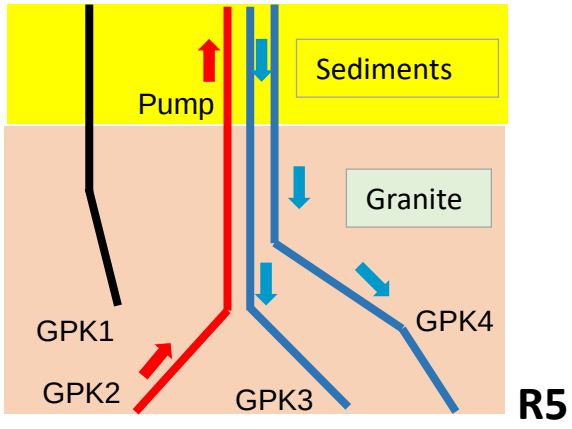
Chemical stimulation
3 reservoirs (R1, R2, R3)

Occurrences of brines

Hydrothermally Altered
Fractured Zones

Induced Seismicity M=2.9
Natural radioactivity (scaling)

Soultz 2018



Hydraulic circulation

1 production & 2 injection wells
Low pressure reinjection

Down-hole pump: LSP

No reinjection pump

Environmental monitoring
(IS, pH, Eh, Corrosion, …)

Soultz wells

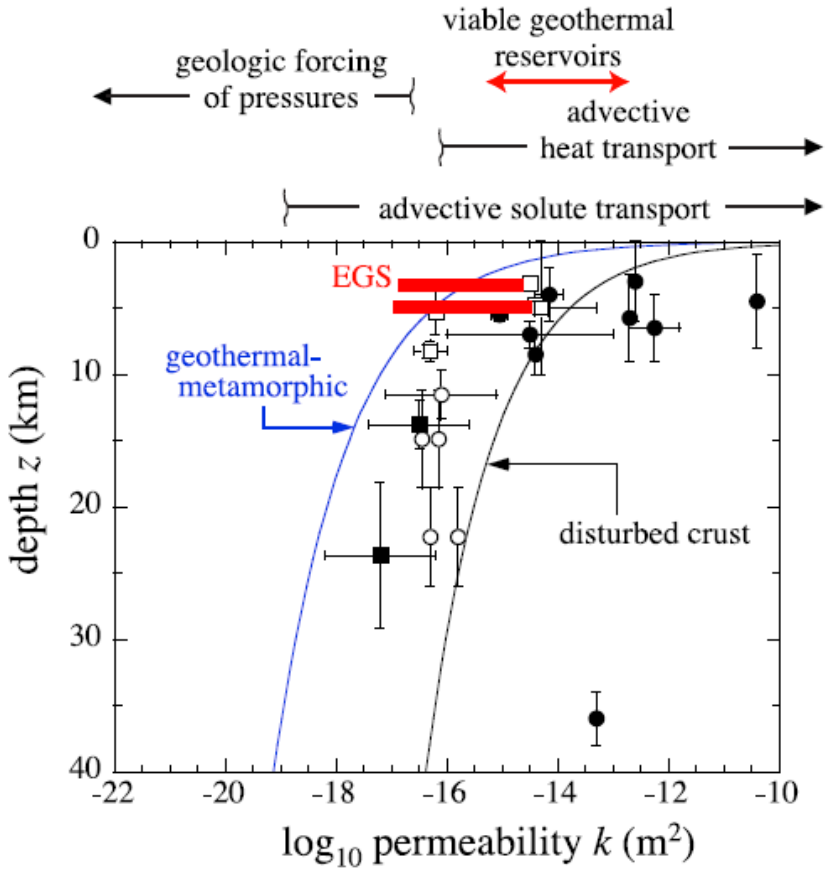
- **GPK-2:**
  - Drilled in 1995 (3.9 km) and deepened in 1999 (5 km)
  - Initial injectivity/productivity index: 0.02 L/s/bar
- **GPK-3:**
  - Drilled in 2002 to 5km
  - Initial injectivity/productivity index: 0.2 L/s/bar
- **GPK-4:**
  - Drilled in 2004 to 5.2km
  - Initial injectivity/productivity index: 0.01 L/s/bar

→ Necessity to apply reservoir treatments to improve hydraulic performance of the wells.

