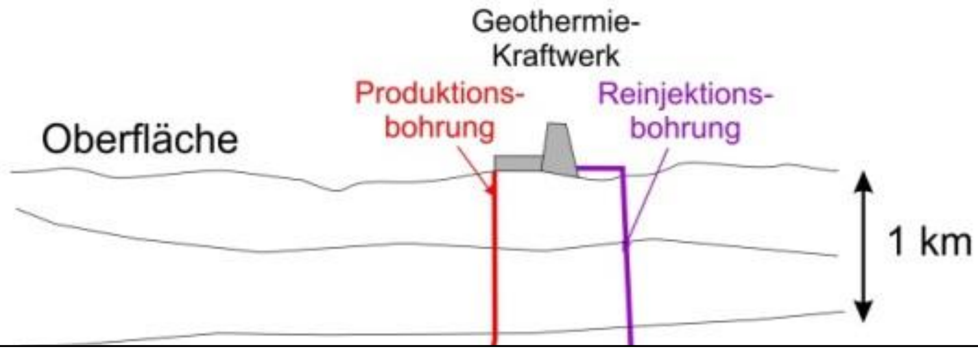
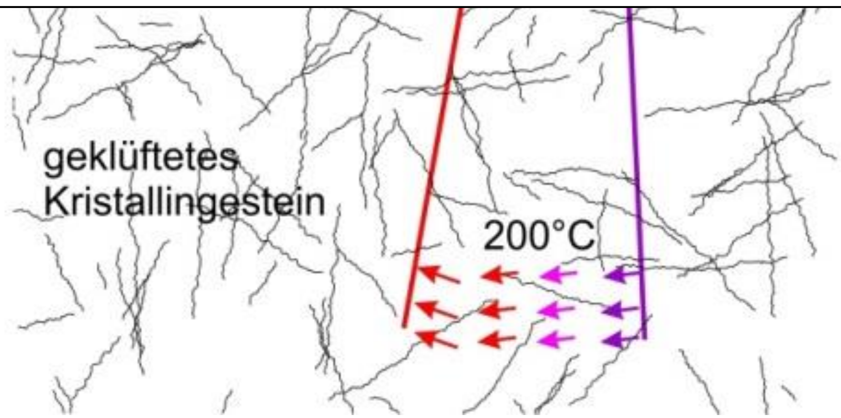
SCCER SoE

SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY



Work Package 1: GeoEnergies



Thomas Driesner

September 14th , 2017

In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

Scope of WP1: goals & challenges

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- **Deep geothermal energy for power production**
  - How can we find permeability at depth?
  - What is deep permeability anyhow?
  - Alternatively: can we engineer it? Physics and modeling of hydraulic stimulation
  - Grimsel experiment
  - Technological aspects: drilling techniques, well optimization, corrosion …
- **CO_2 sequestration**
  - Which geology is favorable and where to find it?
  - What are the problems associated with storage?
- **(Not so) deep geothermal direct heat usage & storage**
  - Exploration and operation

Work Package Structure Phase II

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Task 1.1: Resource exploration and characterization
UniBE, UniL, UniNE, ETHZ

Task 1.2: Reservoir stimulation and engineering
ETHZ, UniNE, UniBE , EPFL

Task 1.3: Hydrothermal resources and geofluids
UniGE, UniNE, EPFL, UniBE

Task 1.4: Geo-data infrastructure and analysis
swisstopo + regional partners

Pilot & Demonstration have been moved to WP5

Reservoir modelling is now between 1.1., 1.2, 1.3, 1.4, and 3.2

Roadmap Evolution

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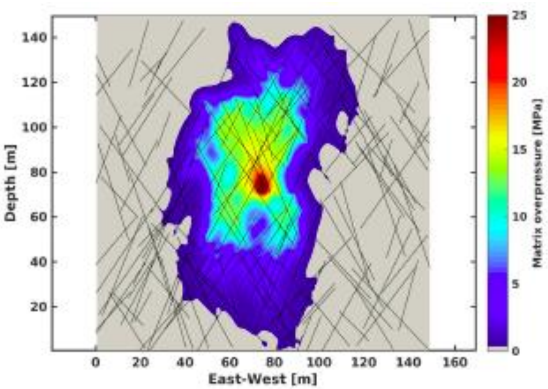
Phase I: three main initiatives

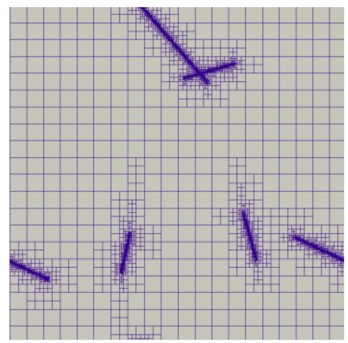
1. Advance the capability to quantitatively model the stimulation process and reservoir operation
2. Advance process understanding and validation in underground lab experiments
3. Execute a petrothermal P&D project, supported by a major scientific monitoring & analysis initiative.

