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# White Paper on Geothermal Energy

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Luca Guglielmetti, University of Geneva

Energy
Swiss Competence Centers for Energy Research

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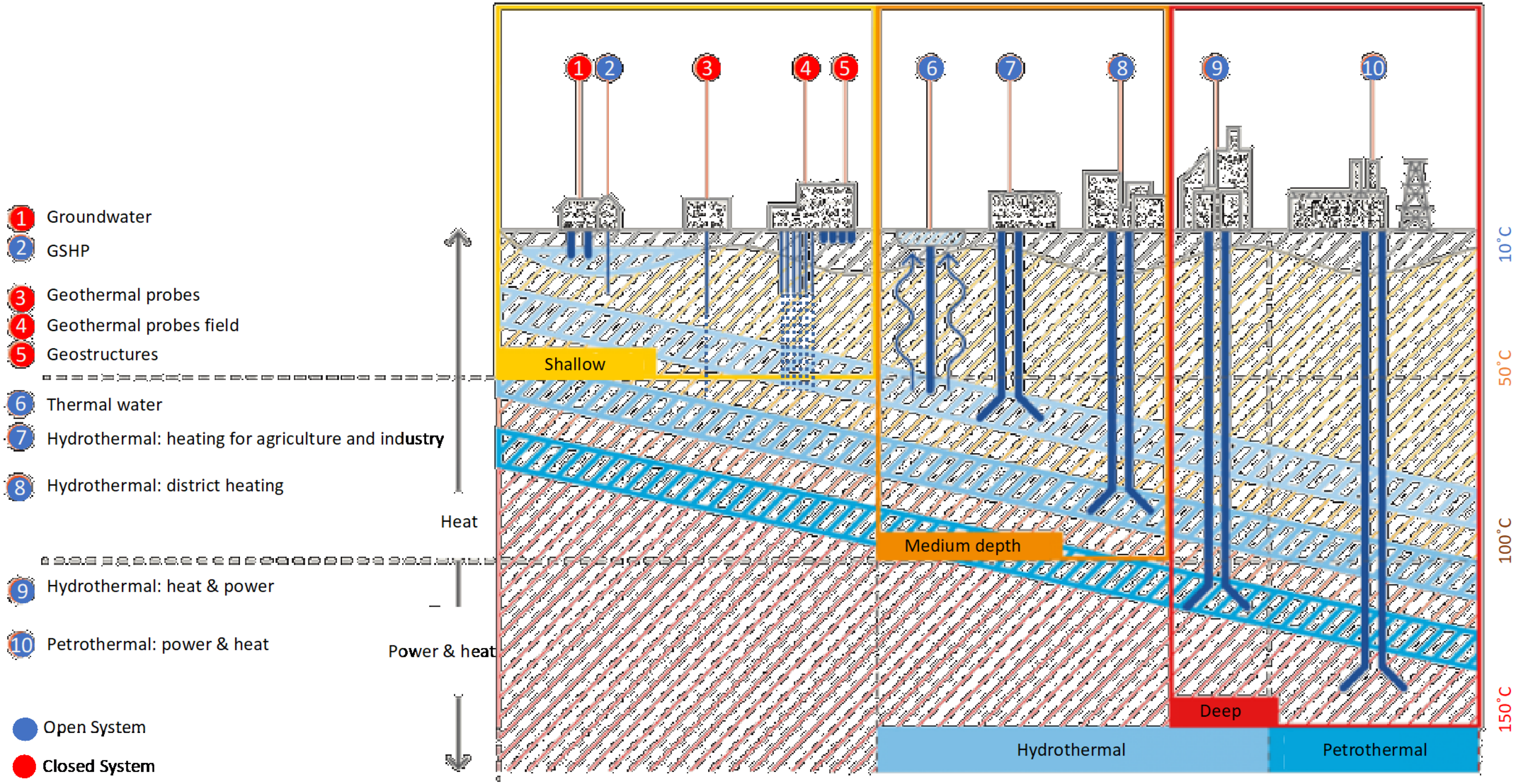
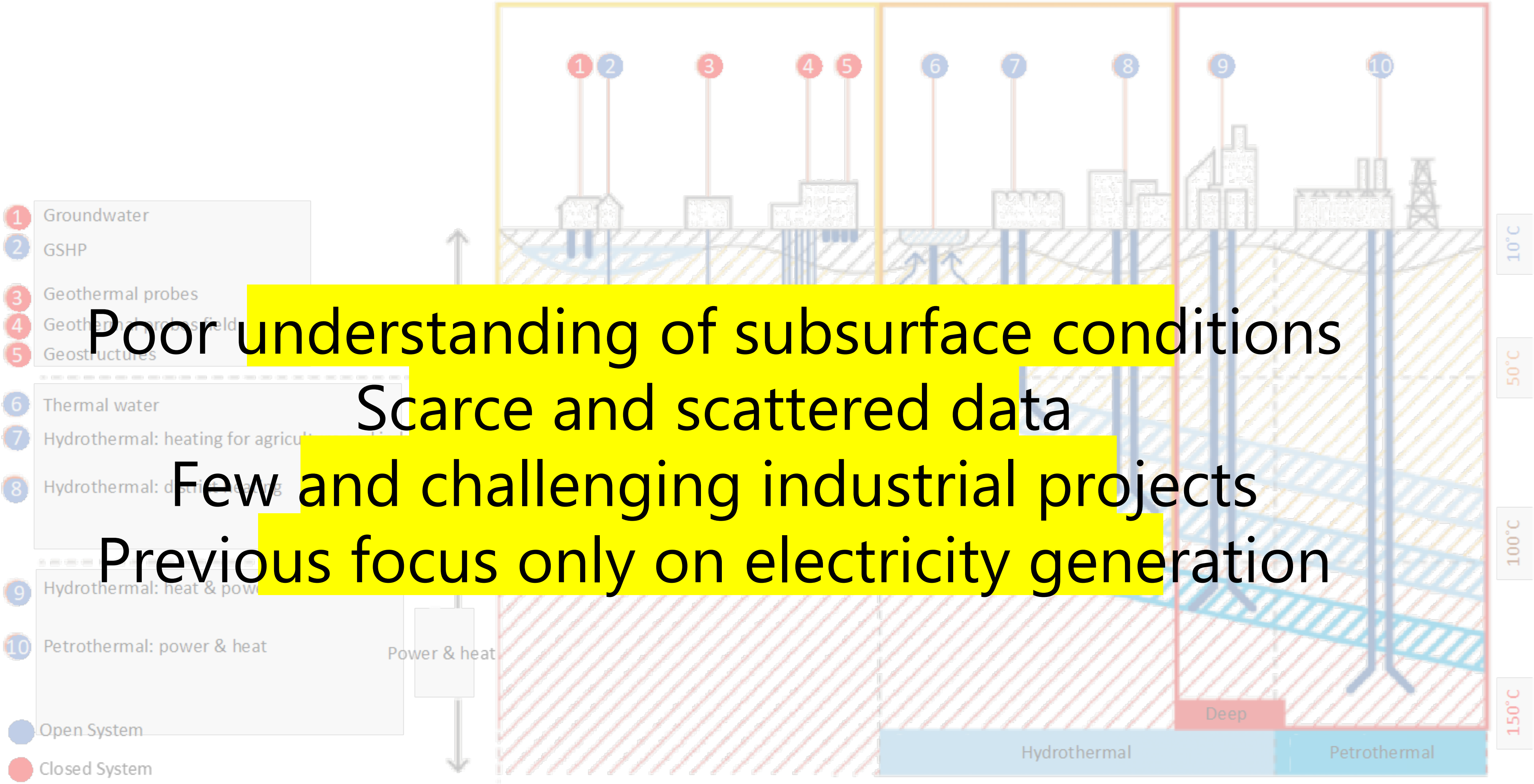
# Opportunities and Challenges for deep Geothermal in Switzerland



