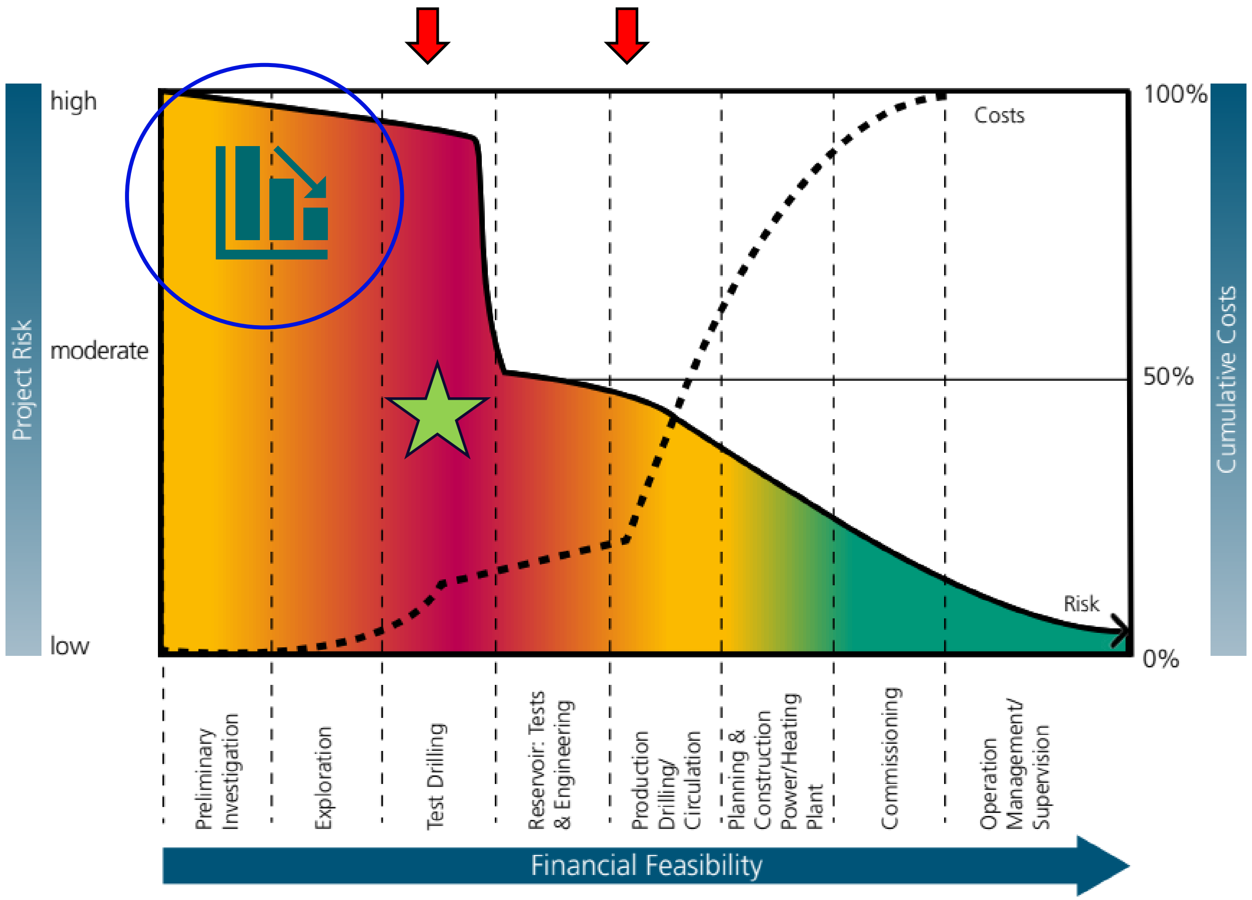
Geothermal Geosolutions: soluzioni integrate per la caratterizzazione, modellazione e riduzione del rischio

Luca Masnaghetti, SLB

Geothermal project lifecycle and economics



Modified after ESMAP, Technical Report 002/12

→ Crucial problem: **identify and characterize the geothermal resource**

→ Drilling the costliest phase, but…

→ Targeting the wells successfully is the game-changer

→ Key parameters:

- Permeability
- Temperature

→ Strategy

- **Understand the subsurface better**
- Reduce the risk early!

