

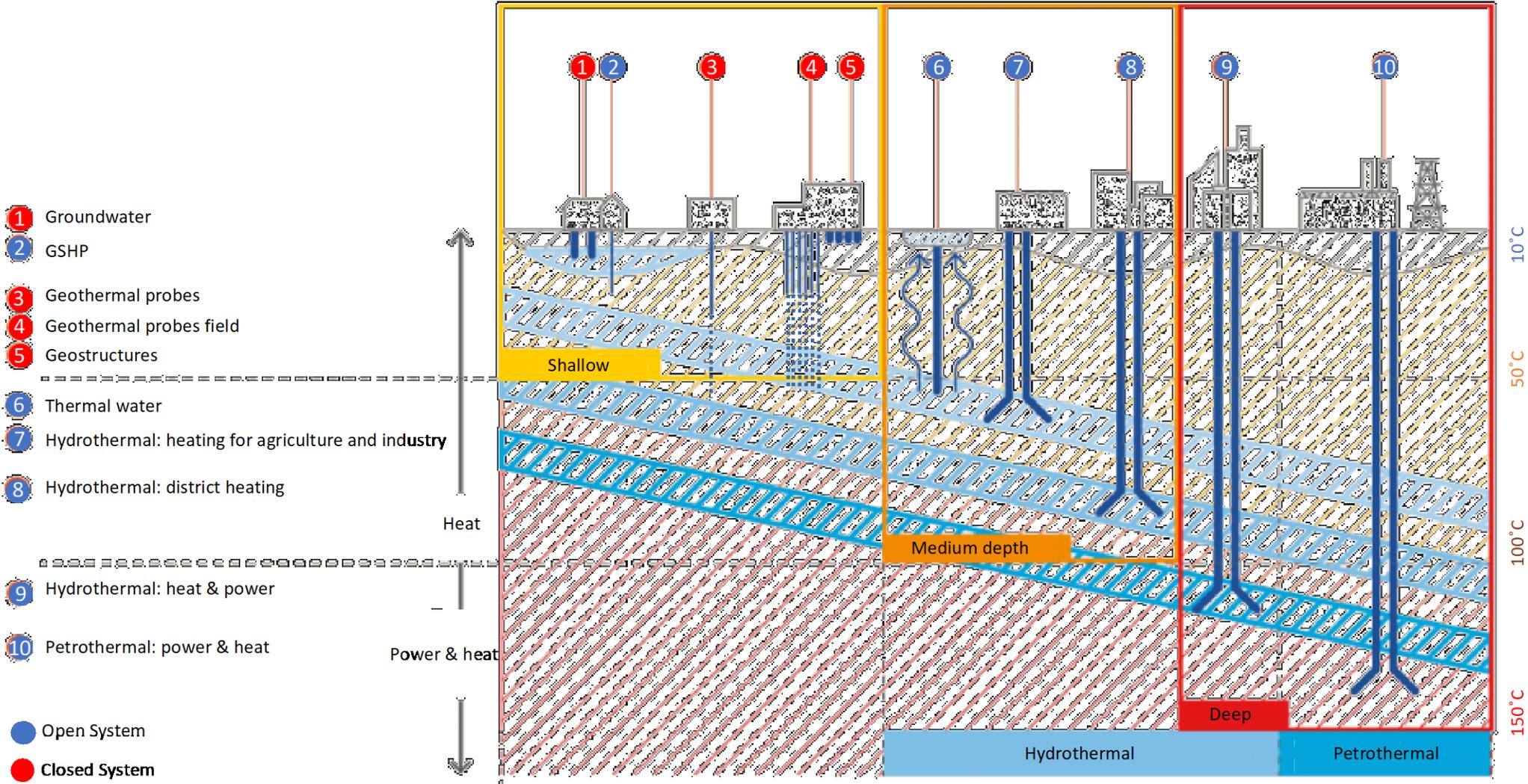
# White Paper on Geothermal Energy

SCCER SoE Annual Conference, November 2, 2020

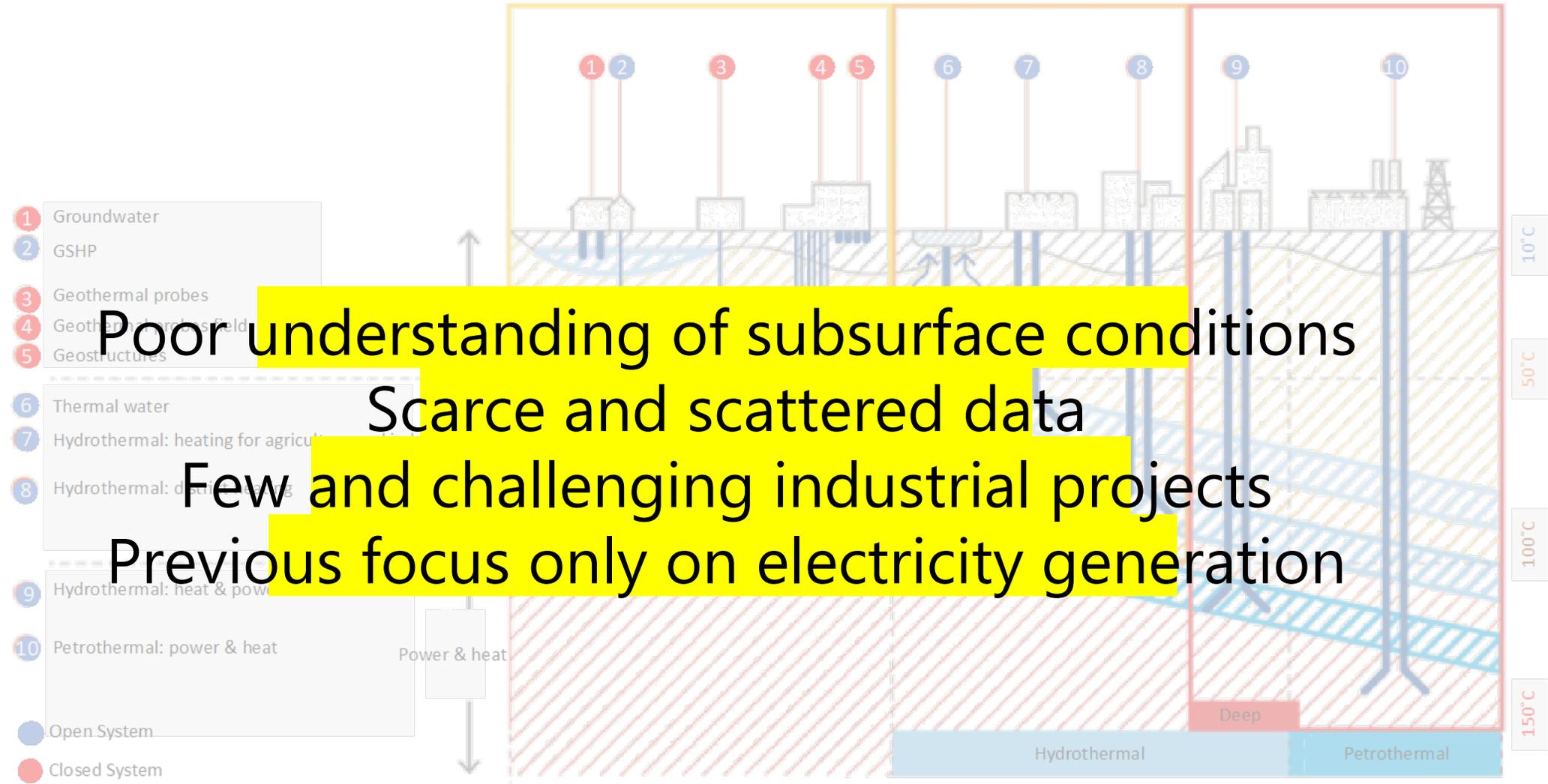
Luca Guglielmetti, University of Geneva



# Opportunities and Challenges for deep Geothermal in Switzerland



# Opportunities and Challenges for deep Geothermal in Switzerland



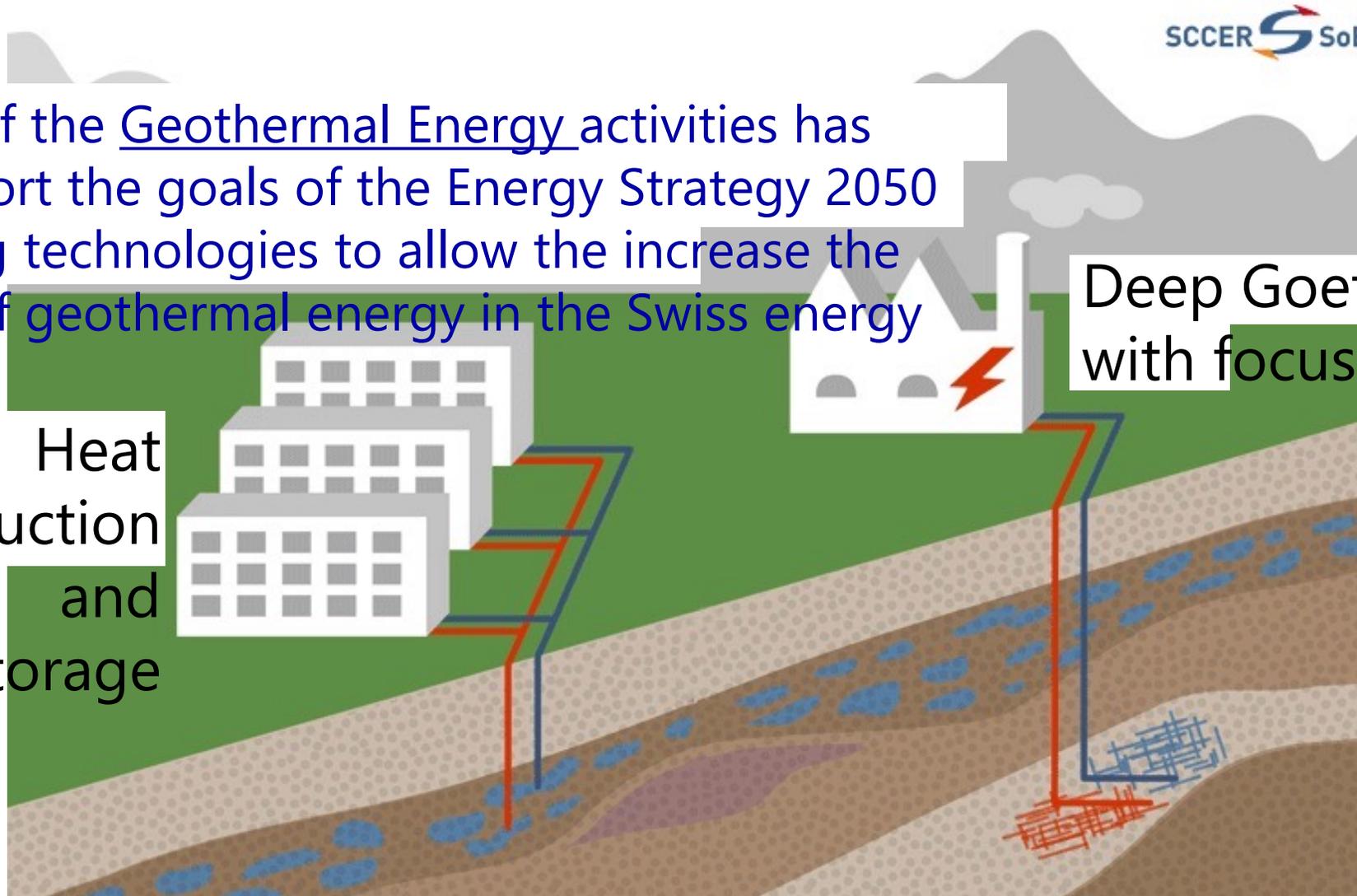
Poor understanding of subsurface conditions  
Scarce and scattered data  
Few and challenging industrial projects  
Previous focus only on electricity generation

# Geothermal Energy in the SCCER-SoE

The mission of the Geothermal Energy activities has been to support the goals of the Energy Strategy 2050 by developing technologies to allow the increase the penetration of geothermal energy in the Swiss energy system

Heat production and storage

Deep Geothermal with focus on EGS



