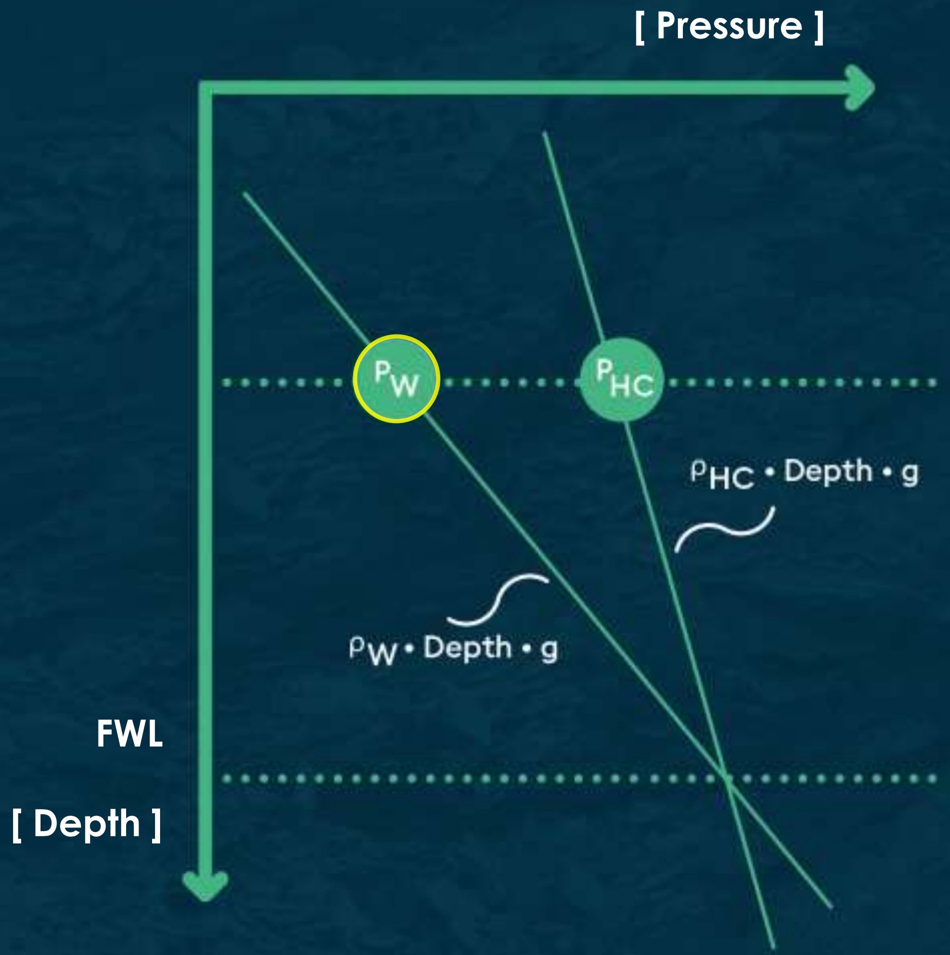
Prototype HLT Pilot Testing Offshore Norway 2024

Trond Rolfsvåg

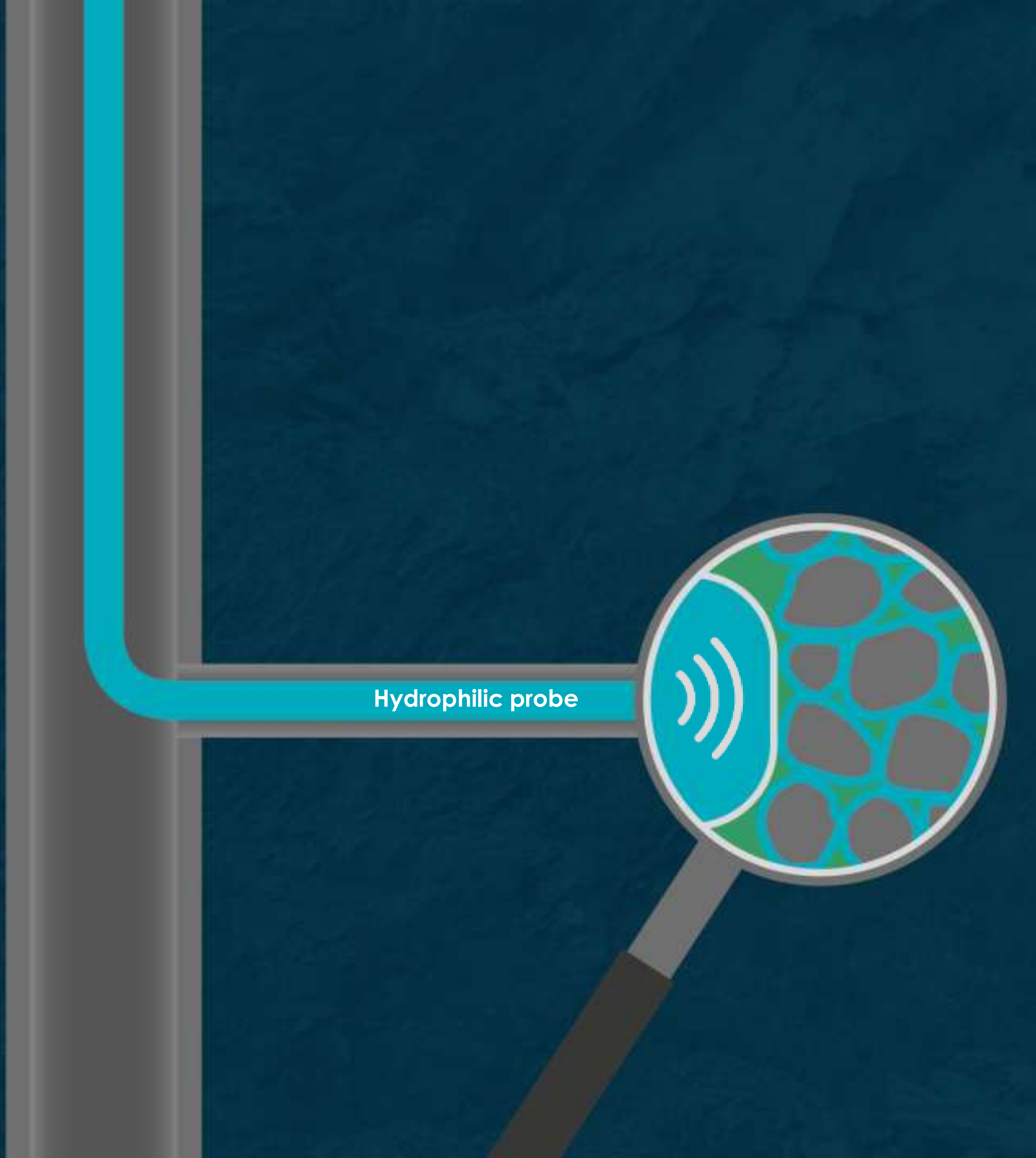
LPS one-day seminar on **New Technology**
November 6th, 2025. The Geological Society, Burlington House, London

Todays menu

- What the HLT can measure
- Conditions
- How to measure
- Offshore Pilots 2024
  Identified weaknesses & Mitigations
  Interpretation of results
- HLT Measurement in reservoirs with perched water



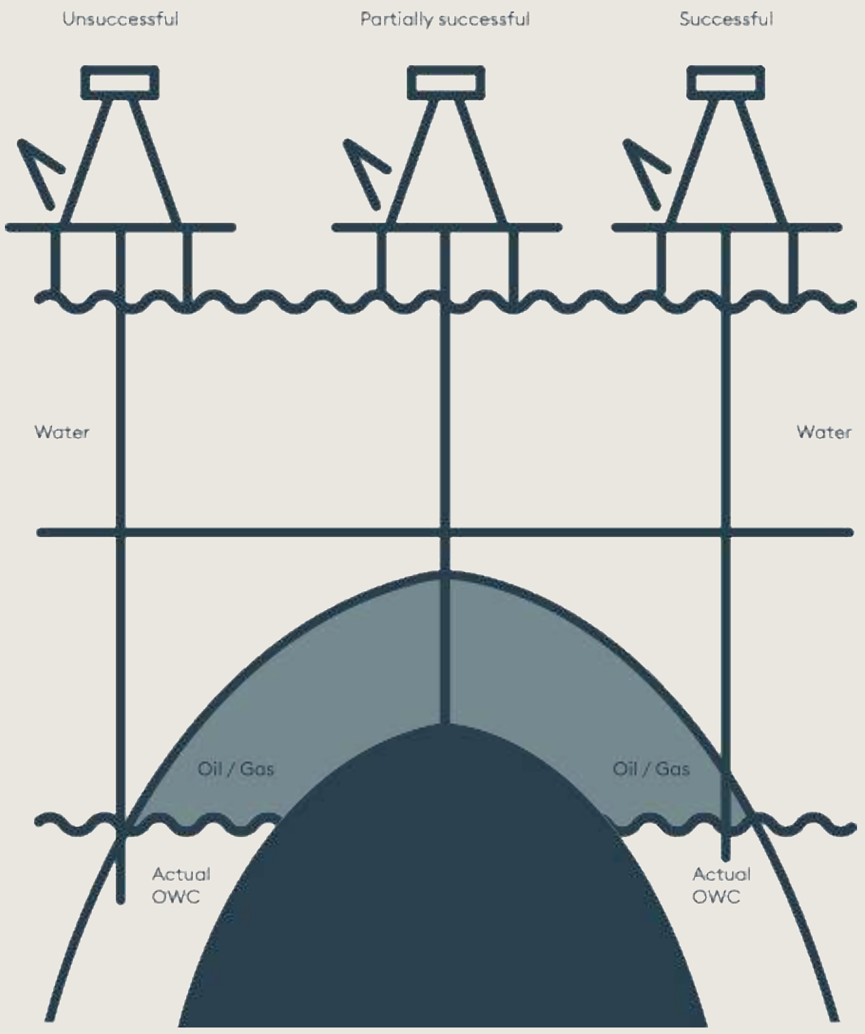
The HLT can measure Pw. This is new art.



What [more] can the HLT measure?

- Water pressure (Pw) and Kw(Swi) in hydrocarbon reservoirs
- Pressure difference between water and hydrocarbon (Pd)
- Estimate the OWC without drilling through it
- Pw and Kw in shale

From find to field in minutes **not years.**



Conditions that must be met:

1. Continuity
- both water and hydrocarbon phases must be continuous.
This condition is normally fulfilled in commercially interesting cases

2. Mobility
- mobility of the so-called "immobile" water saturation can be very low but not zero (normally fulfilled)

3. Vertical equilibrium
- reaching equilibrium can be a very slow process but we assume this condition to be fulfilled in a new discovery

HLT JIP#3 Participants ❤

equinor

vår energi

Harbour Energy

DNO

Hydrophilic

The Hydrophilic Logging Tool

(Prototype)

DETERMINE THE SIZE OF A NEW DISCOVERY

The Hydrophilic Logging Tool (HLT) has been developed to make the exploration and appraisal of hydrocarbon discoveries more efficient. This new wire-line tool will measure the distance to the free-water-level (FWL) and help determine the size of the accumulation.