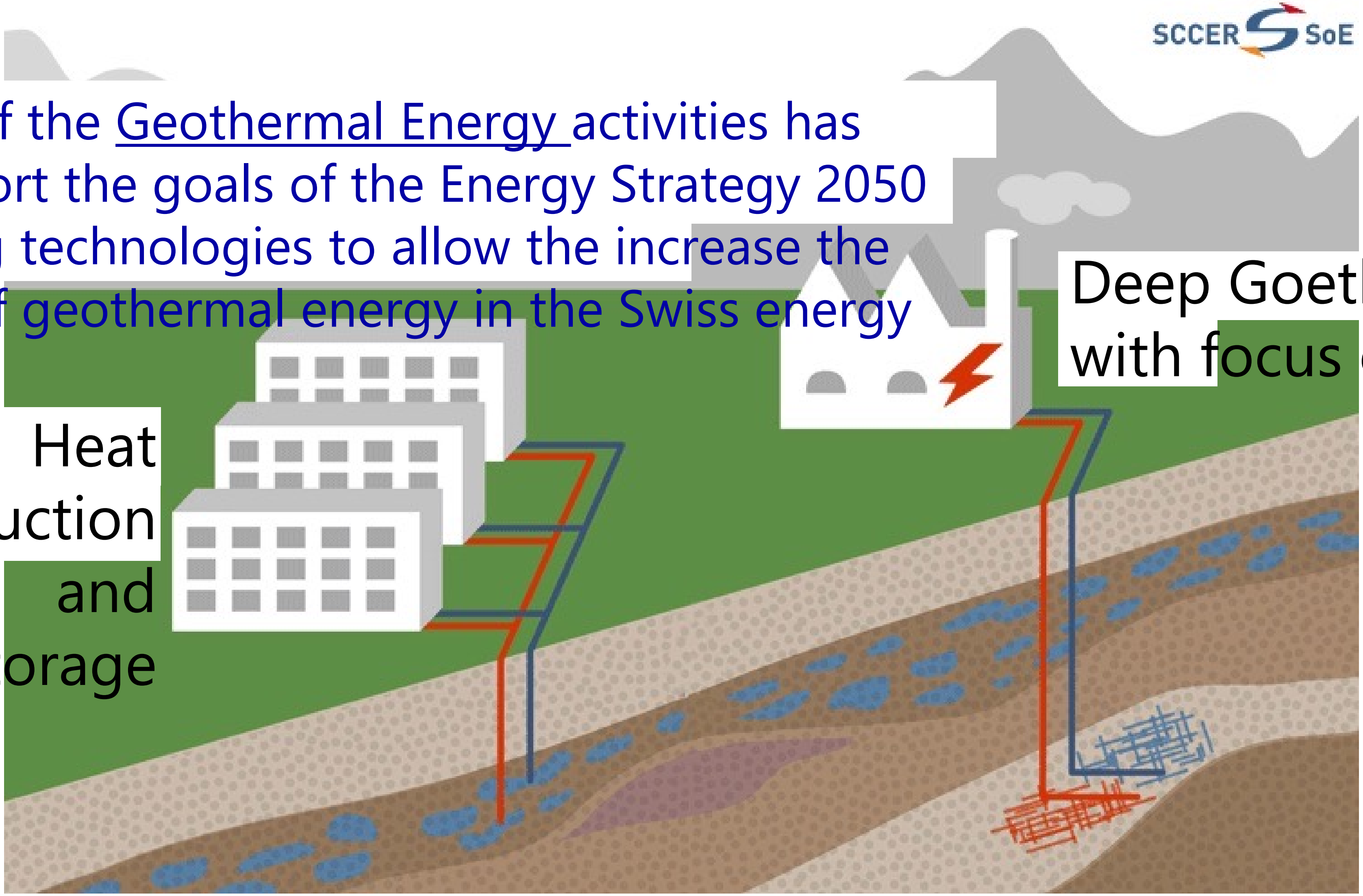
# Opportunities and Challenges for deep Geothermal in Switzerland




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 Goethermal with focus on EGS

# SCCER-SoE Geothermal Energy Research

## Geo-data infrastructure and analysis

Infrastructure to facilitate data access and exchange

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## 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/EGS: Grimsel, Haute-Sorne, Bedretto