# SCCER-SoE Geothermal Energy Research

## Geo-data infrastructure and analysis

Infrastructure to facilitate data access and exchange



SWISS COMPETENCE CENTER for ENERGY RESEARCH  
SUPPLY of ELECTRICITY

## Resource exploration and characterization

Sedimentary aquifers for heat extraction and storage  
Fractured reservoirs in deep crystalline basements and sedimentary units for co-generation of heat and power

## Hydrothermal heat exploitation and storage

Experimental and numerical methods employed at basin and at lab scale in the framework of the *GEothermies* program in Geneva

## Pilots & Demos



Crystalline/EG  
S: Grimsel, Haute-Sorne, Bedretto



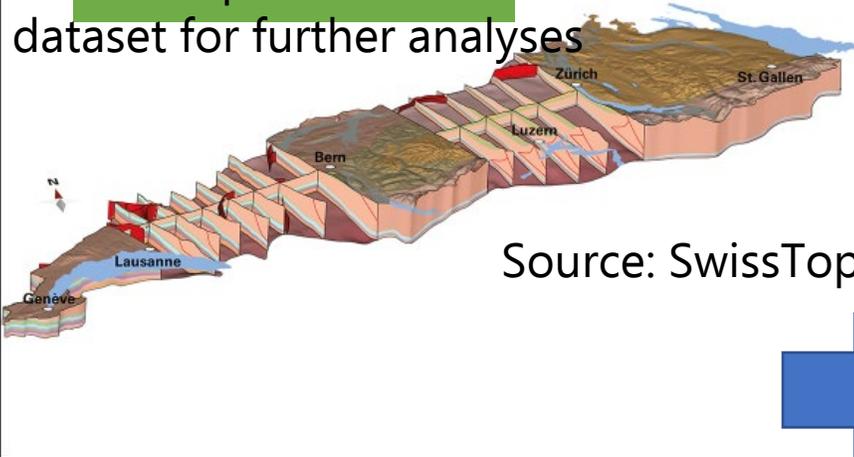
Sedimentary:  
Geneva Basin

## Reservoir stimulation and engineering (EGS)

Understanding of the THM process during stimulation  
Testing at experimental demo sites  
Support decision making and reservoir assessment processes.

