4-7 NOVEMBER 2024
ROTTERDAM, THE NETHERLANDS

GET2024

GEOTHERMAL ENERGY CONFERENCE

MONITORING THE COLD FRONT AND SEISMIC RISKS IN GEOTHERMAL RESERVOIRS

Andrea Vondrak & Alexander van Noort

INTRODUCTION

Geo4all
innovatieprogramma

- Over a decade of geothermal production
- Current operational limits
  - Results from scientific calculations
  - Input from studies on rock mechanics and extrapolated parameters from O&G
- Cooling effect on rock mechanics
  - From theory / laboratory
  - Not from experience
- Unique chance to gain physical data
  - In-situ at depth and in reservoir
  - In the cold front
  - From a producing field

ennatuurlijk aardwarmte

TU Delft
Delft University of Technology

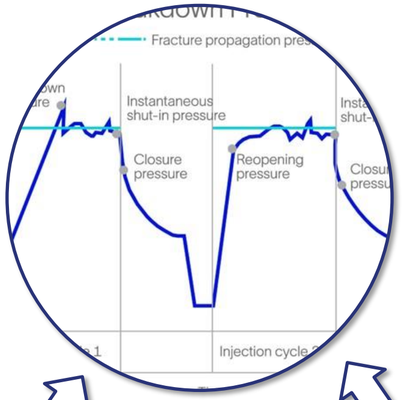
ebn

TNO innovation for life

WEP work well together

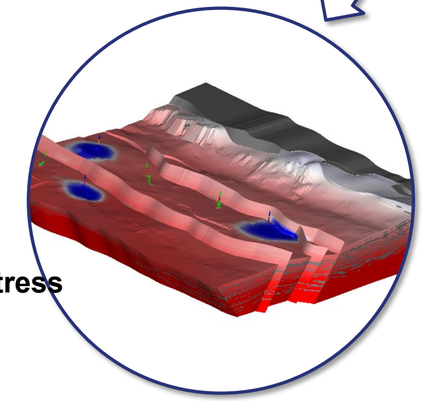
WP4

We have a **3M**



Measuring

In-situ stress, permeability, velocity



Modelling

3D models, cooling, stress

Monitoring

Deep geophones, surface networks, DAS

Lower injection temperatures and higher injection pressure within a safe and optimal production framework

MIDDENMEER

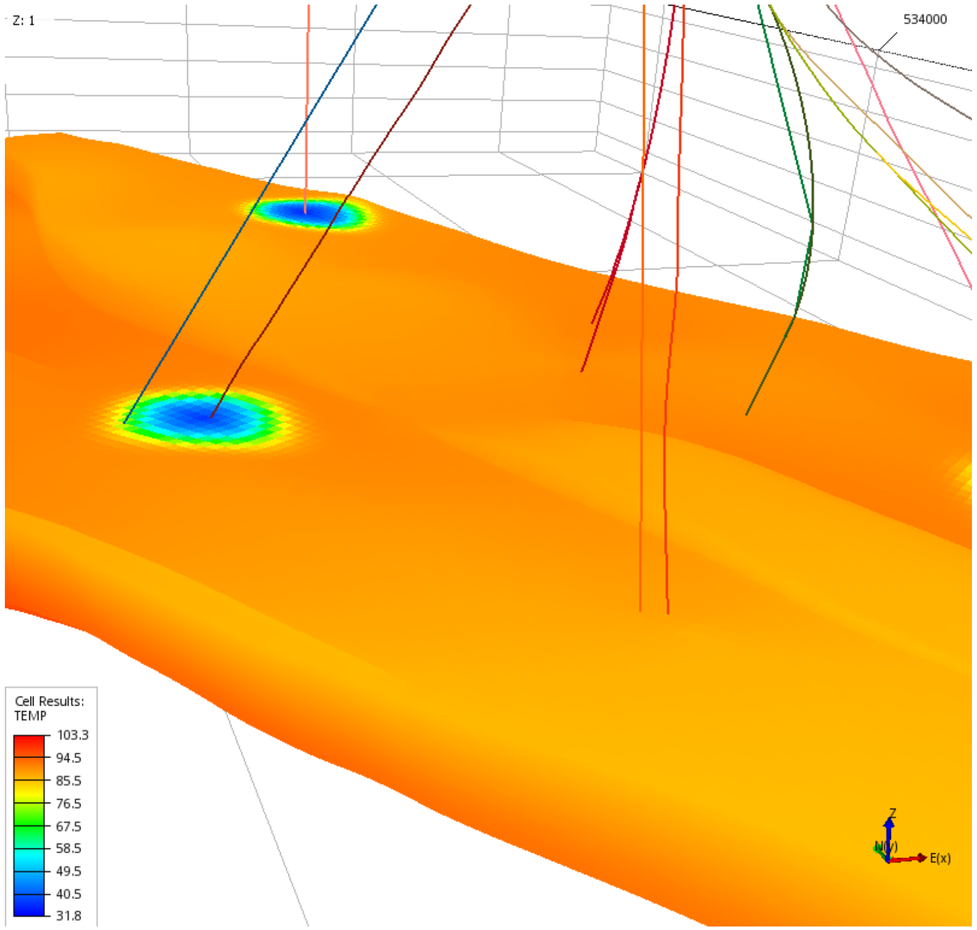
Geothermal Energy by Ennatuurlijk Aardwarmte

