GEOTHERMICA

HEATSTORE

HIGH TEMPERATURE UNDERGROUND THERMAL ENERGY STORAGE

2ND ANNUAL MEETING

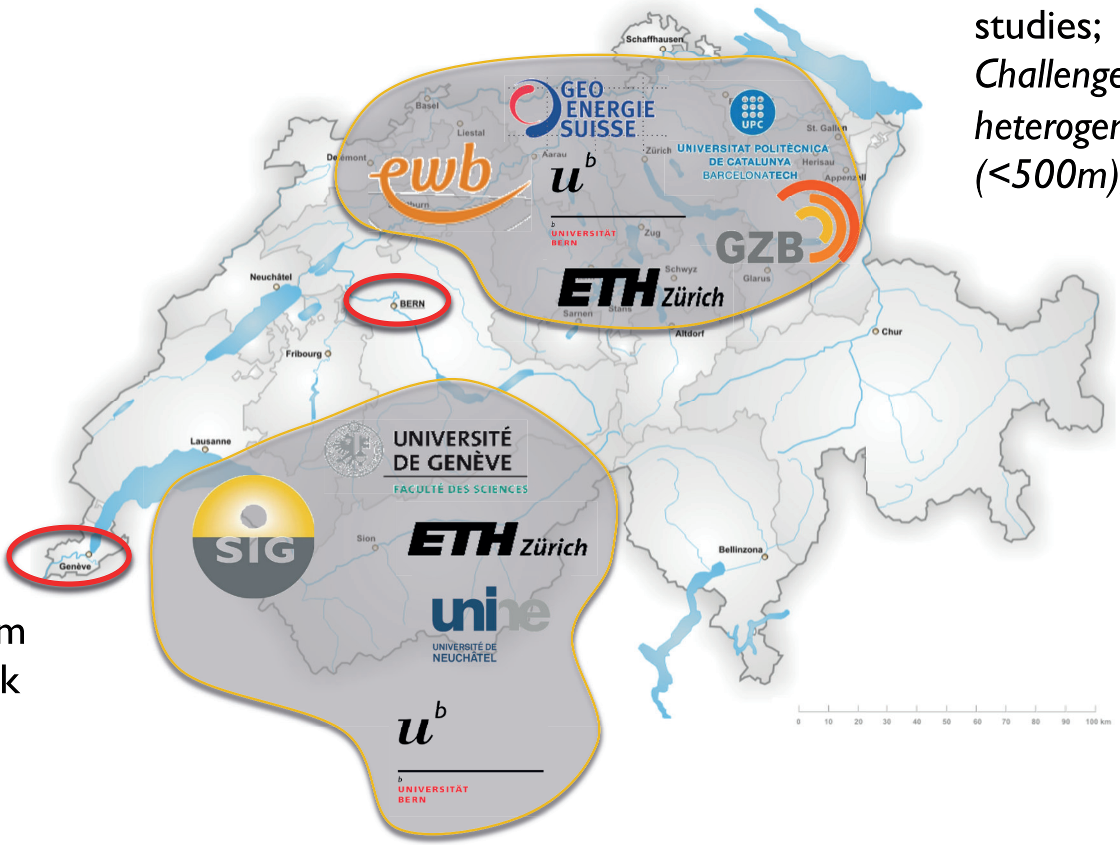
26 MAY 2020

SWISS NATIONAL PROGRAM UPDATE

heatstore High Temperature Underground Thermal Energy Storage

THE SWISS CONSORTIUM

TWO ATES PILOT SITES ATTACHED TO WASTE INCINERATORS



BERN Pilot Site:
Pre-drilling feasibility and design studies;
Challenges: shallow and possibly heterogeneous storage formation (<500m); severe space restrictions.

GENEVA Pilot Site:
Two wells for characterization and testing; scenario and system integration modelling to de-risk decision process
Challenges: complex geologic situation and energy system configuration

heatstore High Temperature Underground Thermal Energy Storage

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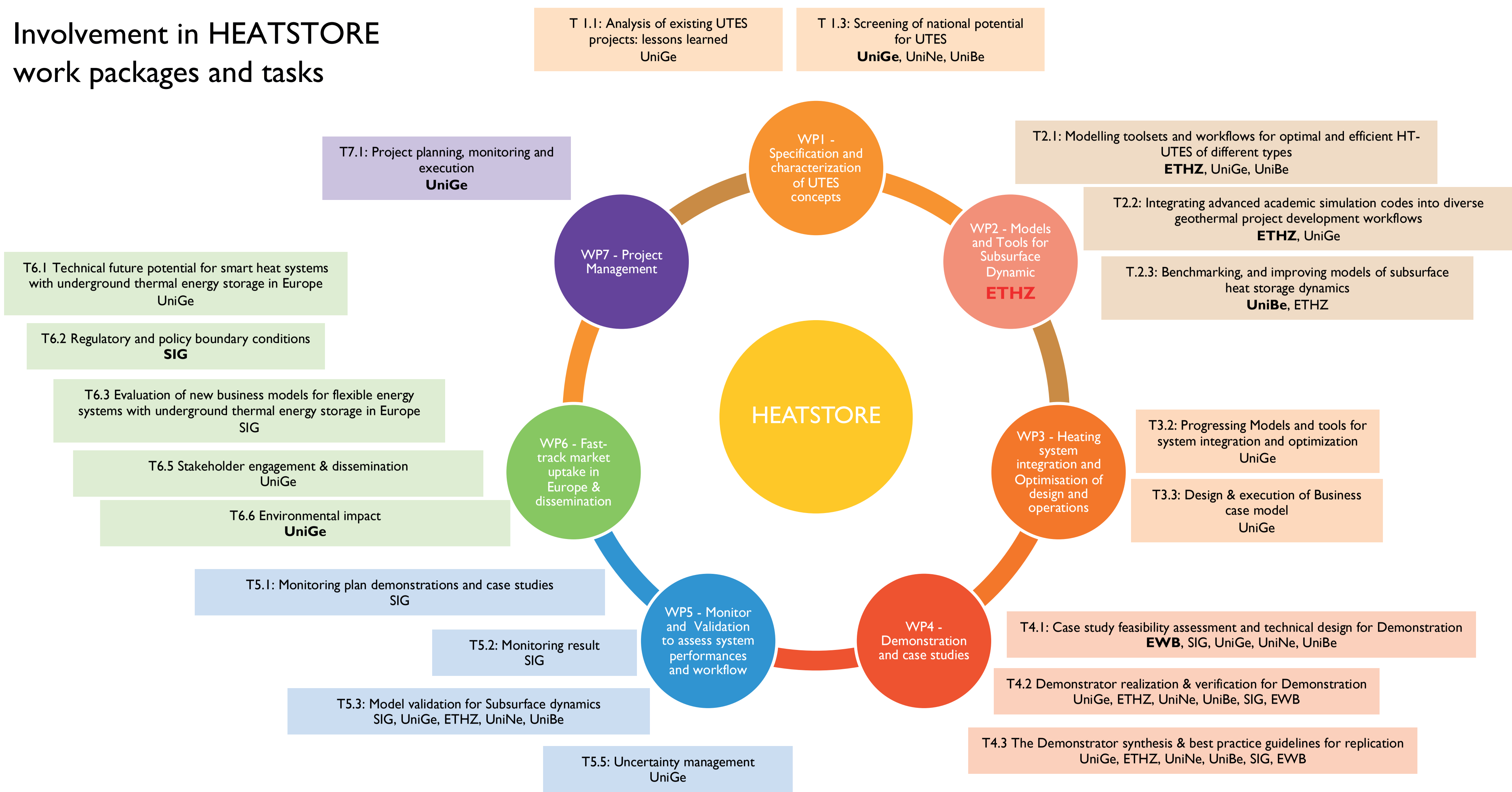
Involvement in HEATSTORE work packages and tasks



THE GENEVA PILOT PROJECT

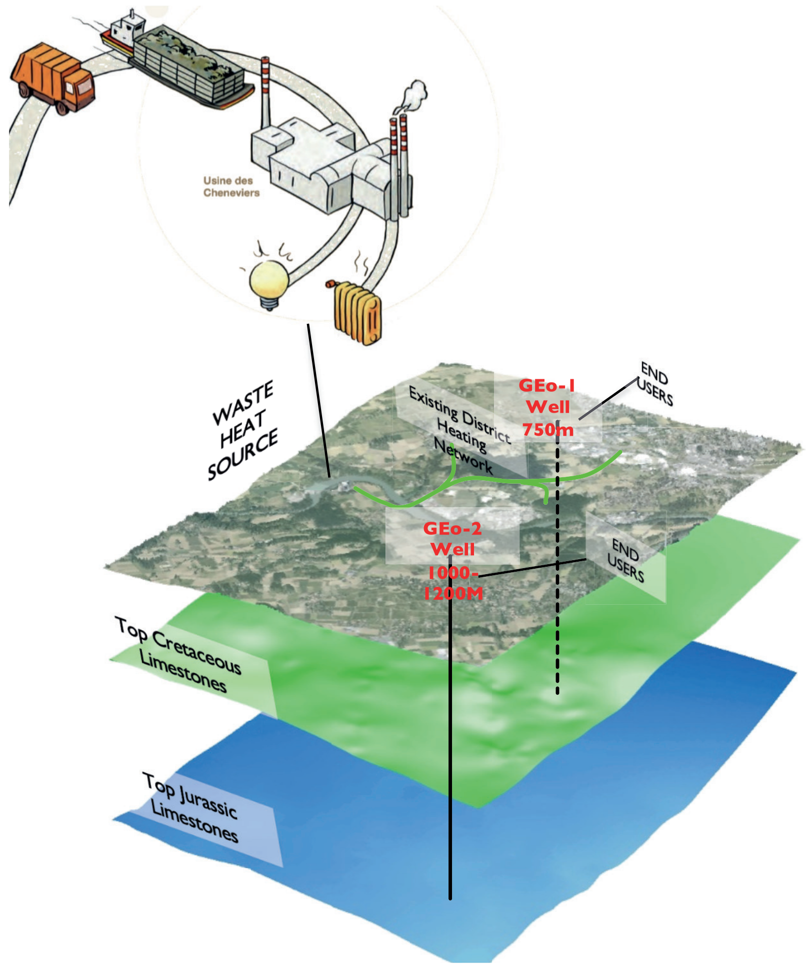
SIG — Drilling, data collection, business case modelling, regulatory framework

UNIVERSITÉ DE GENÈVE, FACULTÉ DES SCIENCES — Subsurface data integration and characterization, energy system scenarios, business modelling, EIA, national coordination

