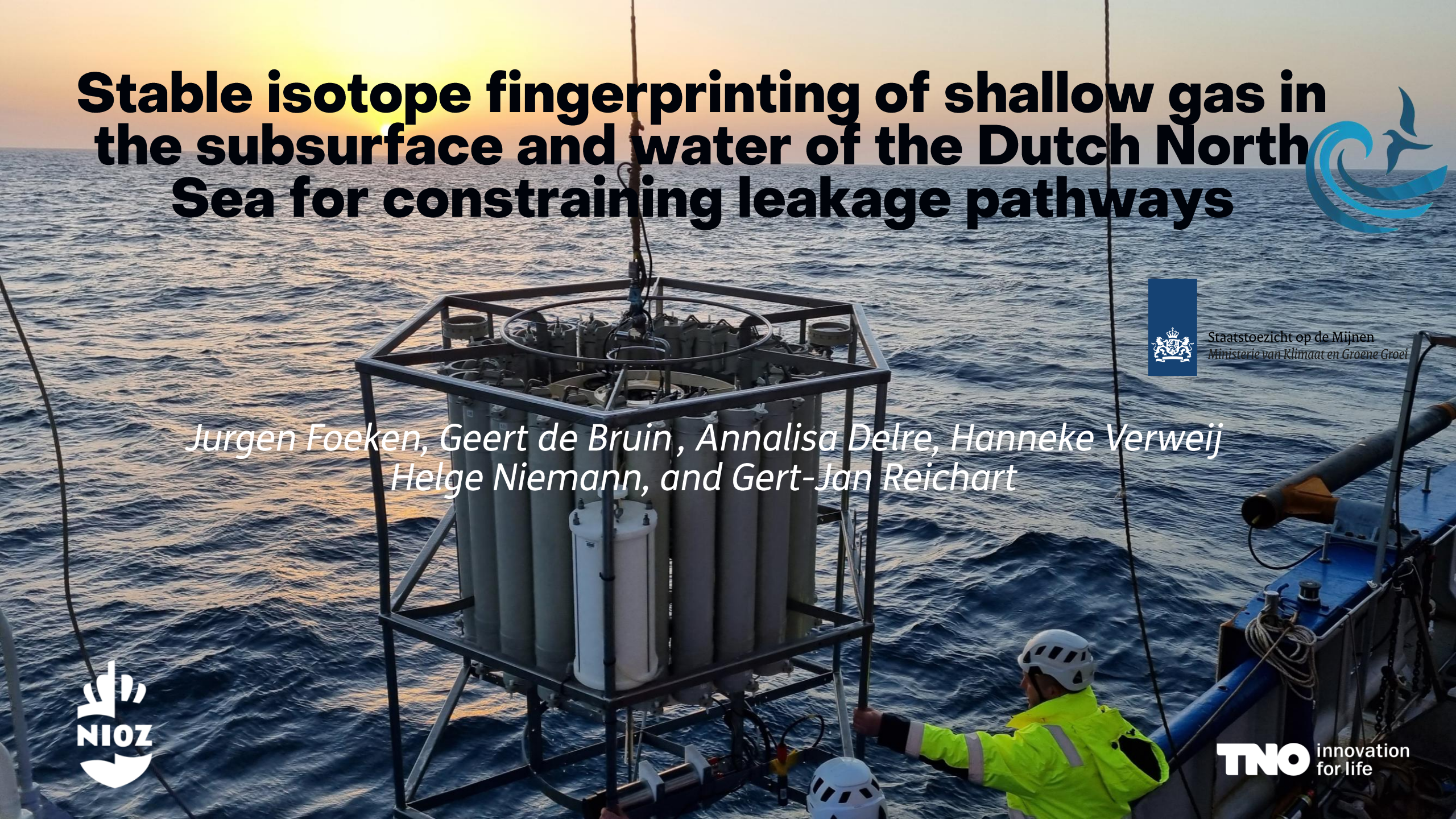
Stable isotope fingerprinting of shallow gas in the subsurface and water of the Dutch North Sea for constraining leakage pathways



Jurgen Foeken, Geert de Bruin , Annalisa Delre, Hanneke Verweij
Helge Niemann, and Gert-Jan Reichart

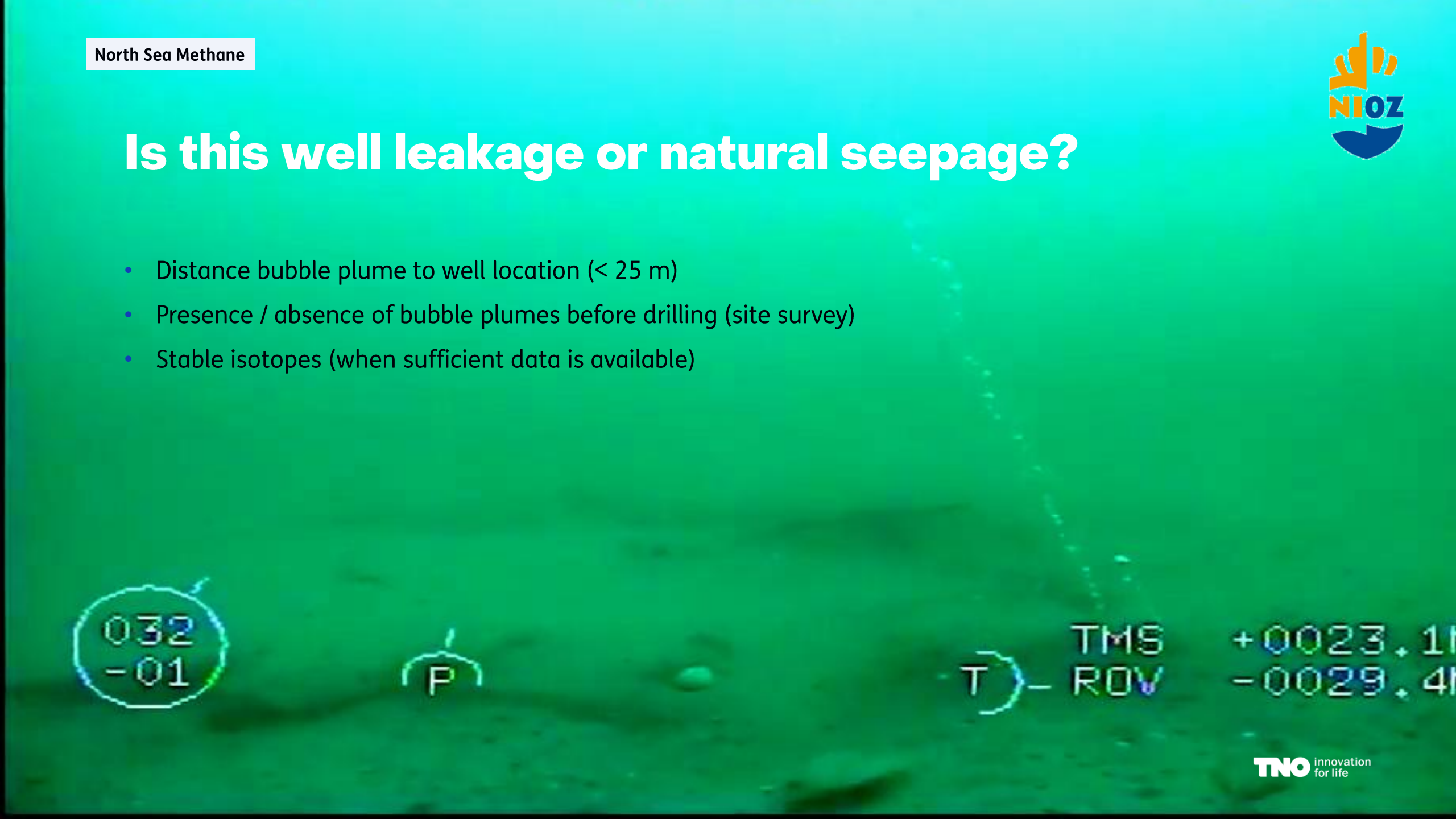
Staatstoezicht op de Mijnen
Ministerie van Klimaat en Groene Groei

NIOZ

TNO innovation for life

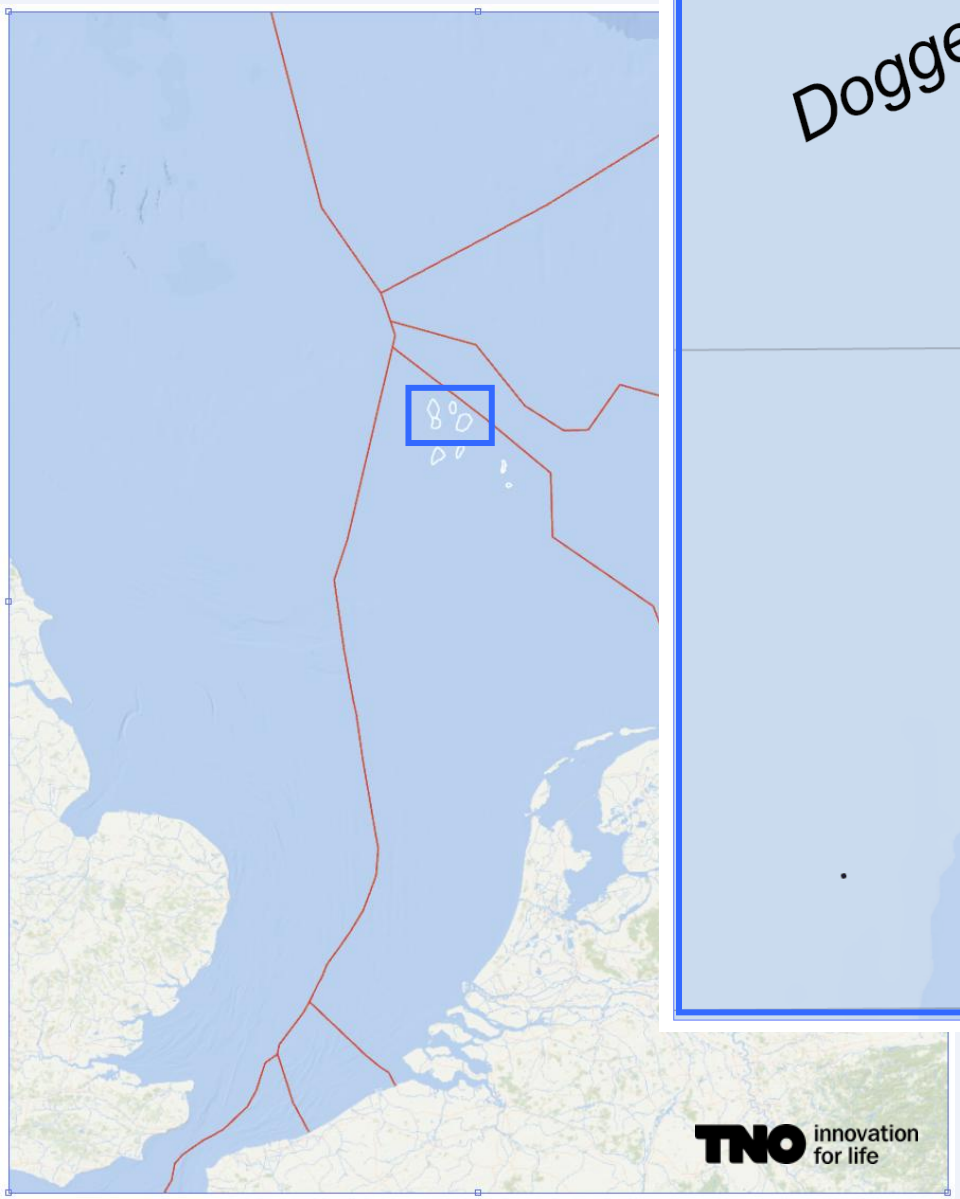
Is this well leakage or natural seepage?

