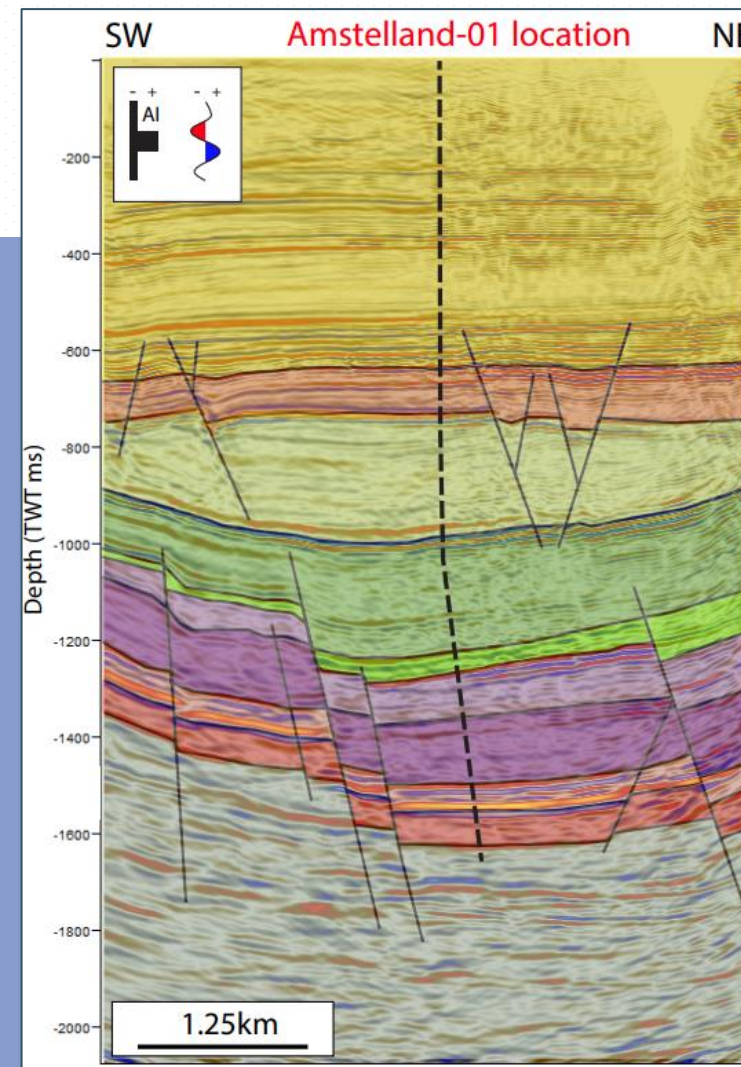# SCAN

The Dutch SCAN Geothermal Exploration Well Campaign: from leads to wells

Marten ter Borgh, Henk van Lochem, Adriaan Janszen, Milan Brussée & Reinout Storm

Energy Geoscience Conference, Aberdeen, 17-05-2023
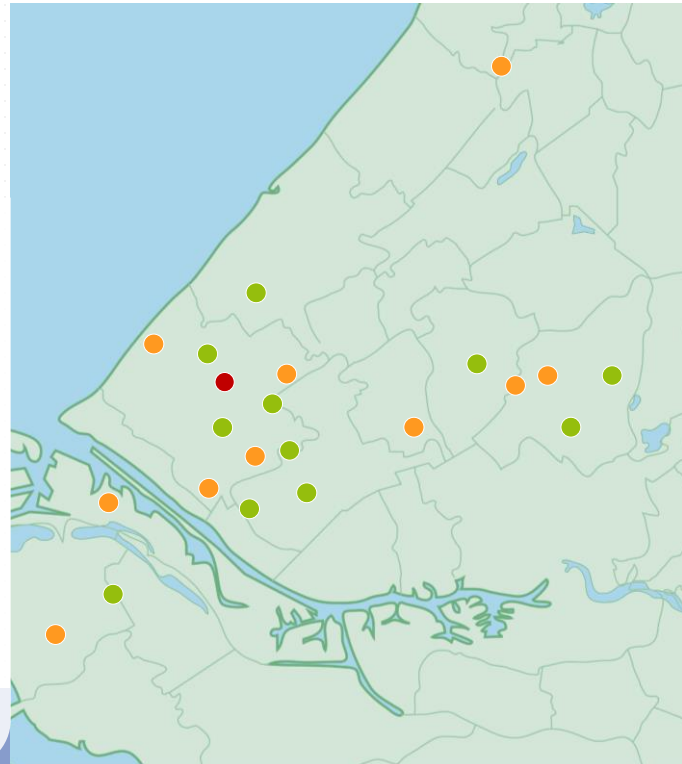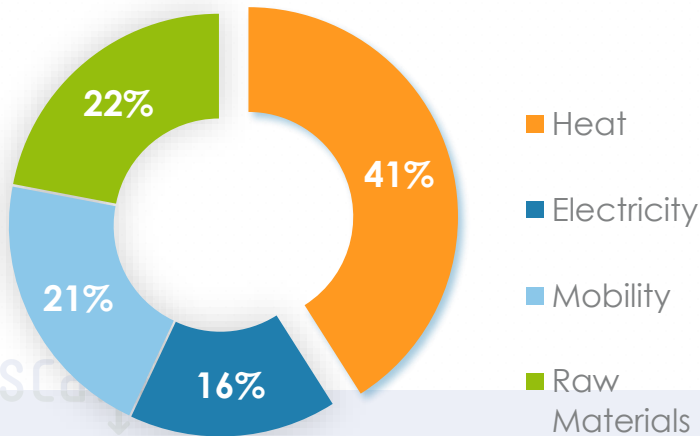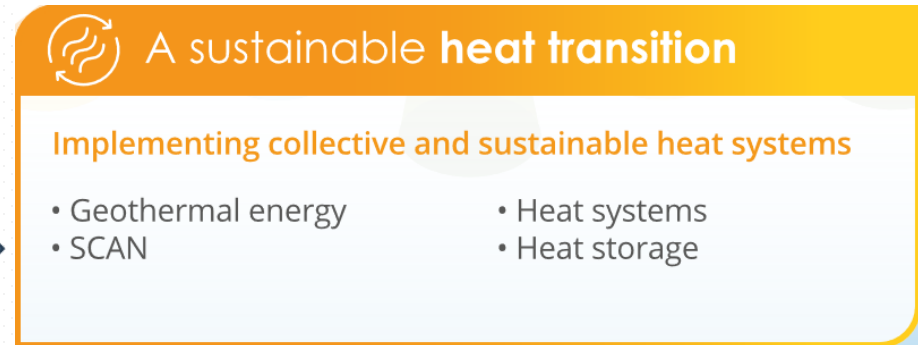
Geothermal Energy in the Netherlands

- Proven source of energy; many producing projects

- Low enthalpy, from saline aquifers

- Direct use: heat for heat

- Between about 700 m and 3 km

- Between about 30 °C and 100 °C

Energy use in the Netherlands

- 22%
- 41%
- 21%
- 16%

- Heat
- Electricity
- Mobility
- Raw Materials

- Producing
- Under Development
- Not producing
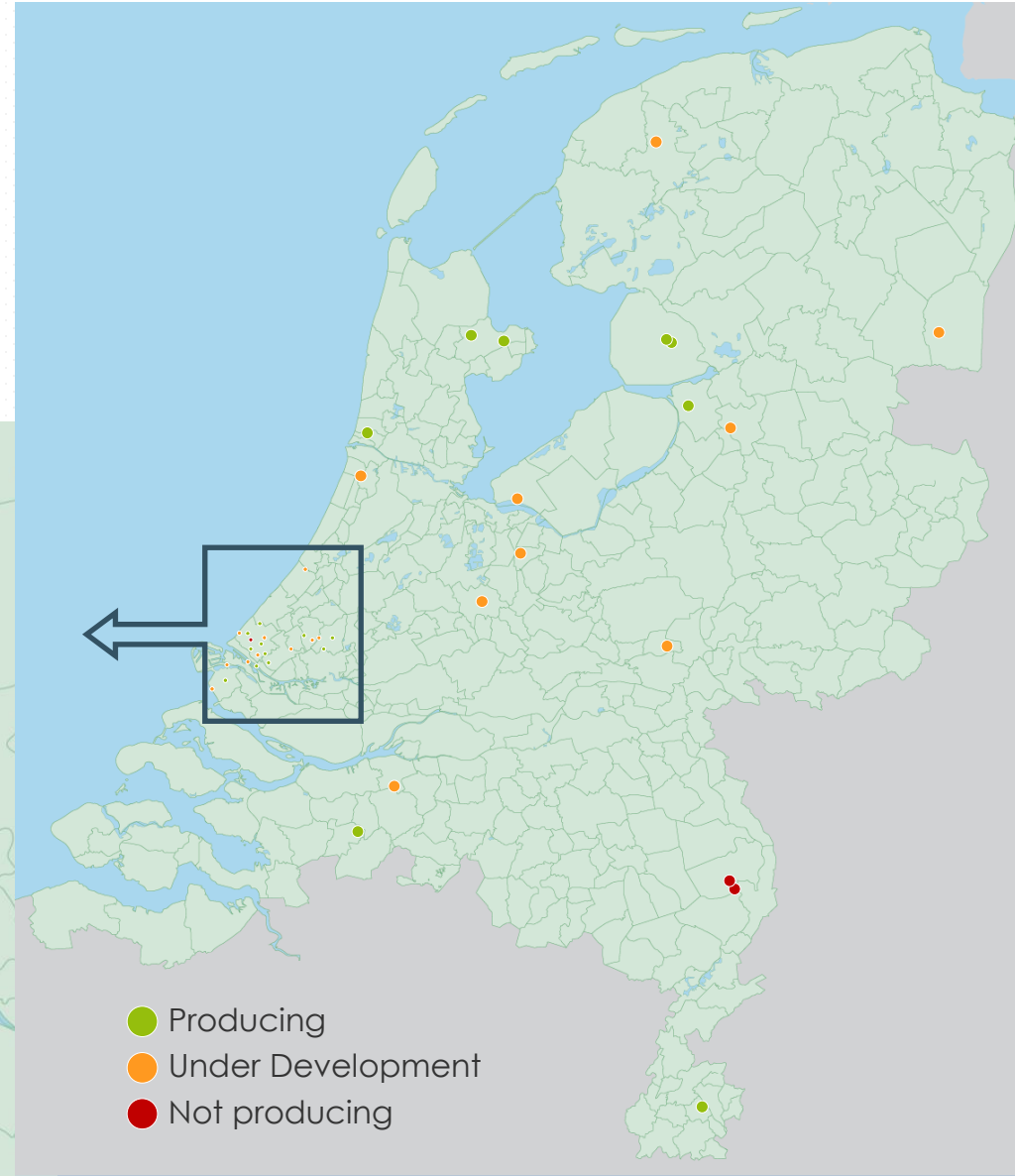
Introduction to EBN

- EBN (Energie Beheer Nederland, www.ebn.nl) was founded 50 years ago. It is a 100% state-owned company with 185 employees based in Utrecht, The Netherlands.