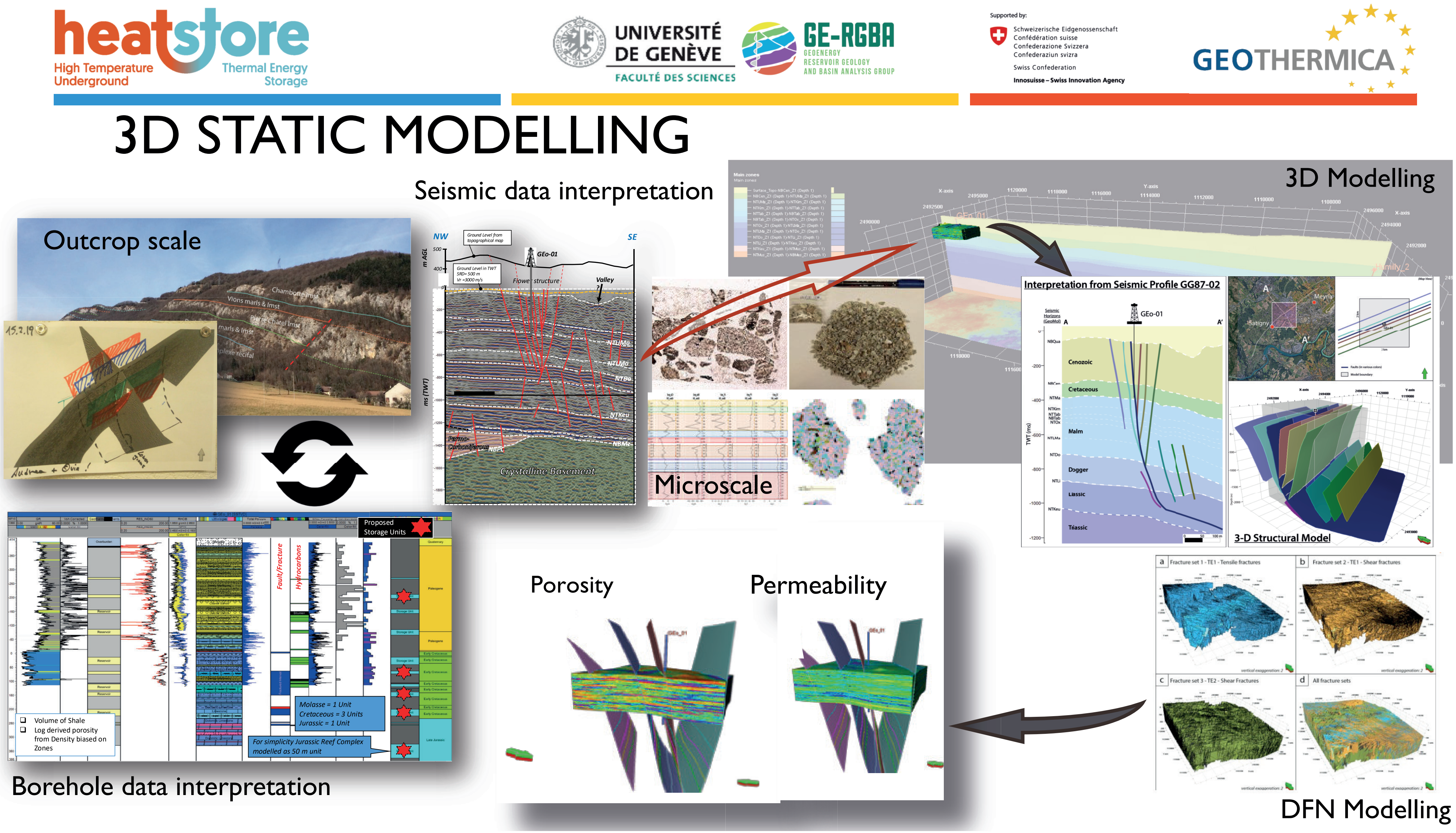
ETH Zürich — TH, THM reservoir modelling

unine, UNIVERSITÉ DE NEUCHÂTEL — Reservoir geomechanical characterization

UNIVERSITÄT BERN — THC modelling, Water-rock interaction laboratory experiments



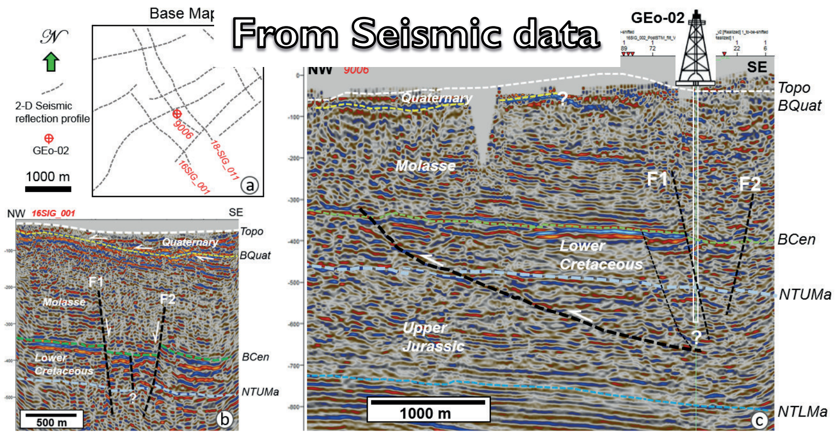
3D STATIC MODELLING

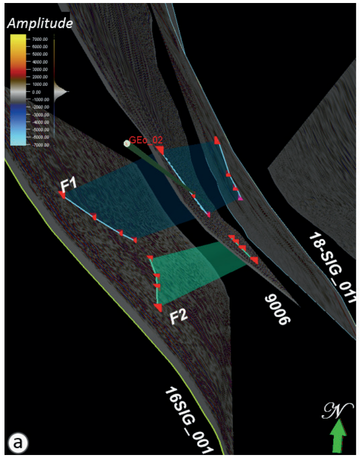


High Temperature Underground · Thermal Energy Storage — heatstore | Université de Genève, Faculté des Sciences | GE-RGBA Geoenergy Reservoir Geology and Basin Analysis Group | Supported by: Schweizerische Eidgenossenschaft, Confédération suisse, Confederazione Svizzera, Confederaziun svizra, Swiss Confederation, Innosuisse – Swiss Innovation Agency | GEOTHERMICA

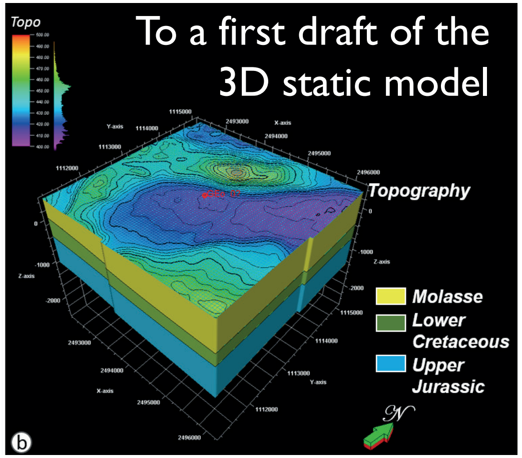
3D MODELLING AT GEO-02

From Seismic data

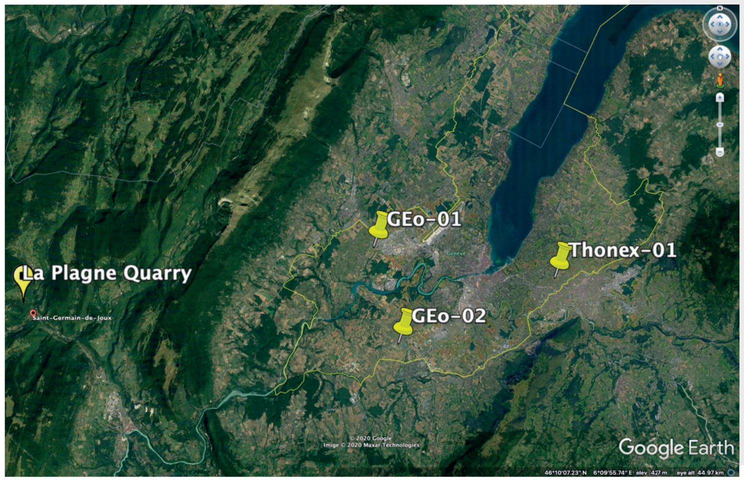




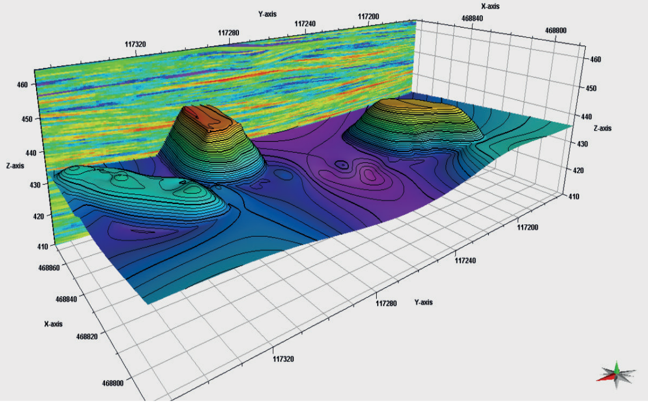
To a first draft of the 3D static model



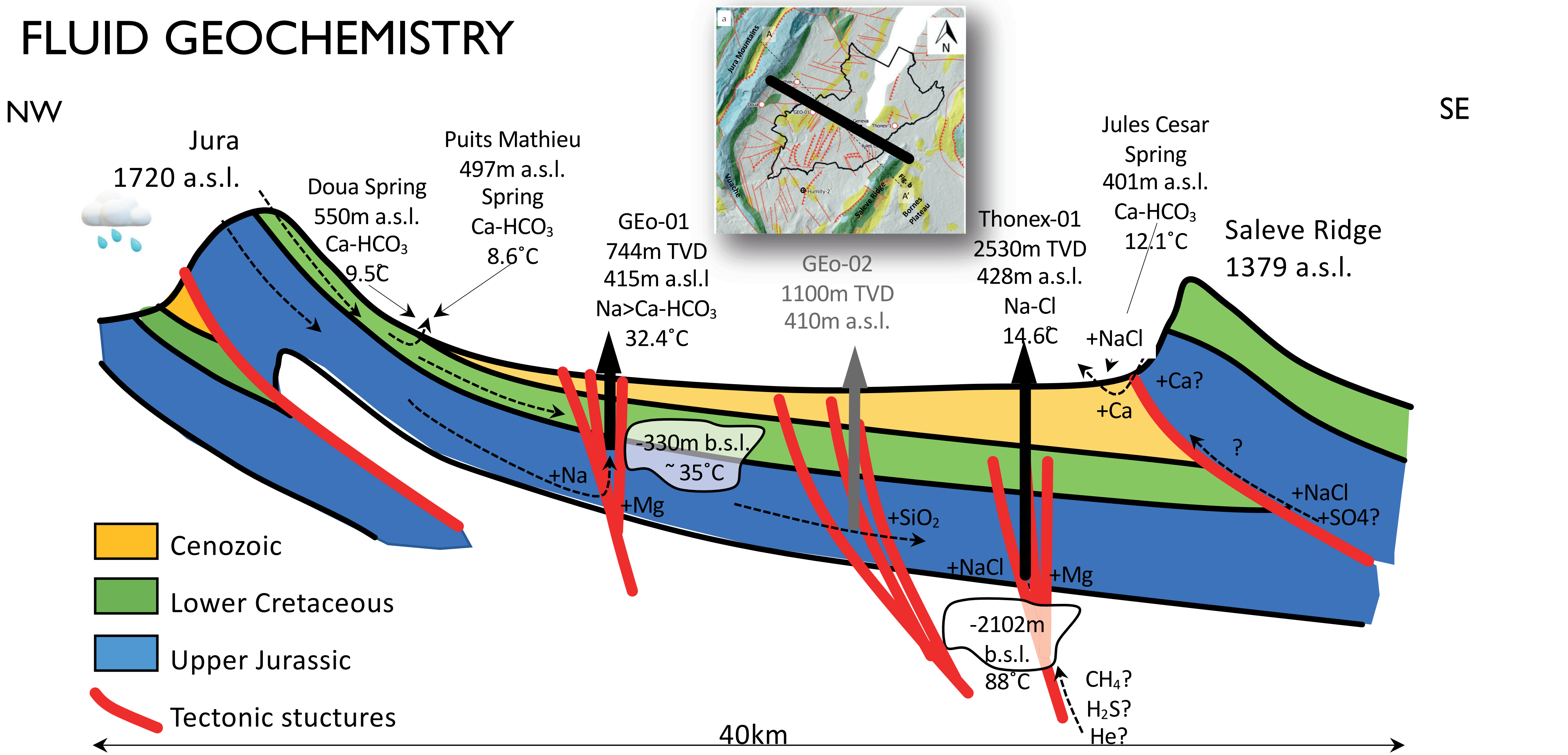
GEo-02 cuttings analysis



Reconstructing the geometry and properties of the Reef Complex by outcrop analysis using UAV



FLUID GEOCHEMISTRY



Guglielmetti et al. 2020

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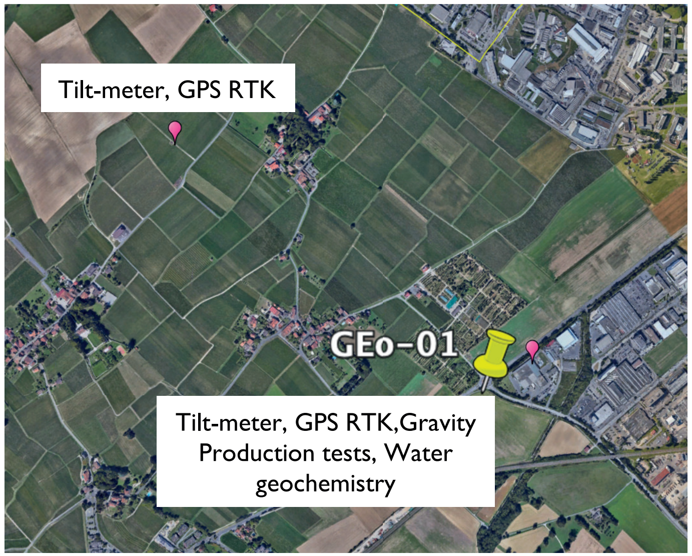
ONGOING FIELD OPERATIONS IN GENEVA (WP3 AND WP5)

- Drilling operations at Geo-02 are ongoing (current status: ~1000m depth reached, Target: 1300m+). Logging is carried out at selected intervals. Cuttings analysis is carried out continuuosly as samples are available
- 3D static modelling at Geo-02



Monitoring plan defined for Geo-01 in Geneva (WP5).