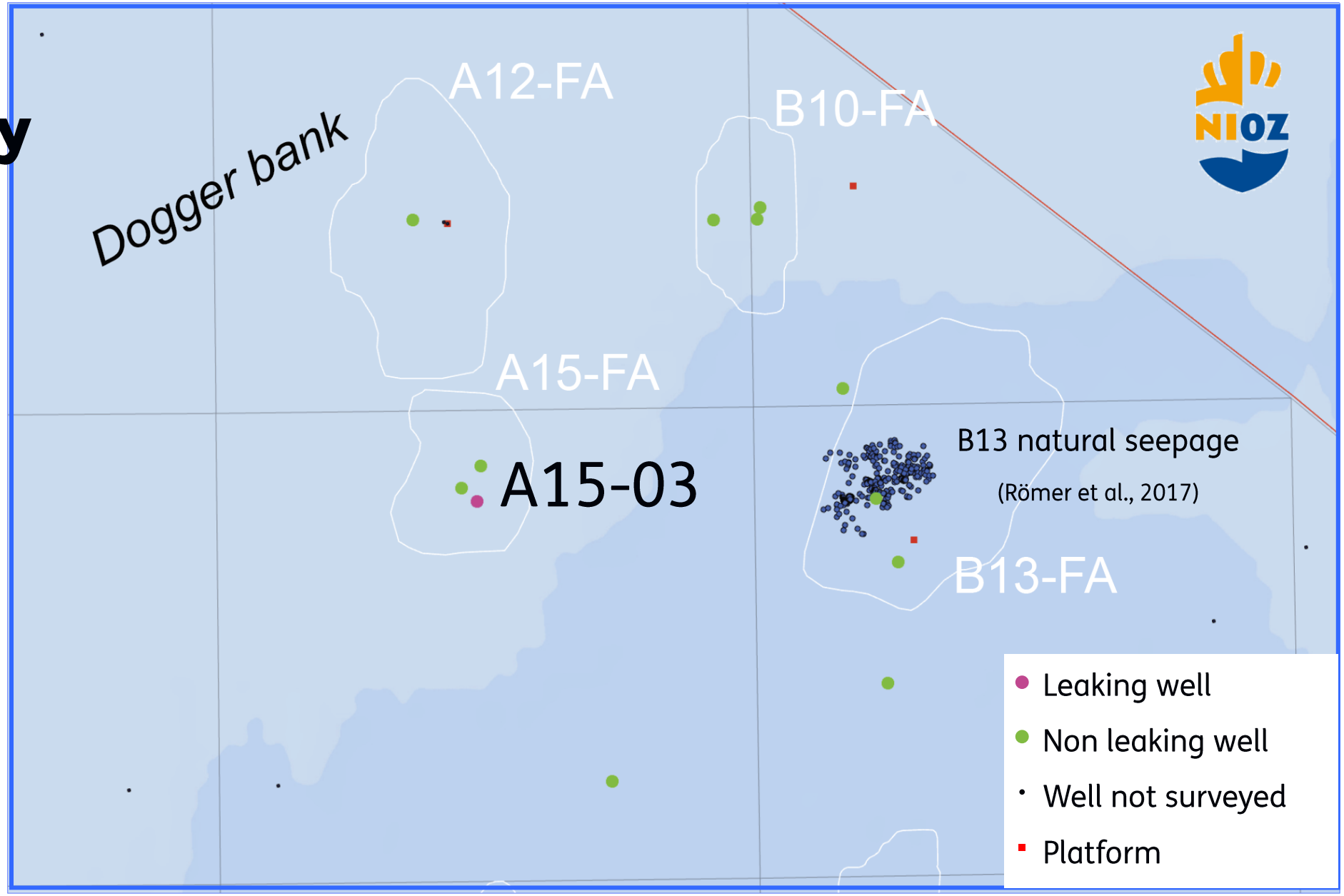
- Distance bubble plume to well location (< 25 m)
- Presence / absence of bubble plumes before drilling (site survey)
- Stable isotopes (when sufficient data is available)



North Sea Methane

2022 Survey





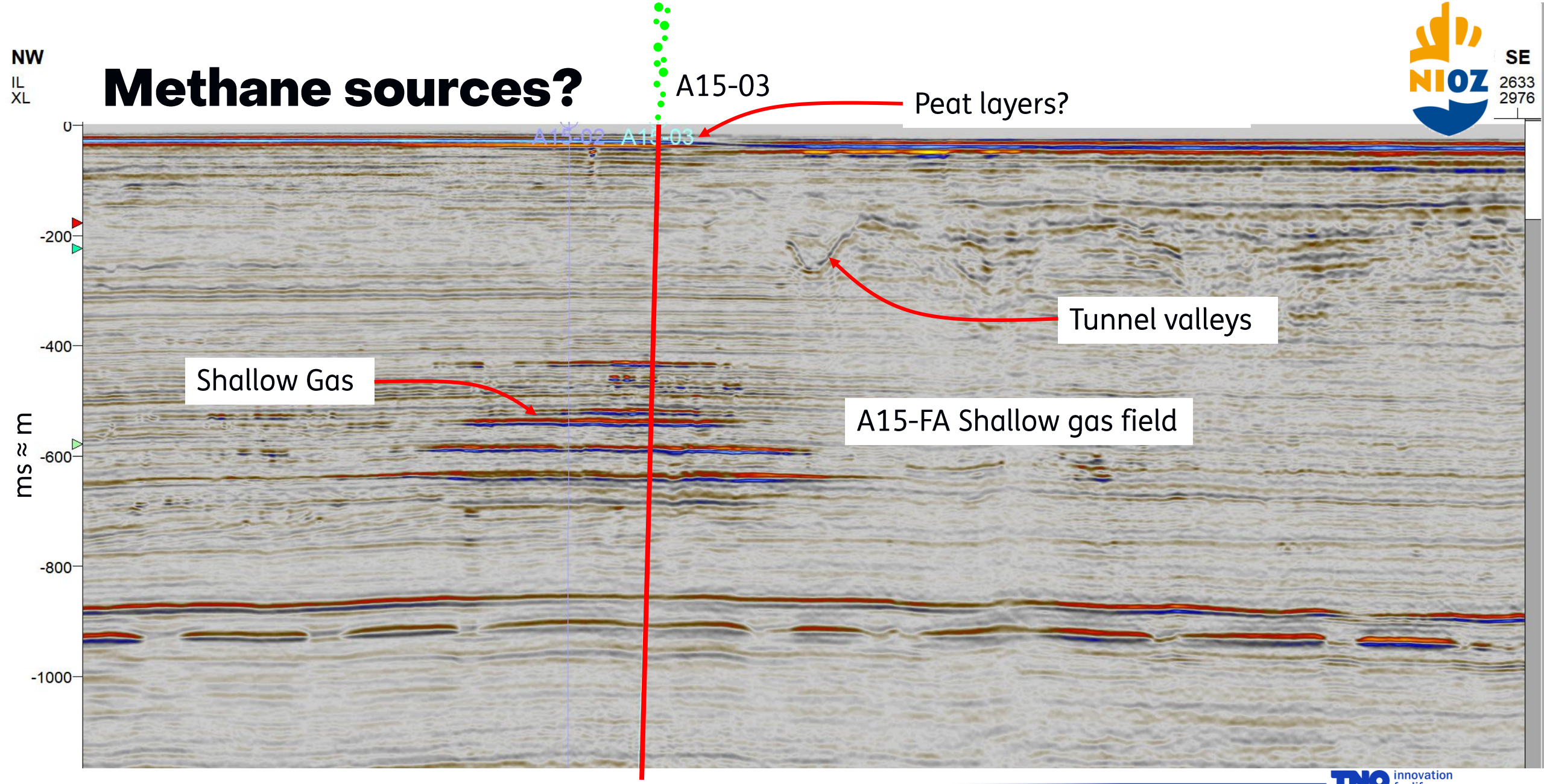
de Bruin et al. (2025)

