EAGE

27-31 OCTOBER 2025
ROTTERDAM, THE NETHERLANDS

GET2025

GEOTHERMAL ENERGY CONFERENCE

CORE WORKSHOP PANTERRA

SCAN Project

By Adriaan Janszen (EBN)

Introduction to SCAN

➜ SCAN stands for Seismische Campagne Aardwarmte Nederland

➜SCAN acquires new data in areas where insufficient subsurface data is presently available for a reliable estimation of geothermal potential

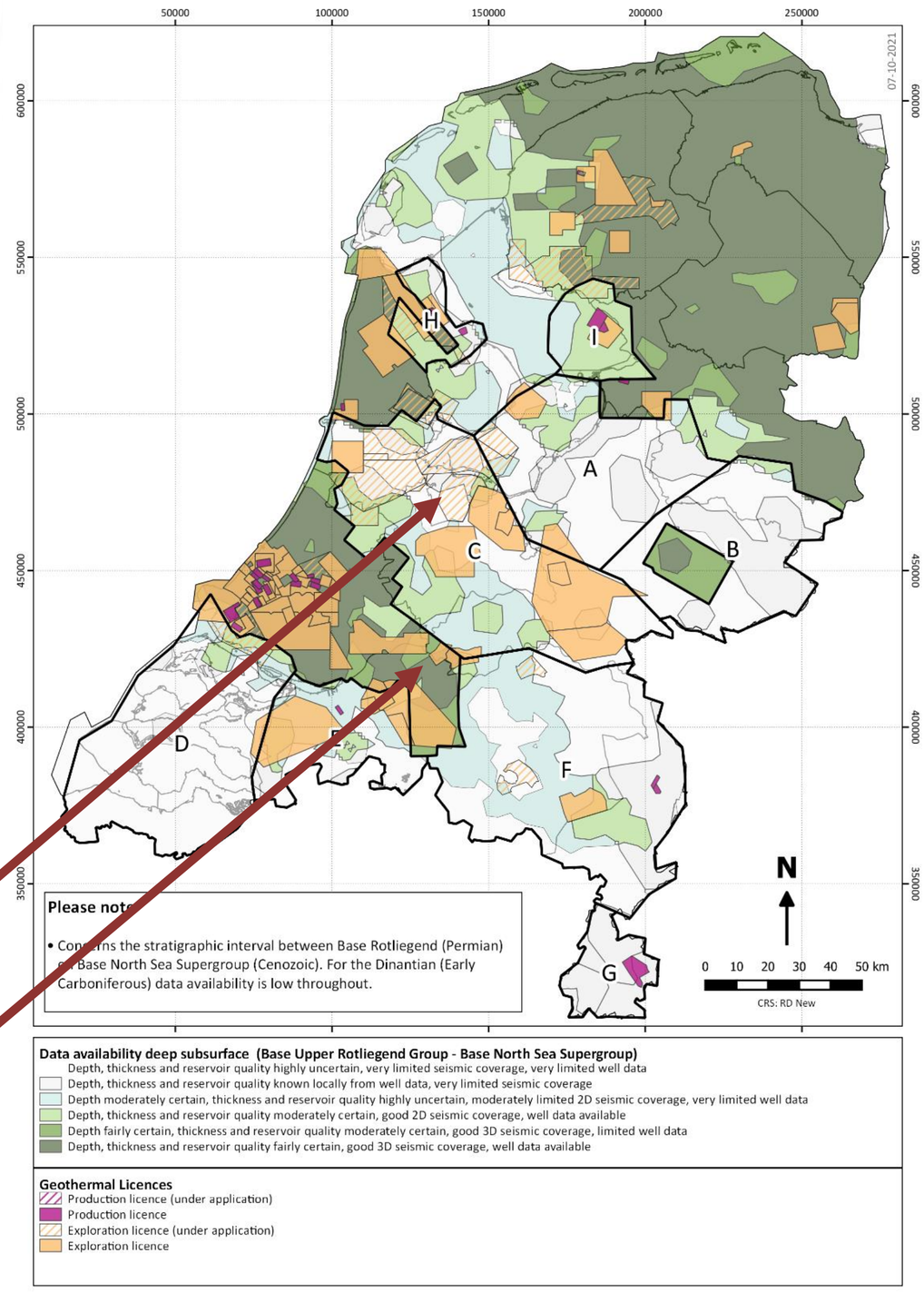
➜Focus on areas with high heat demand

➜Aimed at shallow and deep geothermal (500-4000m)

➜Funded by the Ministry of Climate and Green Growth, executed by EBN and TNO.

SCAN focuses on the ‘white spots’. On this map they’re actually coloured white, grey and light green

3D seismic and abundant well data available: <u>not</u> a ‘white spot’, <u>not</u> part of SCAN

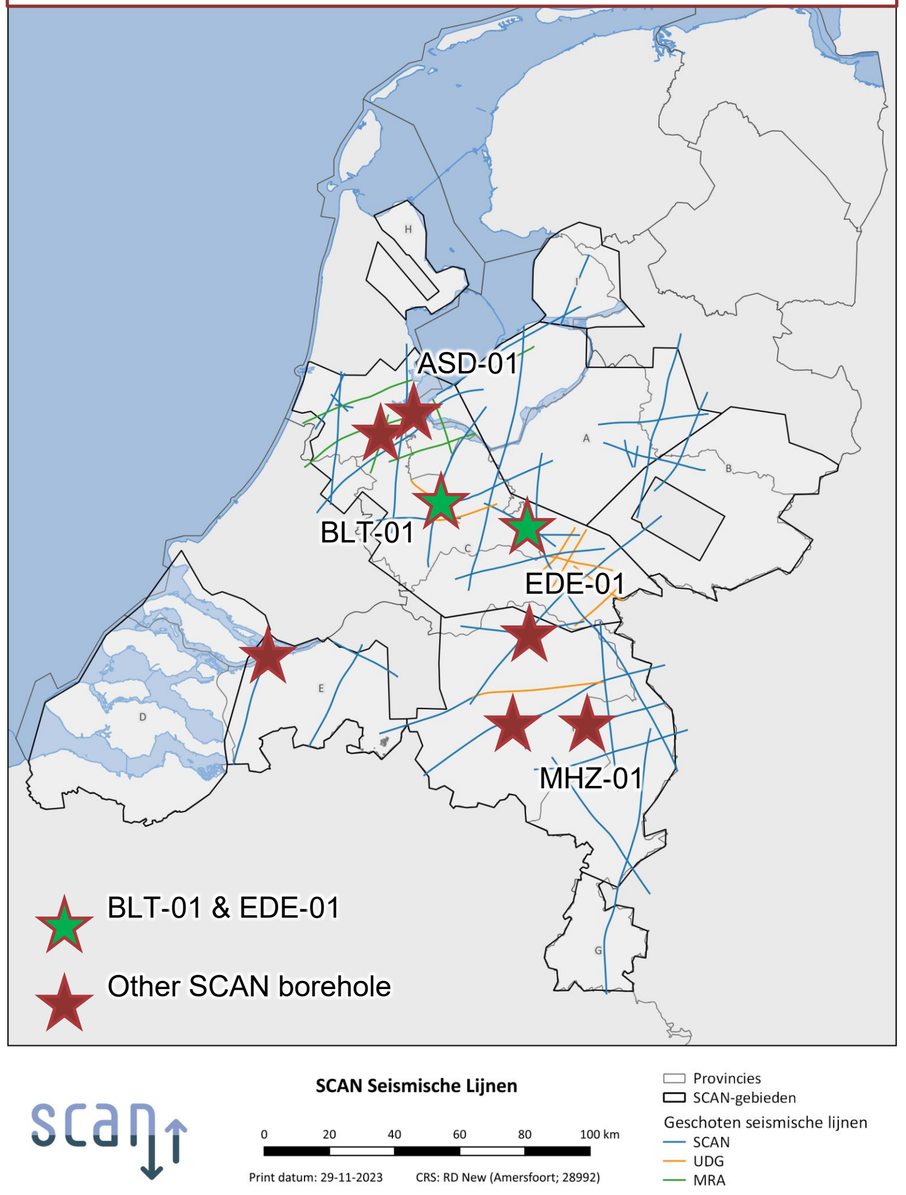


Components SCAN-program

1. **Acquisition 1900km new 2D seismic data and re-processing 7500km old 2D-seismic data**
   - Completed
2. **Acquisition of detailed seismic in areas with proven geothermal potential**
   - Acquisition of Amstelland 3D survey ongoing
3. **SCAN-drilling**
   - ➜ First six wells finalised and decommissioned, seventh well, not yet tested (ASD-01), well eight currently being drilled (MHZ-01)

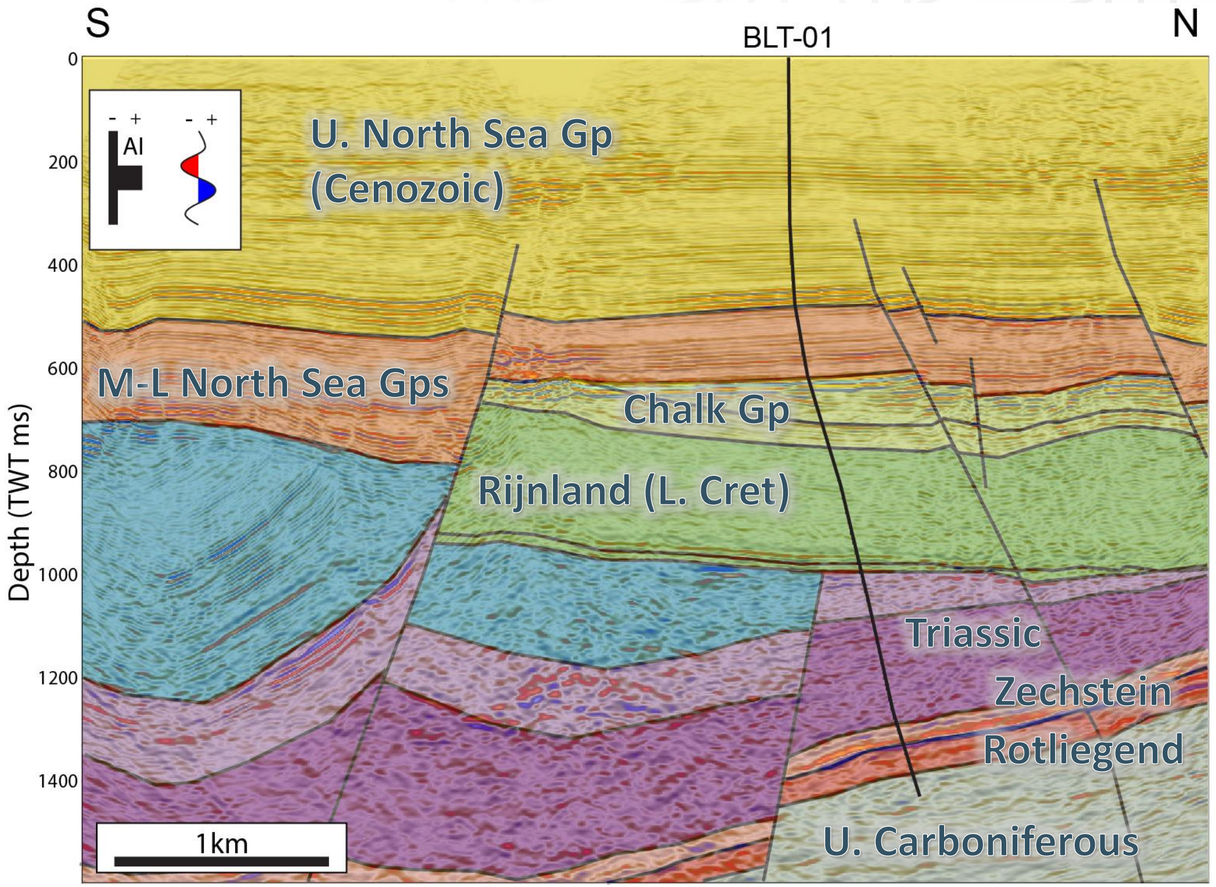
All data and results are published via scanaardwarmte.nl and nlog.nl/scan

