EAGE

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GEOTHERMAL ENERGY CONFERENCE

INTEGRATED APPROACH TO CHARACTERIZE GEOTHERMAL RESERVOIR FLOW POTENTIAL: AN EXAMPLE FROM DE BILT-01

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PERMEABILITY

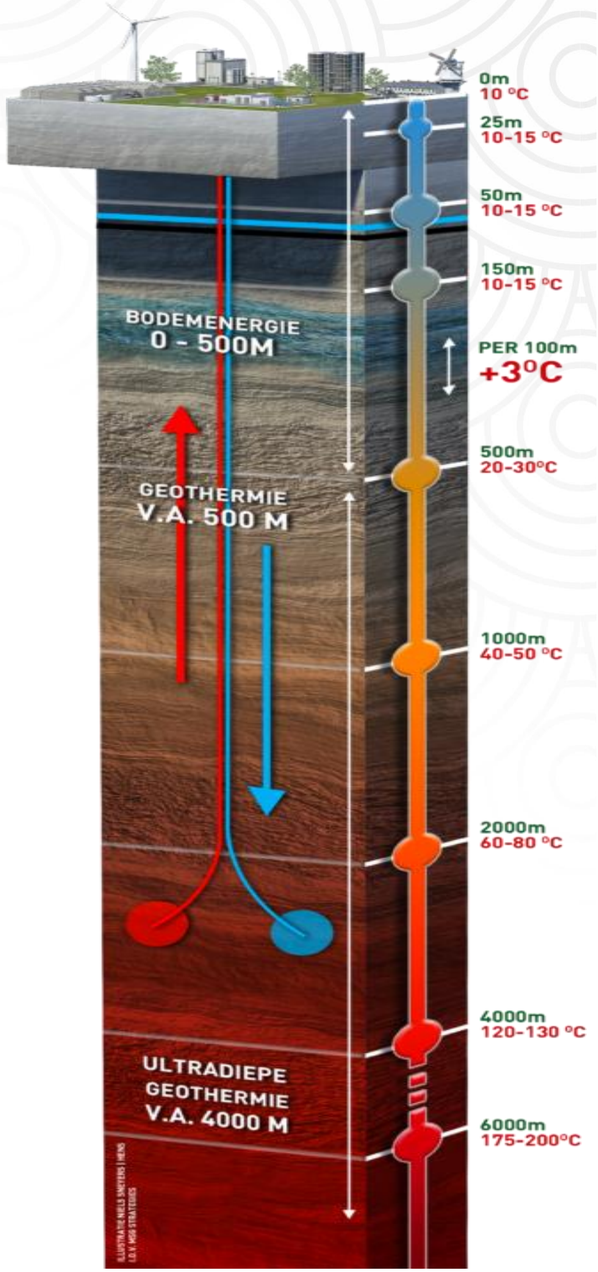
Measurement of fluid flow through porous media/reservoir.

Critical in geothermal energy systems

- **Efficiency and sustainability** of heat extraction

Challenging parameter

- **Direct** subsurface measurements/characterization which captures the reservoir heterogeneity at all scales.



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AGENDA

- Introduction
  - SCAN Project
  - Well Data: De Bilt -01
- Integration Workflow
- Interpretation
  - Logs
  - Core
  - Well Tests & PLT
- Results
- Conclusion

INTRODUCTION

SCAN Project and Permeability

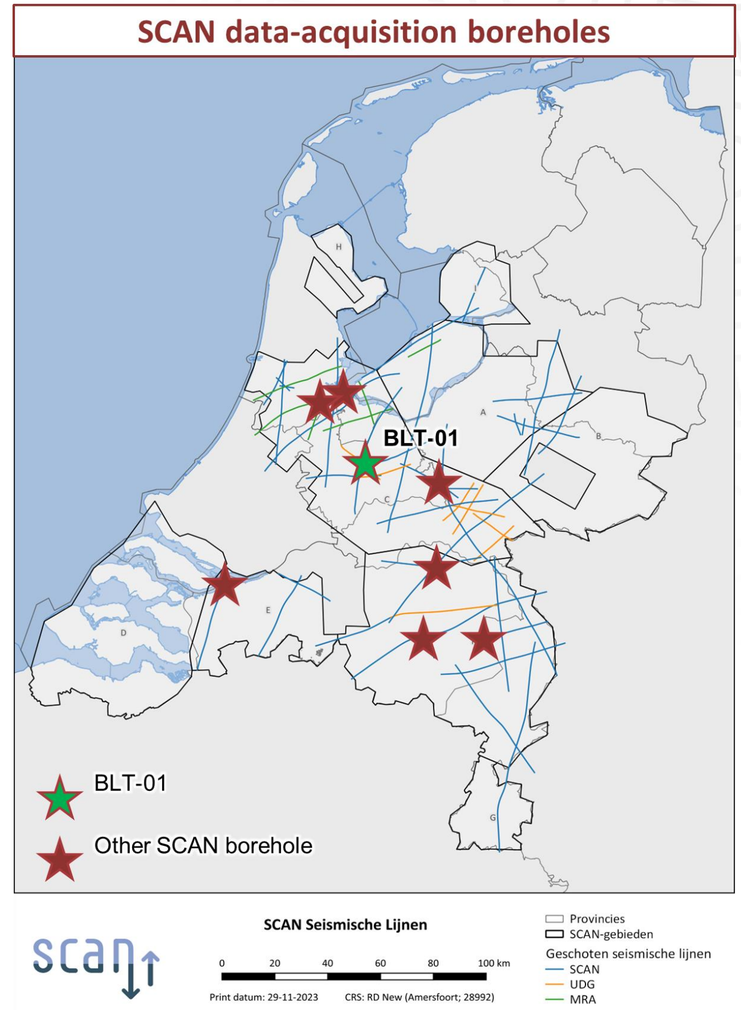
SCAN project (Funded by KGG, executed by EBN and TNO), acquires new data in The Netherlands for geothermal potential.