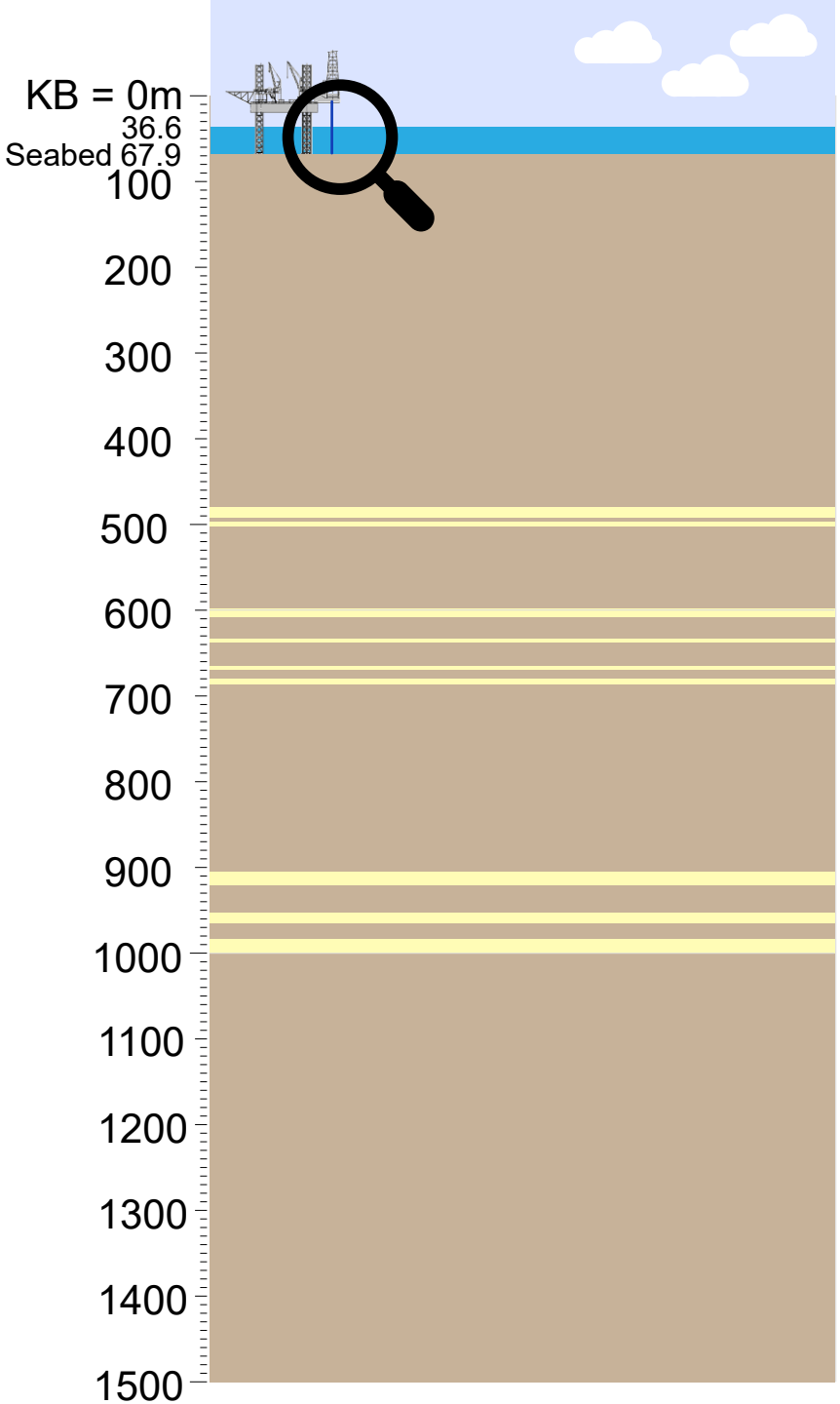
A15-03

Operator:	Wintershall Noordzee B.V.
Drilling:	28-07-1999 to 21-09-1999
Status:	Abandoned
Casing	cut 6 m below mudline
Water depth	31 m

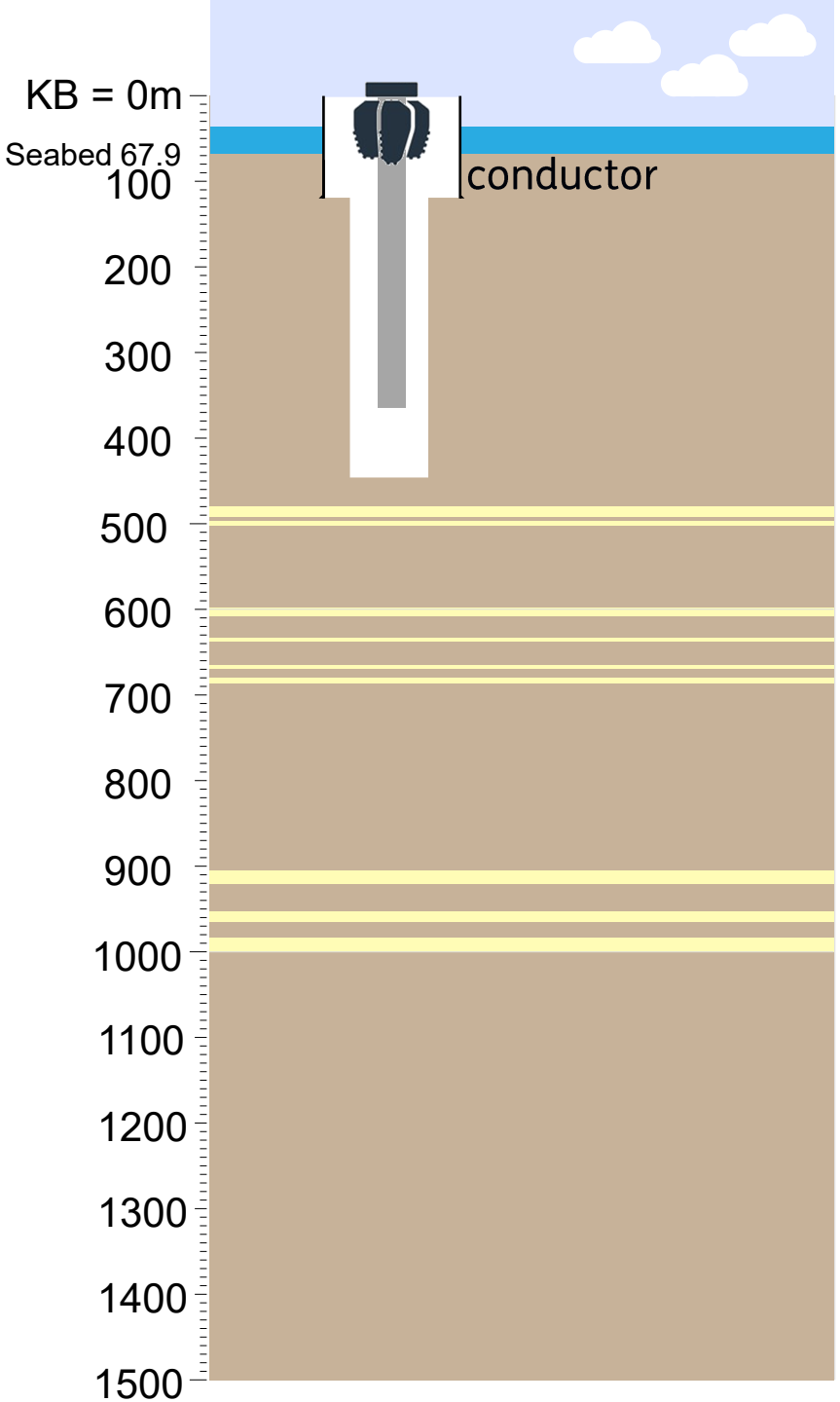
The exploration well A15-3 is located in the Step Graben geological province, in the northern sector of the Dutch North Sea. This well is proposed to prove economic gas reserves in several Plio-Pleistocene reservoirs of the Upper North Sea Group. Two gas prospects in the Upper North Sea Group have been indicated, which both consist of several stacked sand/sandstone reservoirs, alternated with clay/claystone layers. The upper prospect (431-635m TVDSS) consists of poorly consolidated fine sands/sandstones deposited in an upper foreshore setting. The lower prospect (847-960m TVDSS) was deposited by a submarine fan system with a potentially large extent. It consists of very fine sandstones alternating with claystone beds. This stratigraphic trap is sealed up-dip by marine clays.

Methane sources?