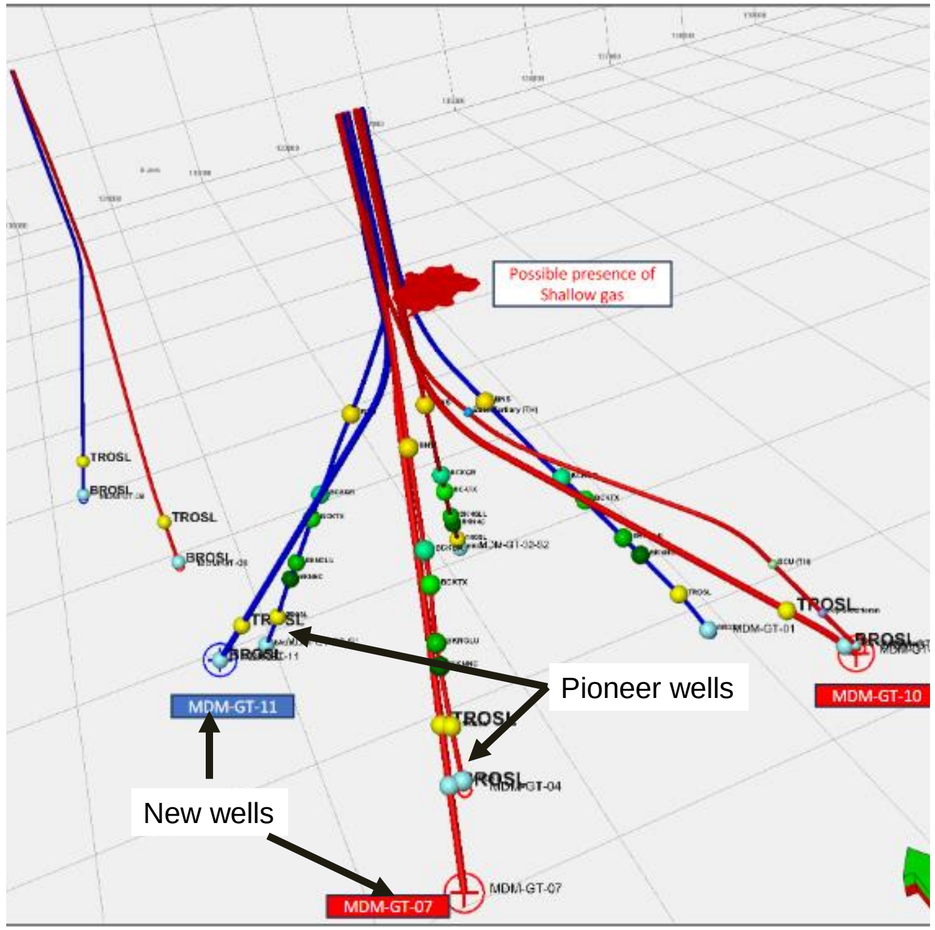
Agriport started in 2005, 7 large greenhouse operators,