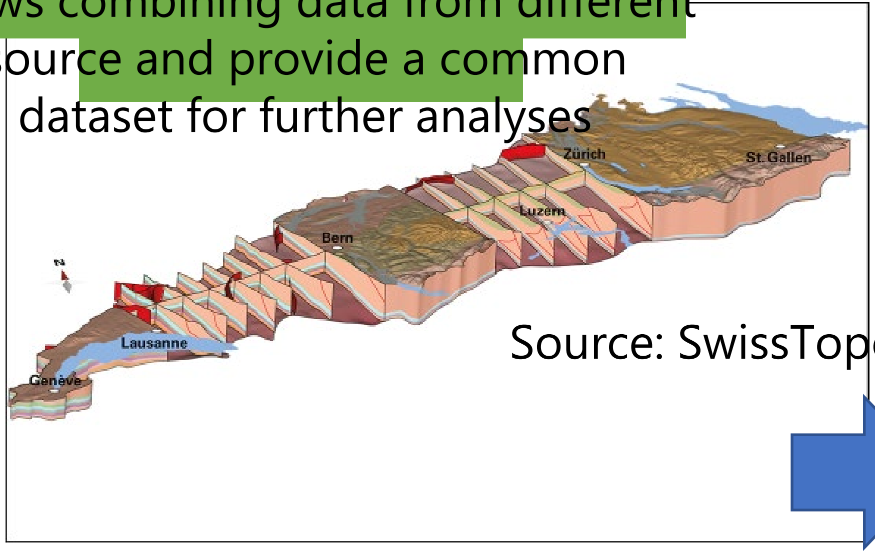
Sedimentary: Geneva Basin

## Reservoir stimulation and engineering (EGS)

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

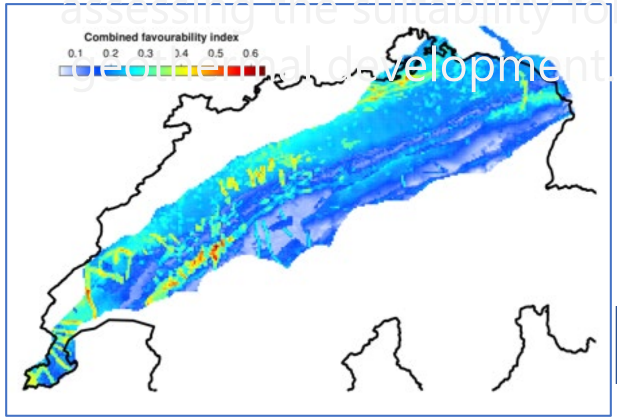
# SCCER-SoE Geothermal Energy Research

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



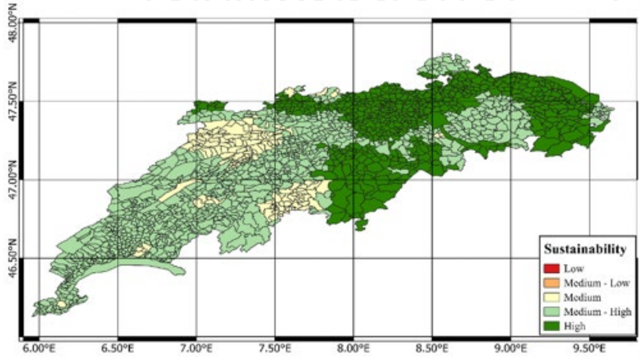

Source: SwissTopo

Subsurface models like the GeoMol model provides opportunities for identifying GEOTHERMAL PLAYS and assessing the suitability for geothermal development




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

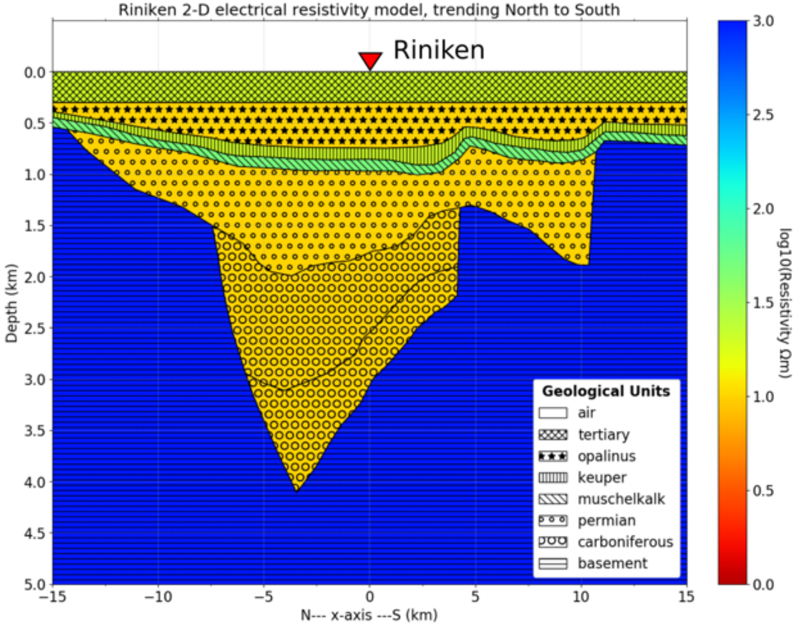
Possible power plant locations are constrained by GEOLOGICAL conditions as well as ECONOMIC,