SCAN data-acquisition boreholes



The SCAN BLT-01 well

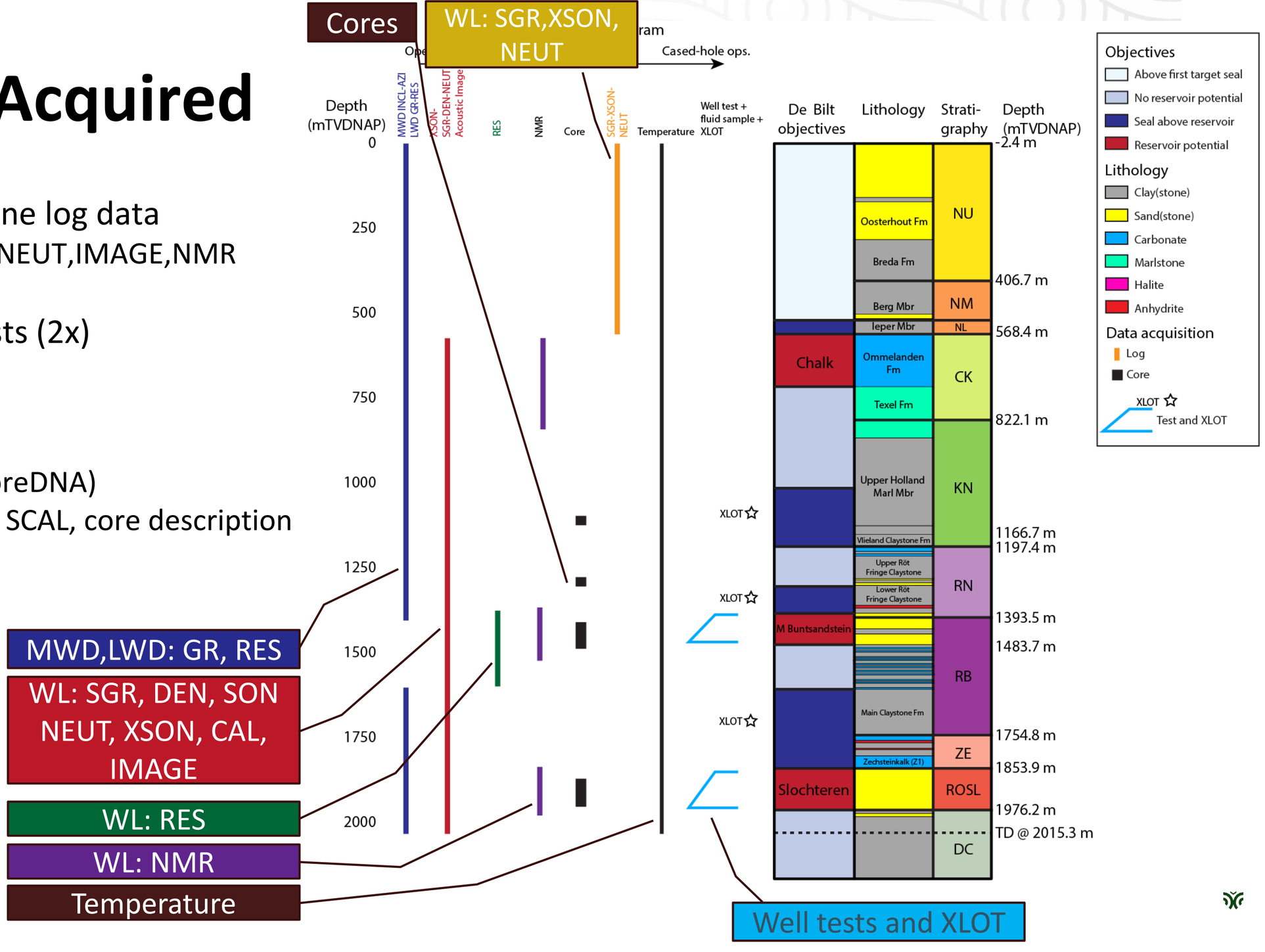
- In vicinity of town of Utrecht with significant heat demand and district heat networks
- Determine geothermal reservoir properties for four target intervals:
  - Primary: Permian Rotliegend sandstones
  - Secondary: U. Triassic Main Buntsandstein
  - Secondary: L. Cret. Vlieland Sandstone Fm
  - Secondary: U. Cret. Chalk Gp
- Determine reservoir formation fluid properties and temperature
- Determine geomechanical properties of the reservoirs, caprock and overburden



- BLT-01 spud in January 2025, TD @ 2123.0 m MD in Carboniferous Limburg Group
- Extensive data acquisition performed throughout well, including over reservoirs, caprocks and overburden

BLT-01 Data Acquired

- Cuttings
- LWD and (OH/CH) wireline log data
  - (S)GR,RES,XSON,DEN,NEUT,IMAGE,NMR
  - Temperature
- Production/Injection tests (2x)
  - PLT
  - Fluid samples
- Core (219m)
  - Screening analysis (CoreDNA)
  - Routine core analysis, SCAL, core description
  - Geomechanical tests
- XLOT (3x)



Core Data

- 219 meter cored
  - Upper Holland Marl Mbr (seal – 18m – 5 ¼”)
  - Röt Sandstone & Lower Claystone Mbr (seal/reservoir – 18m – 5 ¼”)
  - Main Buntsandstein Subgp (reservoir – 85m – 5 ¼”)
  - **Slochteren Fm (reservoir – 98m – 4”)**
- Preserved sections selected for future analysis
- All core material to be stored at TNO after analysis finalised

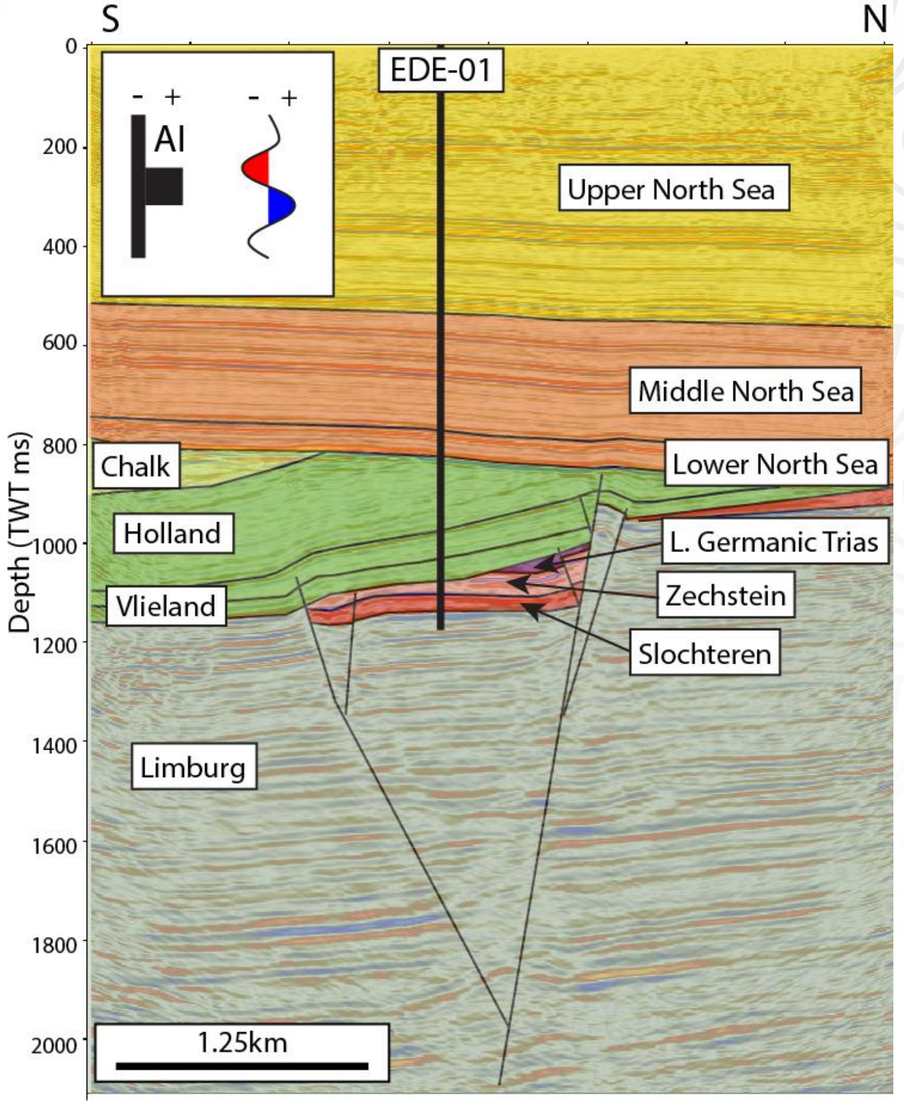
RCA / SCAL	Geomechanics	Sedimentology/ Petrography	Various
• Ambient He poro-perm (H & V) • Stressed Klinkenberg poro-perm • Stressed brine permeability • Formation Resistivity Factor (e.g. ‘m’) • HPMI • NMR calibration	• Single-stage tri-axial tests • Thermal expansion coefficient	• Sedimentological description • Thin sections • Petrography • XRD • (B)SEM	• Core SGR • CoreDNA oa. Grain size, XRF, UCS, Slowness, Probe-perm • Specific heat capacity • Thermal conductivity

