Geo4All – WP4

12 – 06 – 2025

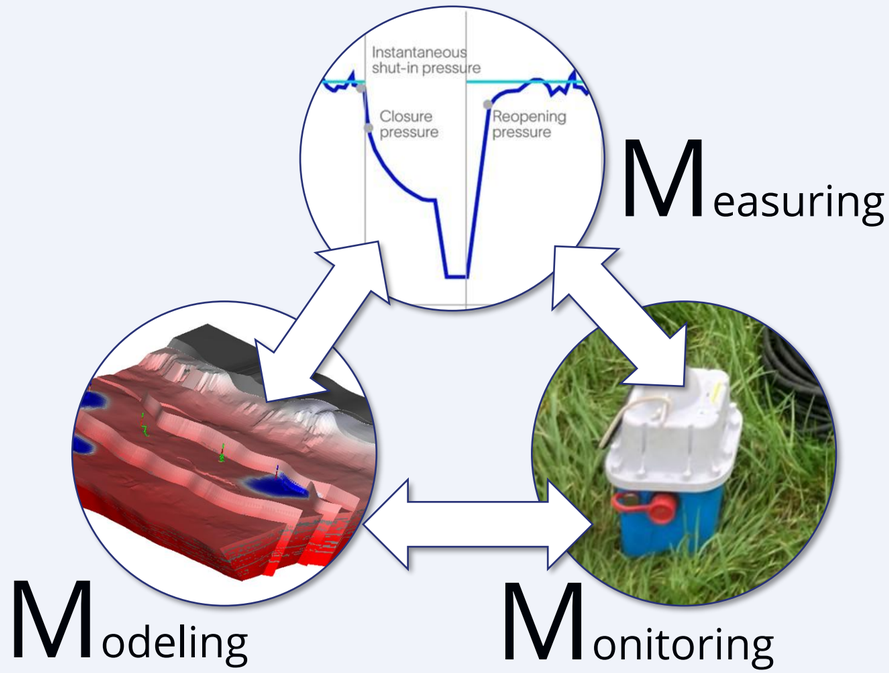
Geothermie & Innovatie, KAS Woerden

Loes Buijze, Elisa Calignano, Angela Pascarella, Deyan Draganov,
David Naranjo, Andrea Vondrak, Henk van Oeveren, and others
working in WP4 Geo4All

TKI Geo4All WP4 – The 3M

Research questions WP4:

- Where is the cooling in space and time?
- How does cooling affect reservoir and fault stability?



TKI NIEUW GAS
Topsector Energie

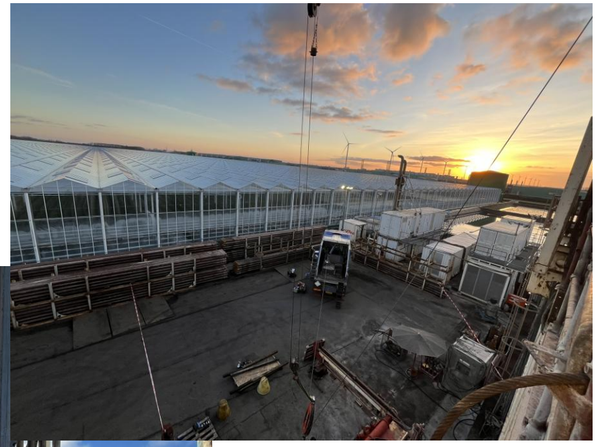
Middenmeer
ennatuurlijk aardwarmte

Kwintsheul
Nature's Heat
Aardwarmte Kwintsheul

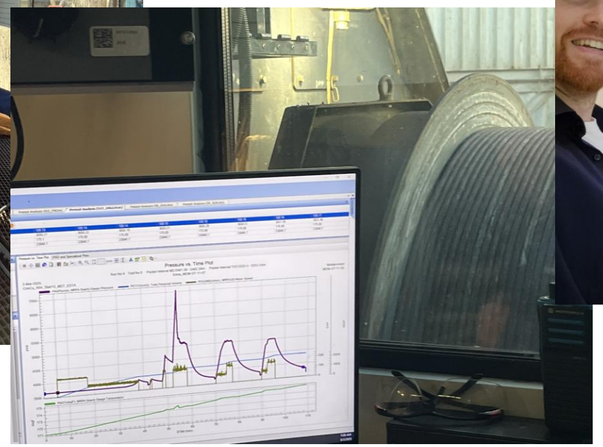
Bleiswijk
GAIA ENERGY

TNO
ebn
WEP work well together
TU Delft
geothermie nederland

WP4 is going full steam



Performed logs & stress test at Middenmeer



ZURICH, SWITZERLAND
6 - 10 OCTOBER 2025

EUROPEAN GEOTHERMAL CONGRESS 2025

Heterogeneous geomechanical properties and cooling in a sandstone reservoir exploited for geothermal production

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Keywords: geothermal, sands

ABSTRACT

In the Netherlands, geotherma
sandstone reservoirs and ex
circulation. All projects need
hazard and risk analysis, part of which requires a
of the SHCA workflow consists of geomechanical
simulations to determine the potential for fault