The HLT will be positioned at the desired depth in the well, locked in place with two packers. The annulus pressure between the two packers is lowered by pumping out some of the drill fluid. The annulus section is then allowed to repressurize to balance the reservoir pressure.

A 24 mm diameter hole through the wall of the well will be drilled while the hole is flushed with oil carried inside the HLT from surface. When the hole has reached the desired depth (max 700 mm for this prototype) a slim (6 mm OD) probe is pushed through a hole in the drill-bit, lands on the fresh surface, connects with the water on the surface of the rock and the pressure of the water inside the reservoir is captured.

The mini-drill string and the probe is retracted. Packers unset.

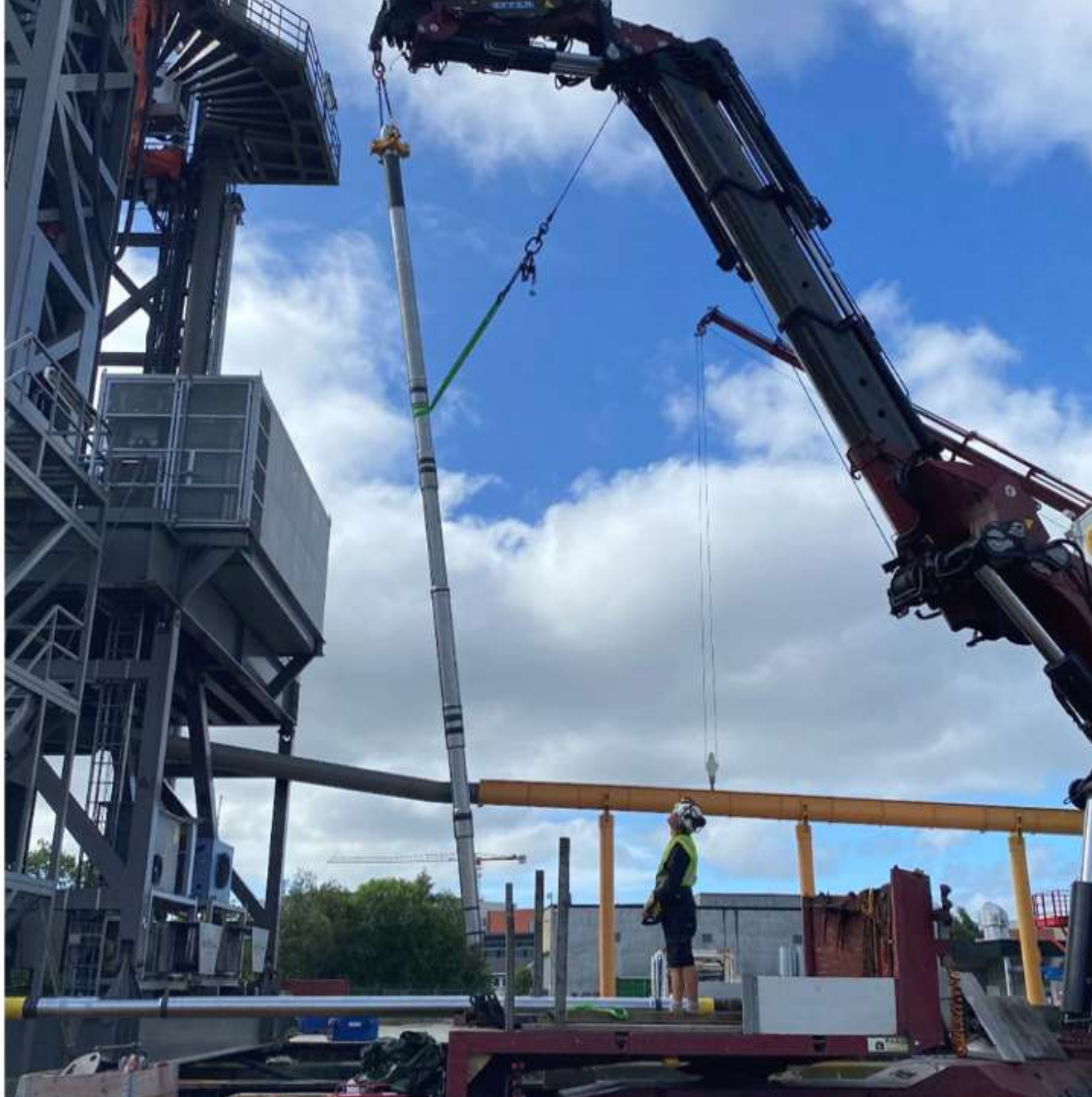
The HLT has been designed to perform this single depth measurement in less than four hours. Repeated measurement is possible.

The speed of measurement is ensured by the following three factors; a fast pressure sensor, accurate placement of the HLT in the well and simulator support for noise reduction and pressure extrapolation. The resulting pressure difference between water and oil will be estimated with better than 0.1 bar accuracy. This typically give an accuracy in the FWL estimate of better than 5 meters.

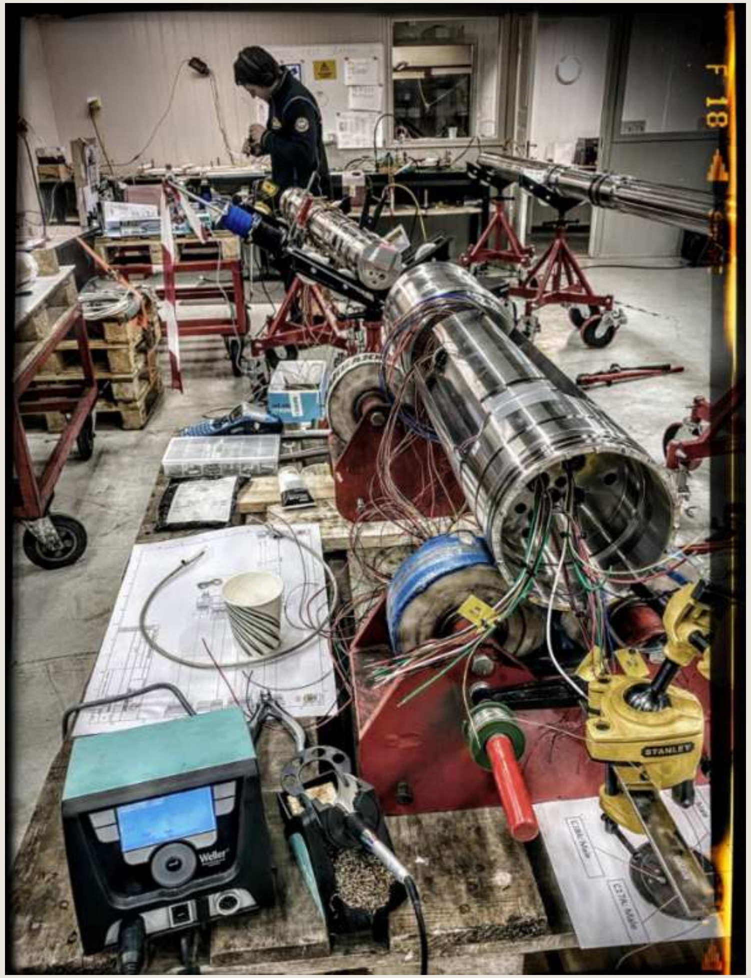
Can also be used in producing fields to measure the remaining oil production potential.

- Open hole wireline tool
- Length: 17 m
- Max OD: 178 mm (7")
- Temperature < 130°C
- Pressure < 350 bar
- Gamma ray (optional module)
- Time < 4 hours
- Mud: OBM
- Multiconductor cable
- Weight: 2082 kg