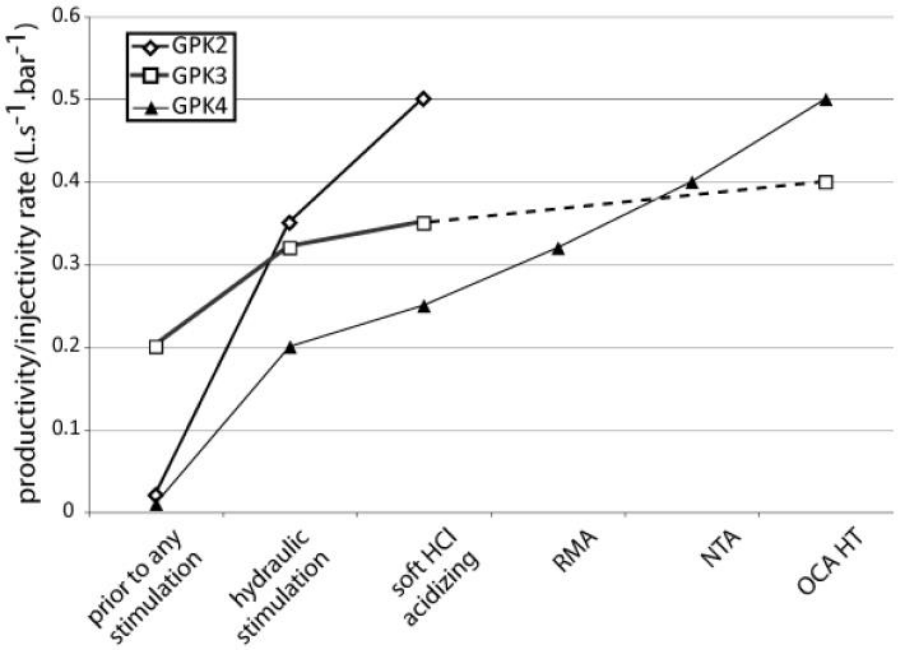
About 15 major stimulations between 1988 and 2007:

- **→ First hydraulic stimulations**
- **→ Second chemical stimulations**
- **→ Further improvements by hydraulic circulation (2005, 2008 to now)**

Permeability enhancement at Soultz



Manga et al 2012



Multi-well and multi-reservoir: R2 (1400-2200m), R3 (3000-3900m), R5 (4000-5400m)

Individual nearly-vertical fault zones determine stimulation results

Maximal natural injectivity index:

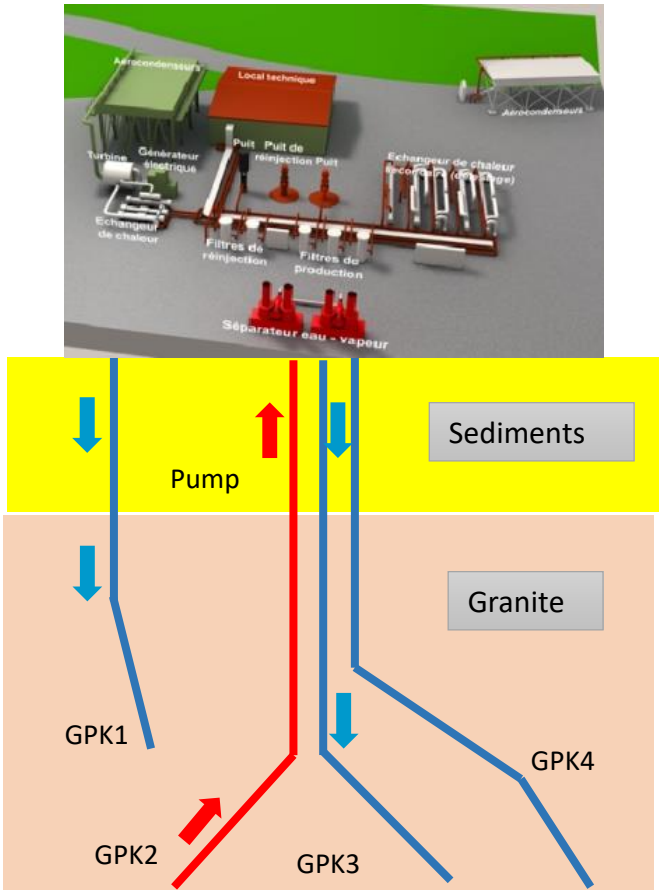
20L/s/bar for GPK2 @2km (fault zone, total mud losses)