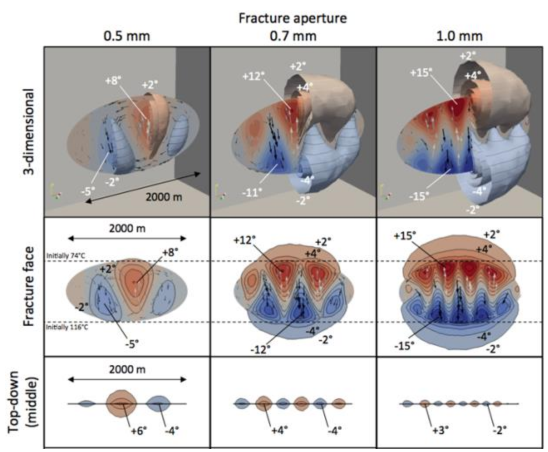
Phase II: four main initiatives

1. Continued development; transition to concrete use of new tools in Phase II
2. Proceed to next larger scale underground lab experiment; implement lessons learned
3. Remains open
4. New: execute (hydrothermal) heat storage and usage demonstrator project (Geneva)

1. Advance the capability to quantitatively model the stimulation process and reservoir operation: Status







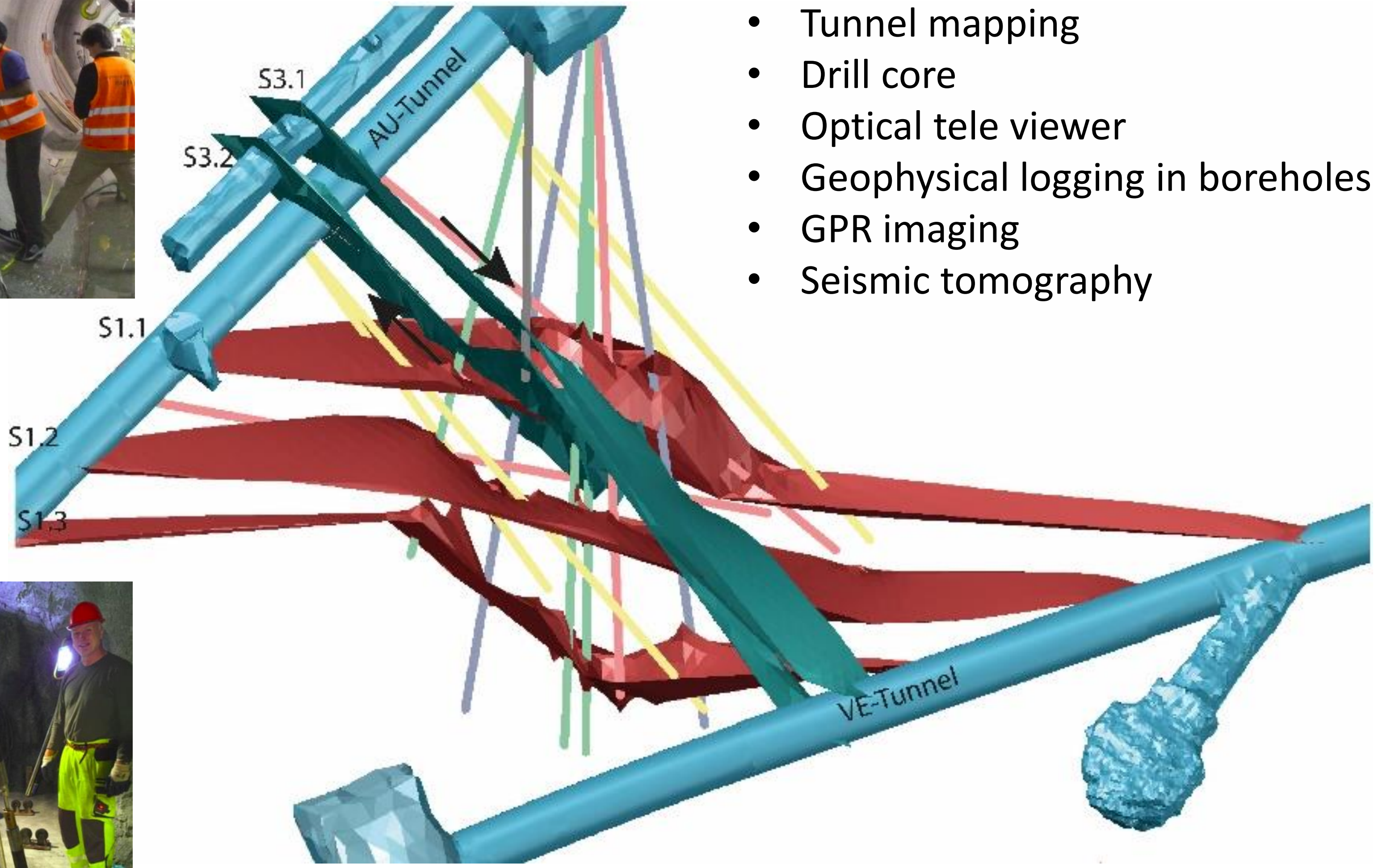
- Ongoing development, transition to application in Phase II
- ETHZ, USI, UniNE, EPFL
- Multi-faceted:
  - Master the simulation of coupled THMC(S) processes on realistic geometries, namely 3D
  - Modelling for experiment planning and data assessment
  - Incorporate into Advanced Traffic Light Systems

2. Advance process understanding and validation in underground lab experiments: The ISC Underground Lab Experiment at Grimsel

NAGRA-operated Test Site attached to KWO infrastructure

Ca. 400 m below surface, fractured crystalline basement rocks

ISC Site Characterization



- Tunnel mapping
- Drill core
- Optical tele viewer
- Geophysical logging in boreholes
- GPR imaging
- Seismic tomography

Hydraulic Stimulating of Structures

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Hydraulic shearing (Feb 2017), injection into existing structures

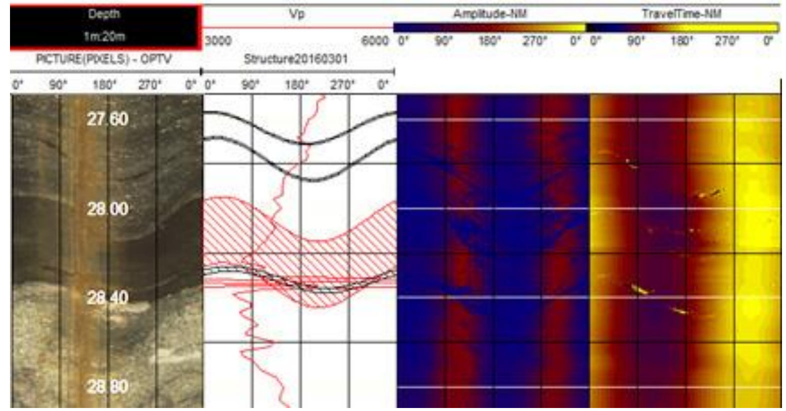
Cycle 1.1: Pressure –controlled, determination of initial injectivity, breakdown of rock