GEO ExPro
THE GLOBAL ENERGY SECTOR FROM A SUBSURFACE PERSPECTIVE

Hamburg geothermal well should have been drilled in another location

Based on a published conceptual geological model of the target reservoir, it is not a surprise that the well disappointed.

By Henk Kombrink November 17, 2022

GEO ExPro
THE GLOBAL ENERGY SECTOR FROM A SUBSURFACE PERSPECTIVE

Geothermal

What went wrong in Leeuwarden?

By Henk Kombrink March 15, 2022

Last year, **a geothermal well** was drilled near the city of Leeuwarden in the north of the Netherlands. The target of the borehole was the Rotliegend of the Friesland Platform, a relatively stable structural element where the Rotliegend had already been proven by previously drilled hydrocarbon exploration wells.

Yet, the **project reported disappointing test results** once the reservoir had been penetrated.

Geothermal project at Lavey-les-Bains, Switzerland unsuccessful

For Geothermie Suisse, the umbrella organization for the geothermal industry in Switzerland, the outcome of the Lavey-les-Bains project proves that the risk association with exploration of the subsurface must not be carried by the business or individual developers. As Switzerland has no oil, gas, or mining tradition, there is very little information on its subsurface. Thus, the risk of failure in geothermal is higher than other renewable energies. To obtain equal treatment, the geological risk must be fully borne by the Confererderation.

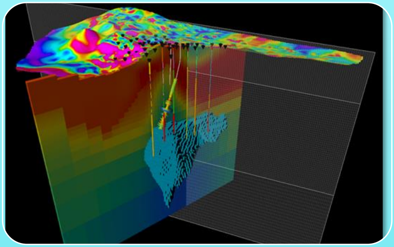
Winter view of Les Bains de Lavey, Switzerland (source: Les Bains de Lavey)

Carlo Cariaga

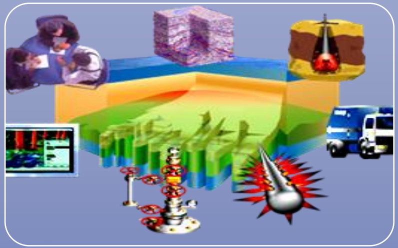
26 Sep 2022

Flowrate of the drilled well at Lavey-les-Bains, Switzerland will not be enough to support the planned geothermal power plant. The rig will now move to the next planned site at Vinzel.

What can we do?



Leverage data-driven, **geophysics-centered** solutions performed on a **digital infrastructure** to perform the workflow



Impact the whole **subsurface characterization workflow** for **geothermal** E&P

From geophysical **inversion** and **resource characterization to geological** and **geothermal modeling**.

Influence drilling decisions

Geothermal modeling engine and **subsurface knowledge-sharing** directly linked **to drilling** and **site development** planning.