- Our mission is 'Towards a sustainable energy system, faster, together'
  - In line with its public role, EBN as a connecting force uses its knowledge of the subsurface and expertise to accelerate the implementation of the Dutch energy and climate policy with the aim of achieving a sustainable, reliable and CO_2-neutral energy system by 2050, at the lowest possible cost to society.

- Our strategic pillars:
  - A sustainable gas system
  - Responsible CO_2 storage
  - System Development for the public interest
  - A sustainable heat transition

A sustainable **heat transition**

Implementing collective and sustainable heat systems

- Geothermal energy
- SCAN
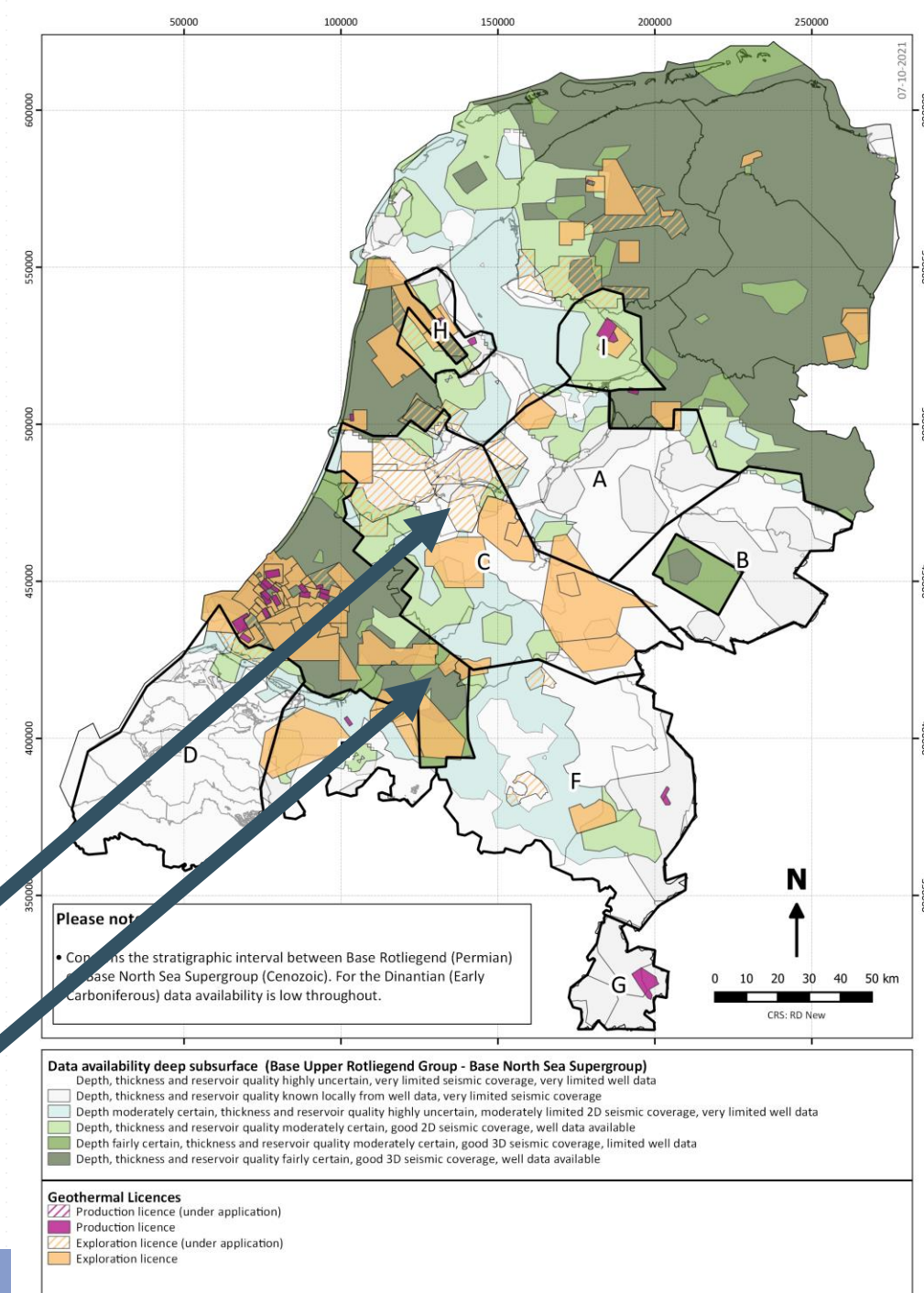- Heat systems
- Heat storage

scan

Introduction to SCAN

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

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

➜ Provides a regional exploration dataset. For development of commercial projects more seismic and more local studies will generally be needed

➜ Funded by the Ministry of Economic Affairs and Climate, 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: not a 'white spot', not part of SCAN
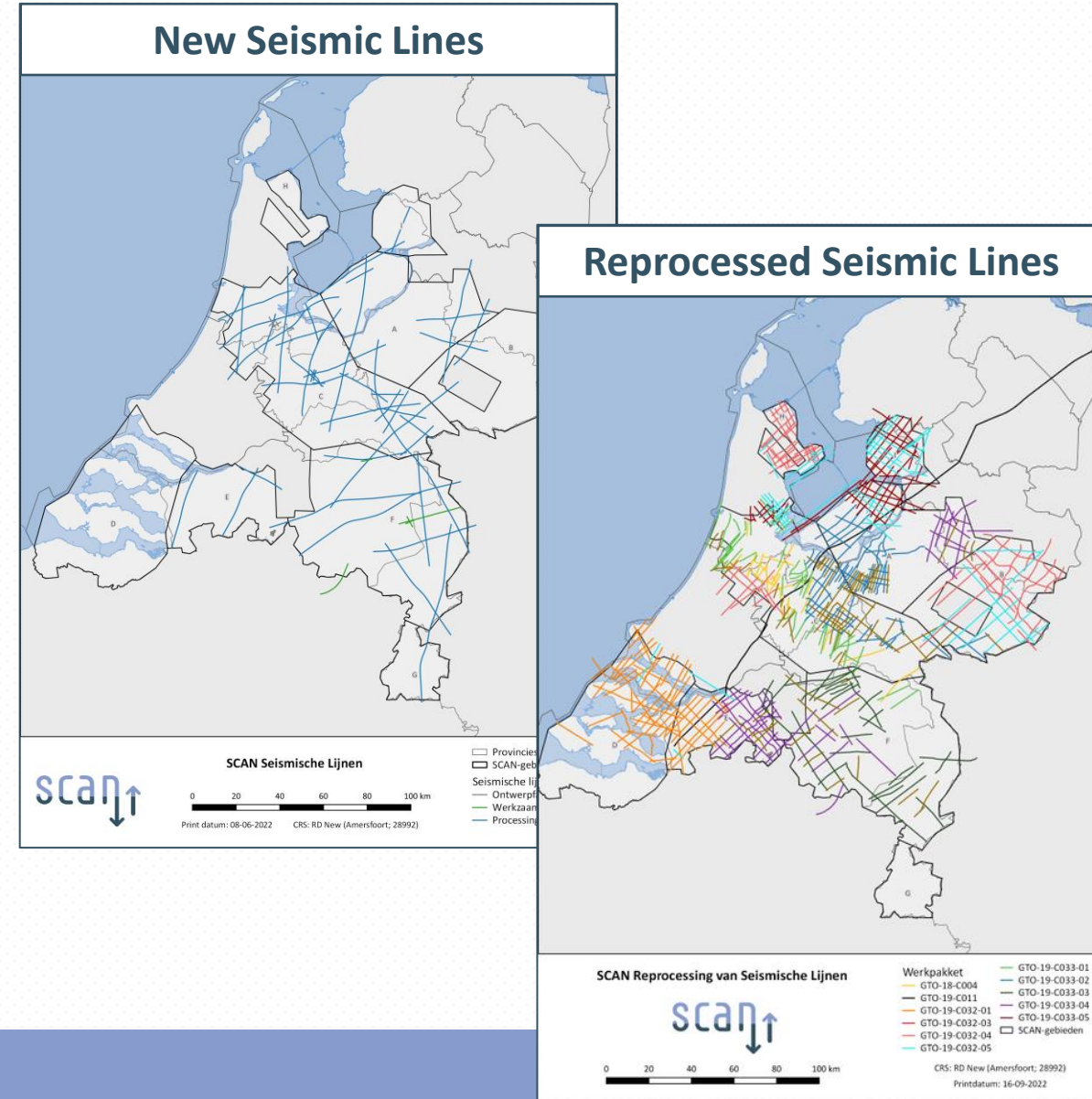

Please note

• Concerns the stratigraphic interval between Base Rotliegend (Permian) – Base North Sea Supergroup (Cenozoic). For the Dinantian (Early Carboniferous) data availability is low throughout.