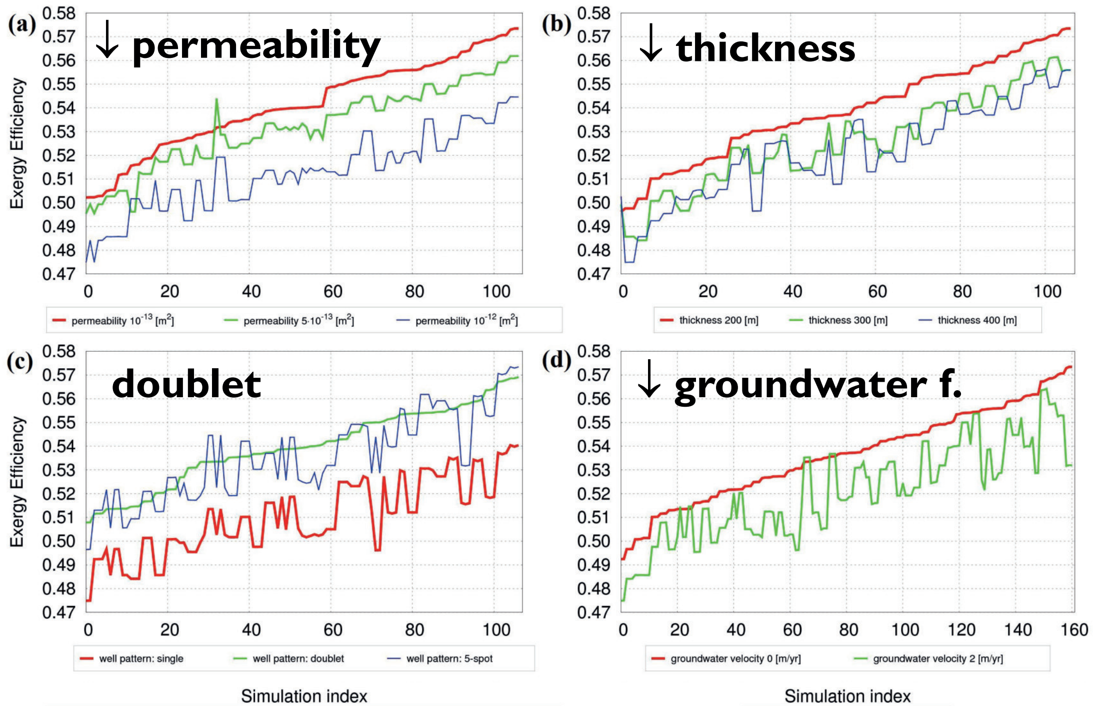
- Ongoing activities:
  - Gravity monitoring
  - Ground deformation monitoring using inSAR ongoing
  - Tiltmeter and GPS measurements starting in 06.2020
- Planned activities:
  - Production tests at Geo-01 starting in 06.2020 for 4-6 months
  - Water chemistry monitoring
  - P-T monitoring on wells and springs around the region

Results will be used for THM modelling (WP2), Validation of predictive models (WP5) and used for environmental impact assessment (Task 6.6.)

WP2: SCENARIO DYNAMIC MODELLING

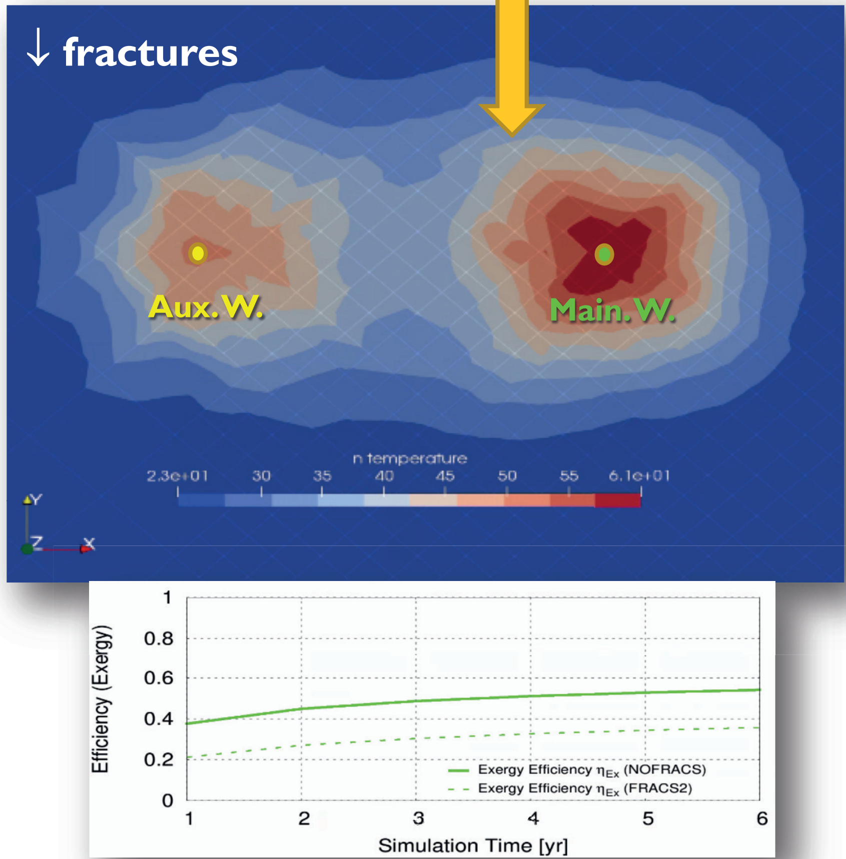
- Measured dynamic effects of: **permeability**, **porosity**, **aquifer thickness**, **well patterns**, **groundwater flow**, **fracture configurations**, **reef structures**, **aquifer depth**, **multiple aquifers**, **auxiliary well injection temperature**. (>1200 simulations)

EOL Exergetic analysis: Each graph represents the comparative effect of a single parameter while coupled to all others.



Extreme case: high re-injection temperature, very low matrix permeability

Fracture spacing:
set 1 ~ 35 [m]
set 2 ~11.6 [m]



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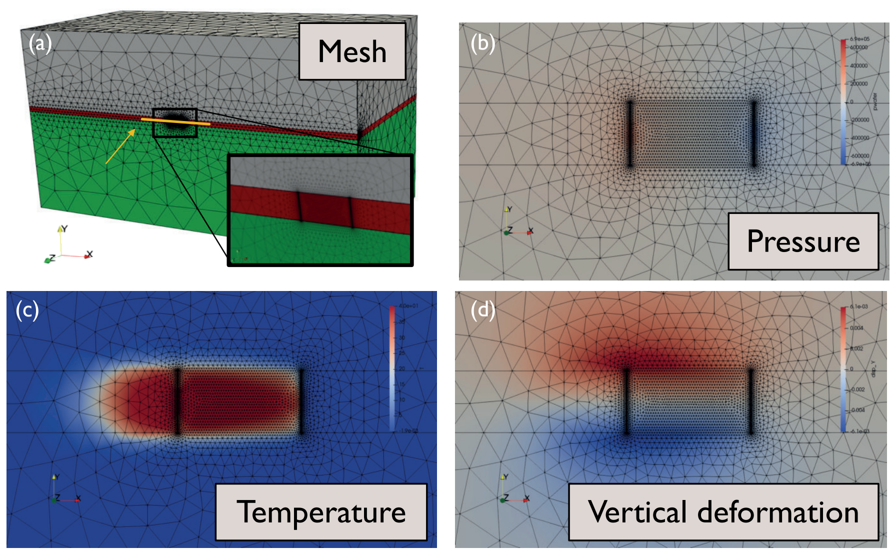
WP2 SCENARIO DYNAMIC MODELLING

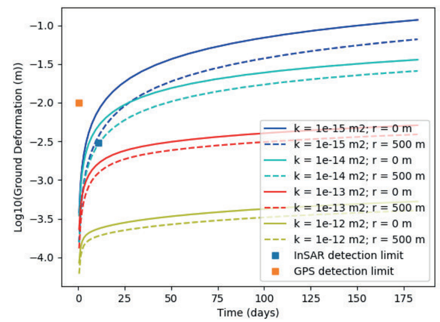
MOOSE

- Improvement to fully-coupled THM modeling for Geneva and Bern
- GEo-01 pumping test modeling – informs monitoring plan and can later calibrate numerical model
- Also continue 'simple' THM reservoir feasibility, well spacing assessment (with T1.3)
- Challenges with numerical convergance being addressed
- Past and future contributions to D2.1, D2.2, and D2.3 (EU-level)