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

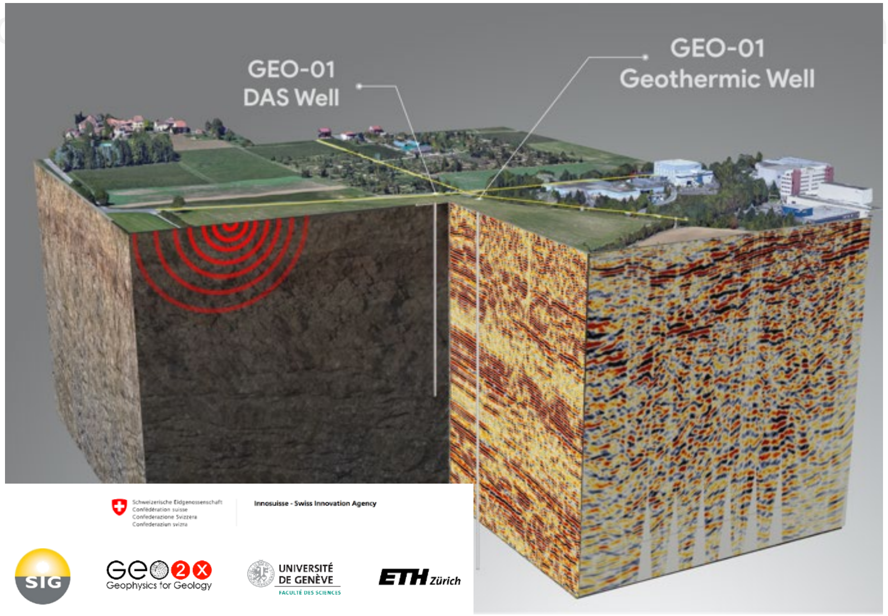



2-D electrical resistivity model for the MT station near the Riniken borehole. (Picture provided by Saar et al.)