First geothermal borehole drilled in 2013, currently 5th Doublet in development

DOUBLET 2 TO DOUBLET 5

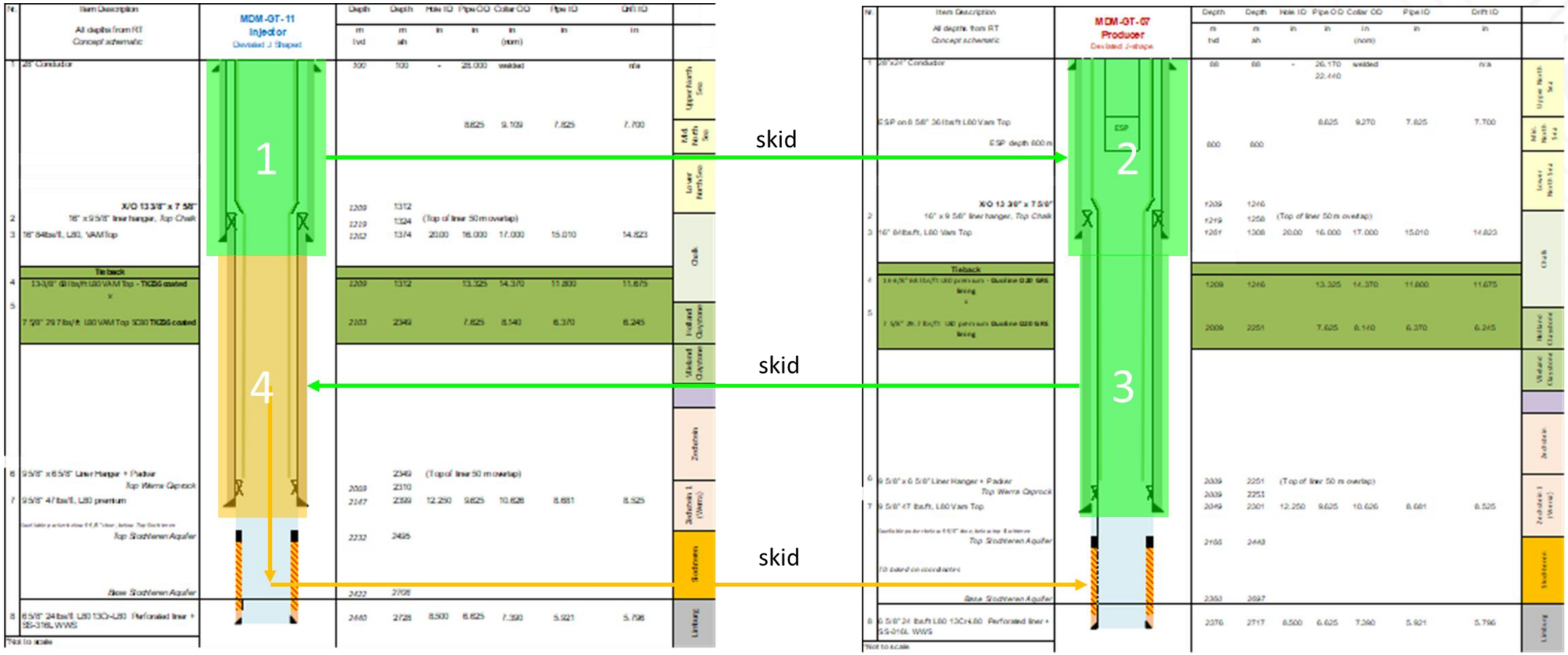
Pioneer wells GT3 &GT4 (DB2) to be replaced