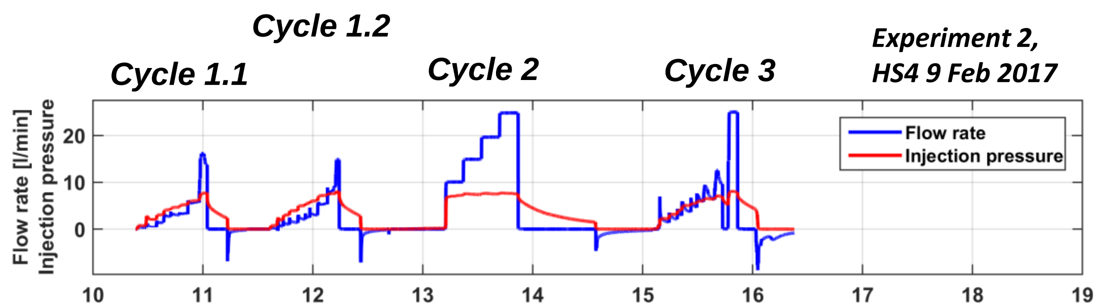
Cycle 1.2: Pressure –controlled, determination of jacking pressure

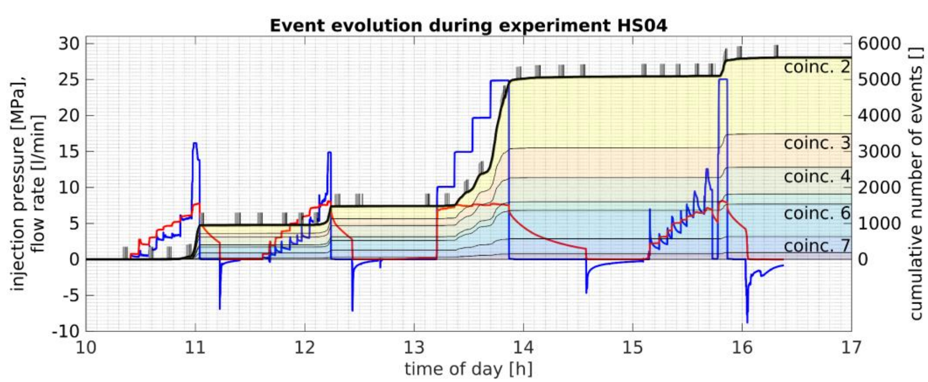
Cycle 2: Rate-controlled, actual stimulation

Cycle 3: Pressure –controlled, determination of final injectivity and jacking pressure

Hydraulic fracturing (May 2017), creating fractures in intact rock







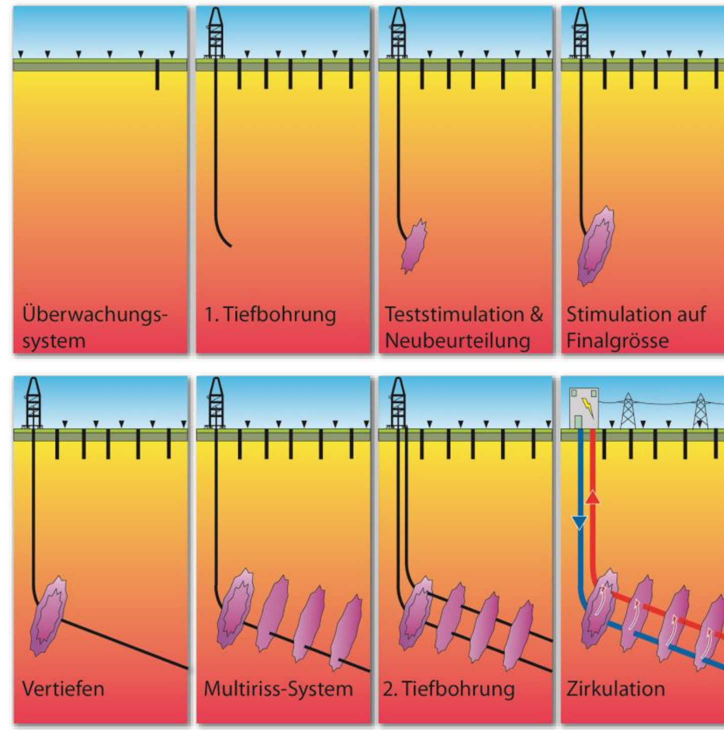
Stimulation Results

Borehole	Test	Structure	Injected Volume [lit]	Initial Trans. [m^2/s]	Final Trans. [m^2/s]	Change in Trans.	Detected Events
SBH3	MHF#1	---	7.9	3.8E-13	1.5E-10	380	1161
	MHF#2	---	10	3.2E-12	2.1E-10	70	482
	MHF#3	---	10.4	2.2E-12	5.0E-12	2	274
SBH4	MHF#4	---	10.9	1.9E-12	1.1E-10	60	2258
	MHF#5	---	9.7	5.9E-13	8.7E-13	2	1692
	MHF#6	---	9.1	2.2E-12	7.0E-11	30	772
	MHF#7	---	11.5	3.1E-12	2.2E-10	70	406
	HTPF#1	S3.1	28.8	3.8E-12	9.1E-10	240	253
INJ1	HS#2	S1.3	797	2.5E-09	2.2E-07	90	1203
	HS#3	S1.2	831	4.8E-10	2.3E-07	490	314
	HS#4	S3.1	1253	1.2E-07	1.2E-07	1	5606
	HS#5	S3.2	1211	1.2E-08	5.5E-08	5	2452
	HS#8	S1.1	1258	2.8E-10	7.5E-08	270	3703
	HF#1	---	971	2.9E-13	7.5E-10	2550	N/A
	HF#2	---	816	4.2E-13	4.0E-10	950	N/A
	HF#3	---	893	3.8E-13	4.5E-10	1190	N/A
	HF#5	---	1235	1.5E-13	6.1E-11	420	N/A
INJ2	HS#1	S1.3	982	8.3E-11	1.5E-07	1850	560
	HF#6	S1.3	943	5.7E-14	1.7E-09	19760	104
	HF#8	---	1501	3.1E-13	1.2E-10	165	362