Geothermal answer products

Geothermal potential analysis

Geophysics

Seismic, EM, gravity

Reservoir characterization

Multiphysics rock properties

Thermal modeling

Heat-in-place

Risk assessment

Porosity and permeability estimation

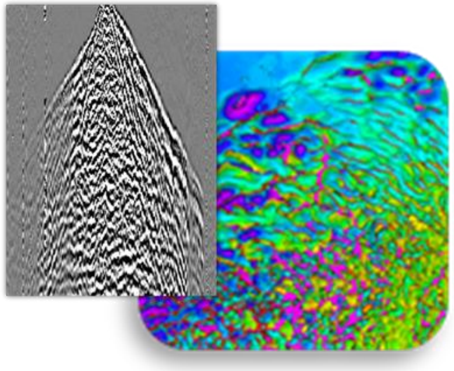
Pore-pressure prediction

Drilling risk

Seismic-driven geothermal exploration

Geophysics
Seismic, EM, gravity

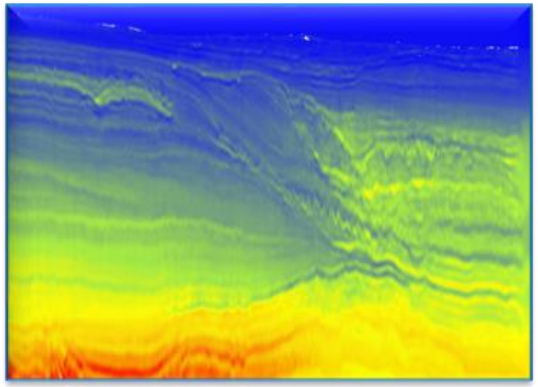
G&G Data



Exploit data

- 2D Seismic, 3D seismic
- Well logs
- Gravity, magnetics, elevation data

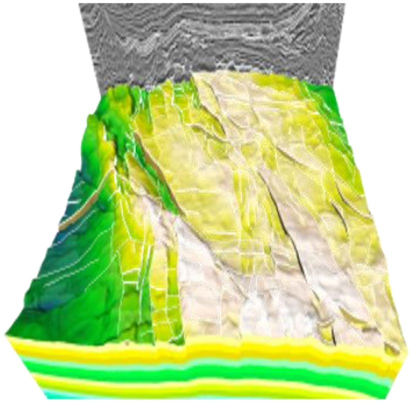
Seismic Processing and Imaging



Deliver from design to imaging

- Survey design and QC
- Advanced noise attenuation
- Near-surface modeling
- 5D interpolation
- Advanced imaging

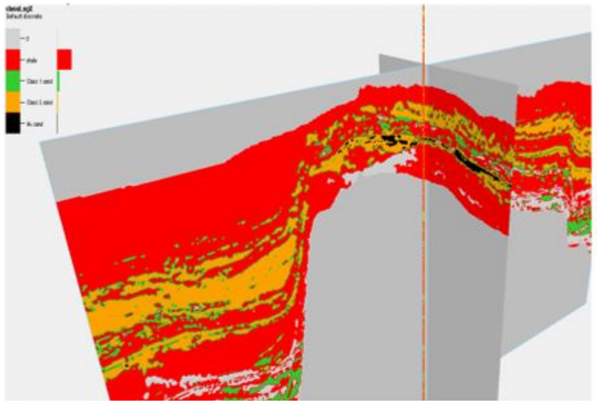
Seismic Interpretation and Attribute Analysis



Delineate subsurface structures

- Geological boundaries
- Geothermal reservoir and caprock
- Fluid flow elements (Faults and Fractures)

Rock Physics and Seismic Inversion



Determine reservoir parameters

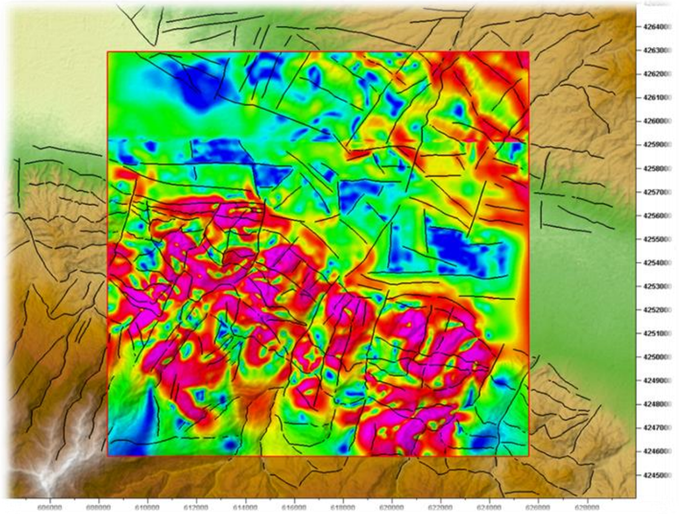
- 3D porosity distribution
- Lithology classification
- 3D thermal conductivity distribution