WELLS DRILLING PROGRESS

GT7 & GT11 are firstly being used for measurements

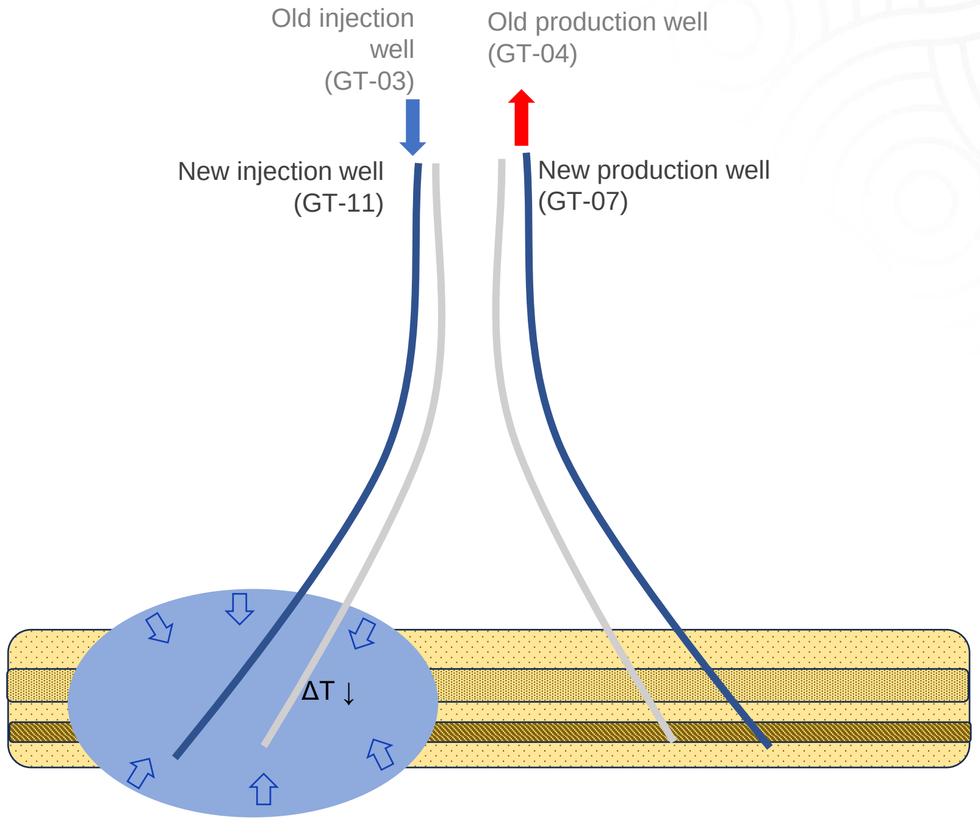


MONITORING

Within the replaced Doublet 2: MDM-GT-03 & -04

Depth top res:	2172m (GT-03) – 2147m (GT-04)
Thickness net:	180 – 188m
NTG:	99-100%
Temperature:	~91°C
Injection T:	mean 35°C
Start injection:	Q4 2014
End injection:	Q4 2024

Old wells (GT-03) can be used for monitoring down to the reservoir level. P&A process of wells will be safely delayed for collection of valuable information.