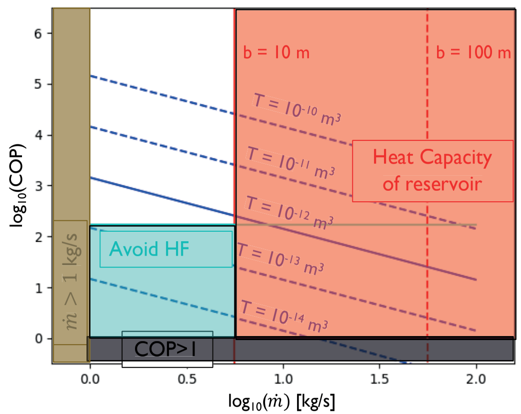
Fully-coupled 3D THM modeling of ATES



GEo-01 pumping test subsidence simulations

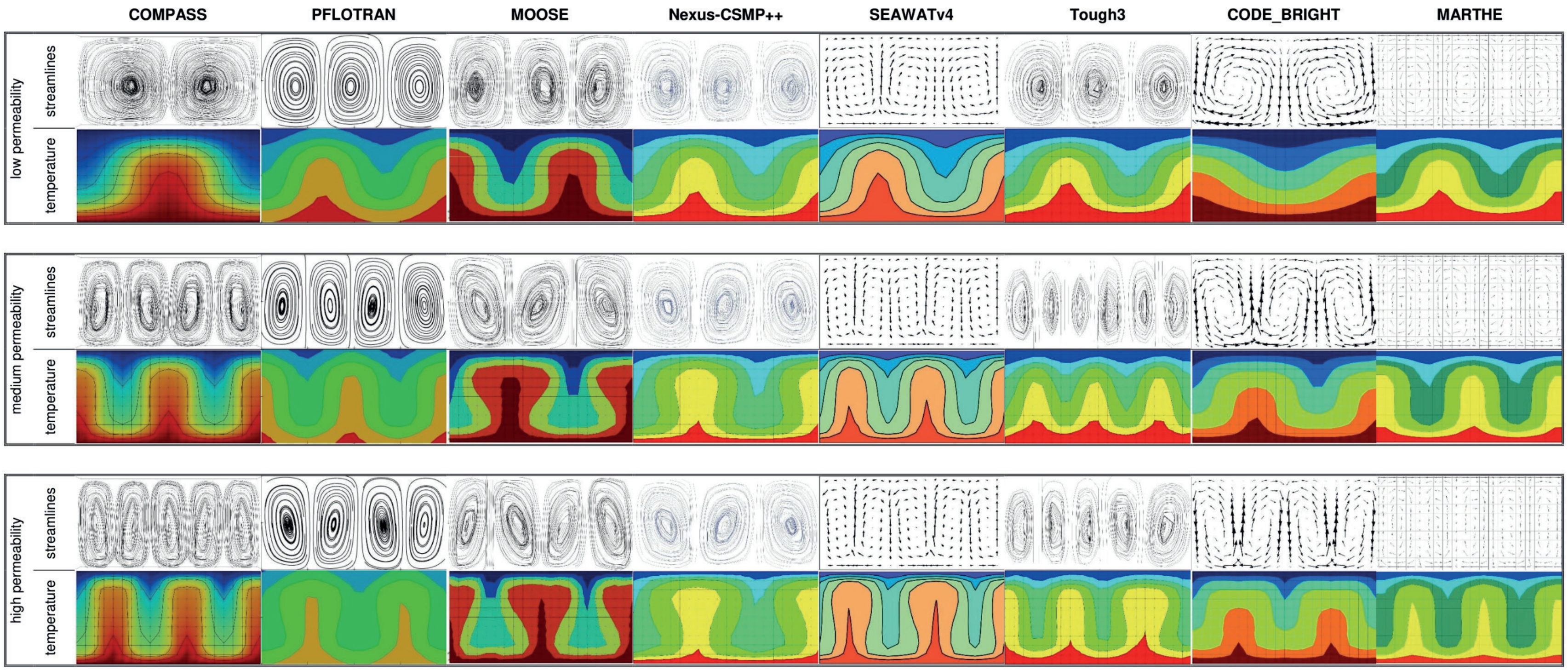


"Simple" THM($) framework for reservoir feasibility, well spacing



WP2 TH MODELLING BENCHMARK CASES

test1	*single well, analytical isothermal transient pressure (i.e. injection)*
test2	*single well, non-isothermal IFDB pumping test*
test3	*heatflow in a horizontal porous pipe. Constant, steady inflow that changes temperature with time.*
test4	*Horton-Rogers-Lapwood problem test (convection cells in porous media)*

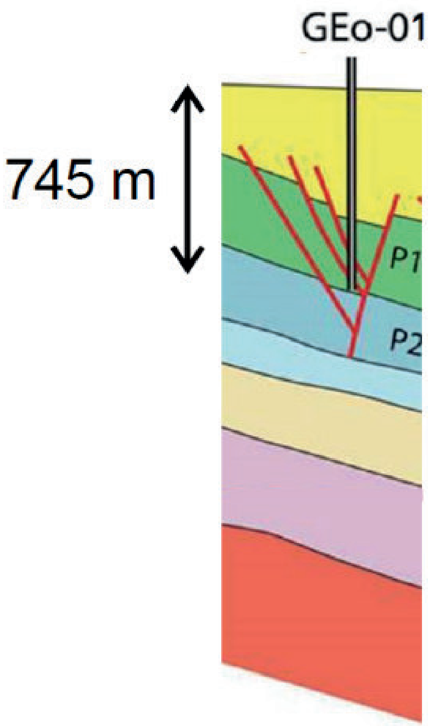


Participant	Simulator	% Complete
BRGM	COMSOL v4.2a	63
	MARTHE	96
	COMPASS	100
ETHZ	Nexus-CSMP++	100
	MOOSE	100
KWR	SEAWATv4	96
UPC	CODE_BRIGHT	100
STY	Tough3	83
UniBe	PFLOTRAN	92
GEUS	Eclipse 100	45

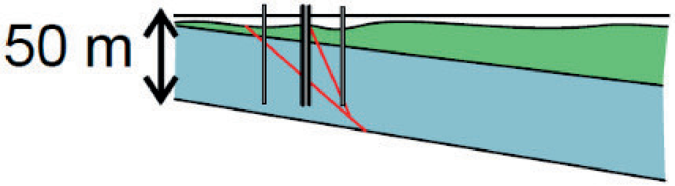
Completion table: Overall completion/submission of the TH benchmarking set by each simulator group. Some participants contributed more than one simulator, and some simulators lacked capabilities to complete all cases.

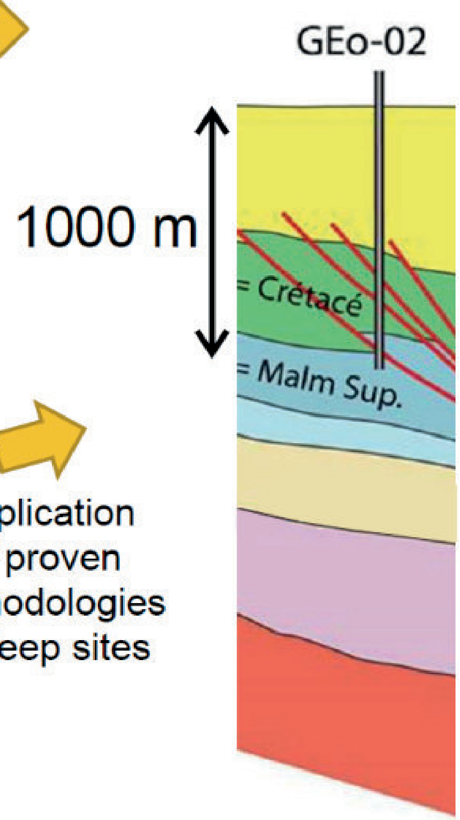
test4 (coarse mesh) simulation results: Each row depicts end snapshots of a simulation involving natural convection in a porous medium of three different permeabilities for each simulator. COMSOL and Eclipse 100 were incapable of performing this test successfully due to limitations.

THERMO-HYDRAULIC TESTS IMPLEMENTATION STRATEGY



Shallow analog test site Concise (VD))





Application of proven methodologies to deep sites

Added value to the project by:

- The possibility to develop and test multiple protocols at low cost (logging and pumping logistic available at CHYN).
- The possibility of validating results with observation holes.

Application of proven methodologies to deep sites

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unine UNIVERSITÉ DE NEUCHÂTEL

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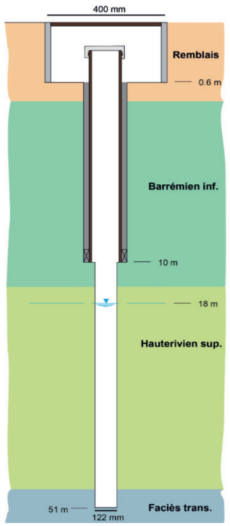
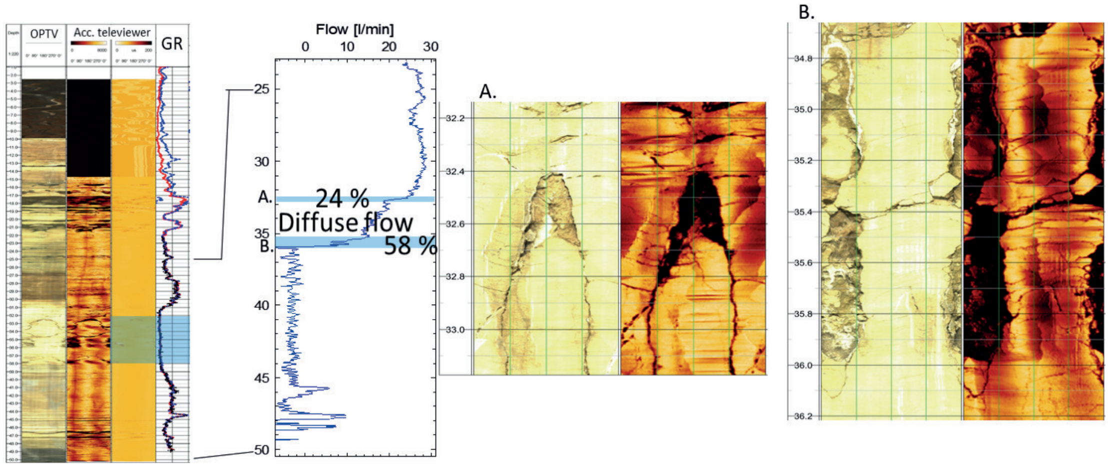
THERMO-HYDRAULIC TESTS IMPLEMENTATION STRATEGY



Some initial data concerning fracturing and flow partitioning have been collected in the wells