March 2023



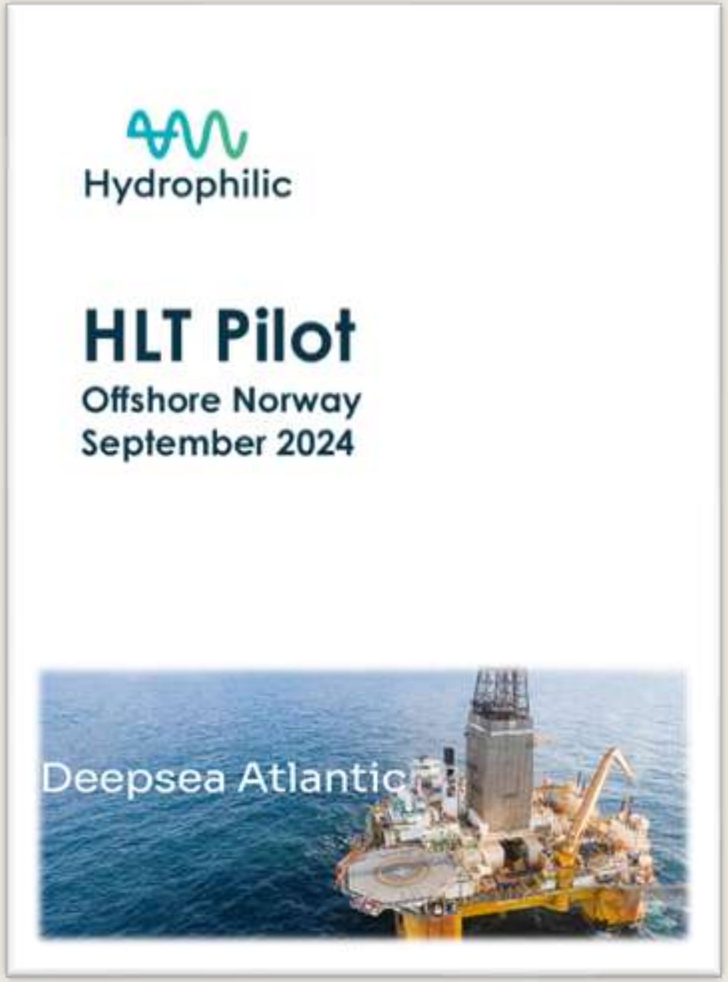
Workshop



Onshore testing

Offshore testing

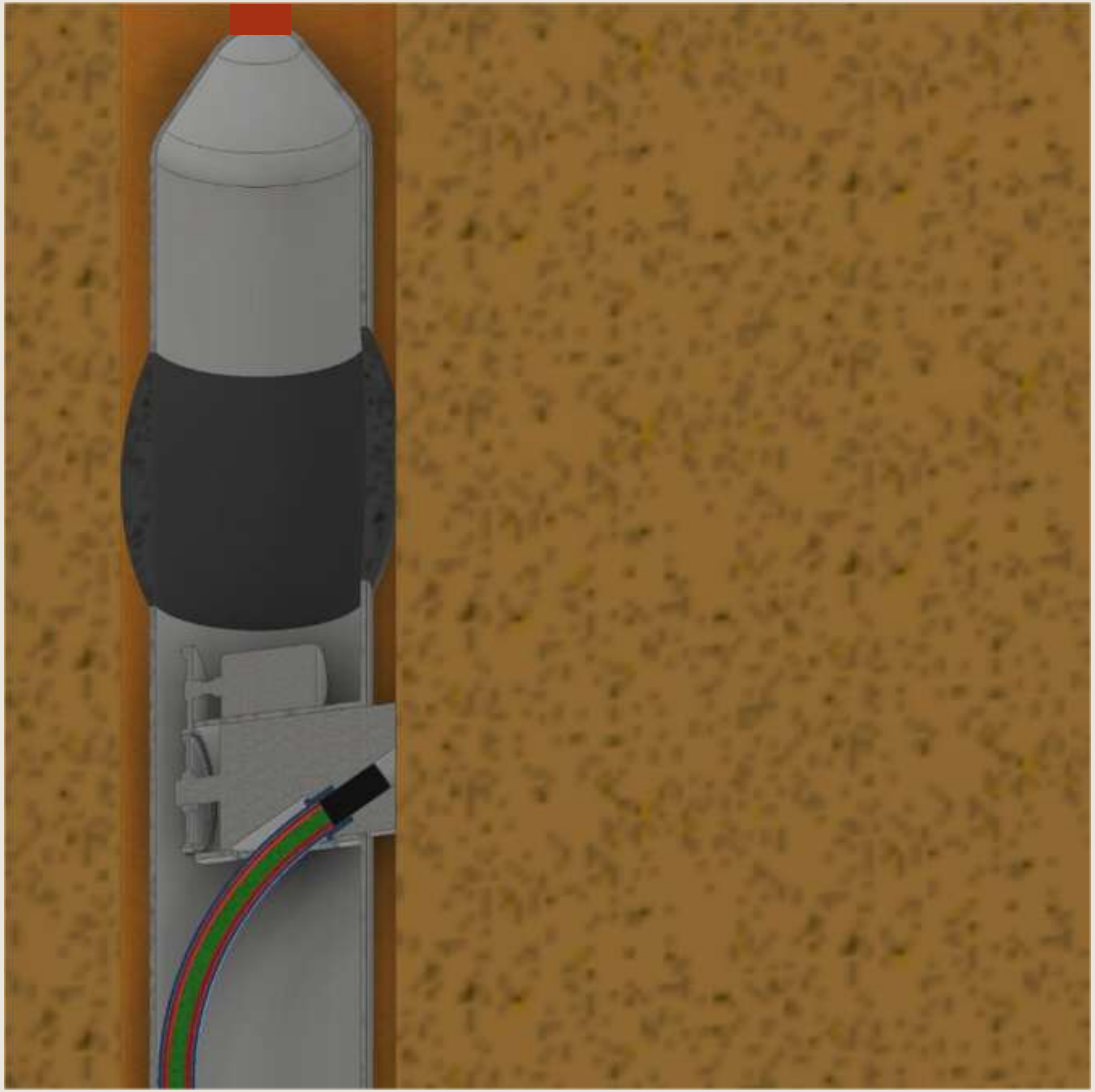
Tool failure



Success!

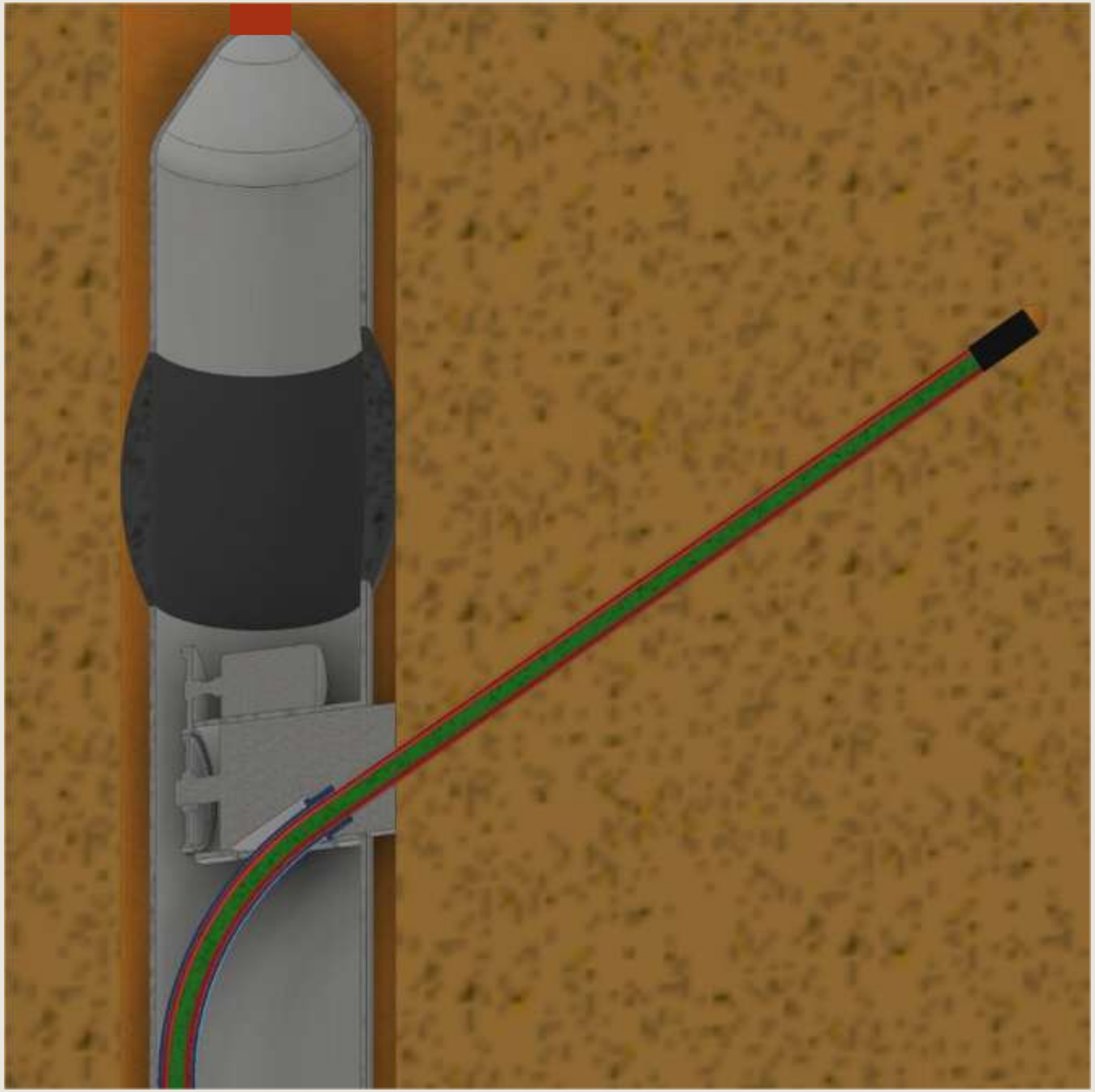
How to measure

The tool is positioned in the formation and locked in place with two straddle packers



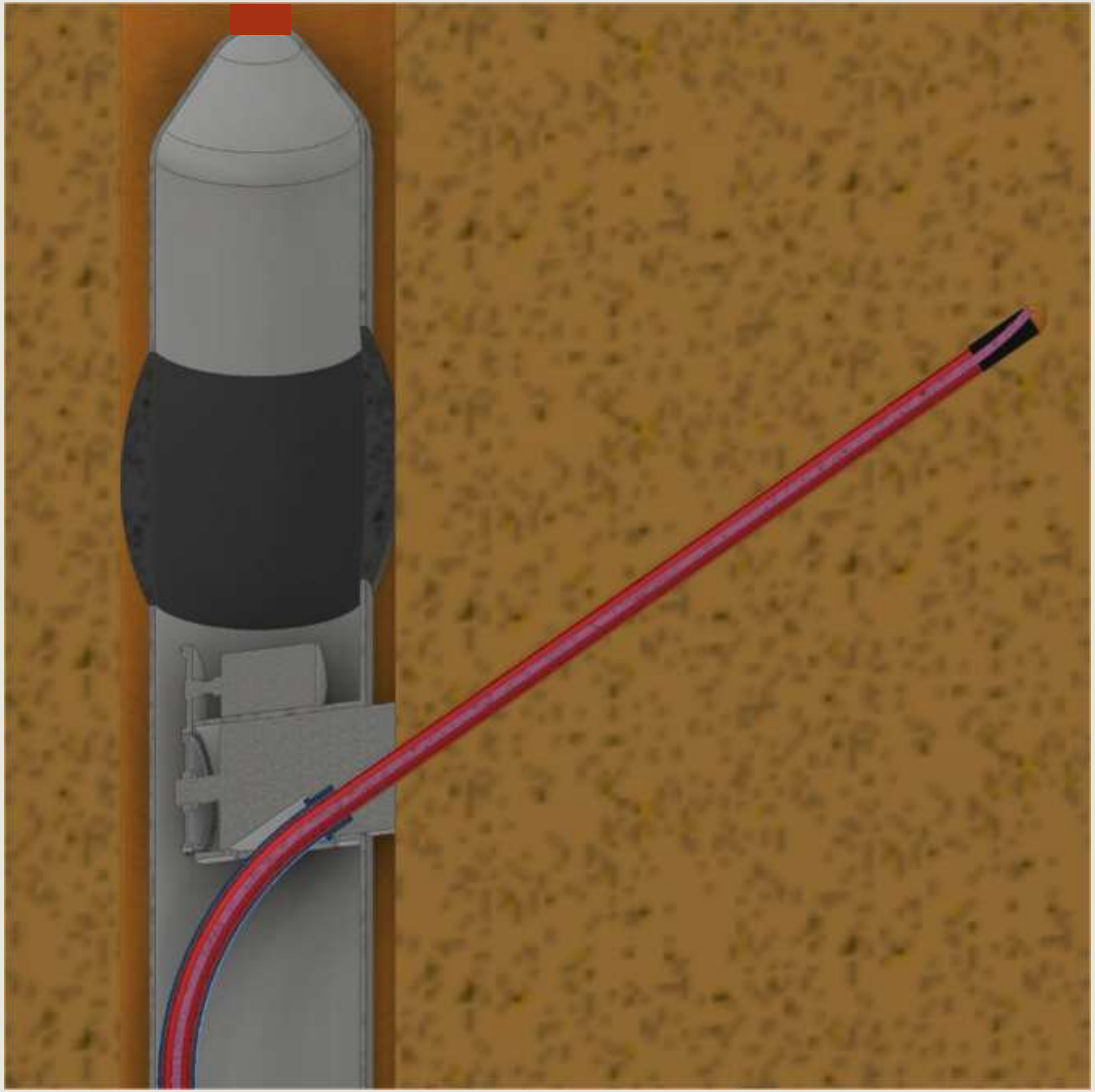
Sequence

1. Drill through wall of well at 45°



Sequence

1. Drill through wall of well at 45°
2. Drilling in the formation



Sequence

1. Drill through wall of well at 45°
2. Drilling in the formation
3. Push the probe & measure Pw

HLT Pilot February 2024

- Tool Failure
- No drilling & No measurement

HLT Pilot February 2024

- Tool Failure
- No drilling & No measurement

Mitigations

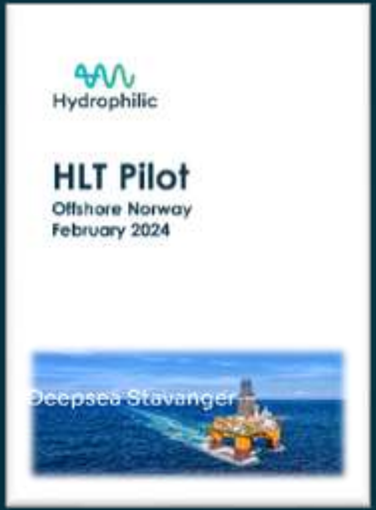
Better probe tip protection (several tool modifications)