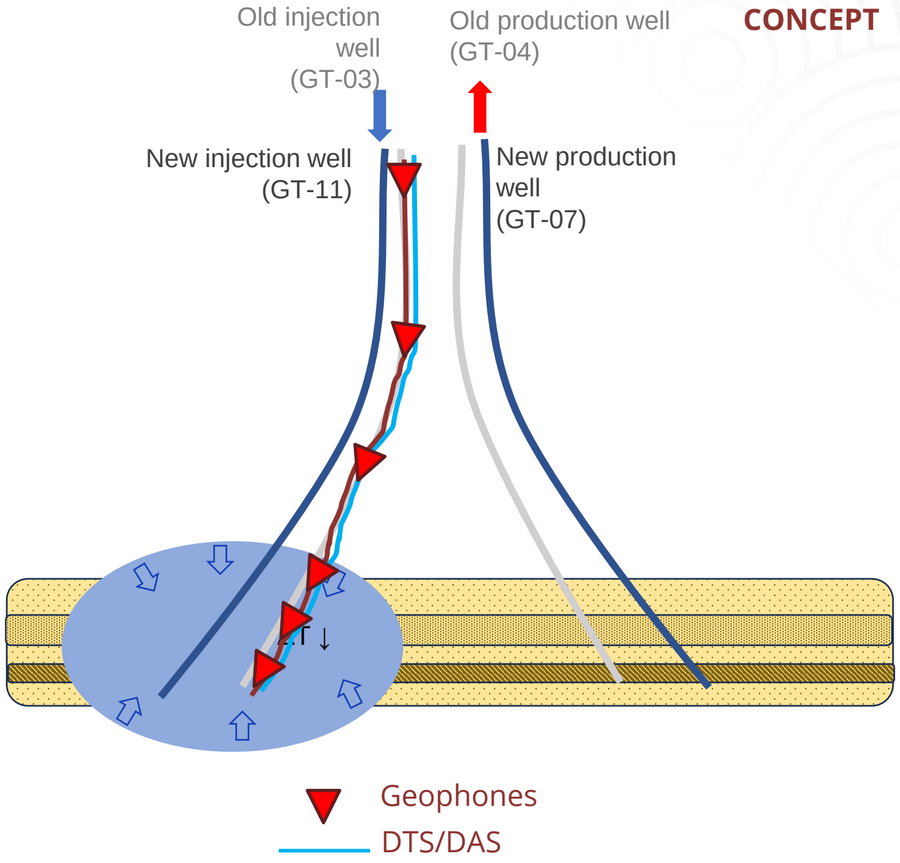
MONITORING

MDM-GT-03 - Deep Toolstring + Fiber optic cable

Aims

- Geophones and tilt meters
  - Detecting microseismicity (or other deformation related to cooling of the reservoir)
  - Measure temperature in the reservoir
  - Combine with fiber optic cable?

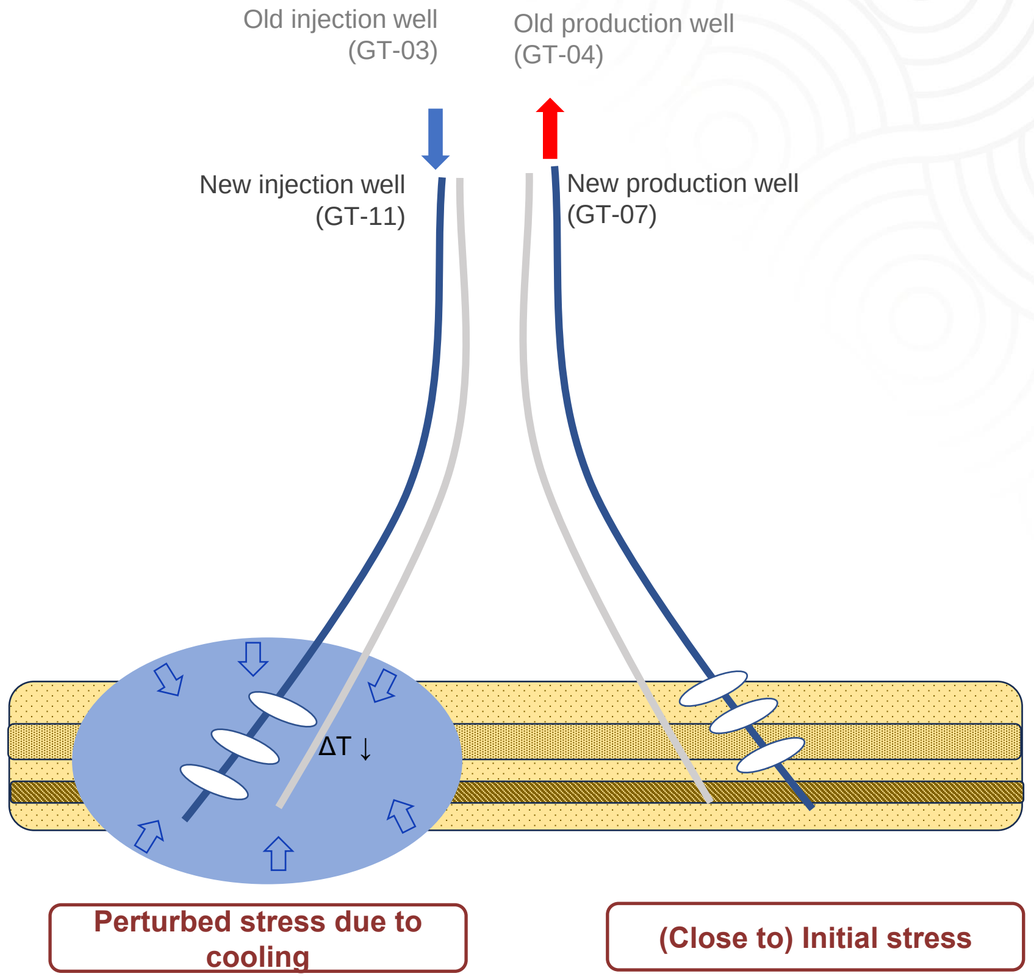
- DTS Fiber optic cable
  - Measuring T profile in the reservoir and caprock and overburdens
  - Measuring re-heating of GT-03 after stop
    - *formation properties*
  - Measuring production start GT-11