Focus: Permeability or flow capacity of geothermal reservoirs in BLT-01 well

Direct measurements are limited and different in scales:

- Core probe and plug data (mm to cm)
- Well tests data (10s – 100s of meters)

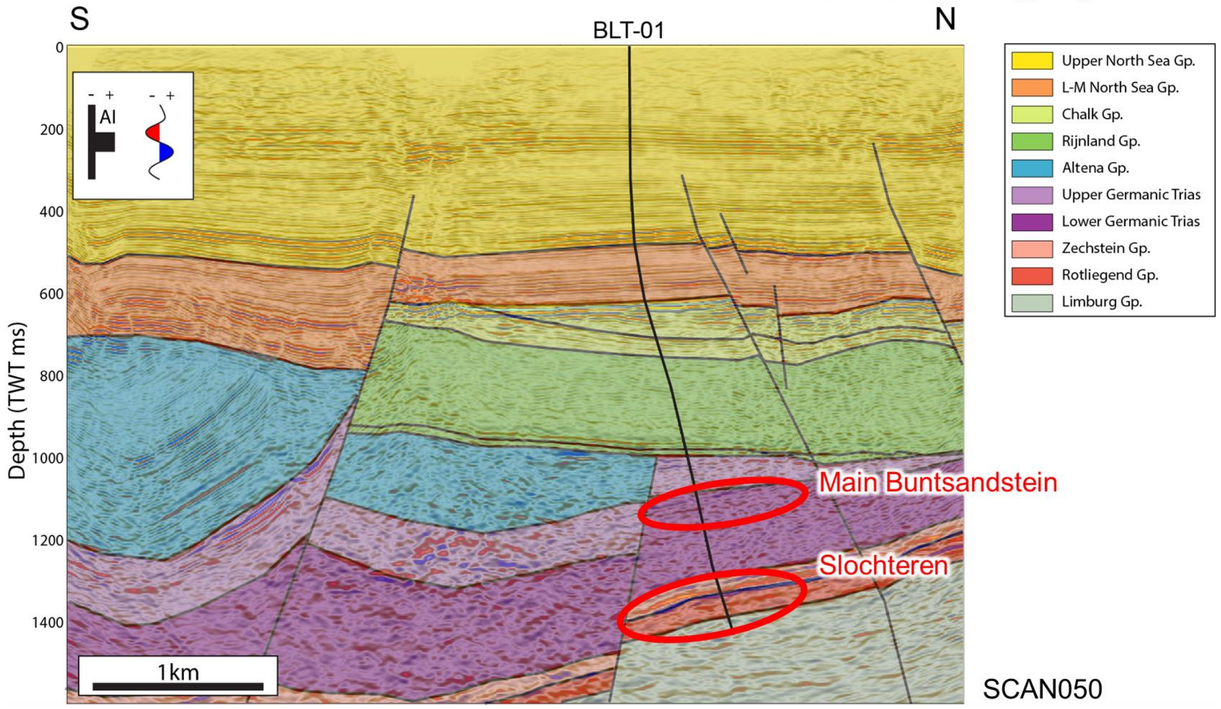
Quantitative comparisons were performed to assess the impact of heterogeneity in reservoir permeability



INTRODUCTION

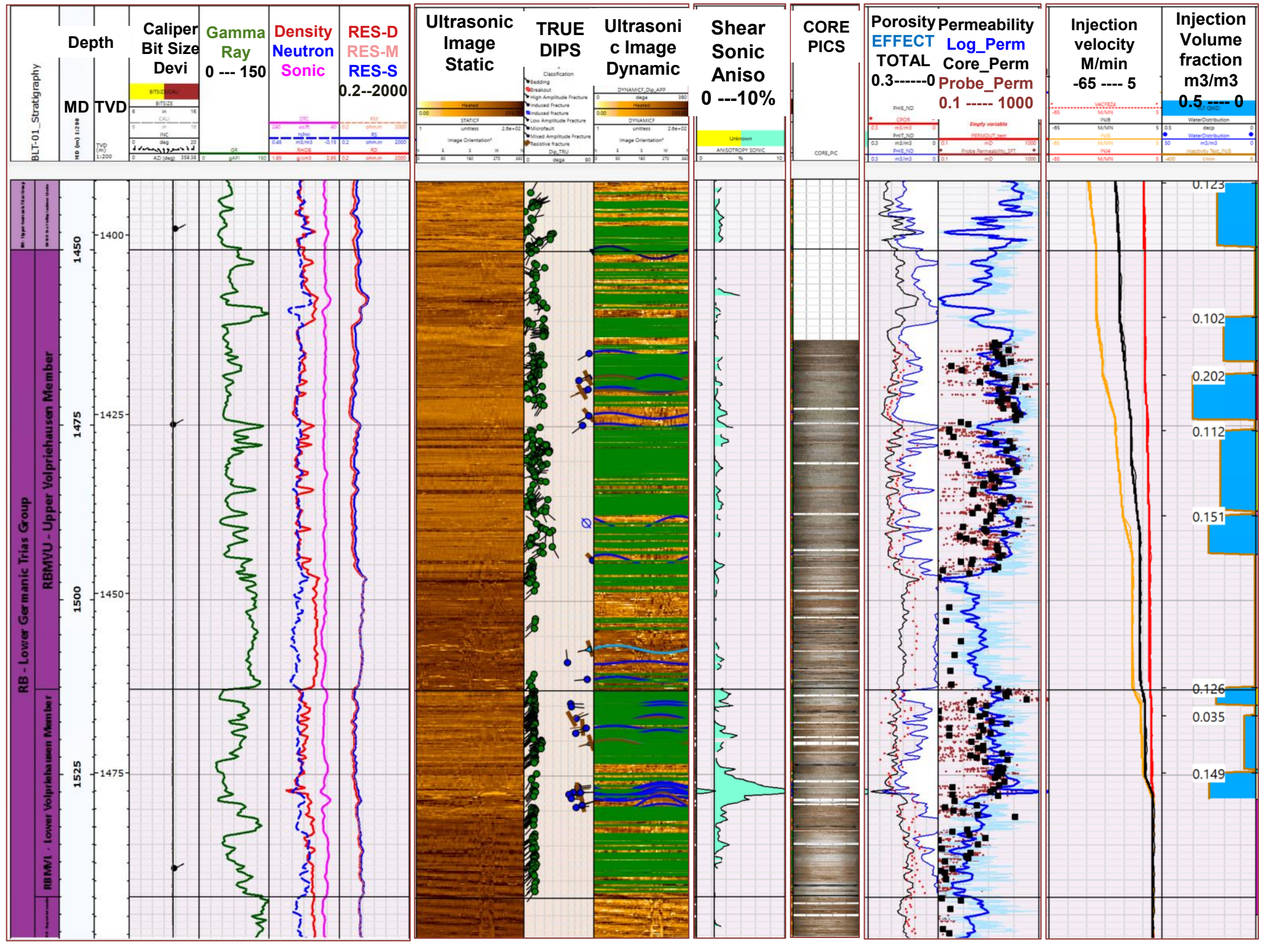
De Bilt-01 (BLT-01)

