

Mitigating Operational Risks with Geomechanical Modelling: A Geothermal Case Study*

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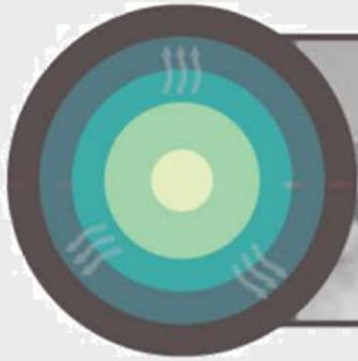
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Abstract

Unlike other renewable energy sources, the appraisal, development, and exploitation of geothermal resources requires understanding the subsurface environment. The presence, quality, and accessibility of suitable heat sources is associated with large uncertainties, whose impact needs to be reduced to make the project economically viable. Geothermal site modelling is a way to reduce these uncertainties, and geomechanical modelling in particular addresses some key risks during the exploration, development, and operation of a site: drilling instability, fracture and fault behaviour, and induced micro-seismicity. We have built an integrated geological, thermo-hydraulic, and geomechanical model of the Rittershoffen geothermal site in France, to demonstrate the feasibility of this workflow with the subsurface data acquired in a typical geothermal project. The site consists of a well doublet targeting fractured sandstone and granite at a depth of over 2 km in a faulted environment and produces 25MW of heat for an industrial site 15 km away. Geological modelling comprised the interpretation of wireline well logs, the inversion of 2D seismic data to understand the rock property distribution, and a discrete fracture model based on tectonic constraints. The distribution of the features interpreted in image logs was analysed to identify the dominant tectonic regimes, using a geomechanically based solution; then a 3D model of the natural fracture network was built, taking into account the geomechanical drivers (paleo-stress state) and the proximity to the main fault. Dynamic fluid and heat flow simulations were then used to forecast the long-term behaviour of the field. Finally, these forecasts were coupled to a geomechanical simulator to obtain the distribution of stress and deformations in space and in time, allowing the quantification of drilling-related risks, such as wellbore stability, and operational risks such as ground deformation, fault reactivation, and induced micro-seismicity. The geomechanical model was used to predict the occurrence of wellbore instability events (such as break-outs, tensile fractures, and losses) in the injector well and compare them with the events observed during drilling. A fair match was observed, confirming the predictive value of the model. 3D geomechanical modelling results confirmed that the cooling of the rock in the vicinity of the injector well is likely to cause plastic strain, resulting in the likely reactivation of fractures and fault segments. The stress and strain tensor could be used to generate synthetic micro-seismic events; their distribution was qualitatively matched with micro-seismic measurements acquired during the stimulation of the injector well, allowing a calibration of the geomechanical model. This integrated study proved that modelling can be a useful tool to predict and mitigate the risks related to the development and operation of the geothermal site, potentially improving its economic and social aspects.

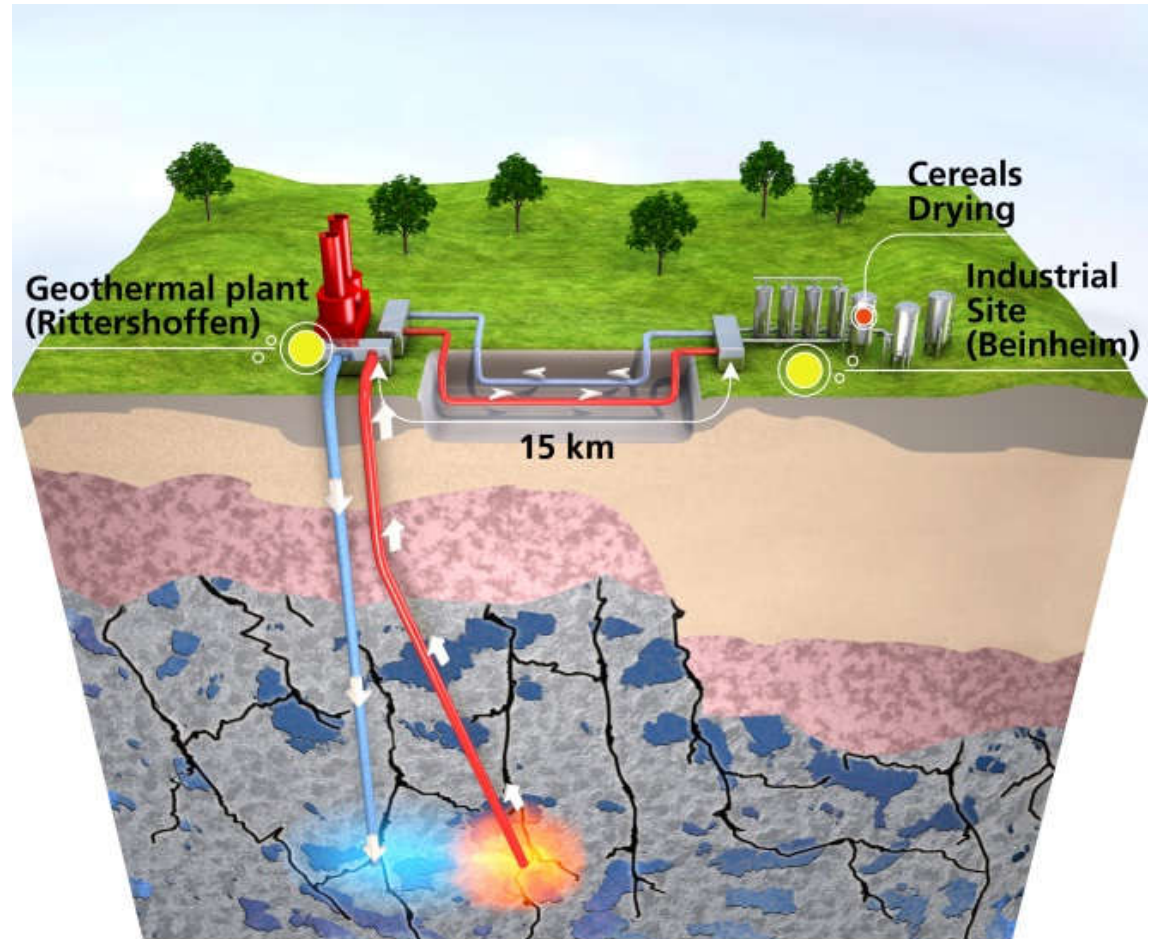


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Utrecht, Netherlands
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Giovanni Sosio, Andreia Mandiuc, Annalisa Campana, Charidimos Spyrou, Schlumberger
Clément Baujard, Albert Genter, ES Géothermie

The ECOGI project in Rittershoffen



Schlumberger

From oilfield services to geothermal services?