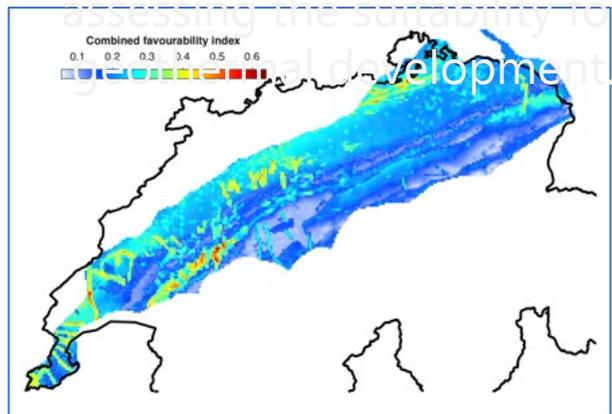
# SCCER-SoE Geothermal Energy Research

3D models such the GeoMol model allows combining data from different source and provide a common dataset for further analyses

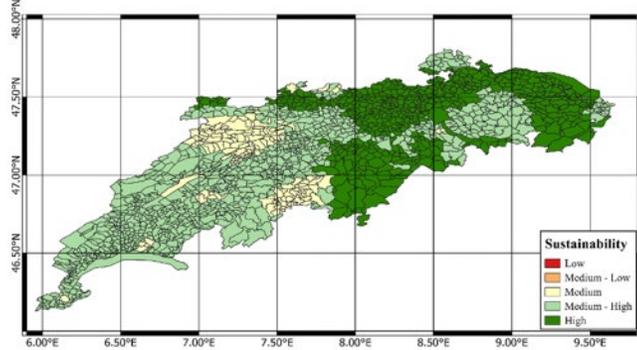


Source: SwissTopo

Subsurface models like the GeoMol model provides opportunities for identifying GEOHERMAL PLAYS and



Possible power plant locations are constrained by GEOLOGICAL conditions as well as ECONOMIC,

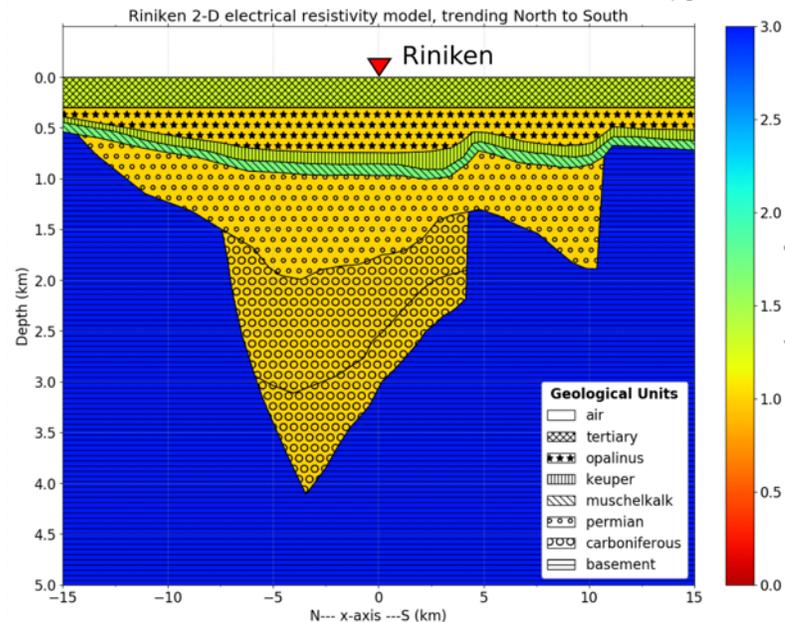


PLAY-FAIRWAY approaches allow valuing the available data within a systematic, evolutive quantitative framework (Valley and Miller, 2020)

Average SUSTAINABILITY map for Deep Geothermal Energy in Switzerland (Picture provided by Saar et al.)

# Improved Exploration Methods

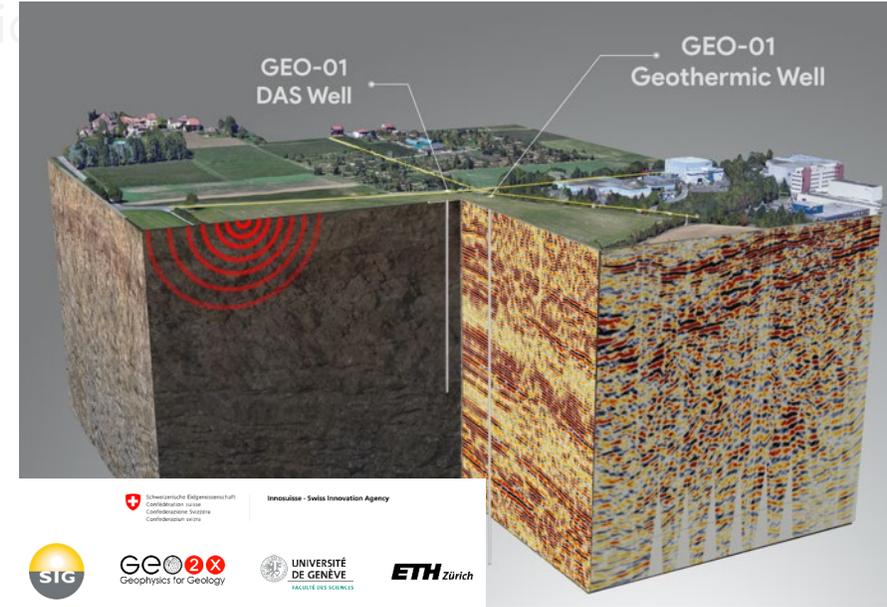
HEAT FLOW data coupled to GEOPHYSICAL measurements are commonly used to depict potential deep targets such as in the case of the Permo-Carboniferous though in



2-D electrical resistivity model for the MT station near the Riniken borehole. (Picture provided by Saar et al.)