- Drilled January-February 2025; TD 2123 m MD
- Extensive data acquisition throughout well:
  - Coring and core analysis (Routine, Special, Probe permeability, etc.)
  - Logging LWD and WL (Standard and advanced tools (Image logs, NMR, etc.)
- Two potential geothermal reservoirs:
  - Triassic Main Buntsandstein
  - Permian Slochteren (Rotliegend)
- Both reservoirs tested for - production and injection in March-April 2025



INTEGRATION WORKFLOW

Permeability – from Core to Log to Well test



Open Hole Logs

Properties from logs : GR, D-N-S, Resistivity,
(Vertical resolution: 30 – 60 cm)

Advanced logs: Image logs, Acoustic data

Confirmation of beddings, Open/Closed Fractures and Anisotropy around (mm – cm)

Continuous Core Probe permeability, Core Poro Perm

Plug porosity and permeability at stress & with Brine (1mm – 1.5cm)

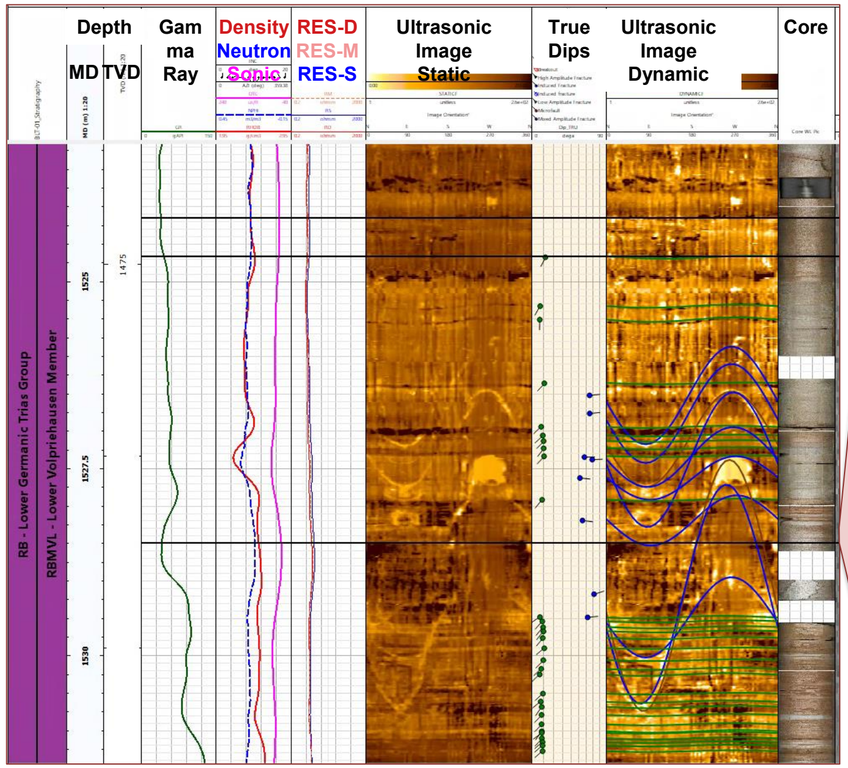
Well Production / Injection PLT Tests

KH frm the perforated zone (10s of m) / Injectivity% from interpreted intervals
(10s of m)