MEASURING

Stress measurements MDM-GT-07 & -11

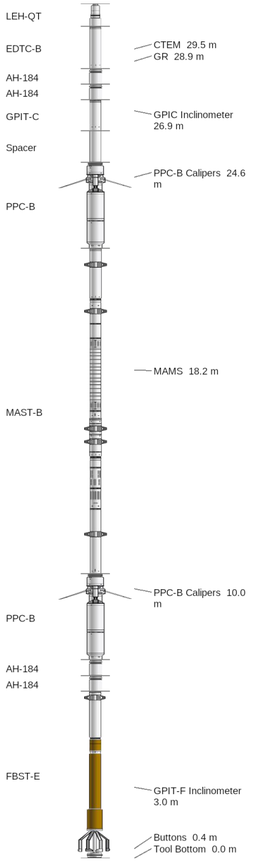
- In-situ stress and stress change: Most important parameters for integrity caprock / seismic hazard
- No measurements of stress in cooled rock at depth
- Unique opportunity at Middenmeer
- Model validation



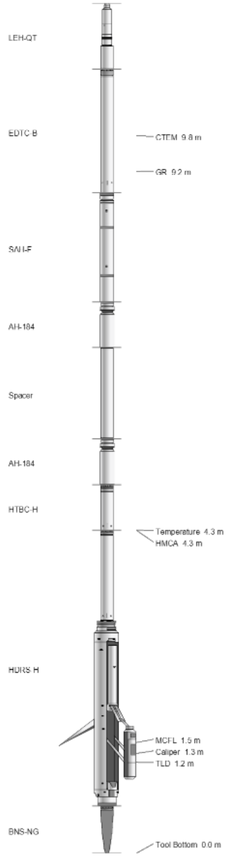
MEASURING

Logs

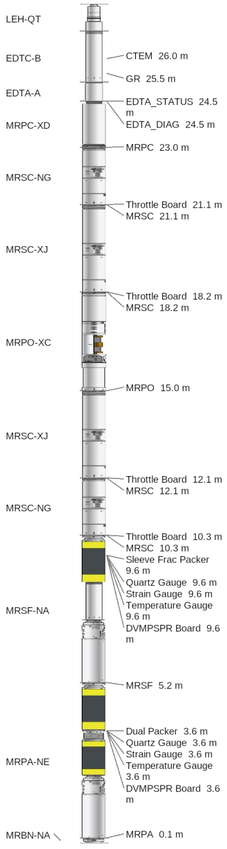
Sonic, Caliper, (FMI GT11)