Physical bypass of rudimentary internal pressure valve

Finalize tool in workshop prior to shipping offshore

Improved procedures

HLT Pilot February 2024



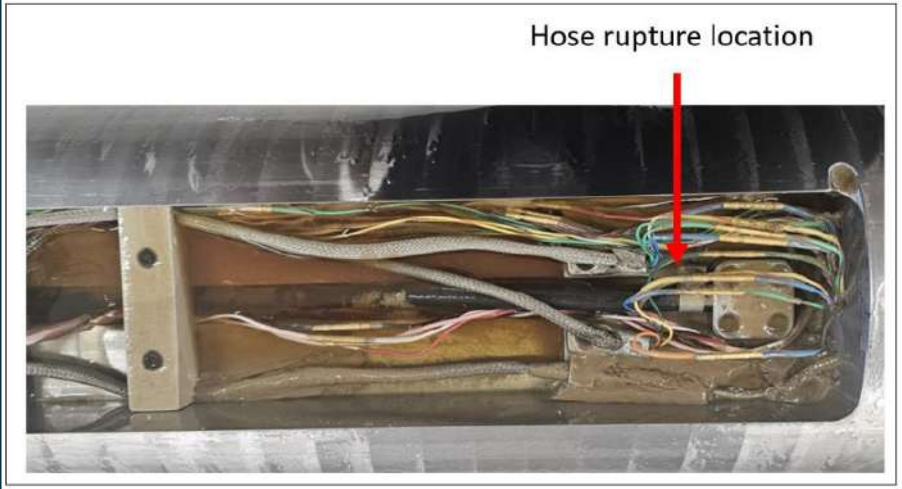


Figure 7 OBM has entered through the drill-string and flexible drill fluid hose

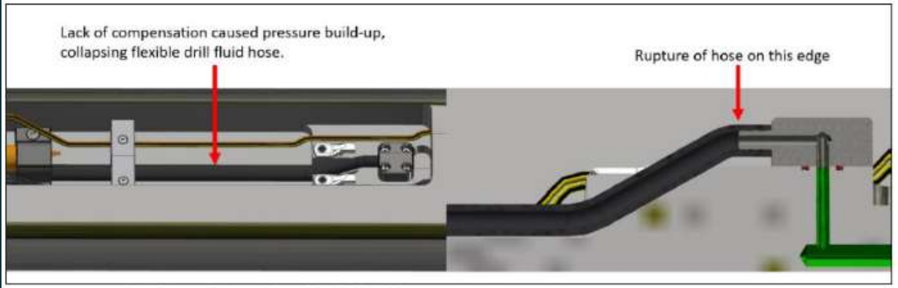
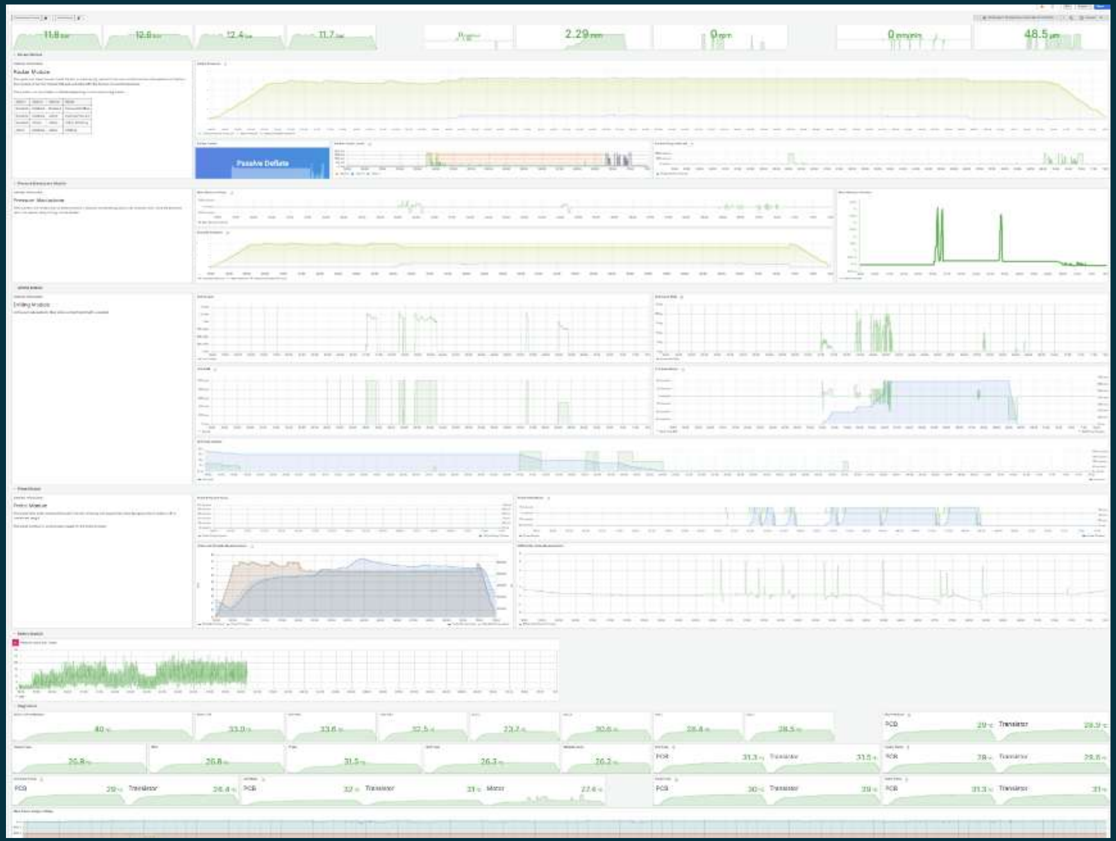
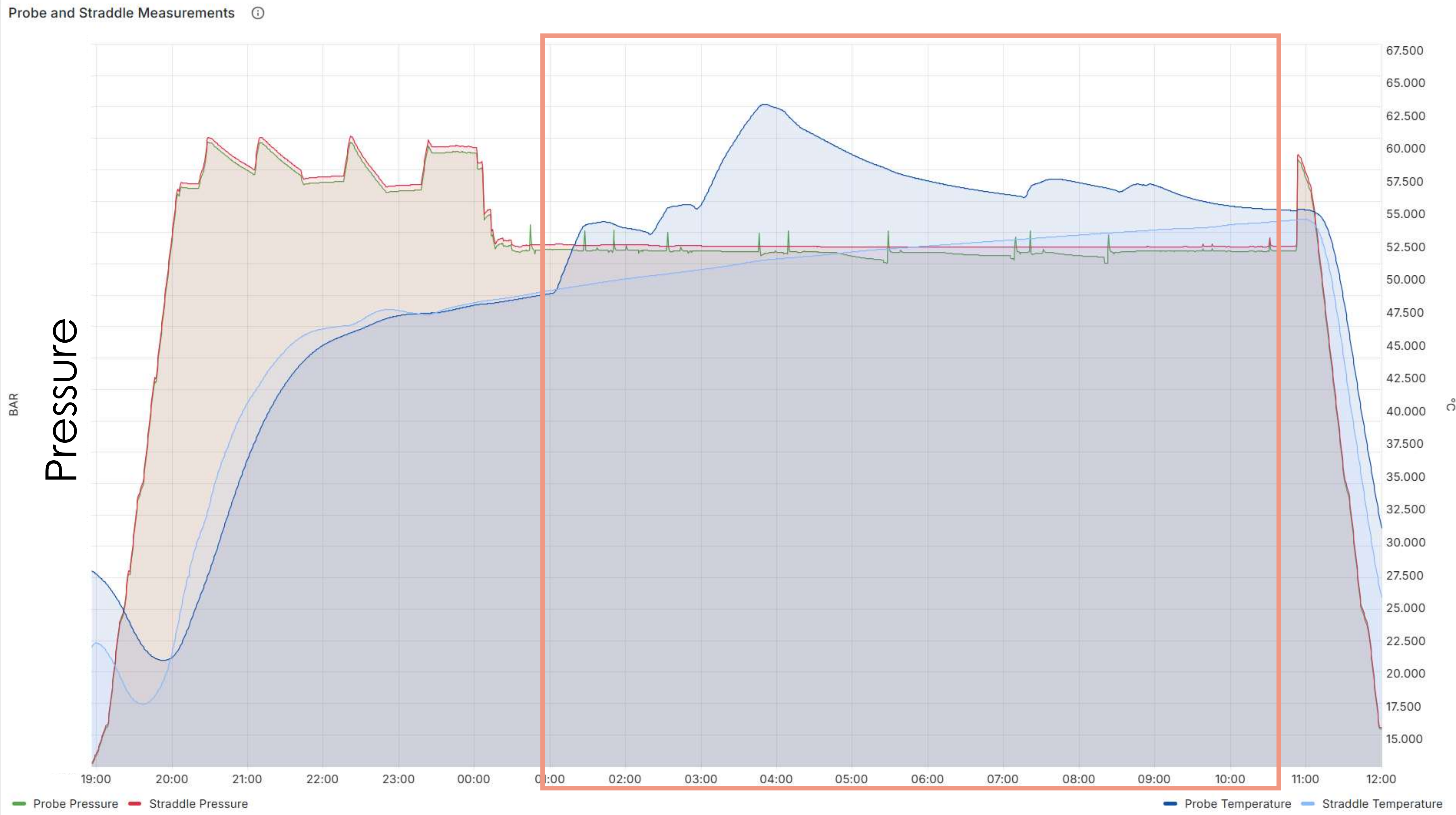