~ 3 orders of magnitude lower @ 5km in GPK2/GPK3/GPK4

Ledesert et Herbert, 2012
Schill et al, 2017

Hydraulic circulations

- **Since 2008, several circulation tests performed**
  - ➢2, 3 or 4 wells involved
  - ➢Continuous seismological monitoring
- **Since 2016, industrial geothermal exploitation**
  - ➢3 wells, 1 production well (GPK2) and 2 injection wells (GPK3/GPK4)
  - ➢GPK1 not used anymore
- **No stimulation during exploitation**
- **Destress project: GPK4 stimulation**
  - **How to transform a bad well into a good well by minimizing the environmental impacts?**



GPK-4 well: Review of hydraulic properties

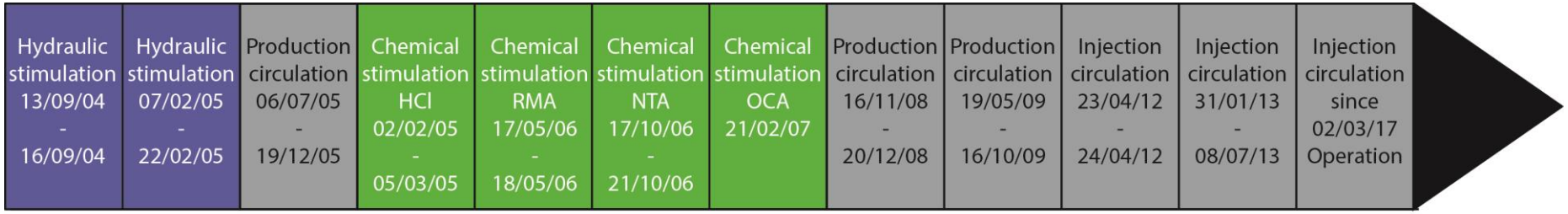
Present

- Used continuously as a second injection since March 2017
- **1/3 of brine** reinjected into GPK4, who's presenting poor hydraulic properties & connection to the reservoir
- Injectivity index currently measured at **0.54 L/s/bar**

DESTRESS project

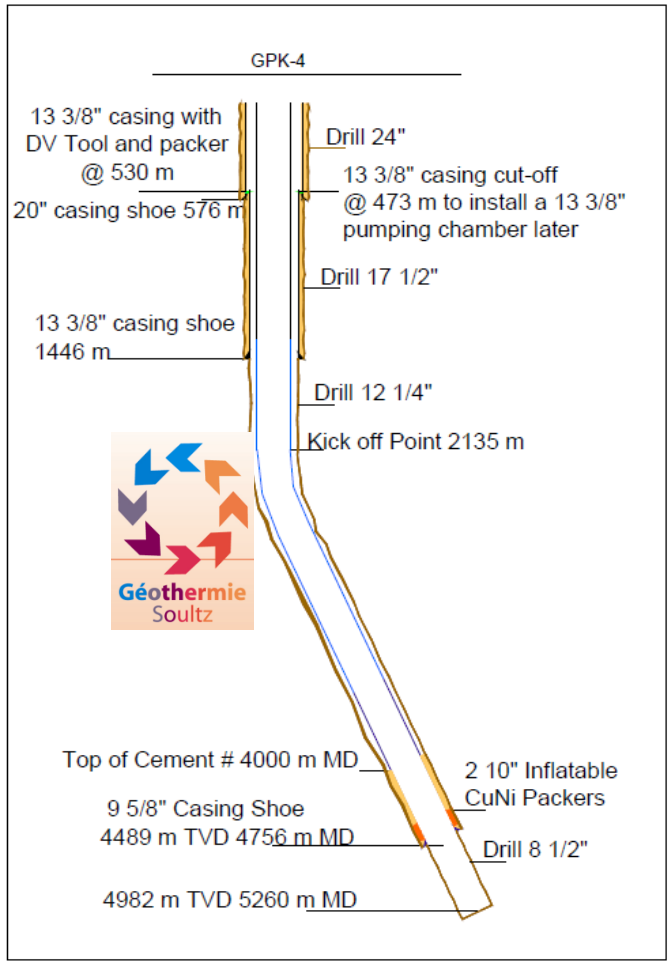
The objective is to apply a soft stimulation to enhance the well injectivity