Röt Fringe Claystone

Main Buntsandstein Subgp

The SCAN EDE-01 well

- In vicinity of towns of Ede and Veenendaal with significant heat demand and district heat networks
- Determine geothermal reservoir properties for two target intervals:
  - Primary: Permian Rotliegend sandstones
  - Secondary: L. Cret. Vlieland Sandstone Fm
- Determine reservoir formation fluid properties and temperature
- Determine geomechanical properties of the reservoirs, caprock and overburden



- EDE-01 spud in February 2025, TD @ 1315.0 m MD in Carboniferous Limburg Group
- Extensive data acquisition performed throughout well, including over reservoirs, caprocks and overburden
- In total 92 m of core acquired

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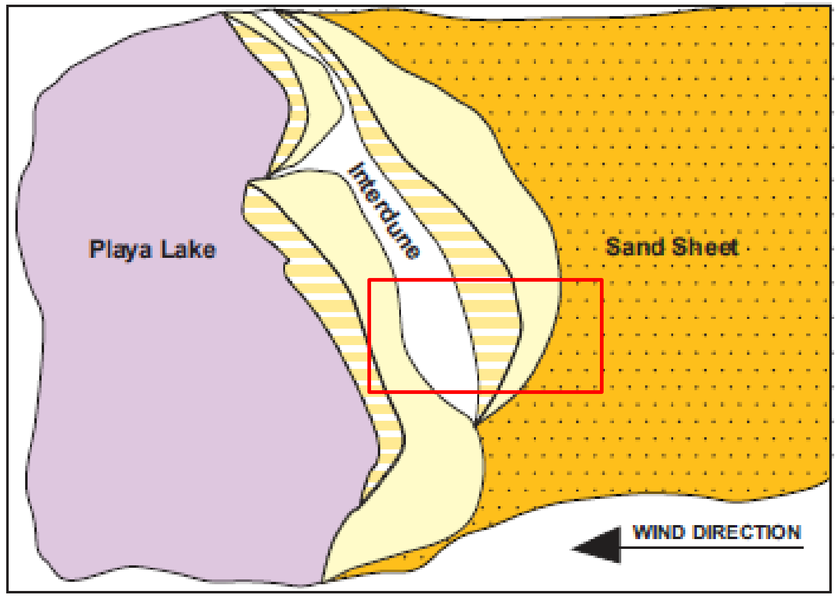
SLOCHTEREN IN BLT-01 & EDE-01

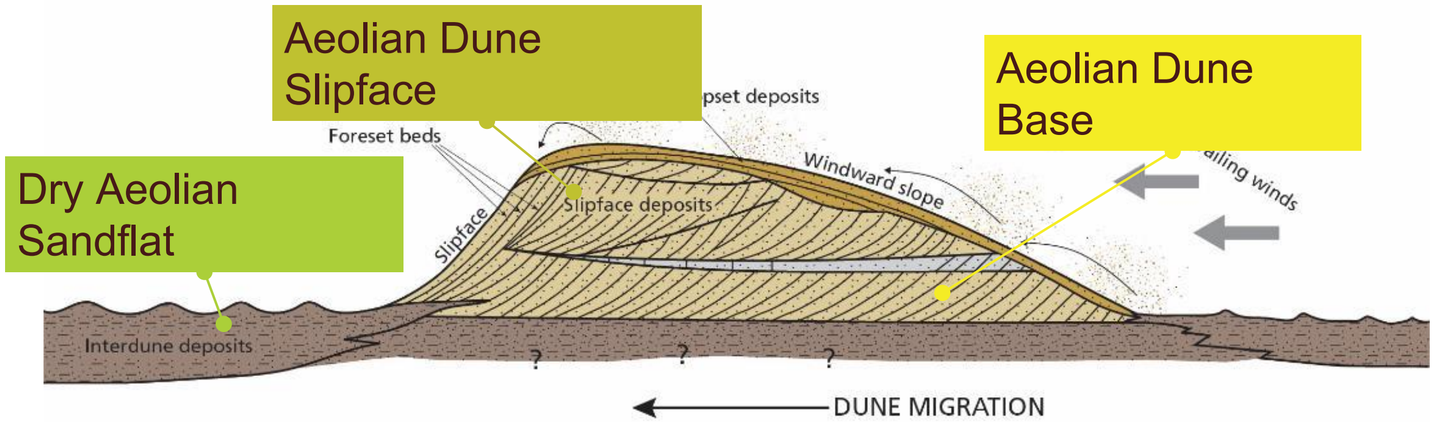
By Adriaan Janszen

Palaeogeography

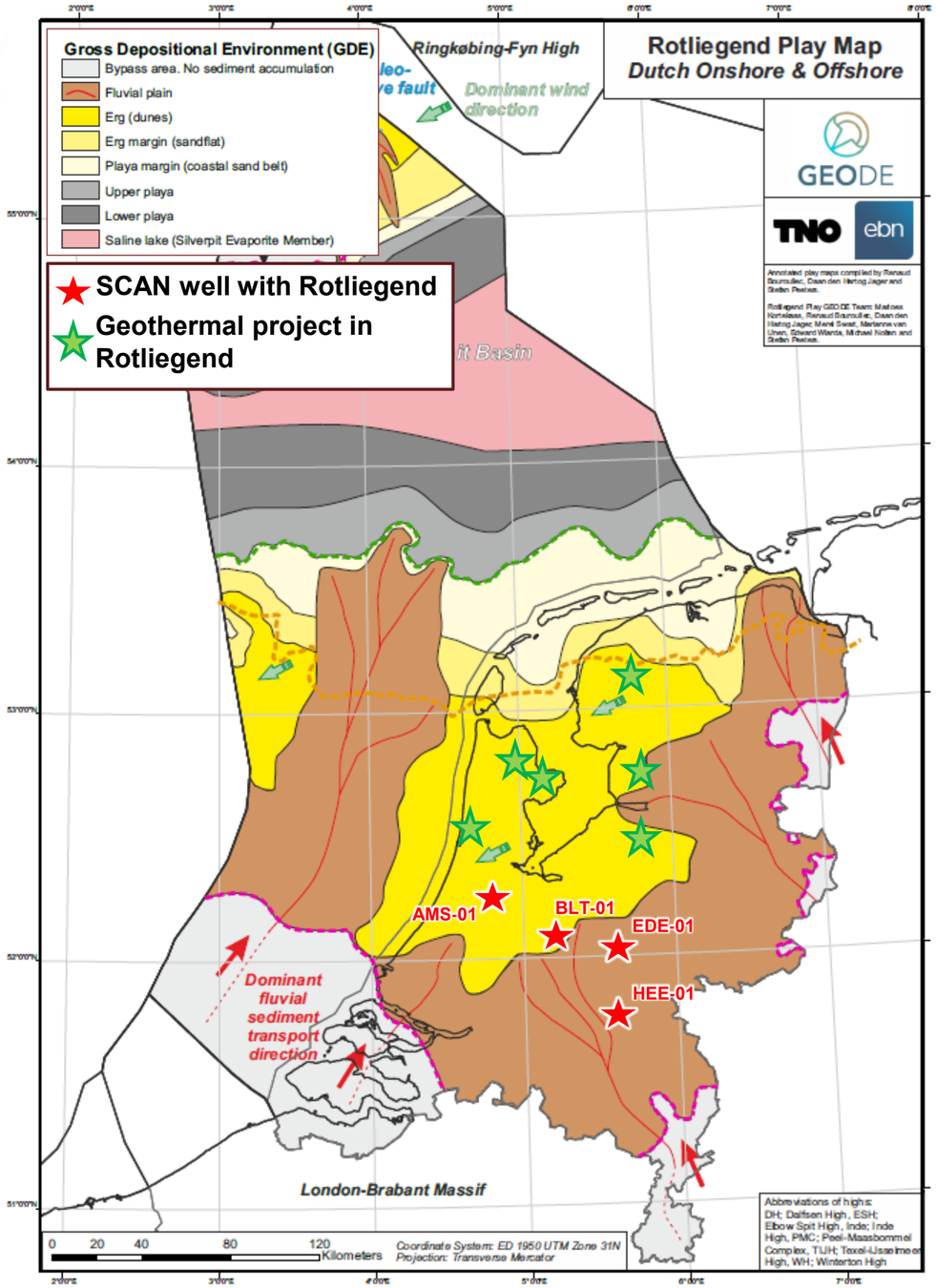
- Slochteren deposited predominantly in “dry” eolian settings. Fluvial deposits rare
- Migrating eolian dunes and interdune areas
- Constant uniform wind direction



Fryberger et al. 2011



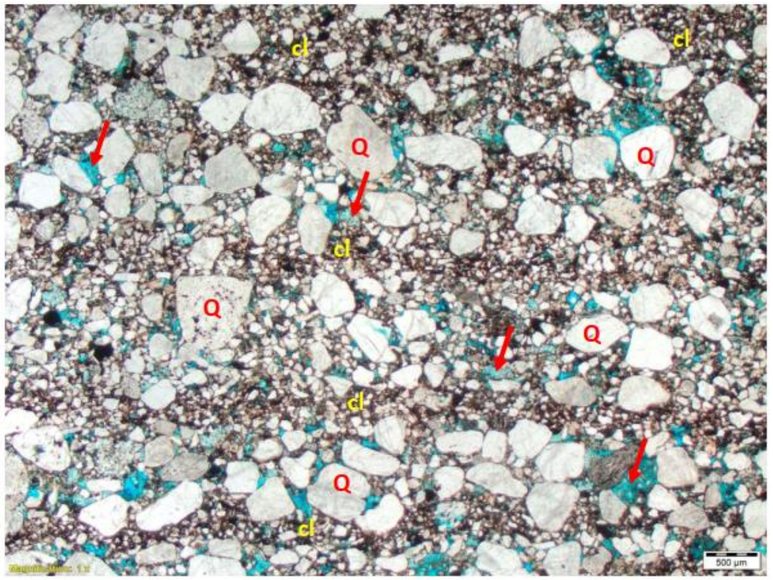
modified from Ahlbrandt and Fryberger (1982)