CRS: RD New

Data availability deep subsurface (Base Upper Rotliegend Group - Base North Sea Supergroup)
  Depth, thickness and reservoir quality highly uncertain, very limited seismic coverage, very limited well data
  Depth, thickness and reservoir quality known locally from well data, very limited seismic coverage
  Depth moderately certain, thickness and reservoir quality highly uncertain, moderately limited 2D seismic coverage, very limited well data
  Depth, thickness and reservoir quality moderately certain, good 2D seismic coverage, well data available
  Depth fairly certain, thickness and reservoir quality moderately certain, good 3D seismic coverage, limited well data
  Depth, thickness and reservoir quality fairly certain, good 3D seismic coverage, well data available

Geothermal Licences
  Production licence (under application)
  Production licence
  Exploration licence (under application)
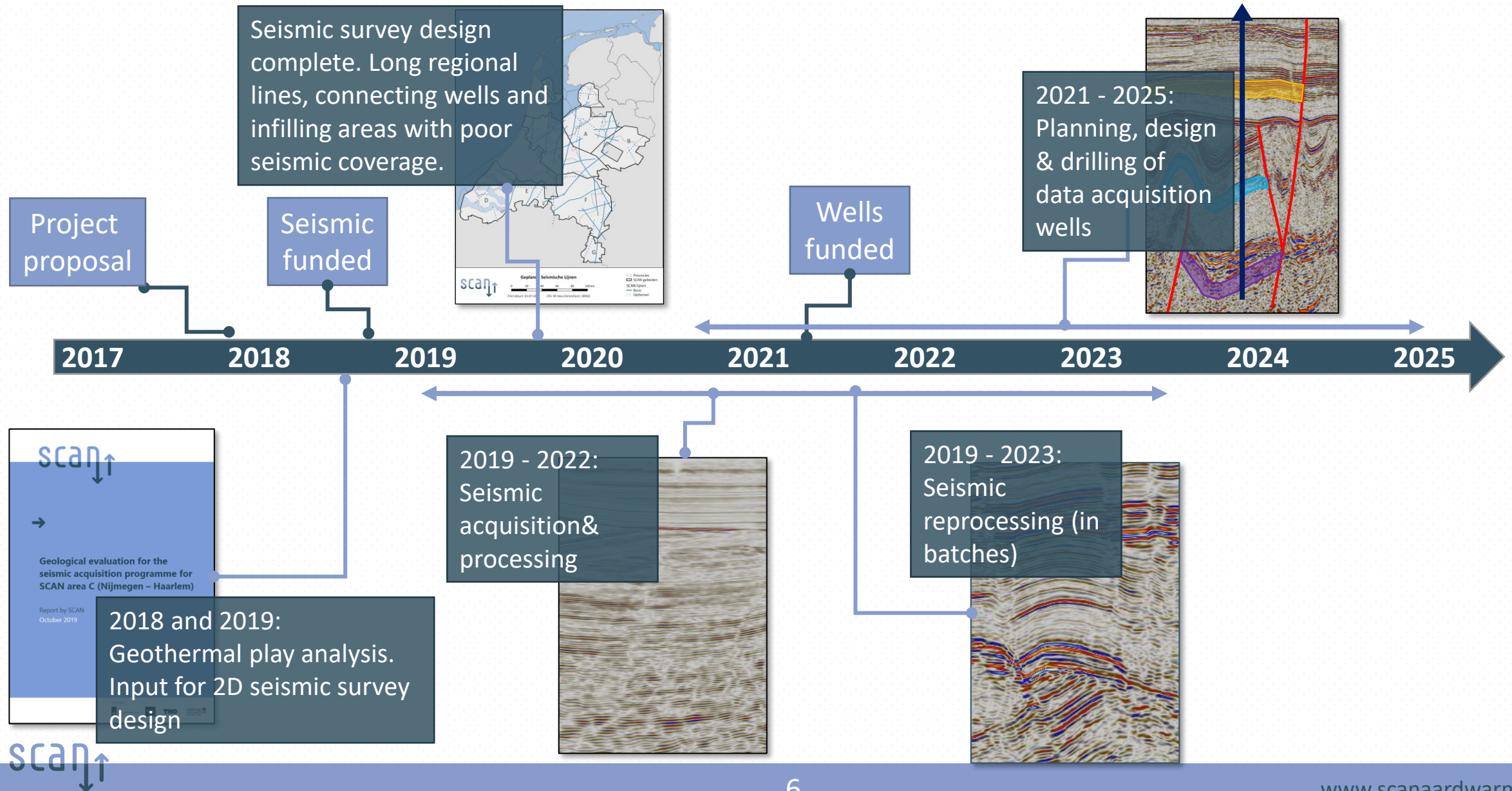 Exploration licence

Components of the SCAN programme

1. **Acquisition of over 1700 km of new 2D seismic data**

   ➜ Regional campaign commenced in September 2019, completed Q1 2022.

2. **Reprocessing of over 7400 km of vintage 2D seismic data (over 250 2D lines)**

   ➜ > 4900 km completed, rest will become available in batches, last batch Q2 2023.

3. **Data well campaign**

   ➜ Spud of first well planned for fall of 2023

All results made public on scanaardwarmte.nl and nlog.nl/scan

New Seismic Lines

SCAN Seismische Lijnen

Print datum: 08-06-2022   CRS: RD New (Amersfoort; 28992)

Provincies
SCAN-geb
Seismische lij
Ontwerp
Werkzaan
Processing

Reprocessed Seismic Lines

SCAN Reprocessing van Seismische Lijnen

CRS: RD New (Amersfoort; 28992)
Printdatum: 16-09-2022

Werkpakket
GTO-18-C004
GTO-19-C011
GTO-19-C032-01
GTO-19-C032-03
GTO-19-C032-04
GTO-19-C032-05

GTO-19-C033-01
GTO-19-C033-02
GTO-19-C033-03
GTO-19-C033-04
GTO-19-C033-05
SCAN-gebieden

SCAN project phases and activities

Seismic survey design complete. Long regional lines, connecting wells and infilling areas with poor seismic coverage.

2021 - 2025: Planning, design & drilling of data acquisition wells

Project proposal

Seismic funded

Wells funded

2017 2018 2019 2020 2021 2022 2023 2024 2025

Geological evaluation for the seismic acquisition programme for SCAN area C (Nijmegen – Haarlem)

Report by SCAN
October 2019

2018 and 2019: Geothermal play analysis. Input for 2D seismic survey design

2019 - 2022: Seismic acquisition& processing

2019 - 2023: Seismic reprocessing (in batches)

SCAN: Geothermal plays

➜SCAN looks at a wide range of geothermal plays

➜**Focus on:**
- ➜Deep and Shallow geothermal (500 m – 4000 m)
- ➜Primary permeability
- ➜Secondary permeability (from karst or leaching)

➜<u>No</u> **focus on:**
- ➜Ultra Deep Geothermal (UDG; >4000 m)
- ➜Fracture / fault permeability
- ➜Artificial/man made permeability systems (fracking, mine galleries, etc.)
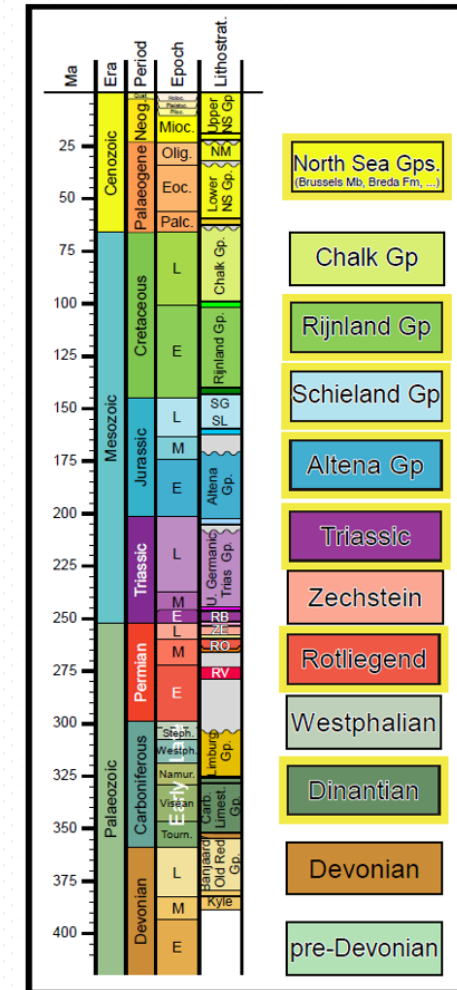
This presentation

✓ Primary play
● Secondary play

SCAN Search Areas for Wells

Search Area for Well

	SCAN Search Area	Primary target	Secondary target(s)
A	Amstelland	Rotliegend (Permian)	Chalk, Rijnland (L. Cret)
B	Utrecht	Rotliegend (Permian)	Triassic, Rijnland (L.Cret), Chalk
C	Ede-Veenendaal	Rotliegend (Permian)	Rijnland (L. Cret)
D	Apeldoorn-Deventer	Rotliegend (Permian)	North Sea (Paleogene), U. Carb.
E	Haarlem-Amsterdam-West	Rijnland (L. Cret)	Schieland (U. Jurassic/L. Cret), Chalk
F	Oss	Triassic	Rijnland, Rotliegend, Chalk Gp (Vaals Fm)
G	Kempen	Triassic	U. Carboniferous
H	Deurne	Triassic	Chalk Gp (Vaals Fm)
I	Eindhoven	North Sea (Neogene& Paleogene)	None
J	West-Brabant Noord	North Sea (Paleogene)	None