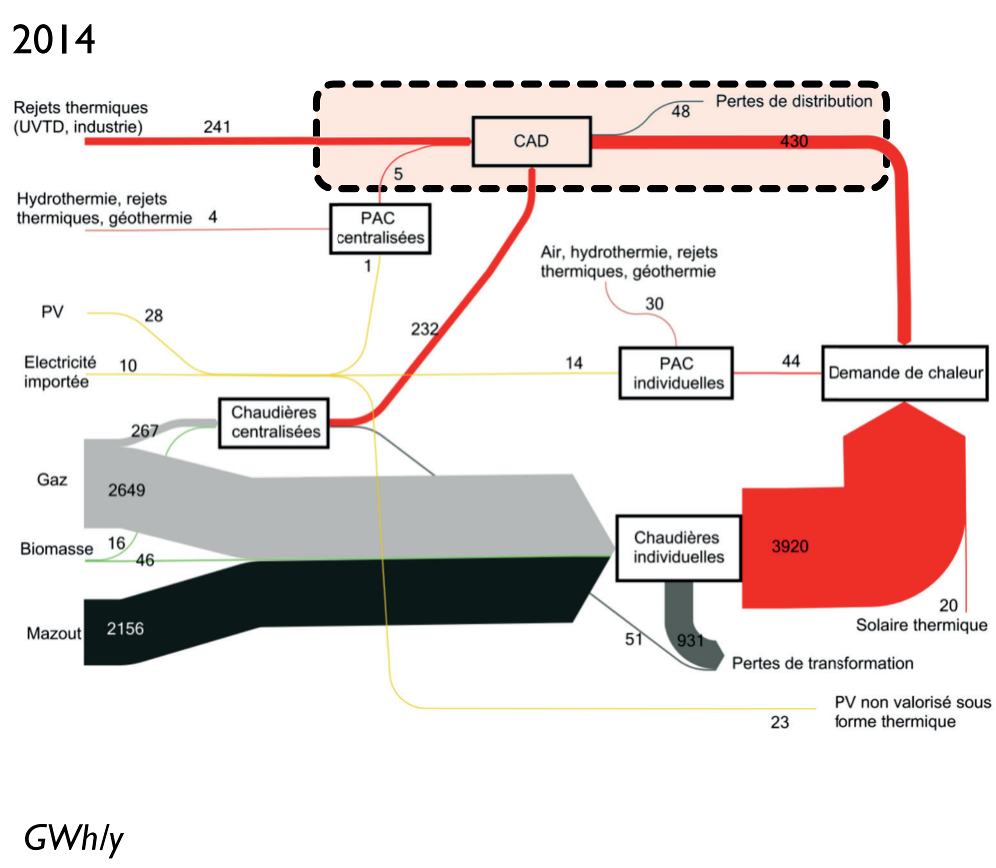


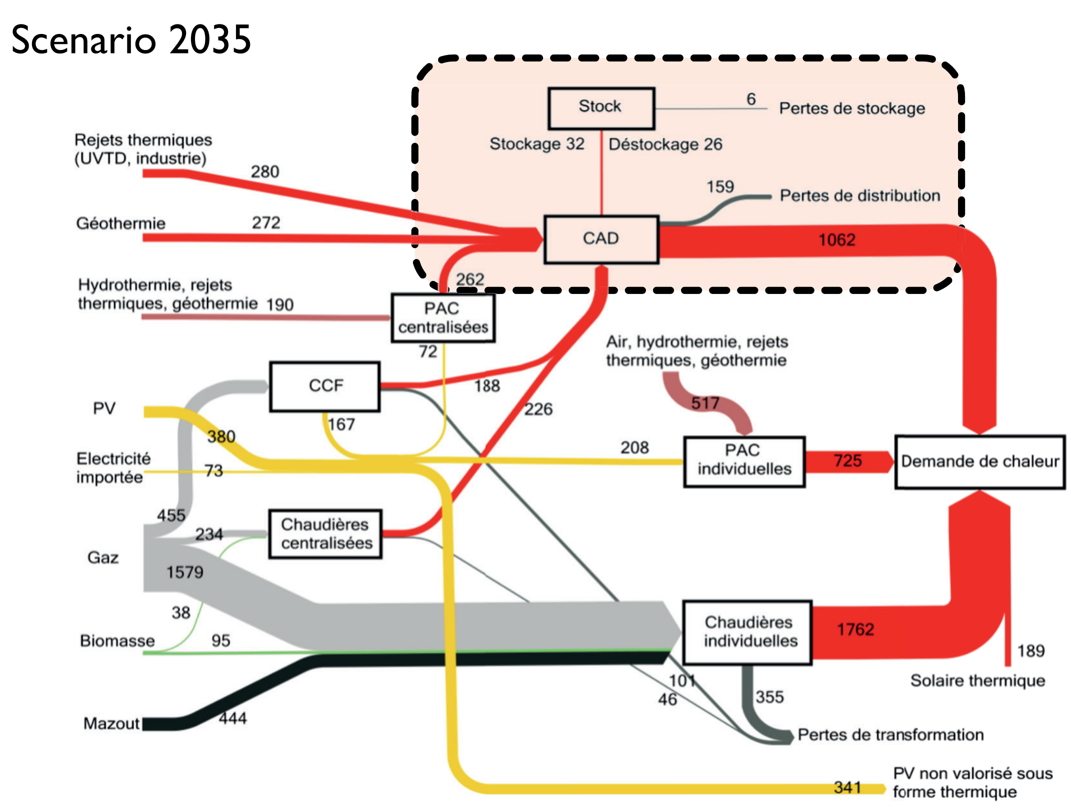
A flow log performed under pumping conditions indicated that two steeply inclined fractures controls 82% of the flow. Such conditions are typical of fractured and karstified reservoirs. The injectivity and productivity of the wells are in order of magnitude favourable for small scale heat storage experiment

Next steps

1. Analyses of fracturing data (as performed in 2019 for GEo-01)
2. Flow characterisation Flowmeter along hole
3. Thermo-hydraulic tests
4. Large scale aquifer context analyses

WP3 - ATES integration into existing energy systems: Prospective scenario for district heating in Geneva





Ref : http://archive-ouverte.unige.ch/unige:93380

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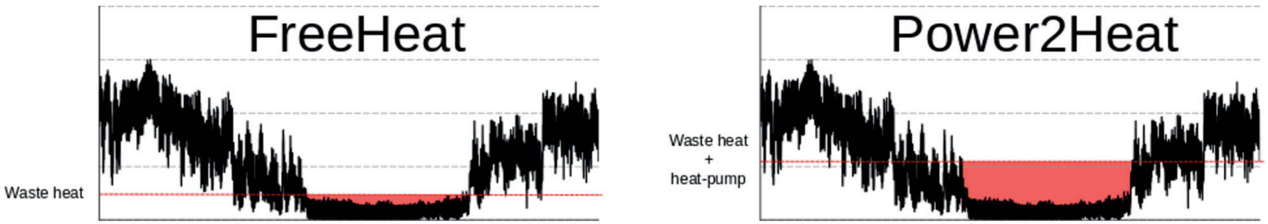
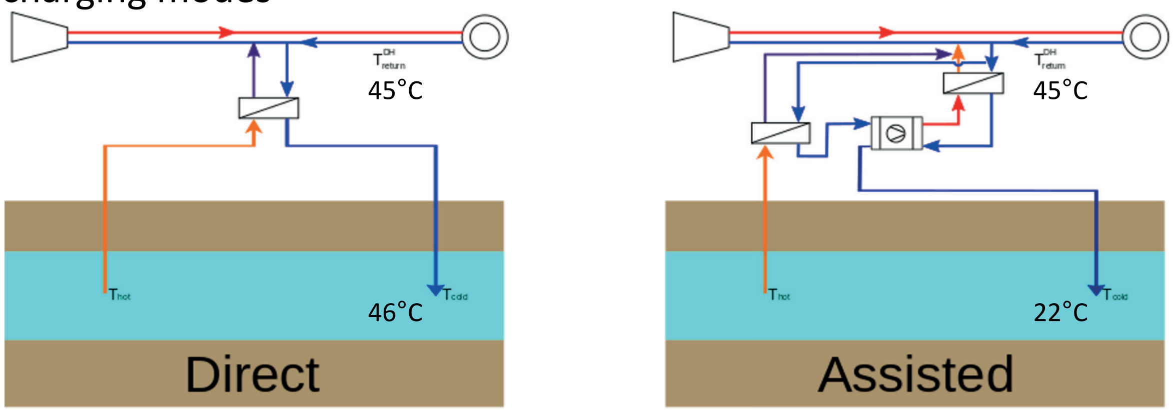
WP3 - ATES integration into existing energy systems: Prospective scenario for district heating in Geneva

2 charging modes



2 discharging modes



⇒ how simulate the interface DH-ATES on a modular system ?

⇒ explicitly integrate DH constraints (energy and temperature) on TH model

⇒ 4 different scenarios to be simulated (TH model) and compared (energy & economy)

⇒ what is the impact of DH return temperature on the whole system (energy, economy, CO_2) ?

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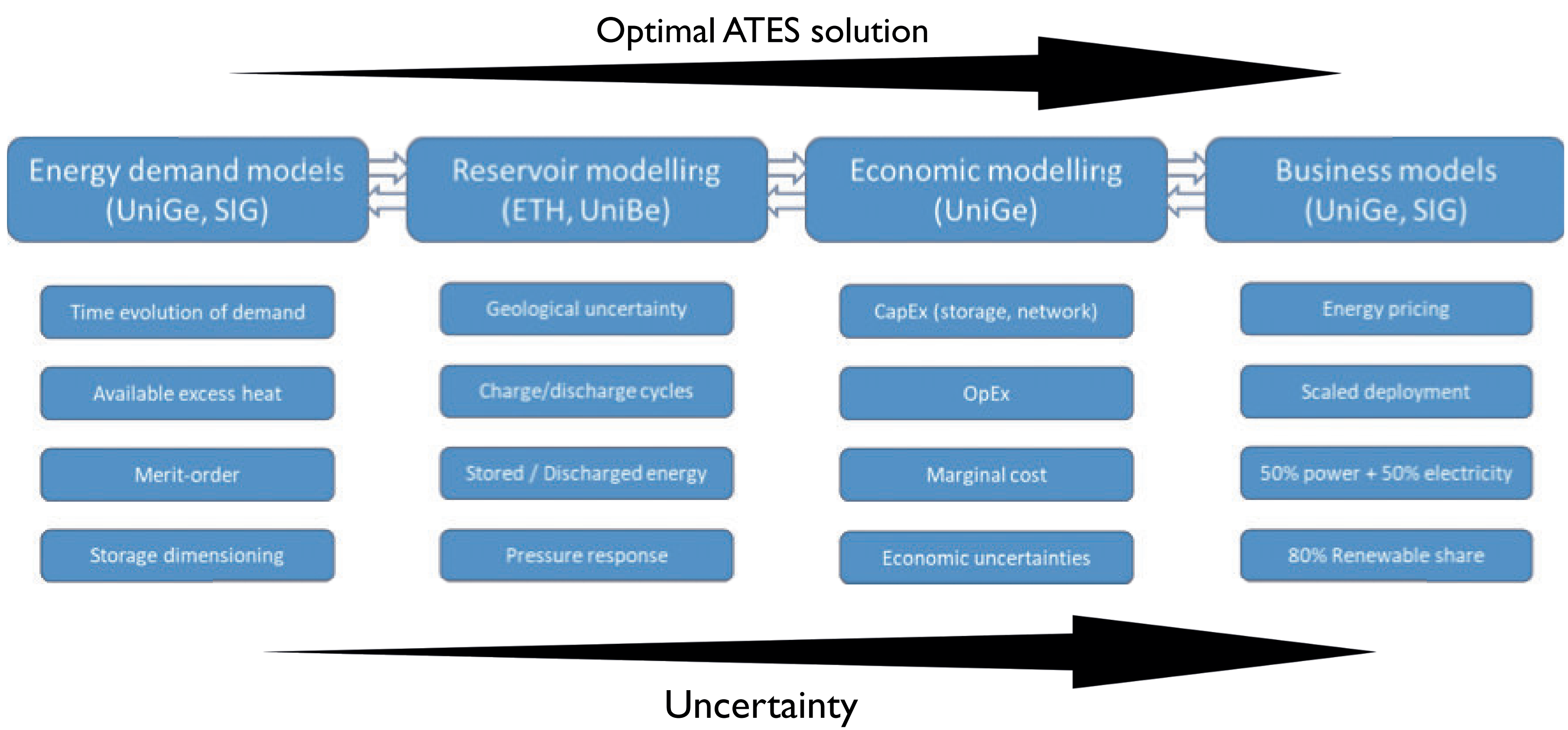
BUSINESS MODELLING

Contribution to the following deliverable:

Deliverable D3.4 - *Design and execution of business case models for the demonstration sites*