GEODE - Kortekaas et al., 2023

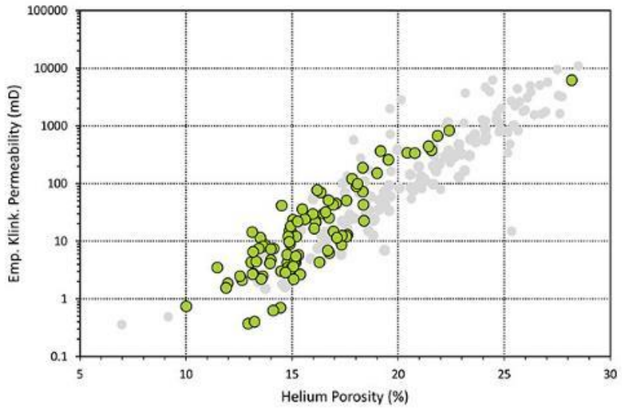
Dry Aeolian Sandflat sub-environment

WELL: AMS-01 SAMPLE NUMBER: 523 DEPTH (m): 2135.67



A. Plane polarised light

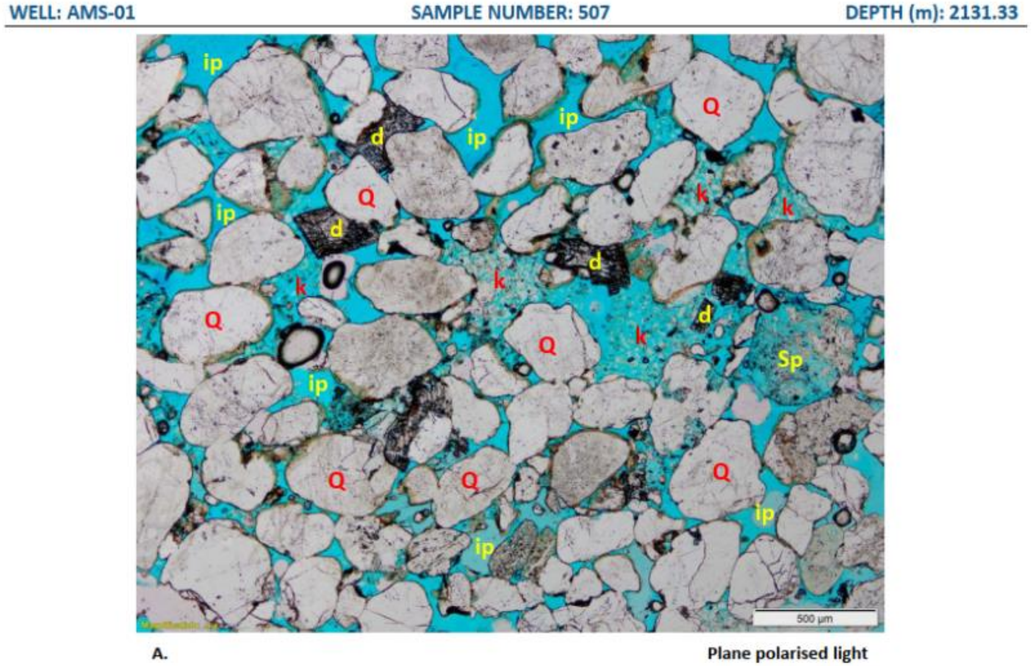
Rotliegend Depositional Sub-Environment
Dry Aeolian Sandflat (Psay)



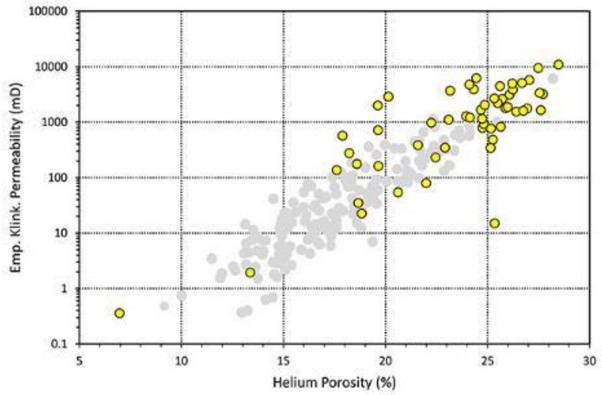
10cm

- ➜ Bimodal sorting
- ➜Fine sand laminae with medium to coarse sand (‘pin-stripe’)
- ➜ Relatively low porosity and permeability

Aeolian Dune Base sub-environment

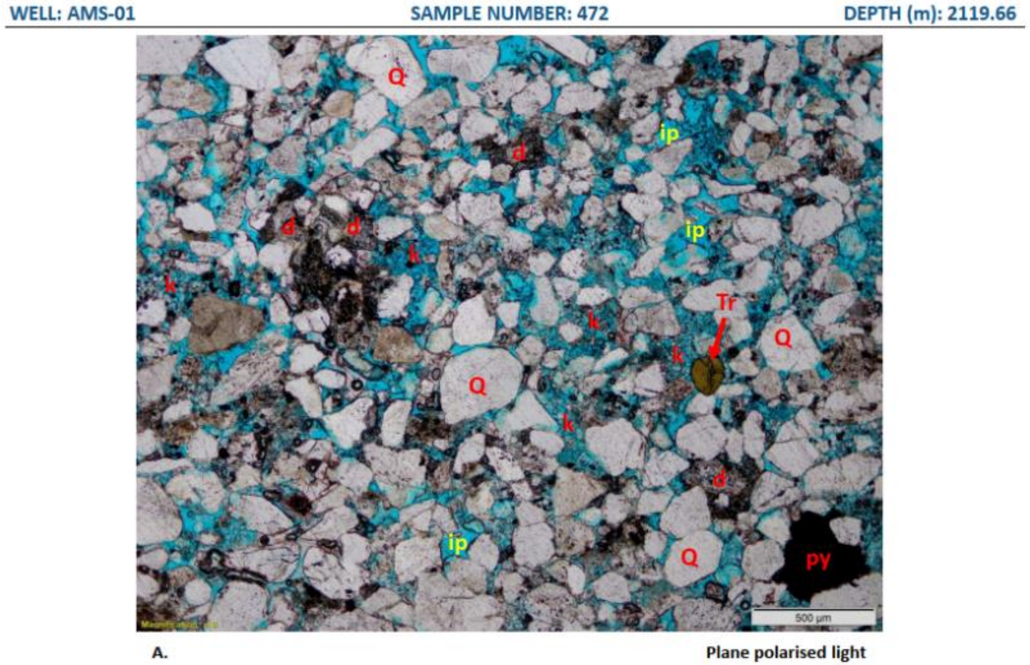


Rotliegend Depositional Sub-Environment
Aeolian Dune base (Adb)

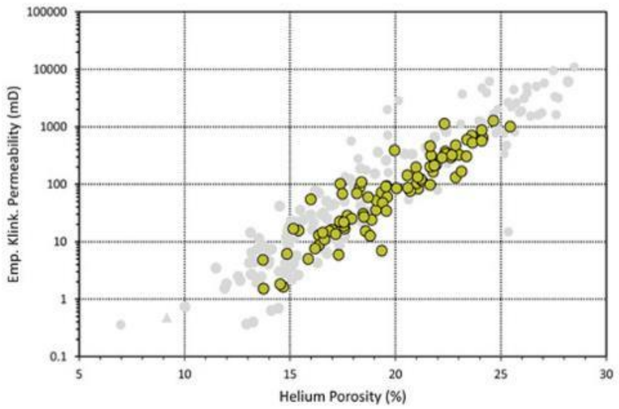


- ➜Low-angle or high-angle cross-bedded
- ➜Dominant medium sand
- ➜Moderately well sorted
- ➜Cm- to dm-thick structureless beds with mm-thick fine sand laminae
- ➜Relatively high porosity and permeability

Aeolian Dune Slipface sub-environment



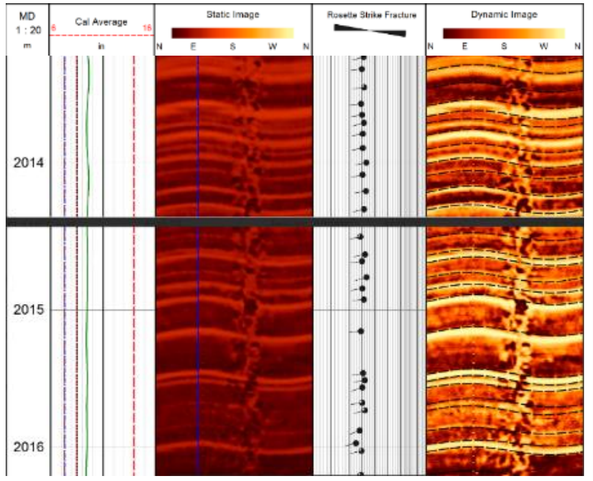
Rotliegend Depositional Sub-Environment
Aeolian Dune Slip Face (Ads)