The combination of different gravity and active seismic using Distributed Acoustic Sensing and SmartSolos

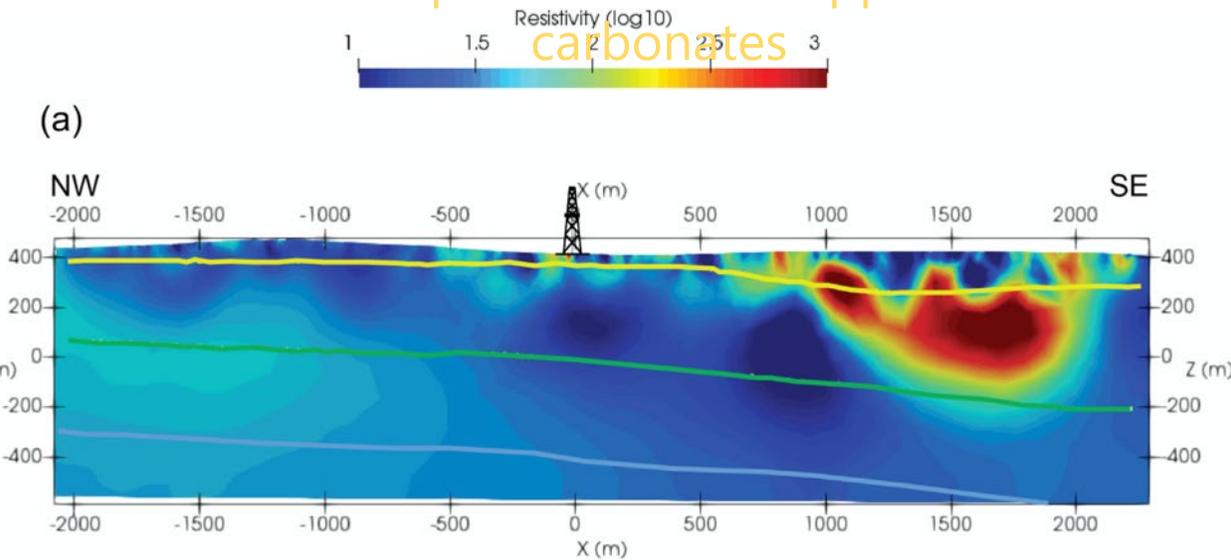
are used to improve the resolution at the region



Multi-component seismic data collected in the framework of the InnoSuisse GECOS project <https://gecos.geoenergy.ch/>

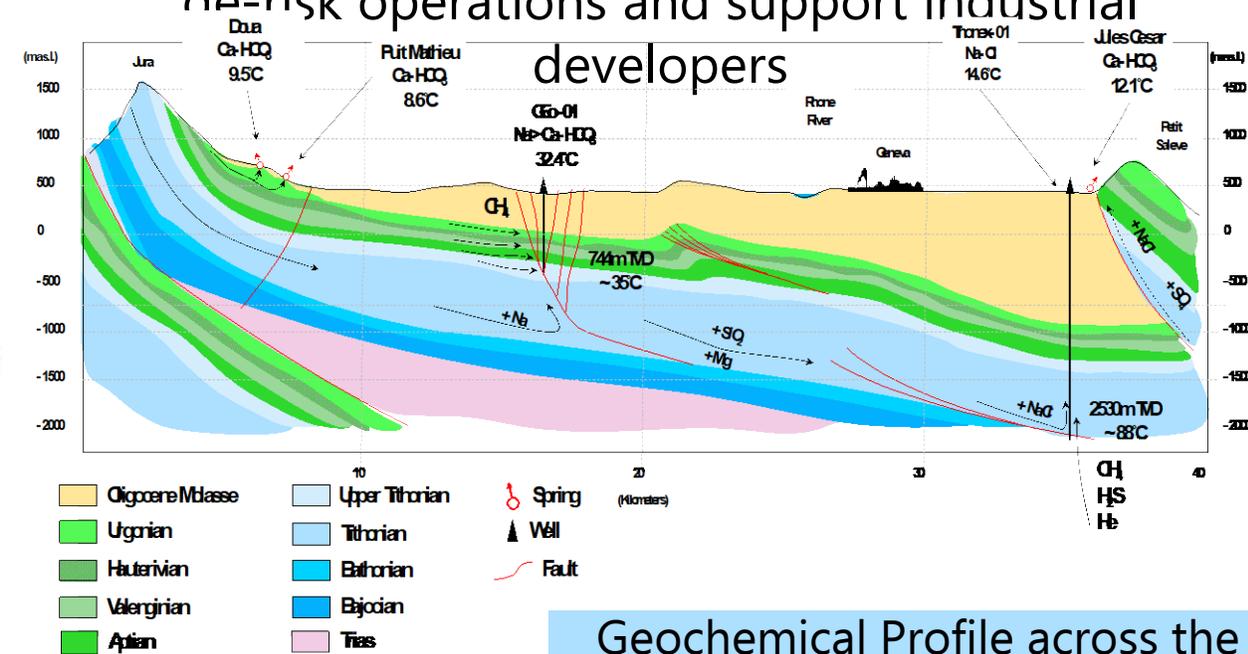
# Improved Exploration Methods

Deep Electric Resistivity Tomography has been applied coupled to seismic and gravity data in the Geneva area to identify potentially fluid saturated units in the upper 1km covering the Molassic sequence and the Upper Mesozoic carbonates