Figure 8 Pressure build-up collapsing flexible drill fluid hose

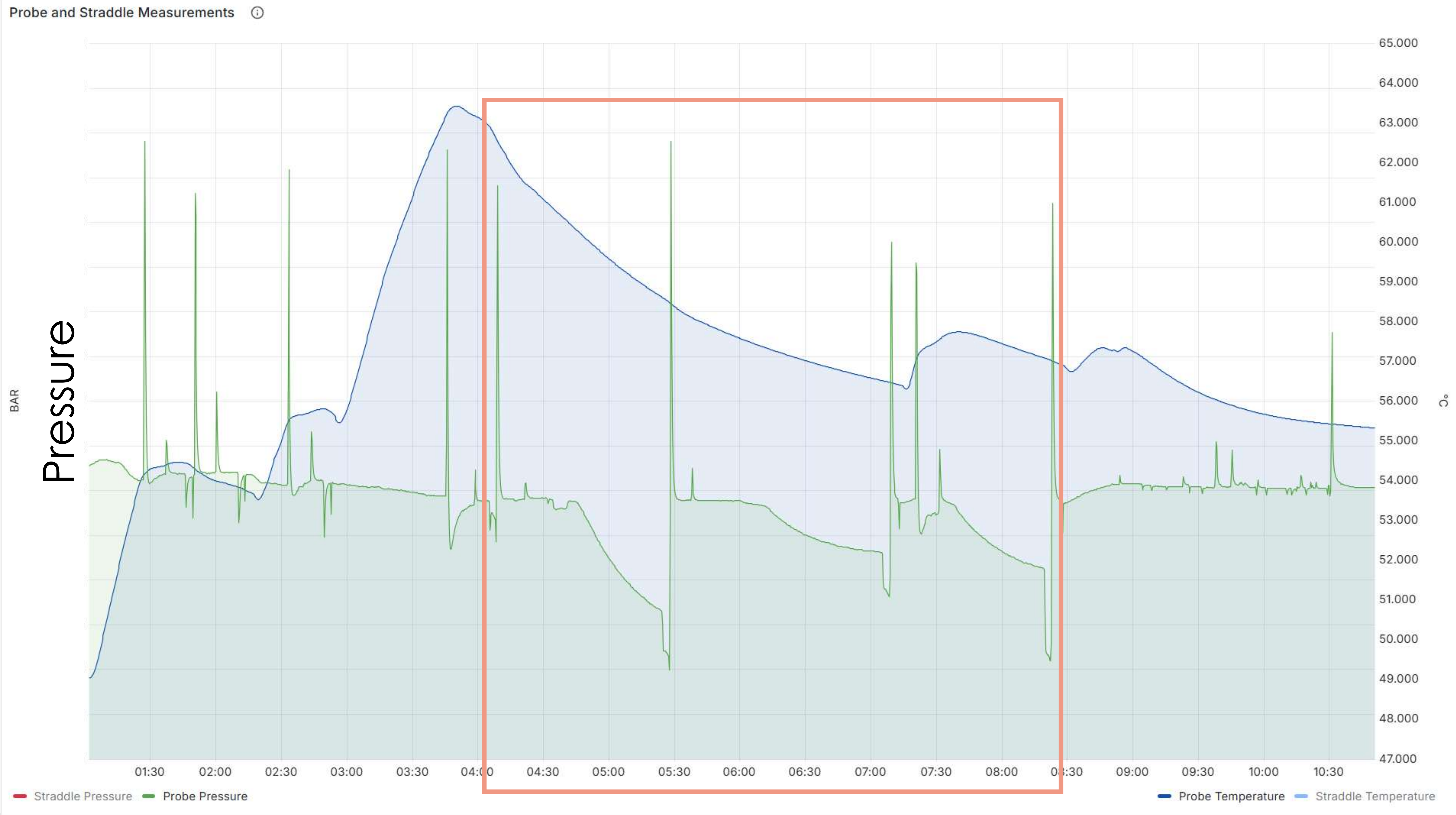
Figure 12 Seal imploded over the probe opening in the drill-bit

Successful HLT Pilot
September 2024



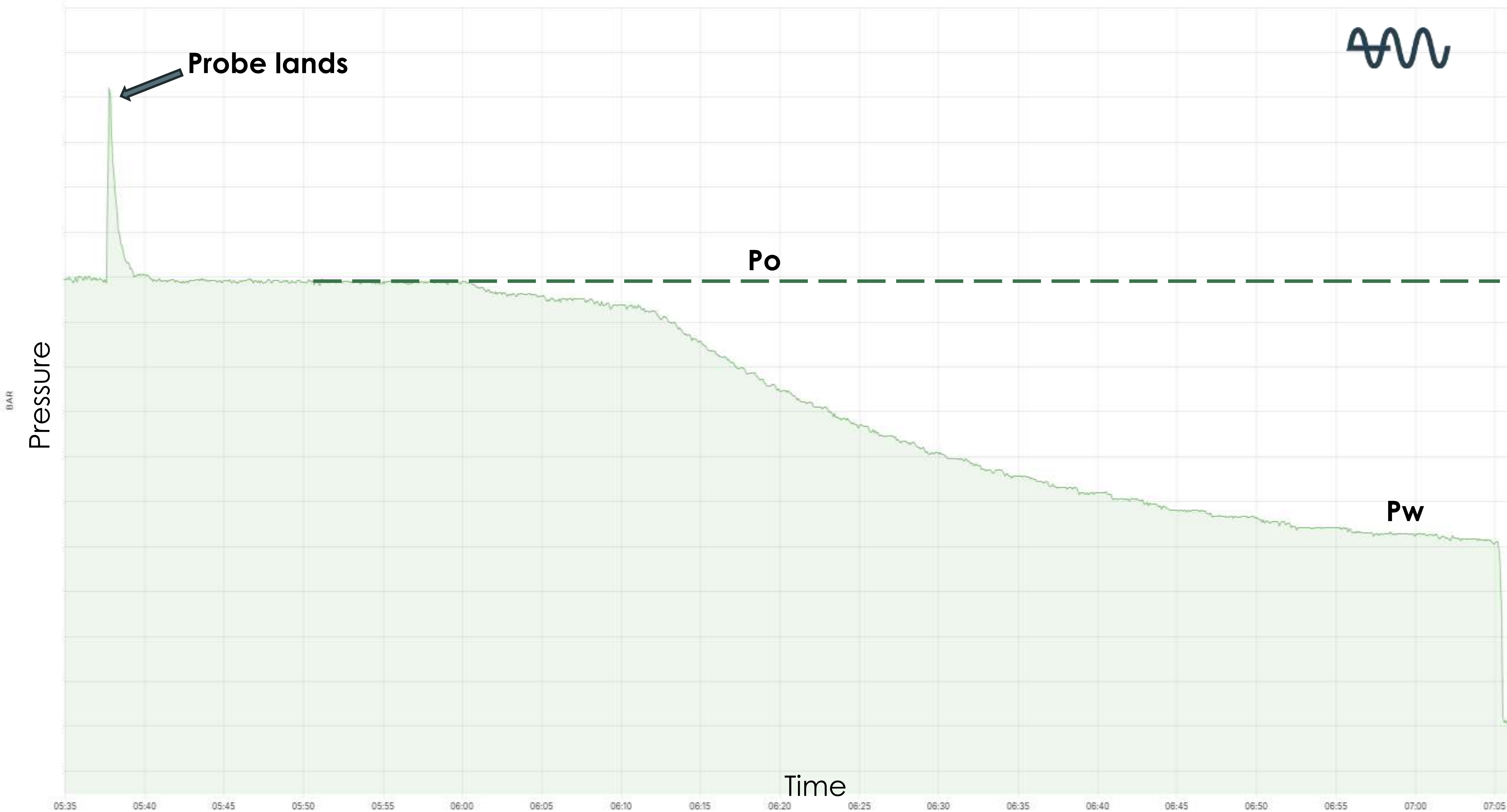


Probe and Straddle Measurements
Pressure
BAR
°C
67.500
65.000
62.500
60.000
57.500
55.000
52.500
50.000
47.500
45.000
42.500
40.000
37.500
35.000
32.500
30.000
27.500
25.000
22.500
20.000
17.500
15.000
19:00
20:00
21:00
22:00
23:00
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
Probe Pressure
Straddle Pressure
Probe Temperature
Straddle Temperature

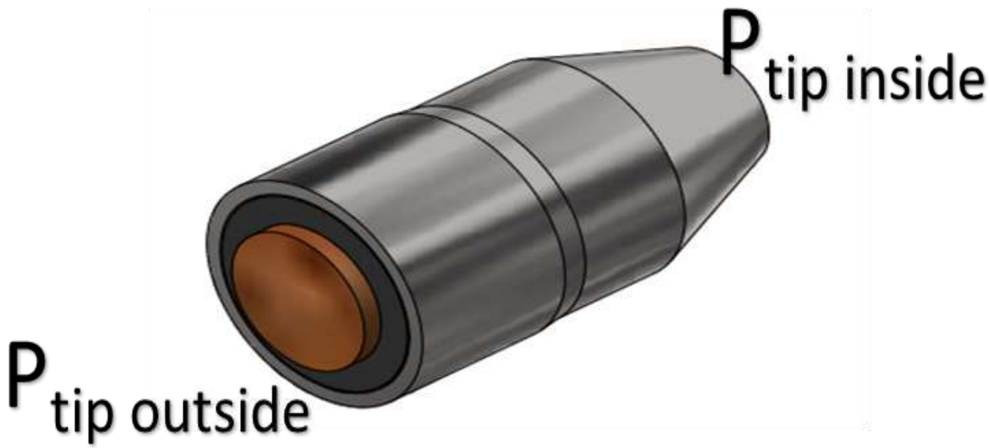

Probe and Straddle Measurements
Pressure
BAR
°C
65.000
64.000
63.000
62.000
61.000
60.000
59.000
58.000
57.000
56.000
55.000
54.000
53.000
52.000
51.000
50.000
49.000
48.000
47.000
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
Straddle Pressure
Probe Pressure
Probe Temperature
Straddle Temperature

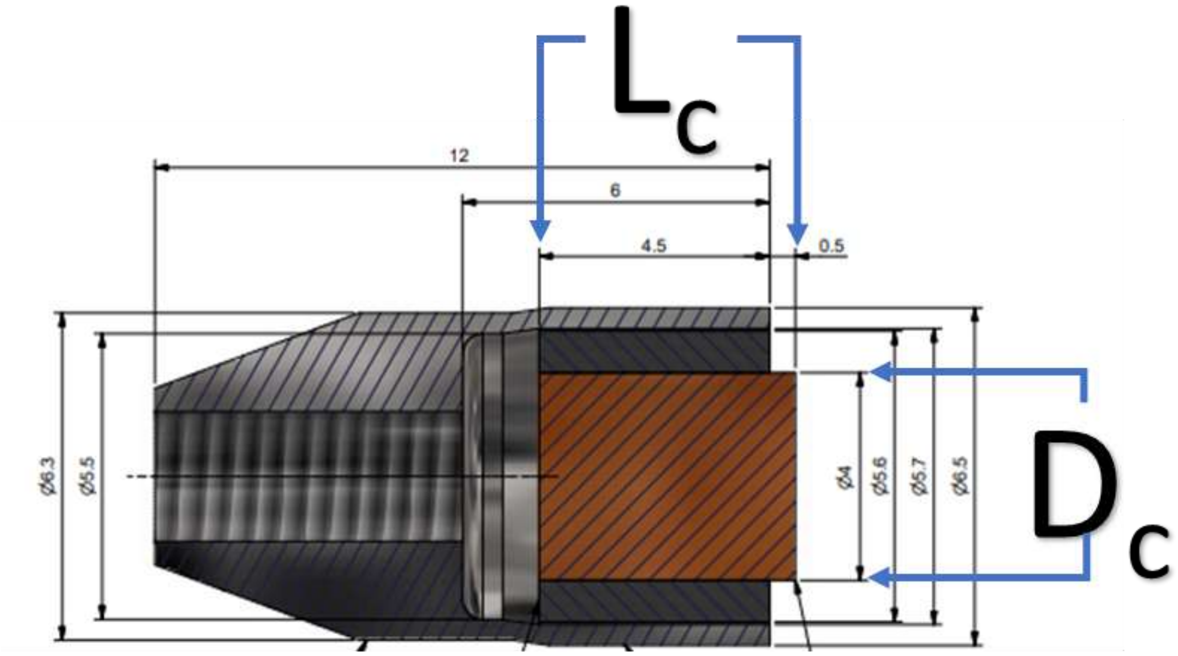
Probe and Straddle Measurements
Pressure
BAR
°C
63.500
63.000
62.500
62.000
61.500
61.000
60.500
60.000
59.500
59.000
58.500
58.000
57.500
57.000
56.500
56.000
04:10
04:20
04:30
04:40
04:50
05:00
05:10
05:20
05:30
05:40
05:50
06:00
06:10
06:20
06:30
06:40
06:50
07:00
07:10
07:20
07:30
07:40
07:50
08:00
08:10
08:20
Probe Pressure
Straddle Pressure
Probe Temperature
Straddle Temperature