Geophysics
Seismic, EM, gravity

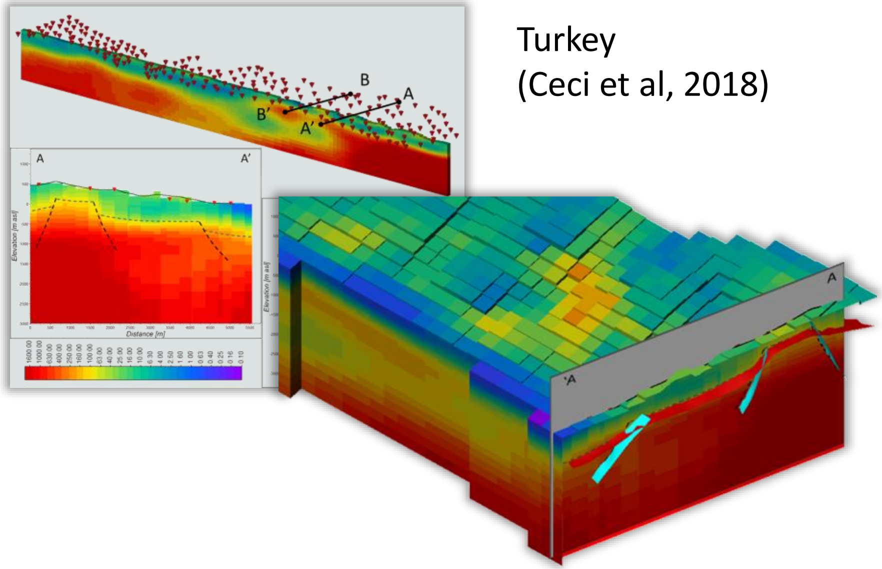
Multiphysics for geothermal exploration

Geophysics

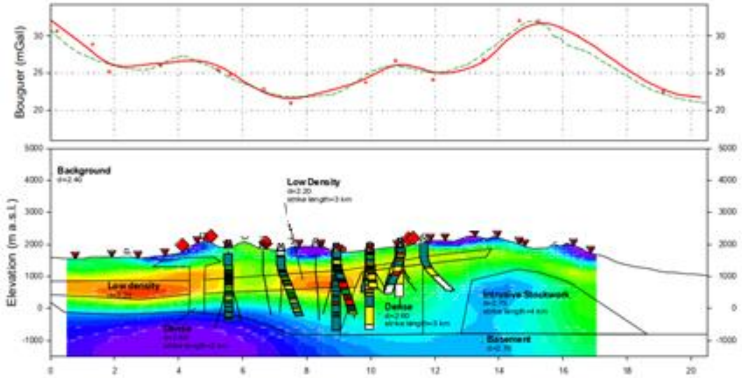
Seismic, EM, gravity



Turkey (Bancalà et al, 2017)



Turkey
(Ceci et al, 2018)



Indonesia

IDENTIFICATION — EXPLORATION CONFIRMATION — DEVELOPMENT MONITORING

Magnetotellurics, Gravity
- Small- / large-basin scale definition and geological framework
- Structural lineaments, fault detection