Tentative Conclusions ISC

- Successful stimulation, orders of magnitude permeability increase, interestingly to +/- similar values
- Induced seismicity well below maximum predicted in preceding risk study
- Data analysis ongoing
- Success because of
  - Rock volume accessible from/in multiple directions for characterization
  - Detailed analysis of characterization allowed optimized planning
  - Excellent infrastructure
  - Funding
  - Excellent staff

3. Execute a petrothermal P&D project, supported by a major scientific monitoring & analysis initiative: Status



Images: Geo Energie Suisse, http://www.geo-energie.ch/

- All permits etc. in place, including federal risk guarantee
- Serious delays due to appeals; start of pilot to late stages of phase II?

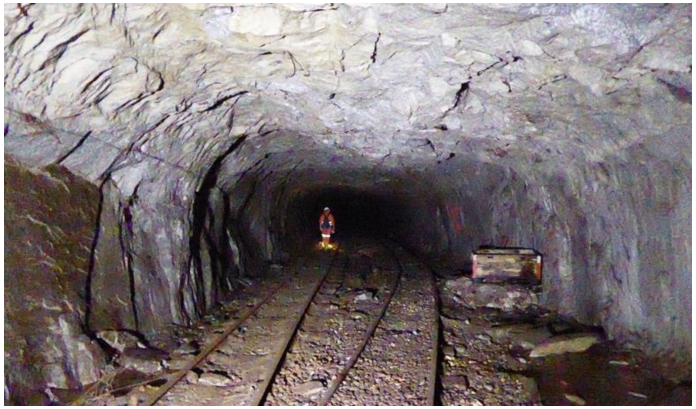
Two alternative routes towards pilots and pilot-like sites

(1) Larger and more diverse underground lab experiments

- Phase II: 10x larger rock volume;
- Less well accessible rock volume -> closer to reality
- Characterization, risk study, stimulation, circulation, technology testing

(2) Participation in international pilots and demonstrators

- Via H2020 DESTRESS, e.g. Pohang site
- New EU proposals:
  - ECO-EGS (pilots in Iceland and Czechia)
  - …



International participation in pilot & demonstration

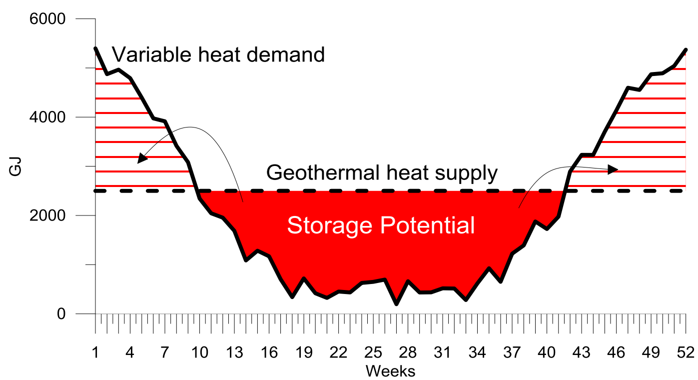
Pohang, South Korea

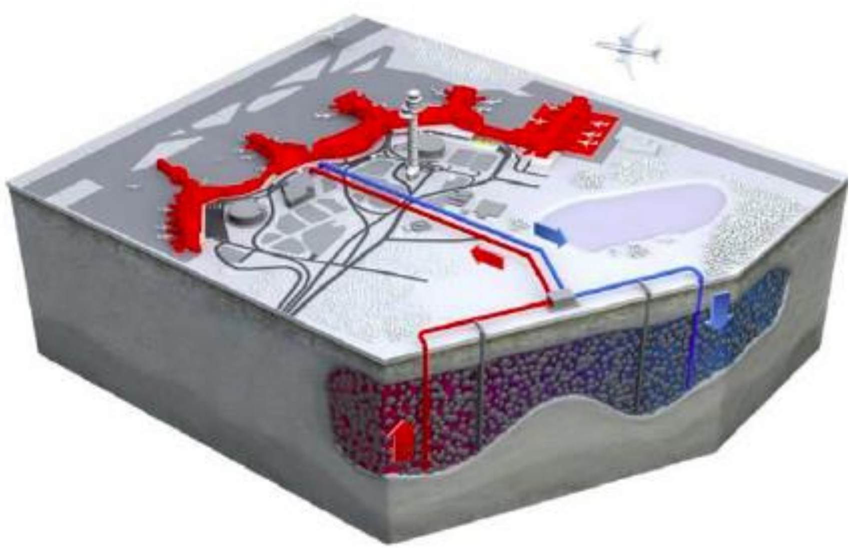
- Partner in DESTRESS -> SED, GES
- ~4.2 km deep
- Active P&D site
- "Soft stimulation" successful (induced seismicity M < 2)

Potentially: Hengill, Iceland & Litomerice, Czechia

- New H2020 proposal ECO-EGS submitted (lead: Iceland)
- Iceland: EGS under extreme conditions
- Real-world testing of SCCER-SoE numerical tools in project development