➜10 Search Areas for Wells

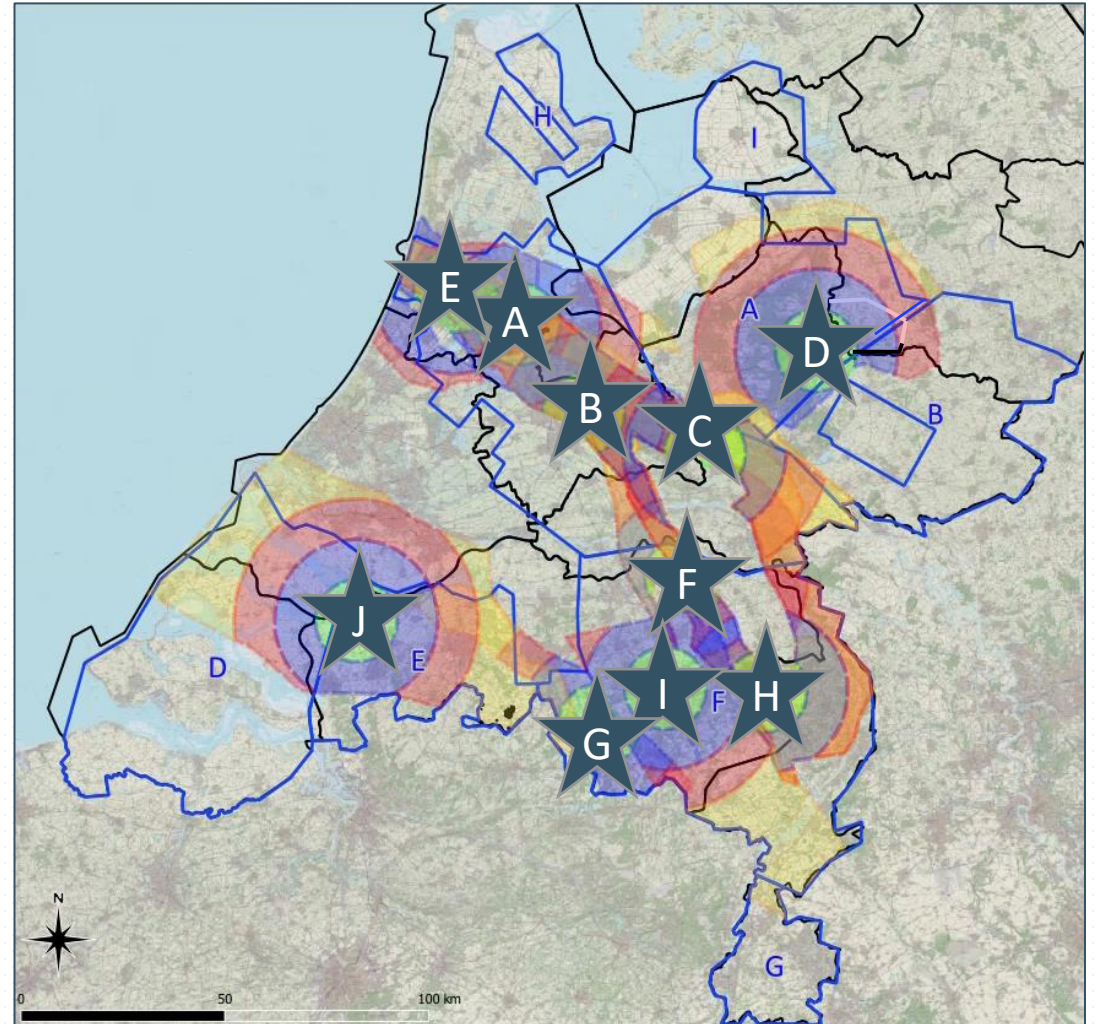➜Current expectation is that we will be able to drill a well in about 7 areas

➜ List is ordered by primary target, does not imply drilling sequence or ranking
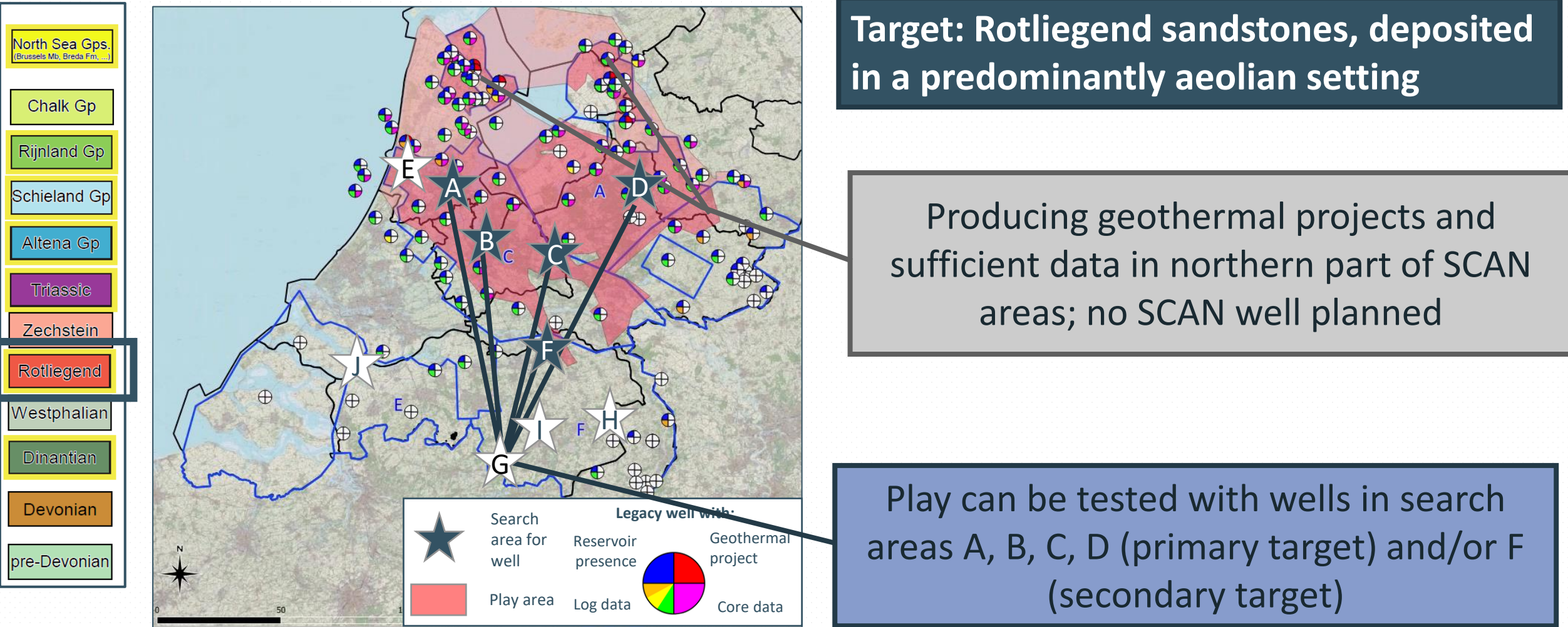
A Play Based Exploration approach for Geothermal

➜ To select search areas, target intervals and well locations we applied a Play Based Exploration workflow

➜ Together, the play segments associated with the search areas have a wide area of influence

➜ Metropolitan areas with high heat demand covered.

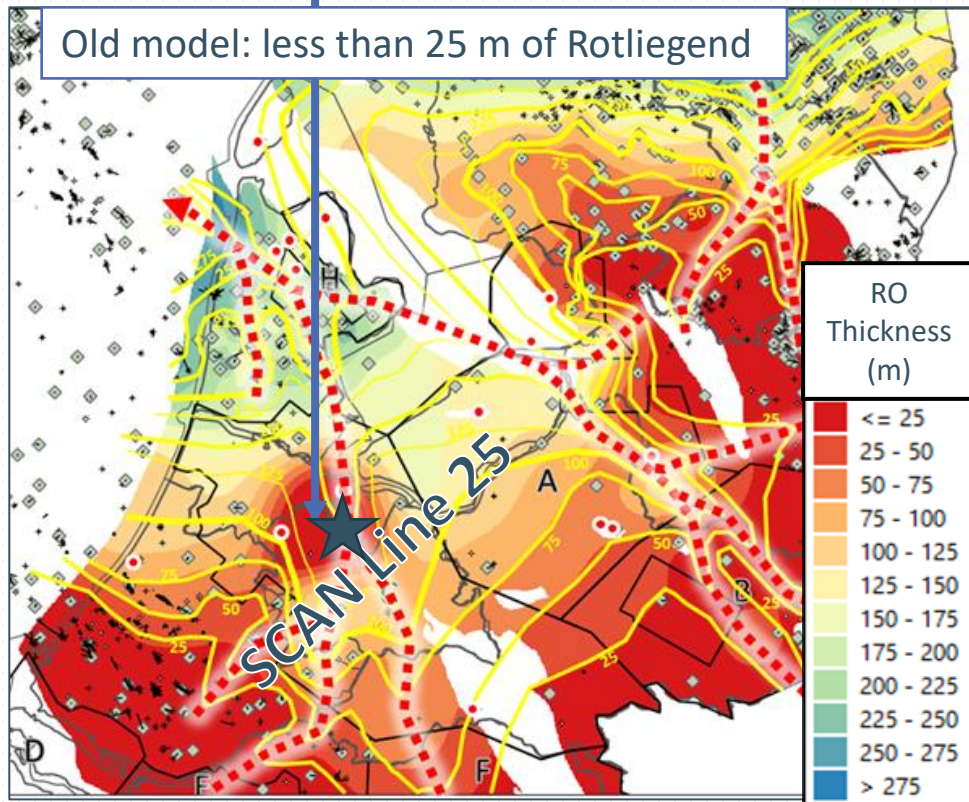Combined extent of play segments for SCAN search areas

Rotliegend Play (Permian)

Target: Rotliegend sandstones, deposited in a predominantly aeolian setting

Producing geothermal projects and sufficient data in northern part of SCAN areas; no SCAN well planned

Play can be tested with wells in search areas A, B, C, D (primary target) and/or F (secondary target)

Legend (stratigraphic column):
- North Sea Gps. (Brussels Mb, Breda Fm, ...)
- Chalk Gp
- Rijnland Gp
- Schieland Gp
- Altena Gp
- Triassic
- Zechstein
- Rotliegend
- Westphalian
- Dinantian
- Devonian
- pre-Devonian

Legend (map):
- Search area for well (star)
- Play area (pink)

Legacy well with:
- Reservoir presence
- Log data
- Geothermal project
- Core data

Thickness of the Permian Rotliegend reservoir

➜ Thickness of the main geothermal reservoir in the Amsterdam/Almere area (Rotliegend) was uncertain prior to SCAN: according to some models hardly any Rotliegend was present

➜ These models were based on the Weesp and Waverveen wells, drilled in the 1970s

Weesp-01 (1970)

Old model: less than 25 m of Rotliegend

SCAN Line 25

RO Thickness (m)

- <= 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 125
- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- > 275

Yellow isopachs: SCAN thickness model
Colours in background: thickness in DGM-Diep v4
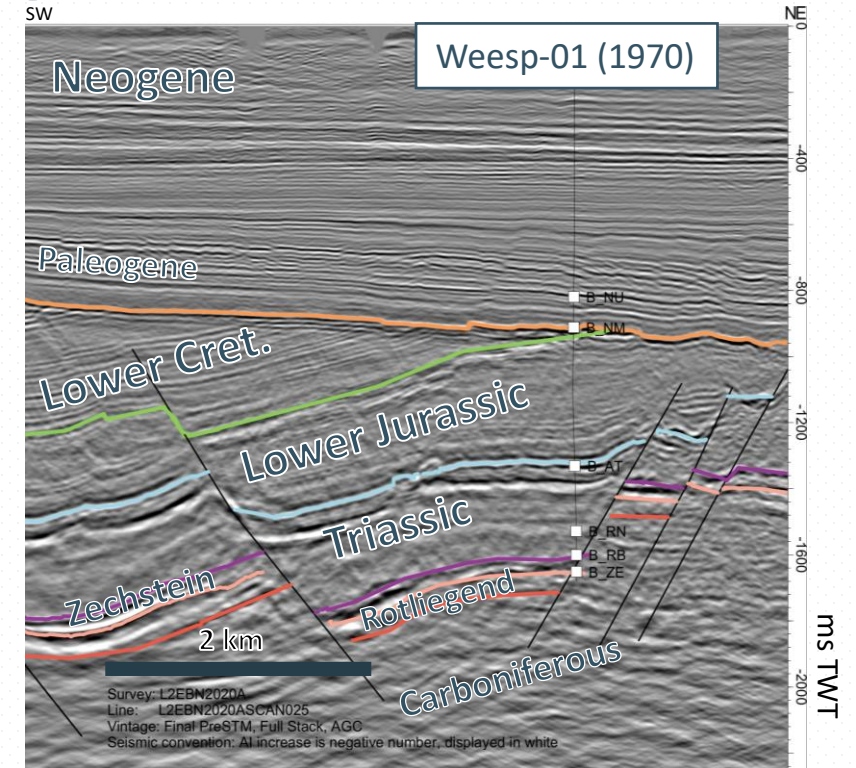
➜ Insufficient seismic data was present at the well locations.