INTERPRETATION

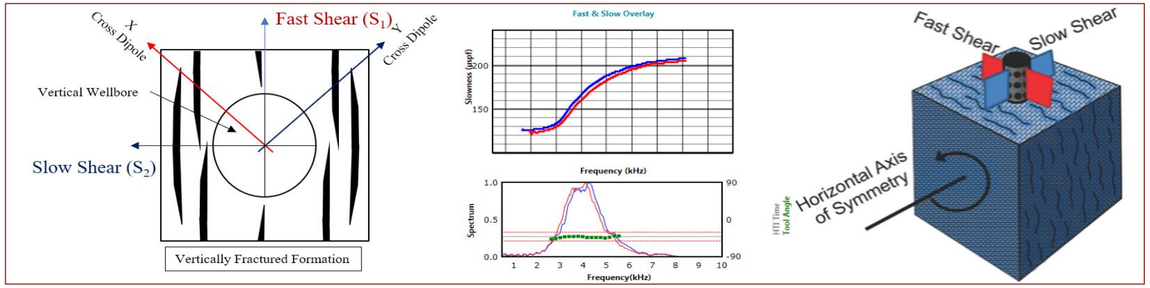
Core and Image Logs

Main Buntsandstein



Core with partially cemented/open fracture from 1528 m MDRT

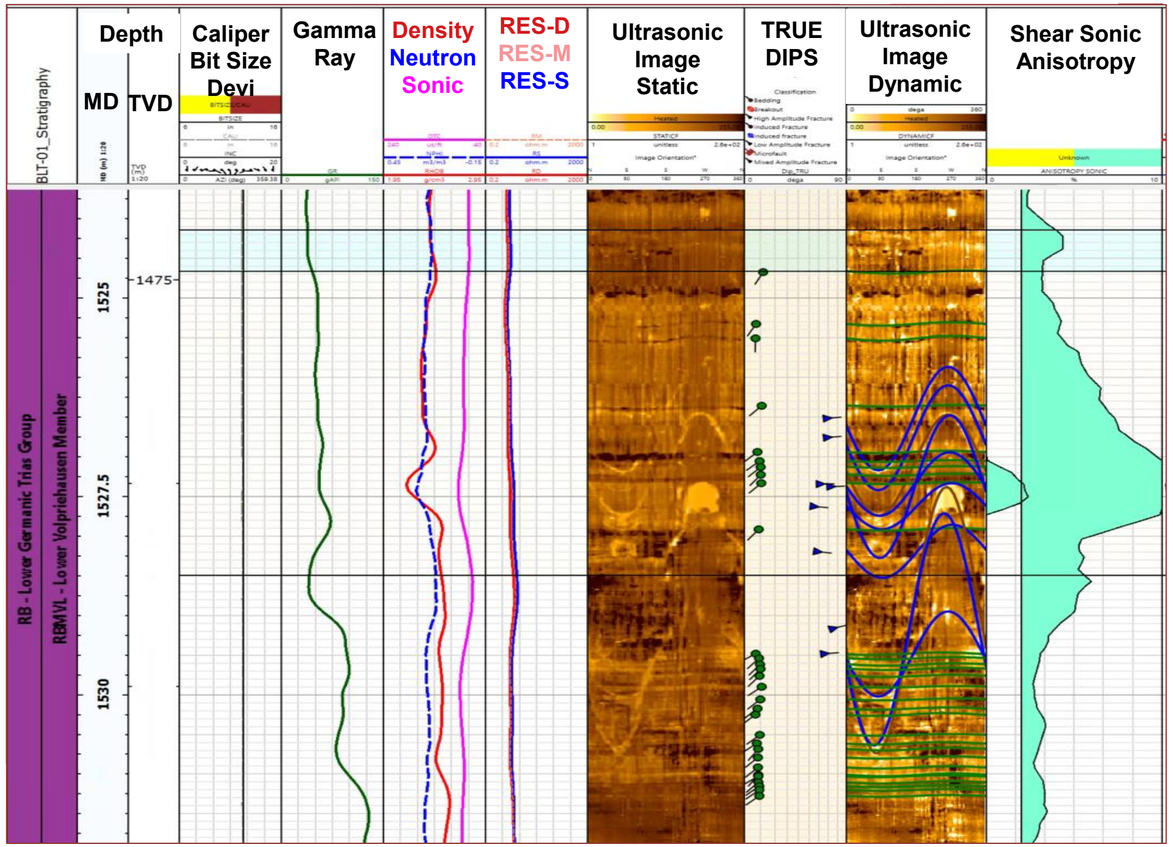
- **Image logs** are one of the best way to capture heterogeneity across the reservoir at a high resolution
- Fractures (open and cemented) were identified and confirmed from **Core data** at certain depths
- Sonic **shear anisotropy** around the fractured zone confirmed the fracture zone in the formation
- The fast-slow shear dispersion plot (below) agrees with fractures beyond the well, (not Hoop stress)



INTERPRETATION

Core and Image Logs

Main Buntsandstein



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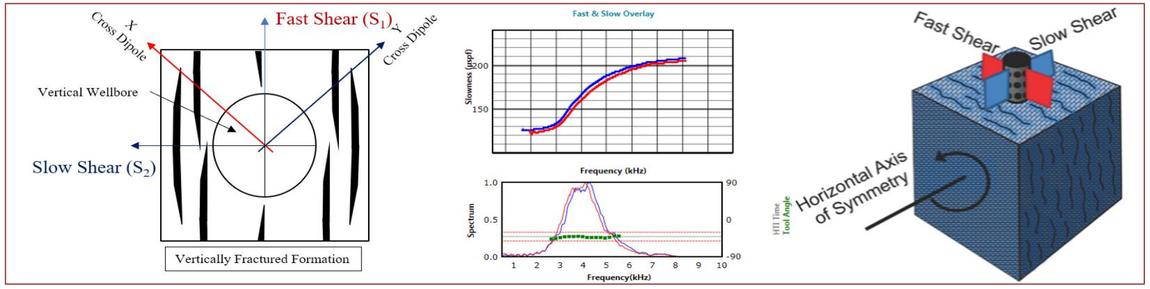
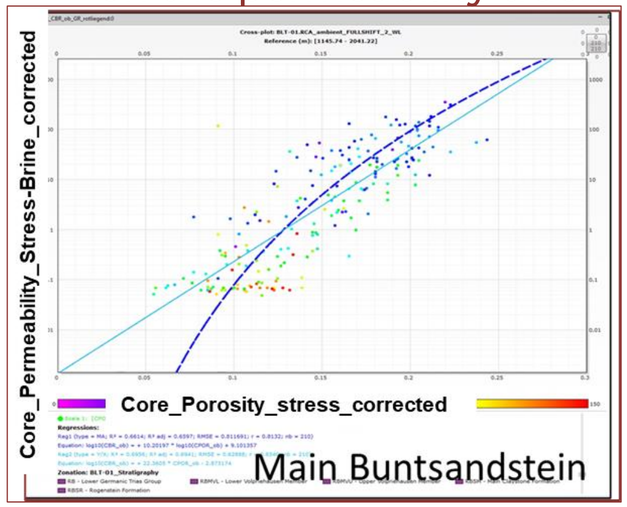
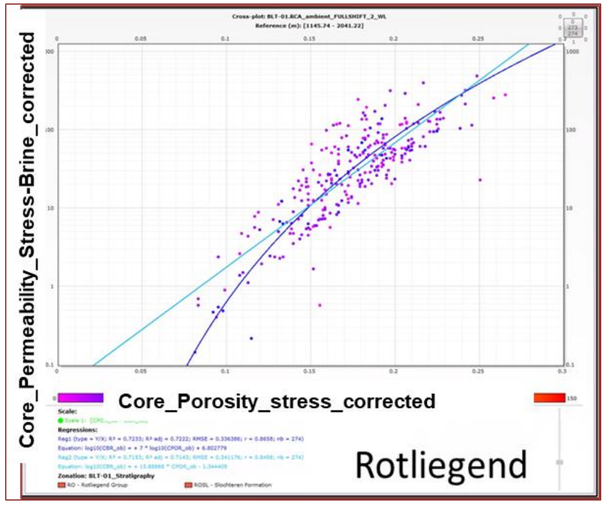