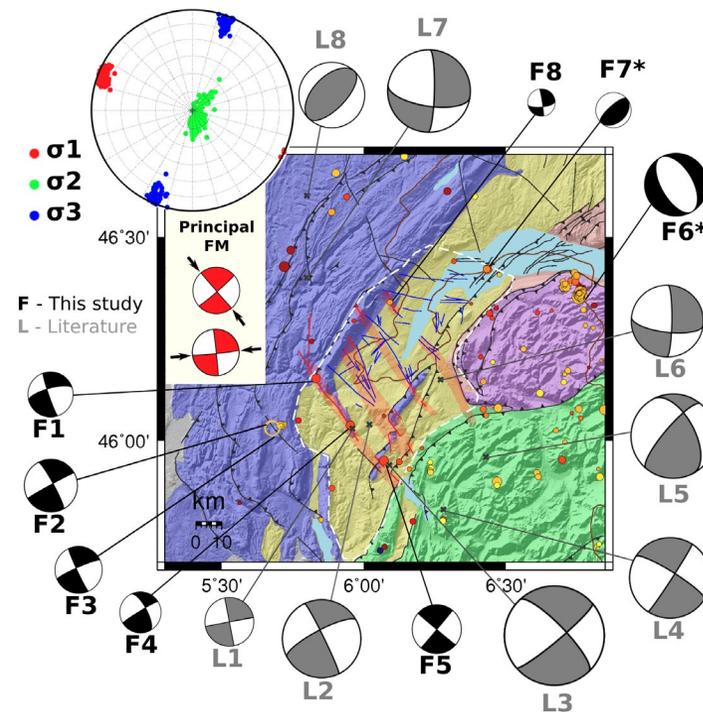
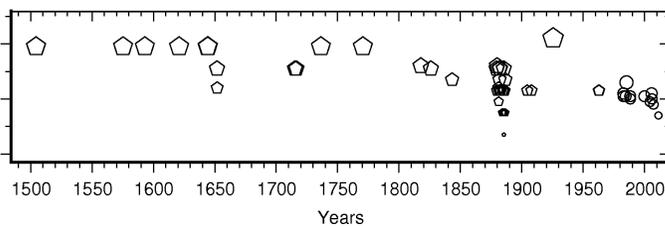
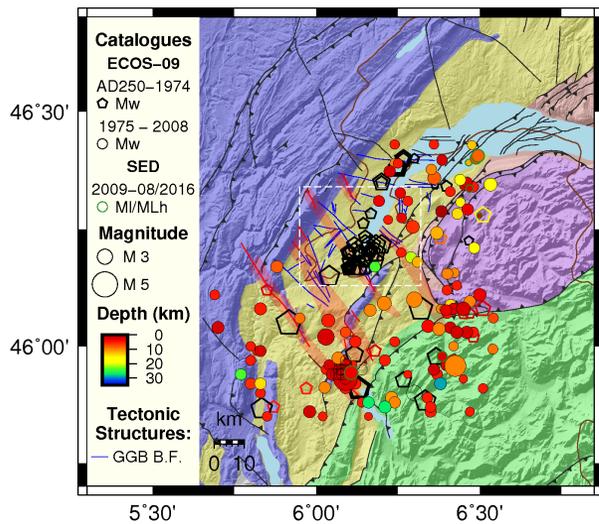
Application of DERT for the investigation of medium-enthalpy geothermal resources in the Geneva area (Carrier et al., 2019)

Fluid geochemistry is an exploration method, complementary to geophysical surveys to characterize deep geothermal circulations, de-risk operations and support industrial developers

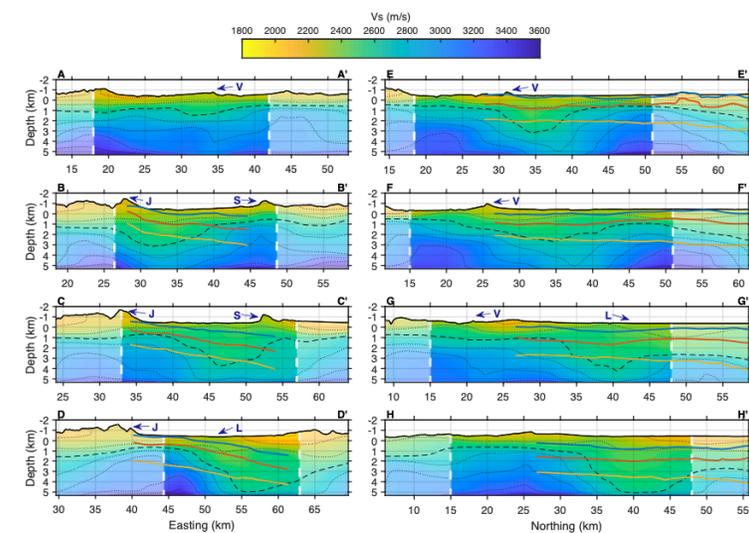


Geochemical Profile across the Geneva Basin (Guglielmetti et al. submitted)

# Improved Exploration Approach



Antunes et al., 2020



Planes et al., 2020

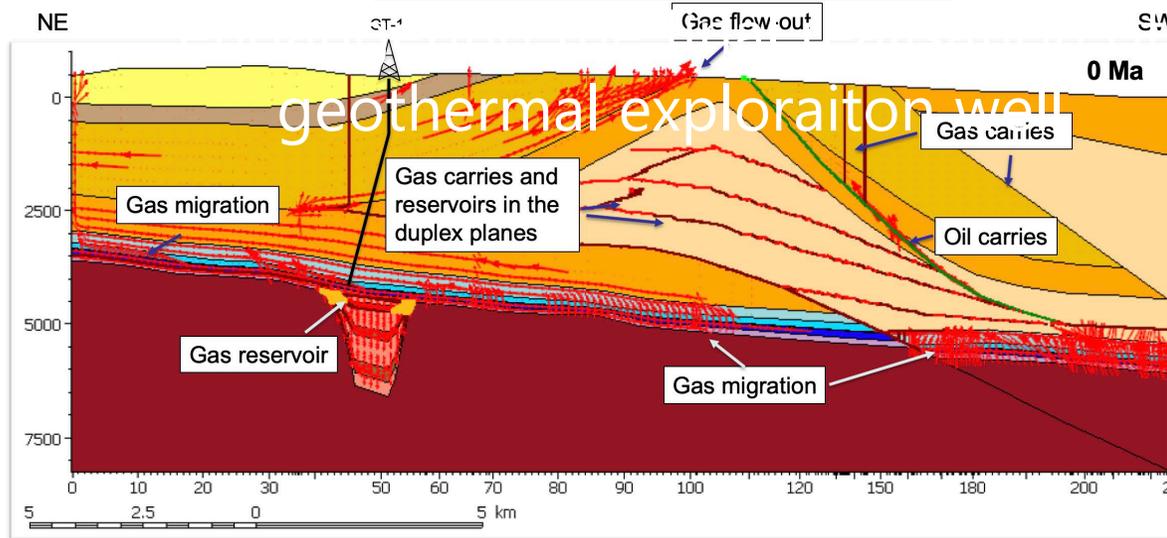
Natural MICROSEISMICITY analysis is another exploration and monitoring technique commonly used in geothermal projects.

In the Geneva area 20 stations have been deployed and application of ambient noise tomography allowed defining the natural state and improve the regional velocity models which are a crucial to improve the

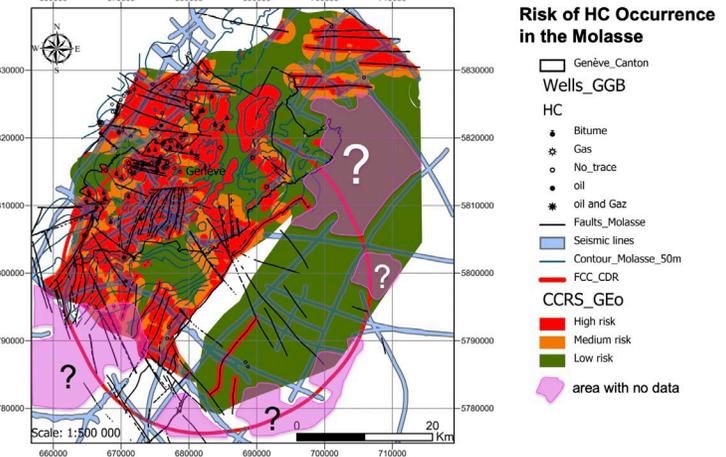
# Improved Exploration Approach

**UNCONGEO: Petroleum system modeling applied to deep-geothermal play helps identifying and quantifying the risk of occurrence of hydrocarbon**