Probe and Straddle Measurements

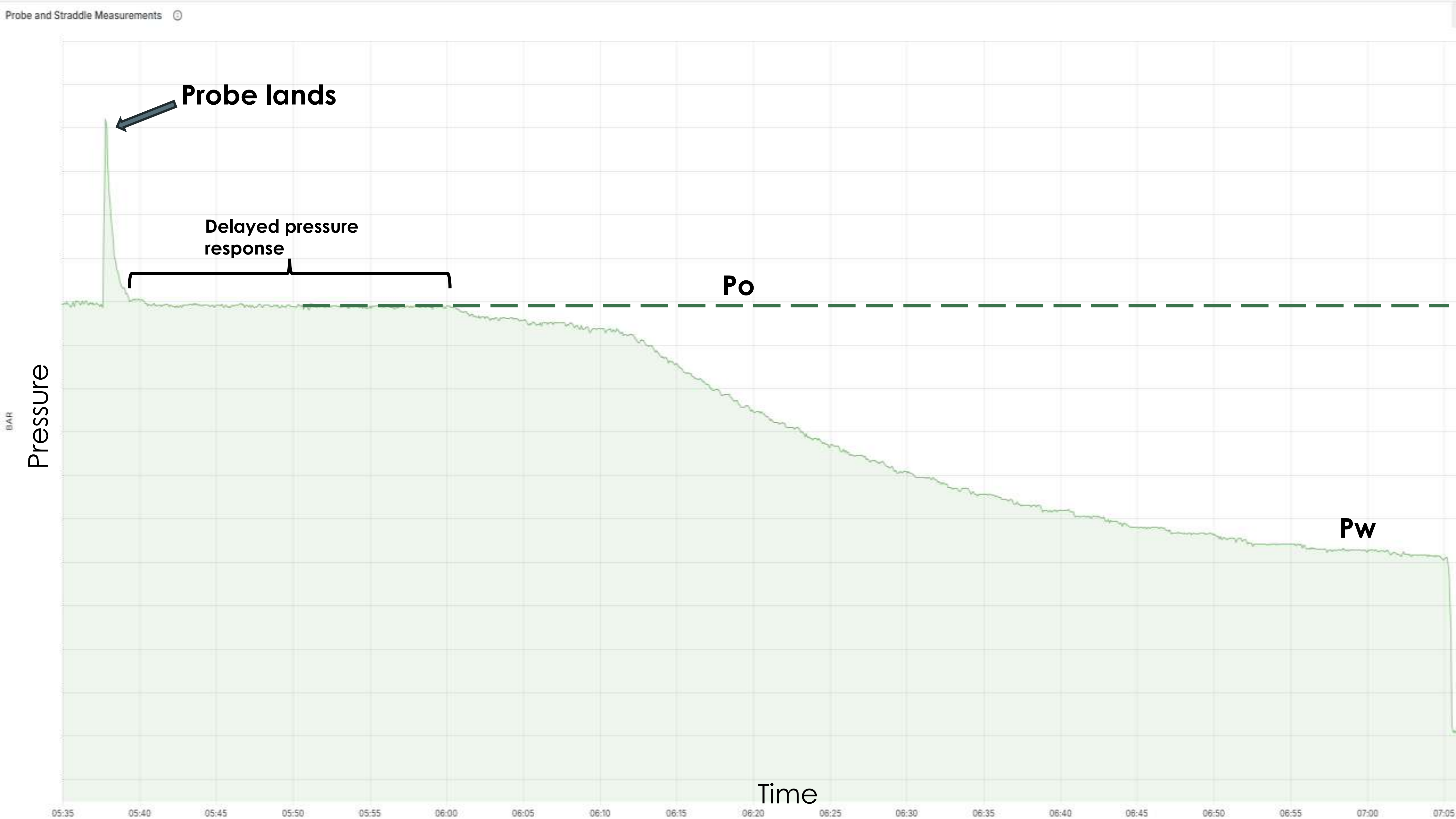


The Probe Tip



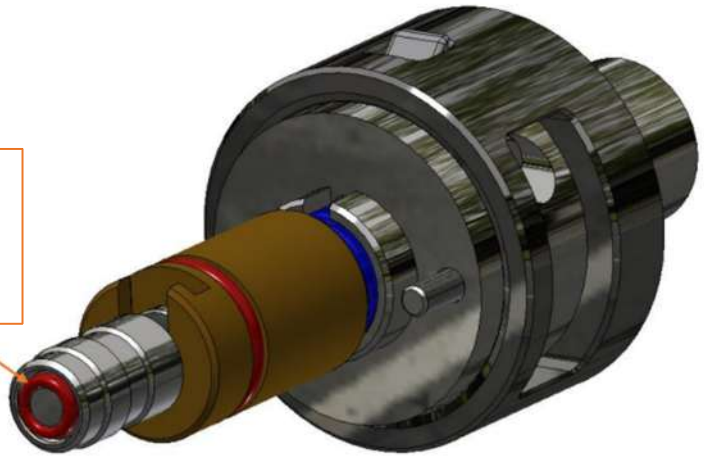


Drill-bit and Hydrophilic probe shown after Ullrigg demo

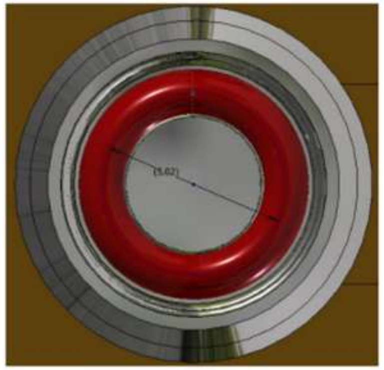


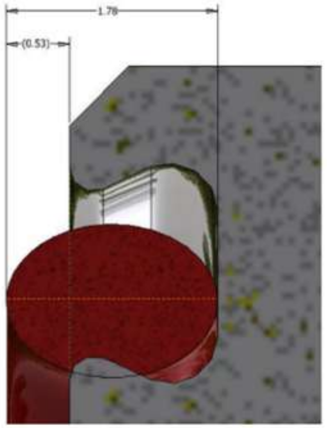
Probe and Straddle Measurements
Probe lands
Delayed pressure
response
Po
Pw
Pressure
BAR
Time
05:35
05:40
05:45
05:50
05:55
06:00
06:05
06:10
06:15
06:20
06:25
06:30
06:35
06:40
06:45
06:50
06:55
07:00
07:05