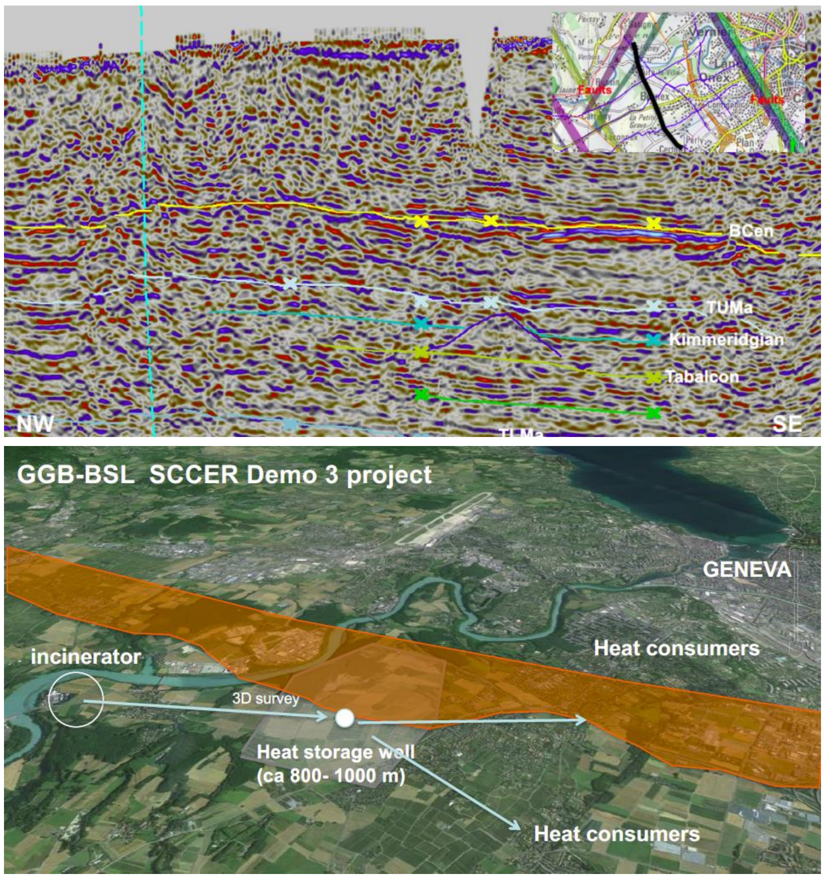
New Play in Phase II: Hydrothermal Heat Storage and Usage





- Strong seasonal variation in heat demand
- Lots of unused waste heat, e.g. from waste incinerators
- Underground heat storage an attractive option
- High temperature (>60°C) storage a novel option
- International interest, start developing now
- Strong CO2 saving

New Task 1.3: Hydrothermal resources and geofluids: exploitation and storage



Images: Moscariello, SCCER-SoE Annual Conference 2016

- Major project in Geneva
- SIG lead, UniGE, …
- From exploration to implementation
- Excellent opportunity for SCCER-SoE
- Stepping stone towards deep geothermal power
- Other projects …

Heat storage: international interest and potential

Table 1 Proposed pilot demonstration projects within the HEATSTORE project

Country	Concept of pilot demonstration	Storage capacity & volume	TRL* advance
Netherlands	Geothermal heat doublets combined with Aquifer Thermal Energy Storage (max 90°C) integrated into a heat network used by the horticultural industry	5-10 MW 20 GWh	7 to 8
France	Solar thermal combined with a Borehole Thermal Energy Storage (55˚C) with lateral heat recovery boreholes	kW range 100 MWh	5 to 8
Switzerland Geneva	The development of a deep Aquifer Thermal Energy Storage system (>50˚C) in Cretaceous porous limestone connected to a waste-to-energy plant	20 MW 30-40 GWh	5-6
Switzerland Bern	Surplus heat storage underground (200 - 500m, max 120 ˚C) in existing district heating system fed with combined-cycle, waste-to-energy and wood fired plants.	~1.7 MWth	6-8
Germany	Mine Thermal Energy Storage pilot plant for the energetic reuse of summer surplus heat from CHP (10-25°C; Δt: 10-15K) for heating buildings in winter.	10-14 kW 35-50 MWh	to 8
Belgium	Demand side management (DSM) of a geothermal heating network including assessment of adding thermal storage	9,5 MW** 3 GWh/y***	DSM:7 to 9

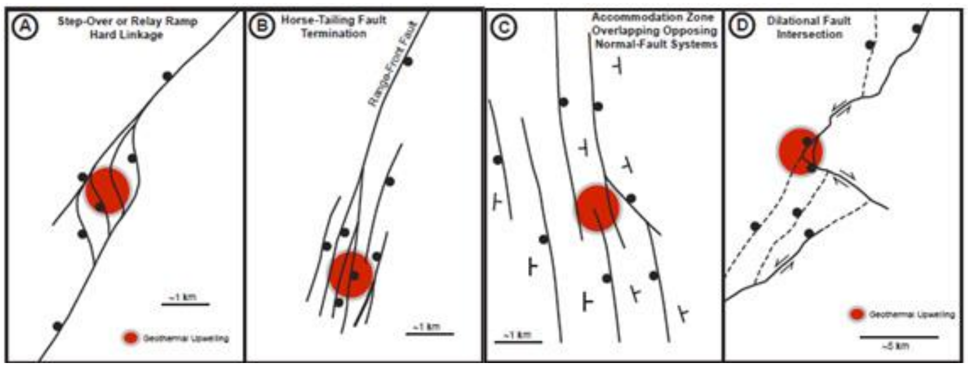
*TRL = technology readiness level, ** Capacity of the geothermal source *** Additional annual heat supply due to smart control