**Uncertainty, Risk & Mitigation Table and Risk Maps helps identifying and visualising key parameters likely controlling the success of a geothermal project**



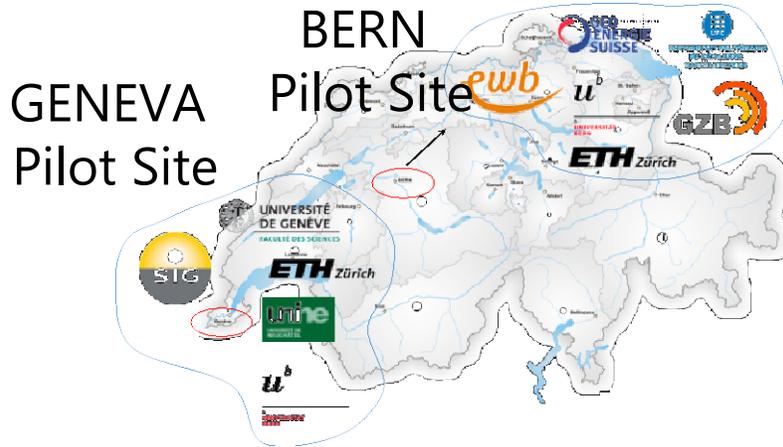
Category	Uncertainty	Level of Uncertainty	Risk	Opportunity	Mitigation action
Reservoir Geology	geometry and distribution of Quaternary aquifers	low	limited impact on permeability and storage capacity of Quaternary aquifers	suitable for Ground Source Heat Pump applications	Revision of the Quaternary 3D model to incorporate the geophysical data (gravity, seismic, electrical)
	presence of general sealstones in the Molasse/Molasse	medium	lack of identification of a general sealstone may lead to overestimation of hydrocarbon potential and to a higher production cost	suitable for heat storage	better image of subsurface (e.g. seismic)
	large fault occurrence	medium	drilling and logging, changing temperature	high water flow rates	
	small fault occurrence	high	drilling and logging, changing temperature	moderate to high water flow	
	differences and geometry of the Molasse/Molasse	medium	under- or overestimation of dimensions could lead to wrong conceptual model and consequent inaccurate definition of drilling target and production development (i.e. heat production, heat storage)	heat storage may be combined through Fault and fracture network to larger storage	
	large production from Triassic units	medium	drilling and logging, changing temperature	high water flow rates	
	production from Carboniferous	high	drilling and logging, changing temperature	high water flow rates potentially favourable for large heat production	
	production from Permian	high	drilling and logging, changing temperature	high temperatures potentially favourable for power production	
	production from Permian	high	drilling and logging, changing temperature	high flow rates and circulation of hot water from deeper subsurface	
	fracture permeability	high	low to no well deliverability	not optimal production, leaving an area out	
Petrophysics	non-consistent Basin Fracture	high	low to no well deliverability	leaving about 50% of the subsurface	
	alteration and sealing of the subsurface	medium	well deliverability negatively affected	leaving about 50% of the subsurface	
	not accurate geophysical model and poor identification of well targets	high	not accurate geophysical model and poor identification of well targets	leaving about 40% of the subsurface	
	misinterpretation of PVT	high	not accurate geophysical model and poor identification of well targets	leaving about 40% of the subsurface	
Fluid Flow	Management gas saturation	medium	reduced heat performance	leaving about 50% of the subsurface	
	geophysical production distribution	medium	drilling and logging, changing temperature	leaving about 50% of the subsurface	
	large hydrocarbon occurrence	high	drilling and logging, changing temperature	leaving about 50% of the subsurface	
	small hydrocarbon occurrence	high	drilling and logging, changing temperature	leaving about 50% of the subsurface	
geophysical production distribution	medium	drilling and logging, changing temperature	leaving about 50% of the subsurface		



Application of PSM in the area of St Gallen predicting gas accumulations at the bottom of the well as actually encountered during drilling (Omode Salé et al., 2019) <https://uncongeo.geoenergy.ch/>

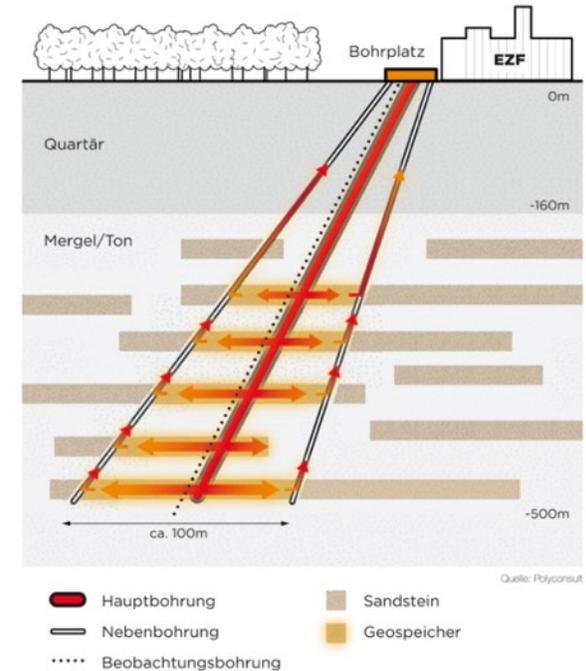
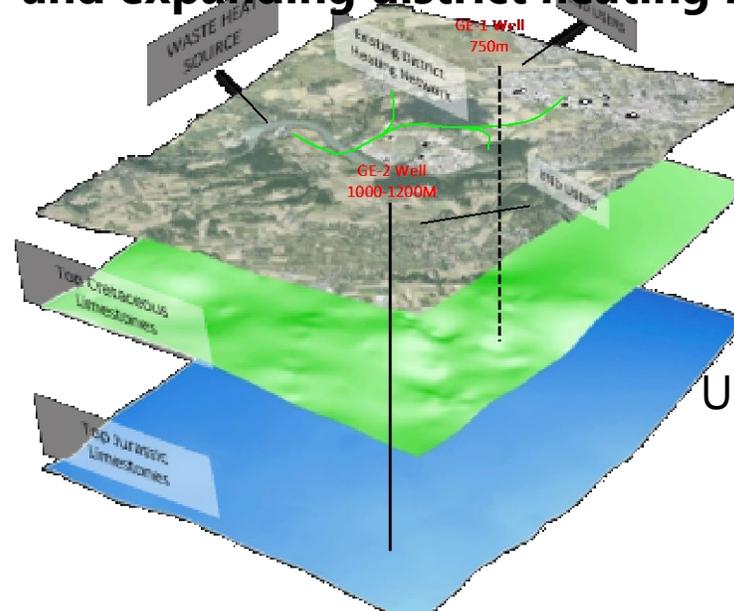
Table of uncertainties, risks and opportunities and Hydrocarbon risk maps showing the likelihood of encountering hydrocarbons associated with geothermal exploration