➜ New SCAN-seismic data shows that the Weesp well drilled the Rotliegend at a location where the reservoir is truncated by a fault. The well is therefore not representative for the region.

➜ Thickness is now de-risked, which is good news for the geothermal potential of the region

➜ Uncertainties remain; a new well will provide much relevant data.

# Permian Rotliegend: reservoir quality

➜ Reservoir quality is another uncertainty affecting the geothermal potential of the Rotliegend

➜ Rule of thumb: transmissivity of about 10 Dm required for an economic project

➜ Few offset wells in Amsterdam area, so a representative selection of regional offset wells was made: about 40% of these have sufficient transmissivity
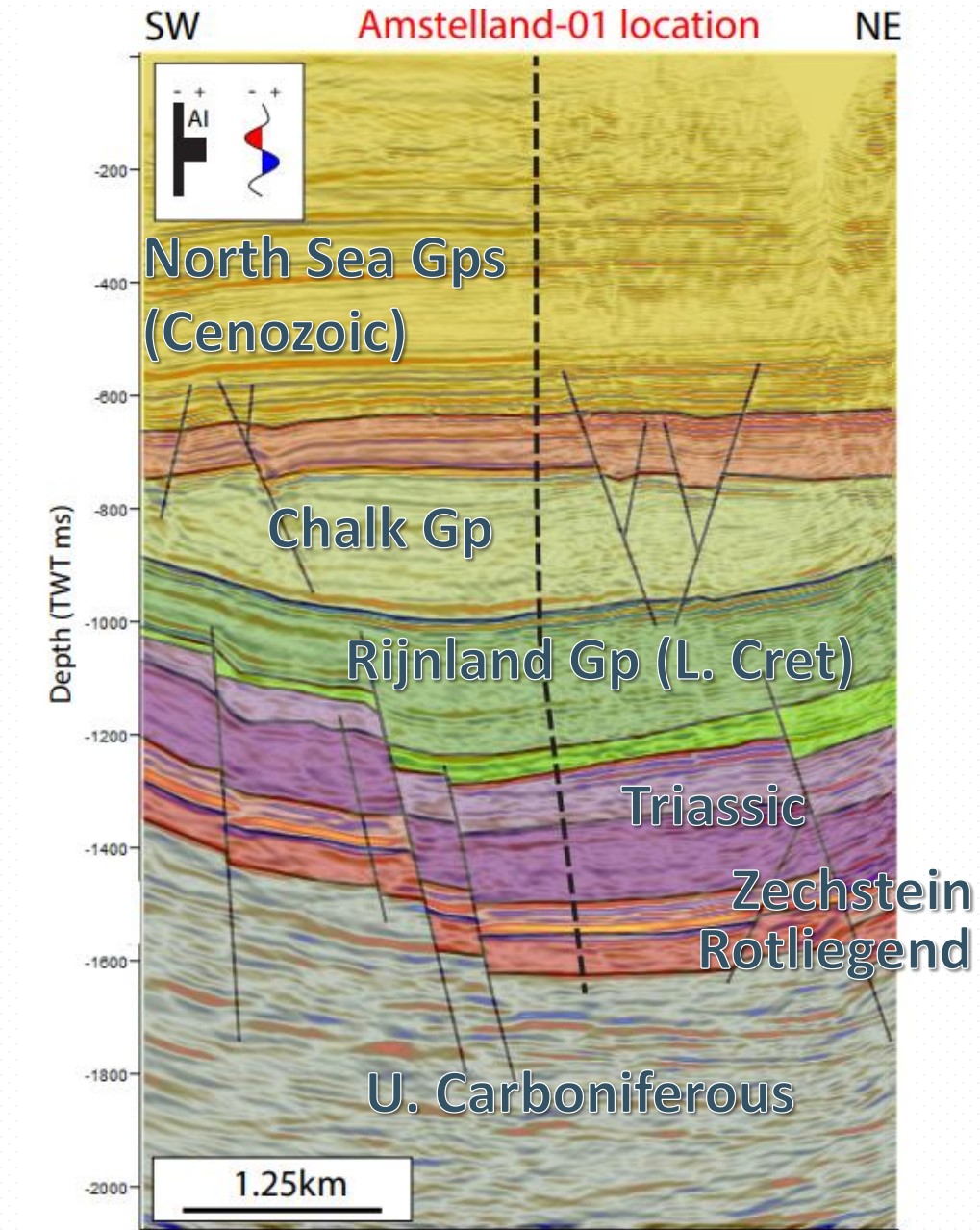
Central Netherlands Rotliegend Slochteren Transmissivity
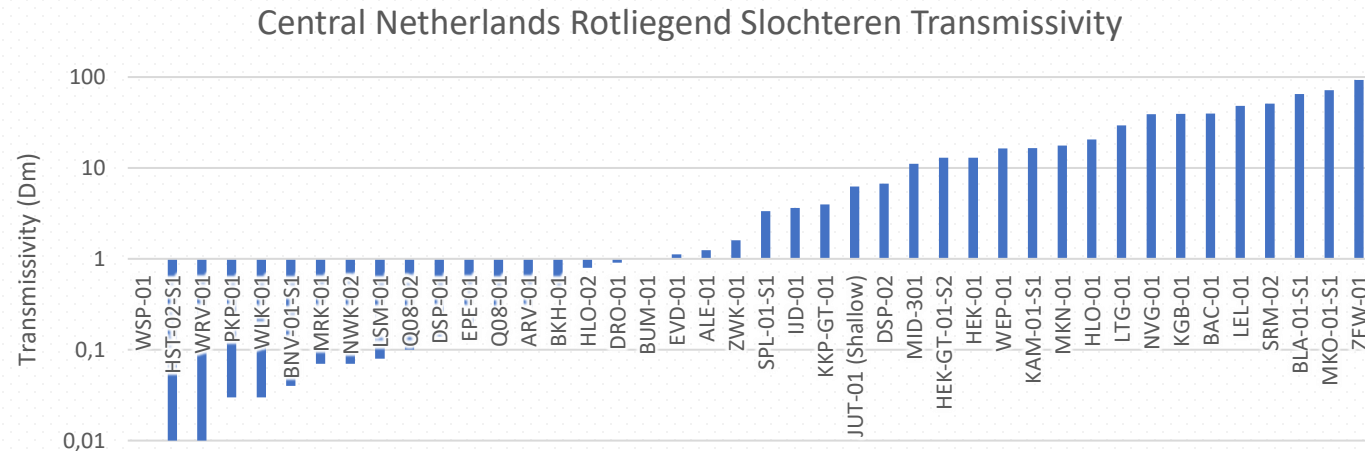
Rotliegend: Seismic Inversion for Porosity

➜Seismic Inversion of SCAN seismic lines in the Amsterdam area by Ikon Science (work in progress)