INTERPRETATION

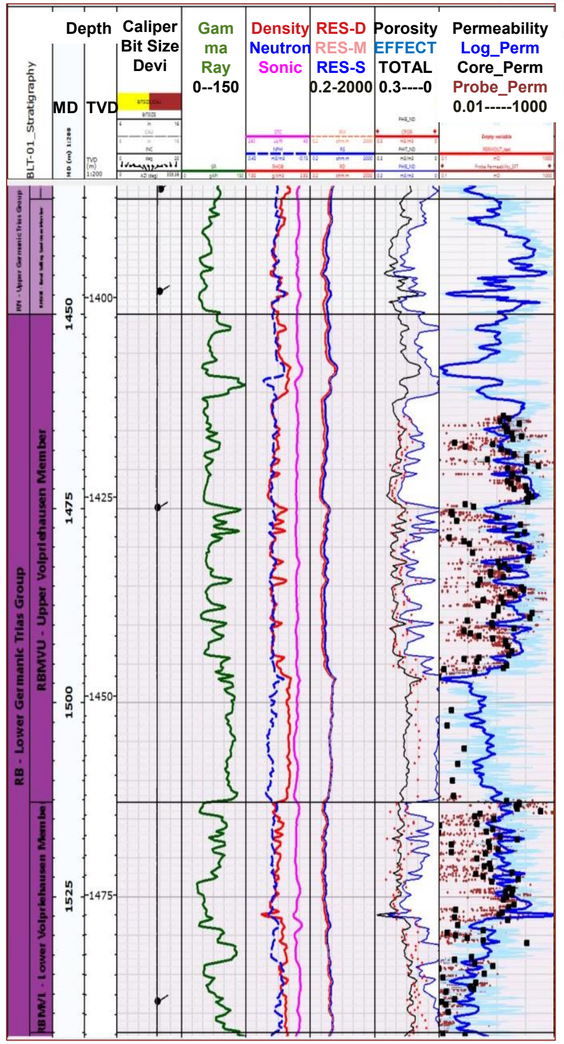
Core Data

- Continuous **Probe air-permeability** measured at mm scale across the entire cored intervals
- Routine Core Analysis data from core plugs were corrected for **Stress** and **Brine** Permeability
- Corrected Poro-Perm transforms used for **Perm_log**
- Uncertainties around the **transform and upscaling** visible on the permeability track

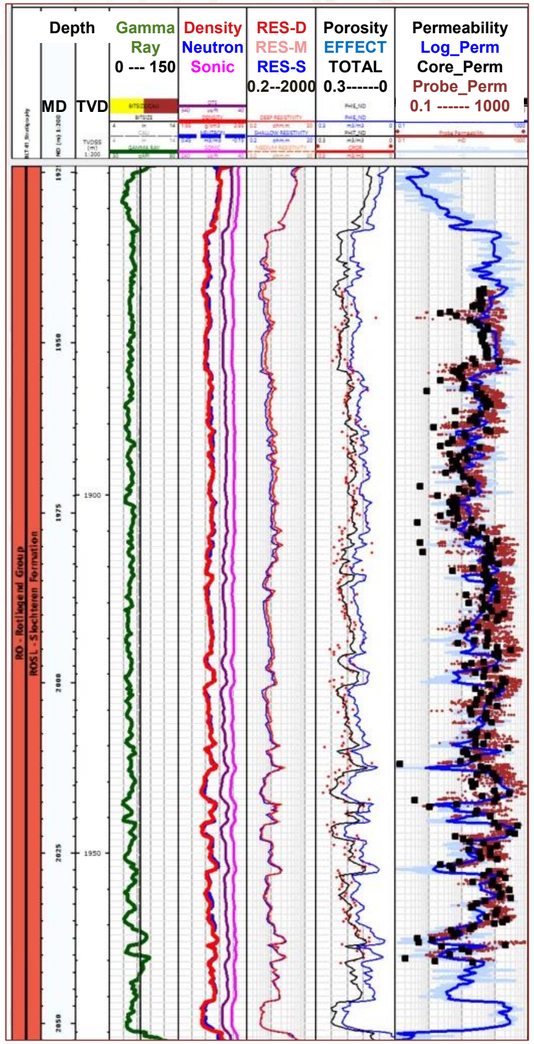




Main Buntsandstein



Rotliegend



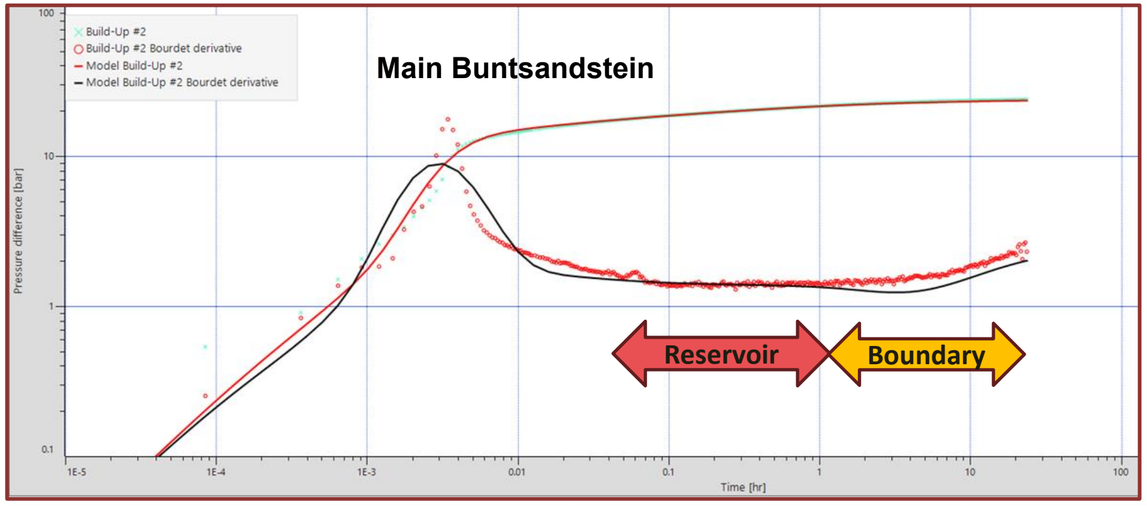
INTERPRETATION

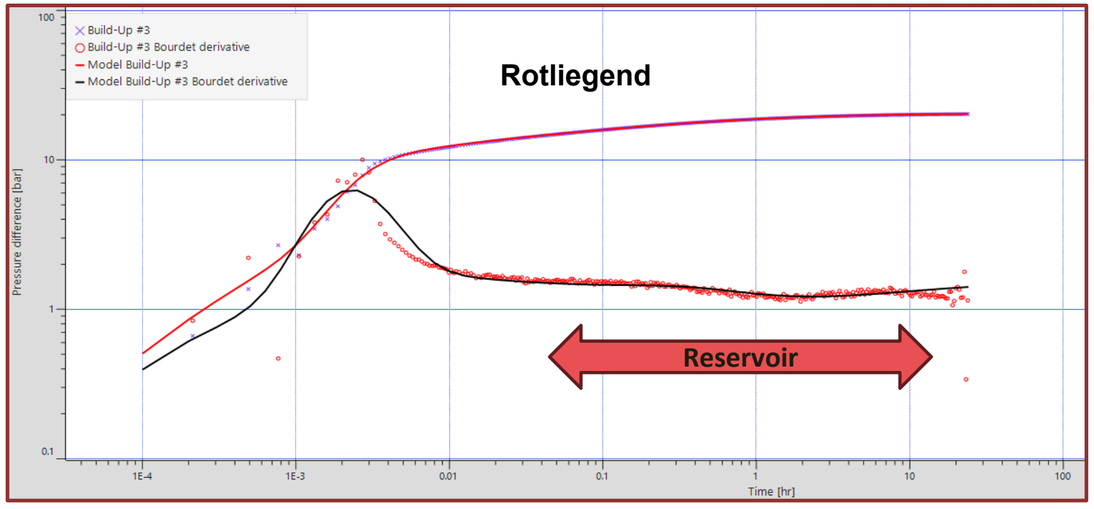
Well Test (Production) Results

Pressure transient analysis of the buildups of the production phase shows:

- Minimal variation in transmissibility throughout the reservoir (until the extent of the test)
- Matrix driven flow

The match between the average **Perm_log** and average well test permeability is good (0.7 – 0.8 multiples).