KB = 0m
36.6
Seabed 67.9
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

A15-03



A15-03

NIOZ

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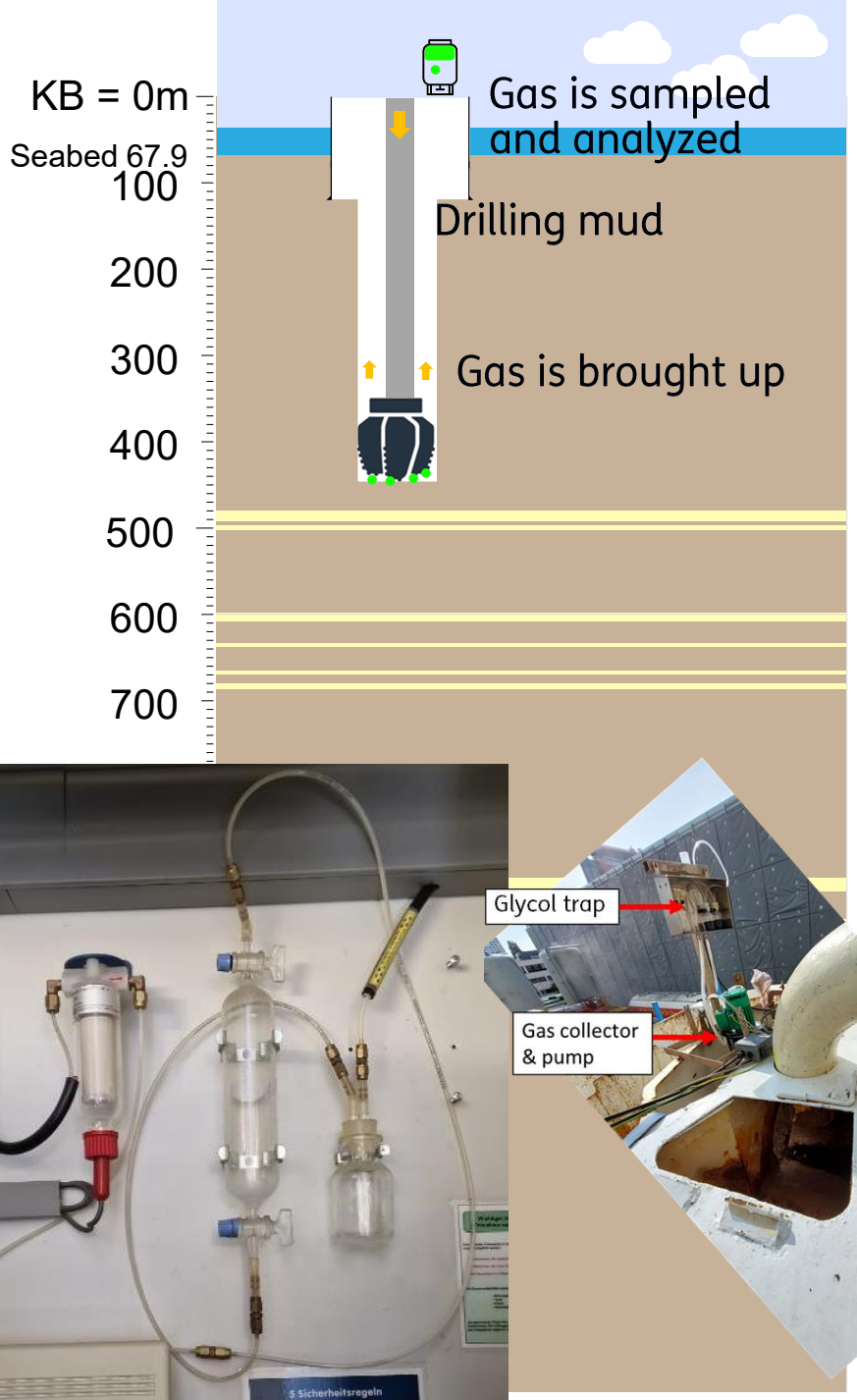
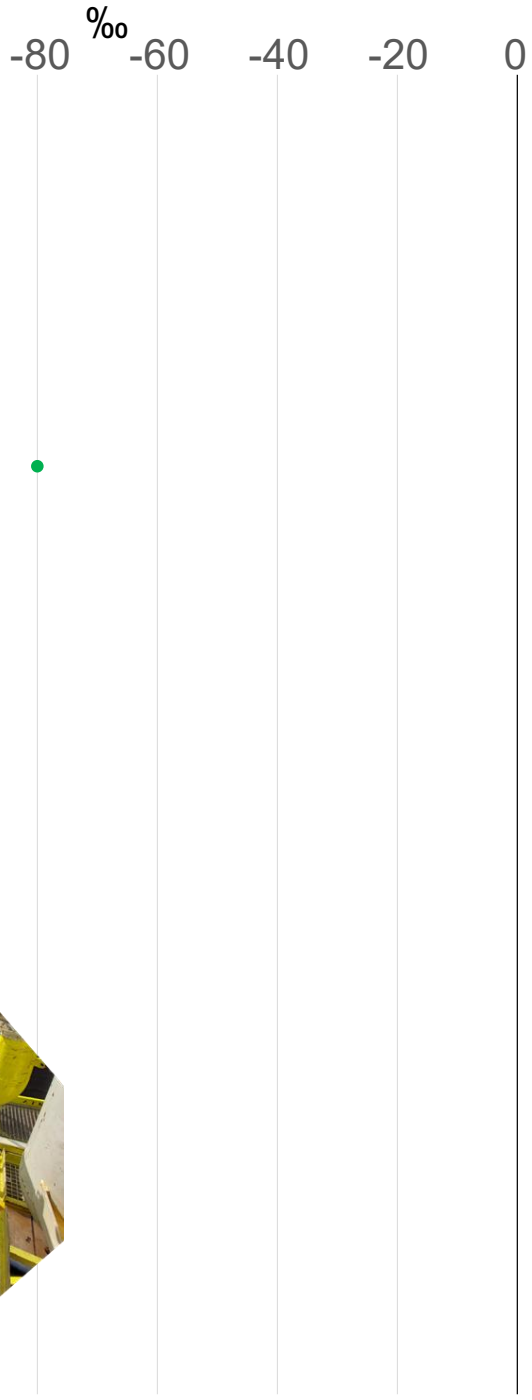
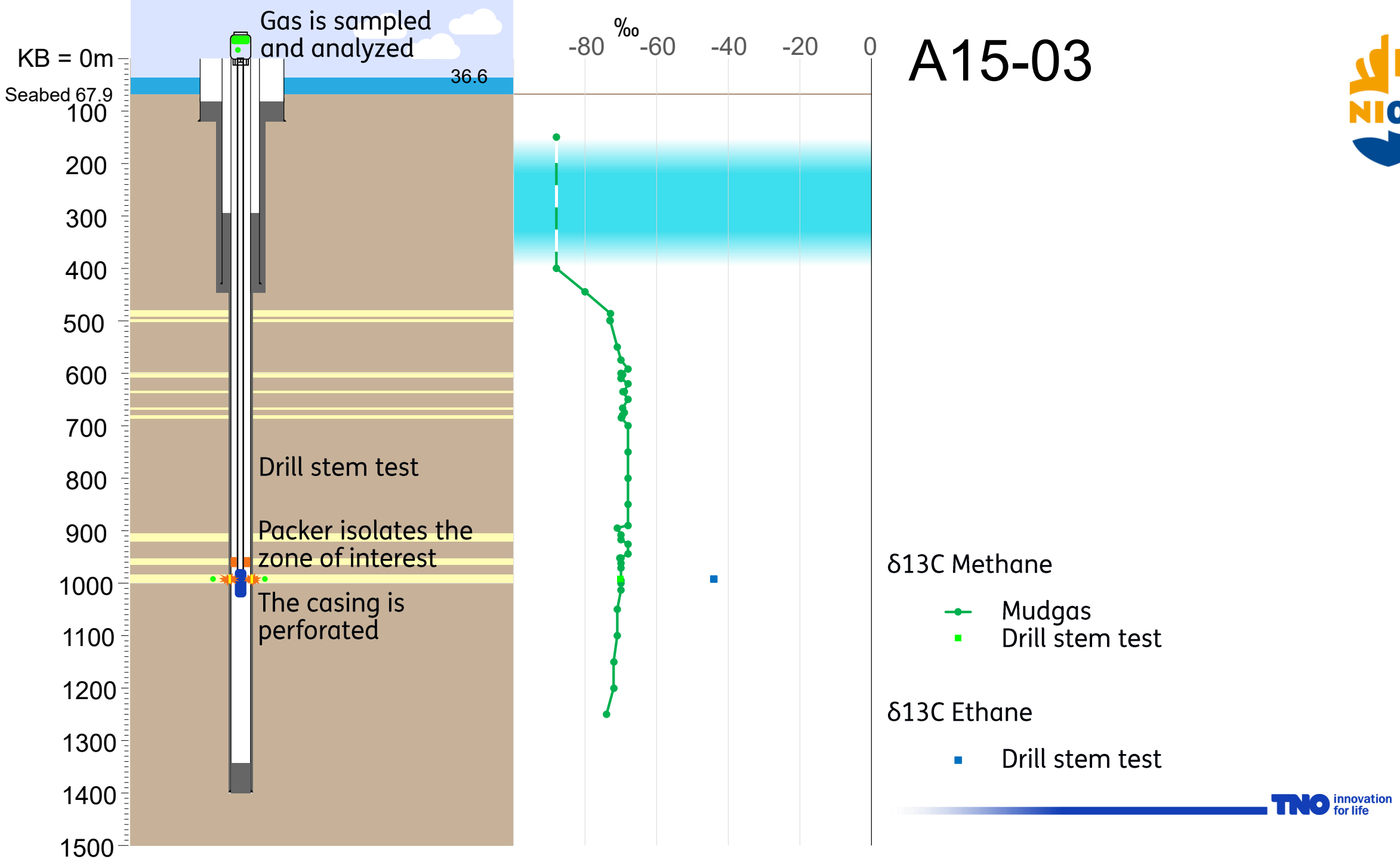
A15-03