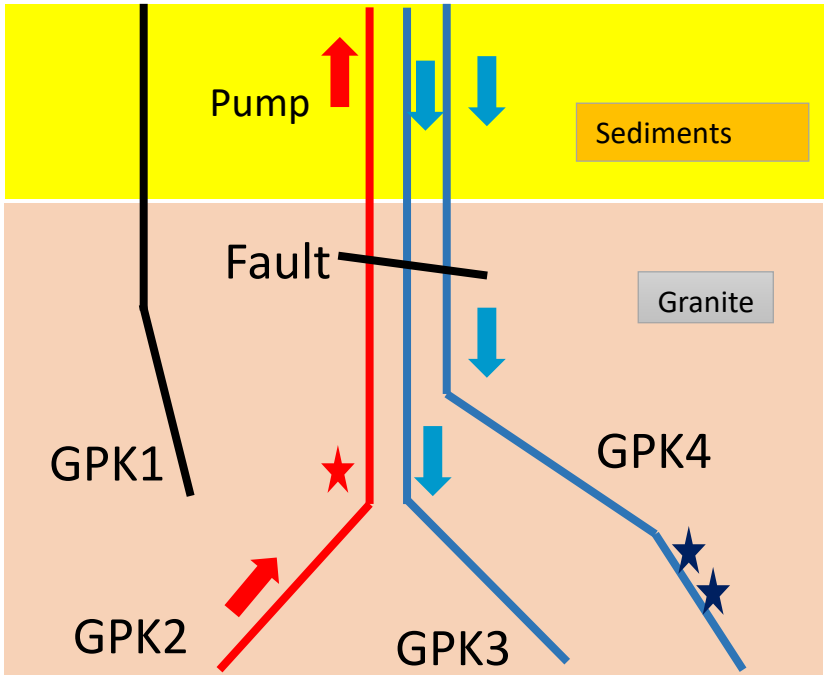
- Review of past –stimulation performed into GPK-4 to design suitable strategy



Before any stimulation, a baseline acquisition is required, notably in terms of fluid geochemistry

GPK-4 technical design





Highly deviated well

Large permeable fault @2100 m

Open-Hole section 4756-5260 m MD

Only the last 700 m of the cased part are cemented

504 m in a two-mica fined grained granite

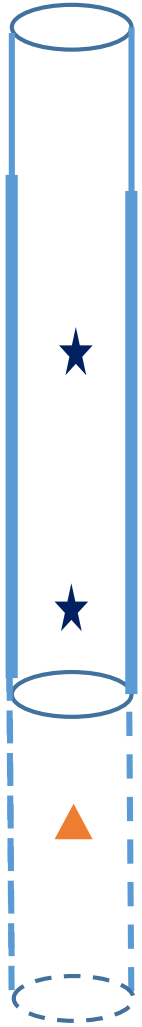
From 5000 m MD, OH not accessible

Occurrences of leak in the cased part of GPK4 observed after chemical stimulations

- ***~4380 m MD: fractures zone, IS during stimulation***
- ***~4720 m MD: mud losses, fracture zone, ovalization***