Technical solutions

- Resource assessment
 - Exploration (e.g. geophysics)
 - Logging and testing
 - Modelling and simulation
 - Software
- Well construction and completion
 - Drilling, bits, muds
 - Integrated drilling management
 - ESPs
- Production management

Social factors

- Risk assessment
- Risk mitigation:
 - Drilling stability
 - Induced seismicity
 - Stimulation techniques
 - Well integrity
- Visualization, communication, training



GeothermEx

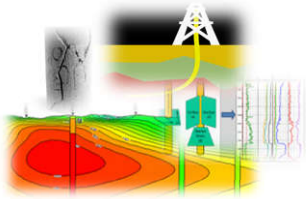
A Schlumberger Company

SIS



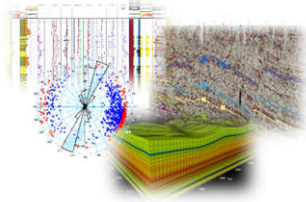
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Integrated modelling workflow: from data acquisition to geothermal operations



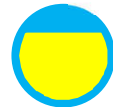
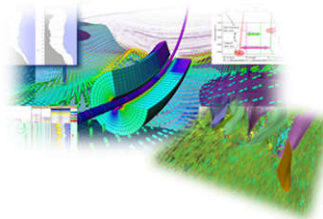
SUITABLE INPUTS

- Wireline Logging, LWD
 - > Petrophysical
 - > Acoustic
 - > Imaging
- 2D/3D Seismic, EM, Gravimetry
- Well tests
- Core data
- Drilling data



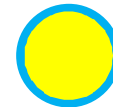
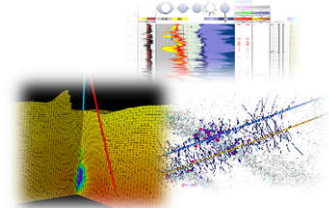
DATA INTEGRATION

- Inputs QC
- Integration in a single platform
- Advanced processing and interpretation



ANALYSIS & MODELLING

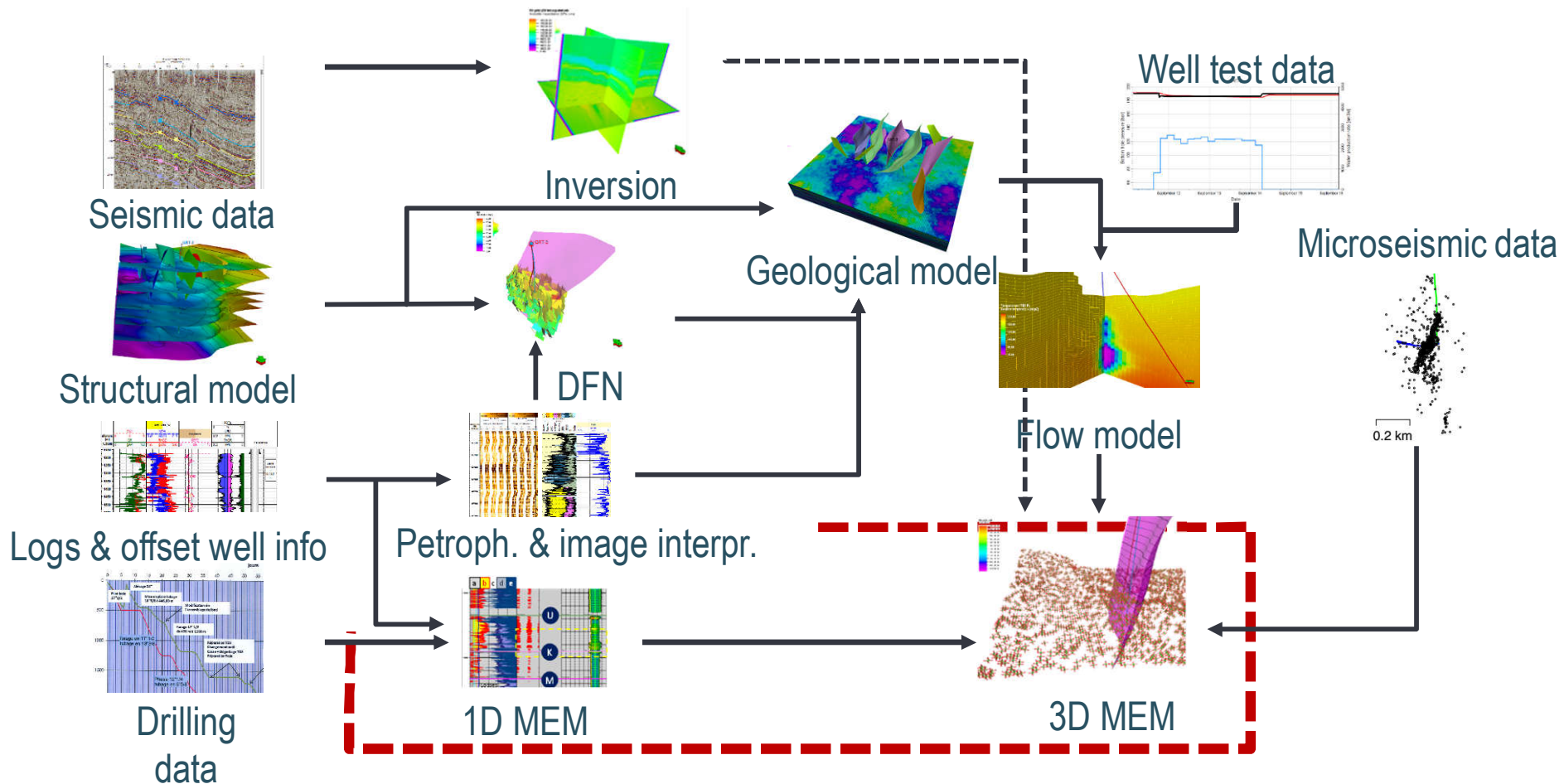
- Build 3D static model:
 - > geological structure
 - > rock properties
 - > fracture network
- Model dynamic behavior:
 - > production/injection
 - > heat flow and temperature changes
 - > stress and strain



APPLICATION & DESIGN

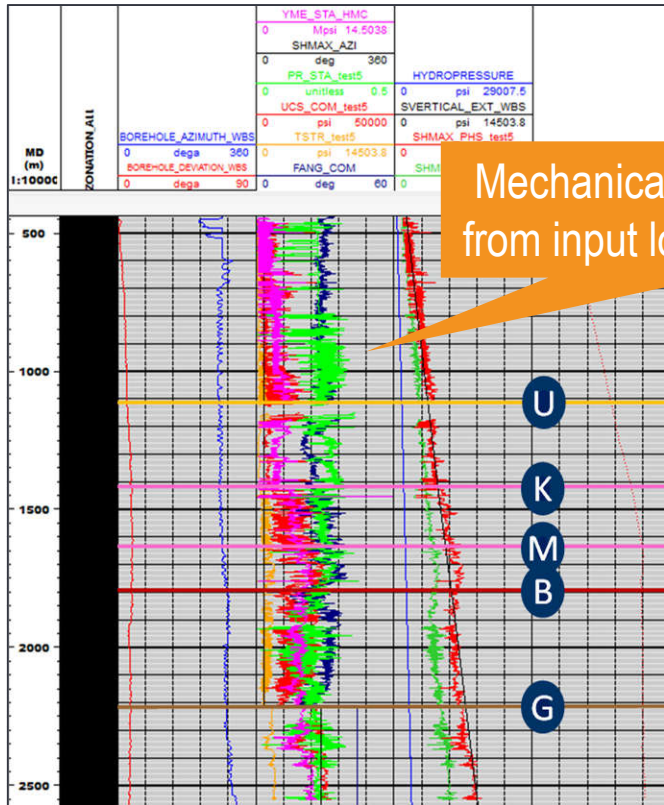
- Well placement/design
- Completion optimization
 - > Casing/tubing size
 - > Optimum flow rates
 - > Stimulation design
- Risk mitigation
 - > Drilling risks
 - > Well integrity
 - > Subsidence
 - > Induced seismicity