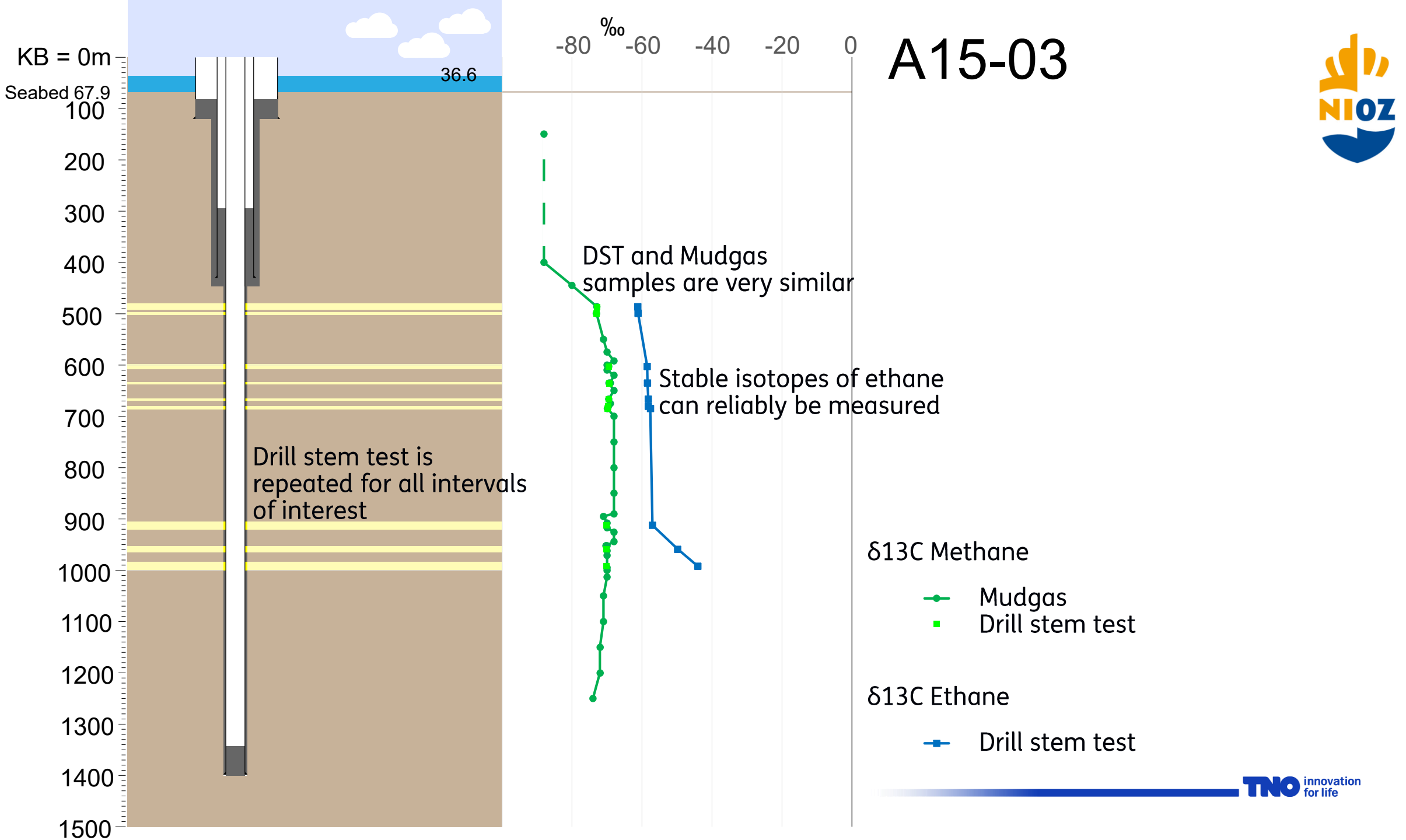


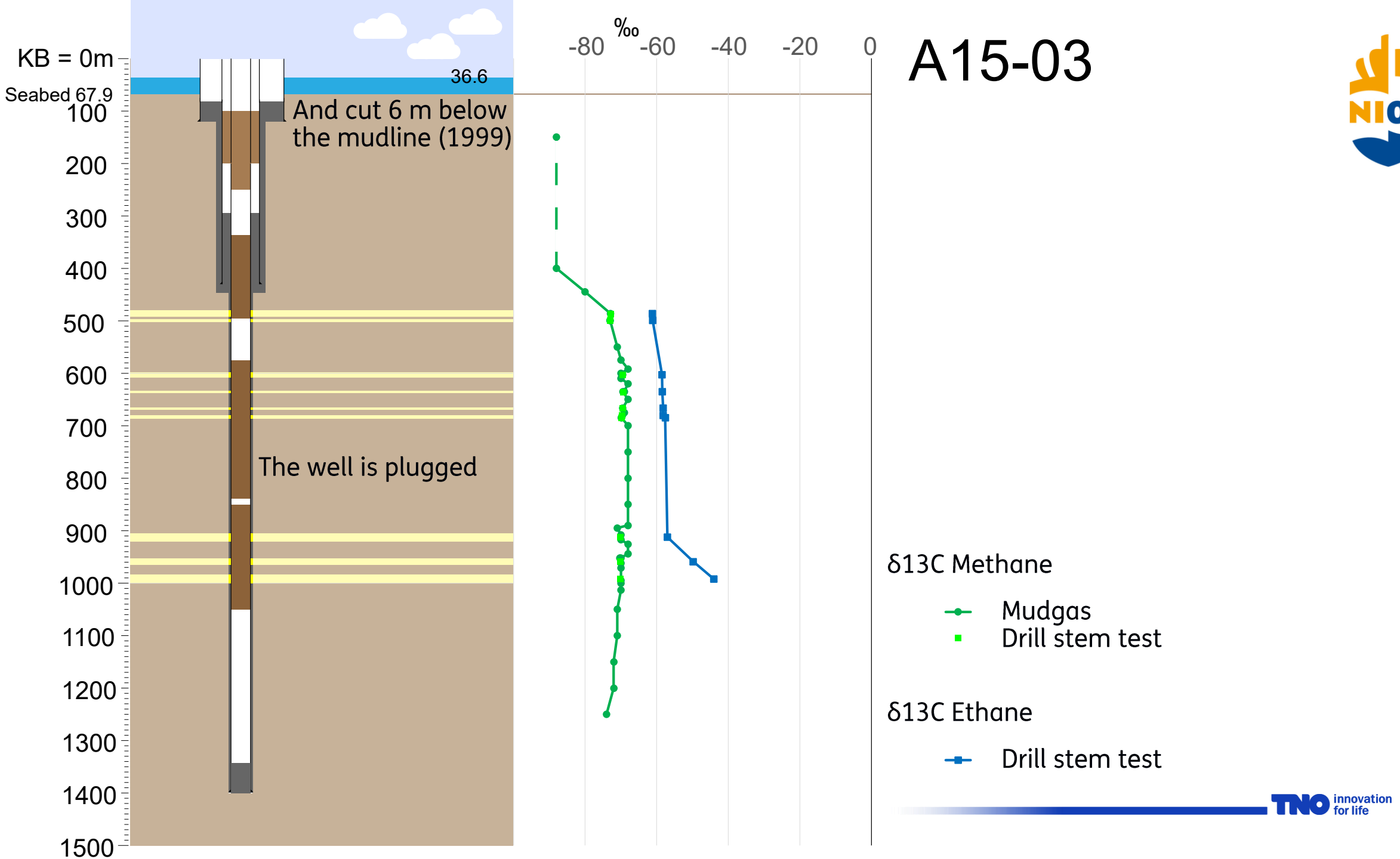


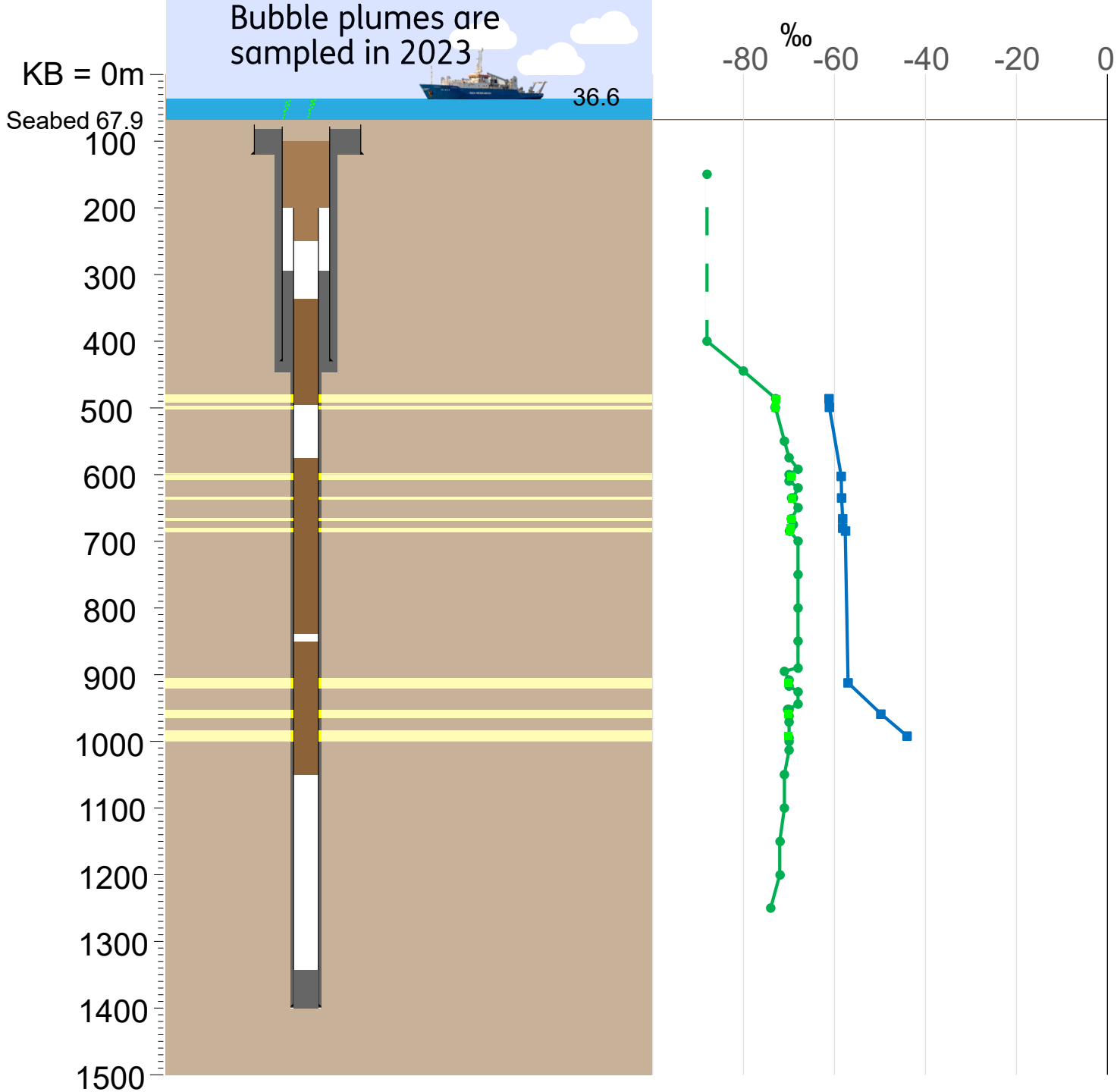
δ13C Methane

- Mudgas


Gas is sampled and analyzed
KB = 0m
Seabed 67.9
36.6
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Drill stem test
Packer isolates the zone of interest
The casing is perforated
‰
-80
-60
-40
-20
0
A15-03
δ13C Methane
Mudgas
Drill stem test
δ13C Ethane
Drill stem test
NIOZ
TNO innovation for life


A15-03
KB = 0m
Seabed 67.9
36.6
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
‰
-80
-60
-40
-20
0
Drill stem test is repeated for all intervals of interest
DST and Mudgas samples are very similar
Stable isotopes of ethane can reliably be measured
δ13C Methane
Mudgas
Drill stem test
δ13C Ethane
Drill stem test
NIOZ
TNO innovation for life


KB = 0m
Seabed 67.9
36.6
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
And cut 6 m below the mudline (1999)
The well is plugged
‰
-80
-60
-40
-20
0
A15-03
δ13C Methane
Mudgas
Drill stem test
δ13C Ethane
Drill stem test
NIOZ
TNO innovation for life