➜Aim: assess porosity

➜Preliminary results are promising; good reservoir quality predicted.
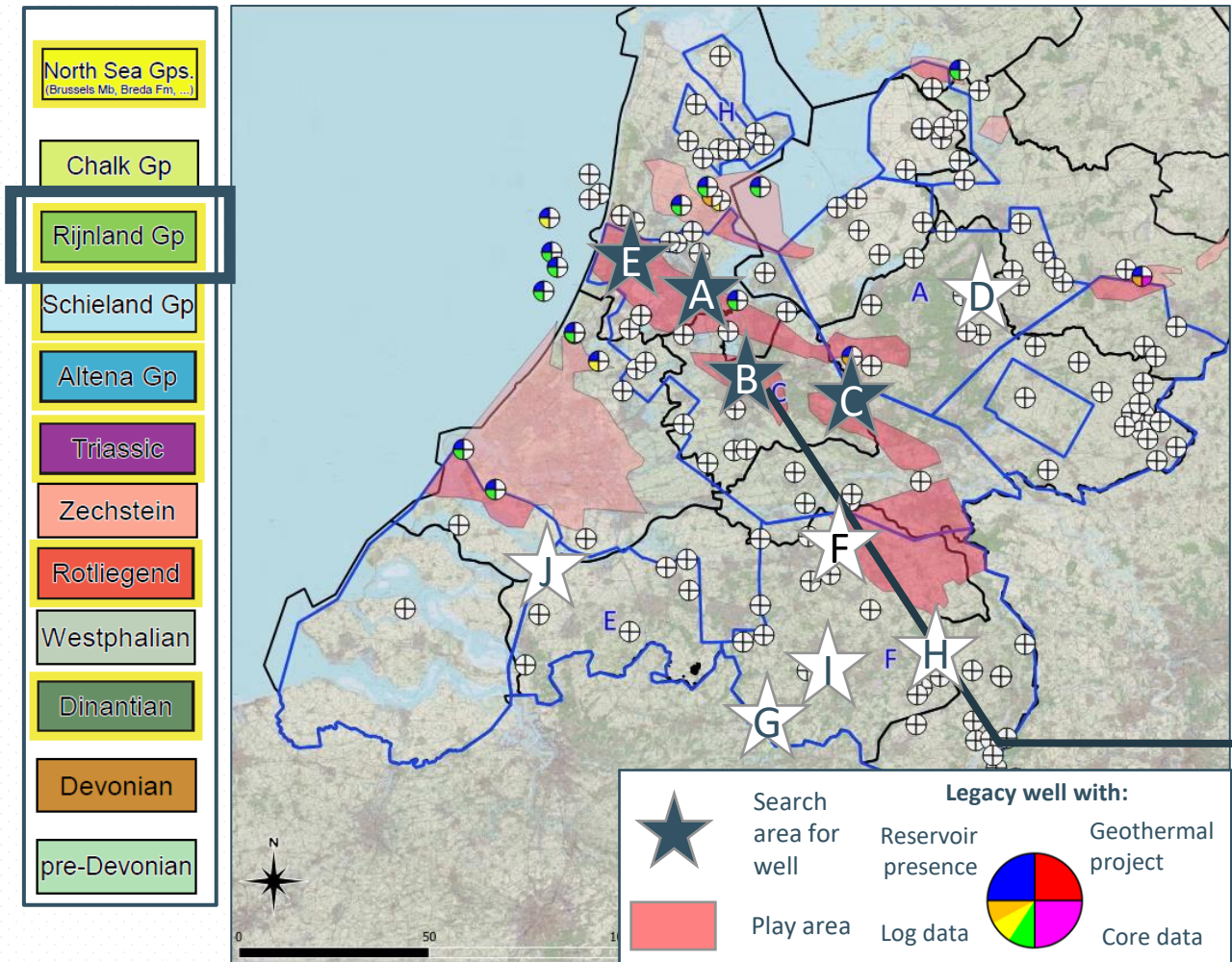
➜Amstelland well will validate results
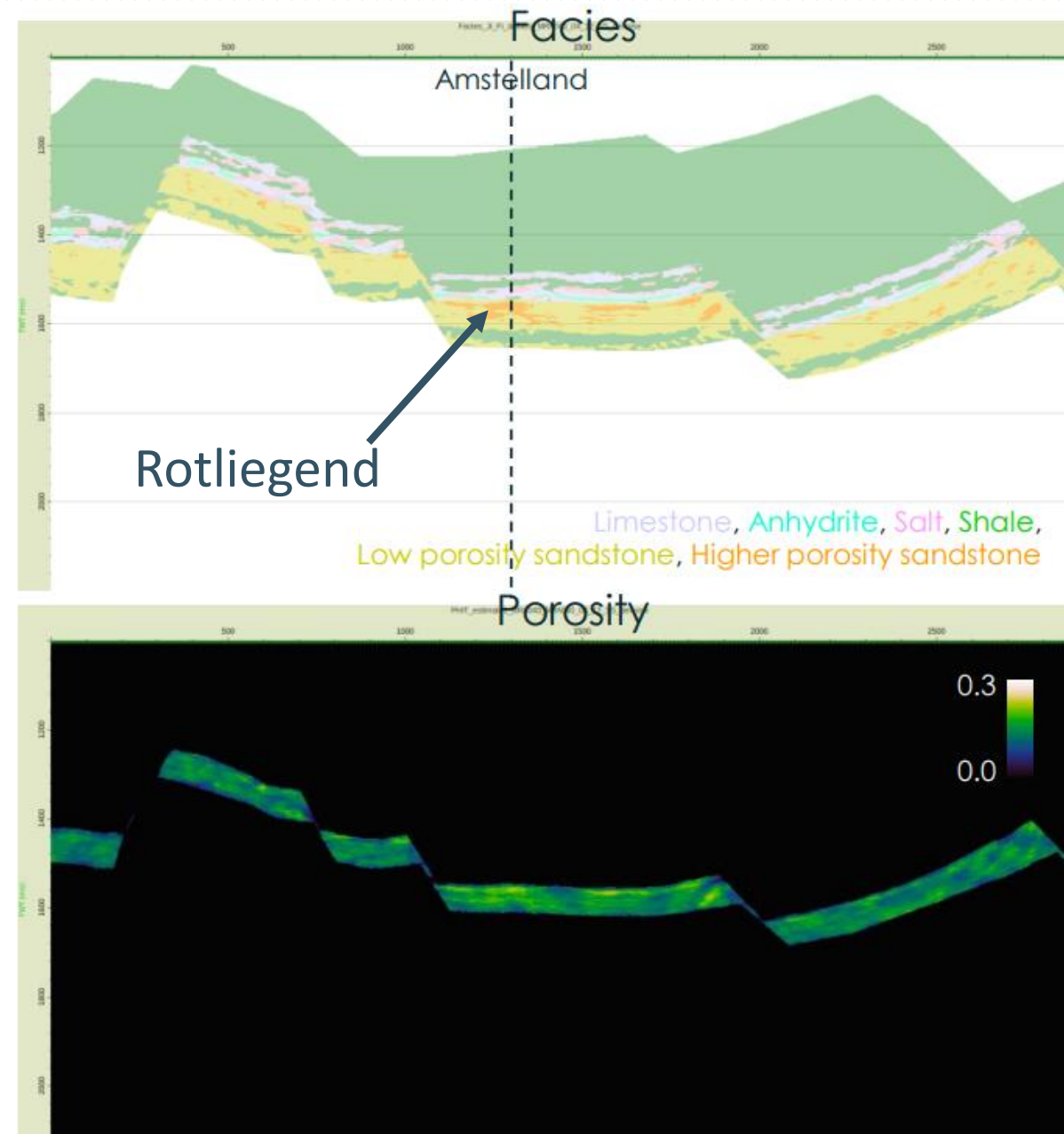
Rotliegend

SCAN Well Amstelland

➜First SCAN geothermal data-acquisition well

➜Planned for fall of 2023

➜ Geothermal targets:
   ➜Primary: Permian Rotliegend (ROSL) sandstones (~87°C)
   ➜Secondary: L. Cret. Rijnland Gp (KN) sandstones (~62°C)
   ➜Secondary: U. Cret. Chalk Gp (CK) (~39°C)

➜Main uncertainty for primary target: permeability. Chance of presence of sufficiently permeable reservoir estimated at 65%

SW   Amstelland-01 location   NE

North Sea Gps (Cenozoic)

Chalk Gp

Rijnland Gp (L. Cret)

Triassic

Zechstein
Rotliegend

U. Carboniferous

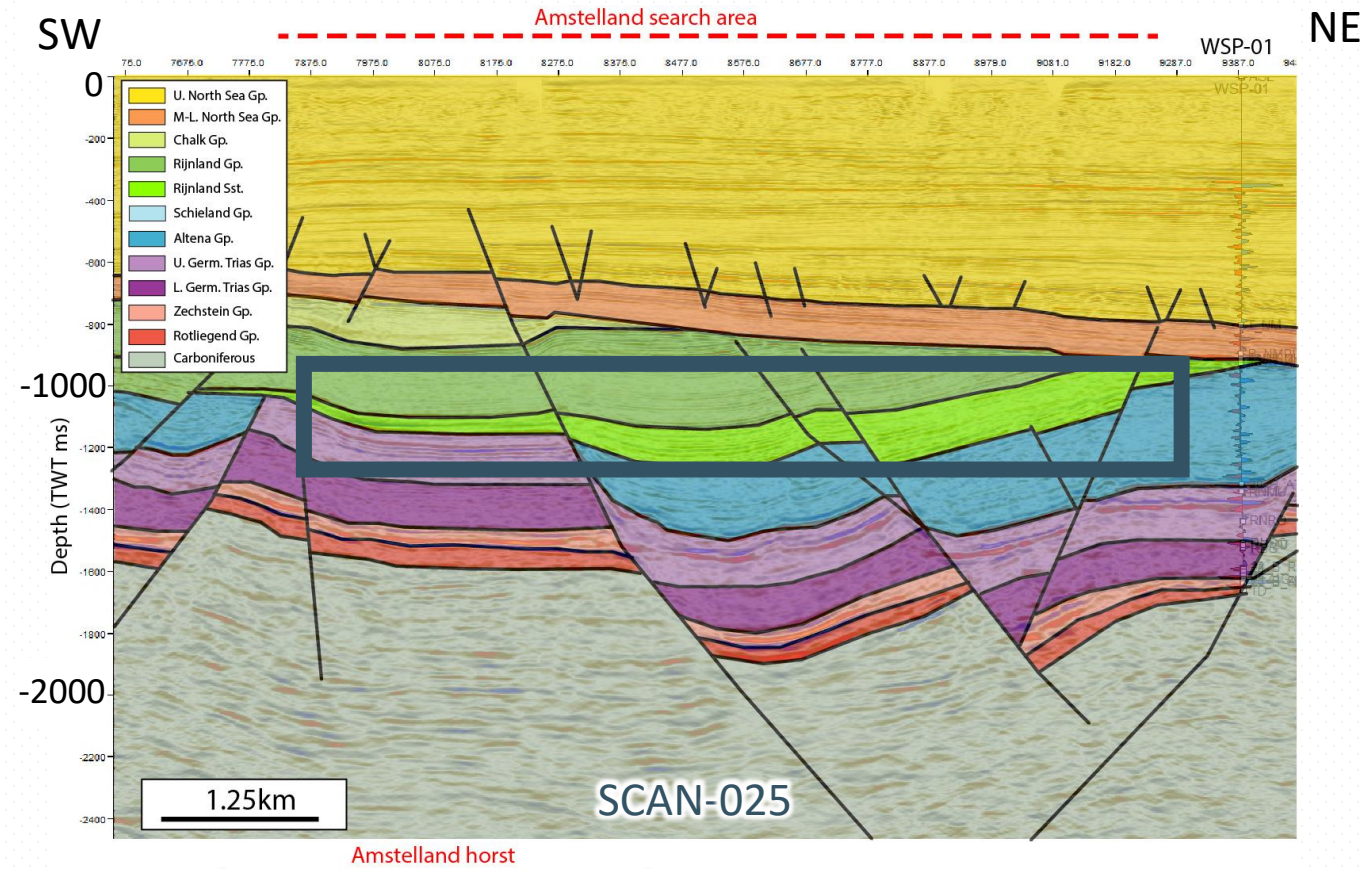1.25km

Rijnland Play (Lower Cretaceous)

Target: Rijnland Group Lower Cretaceous shallow marine sandstones (Vlieland Sst Fm (NL)/Lower Greensand Gp (UK) equivalent)