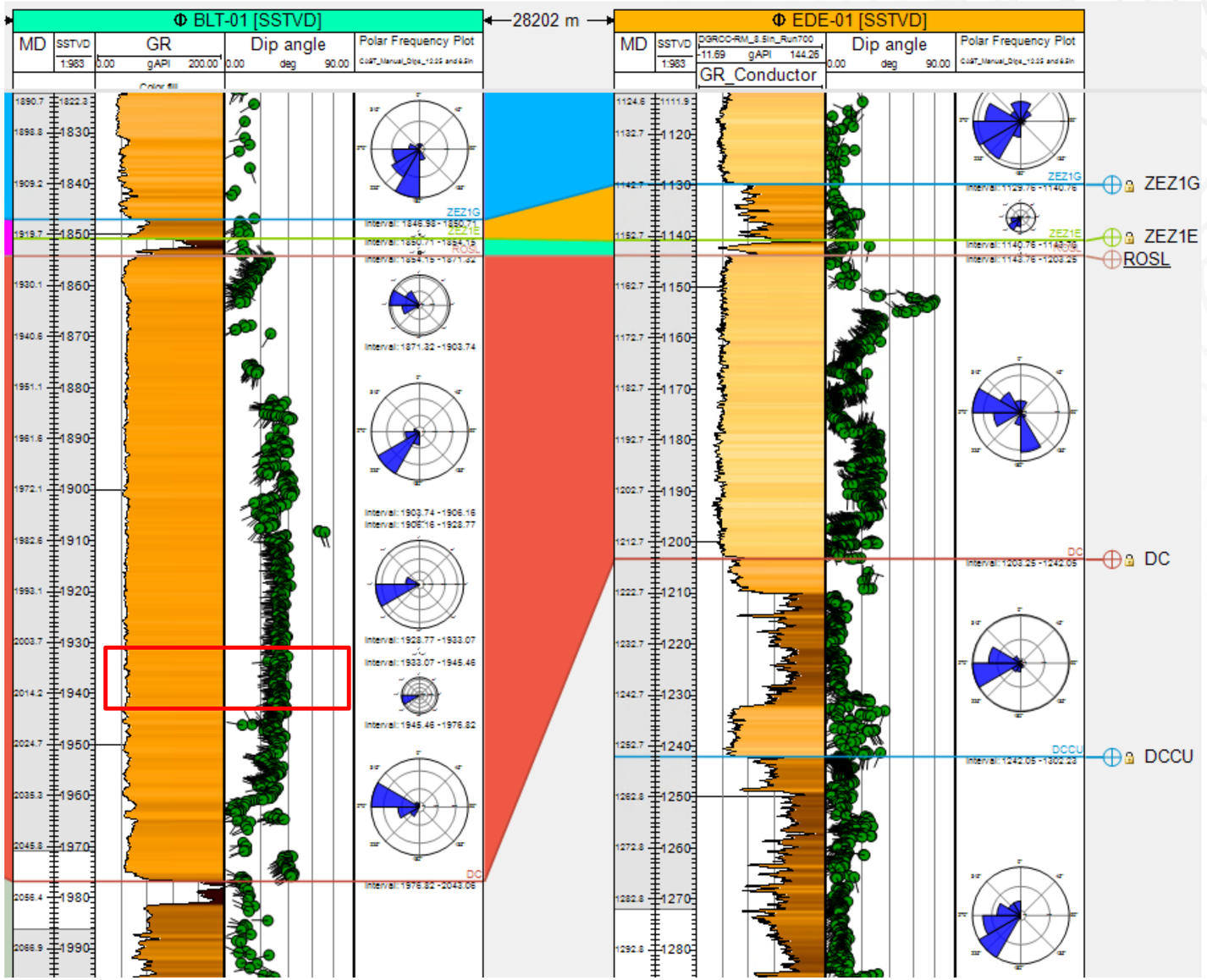


- ➜Mm- to cm-thick low-to high-angle cross-beds
- ➜Fine to medium sand (upward fining trend within units)
- ➜Medium sand beds often tapered
- ➜Medium porosity and permeability

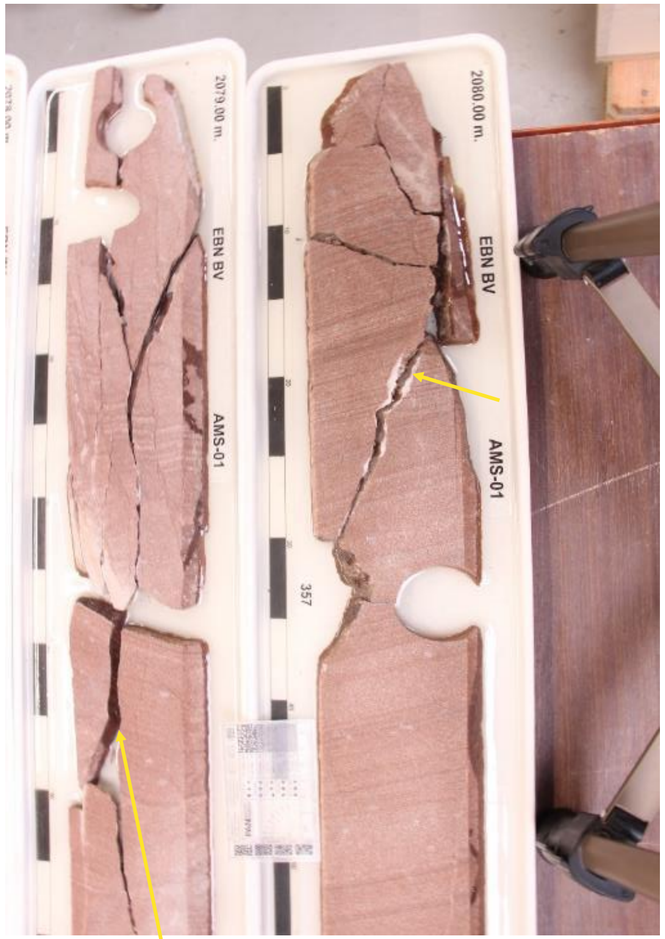
Image log data

BLT-01 acoustic image log



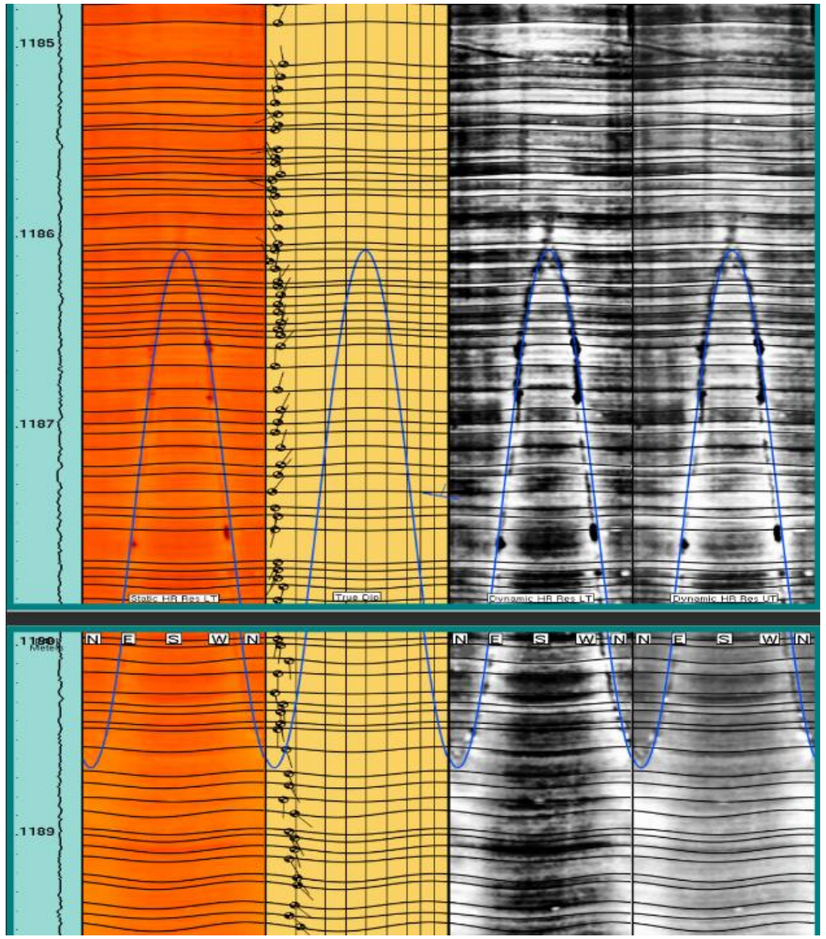


(Partly) Cemented Fractures



open fracture?

EDE-01 acoustic image log

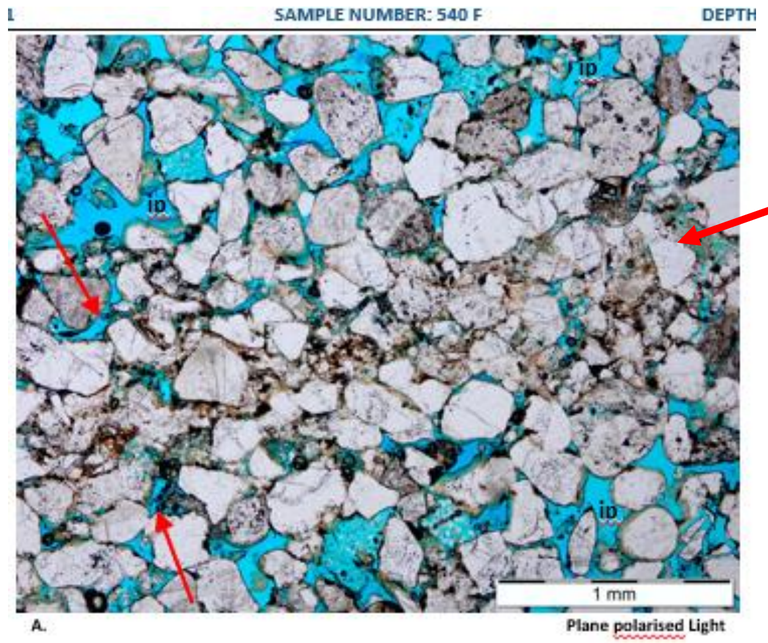


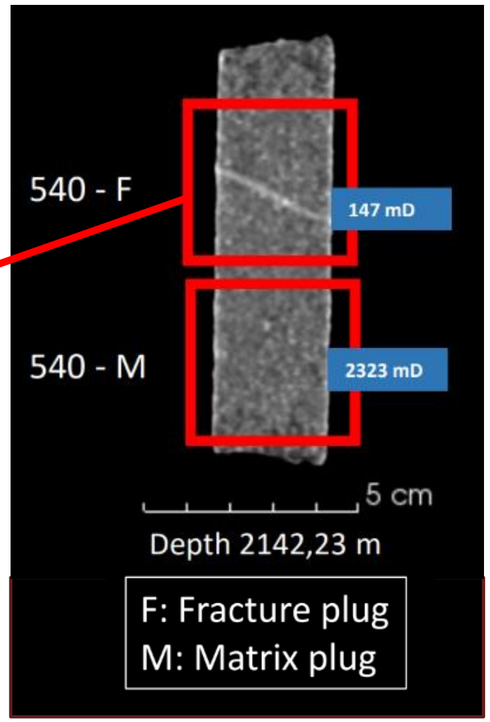
➜High angle to near-vertical fractures, partly or completely cemented.