Integrated modelling workflow: a geothermal case study



Geomechanics for risk mitigation

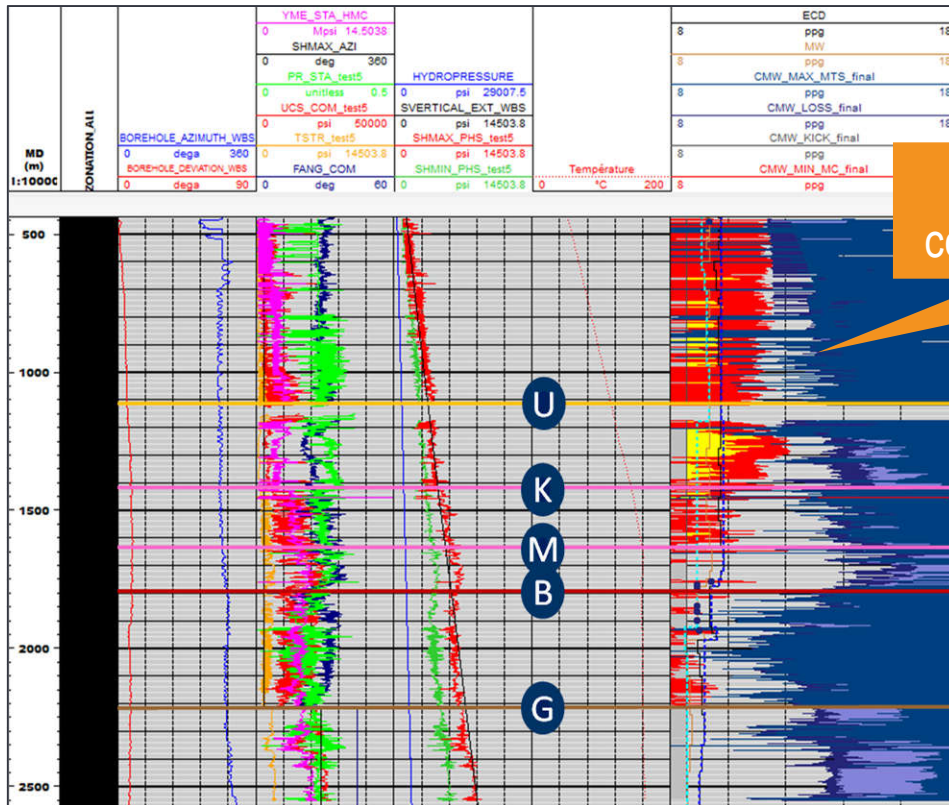
Wellbore stability – Validation (injection well)



Mechanical properties and stress from input logs (density and sonic)

Geomechanics for risk mitigation

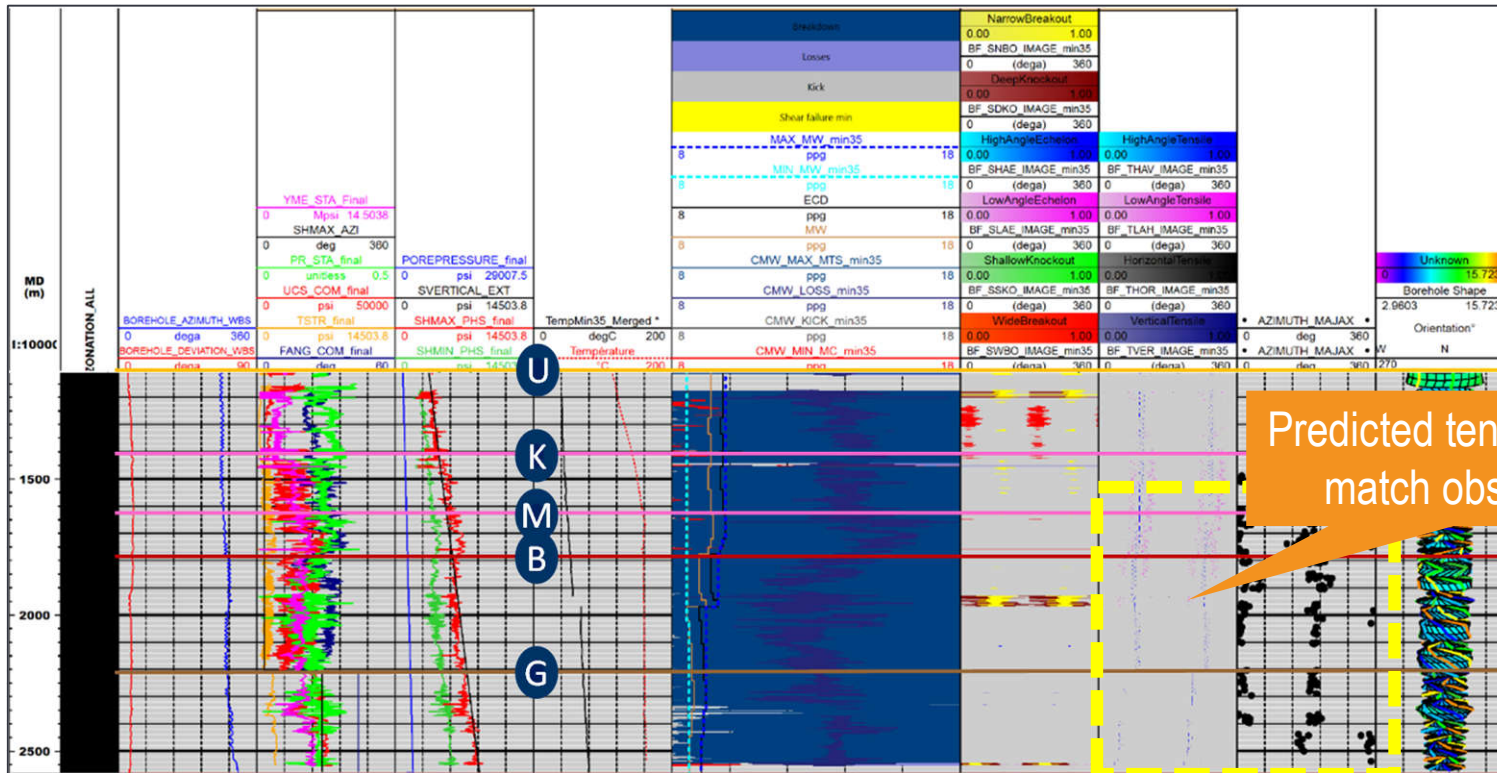
Wellbore stability – Validation (injection well)