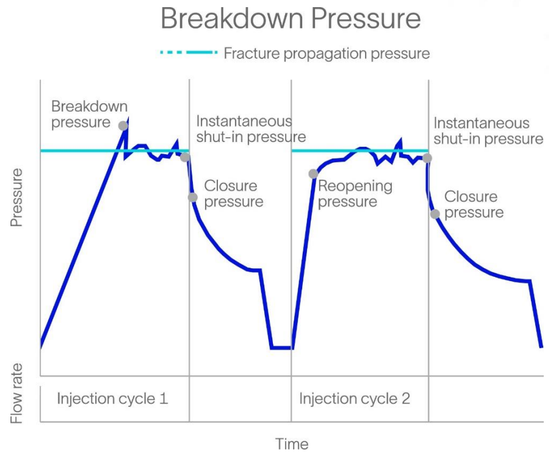


Density, Temperature



Minimal horizontal stress





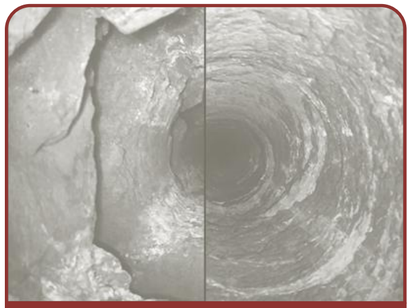
https://www.slb.com/products-and-services/innovating-in-oil-and-gas/reservoir-characterization/surface-and-downhole-logging/wireline-openhole-logging/insitu-measurements-geomechanical-profiling-workflow

Porosity, hole shape, fractures → moduli ← Porosity, temperature

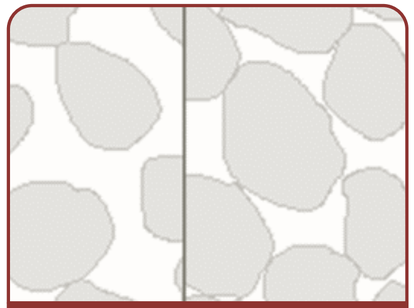
Cooled and a priori → thermal compaction coefficient

MEASURING

Logs

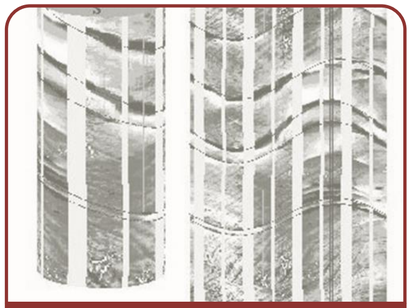


Gun barrel

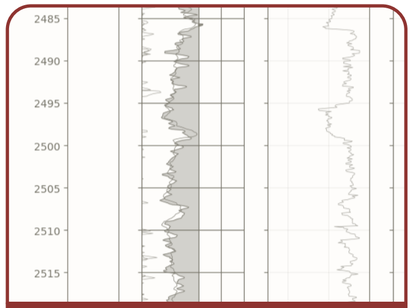


Low porous

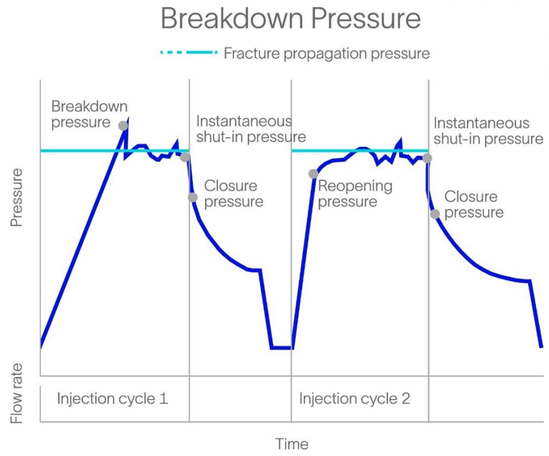
Cooled



No natural fractures



Homogenous



https://www.slb.com/products-and-services/innovating-in-oil-and-gas/reservoir-characterization/surface-and-downhole-logging/wireline-openhole-logging/insitu-measurements-geomechanical-profiling-workflow