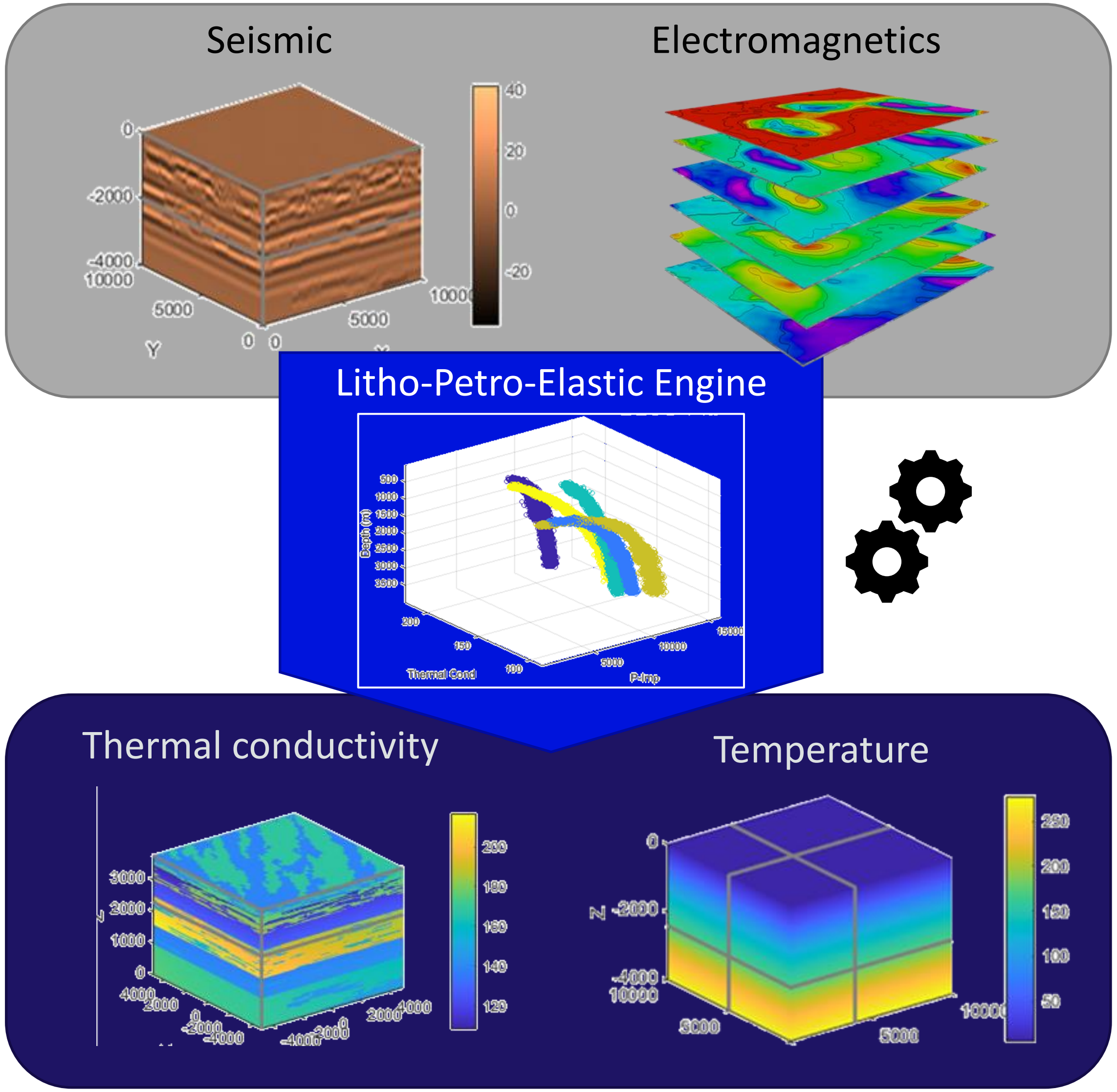
Magnetotellurics, Gravity
- Lithology change mapping
- Near-surface modeling
- Rock physics characterization

Magnetotellurics, μ-Gravity, X-well EM
- Well planning
- Time-lapse reservoir monitoring (4D)
- Derisking for subsidence

Geophysical thermal characterization & modeling

Reservoir characterization
Multiphysics rock properties

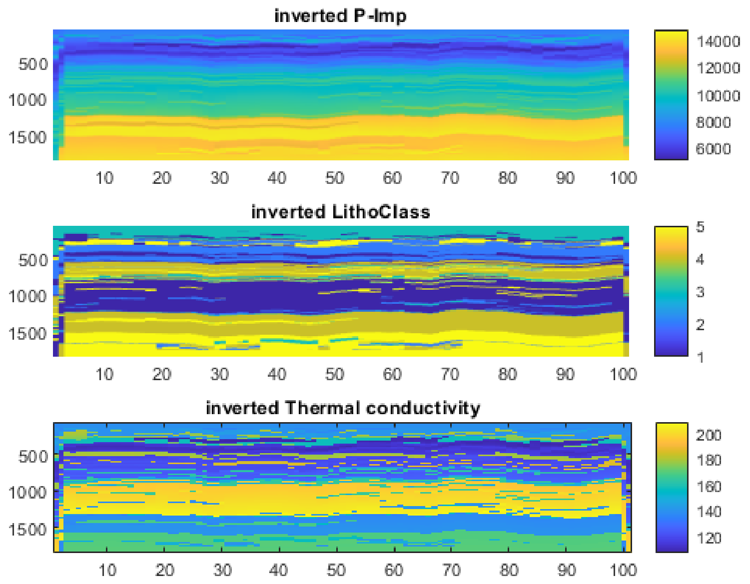
- → Highly automated solution
  - – Integration of EM and/or Seismic data
  - – Utilizing advanced LPE engines
  - – Estimate 3D subsurface thermal properties and temperature
- → Advanced coupled geothermal modeling and simulation engines
- → Transform subsurface models into engineering decisions