Computed critical mud weights compared with actual mud weight

Geomechanics for risk mitigation

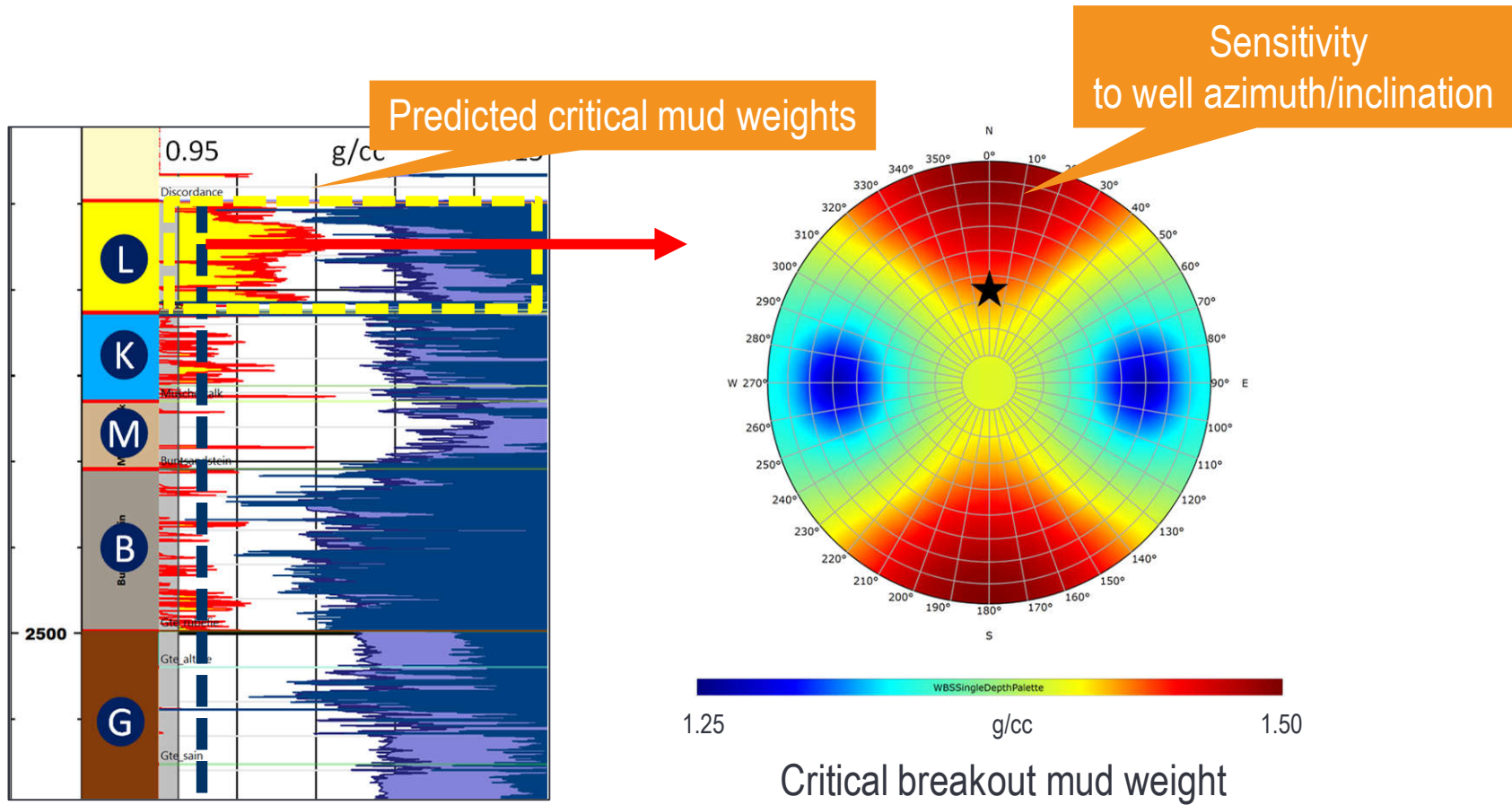
Wellbore stability – Thermal effects



Predicted tensile fractures match observations

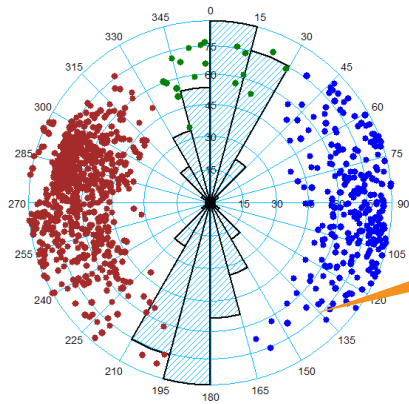
Geomechanics for risk mitigation

Wellbore stability – Prediction (production well)

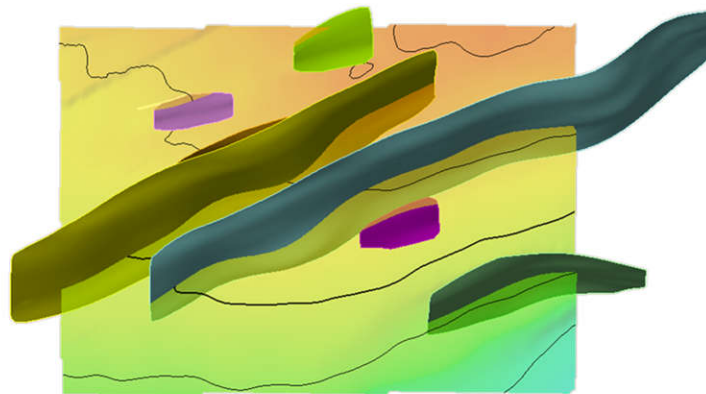


Geomechanics for risk mitigation

Tectonic-based fracture modelling

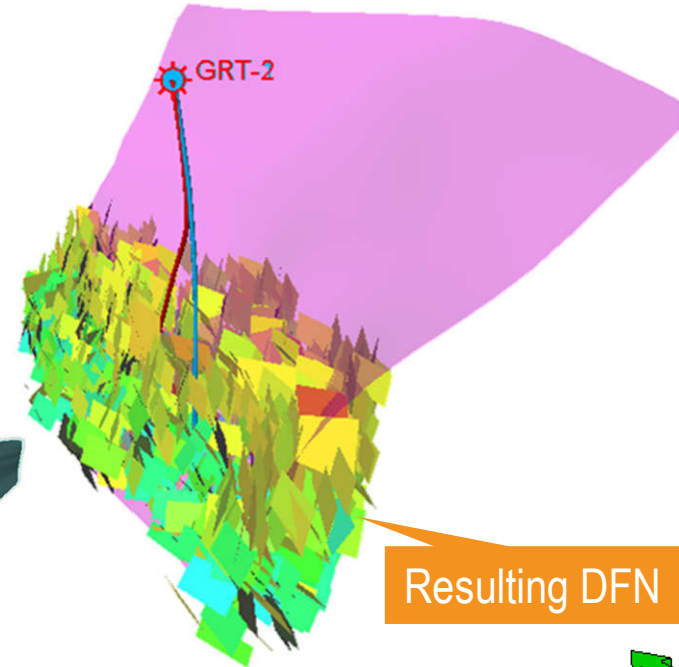
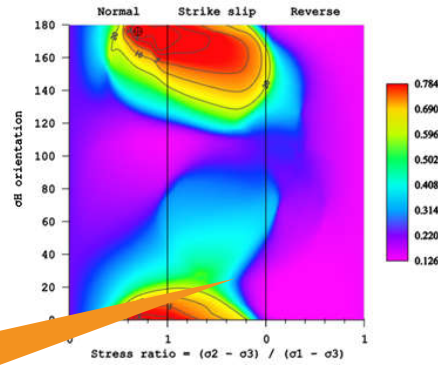
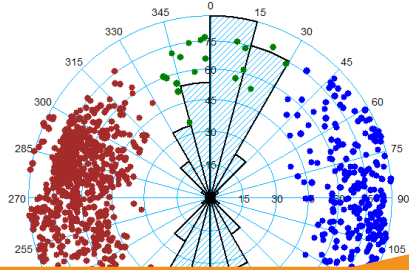