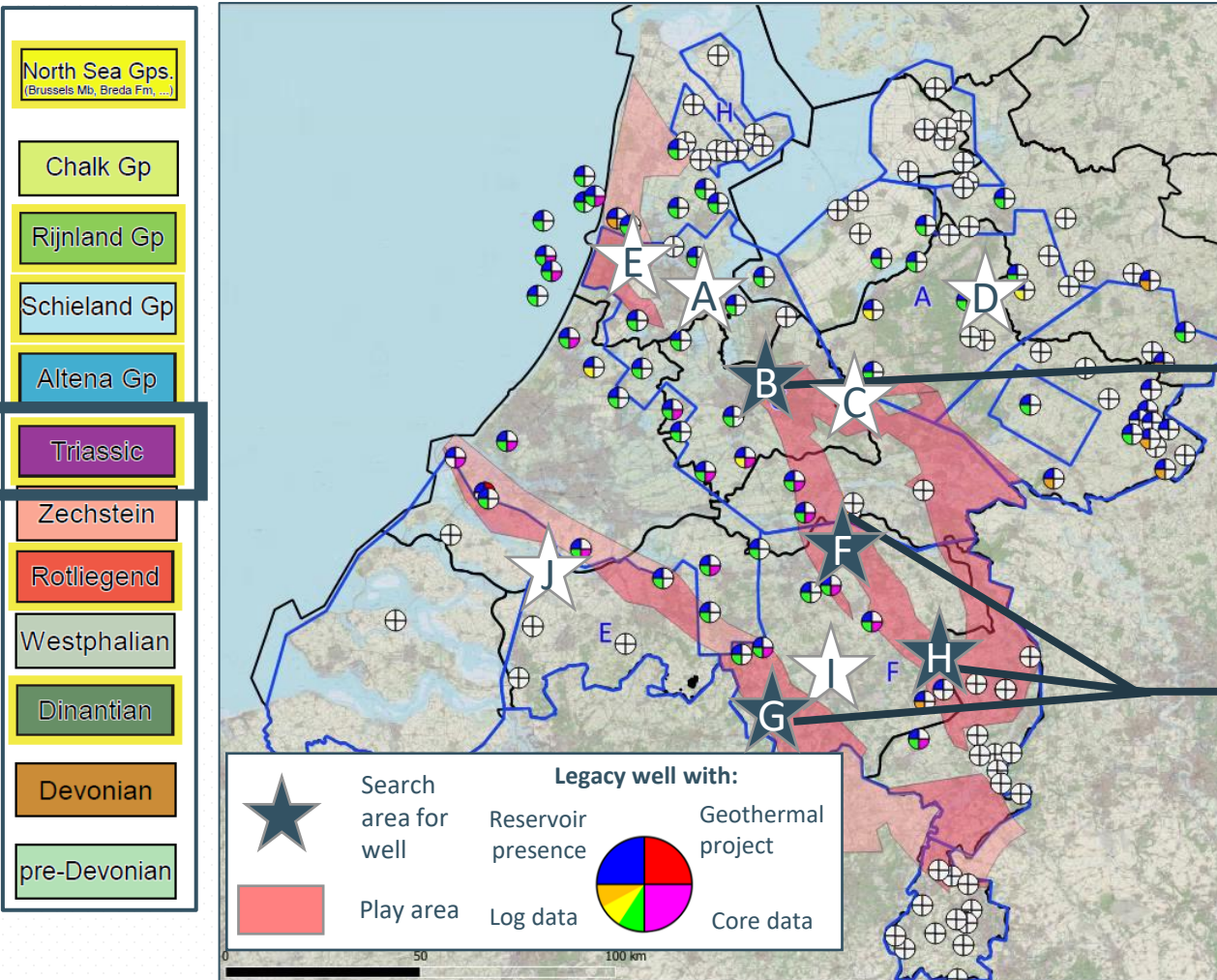Play can be tested in search area E as a primary target, and in A, B and C as a secondary target

Legend (stratigraphic column):
- North Sea Gps. (Brussels Mb, Breda Fm, ...)
- Chalk Gp
- Rijnland Gp
- Schieland Gp
- Altena Gp
- Triassic
- Zechstein
- Rotliegend
- Westphalian
- Dinantian
- Devonian
- pre-Devonian

Legend (map):
- Search area for well
- Play area
- Legacy well with:
  - Reservoir presence
  - Log data
  - Geothermal project
  - Core data

Rijnland Play (Lower Cretaceous)

➜ **Lower Cretaceous Rijnland Gp marine sandstones** (Vlieland Sst Fm (NL)/Lower Greensand Gp (UK) equivalent

➜ Rijnland Gp is main geothermal aquifer in West Netherlands Basin, together with Schieland Gp (UK: Wealden Gp)

➜ **No wells providing a valid test of this aquifer available in Central Netherlands, geothermal potential is unknown**

➜ Seismic facies suggests reservoir may be present.

➜ **Amstelland well will test this potential aquifer.**

　➜ Chance of effective reservoir estimated at 30%

Triassic Plays

Legend (map):
- North Sea Gps. (Brussels Mb, Breda Fm, ...)
- Chalk Gp
- Rijnland Gp
- Schieland Gp
- Altena Gp
- Triassic
- Zechstein
- Rotliegend
- Westphalian
- Dinantian
- Devonian
- pre-Devonian

Legend:
- ★ Search area for well
- Play area
- Legacy well with: Reservoir presence, Log data, Geothermal project, Core data

Target: Triassic sandstones (Nederweert Fm, Main Buntsandstein Subgp, Röt Fringe Sst Mb)
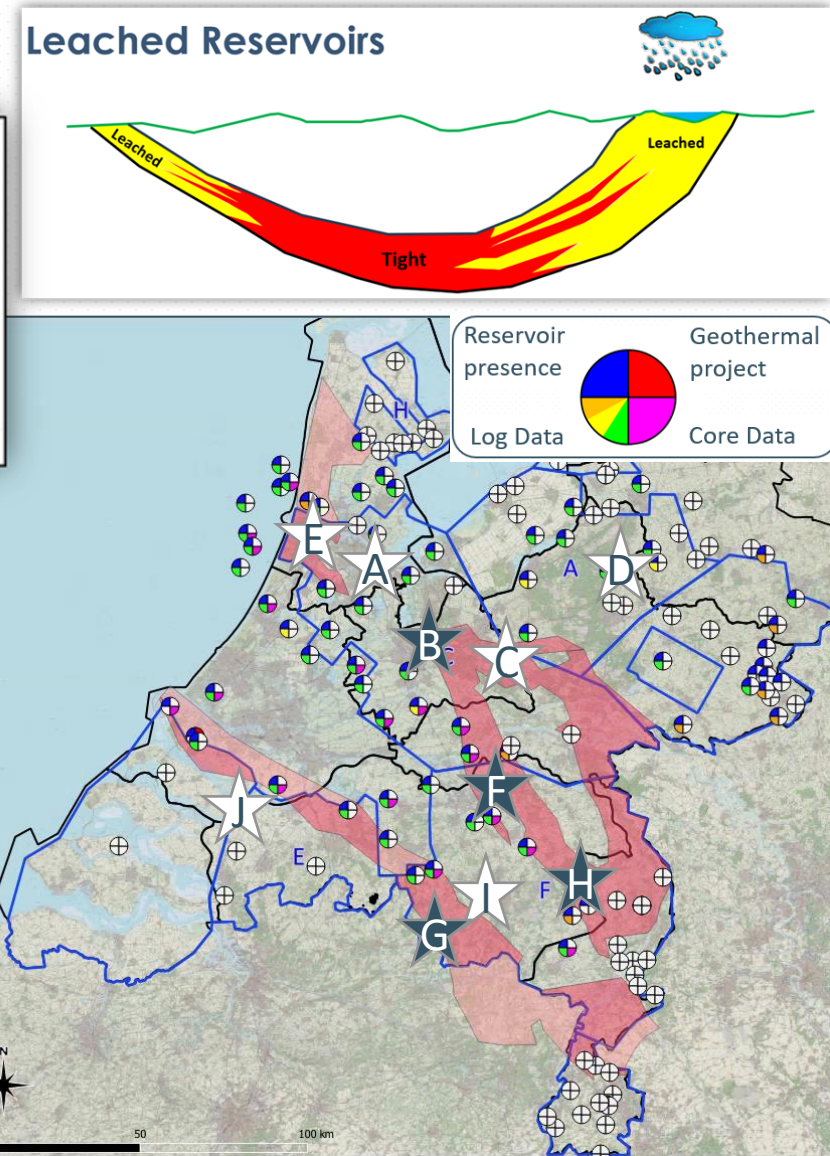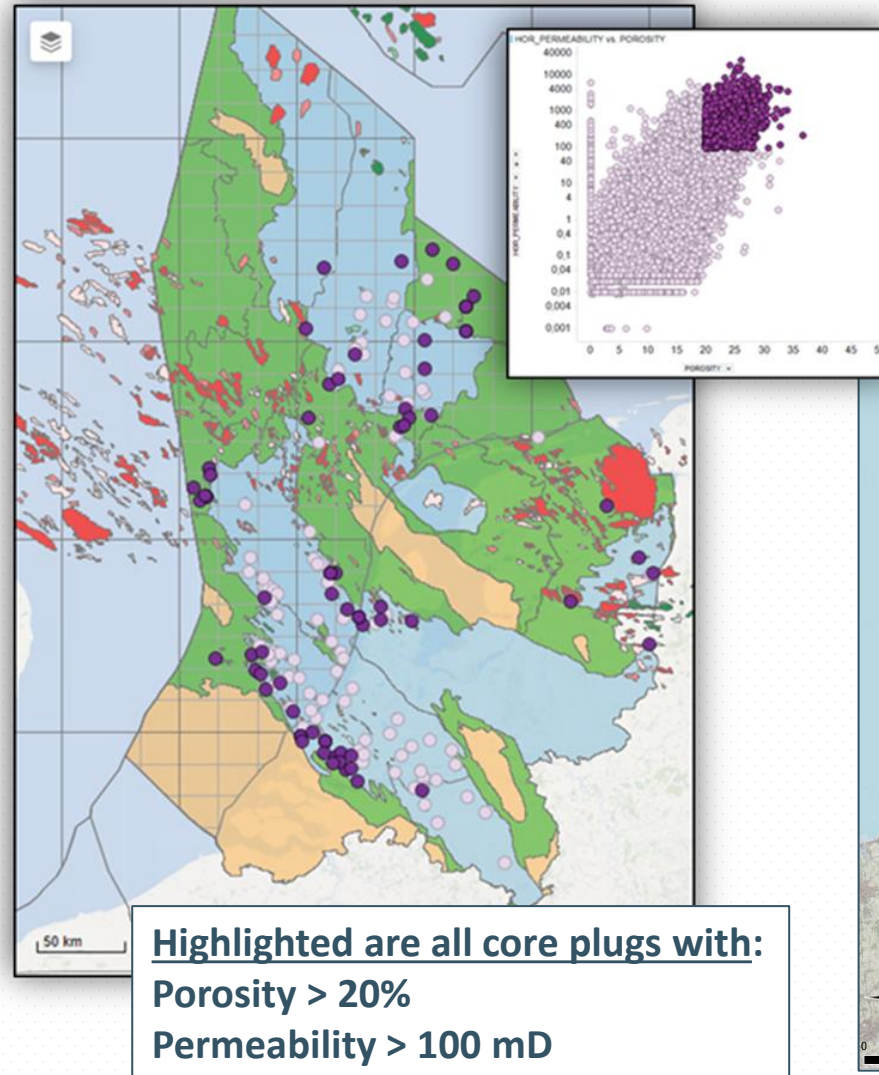
Northern edge of play can be tested in search area B as a secondary target