GEOTHERMICA-ERANET, pre-proposal HEATSTORE

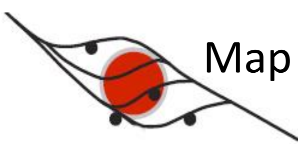
Transition to Phase II: Research Progress or How Thing Fit Together

- NFP70 and other PhD/Postdoc projects now mostly in year 3 or 4 -> mature projects
- Results will be input for re-formulated roadmap
- Several clusters of activities
- New partners & activities complementing existing work: e.g., Le Campion & Violay at EPFL

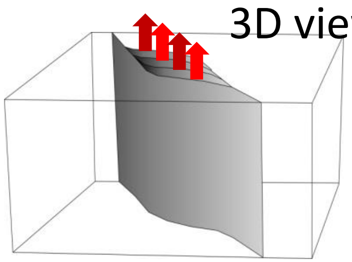
Optimal Targets for Deep Geothermal



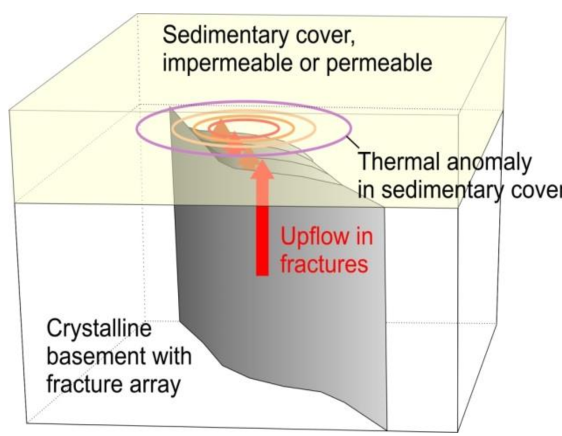
Faulds et al. GRC 2011



Map view



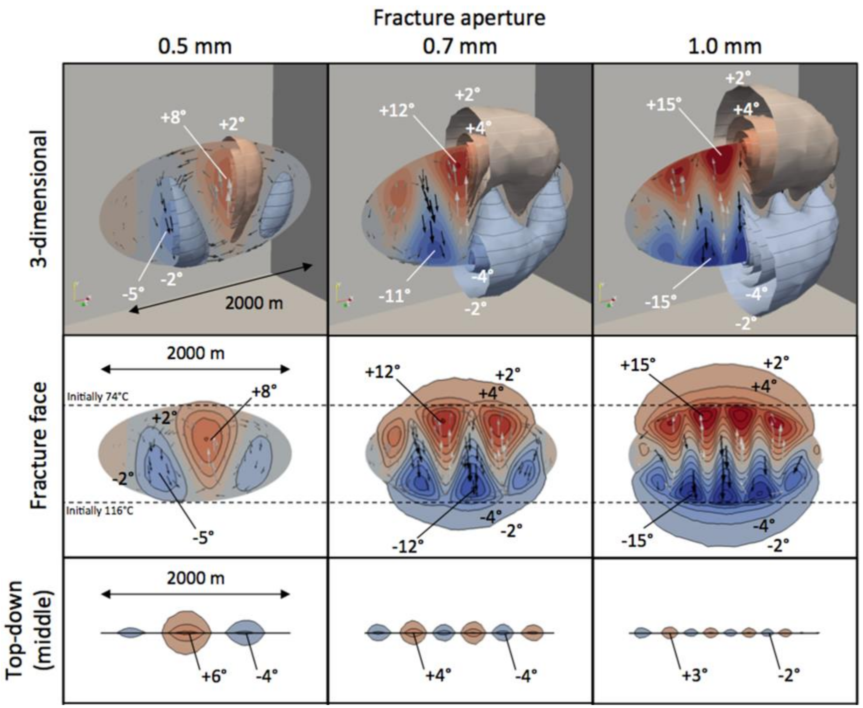
3D view

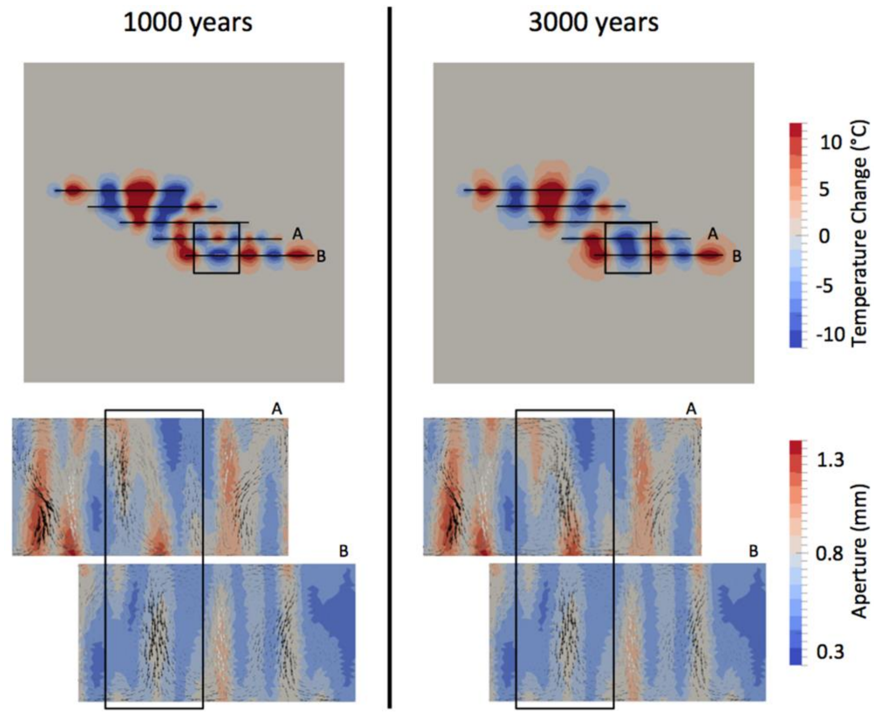


- Modern surface geothermal often in specific structures
- Similar ones to be expected at depth
- Why are they favorable?
- How to find them?
- How to create a reservoir in there?