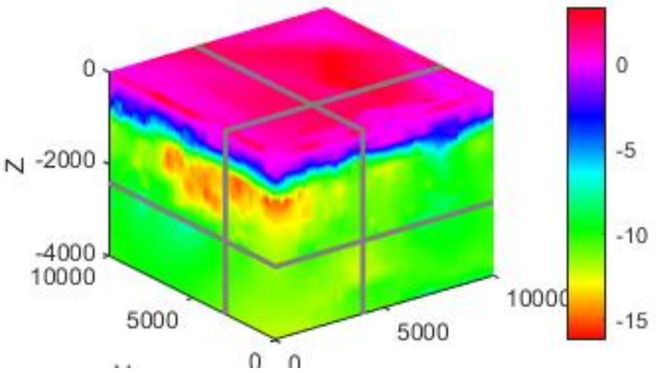


Inverse geothermal modeling

Thermal modeling
Heat-in-place

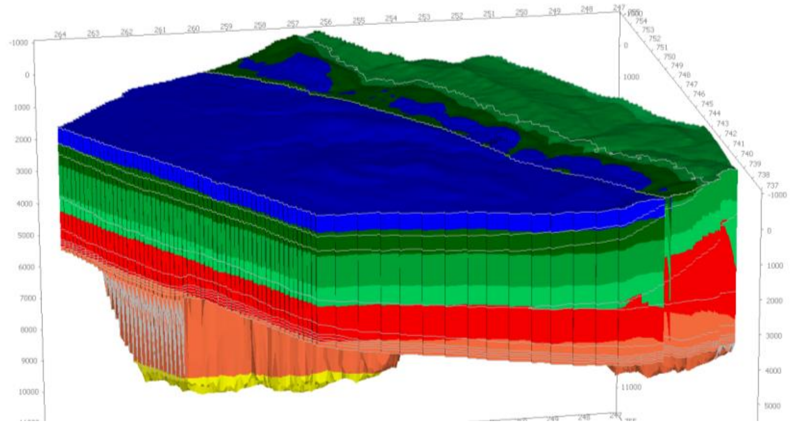
- Solve geothermal inverse problem
- From temperature measurements to thermal properties
- Using geophysical information and data assimilation techniques to integrate temperature and geophysical observation.
- To identify
  - potential geothermal "sweet spots"
  - potential deviations from background model

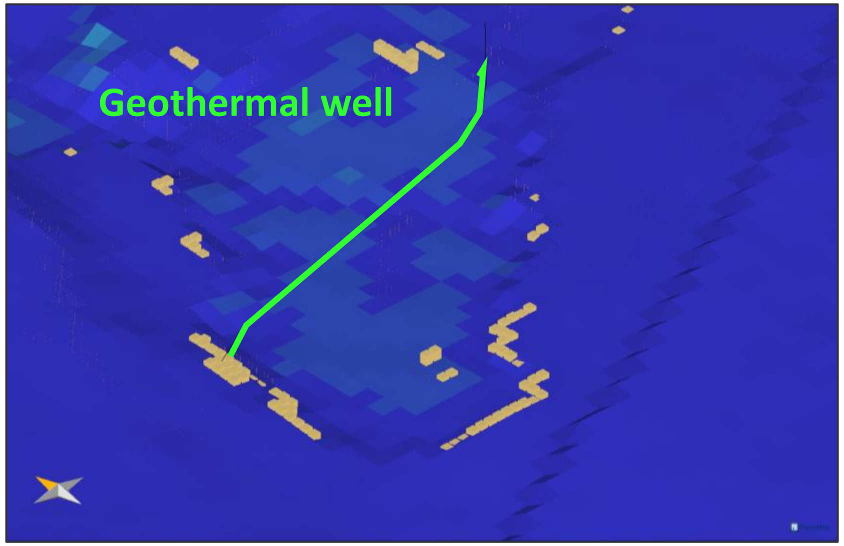




Drilling risk for hydrocarbon presence

- Assess the potential maturity of organic material
- Predict hydrocarbon presence in the sedimentary basin along the planned geothermal well trajectory
- Detect unexpected presence of overpressurized HC accumulations.
- Reduce blow-out risk