# Hydrothermal heat exploitation and storage



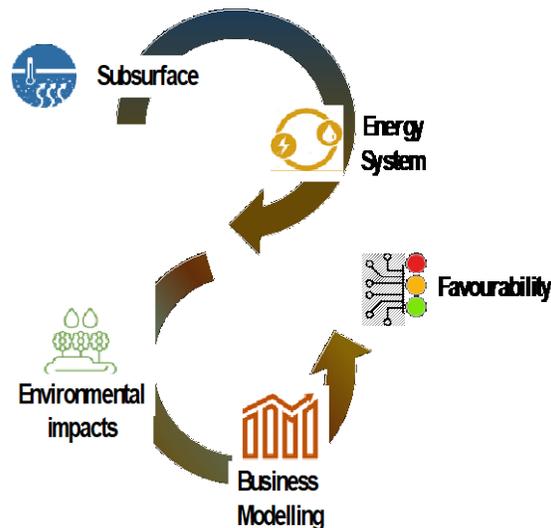
Underground heat storage in fractured Mesozoic carbonates

Loading cycle during summer; un-loading during winter into the existing and expanding district heating network



Underground heat storage in sandstones of the Lower Freshwater Molasse (USM)

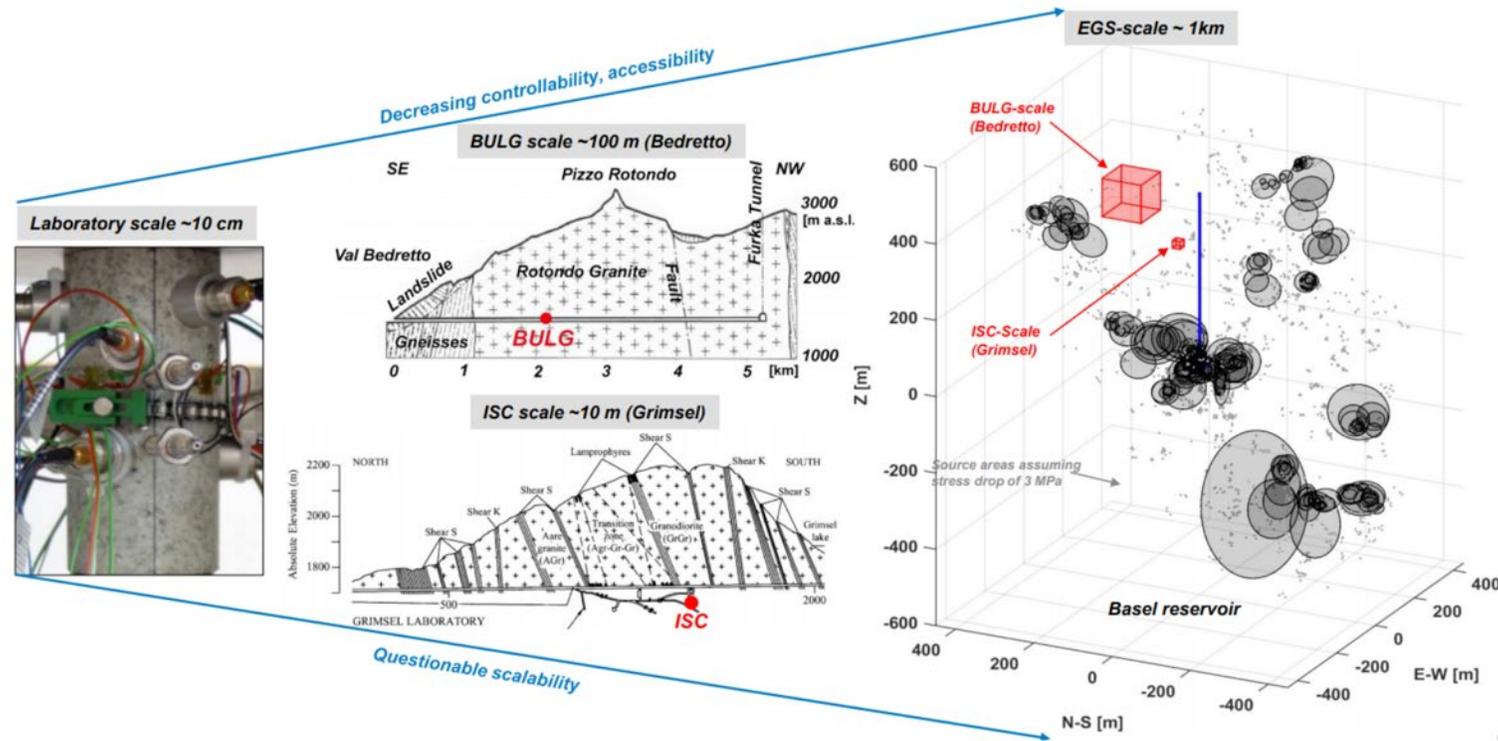
Loading cycle during summer; un-loading during winter into the existing and expanding district heating network



# Improved Reservoir Characterisation

For EGS projects understanding of the interplay between the FRACTURE NETWORK, the IN-SITU STRESSES and the SEISMICITY is of crucial importance.

In Grimsel and Bedretto these challenges are investigated at different scales to define the optimal procedures to implement EGS systems



# Improved Reservoir Stimulation



The GRIMSEL "In-situ Stimulation and Circulation (ISC) project aimed at a better understanding of HYDRO-SEISMO-MECHANICAL coupled processes that are associated with HIGH PRESSURE FLUID injections in a CRYSTALLINE ROCK mass. Experiments were carried out at laboratory scale (a few centimeters) and at intermediate scale (a few tens of meters).