Play can be tested in search areas F, G and H
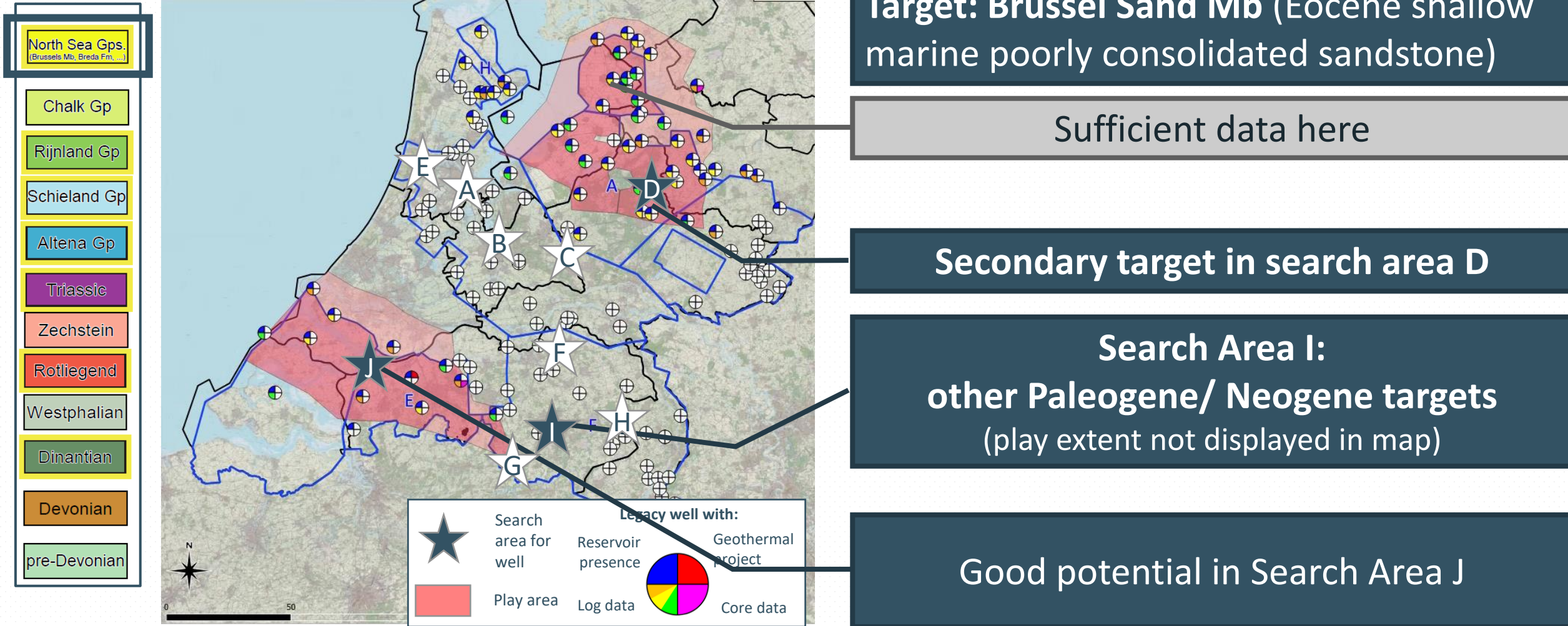
Triassic plays: leaching

➔ Secondary porosity created by leaching may be an important mechanism for enhanced permeability

➔ Occurs at basin edges where reservoirs are present below an unconformity (highlighted points in map)

➔ Untested concept in southeastern Netherlands

➔ Four search areas can test this concept

Highlighted are all core plugs with:
Porosity > 20%
Permeability > 100 mD

Lower North Sea Group - Brussels Play

Target: Brussel Sand Mb (Eocene shallow marine poorly consolidated sandstone)

Sufficient data here

Secondary target in search area D

Search Area I:
other Paleogene/ Neogene targets
(play extent not displayed in map)

Good potential in Search Area J

Legend (map):
- North Sea Gps. (Brussels Mb, Breda Fm, ...)
- Chalk Gp
- Rijnland Gp
- Schieland Gp
- Altena Gp
- Triassic
- Zechstein
- Rotliegend
- Westphalian
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- pre-Devonian

Legacy well with:
- Search area for well
- Reservoir presence
- Geothermal project
- Log data
- Core data
- Play area

Data-acquisition in wells

Extensive data acquisition is planned in SCAN wells. Amstelland well shown as example

→ Cores
- → Reservoirs: Porosity/permeability data
- → Reservoirs: Sedimentology and diagenesis (incl. descriptions and thin sections)
- → Geomechanical tests (note: also for sealing intervals)

→ Production / injection tests
- → Flow rate and transmissivity
- → Temperature, pressure and water composition

→ Well Logs, both reservoirs and overburden
- → Gamma Ray, Sonic (Vp/Vs), density/neutron, resistivity (whole well)
- → Image logs (for sedimentology and diagenesis, fractures and stress directions)
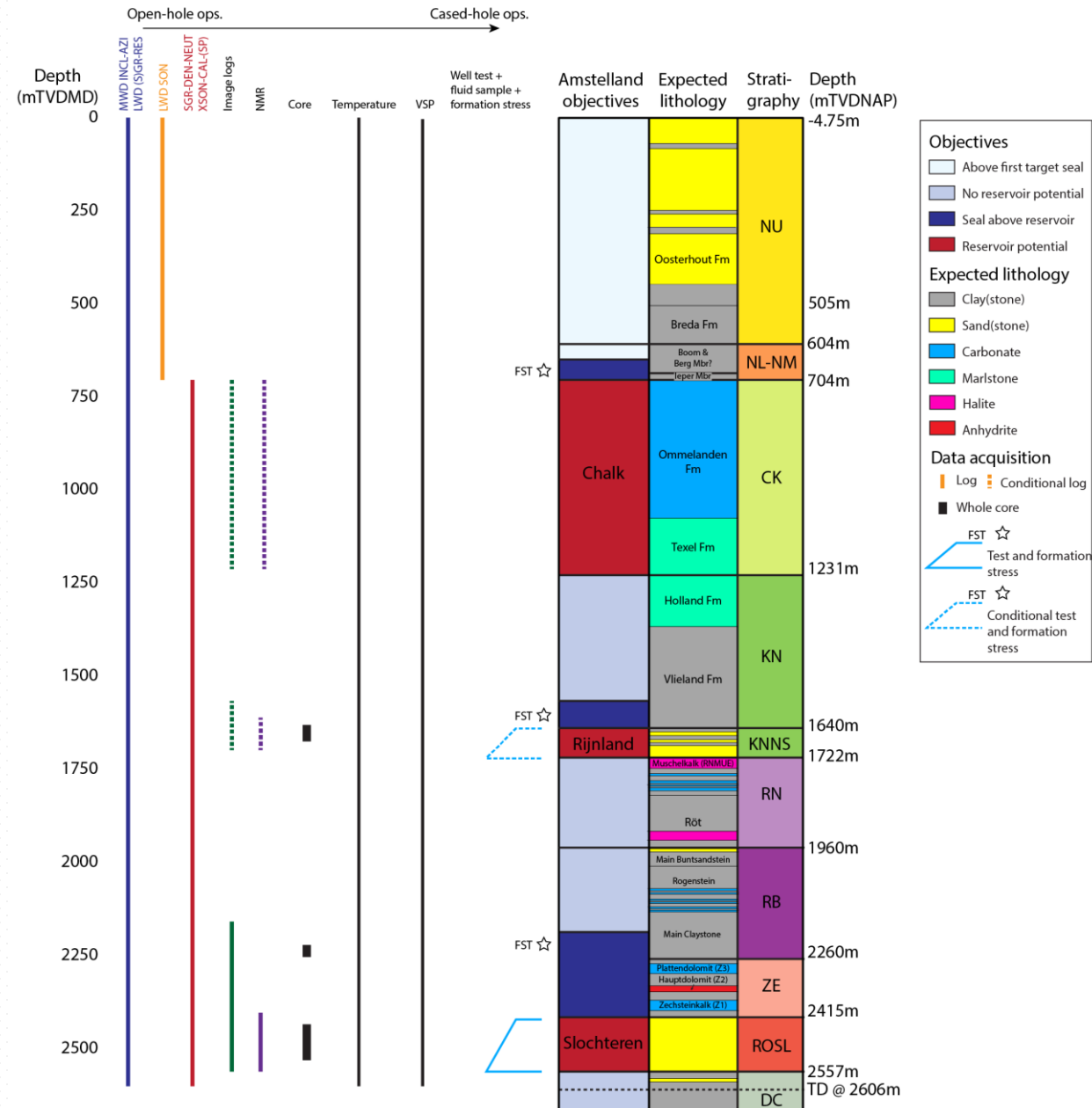- → NMR log (for permeability)
- → Temperature

→ Vertical Seismic Profile (for robust correlation onto regional seismic grid)

→ XLOT (Extended Leak-off Test)
- → Determination of caprock integrity

→ Cuttings and biostratigraphy
- → Vitrinite reflectance, apatite fission track, …
- → Dating and correlation of relevant intervals

Conclusions

➜ Based on the new SCAN regional seismic lines **promising geothermal aquifers** have been identified in previously underexplored parts of the Netherlands

➜ **Data acquisition wells** will be drilled to further assess the geothermal potential of these aquifers

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