EGC article submitted

Stress test video interviews

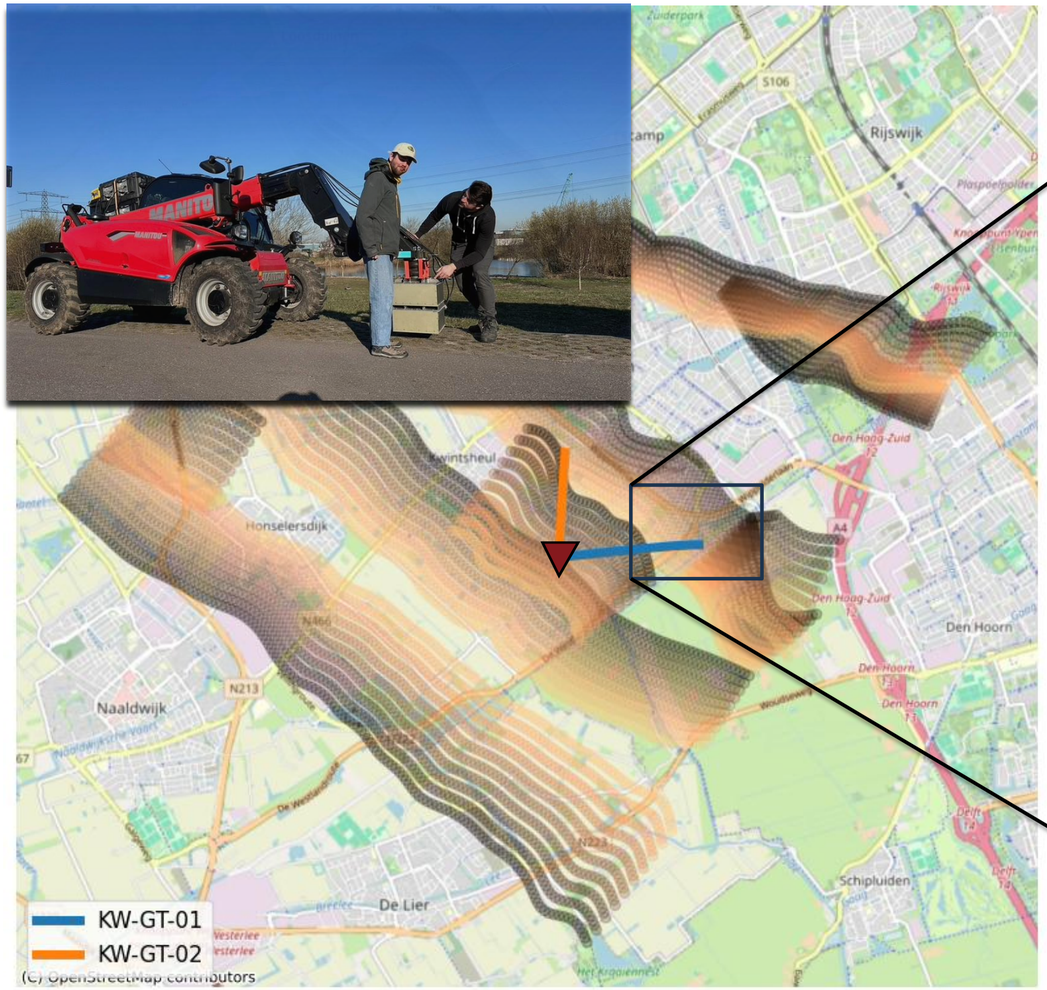
First active survey at Kwintsheul

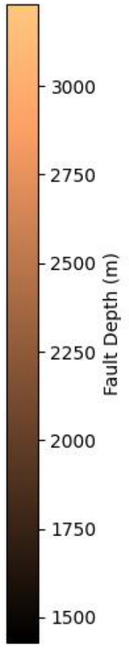
Geo4all innovatieprogramma

Mede mogelijk gemaakt door: TKI NIEUW GAS Topsector Energie

Seismic survey at Kwintsheul

Completed shallow seismic survey (~400 m)





Update on acquisition

- 260 shot positions in 3 days working from 08:00–18:00 with 4 people.
- The road to the North has heavy traffic during the day.
- There are houses next to the Northeastern part of the line.

Some conclusions

- Seismic acquisition in urban areas requires careful planning and anticipation
- Hiring a traffic-management company and shooting at night both add cost and complexity
- Acquisition design with modeling tools is essential to meet our imaging goals
- Optimized source spacing cuts shot positions by ≈ 54%, roughly halving field time

Logs and stress test MDM-GT-11-S2

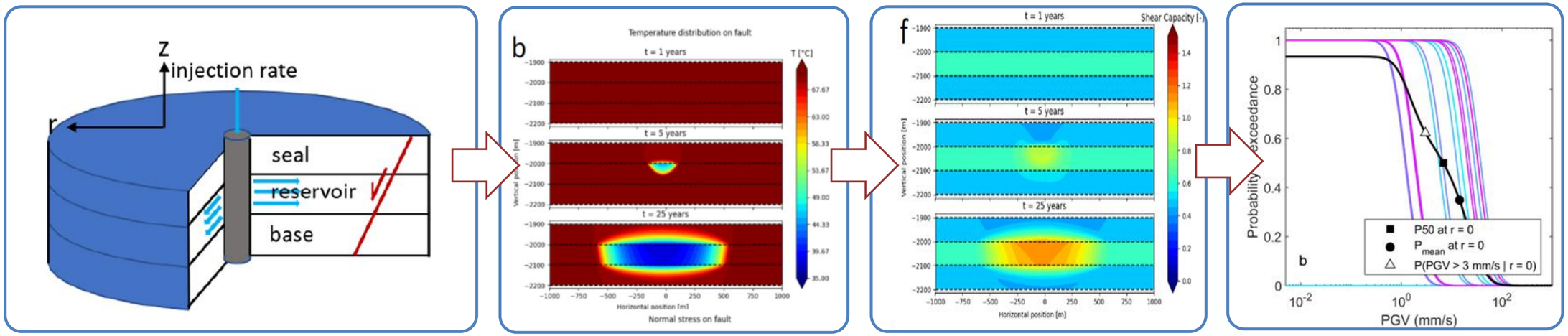
Stress in the subsurface. Why was that important again?