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

are used to improve the resolution at the

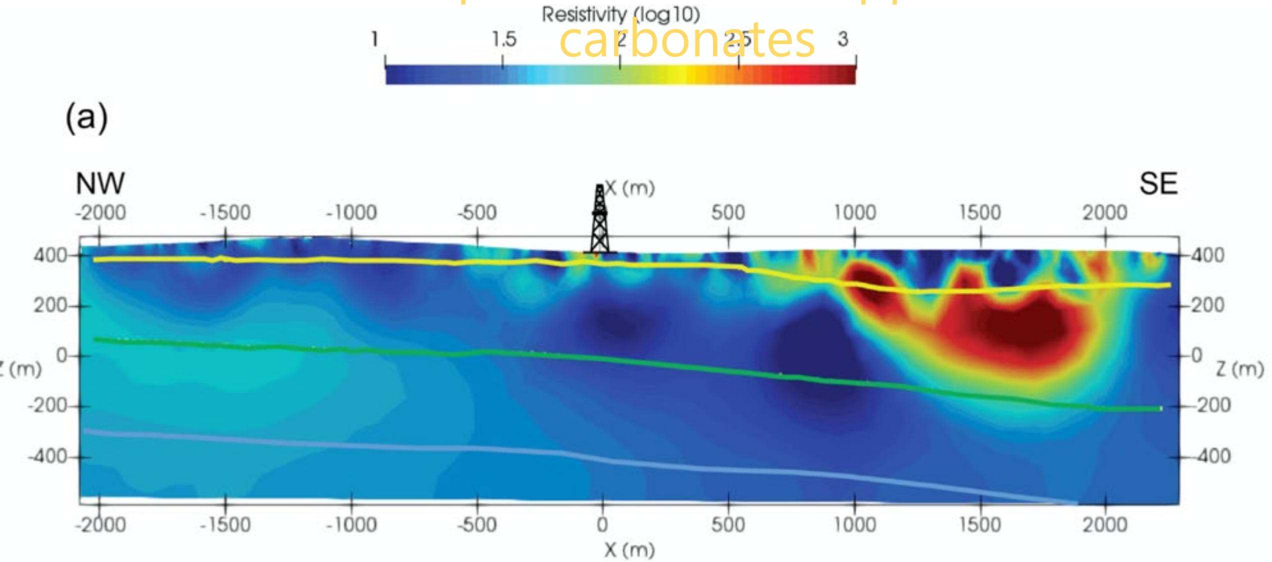
regi




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

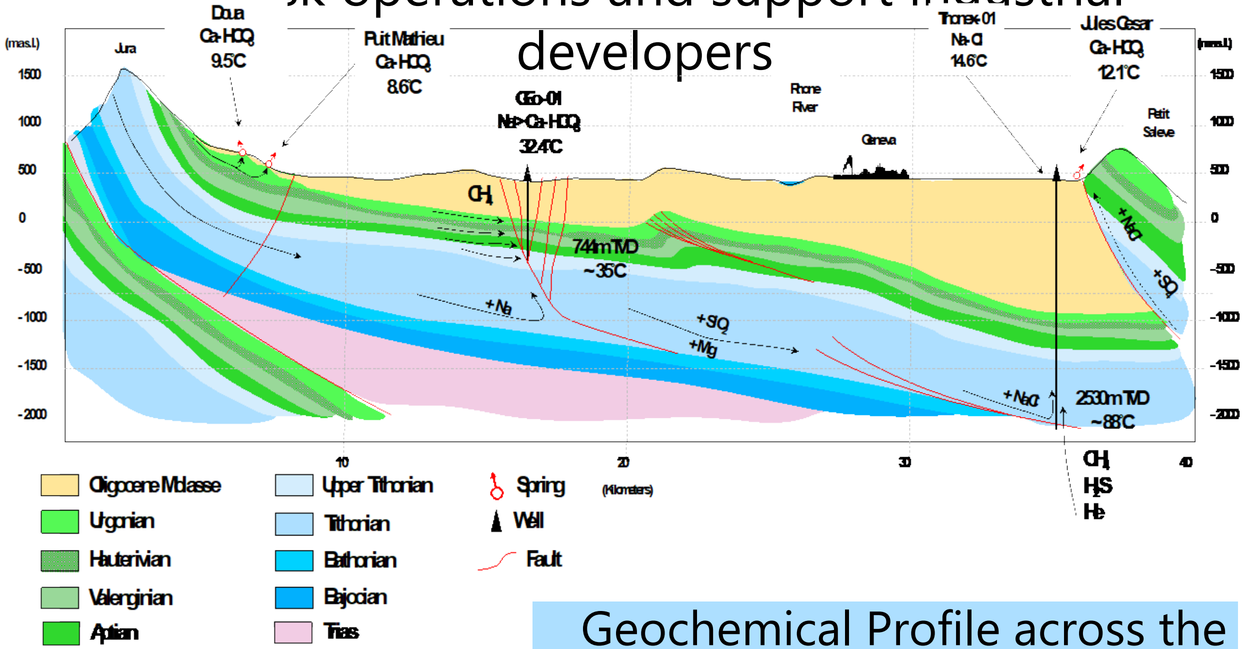
# Improved Exploration Methods

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

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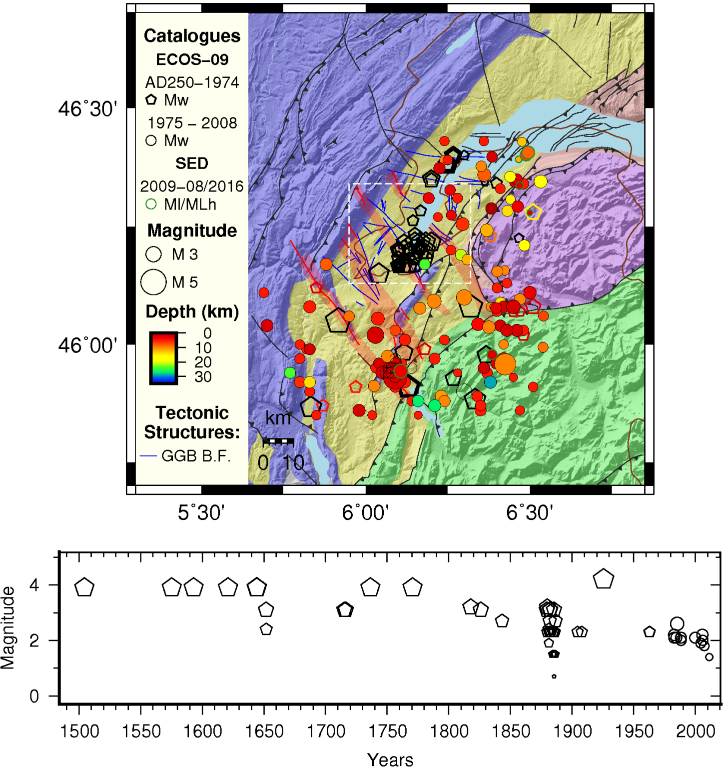
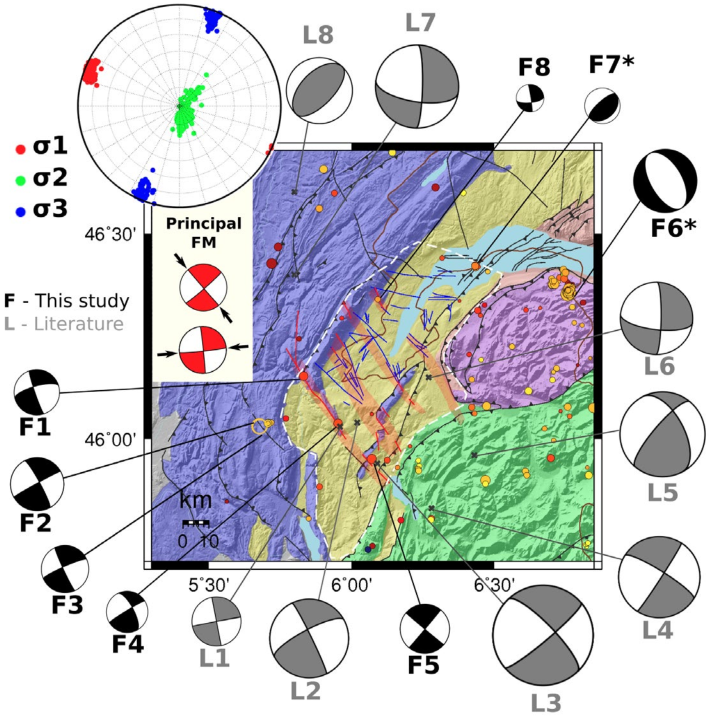
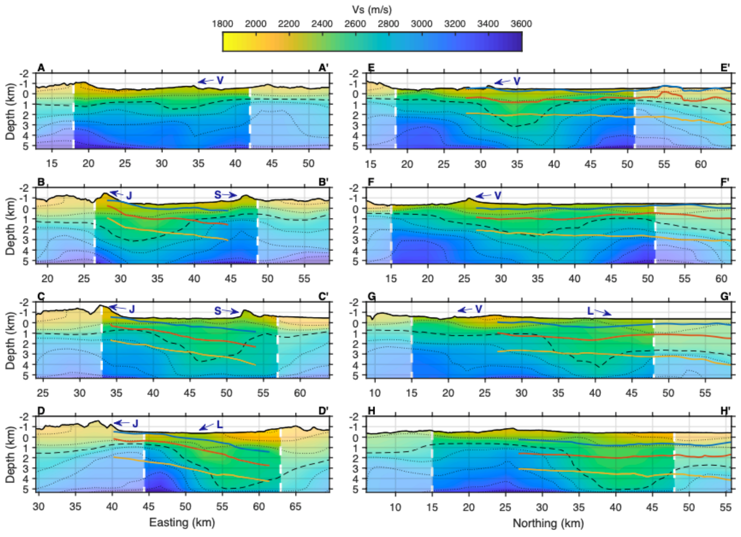