Formation	Well Test data (Darcy.m)	Net Perforated interval (m TVD)	Avg Permeability from WT analysis (mD)	Avg Permeability from Core calibrated logs (mD)
Main Buntsandstein	4.7	93.7	**50**	**64**
Rotliegend	4.8	118.3	**39**	**53**

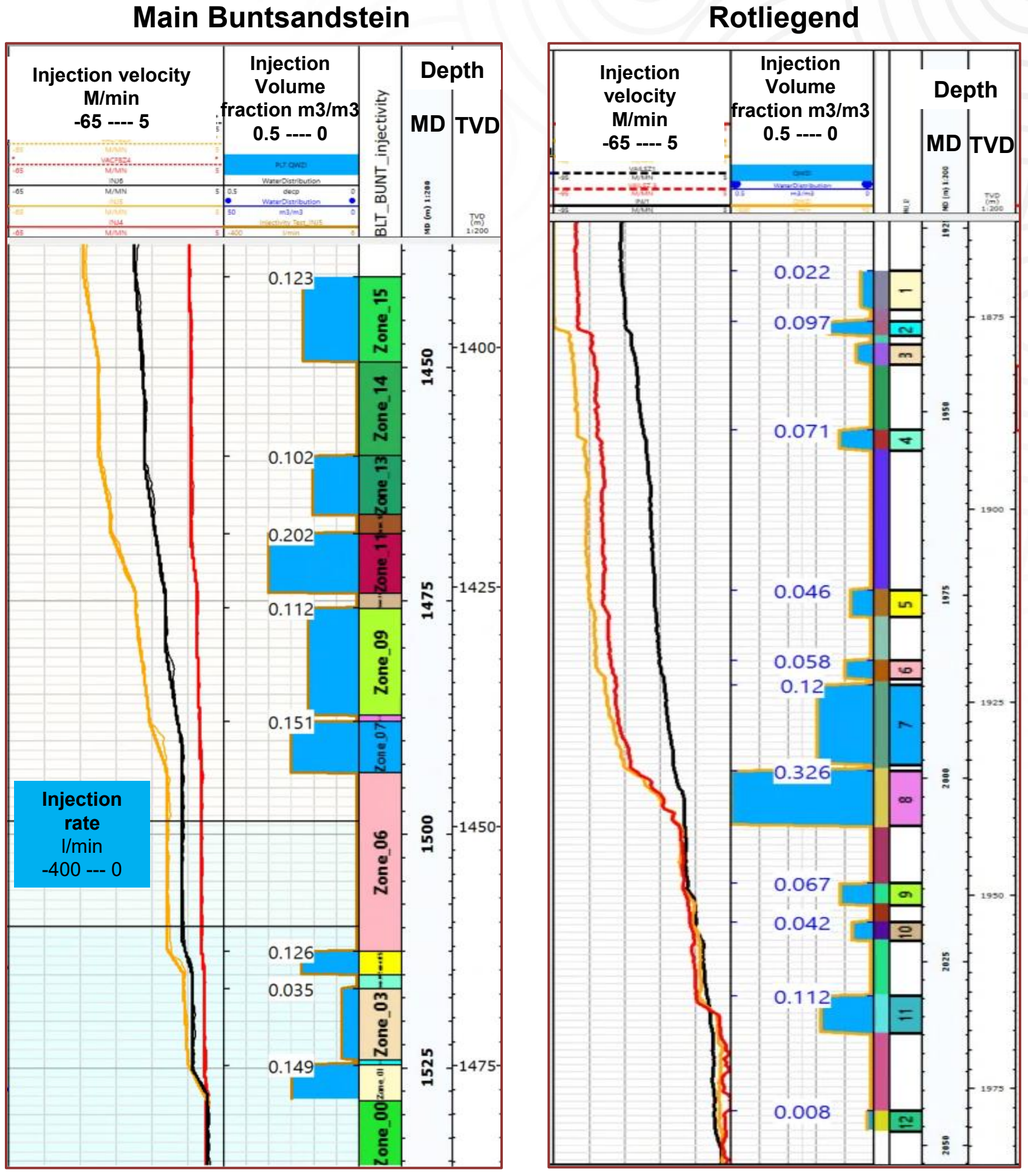
INTERPRETATION

PLT Injection Log

- PLT logging during injection test, showed zonal contribution (Flow zones – FZ) within perforated interval in both the reservoirs,:
  - Injection rate (blue bars)
  - Injection volume (fractions)
- From the core calibrated Perm_Log, averages were calculated per PLT flow zones and factored in terms of total average permeability,