Model of injection well & reservoir

PT Changes on fault

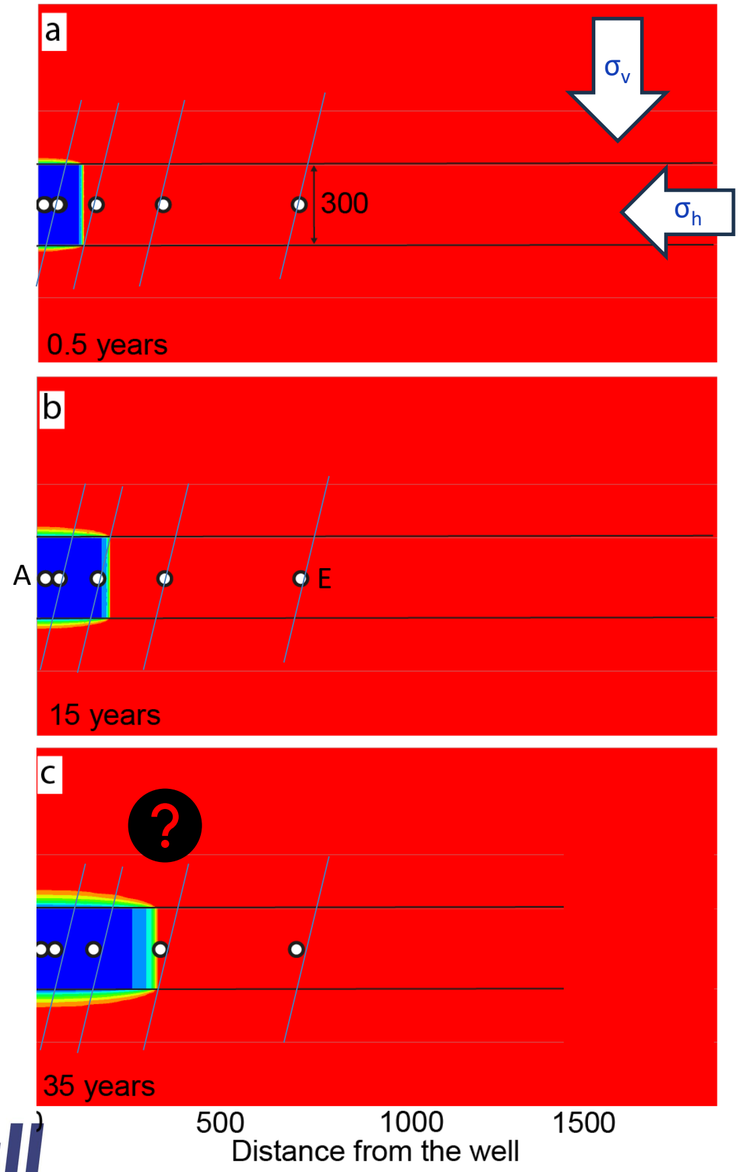
Stress change, fault reactivation

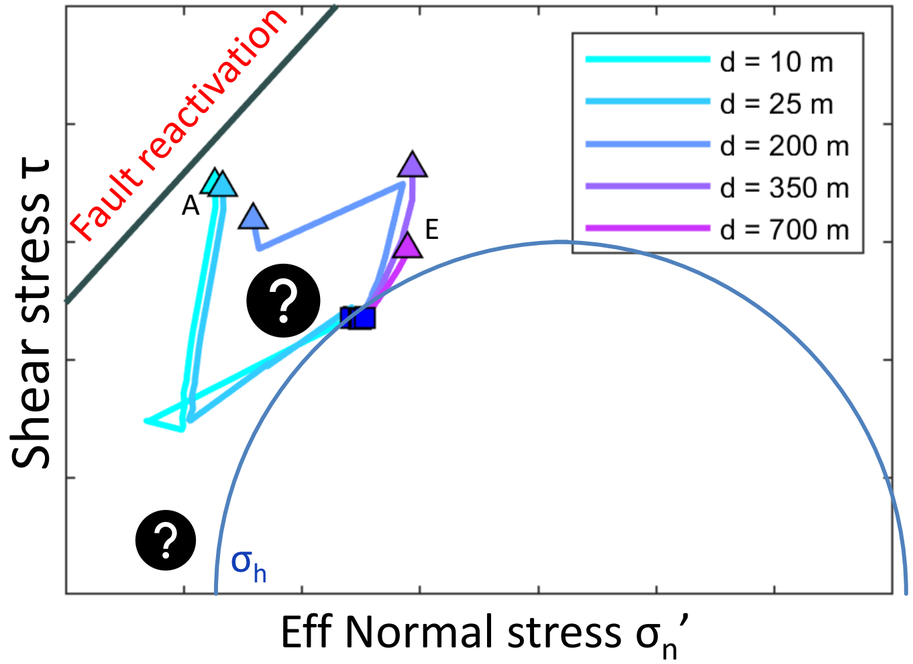
M_{LCE} and PGV



- Stress and elastic moduli are key SRIMA inputs for SHRA & TAS
- Guides limitations on flow and injection T