Input – image log interpretation
and structural model



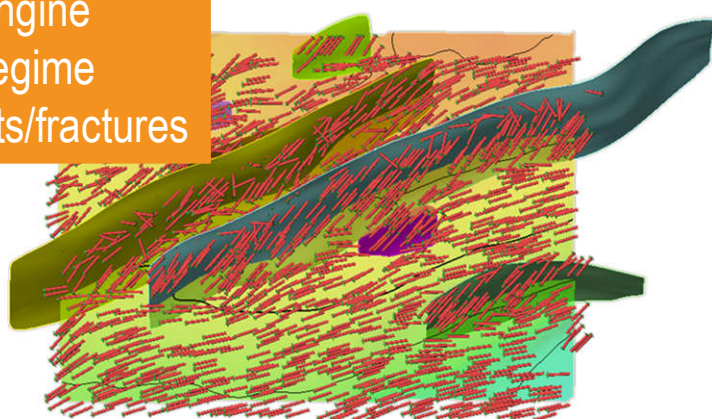
Geomechanics for risk mitigation

Tectonic-based fracture modelling



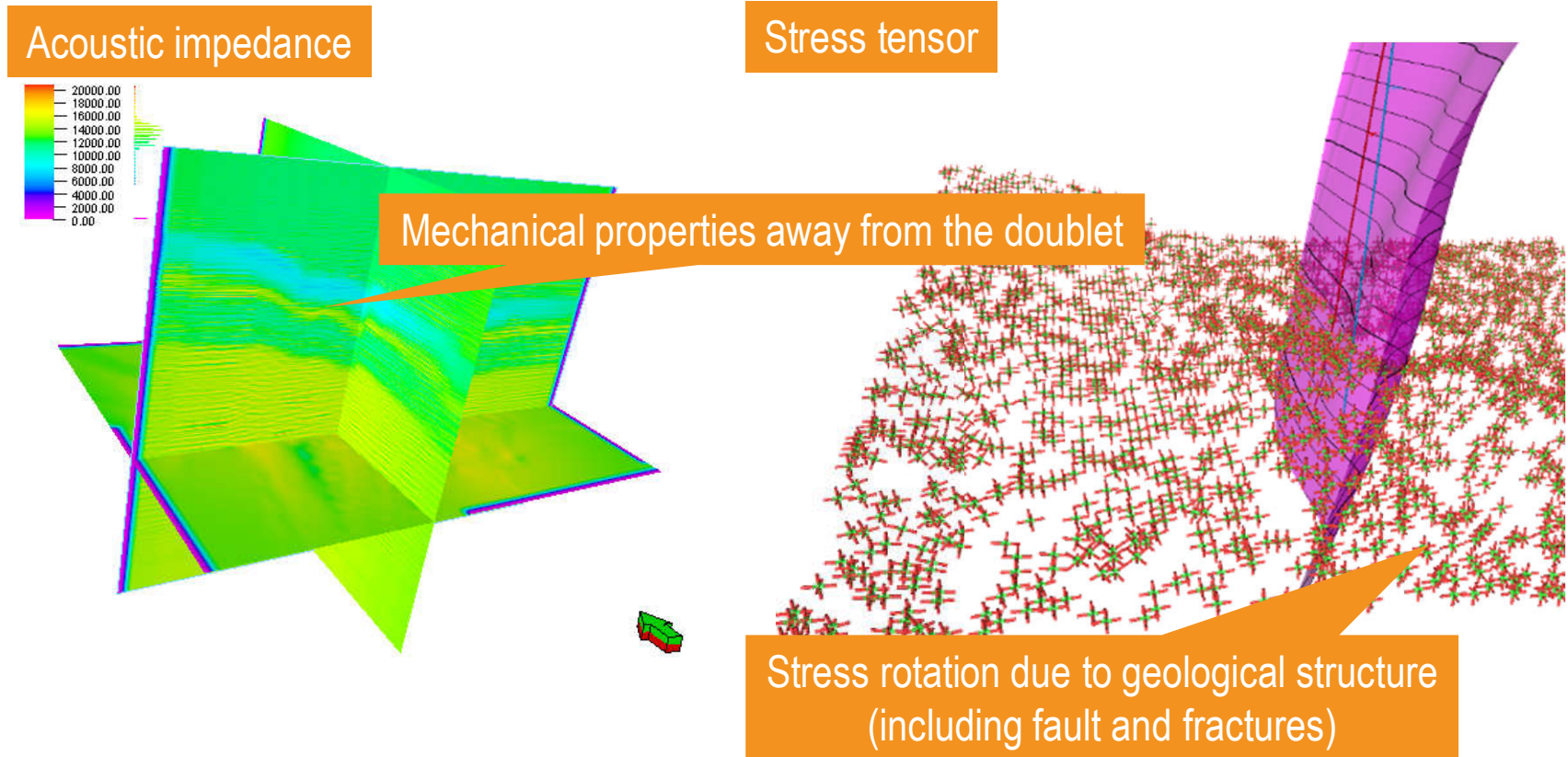
Geomechanical engine identifies stress regime linked to observed faults/fractures

Resulting DFN



Geomechanics for risk mitigation

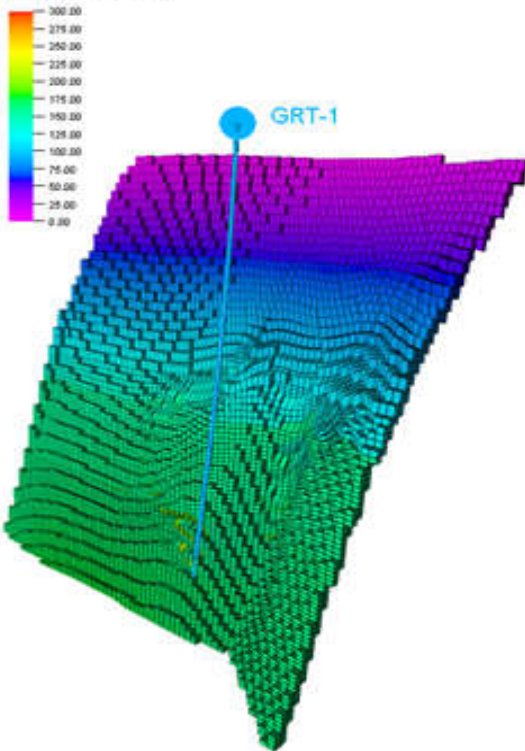
Seismic inversion and 3D geomechanical modelling