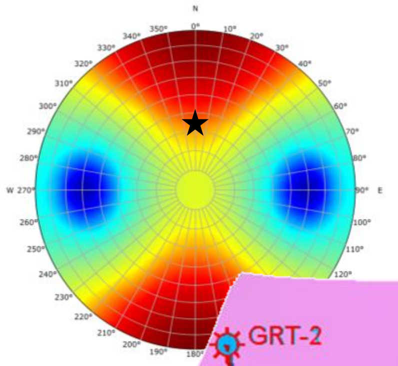




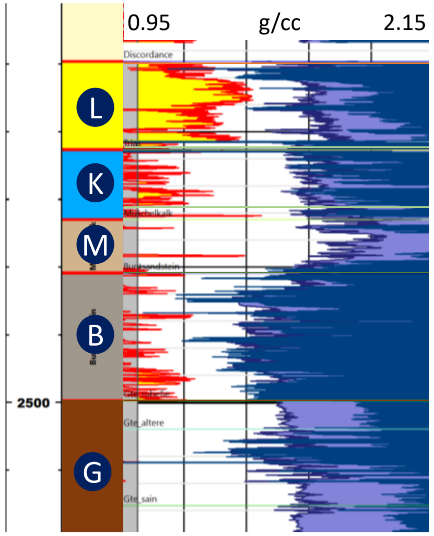
Switzerland (Omodeo-Salé, S. et al, 2020)

Geomechanical Risk Assessment

Drilling risk

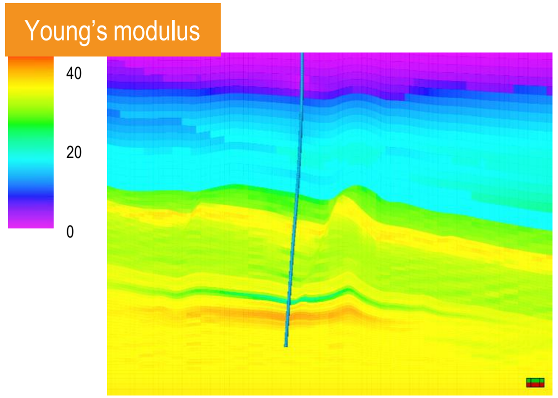


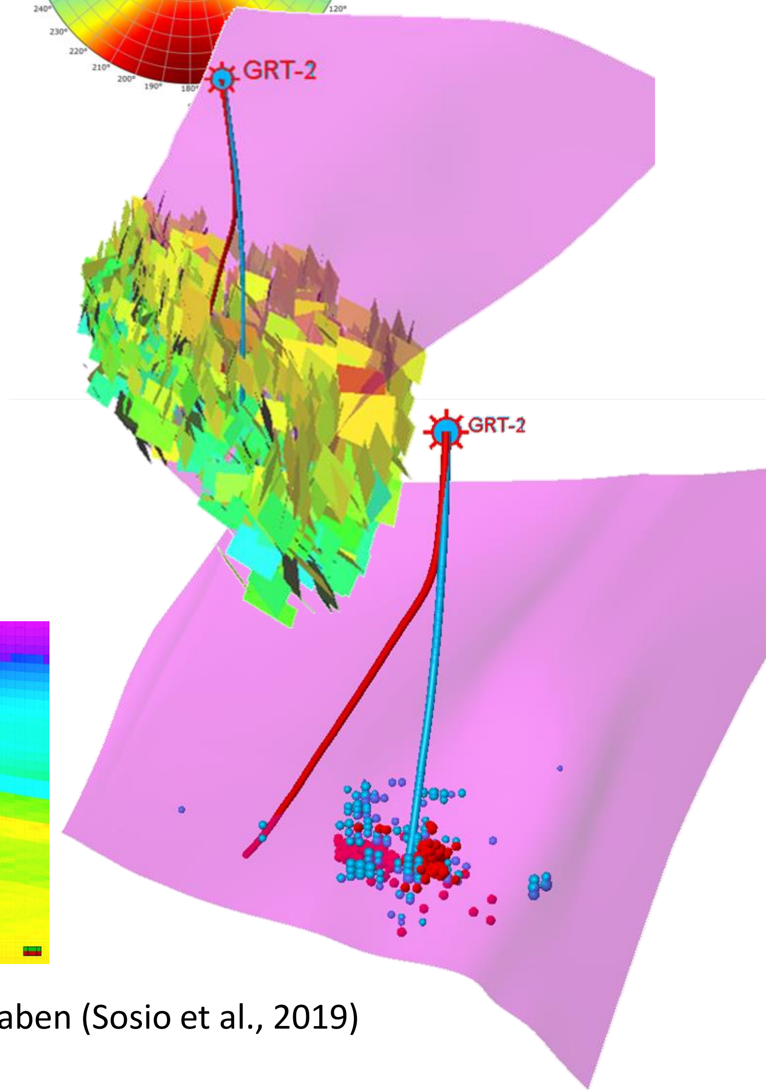
→ 3D mechanical earth model (MEM) populated with geo-solutions (e.g. inversion, fracture model)