Fokker et al. 2023





Substantial model assumptions & uncertainties

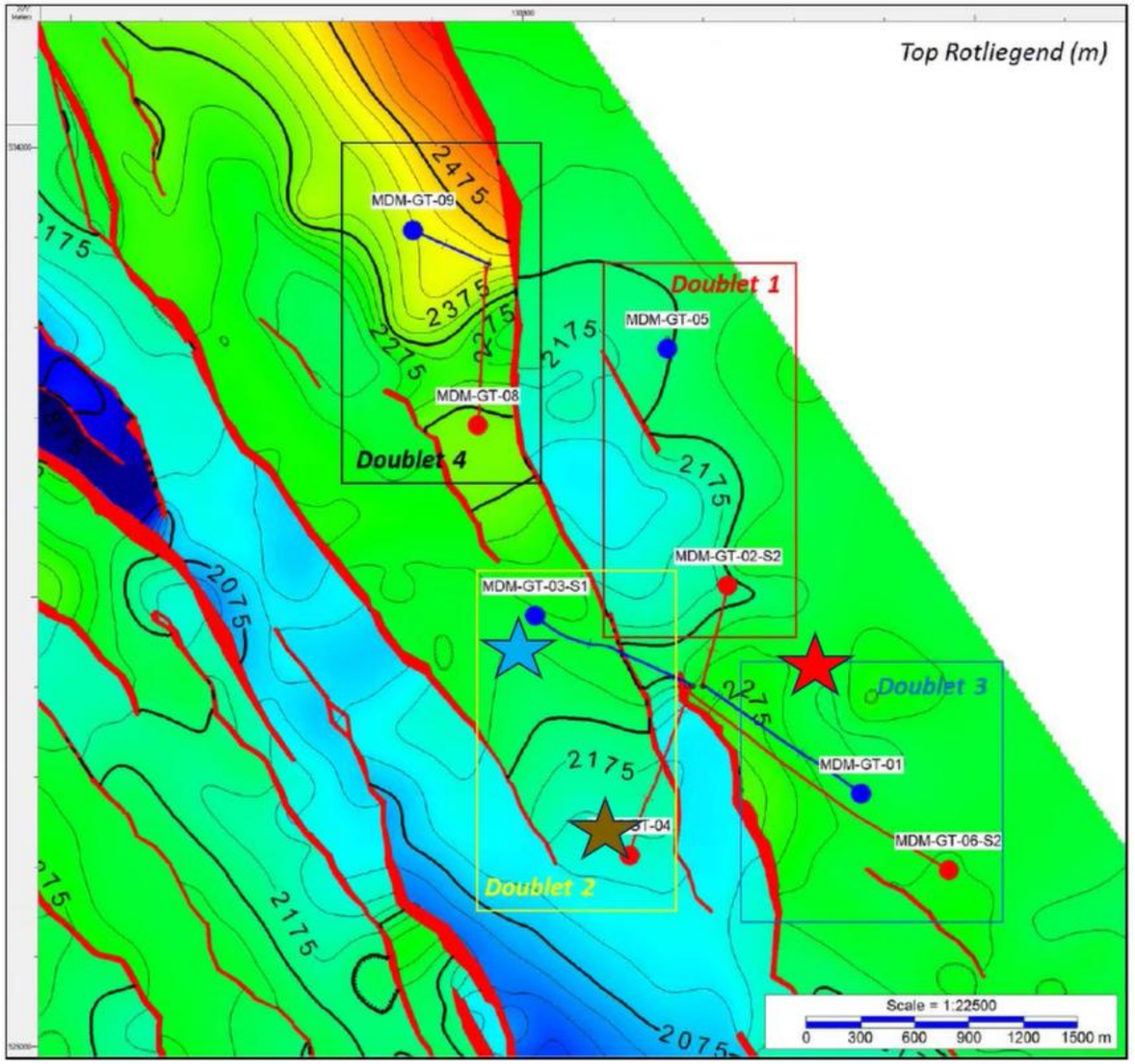
No field validation. Outcomes (too) conservative?