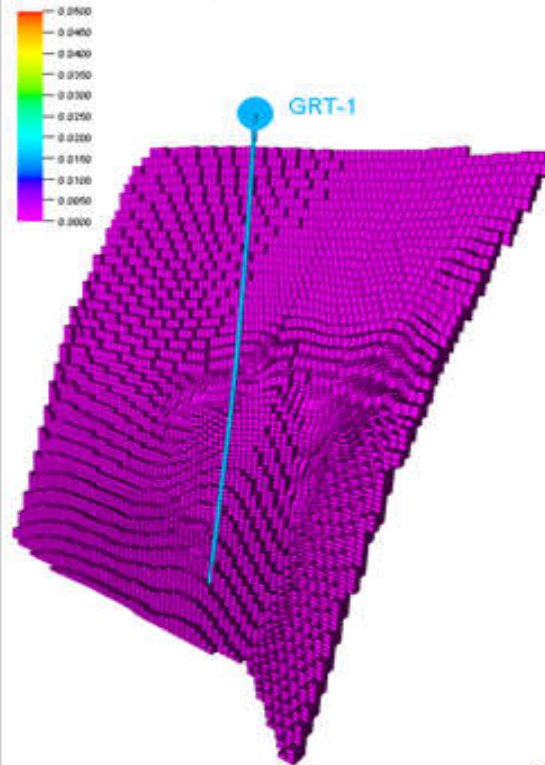
Geomechanics for risk mitigation

Coupled flow/mechanical simulations

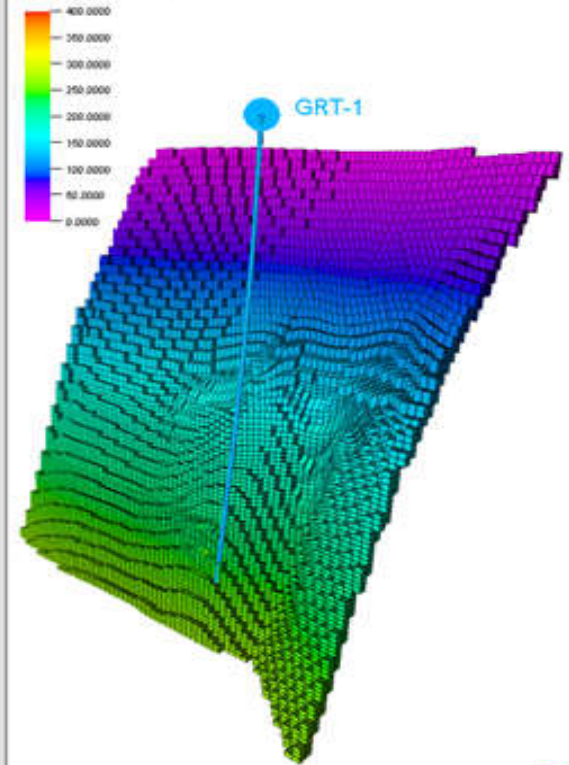
Temperature



Fault plastic strain



Pressure

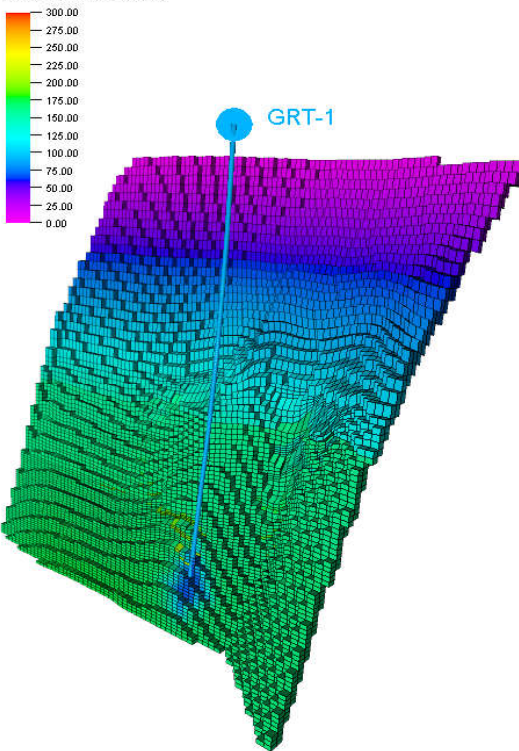


Pre-injection

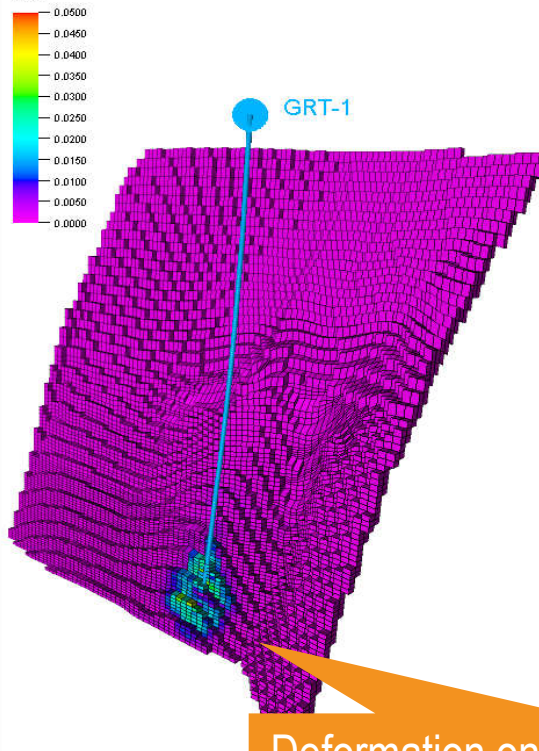
Geomechanics for risk mitigation

Coupled flow/mechanical simulations

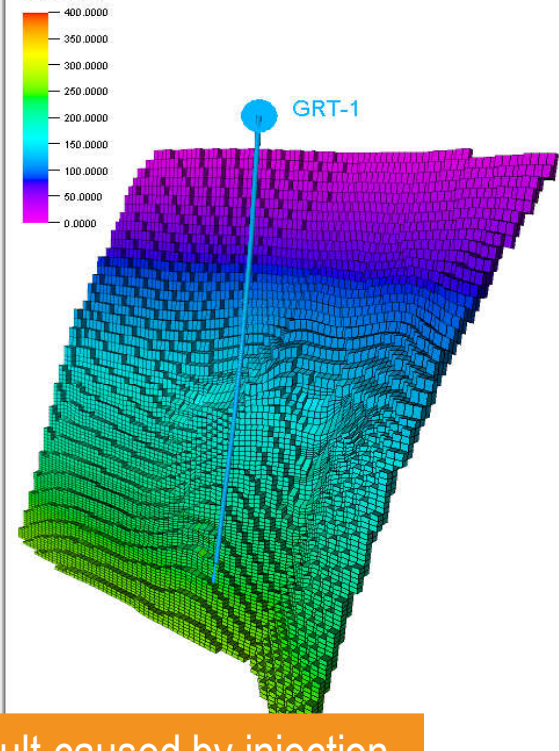
Temperature



Fault plastic strain



Pressure



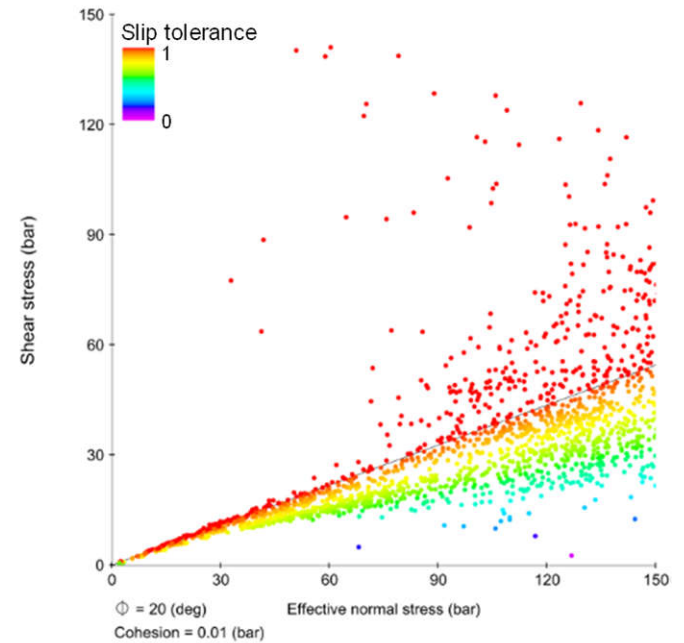