Antunes et al., 2020




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

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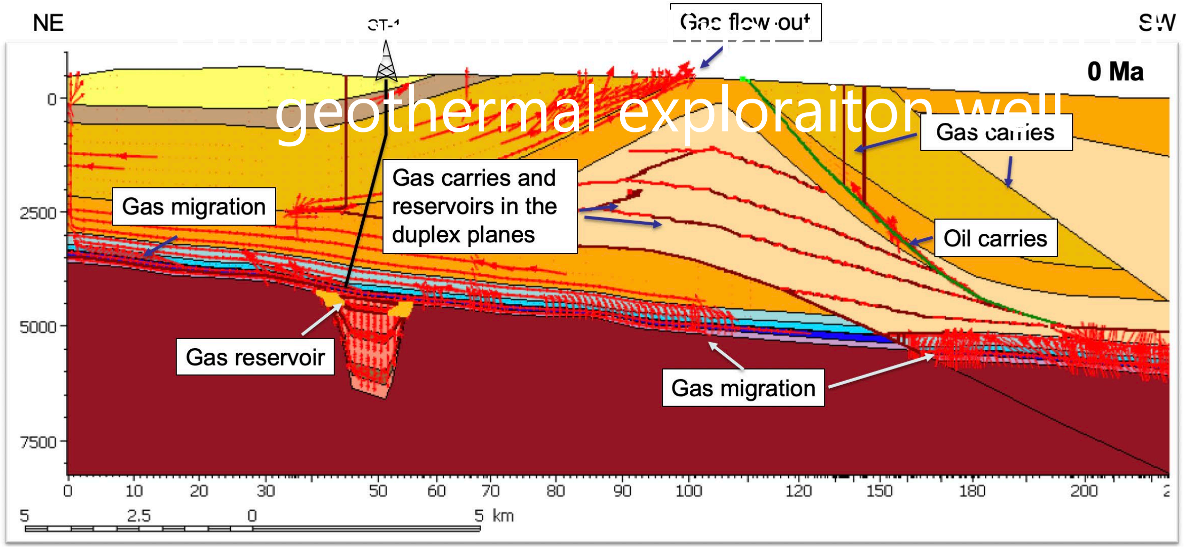
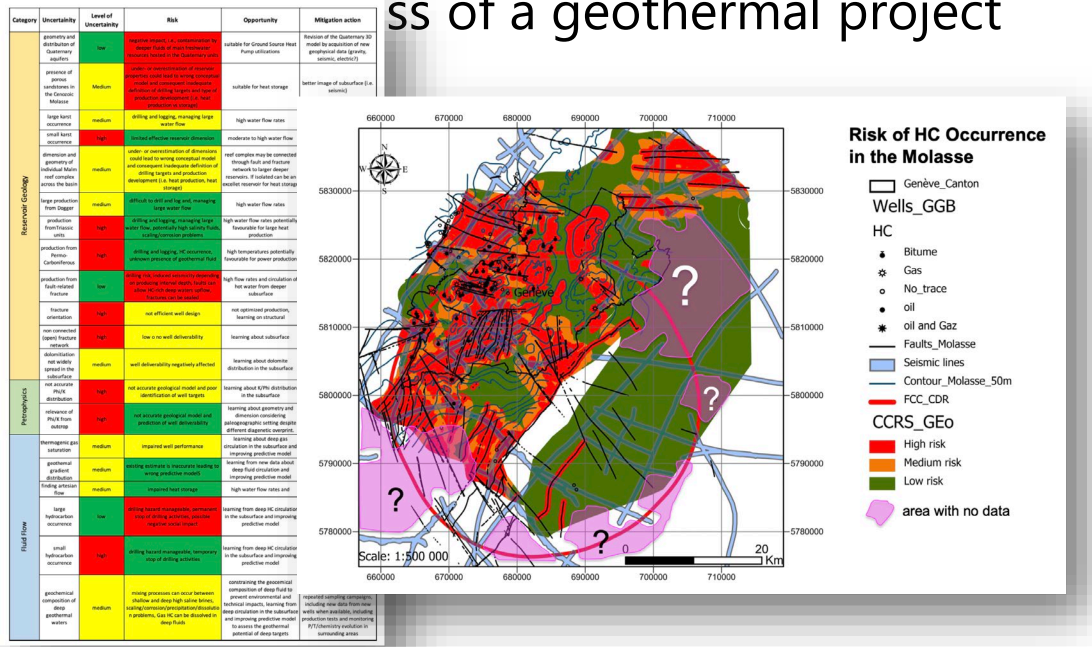
UNCONGEO: Petroleum system modeling applied to deep-gothermal play helps identifying and quantifying the risk of
ence of hydrocarbon
geothermal exploraiton well




Uncertianity, Risk & Mitigation Table and Risk Maps helps ideitifiing and visualising key parameters likely controlling the
ss of a geothermal project




Application of PSM in the ara of St Gallen predicting gas accumulations at the bottom of tth well as actually encoutered during drilling (Omode Salé et al., 2019)

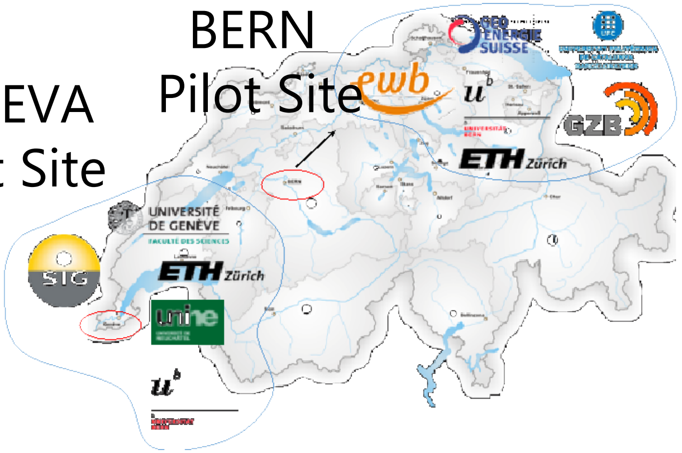
https://uncongeo.geoenergy.ch/

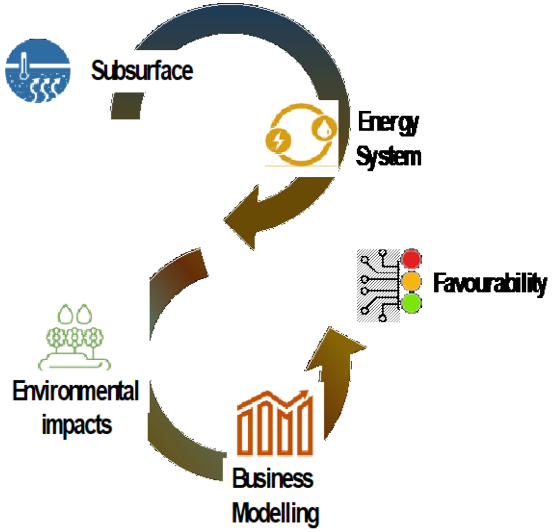
Table of uncertainties, risks and opportunities
and Hydrocarbon risk maps showing the likelohood of encoutering hydrocarbons associated with geothermal exploration