Geo4all innovatieprogramma

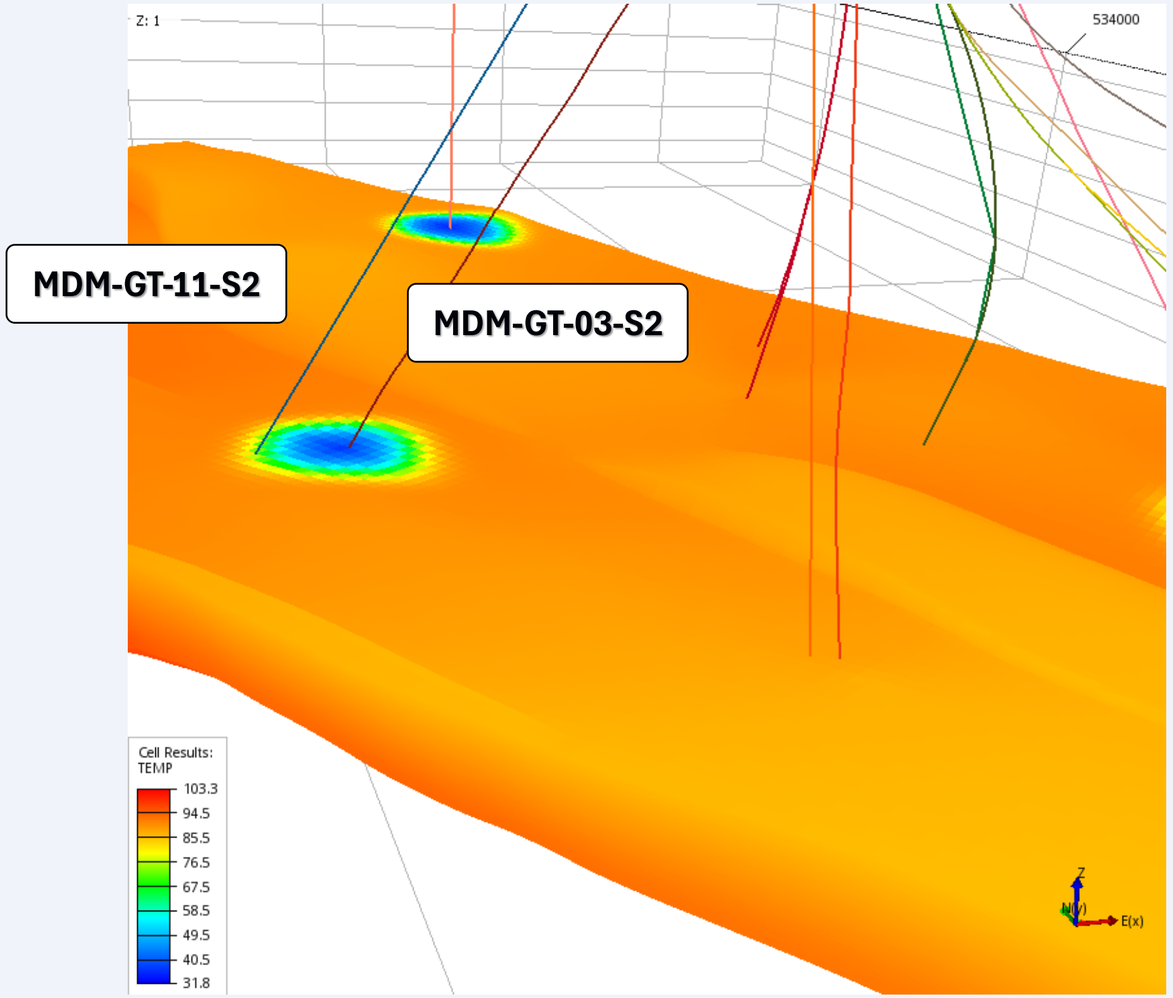
Mede mogelijk gemaakt door: TKI NIEUW GAS Topsector Energie

Middenmeer Geothermal

Operator	Ennatuurlijk Aardwarmte
Reservoir	Slochteren Formation
Top depth	2.2 – 2.4 km
Temperature	~92°
Injection start	2014 (Doublet 2)
Injection rate	136 m^3/hr
Injection T	~35°



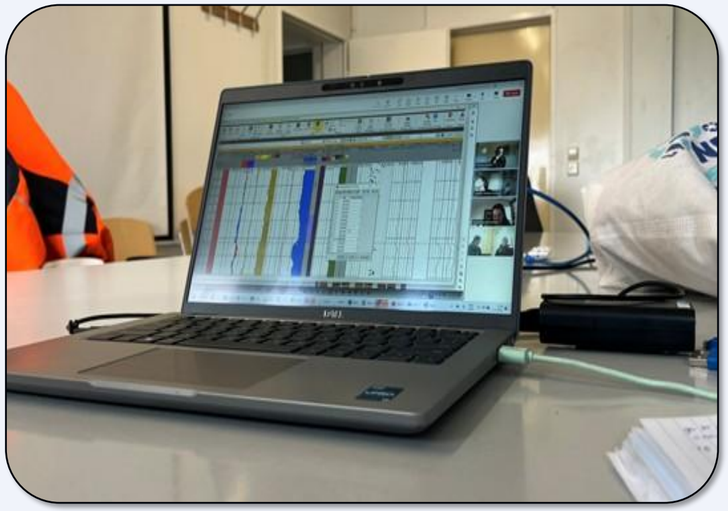
Unique opportunity to probe the ‘cold front’ at MDM



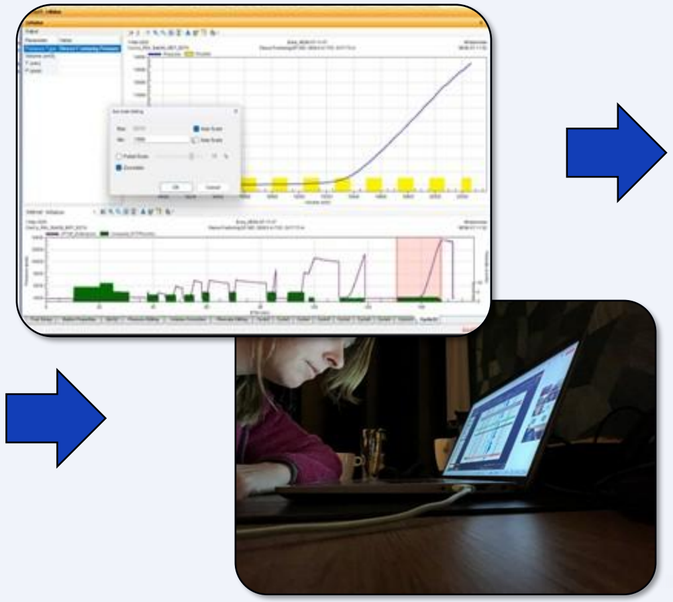
Logging and stress test campaign MDM-GT-11-S2

Run #1 (~16 hrs)	Run #2 (~10 hrs)	Run #3 MDT Tool (~20 hrs)
Sonic log, caliper	Density log	Microfracs 3 stations (1m interval)
FMI log (image log)	Temperature log	PMT test
Porosity log, temperature log		Temperature log