nal compaction coefficient

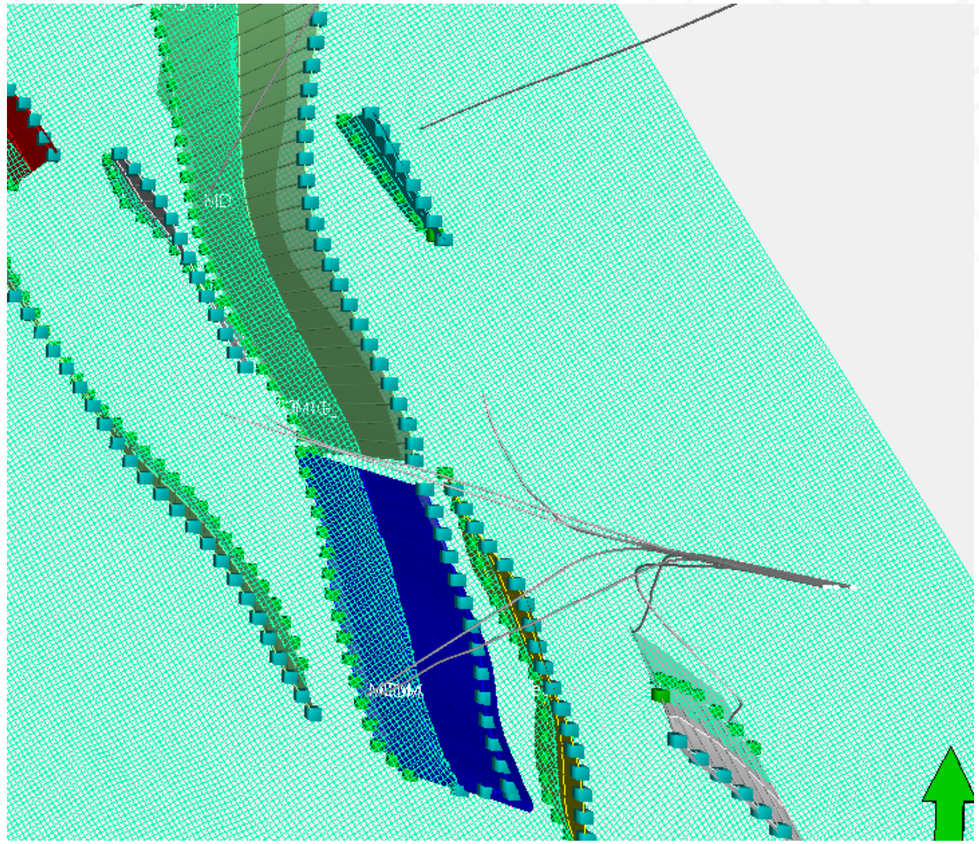
MODELLING

Finally: modeling, analyzing and improvement

All results of the work packages, and in detail WP4, the “3M” will be used to model, interpret and analyse the subsurface and the impact of geothermal production of the conditions and parameters.

Analysis and continuous monitoring and modelling will allow us to evaluate the safe practices and optimization for more sustainable heat production.

Initial modelling to be performed in collaborative teams of ENNA, TNO, TUD and EBN.



RESULTS & FUTURE

Always safe and sustainable heat production

- Real Data from in situ measurements
- Match measured results to scientific interpretations & calculations
- Actual understanding of cooling effects
- Continuously monitor impact on, and response of geothermal production
- Opportunity to improve business case with reduced risk by understanding impact and conditions while increasing operational boundaries
  - Injection temperature, Flow rates, Pressures, location and depths

What do you think?