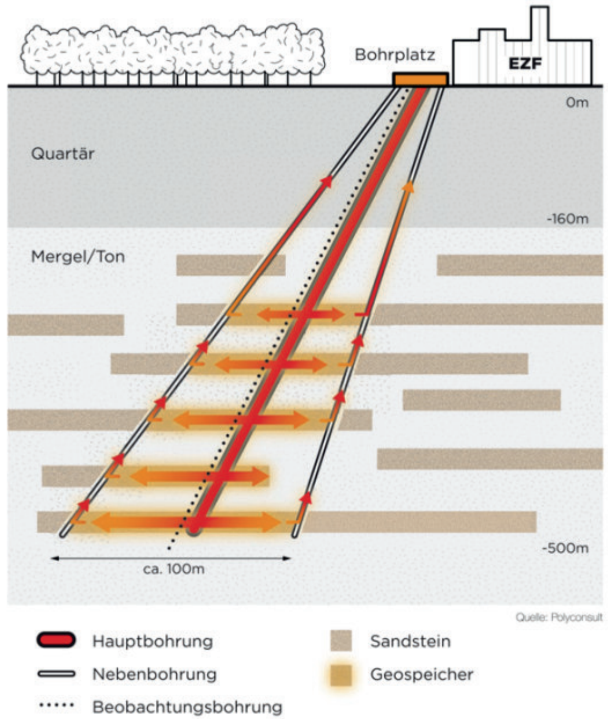
THE BERN PILOT PROJECT

ewb — Project owner

GEO ENERGIE SUISSE — Project engineering partner

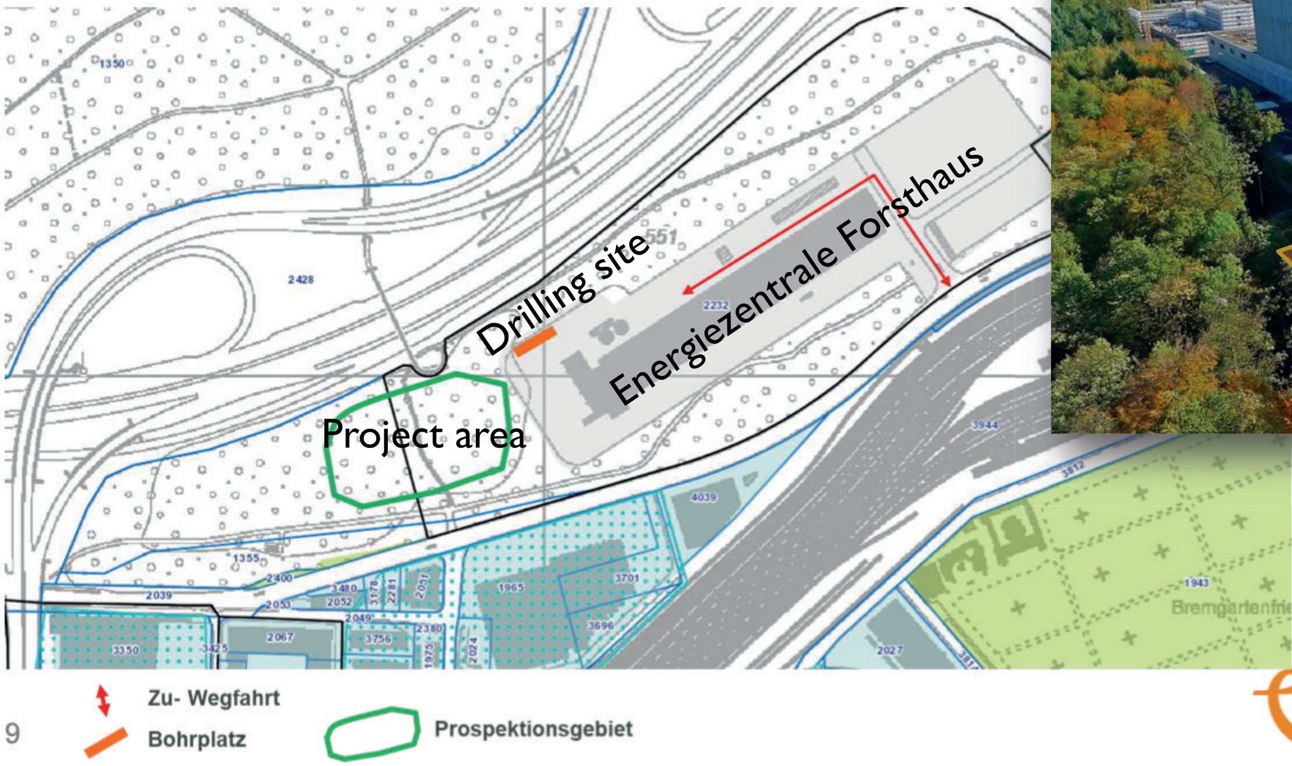
UNIVERSITÄT BERN — Water-rock interaction laboratory experiments and modelling

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH — THMC reservoir modelling

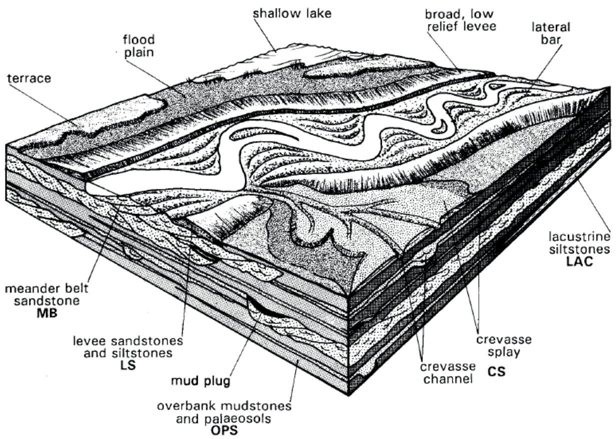


- Underground heat storage (P_{th} 3-12 MW of excess industrial heat) in sandstones of the Lower Freshwater Molasse (USM)
- Loading cycle during summer; un-loading during winter into the existing and expanding district heating network

THE BERN PROJECT

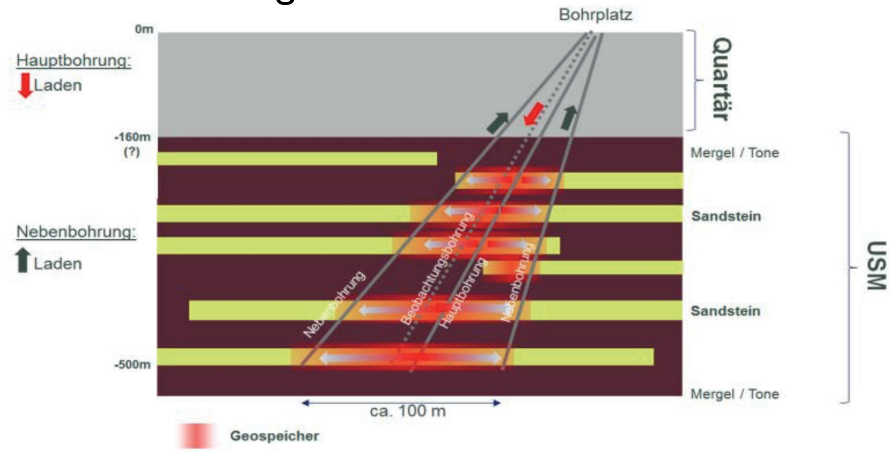


CONCEPT AND GEOLOGY BERN

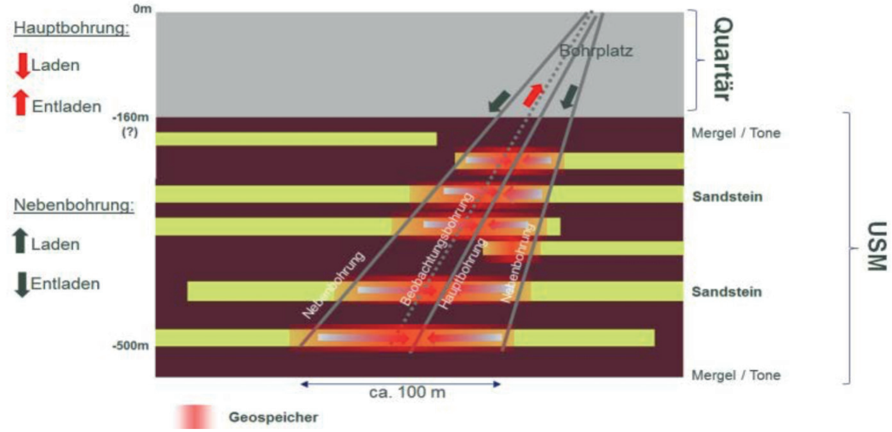


Target: sandstones in former meander systems.
Strong heterogeneity is biggest exploration risk.

Loading



Unloading



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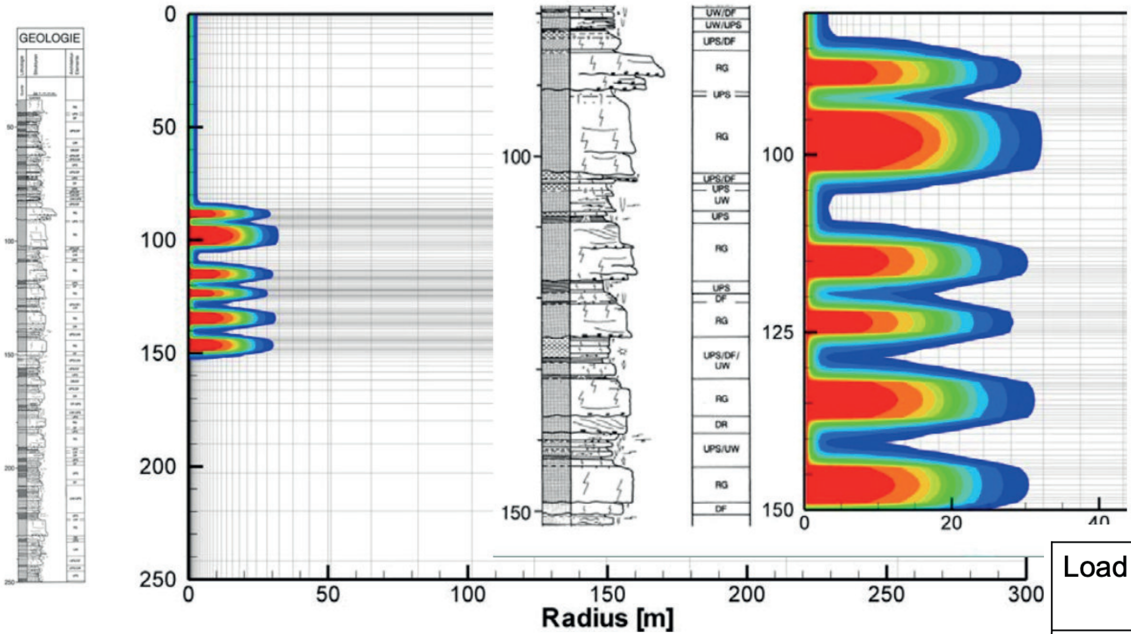
THE BERN PROJECT



Predictive Modelling of storage performance

Key figures

Load /Unload power	4 MWth	Waste heat EZF oder deep geothermal
Loading temperature	90°C	
Unloading temperature	60-85°C	
Loading time	217 d	«Summer»
Unloading time	146 d	«Winter»
Storage losses	~ 40%	Thermal-hydraulic modelling
Flow rates	25 l/s	Depending on reservoir

heatstore High Temperature Underground Thermal Energy Storage

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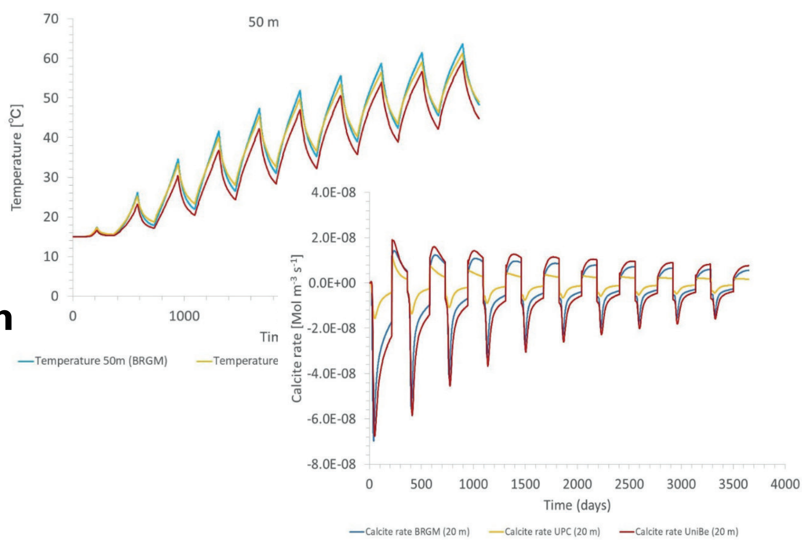
WP2 THC MODELLING AND LAB EXPERIMENTS

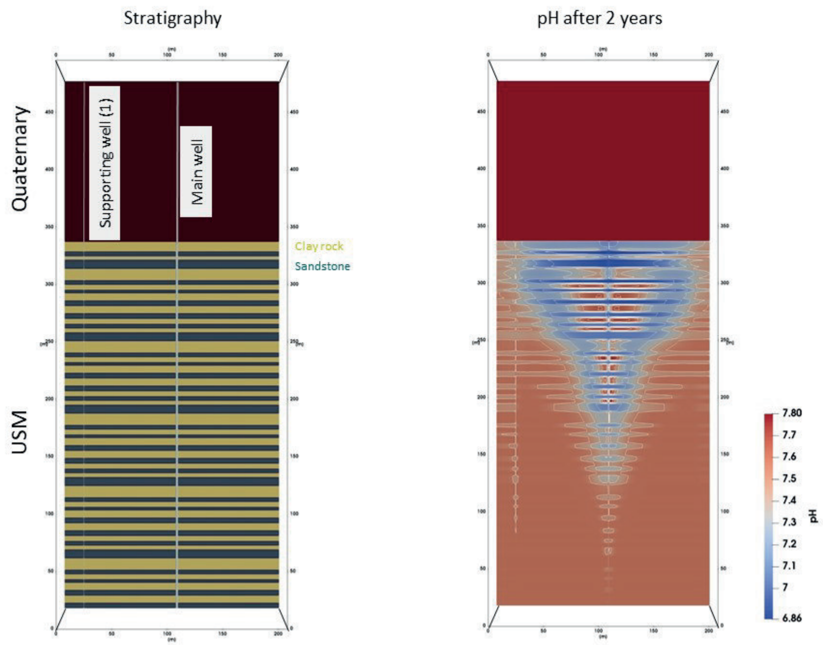
- Literature study of (hydro)geochemical problems encountered in previous HT-ATES operations
- Constrain regional geology and hydrogeology by studying drill cores and groundwater samples from shallow wells around the Forsthaus site.
- Experiments to assess carbonate scaling when heating reservoir waters during loading of the HT-ATES and mineral reactions in the reservoir and the resulting changes to fluid chemistry during the storage period.
- Development of a preliminary site-specific (THC) numerical simulation model for the Forsthaus site