➜Virtually no displacement to rarely mm-scale displacement

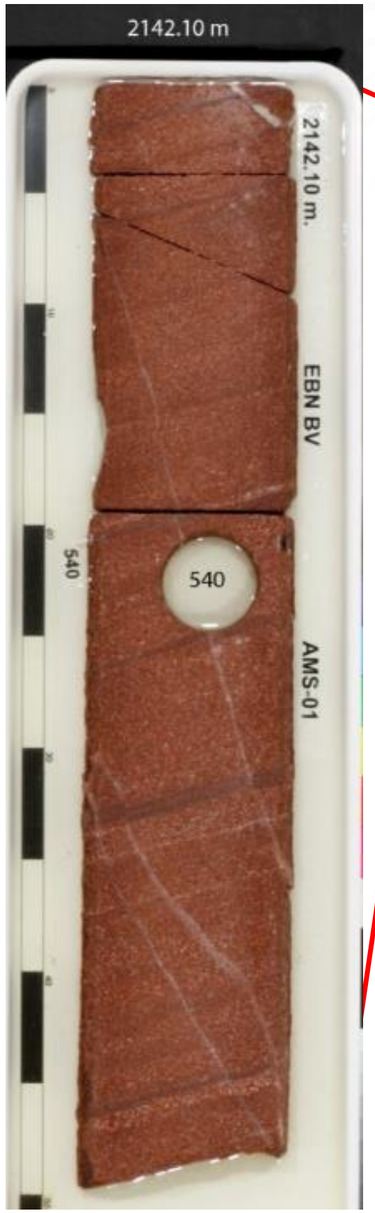
Deformation bands

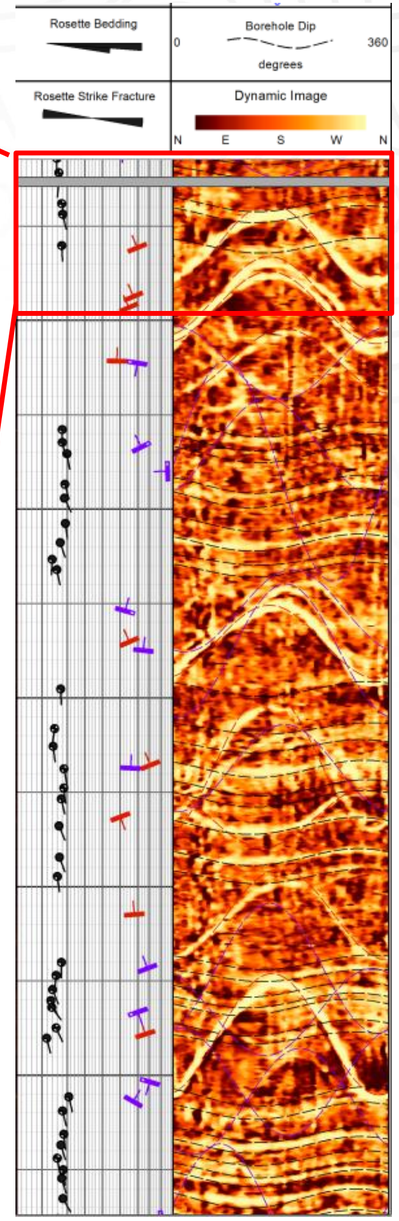
- ➜High-angle features in AMS-01 acoustic image log and core
- ➜Single discontinuities to swarms of quartz-cemented bands, often conjugate sets
- ➜Up to mm-scale displacement
- ➜Bands significantly less permeable than matrix (~25x)
- ➜Few observed in EDE-01, none in BLT-01

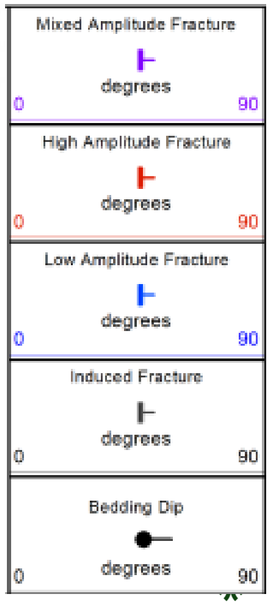




Dynamic acoustic image:
Light means high velocity = low porosity

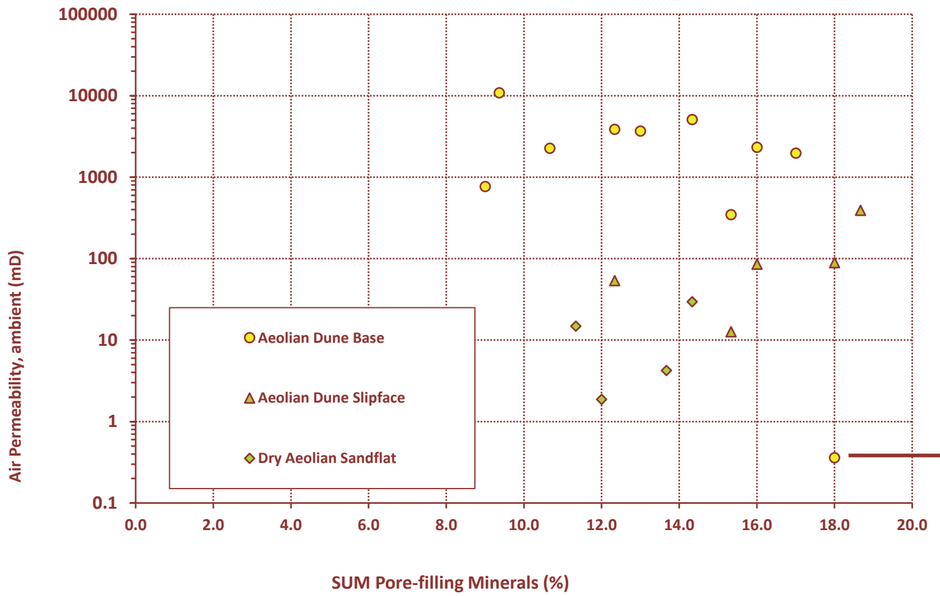


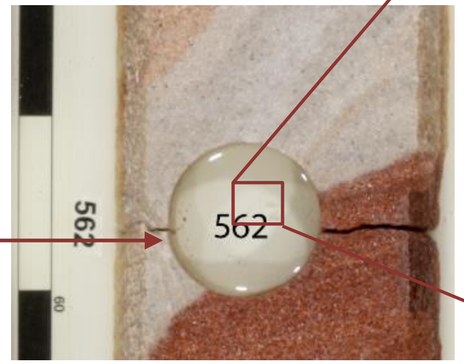


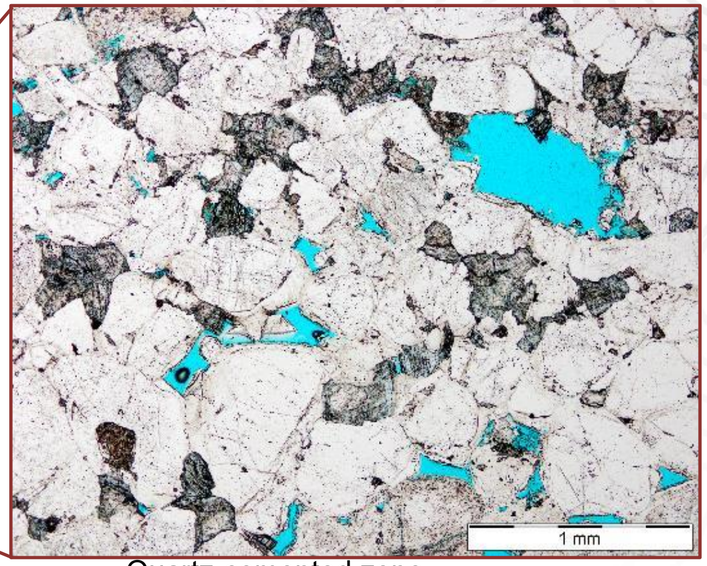


Diagenetic cements

Role of diagenetic cements minor in AMS-01, despite local effects (e.g. quartz-cemented zones)
Evaluation in progress in BLT-01 and EDE-01