→ One 3D MEM for several applications

- Drilling stability
- Wellbore integrity
- Subsidence/uplift
- Fault and reservoir stability
- Induced seismicity





→ Proven geothermal applications

Rhine Graben (Sosio et al., 2019)

Directions for the Future

Instrumentation

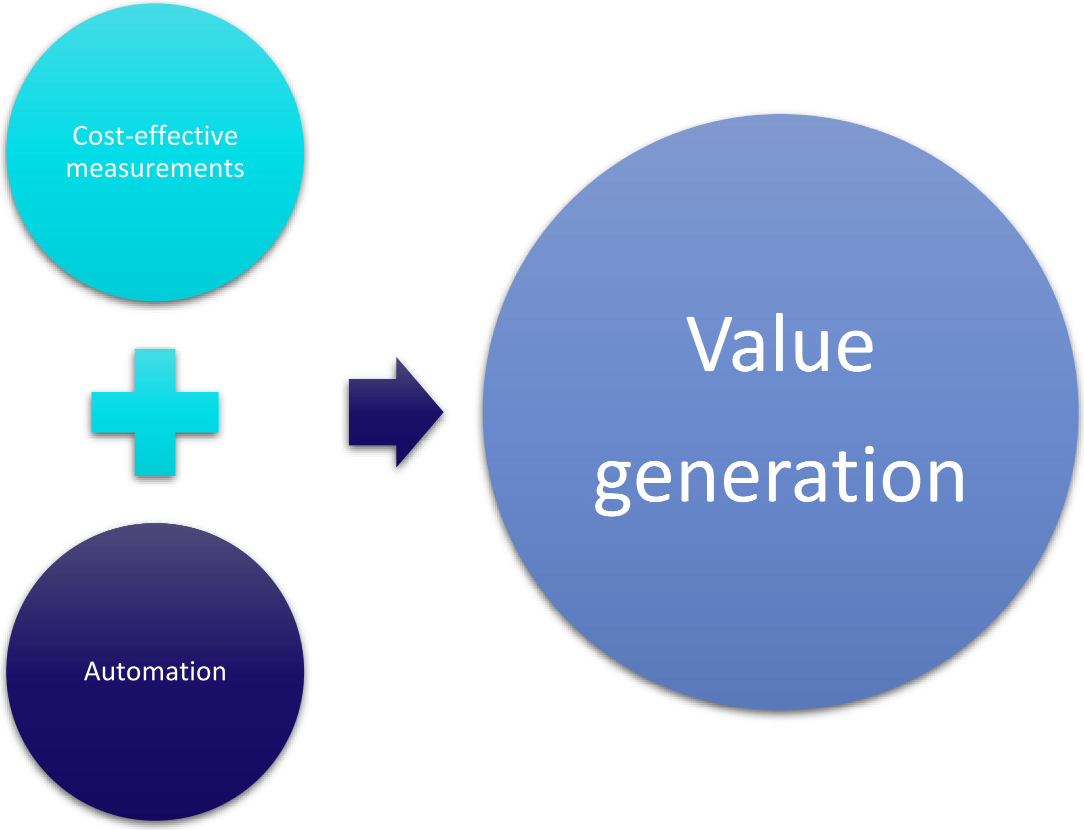
→ Use jointly
  – Surface distributed acoustic sensing (S-DAS)
  – Distributed temperature sensing (DTS)

→ to generate cost-effective measurements

→ to be integrated within geophysics-centered geothermal inversion workflows

Automation

→ Automatic processing and interpretation



Derisk geothermal projects with the 4 G's