# Hydrothermal heat exploitation and storage

GENEVA Pilot Site

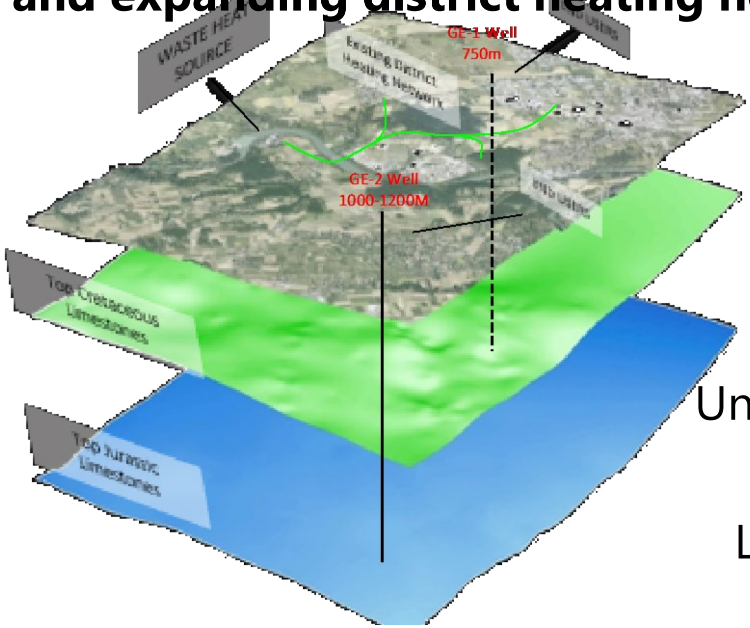
BERN Pilot Site

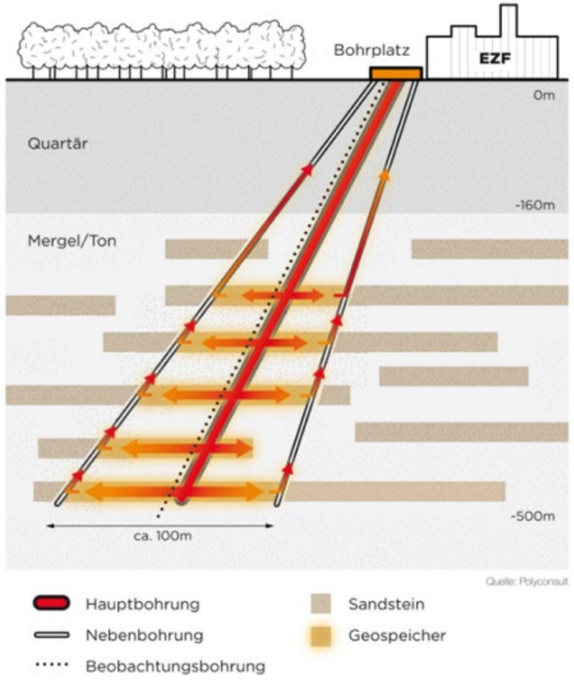



**Underground heat storage in fractured Mesozoic carbonates**

**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

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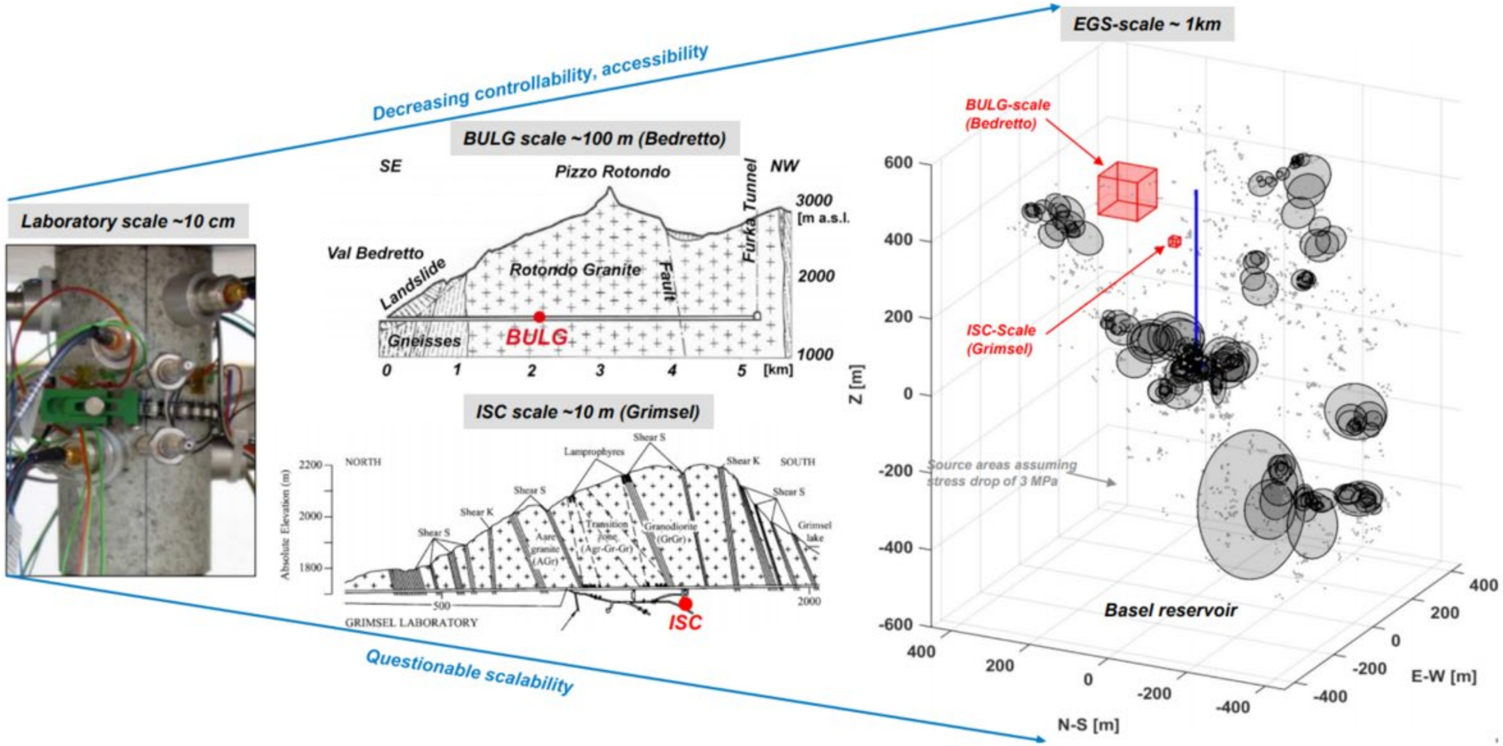
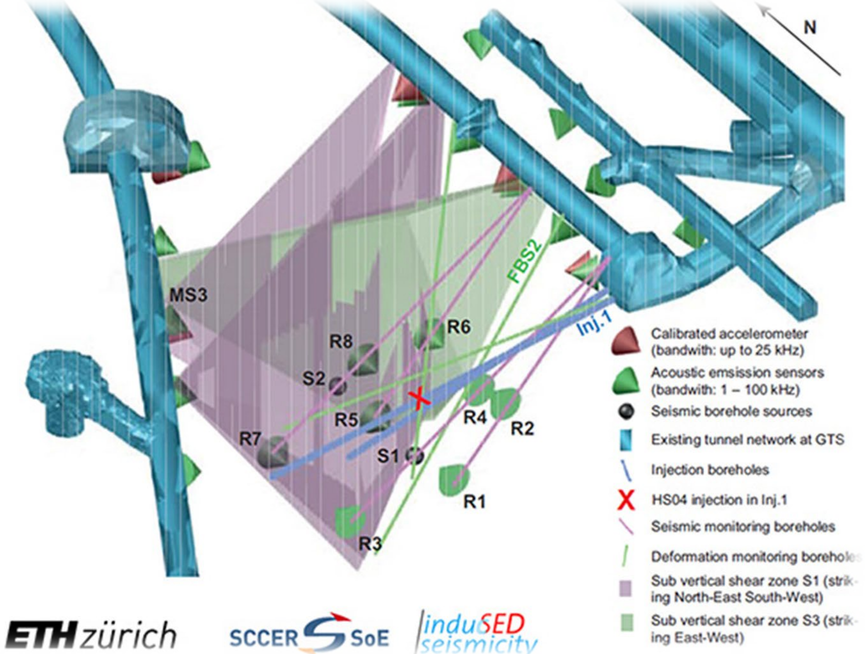
For EGS projects understanding of the interplay between the FRACTURE NETWORK, the IN-SITU STESSES and the SEISMICITY is of crucial importance.
In Grimsel and Bedretto these challenges are investigated at different scales to define the optimal procedures to implement EGS systems