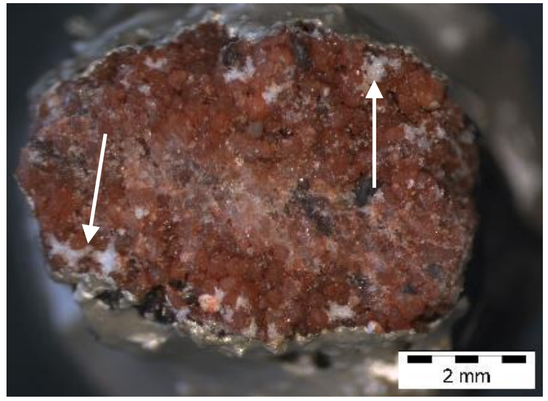




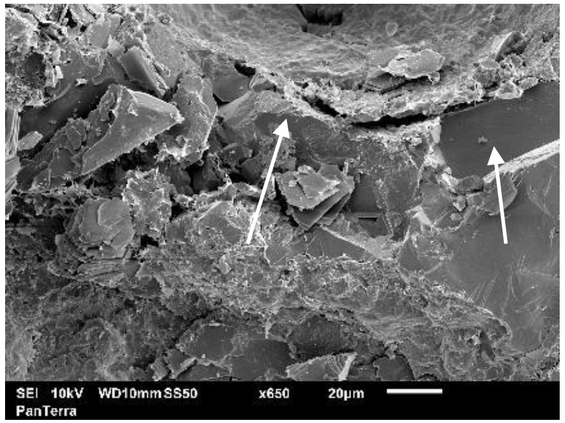


Quartz-cemented zone

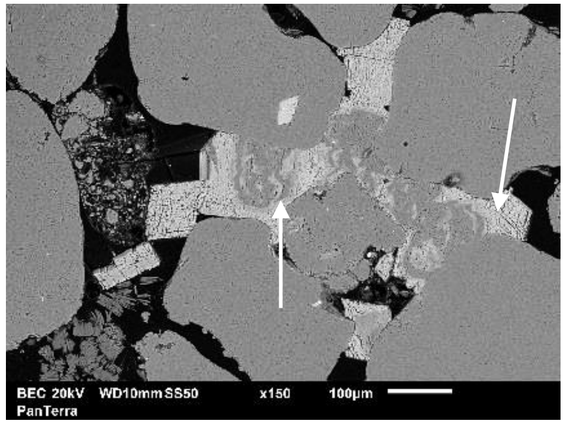
Kaolinite



Quartz



Dolomite



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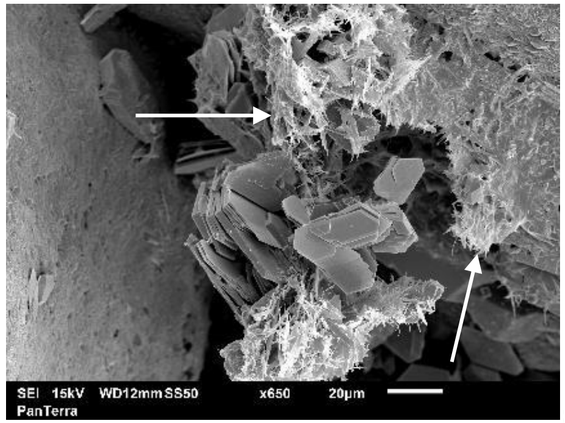
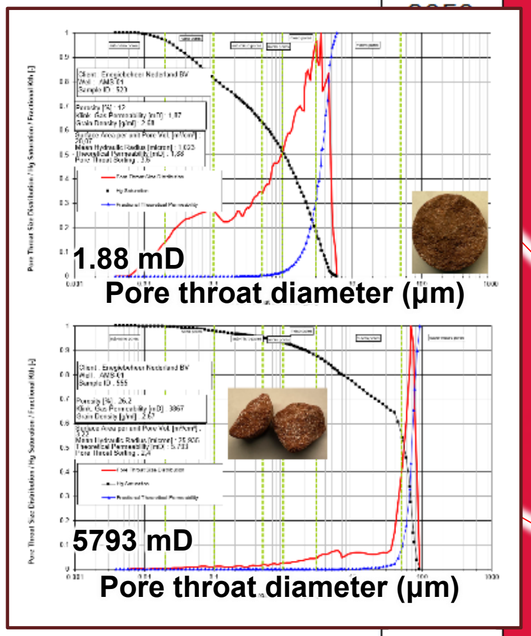
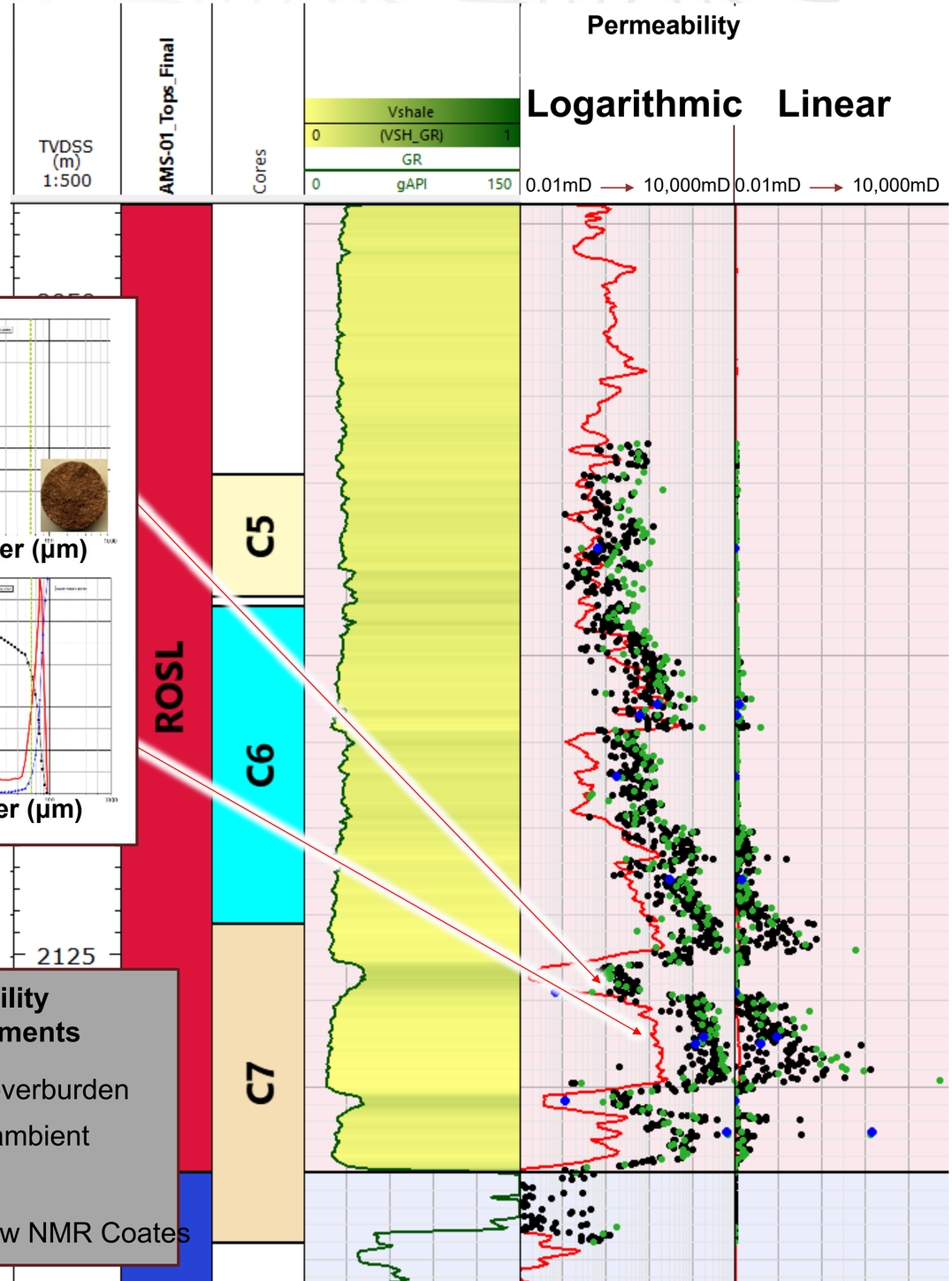


Permeability Measurements

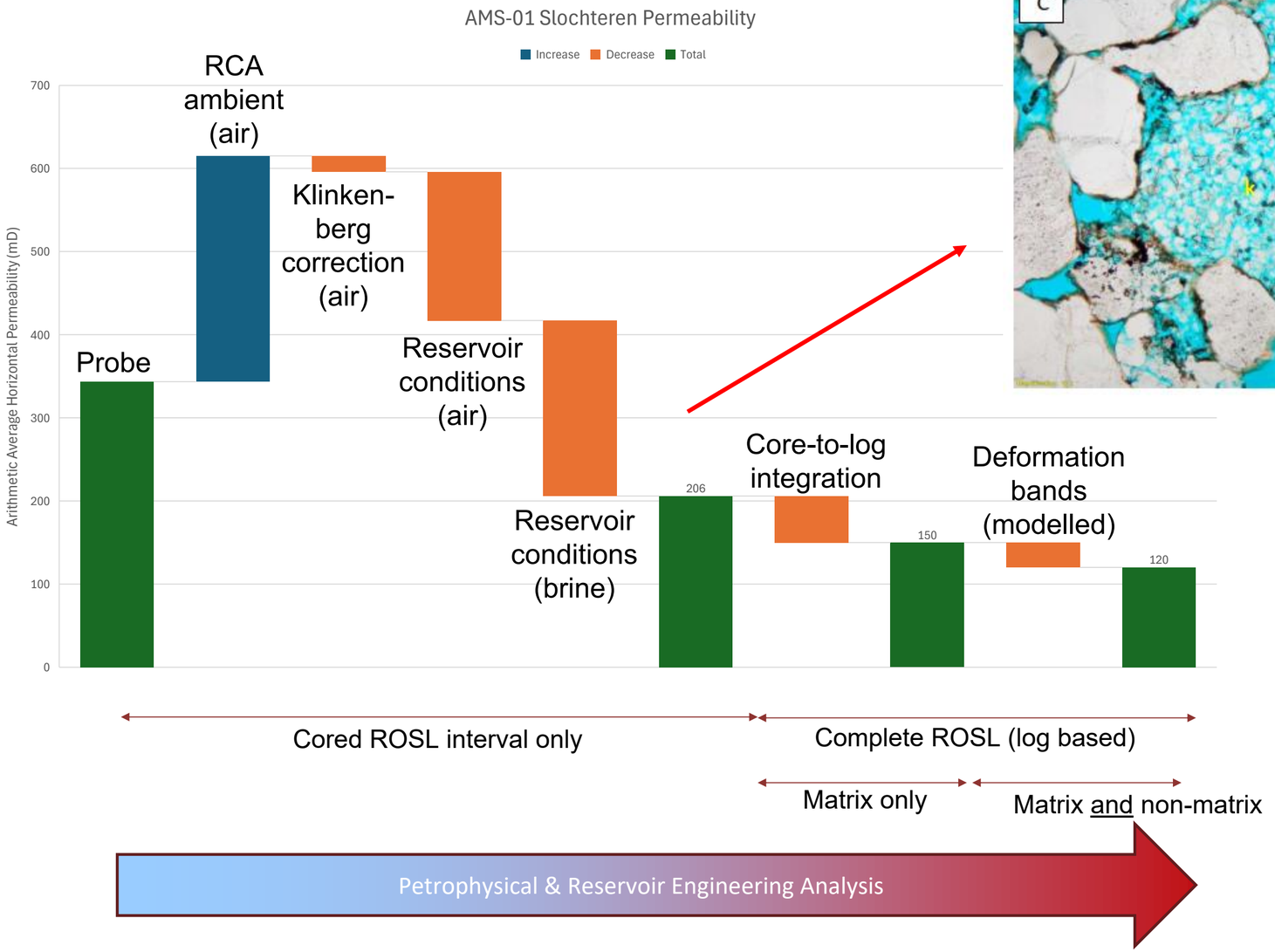
Permeability is the key geothermal reservoir property!