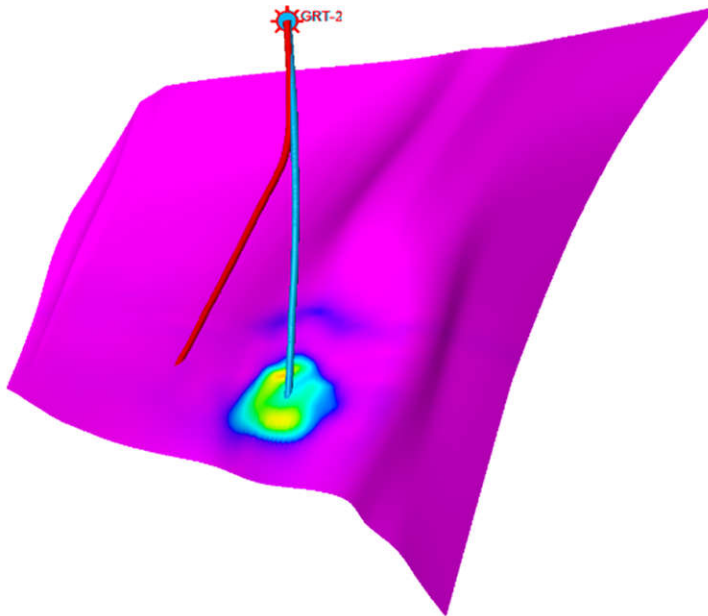
After 20 years

Deformation on fault caused by injection
(after 20 years of operations)

Geomechanics for risk mitigation

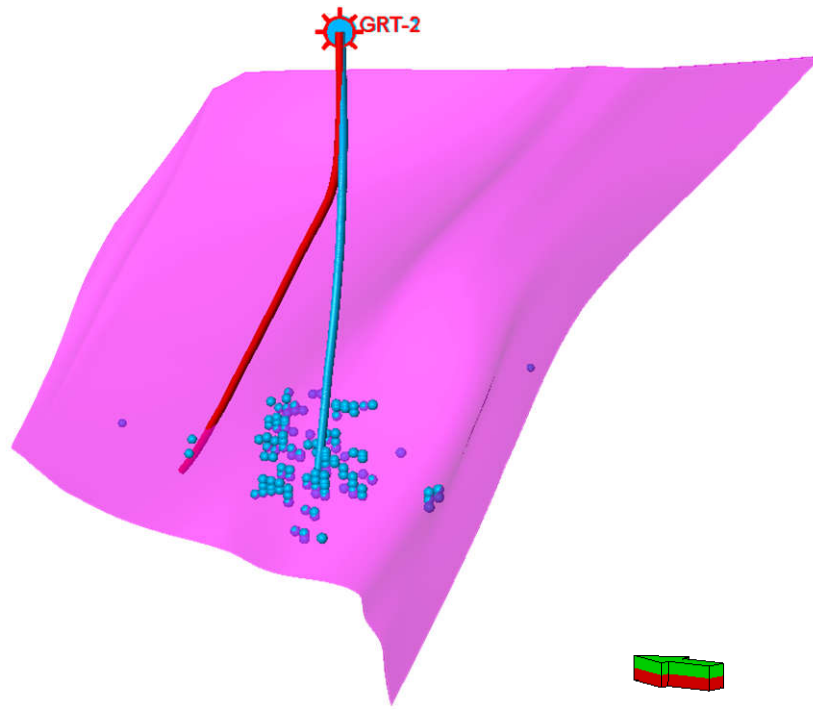
Prediction of fault stability and induced microseismicity

Fault plastic shear strain
0.013
0



Geomechanics for risk mitigation

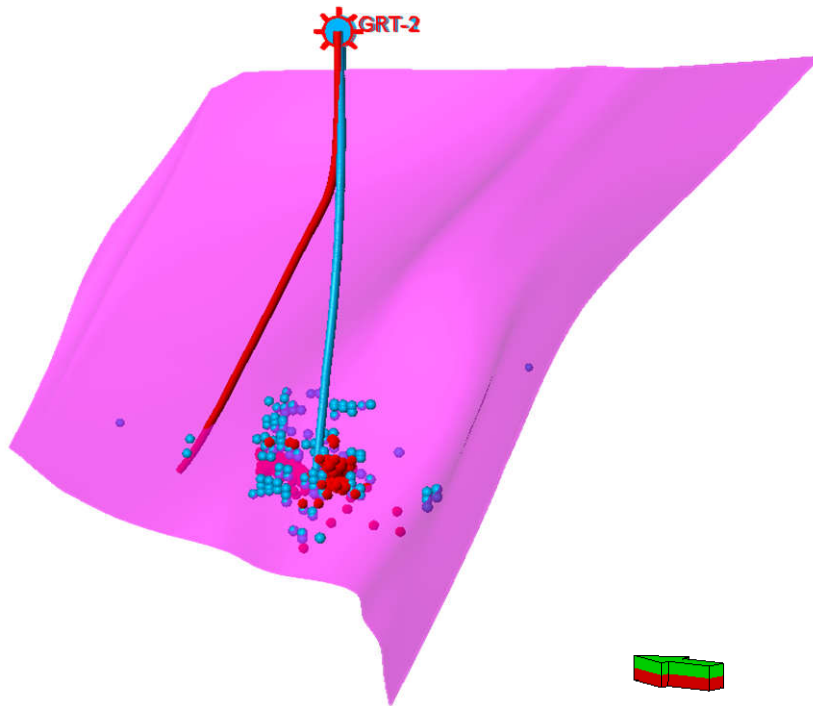
Prediction of fault stability and induced microseismicity



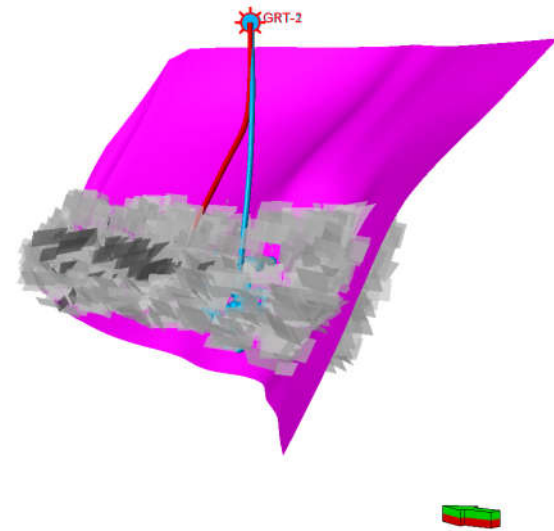
- Estimated microseismic events
- Measured microseismic events