The Probe Valve



Check Valve





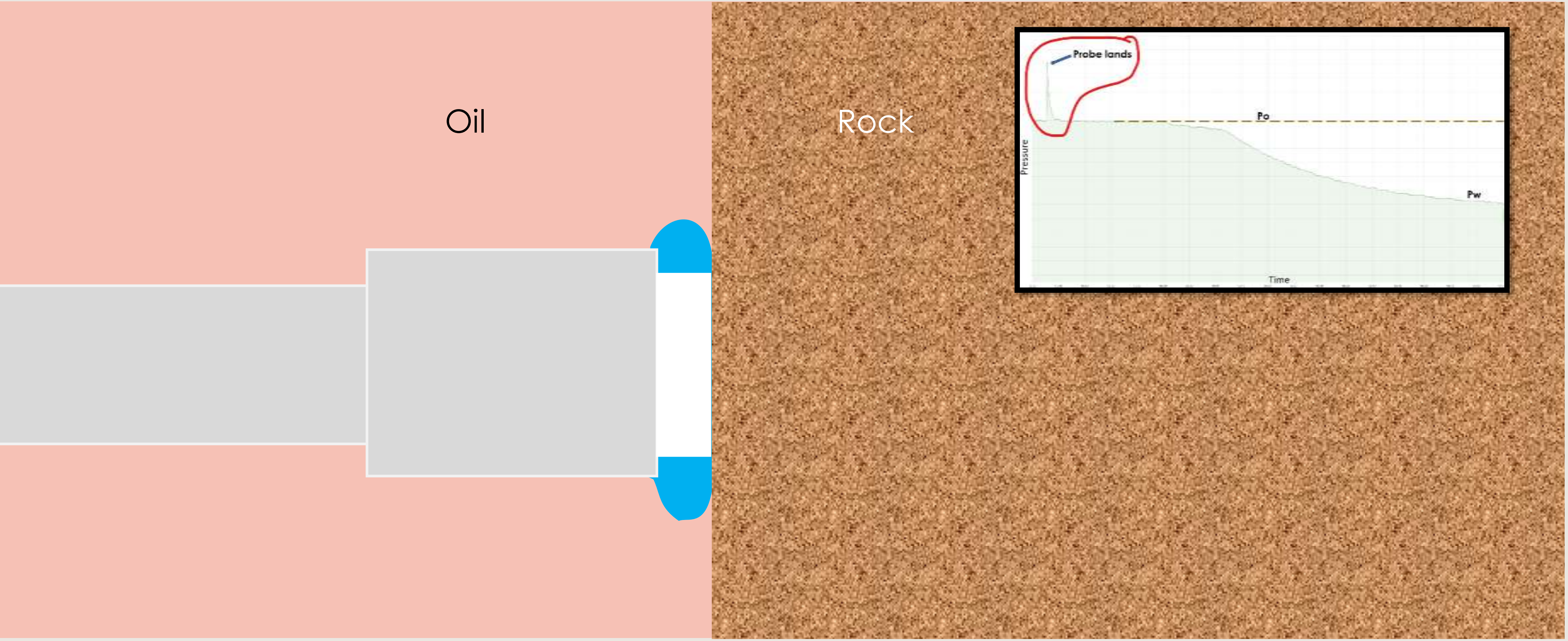
Probe in oil


Oil
Ceramic filter
Water filled tubing connecting probe to sensor
Probe tip

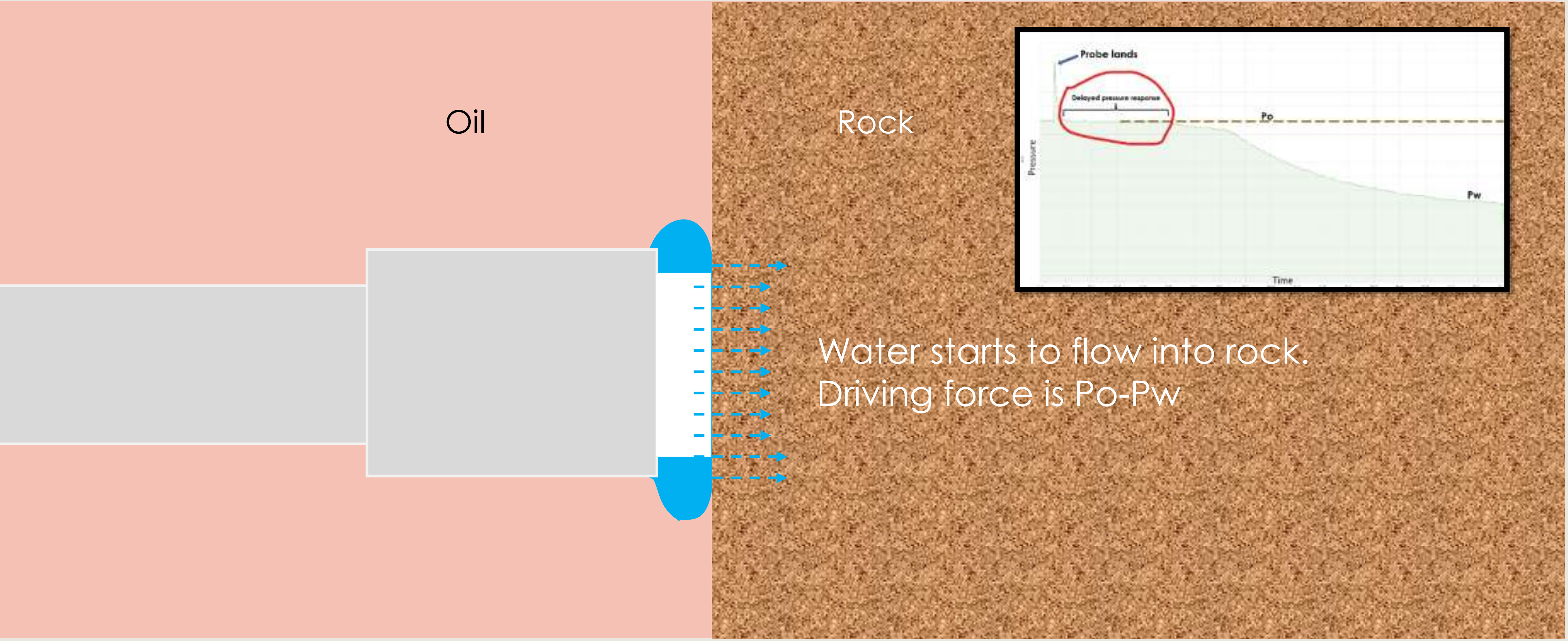
Probe in oil with water pillow

Probe with water pillow at TD

Probe with water pillow at TD

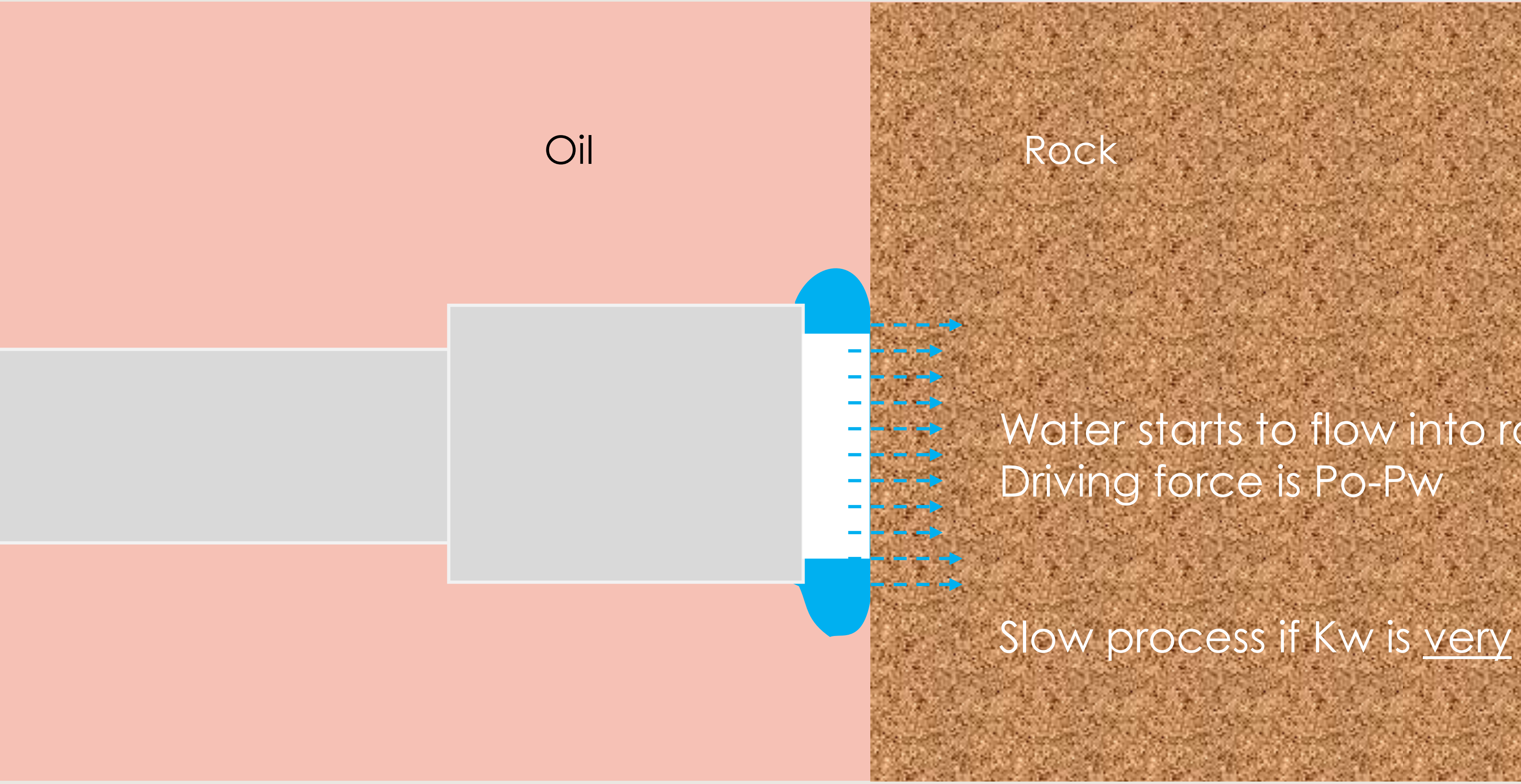


Probe with water pillow after TD



Water starts to flow into rock.
Driving force is Po-Pw

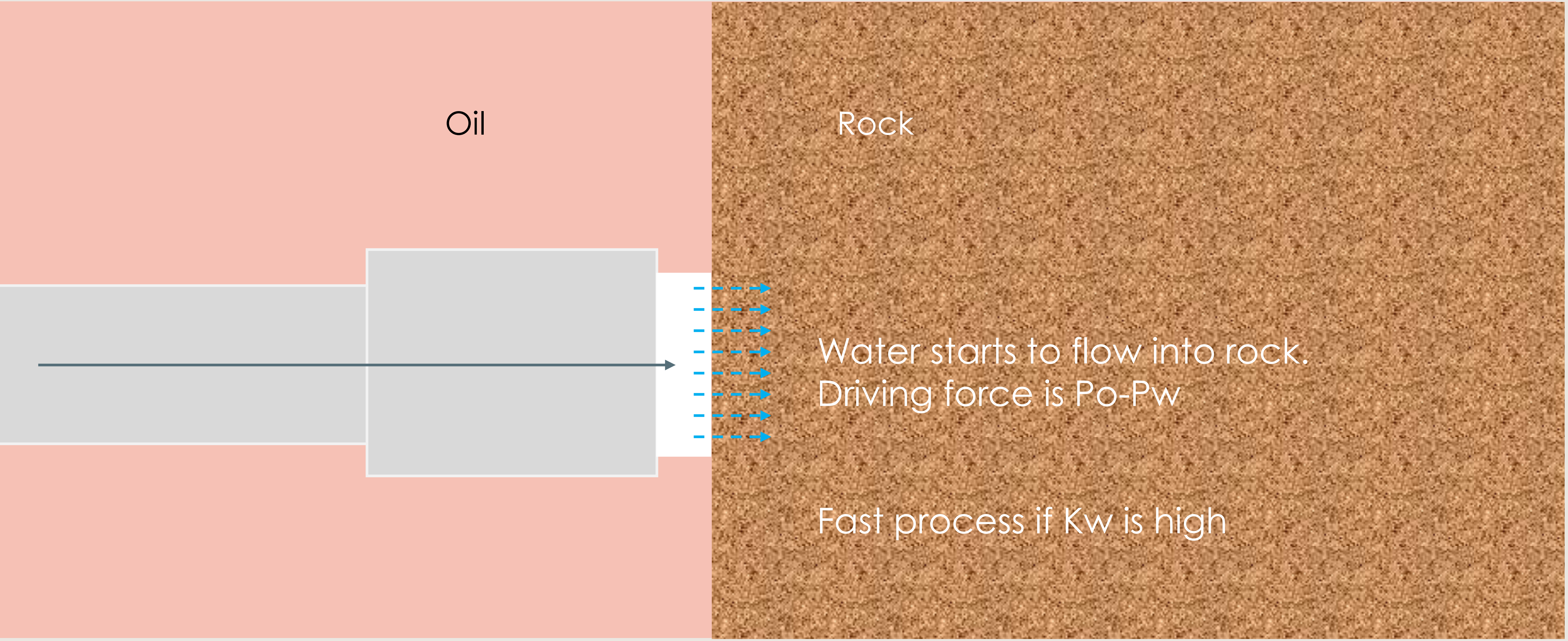
Probe with water pillow after TD



Water starts to flow into rock.
Driving force is Po-Pw

Slow process if Kw is <u>very</u> low

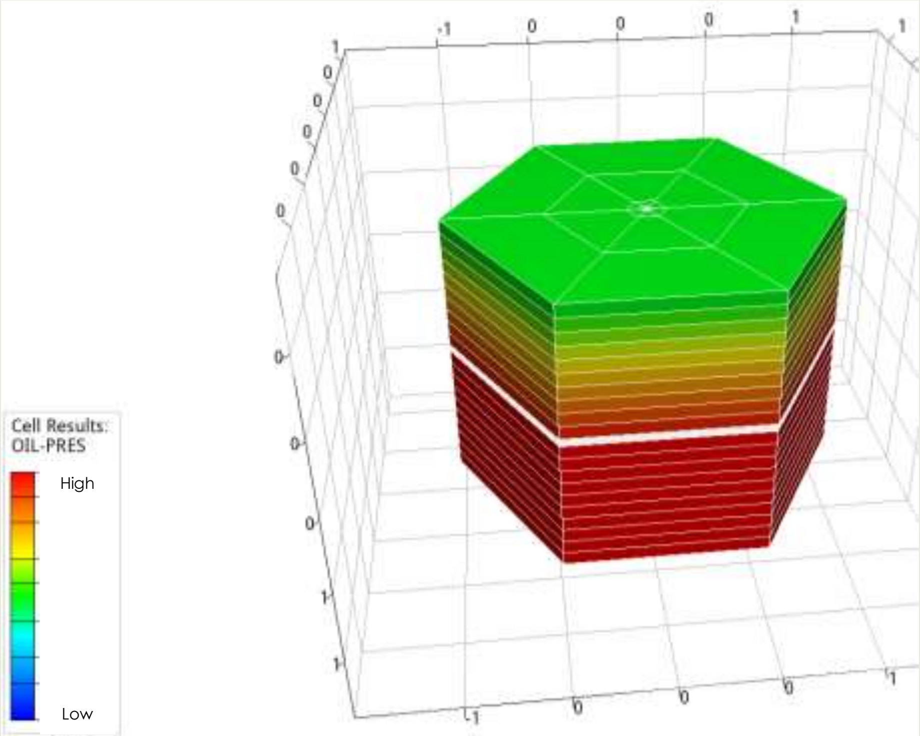
Probe with water pillow after TD