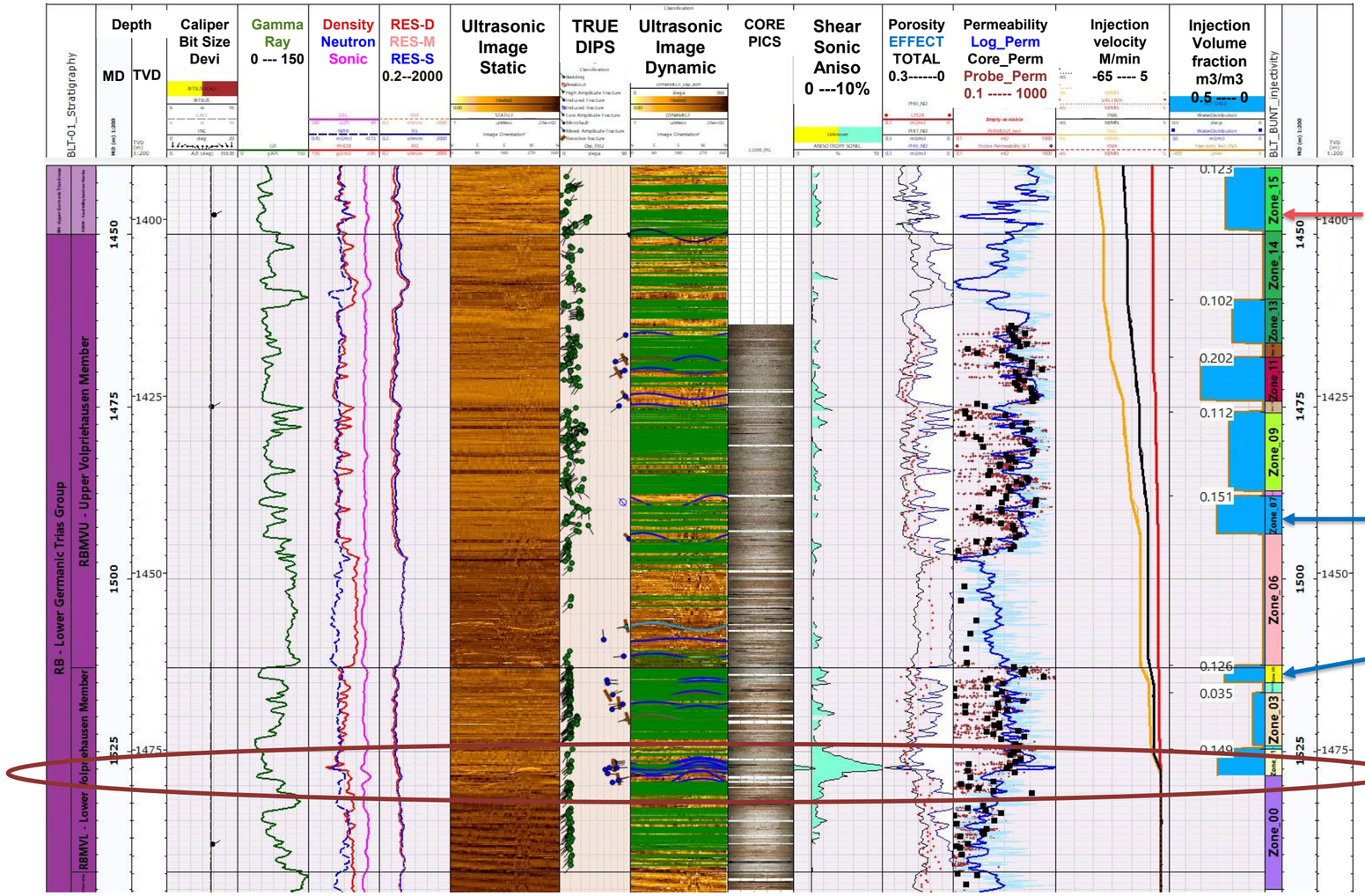
$$\text{Fraction Perm\_log\_avg} = \frac{\text{Avg\_Perm\_Log per FZ} * \text{FZ\_length}}{\text{Avg\_Perm\_log of Perforated zone} * \text{Perforated interval}}$$

- The injection volume fraction from PLT Flow Zone compared with Fraction Perm_Log_avg.



RESULTS

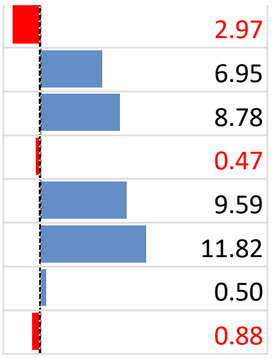
Comparisons of Permeability - Buntsandstein