Data



Data

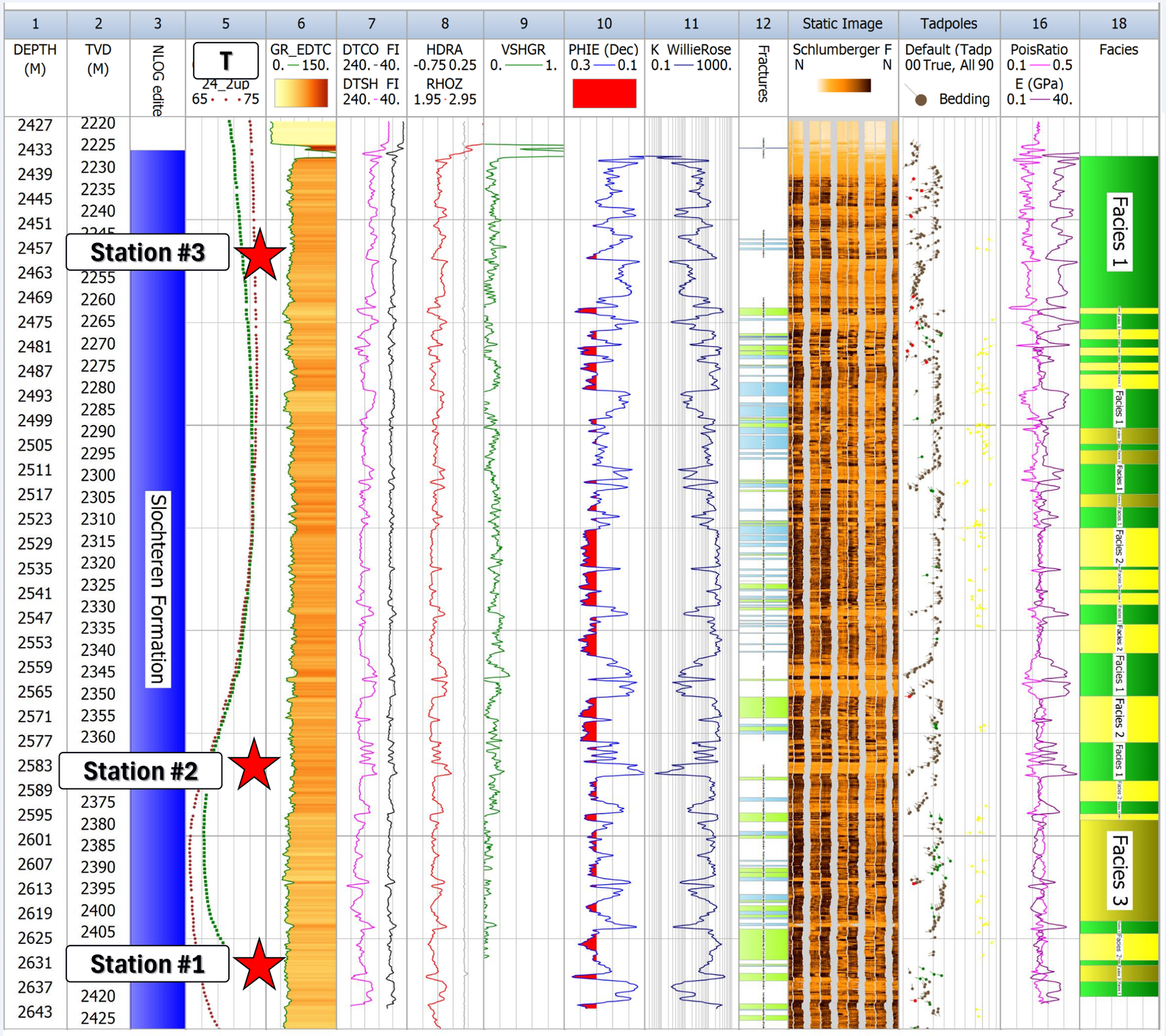


Selection of microfrac stations

- Borehole condition
- Low permeability
- Free of fractures
- Showing evidence of cooling


Linde
TREUDE
Linde


Schlumberger



See also Buijze et al. (2025) EGC submitted

Log results

- Lower and higher porosity facies (cf. SCAN well AMS-01)
- Natural fractures (sealing)
- Heterogeneous T with depth*

*NB T profile still perturbed by drilling

INTERPRETATION ONGOING

Key Observation #1

Cooling appears to be heterogeneous with depth and may be lesss than expected

→ No/Less cooling of caprock

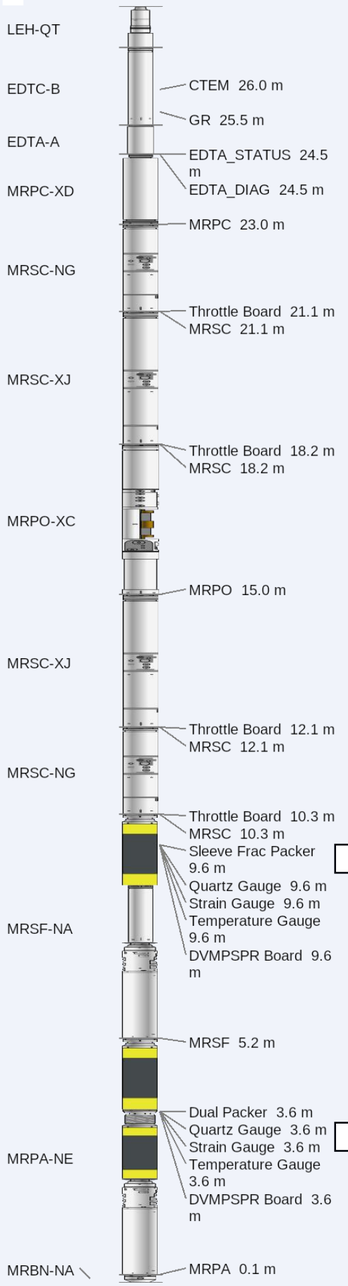
→ Less fault area affected → lower M?