80% of flowrate via casing leaks and 20% in the OH

Fracture fillings are the best candidates to dissolve



MD

4000m

4380 m

4720 m

4756 m

5000 m

5260 m

Hydrothermal minerals

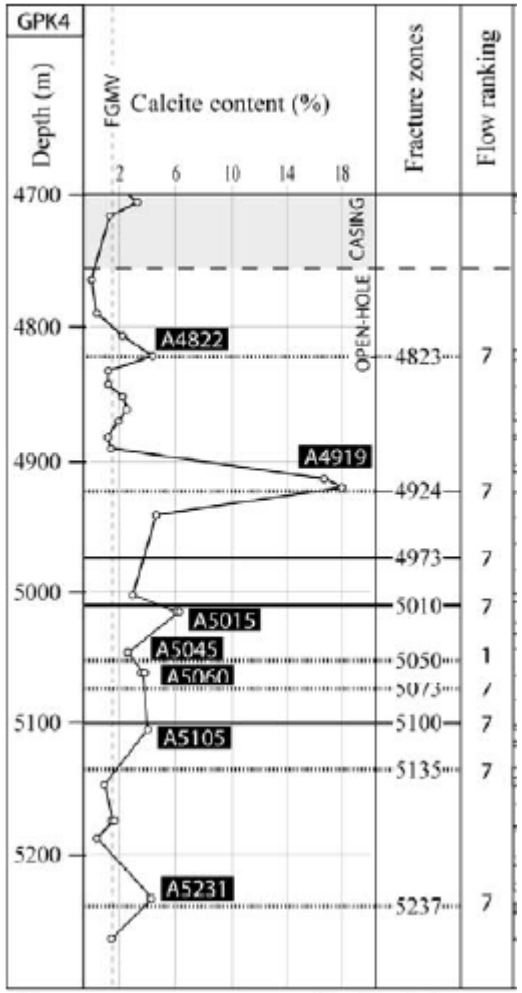
Illite/chlorite, calcite, haematite

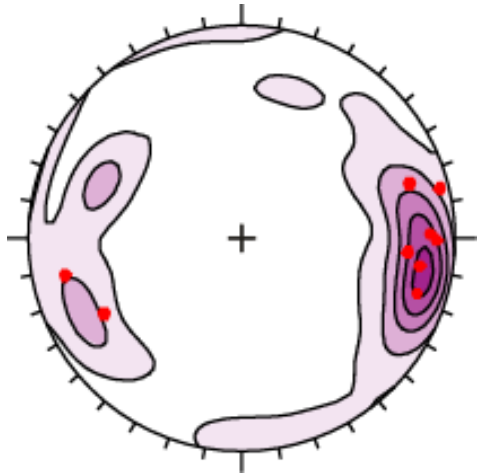
Illite/chlorite

4756 m

18% calcite @4973 m
Illite/chlorite

5260 m





Fracture geometry in OH
Dezayes et al 2010

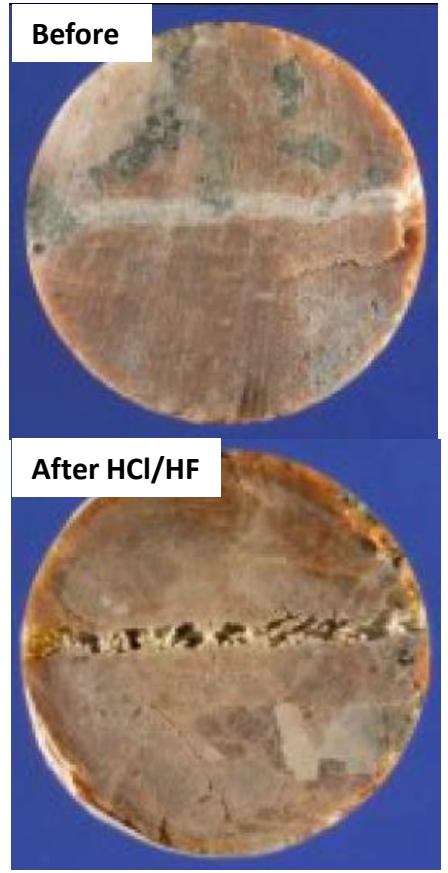
Calcite content
Herbert & Ledesert 2012

Which minerals could be dissolved in which acids?

Inorganic and organic	HCl-HF, HBF_4	Nearly inert in acids
Carbonates	**Silicates**	**Sulfates/Sulfides**
Calcite $CaCO_3$	Secondary Quartz SiO_2	Gypsum $CaSO_4$ x $2H_2O$
Dolomite $CaMg(CO_3)_2$	Clay minerals Illite, I/S, Chlorite	Anhydrite $CaSO_4$
Ankerite $Ca(Fe,Mg)(CO_3)_2$		Barite $BaSO_4$