Geomechanics for risk mitigation

Prediction of fault stability and induced microseismicity



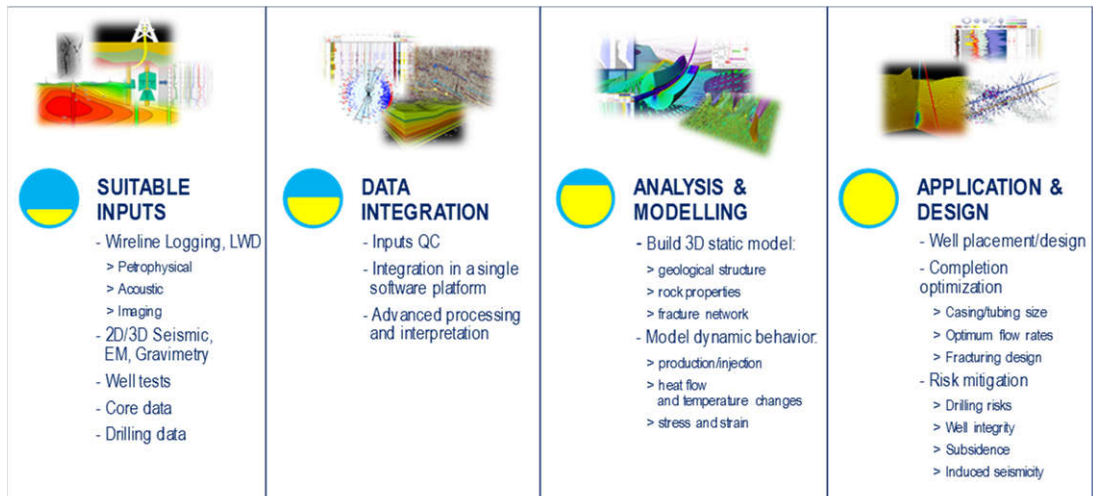
- Estimated microseismic events
- Measured microseismic events



Mitigating operational risks with geomechanical modelling

Conclusions

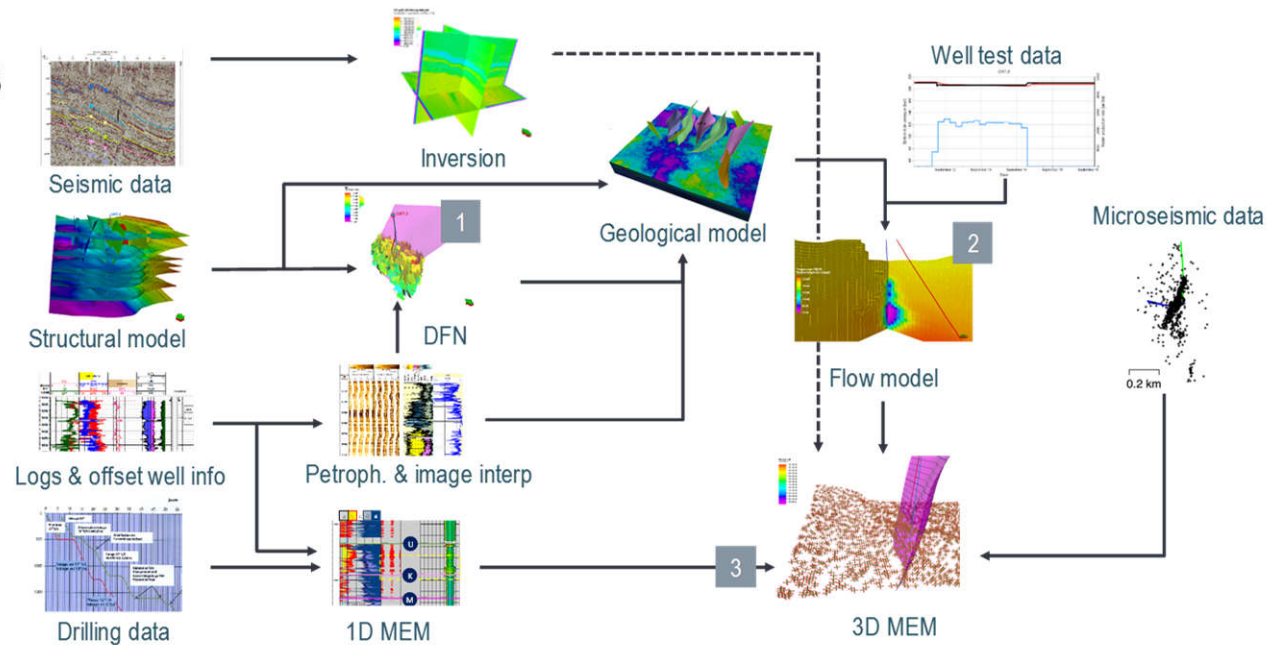
- Expertise linked to operations:
from data acquisition
to site engineering



Integrated Modelling of geothermal resources

Conclusions

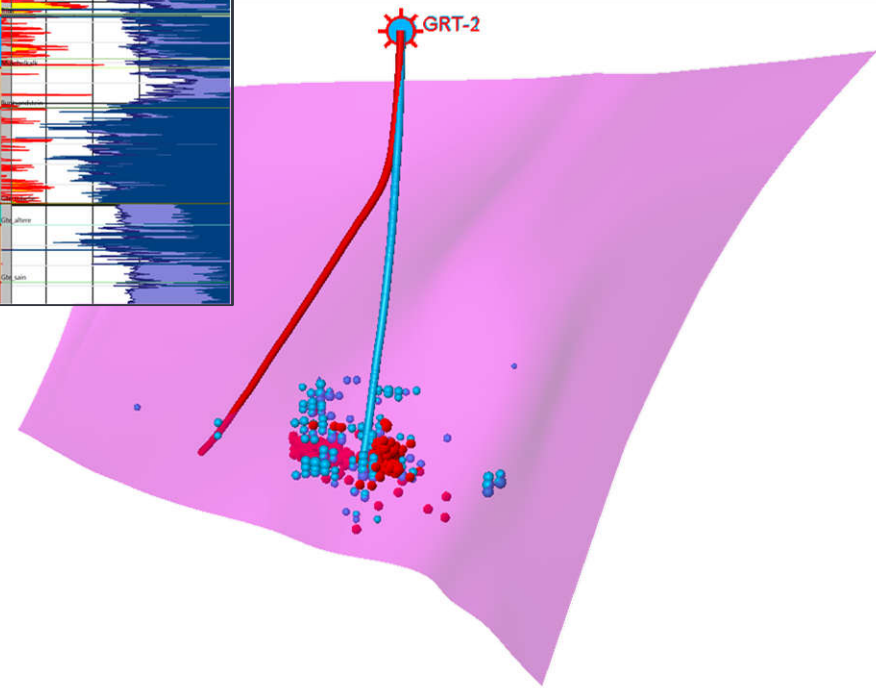
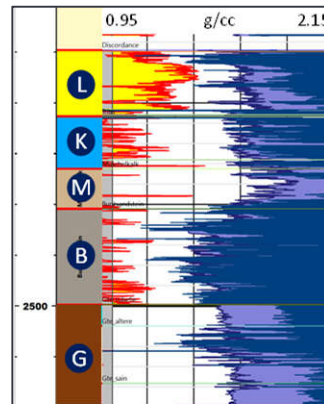
- Expertise linked to operations: from data acquisition to site engineering
- Modelling workflows validated to predict site performance



Integrated Modelling of geothermal resources

Conclusions

- Expertise linked to operations: from data acquisition to site engineering
- Modelling workflows validated to predict site performance
- Quantification of operational risks to improve economics and public perception



Thanks!

**Giovanni Sosio, Andreia Mandiuc, Annalisa Campana, Charidimos Spyrou,
Clément Baujard, Albert Genter**

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