Heat Transfer in Fracture Systems

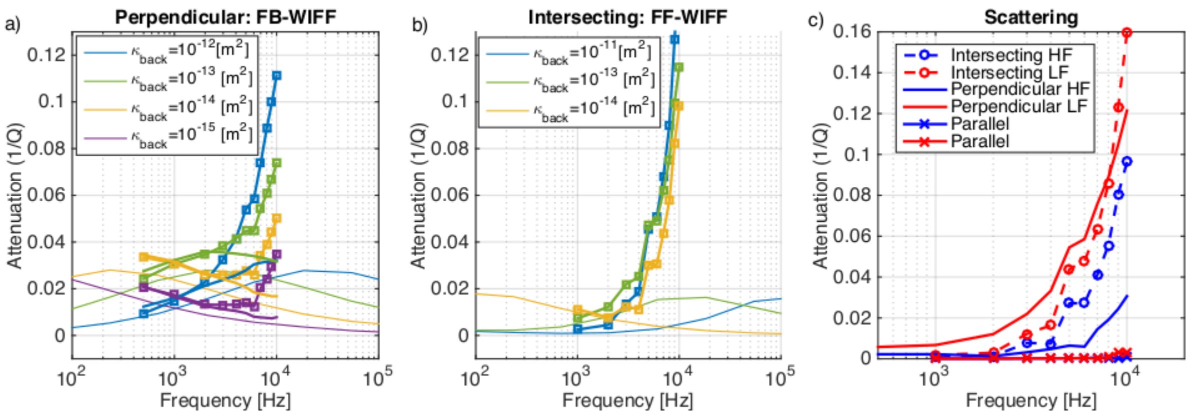
New results from NFP70 "Modelling Permeability"

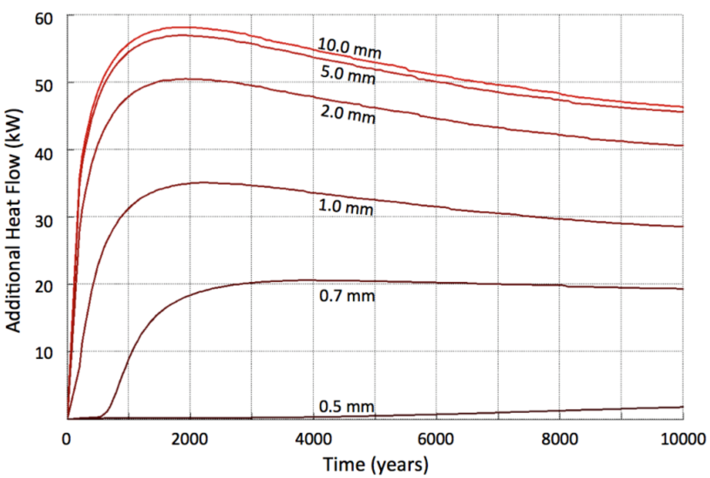


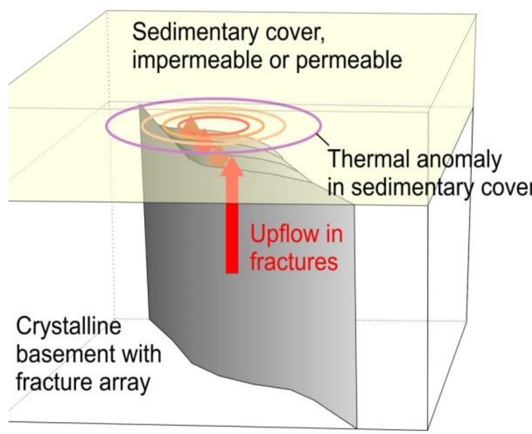


How to find them?