A15-03

δ13C Methane

Mudgas

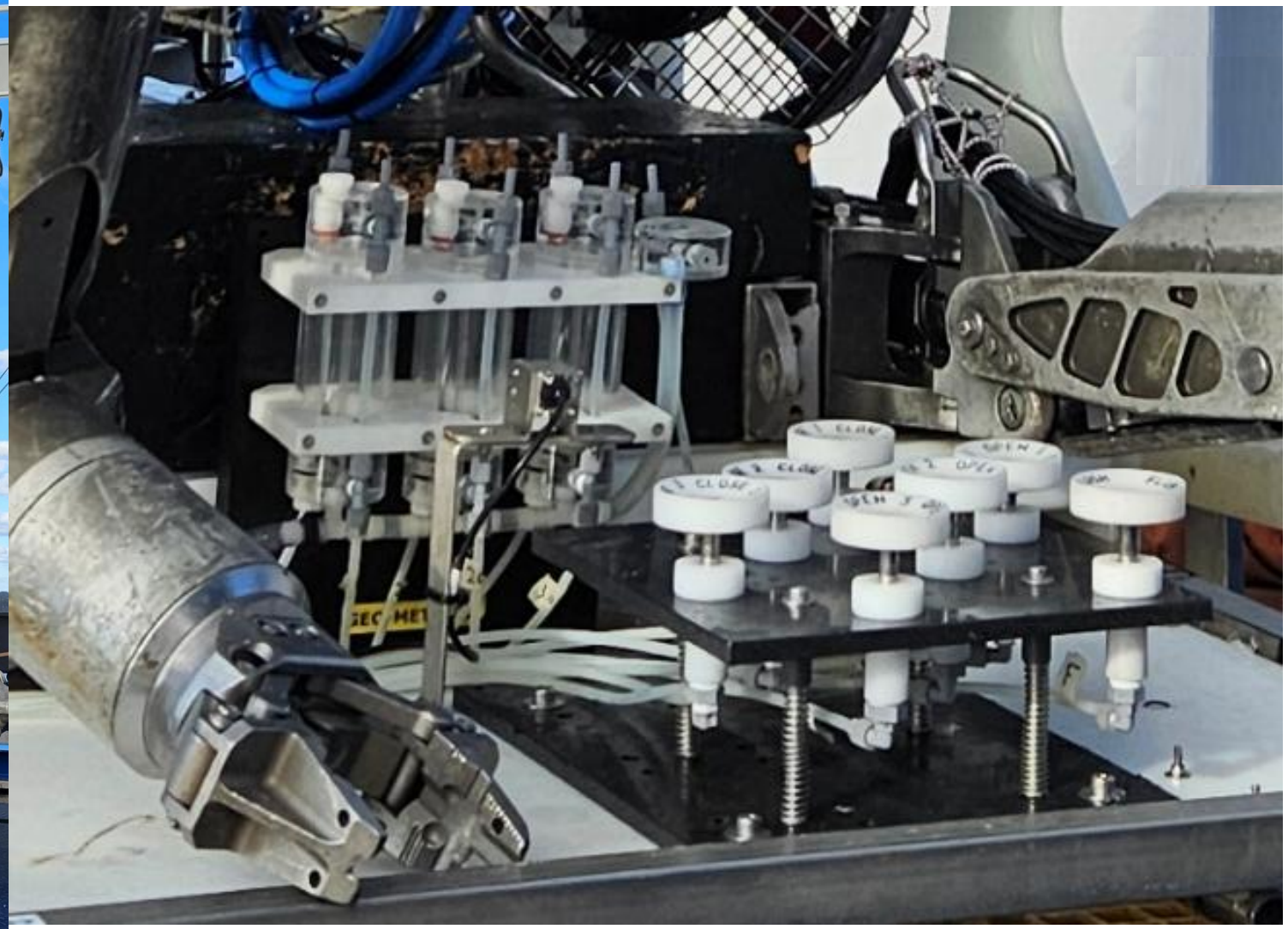
Drill stem test

δ13C Ethane

Drill stem test

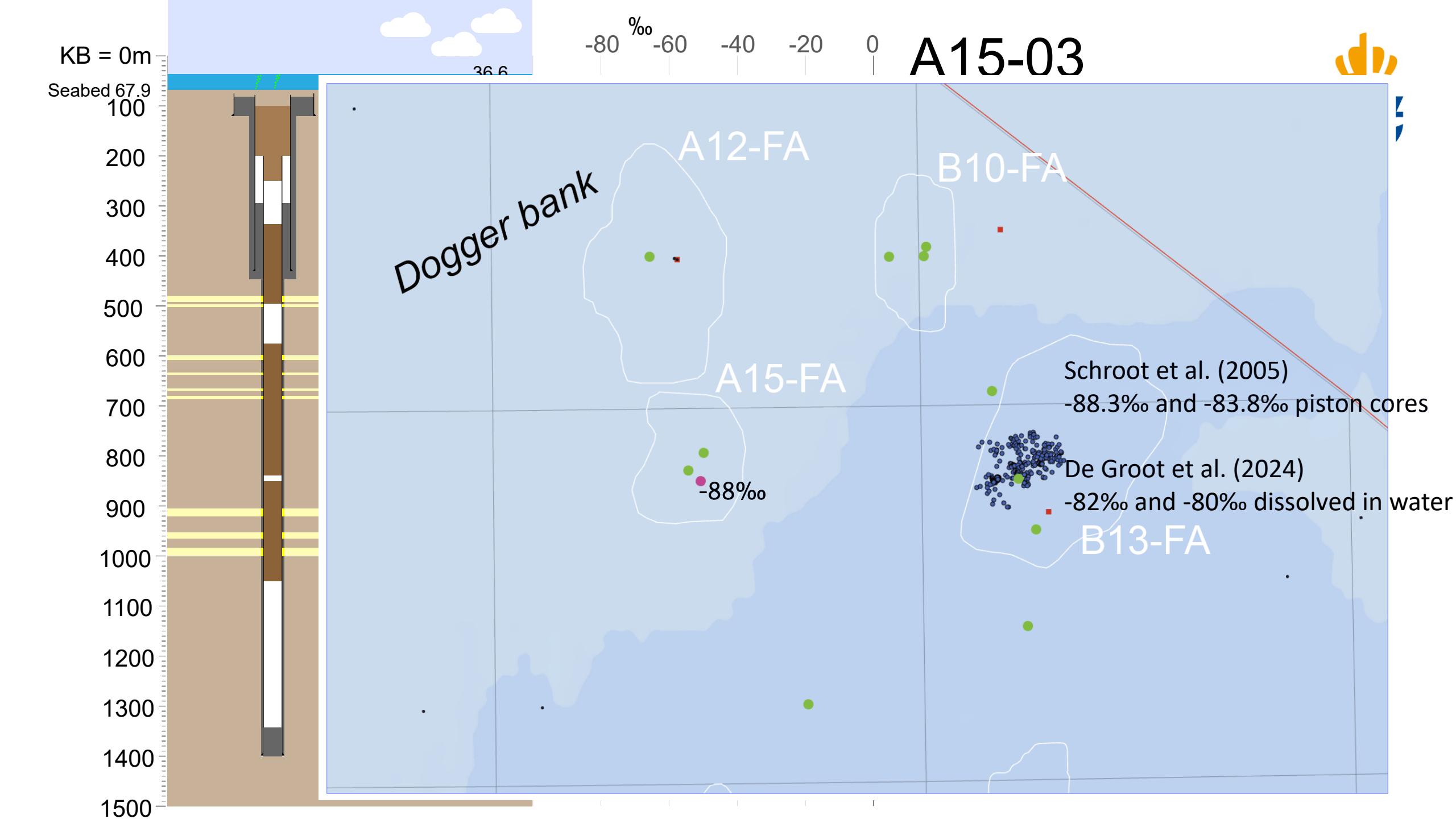
innovation for life

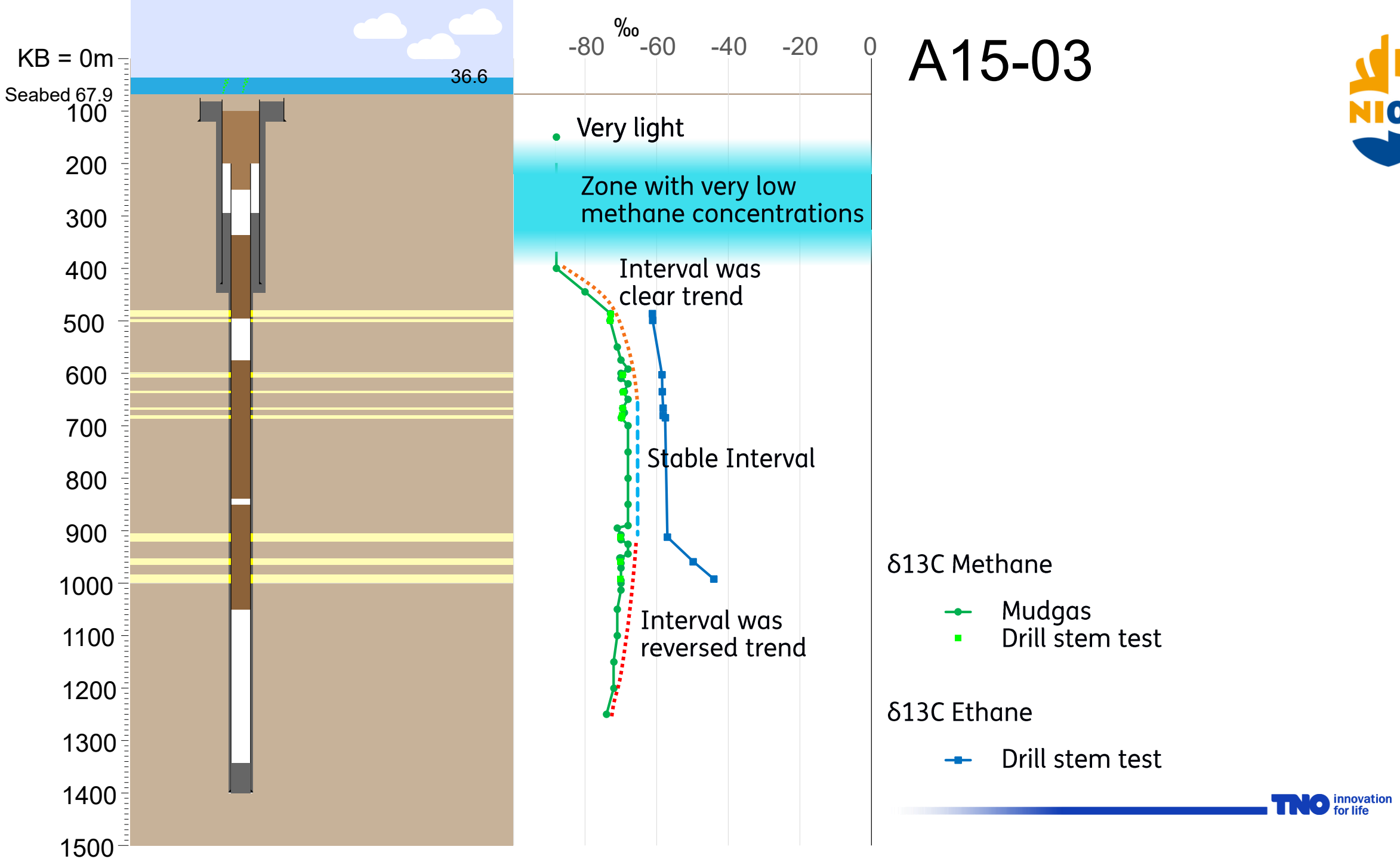

980
bluestream



NIOZ

TNO innovation for life


KB = 0m
Seabed 67.9
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
36.6
‰
-80
-60
-40
-20
0
A15-03
Dogger bank
A12-FA
B10-FA
A15-FA
B13-FA
-88‰
Schroot et al. (2005)
-88.3‰ and -83.8‰ piston cores
De Groot et al. (2024)
-82‰ and -80‰ dissolved in water