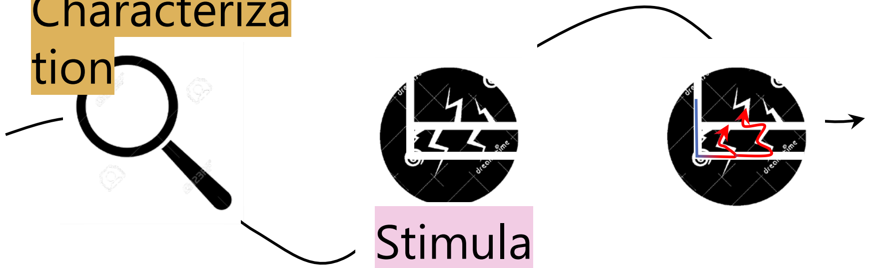
# Improved Reservoir Stimulation

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

# Improved Reservoir Stimulation

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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 Geoenergies”, researchers studiy 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.

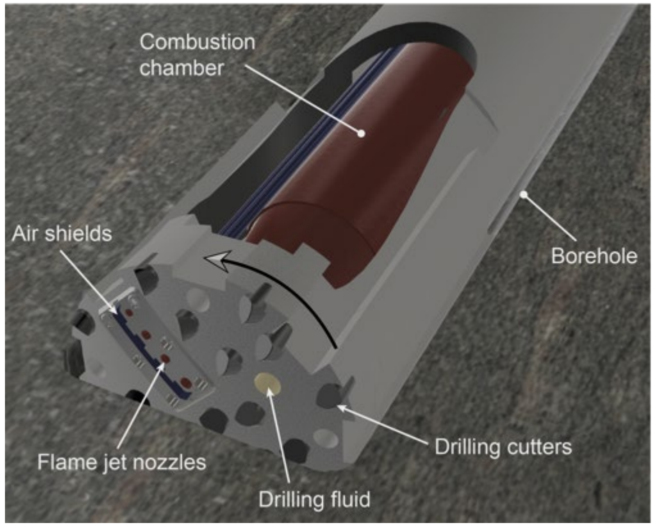
Researchers are conducting different experiments focusing on the geothermal processes involved.

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.

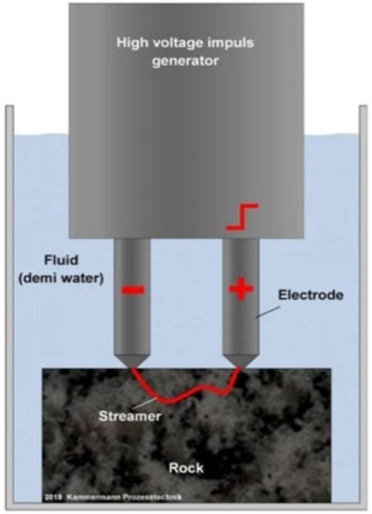
Pictures from http://www.bedrett

# 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

# Recommendations from SCCER-SoE

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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


Source: Guglielmetti et al. 2020
@GeothermalPills

Geothermal Tomatoes in Schlattingen (TG)

Geothermal Cheese(ITA)

Geothermal Beer (ITA)

Geothermal Caviar in Frutingen Tropenha

Geothermal Wasabi (ISL)

# Thank you

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