Two most likely encountered during HT-ATES operations at the Forsthaus site:

carbonate scaling

mineral dissolution/precipitation reactions





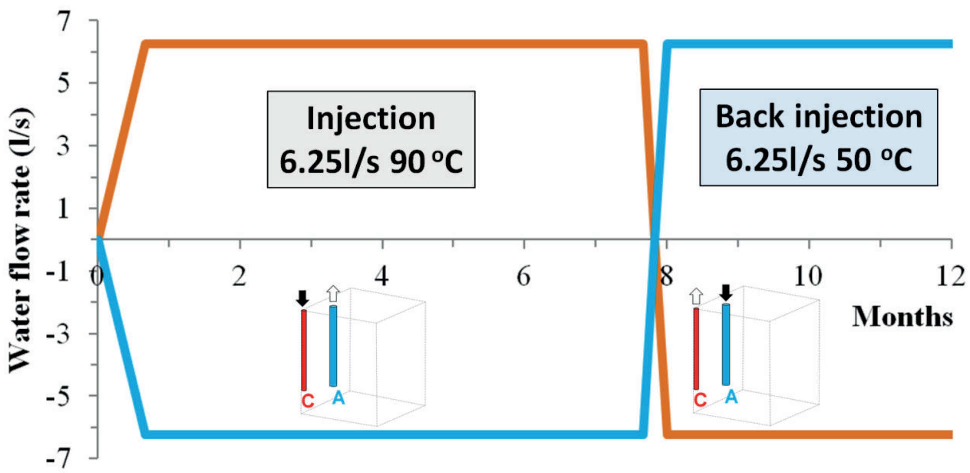
CODE_BRIGHT THM MODEL

T: $$R\rho_l\phi c_l \frac{DT}{Dt} + \nabla\cdot(-\lambda\nabla T) + c_l\rho_l \mathbf{q}_l\cdot\nabla T = 0$$

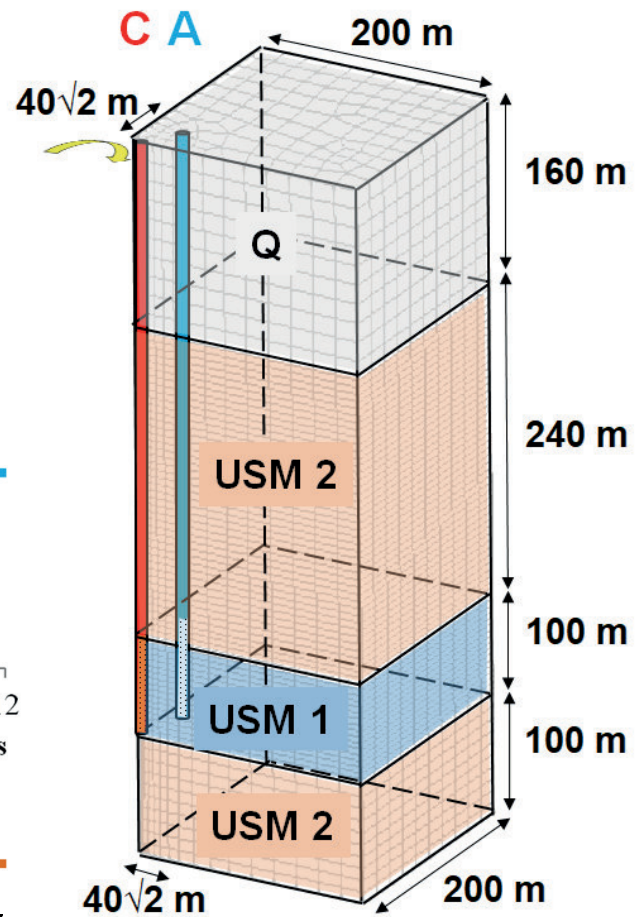
H: $$\phi\frac{D\rho_l}{Dt} + \frac{\rho_l(1-\phi)}{\rho_s}\frac{D\rho_s}{Dt} + \rho_l\nabla\cdot\dot{\mathbf{u}} + \nabla\cdot(\rho_l\mathbf{q}_l) = 0$$

M: $$\frac{D\phi}{Dt} = \frac{(1-\phi)}{\rho_s}\frac{D\rho_s}{Dt} + (1-\phi)\nabla\cdot\dot{\mathbf{u}}$$

M: $$G\nabla^2\dot{\mathbf{u}} + \left(K - \frac{2G}{3}\right)\nabla(\nabla\cdot\dot{\mathbf{u}}) - \frac{2G\alpha_T}{3}\frac{\partial}{\partial t}\nabla T - \frac{\partial}{\partial t}\nabla p_l = 0$$

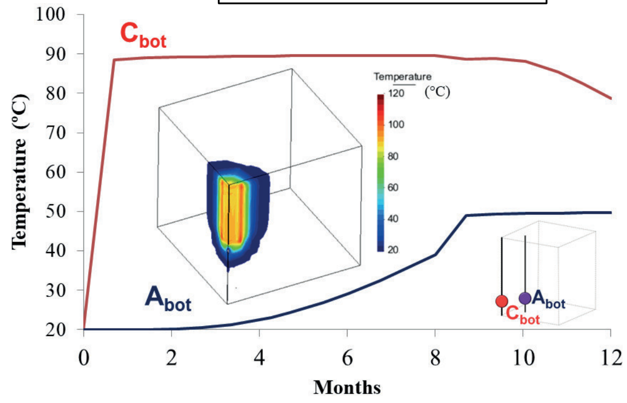


Flow rate for a quarter model: 25 l/s /4 = 6.25 l/s

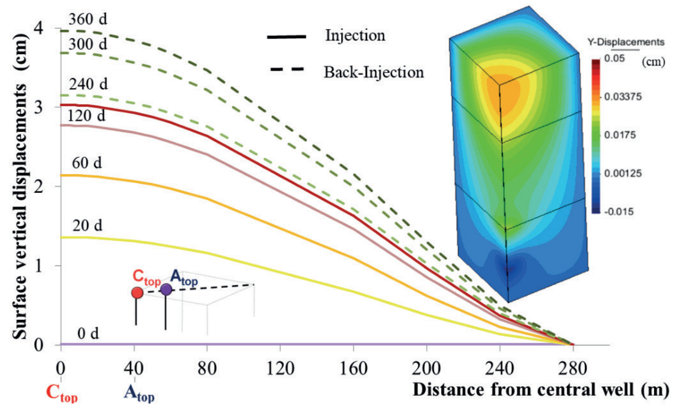


CODE_BRIGHT THM MODEL

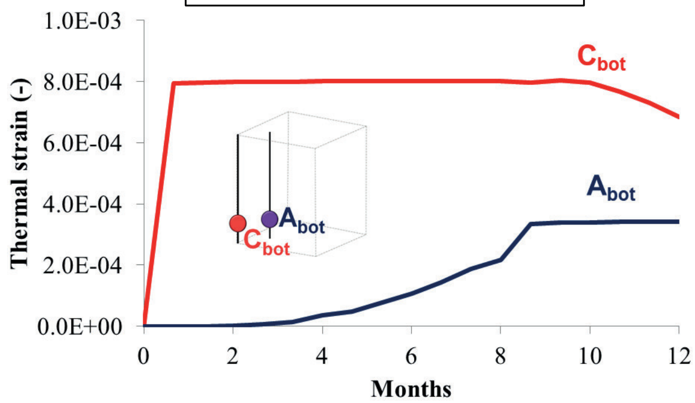
TEMPERATURE



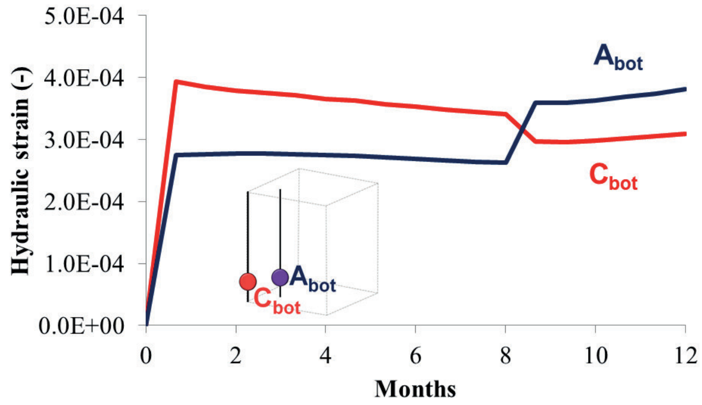
SURFACE VERTICAL DISPLACEMENTS



THERMAL STRAIN



HYDRAULIC STRAIN



WP1 - T1.3 - SCREENING OF NATIONAL POTENTIAL FOR UTES (LEADER: UNIGE)

1st Telco: 2020.01.21
2nd Telco: 2020.04.16
3rd Telco: 2020.05.20

Heatstore - WP 1.3

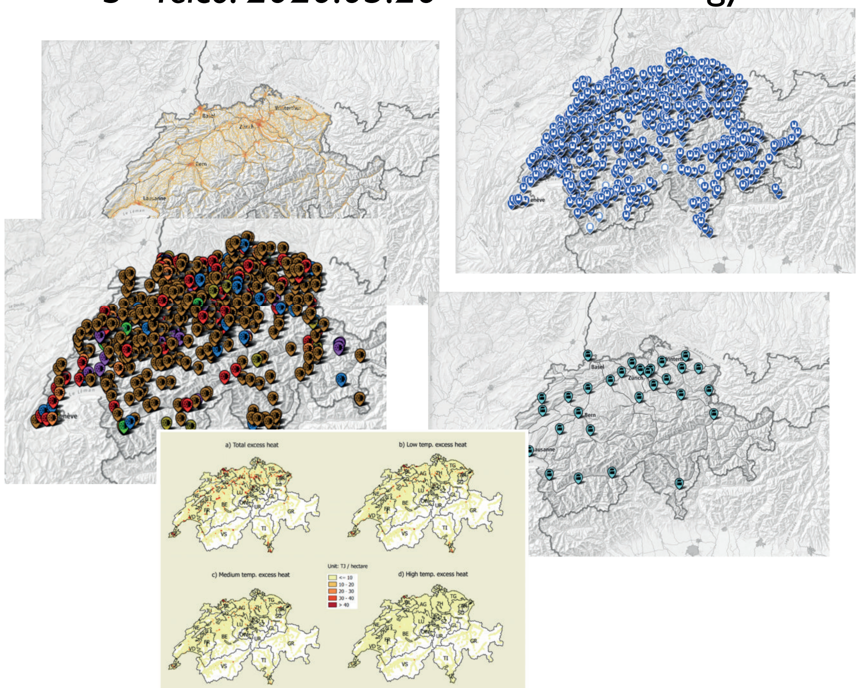
Screening of National potential of UTES

	Categories	ATES (IF Technology)	BTES (France)	PTES (GEUS)	MTES (GZB)
Subsurface	**Aquifer:**				
	Cap rock				
	Groundwater:				
	Others:				
Surface	Type of heat source				
	Surface average temperautre (°C) T_{air}				
	Temperature of excess heat (°C) T_{exc}				
	Seasonality of the excess heat				
	Operating temperature of the DH network (°C) T_{DH}				
	Amount of heat demand (MWh_y)				
	Seasonality of the heat demand				
	Loading period (hours)				
	Unloading period (hours)				
	Resting period (hours)				
	Proximity				
Operating	Injected fluid volume (m^3) V_f				
	Energy (J) E				
	Thermal Power (W) P				
	Energy recovery factor η				
	Temperature of the injected water at the cold well (°C) T_{cold}				
	Temperature of the injected water at the warm well (°C) T_{warm}				
	Cut-uff temperature for the unloading phase (°C) T_{lim}				
	Minimum well pressure (bar) bhp_{min}				
	Maximum well pressure (bar) bhp_{max}				
	Injection rate ($l \cdot s^{-1}$) Q_{inj}				
	Production rate ($l \cdot s^{-1}$) Q_{prod}				
	Depth of probes				
	Numeber of probes				
	Wrking fluid				
	Offset between probes				
	Need of a Heat Pump				