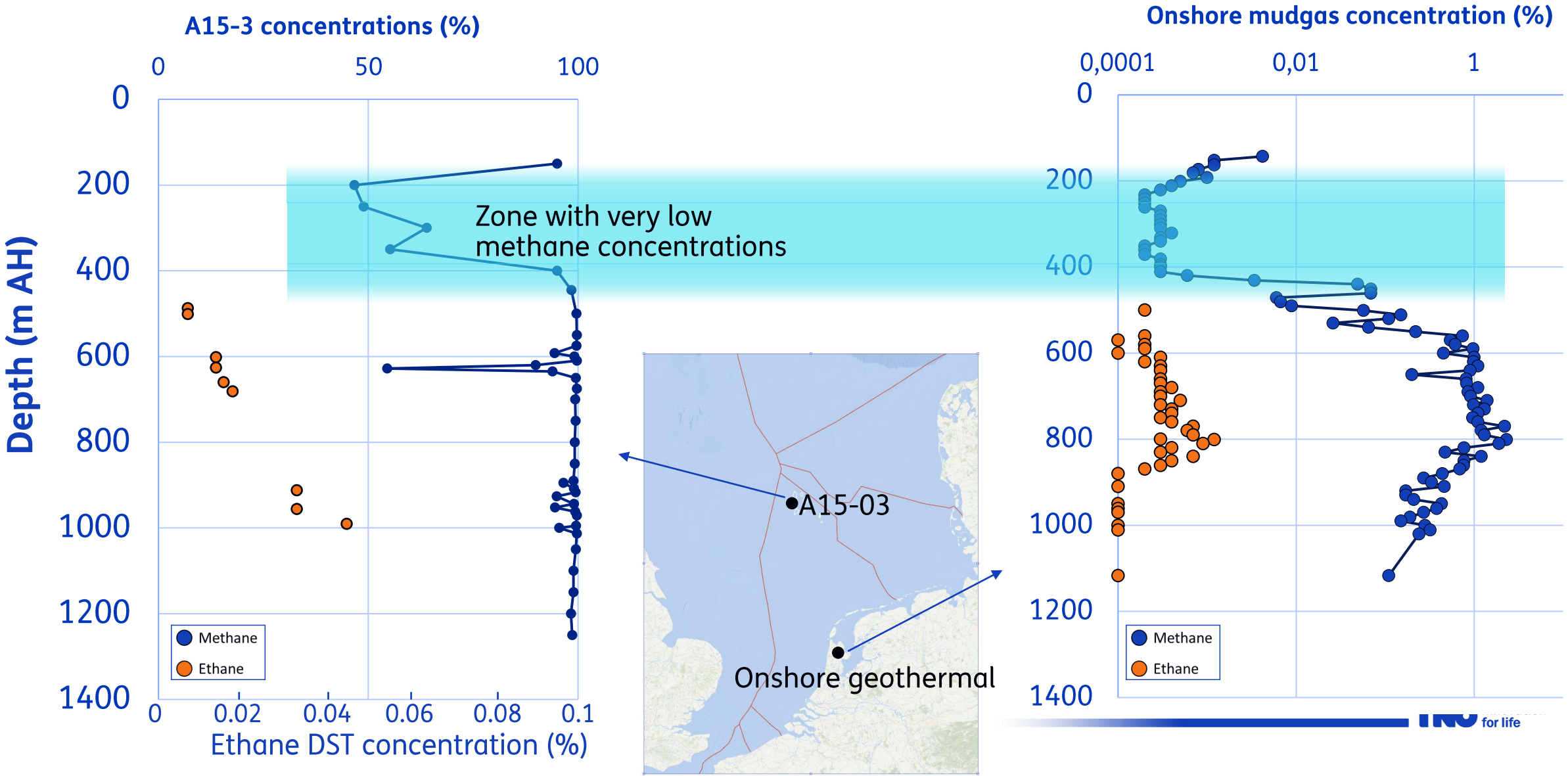


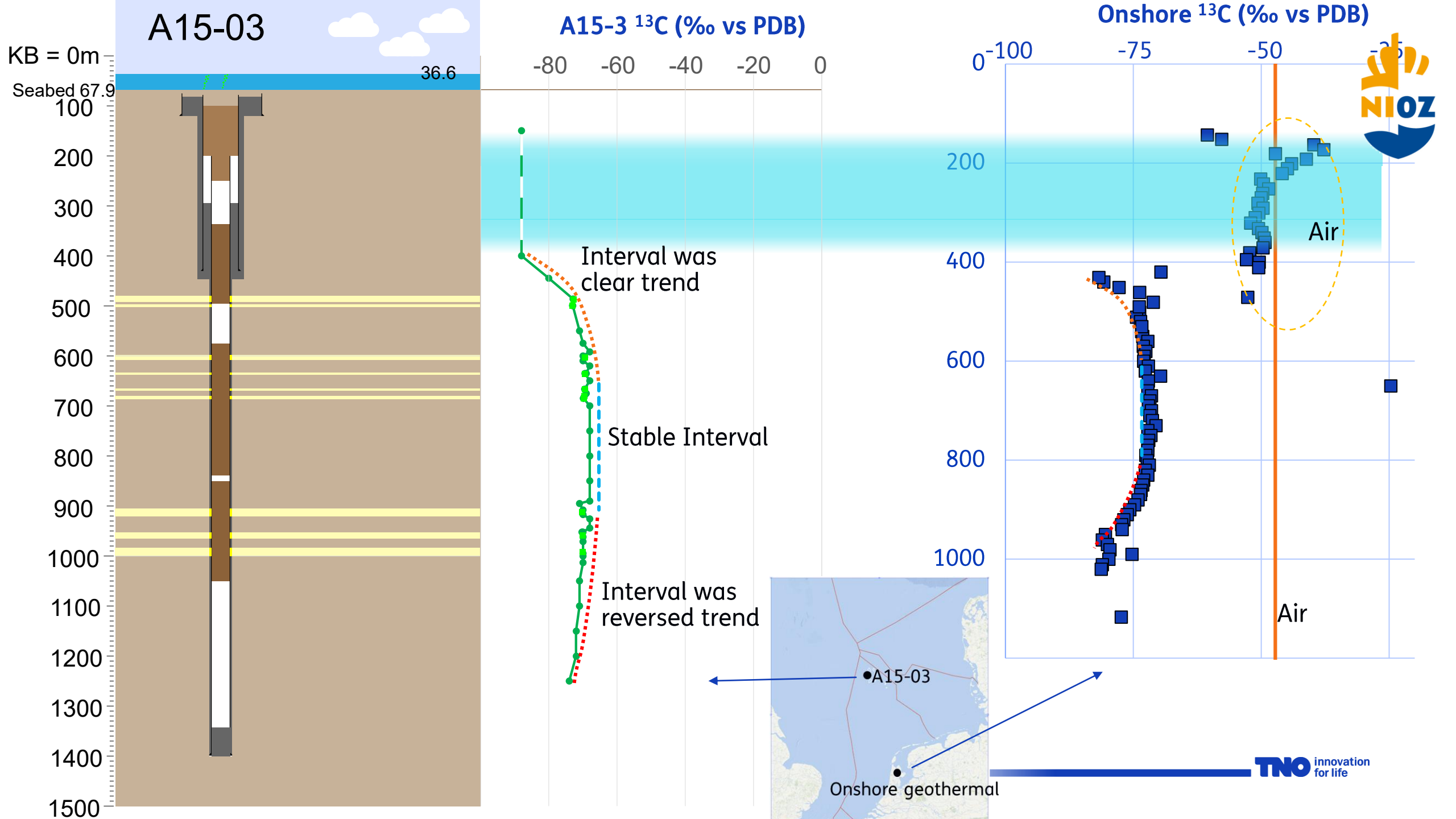
A15-03

NIOZ

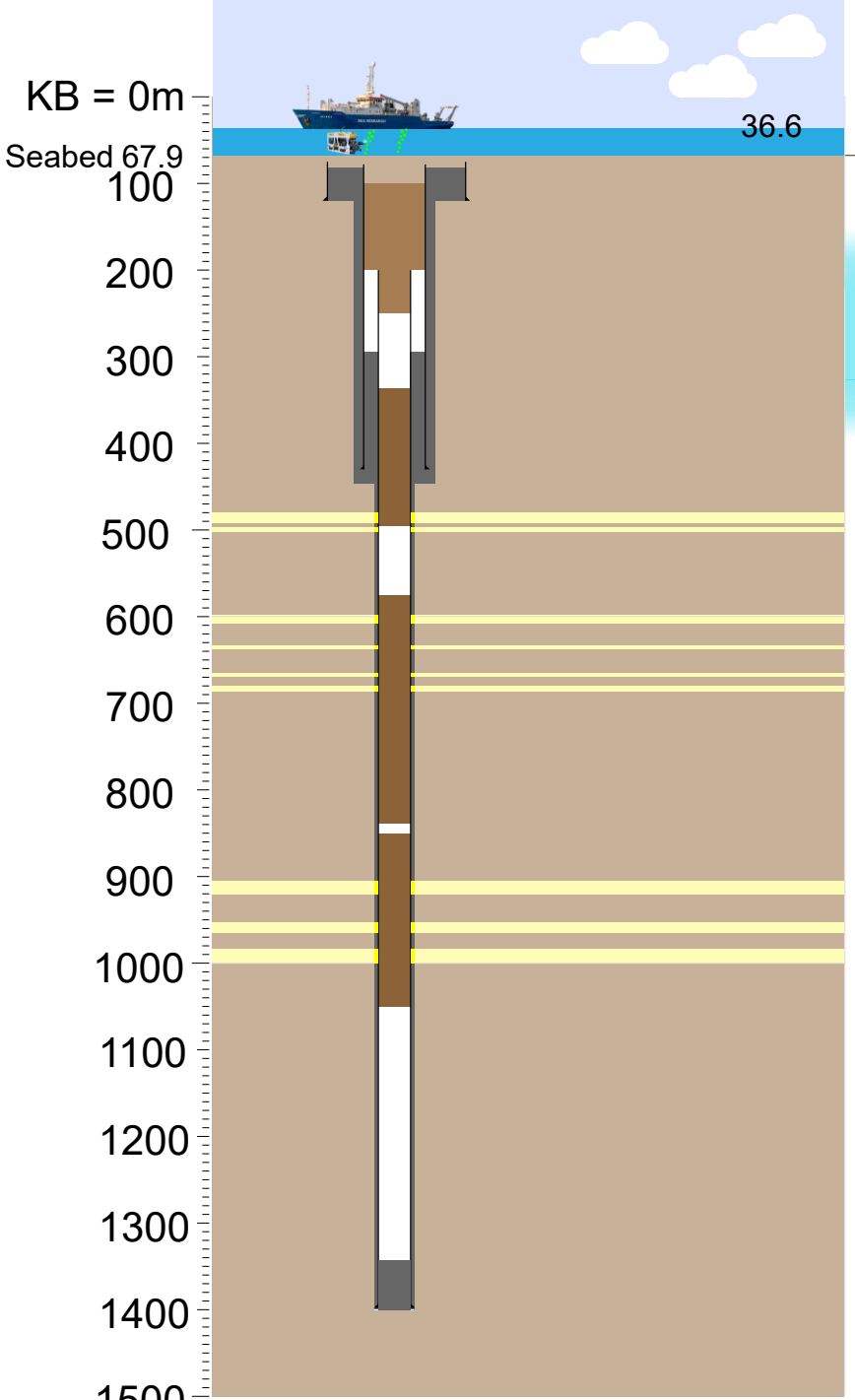
TNO innovation for life

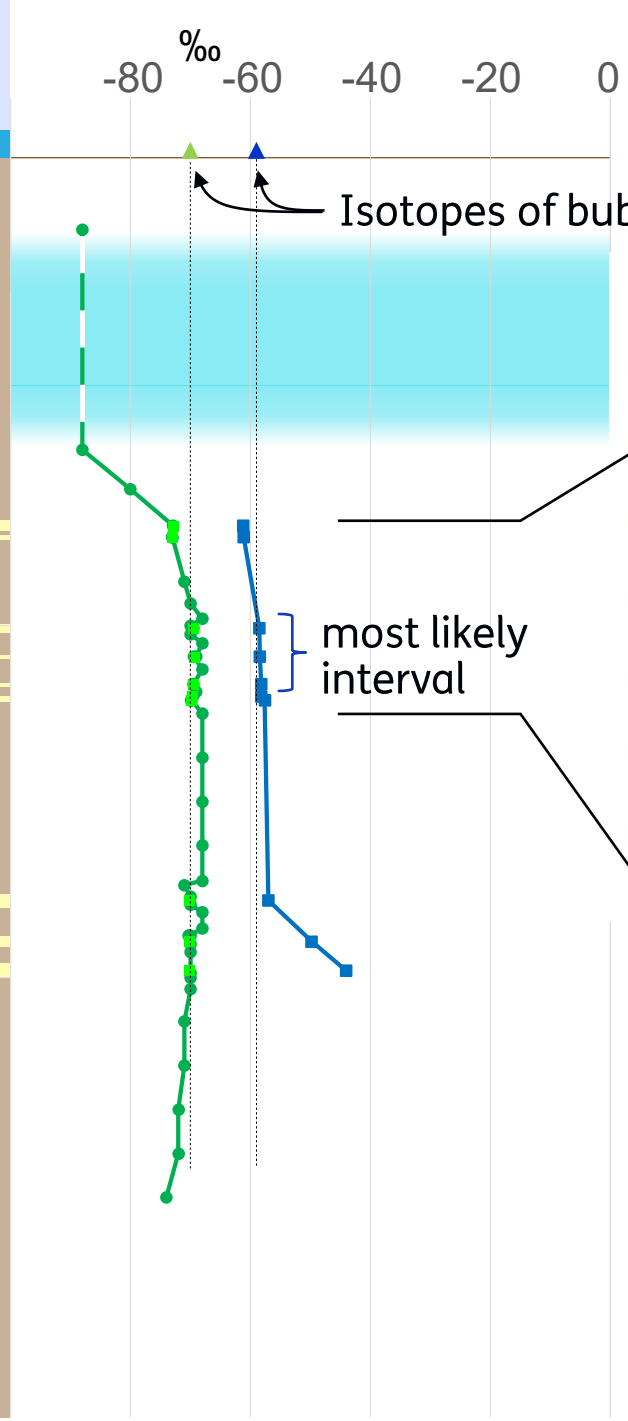
Methane concentrations offshore vs onshore

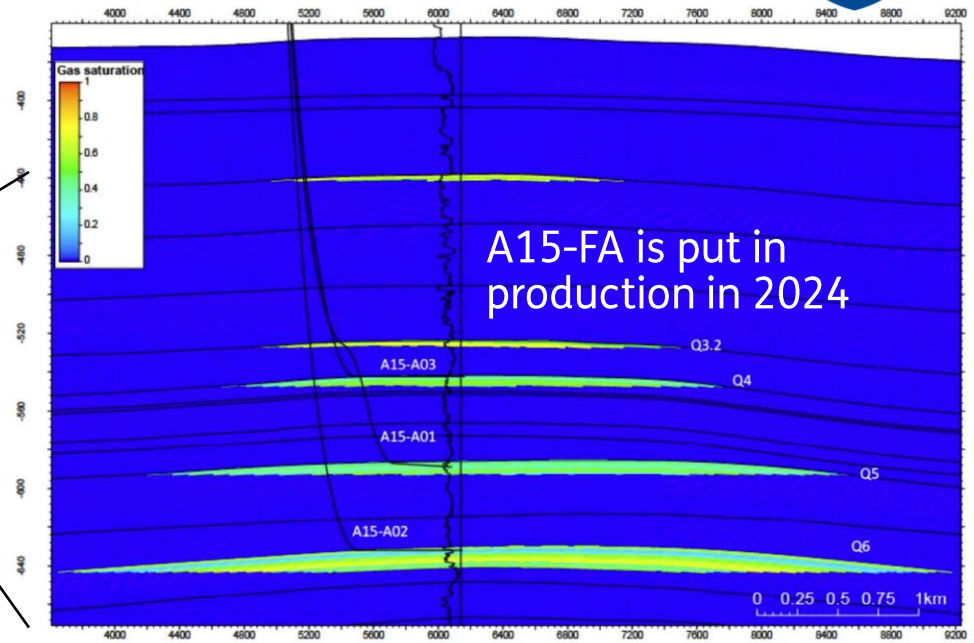



A15-03
KB = 0m
Seabed 67.9
36.6
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
A15-3 13C (‰ vs PDB)
-80
-60
-40
-20
0
Interval was clear trend
Stable Interval
Interval was reversed trend
Onshore 13C (‰ vs PDB)
0
-100
-75
-50
200
400
600
800
1000
Air
Air
A15-03
Onshore geothermal
NIOZ
TNO innovation for life

A15-03







δ13C Methane