The project was divided into three

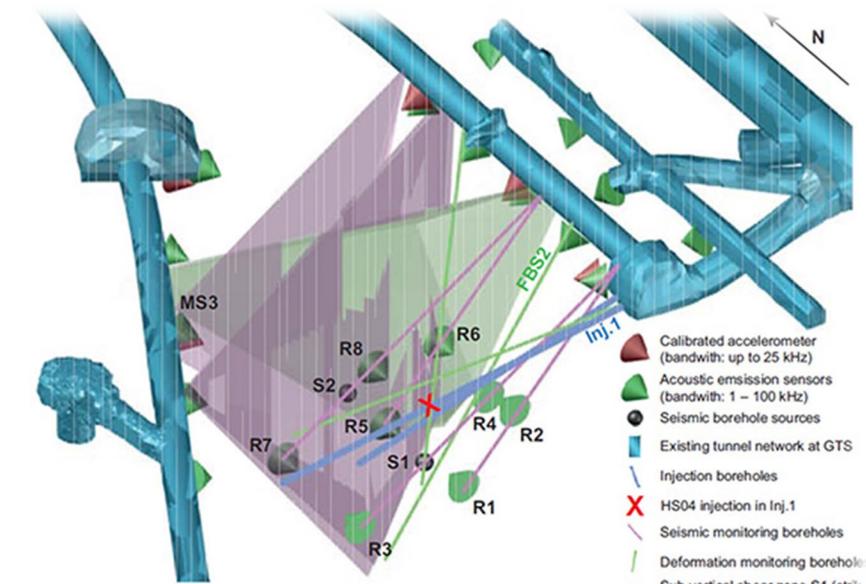
main phases:  
**Characterization**



**Stimulation**



**Circulation**



- Calibrated accelerometer (bandwidth: up to 25 kHz)
- Acoustic emission sensors (bandwidth: 1 – 100 kHz)
- Seismic borehole sources
- Existing tunnel network at GTS
- Injection boreholes
- HS04 injection in Inj.1
- Seismic monitoring boreholes
- Deformation monitoring boreholes
- Sub vertical shear zone S1 (striking North-East South-West)
- Sub vertical shear zone S3 (striking East-West)

# Improved Reservoir Stimulation

The BEDRETTO RESERVOIR PROJECT addresses questions associated with the validation of stimulation procedures and the sustainable utilization of heat exchangers in the deep underground



In the "Bedretto Underground Laboratory for Geoennergies", researchers study techniques and procedures for a safe, efficient, and sustainable use of geothermal heat.

To this end, a sufficiently permeable reservoir is necessary which is accessible on a long-term basis.

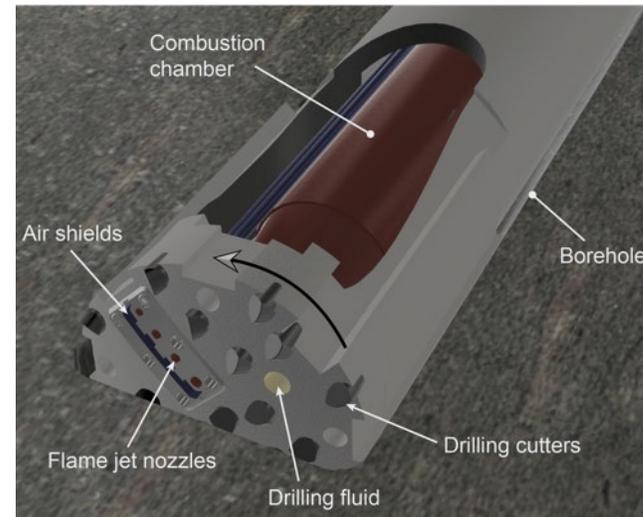


Researchers are conducting different experiments focusing on the geothermal processes involved. By drilling several boreholes, allowing to collect rock cores for rock characterization and to place a variety of sensors to track even the smallest changes in stress, pressure, and fluid movements.

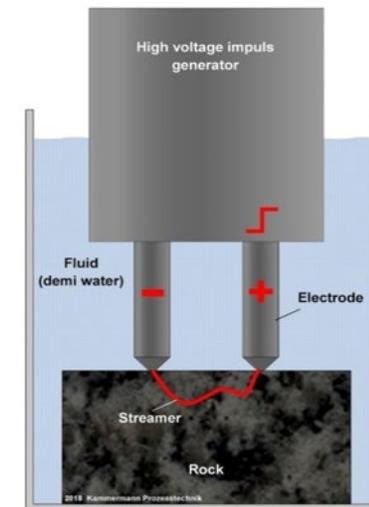


# Improved Drilling Engineering

Drilling and completion activities represent one main cost component of any geothermal development project. Indeed, accessing deep (>3km) geothermal resources, typically found in hard crystalline rocks (such as granites can account for more than 50% of the overall project costs due to the complexity of the operations



Schematic view of the Combined Thermo-Mechanical Drilling (CTMD) technology (Rossi et al., 2020)



(PPGD) principle, (Rossi et al., 2020)

Combined Thermo-Mechanical Drilling (CTMD) based on removing the rock by thermal loading and Plasma-Pulse Geo-Drilling (PPGD) which is a contact-less drilling technology that uses high-voltage electric pulses to break the rock have been studied to propose innovative technology to facilitate drilling operations for deep

Geothermal Energy covers a wide range of applications but to successfully achieve the full potential of the geothermal development, several key challenges can be identified:

- **Subsurface characterization** by extracting the maximum values from borehole data, by adopting as a standard high-resolution exploration and monitoring methods, THMC modelling, Machine Learning and Artificial Intelligence techniques
- **Energy System integration** to define the «what, where, why» of geothermal energy supply
- **Improvements of the legal framework** to remove current barriers to industrial development
- **Increase the economic viability of deep projects** by reducing the costs of drilling, combining Heat, Power and Metal Extraction
- **Improvement of the social perception**

# From Science to Fork

Geothermal Cheese(ITA)



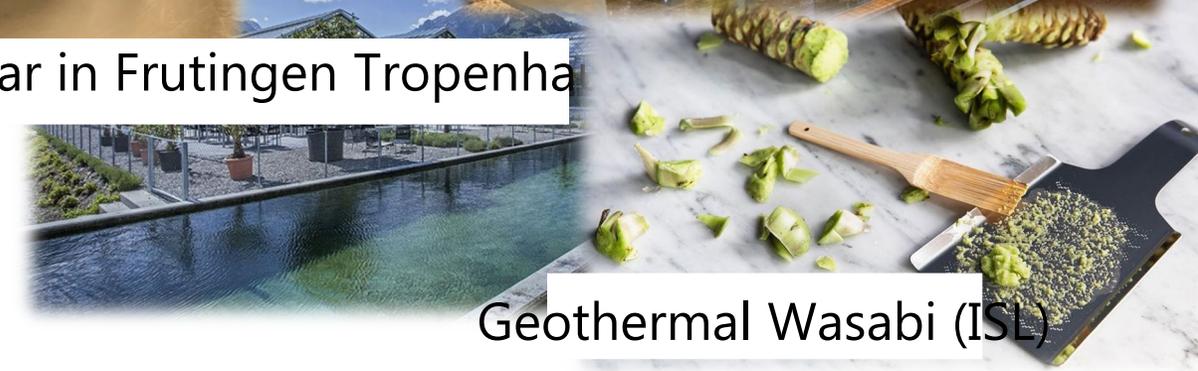
Geothermal Tomatoes in Schlattingen (TG)



Geothermal Beer (ITA)



Geothermal Caviar in Frutigen Tropenhaus



Geothermal Wasabi (ISL)

## Geothermal Food



Source: Guglielmetti et al. 2020  
@GeothermalPills

# Thank you



**Energy**

Swiss Competence Centers for Energy Research



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