WP1 - T1.3 - SCREENING OF NATIONAL POTENTIAL FOR UTES (LEADER: UNIGE)

1st Telco: 2020.01.21
2nd Telco: 2020.04.16
3rd Telco: 2020.05.20

Energy Data



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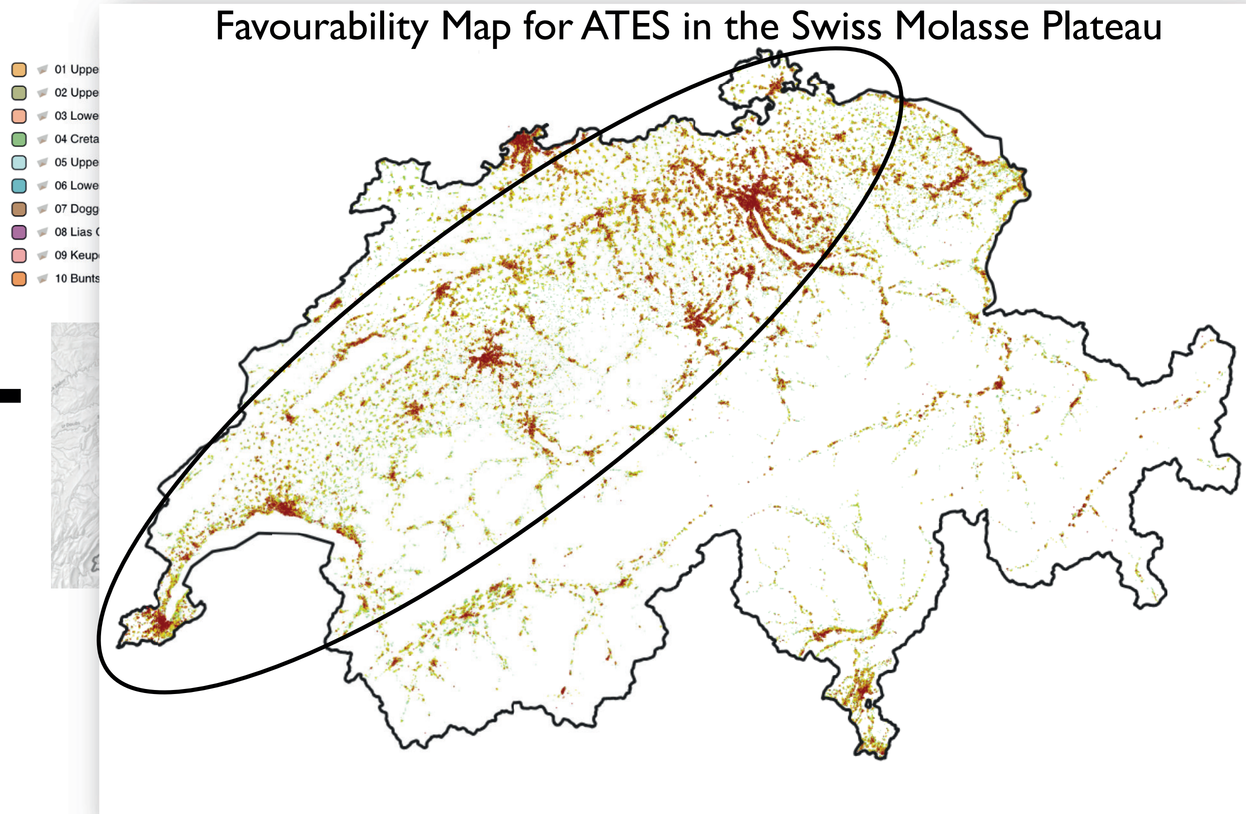
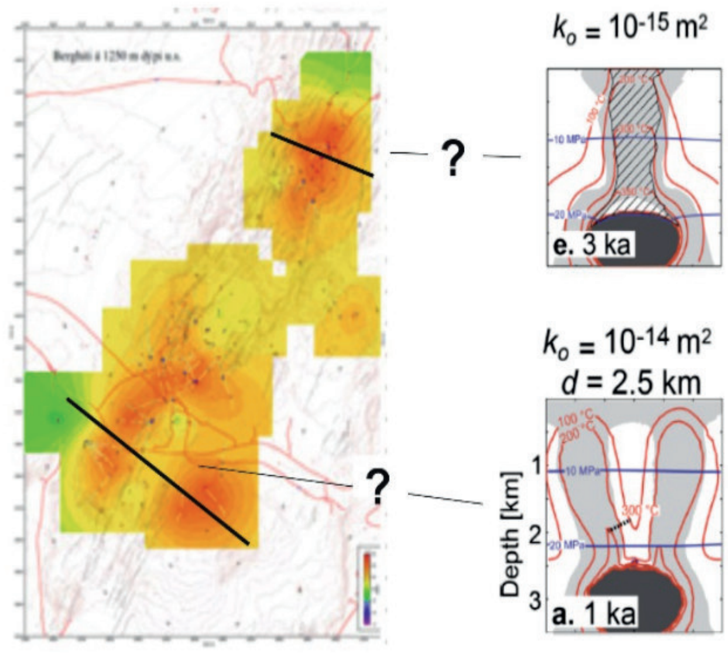


WP2

Strong international collaboration is particularly ongoing in the WP2 "Models and Tools for Subsurface Dynamics:

- ETH Zürich has the overall WP lead and coordinates Task 2.1 "Modelling toolsets and workflows for optimal and efficient HT-UTES of different types"
- For the Bern/EWB project the **University of Catalunya** is one of the subsurface dynamics modelling partners,.
- UniBE is leading Task 2.3 on "Benchmarking and improving tools of subsurface heat storage dynamics.
- In Task 2.2 "Integrating advanced academic simulation codes into diverse geothermal project development workflows, ETHZ is collaborating intensely with **Reykjavik Energy (Iceland)** and the partners from the **Azores** on translating the modelling capabilities to broader geothermal applications beyond heat storage



Temperature distribution in the Hengill area (Iceland)

WP6 – T6.2 REGULATORY AND POLICY BOUNDARY CONDITIONS (LEADER: SIG)

The problematic of task 6.2 is the various regulatory framework of each member states and the current limitation of implementing UTES technology.

To achive the goal of task 6.2 we have to propose a kind of Best practice Guide for Members States that have to make evolving their Regulatory framework.

The ongoing activities are :

1. Synthetize the regulatory framework of each member states for UTES technology
2. Pointing out what are the current limitation for implementing UTES technology
3. What is possible to change easily and how it can be done.

Then we have to choose the country which has the less bad regulatory framework solution and make evolving it to an ideal implementing Guide.

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WP6 – T6.6 ENVIRONMENTAL IMPACTS (LEADER: UNIGE)

1st Telco: 2020.01.21
2nd Telco: 2020.04.16
3rd Telco: 2020.05.27

SUGGESTION:
Move the focus on EFFECTS rather than IMPACTS:
assessing the impacts of the identified effects becomes inevitably difficult because there are so many different geo(hydro)logical conditions we then need to incorporate as well as many different other functions.

The case studies in the different countries can then illustrate how the effects manifest them selves under various conditions, how these effects can be prevented of mitigated and what the impact is on local other uses of the subsurface.

Would it be good to also address the **positive environmental effects**?

Heatstore - WP 6.6

Assessment of Environmental Impacts for UTES technologies in Europe

	Categories	ATES	BTES	PTES	MTES
Subsurface	Exploration				
	Drilling				
	Gourndwater pollution				
	Induced seismicity				
	Subsidence				
	Groundwater pollution				
	Well integrity				
	Corrosion				
	Clogging & scaling				
	Modification of formation water quality (chemical, micro-biological)				
	Heat losses				
	Other relevant elements				
Surface	Air emissions				
	Solid and Liquid Waste				
	Noise Pollution				
	Land Use				
	Wildlife and vegetation				
	Heat losses in the distribution system				
	Other relevant elements				

- End of July 2020: Protocol defined
- End of October 2020: Identification and description of the effects
- End of 2020: Integration of inputs from pilot sites

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MEETINGS AND DISSEMINATION

- Workshops:
  - European Consortium:
    - 2019-04-08: WP2 Meeting (Geneva)
  - Swiss Consortium
    - 2018-10-08: Kick-Off Meeting Swiss Consortium (Geneva)
    - 2018-11-19: WP2 Meeting (Geneva)
    - 2019-01-10: WP2 Meeting (Neuchatel)
    - 2019-02-11: WP2 Meeting (Zurich)
    - 2019-05-22: Annual Meeting (Bern)
    - 2019-11-23: Semestral Meeting (Fribourg)
    - 2020-03-23: Semestral Meeting (Telco)

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MEETINGS AND DISSEMINATION

- Publications:
  - Swiss Consortium (2020): *HEATSTORE SWITZERLAND: New Opportunities of Geothermal District Heating Network Sustainable Growth by High Temperature Aquifer Thermal Energy Storage Development* - WGC 2020, Reykjavik
  - Eruteya et al. (2020): *3-D Static Model to Characterize Geothermal Reservoirs for High-Temperature Aquifer Thermal Energy Storage (HT-ATES) in the Geneva Area, Switzerland* - WGC 2020, Reykjavik
  - Mindel & Driesner (2020): *HEATSTORE: Preliminary Design of a High Temperature Aquifer Thermal Energy Storage (HT-ATES) System in Geneva Based on TH Simulations* - WGC 2020, Reykjavik
  - Birdsell & Saar (2020): *Modeling Ground Surface Deformation at the Swiss HEATSTORE Underground Thermal Energy Storage Sites* - WGC 2020, Reykjavik
  - *Sohrabi & Valley (2020):Thermo-Hydraulic-Mechanical (THM) Experiments and Numerical Simulations to Quantify Heat Exchange Characteristics of Fractured Limestone Reservoirs for Aquifer Thermal Energy Storage (ATES)* - WGC 2020, Reykjavik
  - Guglielmetti et al. (2020): *Geochemical Characterization of Geothermal Waters Circulation in Carbonate Gothermal Reservoirs of the Geneva Basin (GB)* - WGC 2020, Reykjavik
  - Ferreira de Oliveira et al. (2020): *Application of Chemostratigraphy and Petrology to Characterize the Reservoirs of the Mesozoic Sequence Crossed by the Geo-01 Well: Potential for Direct Heat Production and Heat-Storage* - WGC 2020, Reykjavik
  - Koornneef et al. (2020): *HEATSTORE Project Update: High Temperature Underground Thermal Energy Storage* - WGC 2020, Reykjavik
  - Kallesoee et al. (2020): *HEATSTORE – Underground Thermal Energy Storage (UTES) – State of the Art, Example Cases and Lessons Learned* - WGC 2020, Reykjavik

heatstore
High Temperature Underground Thermal Energy Storage

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THE PEOPLE…

THANK YOU