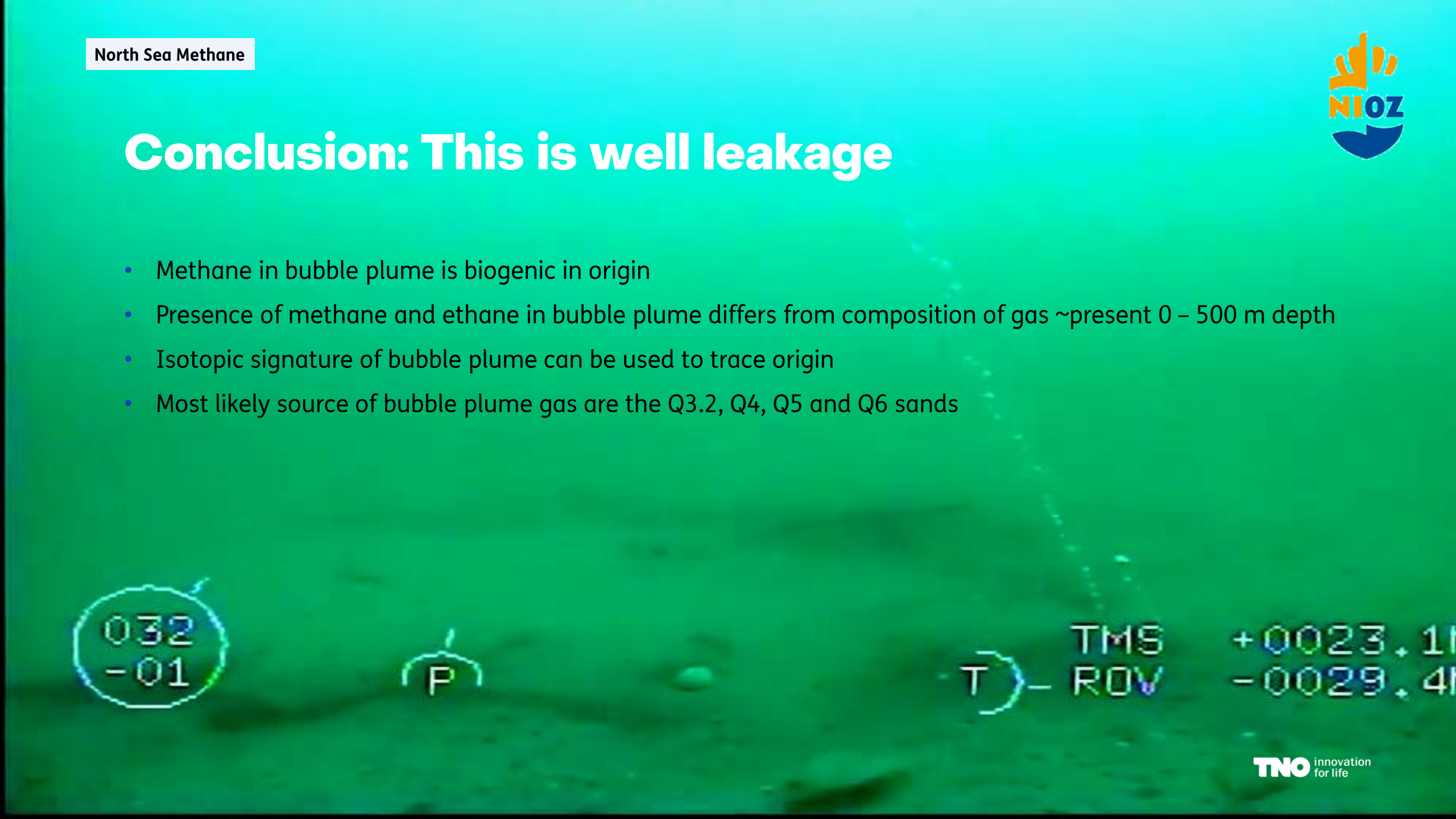
- Mudgas
- Drill stem test
- Bubbel plume

δ13C Ethane

- Drill stem test
- Bubbel plume

Conclusion: This is well leakage

- Methane in bubble plume is biogenic in origin
- Presence of methane and ethane in bubble plume differs from composition of gas ~present 0 – 500 m depth
- Isotopic signature of bubble plume can be used to trace origin
- Most likely source of bubble plume gas are the Q3.2, Q4, Q5 and Q6 sands



Theme name

Place text here

Thank you

Acknowledgements

SodM: Ron Leichsenring, Barend Engelenburg

EN natuurlijk

NIOZ Rv Pelagia crew

TNO onshore mudgas sampling

TNO innovation for life