UniL, UniBE, ETHZ, …



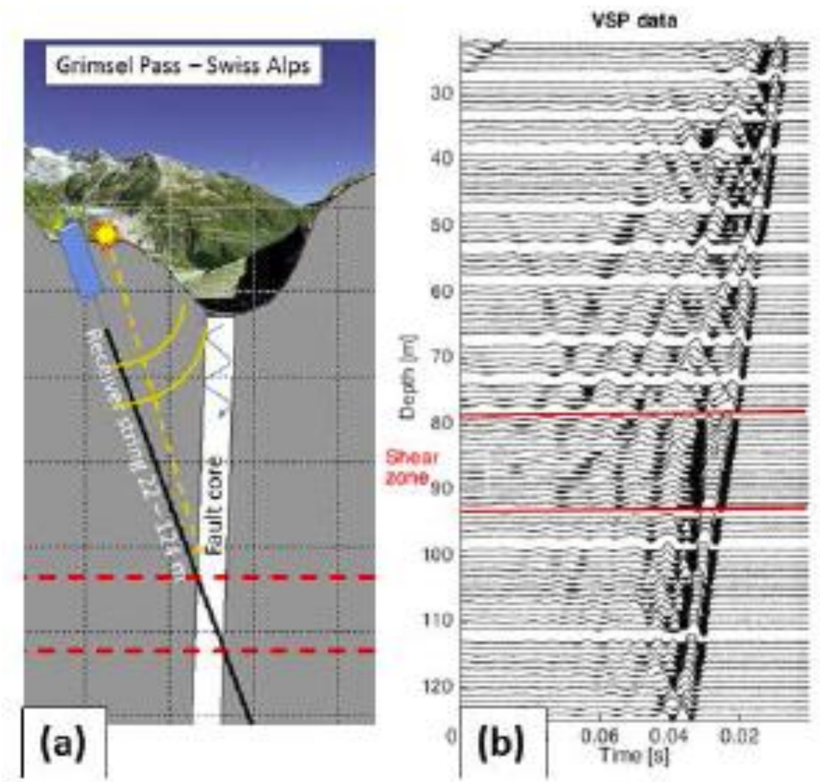


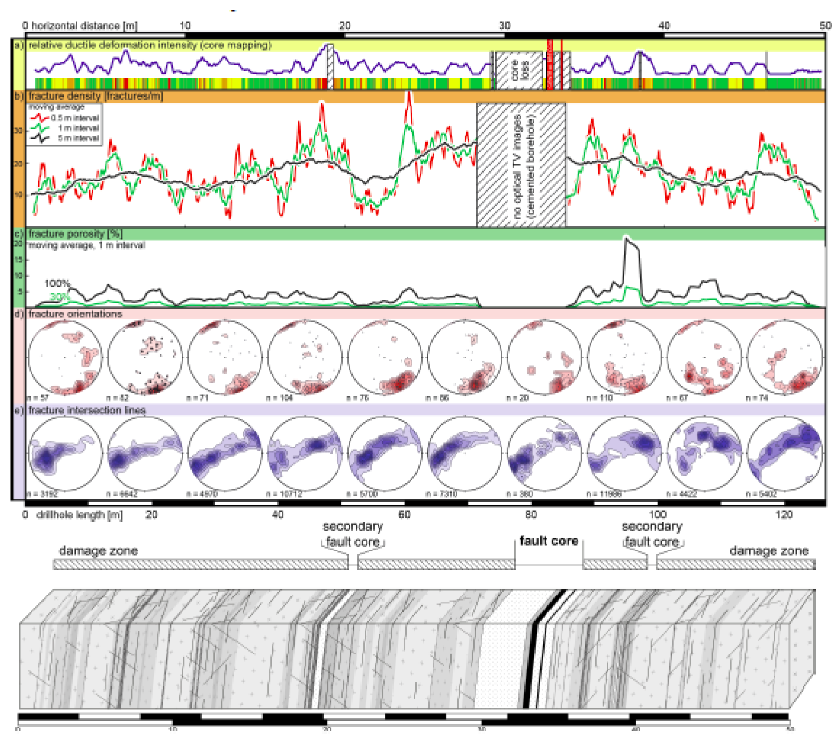


- Towards seismic properties of fractured media (UniL)
- Quantifying thermal anomalies as function of fracture network (ETHZ)

How to characterize them?

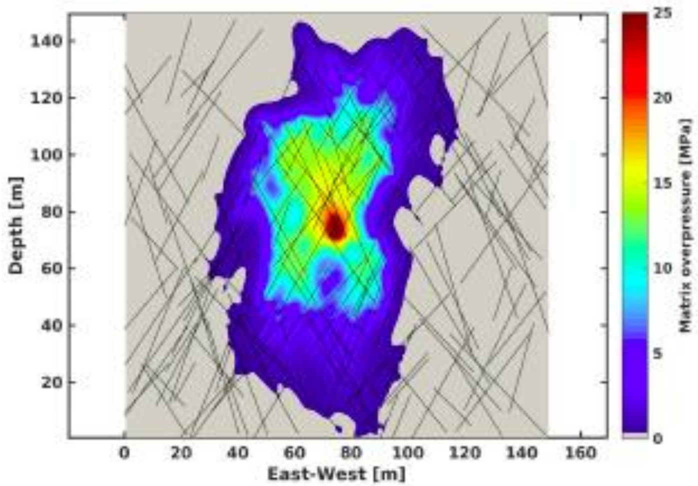
NFP70 UniBE, UniL, …

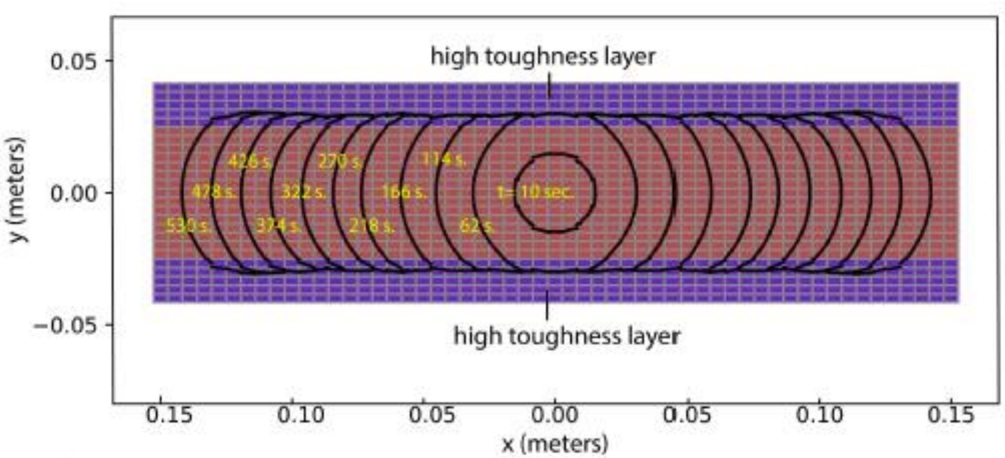




How to stimulate/engineer them?

ETHZ, UniNE, EPFL, …





- Fluid pressure propagation and induced seismicity
- Fracture mechanics
- Fracture-fracture interaction
- Permeability design
- …
- Plus: underground lab experiments

Summary

- First research maturing
- Nicely integrated directions
- All these will have lessons learned that will feed into P&D or exploration/characterization or reservoir assessment & engineering