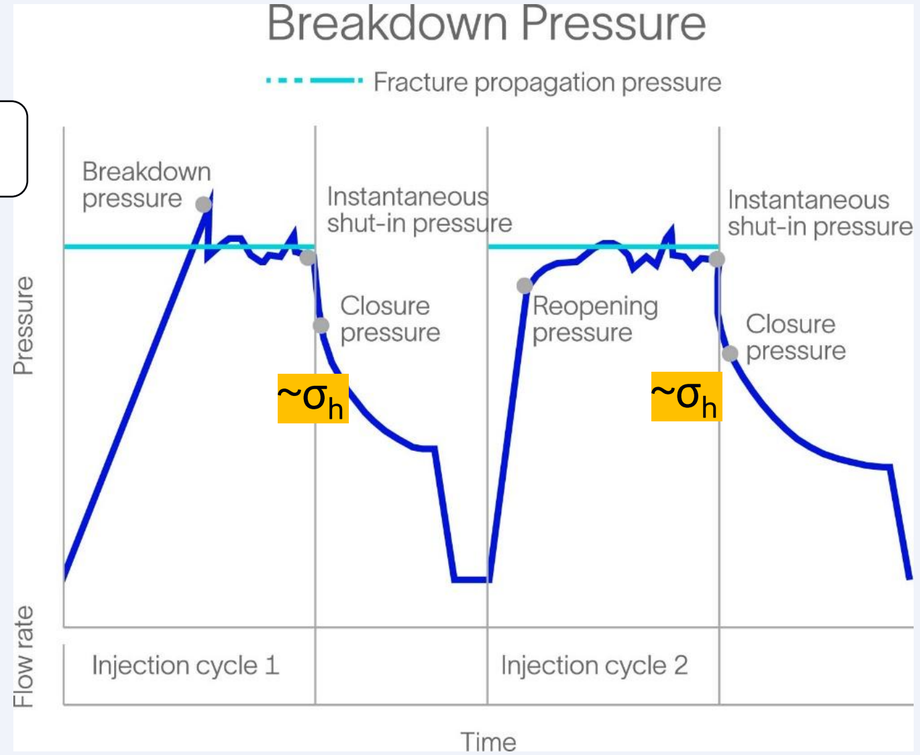
Key Observation #2

Elastic moduli appear relatively low, especially in the high porosity intervals

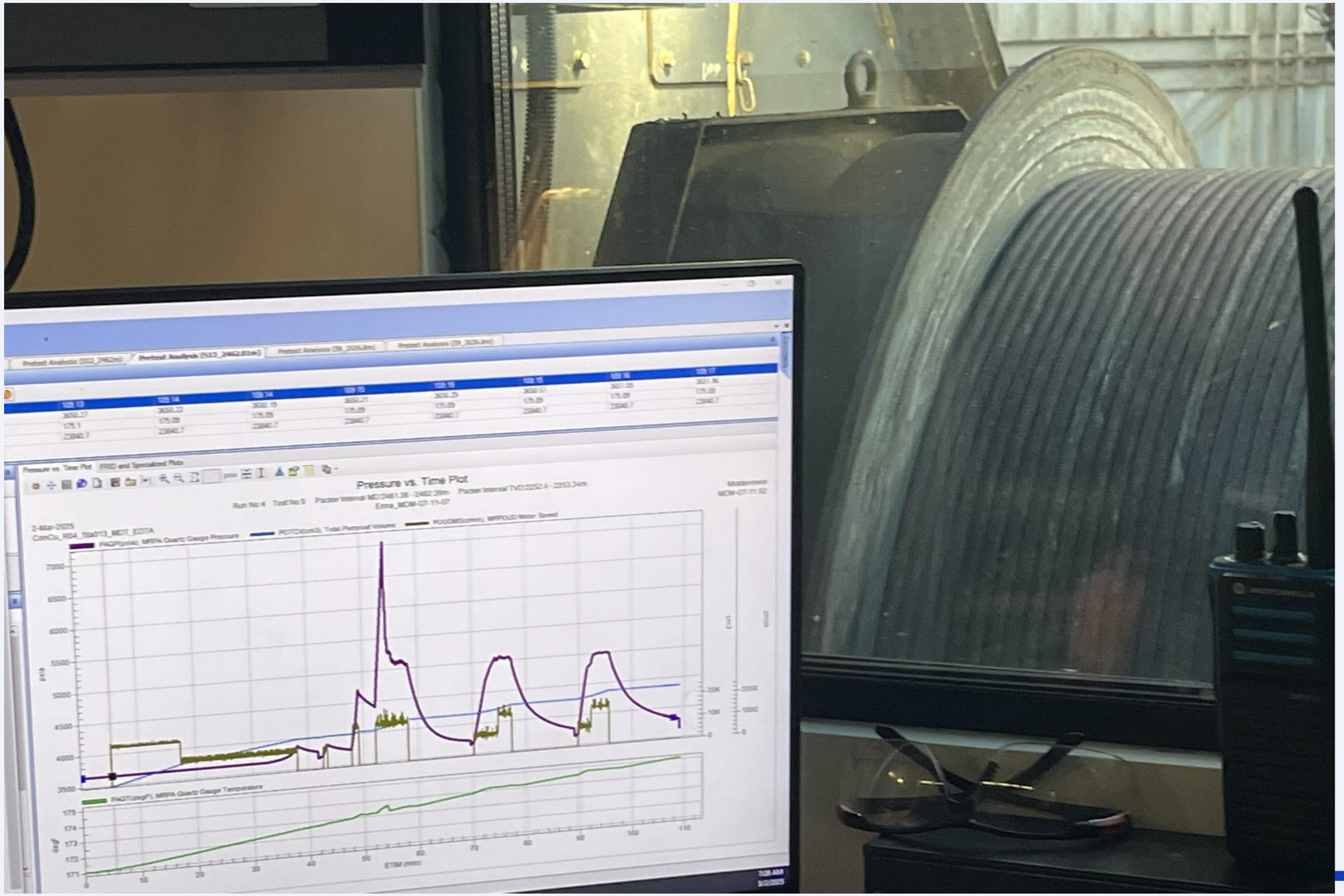
→ Less stress build up

Stress measurements

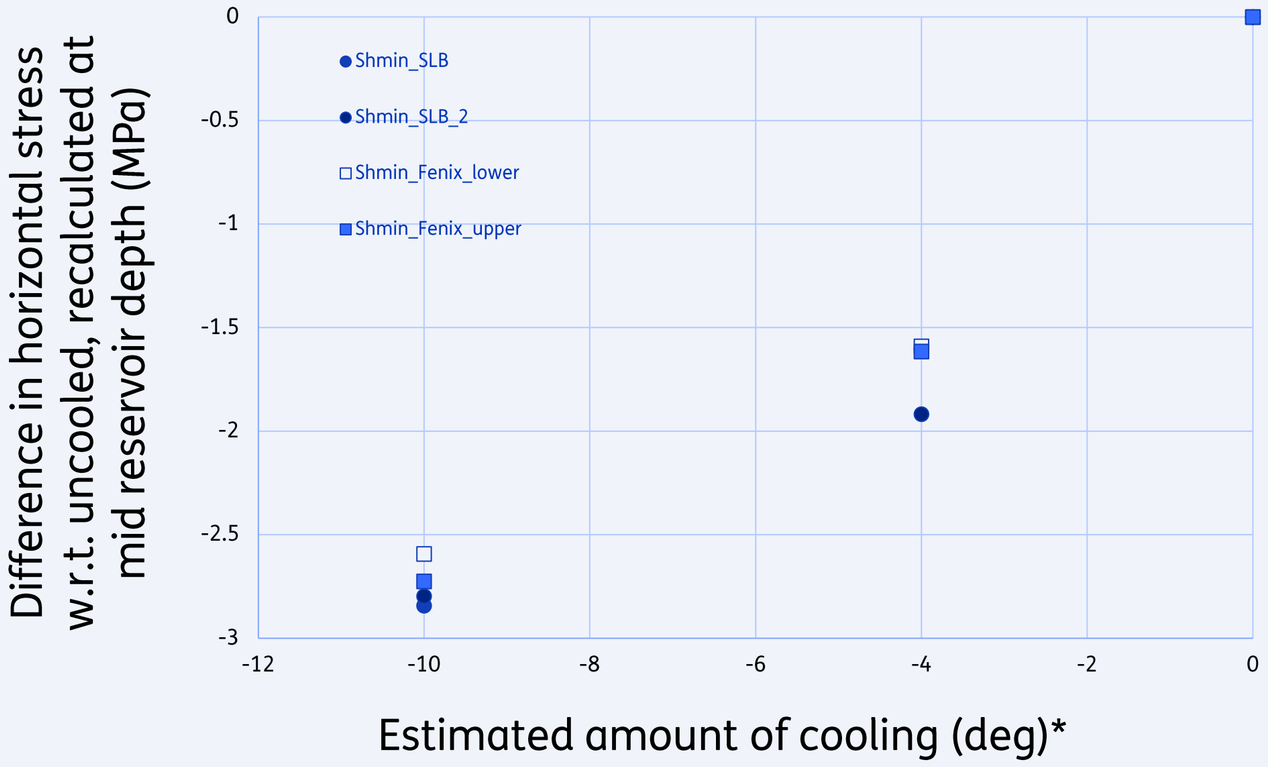




Stress test was successful!



Stress change and cooling



** NB T-Profile is perturbed by drilling. Cooling may be more*

- Stress change is in range of what is predicted in simplified models
- May be biased towards larger stress change because taken in stiffer, low permeability layers

Key Observation #3

Thermo-elastic stress change was observed

Interpretation ongoing

Outlook: Continue the 3M

https://innovatie.geothermie.nl/

TKI Geo4All & TKI DHARA

- Repeating the logs and stress test at Middenmeer in uncooled reservoir
- Geophones to 2 – 2.3 km depth at Bleiswijk & Middenmeer
- Local seismic monitoring networks at 4 sites (Q4 2025)
- Temperature logs cooled and uncooled reservoir Bleiswijk (Q3 2025)
- Seismic survey for S-wave velocity model (Q2 2025)
- Modeling, interpretation

Other

- Stress tests in GTD at Delft
- Stress database, integrate SCAN results
- Setting up a Joint Industry Project on Stress Database ..
- .. And many more research projects (MOOI, NWO-OTP, ..)

Conclusions

- Logging and stress tests were performed successfully in a cooled reservoir interval at Middenmeer Geothermie
- The ‘cold front’ was (likely) observed
- Cooling and flow appear heterogeneous with depth, as a result of facies, porosity, sealing fractures, ….
- Thermo-elastic stress change was observed, in line with model predictions

- Data used to obtain permit for lower injection T at MDM

Keep 3M-ing! Data is key

Thank you! Questions?

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