Transmissivity Difference PLT and Log

- | +

Difference of Avg_log_Perm Fraction vs Injection volume Fraction %

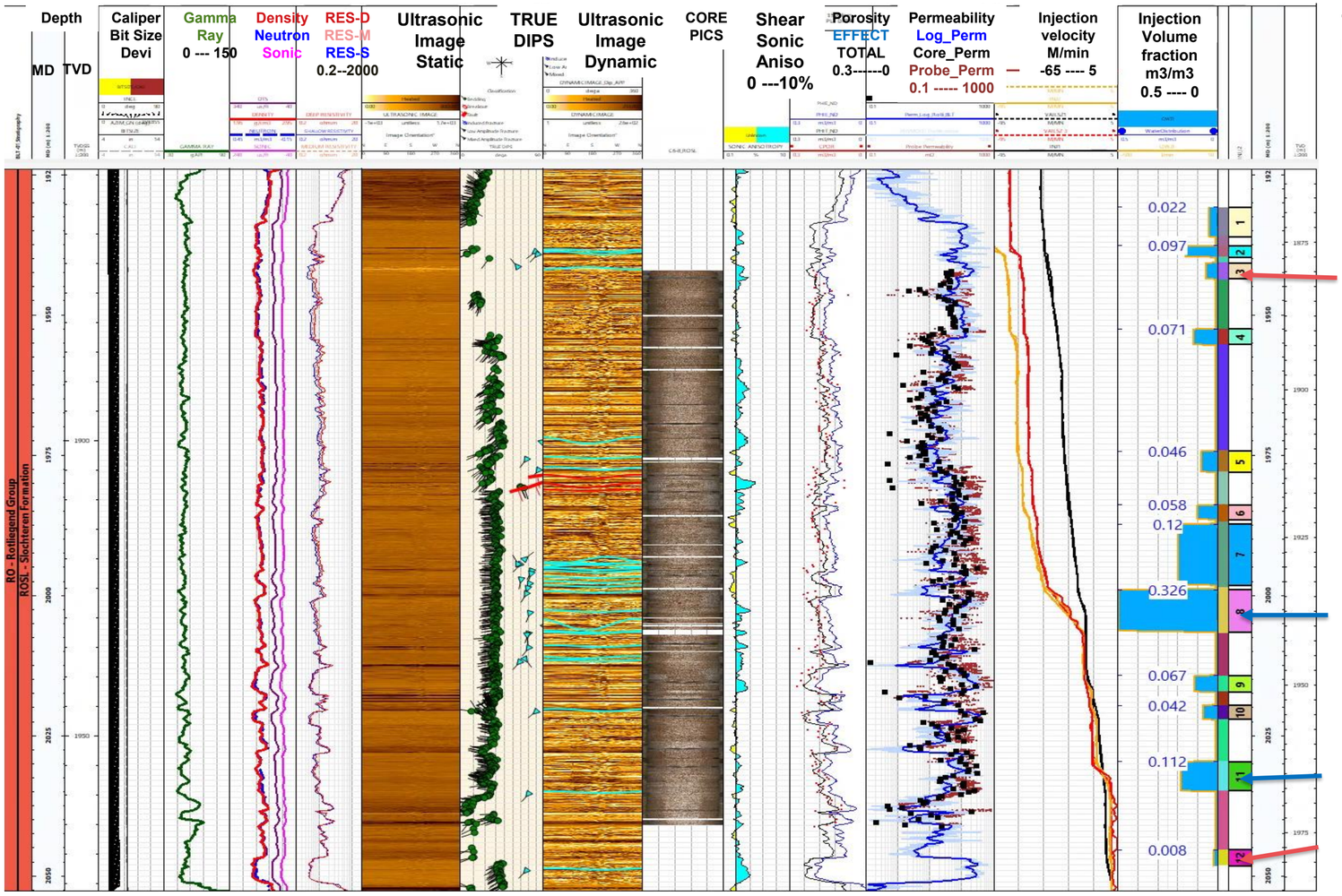


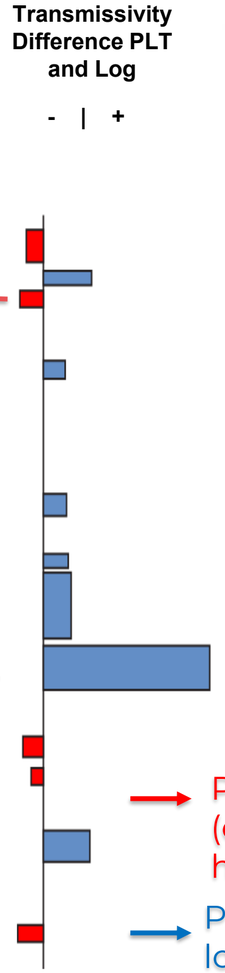
PLT injection < Avg Log permeability (e.g.: cemented micro fault or layered heterogeneity)

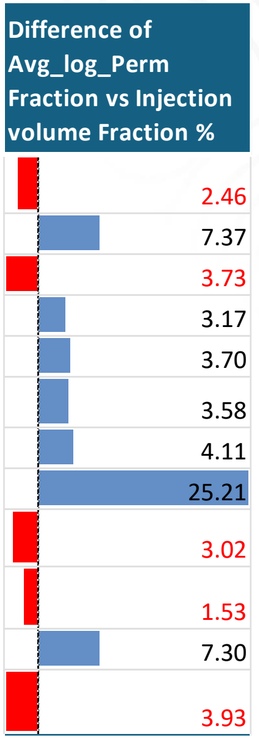
PLT injection > Avg Log permeability log (e.g.: Open Fracture Zone)

RESULTS

Comparisons of Permeability - Rotliegend





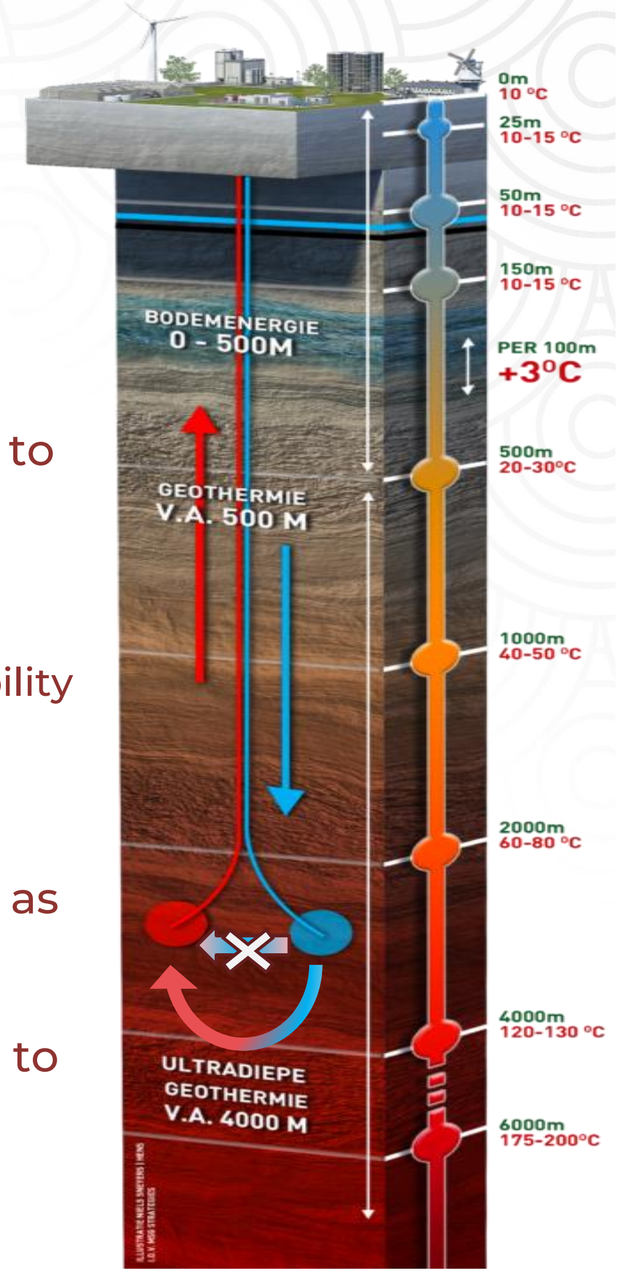


→ PLT injection < Avg Log permeability (e.g.: cemented micro fault or layered heterogeneity)

→ PLT injection > Avg Log permeability log (e.g.: Open Fracture Zone)

CONCLUSION

- Permeability must have good control over **scale, range and uncertainty**.
- **Multi-scale data analysis** enhances the reliability of interpretation leading to **a stronger understanding** of flow behavior.
- In the case of BLT-01:
  - Matched the large scale **'dynamic'** reservoir producibility to **'static'** log permeability
  - Established the matrix flow.
  - Identified **deviations** within flow zones and possible causes.
- **Quantifying flow behavior** is crucial to understand reservoir performance, as it has direct effect on power output and thermal breakthrough.
- Key take away – **integration, calibration, and verification** of available data, to have a better control over Permeability



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*I acknowledge my **colleagues at EBN** for their support and approval for this talk and my **co-authors** for their valuable contributions.*

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THANK YOU

Any questions?