Fined-grained two mica granite

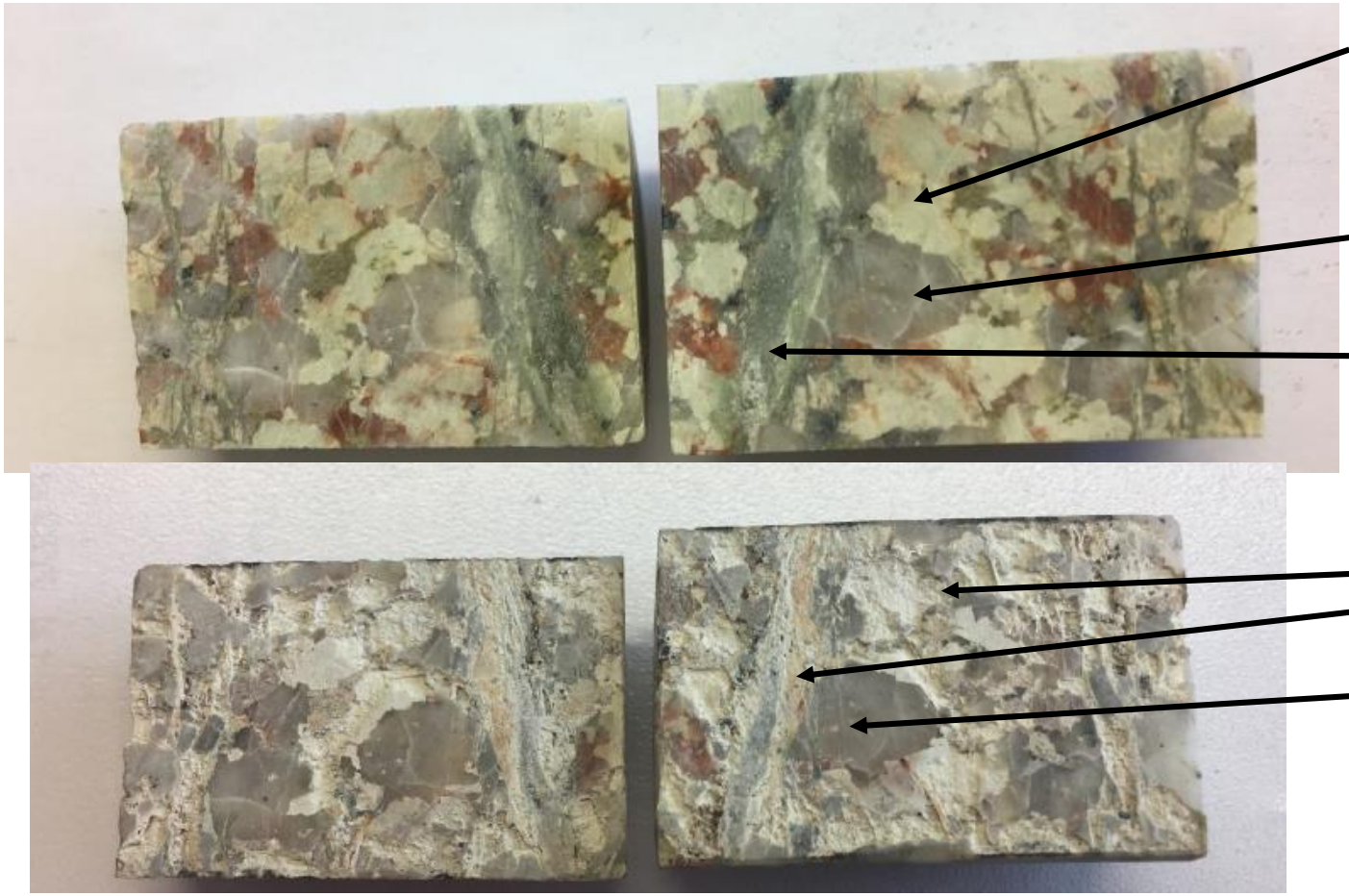
Soultz granite sample



Fracture filling
Clays, Quartz & Carbonates

Dissolutions of secondary silicates? Example at core scale at 140°C.

<----------**DZ**---------->**QV** <-**DZ**><**DZ**---->**QV**<----------**DZ**---------->



Secondary illite (clay bearing K) located in the Damage Zone (**DZ**) around the Quartz Vein (**QV**) Sample @1674m

Relics of primary K-feldspar, partly transformed into illite

Secondary quartz sealing veins

Strong dissolutions of illite and secondary quartz vein

K-feldpars are not affected

Improvement of hydraulic performance after chemical treatment: factor 4 and 30

From Lummer et al., 2018

Conclusion and perspectives

- Soultz is an operating plant with an availability >90%
- Exploitation of a natural brine circulating within fractures/fractures zones
- Soultz is the only operating site in DESTRESS with chemical treatments planned during exploitation by minizing induced seismicity activity and by using, as much as possible, friendly chemicals
- On-going GPK-4 well integrity study prior to any chemical treatments with the contribution of laboratory experiments and geochemical modelling. Need to take into account the complex history of the well (casing, leaks, cement, OH access) and the local geology (depth, fracture filling, permeable fractures)
- Stimulation design and strategy still under discussion in the framework of Destress. We still consider that GPK-4 well is a good candidate for applying soft stimulation
- Soultz will be used in the coming years to produce more electricity by reinjecting at lower temperature. It will be investigated in the framework of new H2020 project. Typically we intend to reinject at 40°C for producing electricy from mobile ORC.

Thank you very much for your attention

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es

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