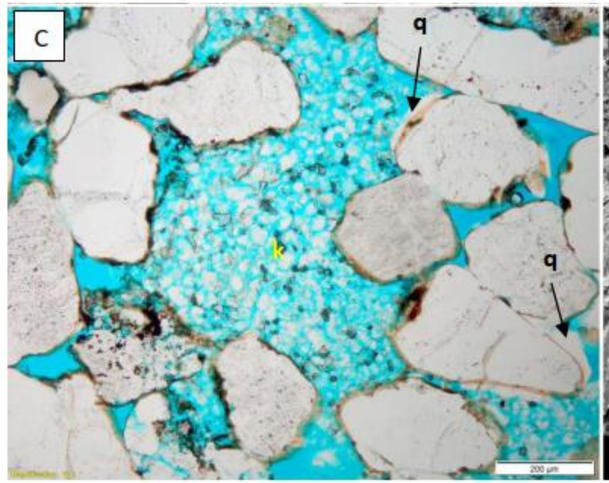
- ➜Probe permeability
  - ➜Every 3cm, performed on uncleaned core
- ➜Routine air permeability
  - ➜Every 33cm horizontal, every 100cm vertical
- ➜Klinkenberg air and brine permeability at reservoir conditions
  - ➜10 horizontal plugs for each
- ➜Mercury-Injection Capillary Pressure (MICP/HPMI)
  - ➜Pore-throat diameter => Theoretical permeability
- ➜NMR logs
  - ➜Timur-Coates model yields permeability
- ➜Well test
  - ➜Transmissivity (permeability * reservoir height)

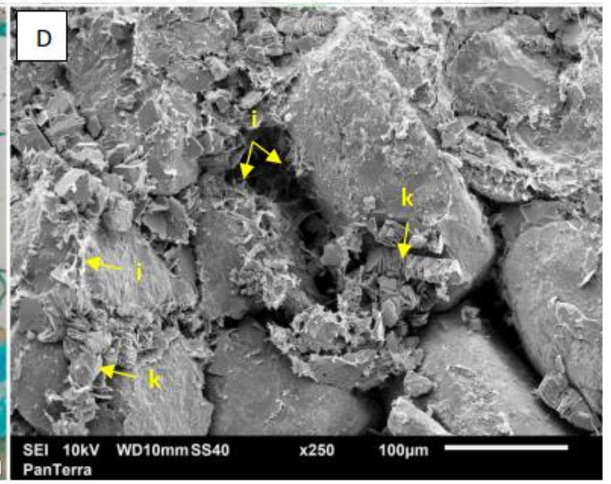




Permeability Measurements (AMS-01)

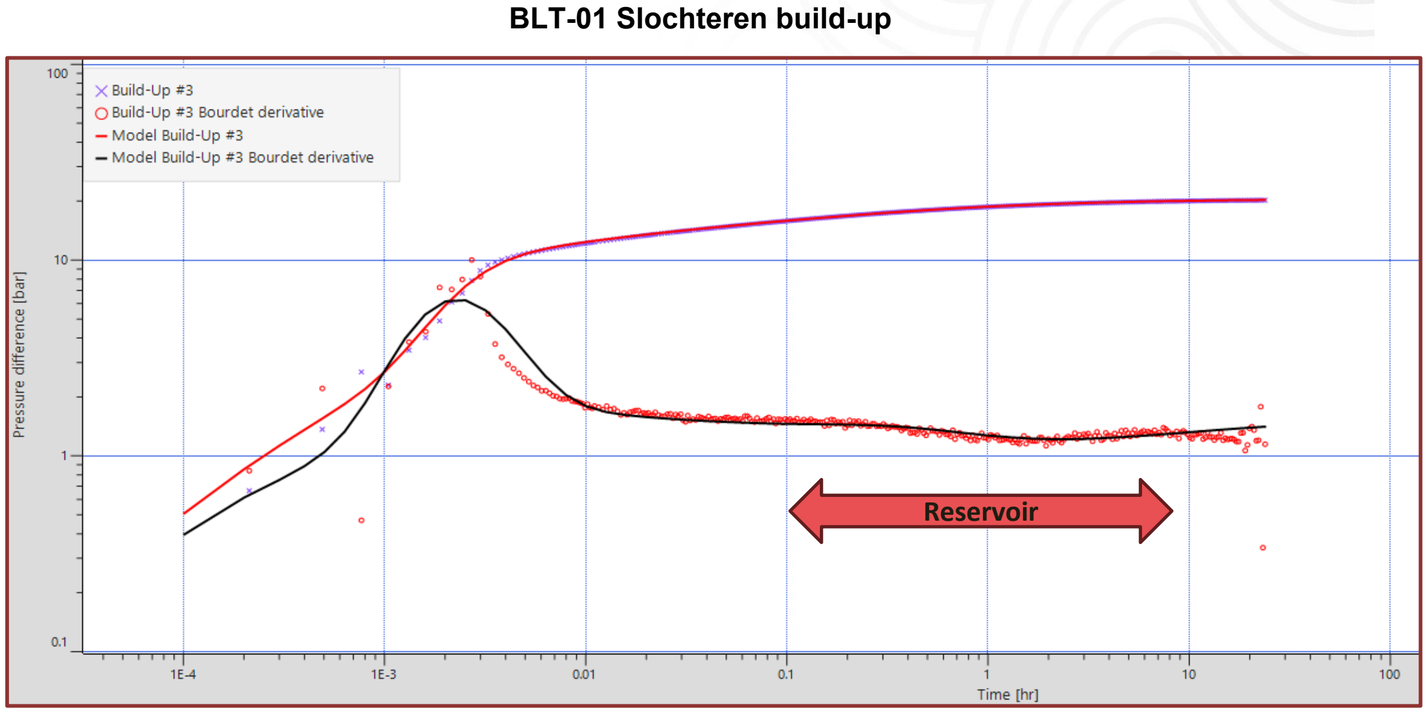






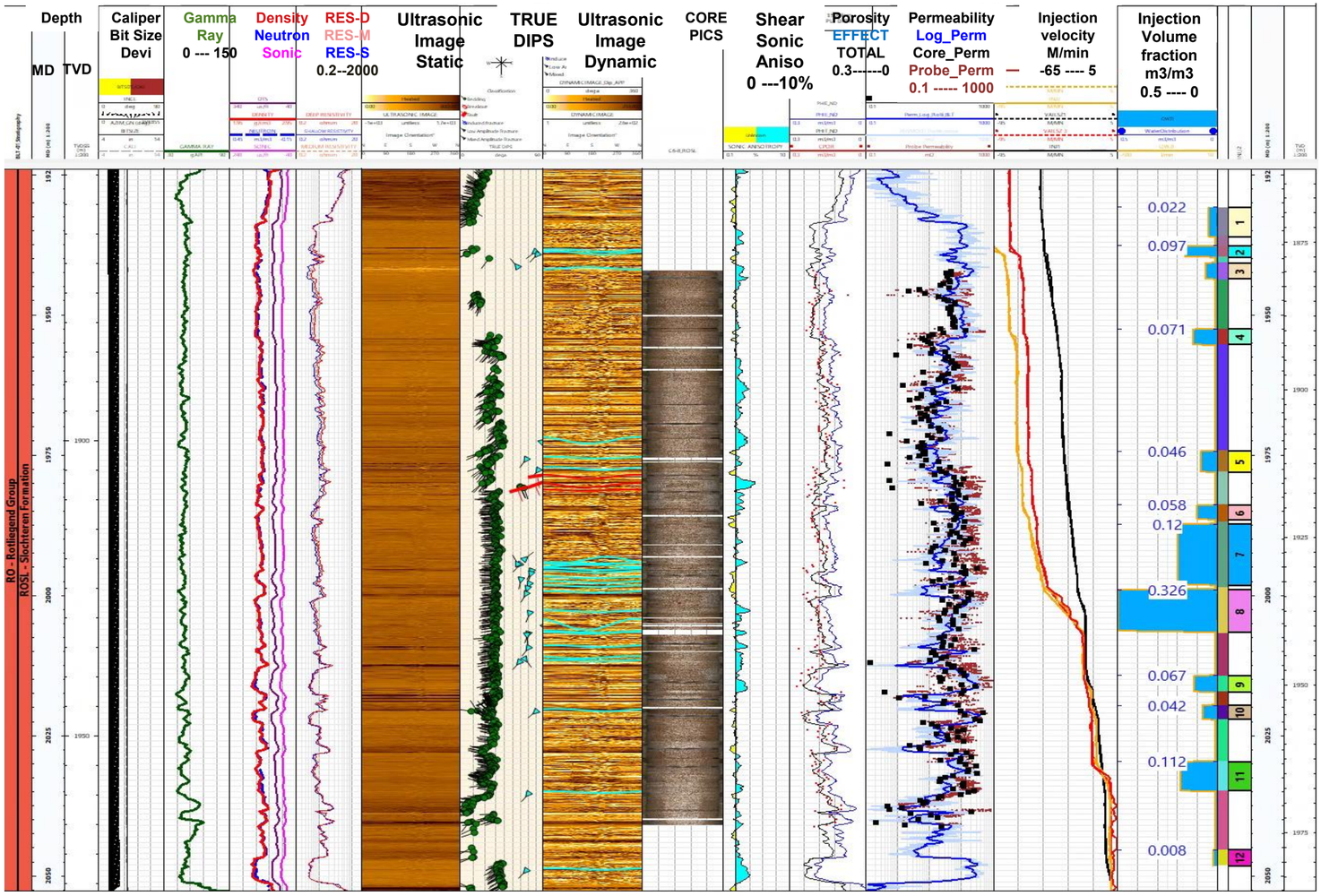
Integration Production and Injection Tests

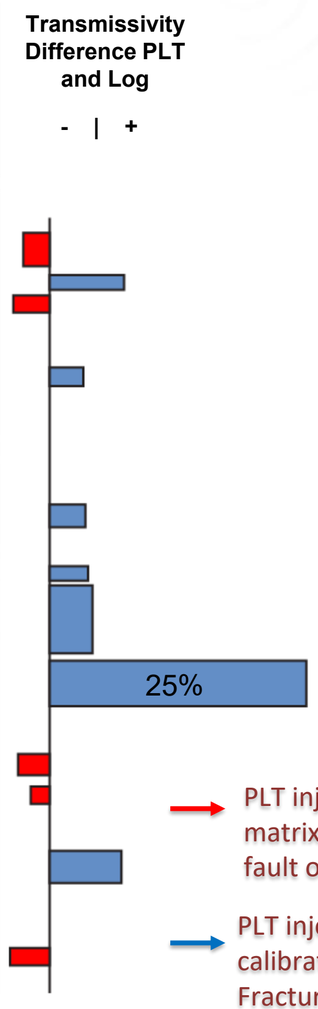
- ➜Slochteren in BLT-01 and EDE-01 production- and injection-tested
- ➜Pressure Transient Analysis on build-up data gives transmissivity (and skin)
- ➜Preliminary analysis of the Slochteren test in BLT-01 shows a transmissivity of approximately 4.8 Dm (average permeability of 40md)
- ➜Preliminary analysis of the Slochteren in EDE-01 shows a transmissivity of approximately 70-90 Dm (average permeability of 1180-1510 md)



TRANSMISSIVITY DISTRIBUTION

Comparisons of Permeability - Rotliegend





PLT injection contribution is lower than matrix permeability (e.g.: cemented micro fault or layered heterogeneity)

PLT injection contribution is higher than calibrated matrix permeability log (e.g.: Open Fracture Zone)