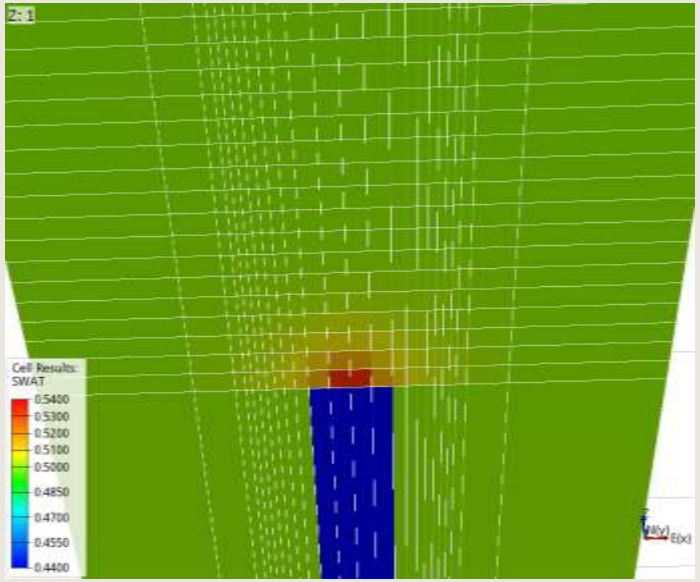
Interpretation of measurements

Estimating Pd and the vertical distance to FWL

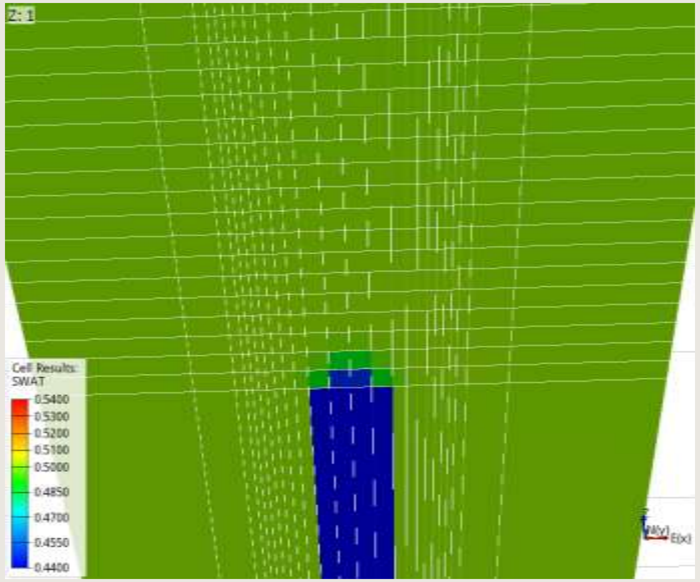
Simulator



Water saturation:
First period after probe landing:
Flow from probe into the formation.



Later – imn a cooling down scenario:
Flow from the formation into probe.

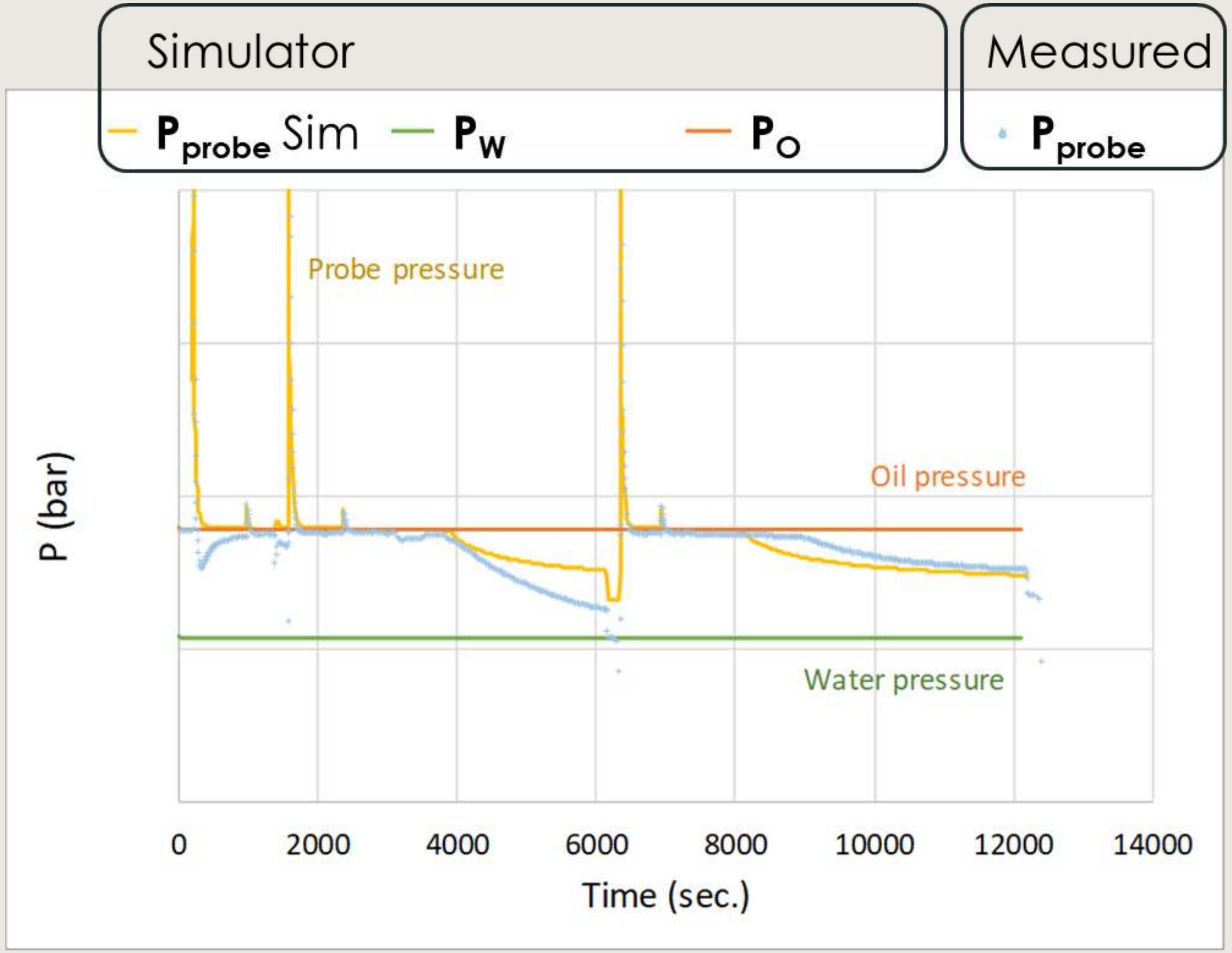


Purpose built numerical simulator, NORCE, Arild Lohne → Aruoture Voke Omekeh

Not including temperature

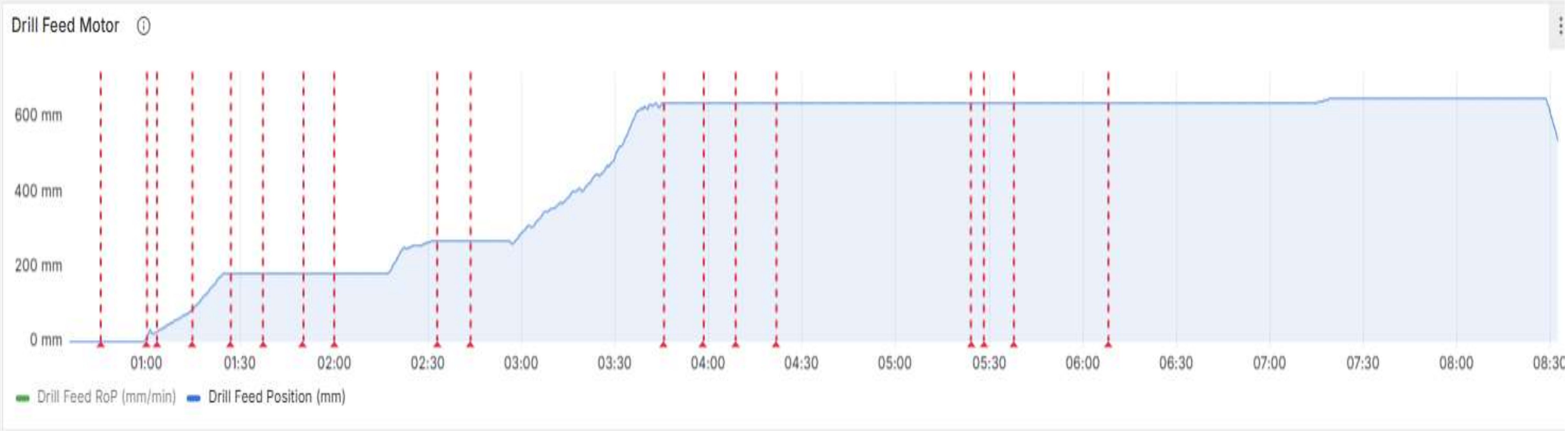
Probe pressure could <u>not</u> be matched

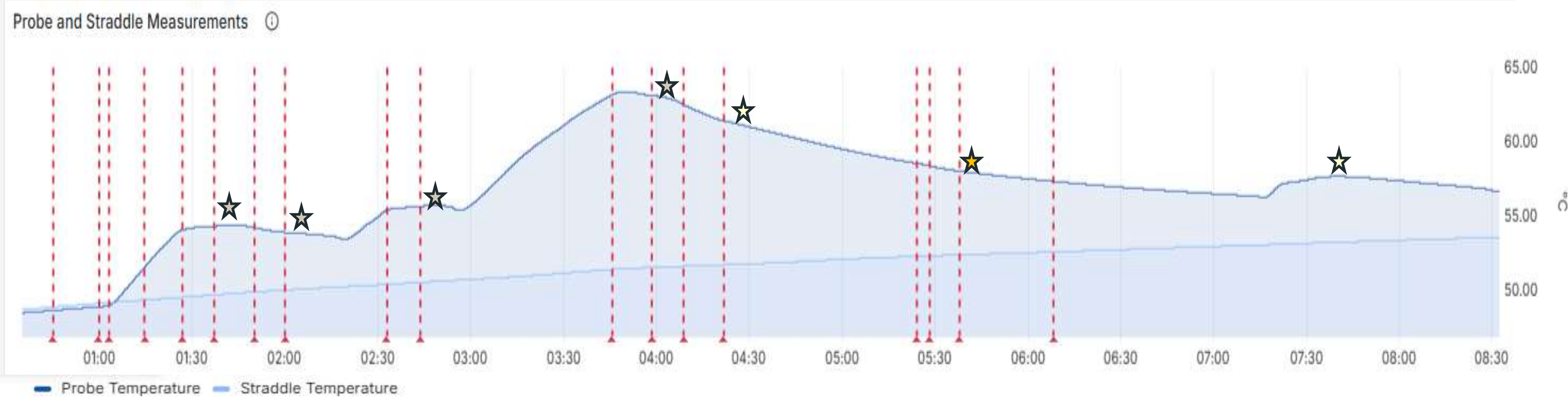
Temperature <u>must</u> be included in simulation model

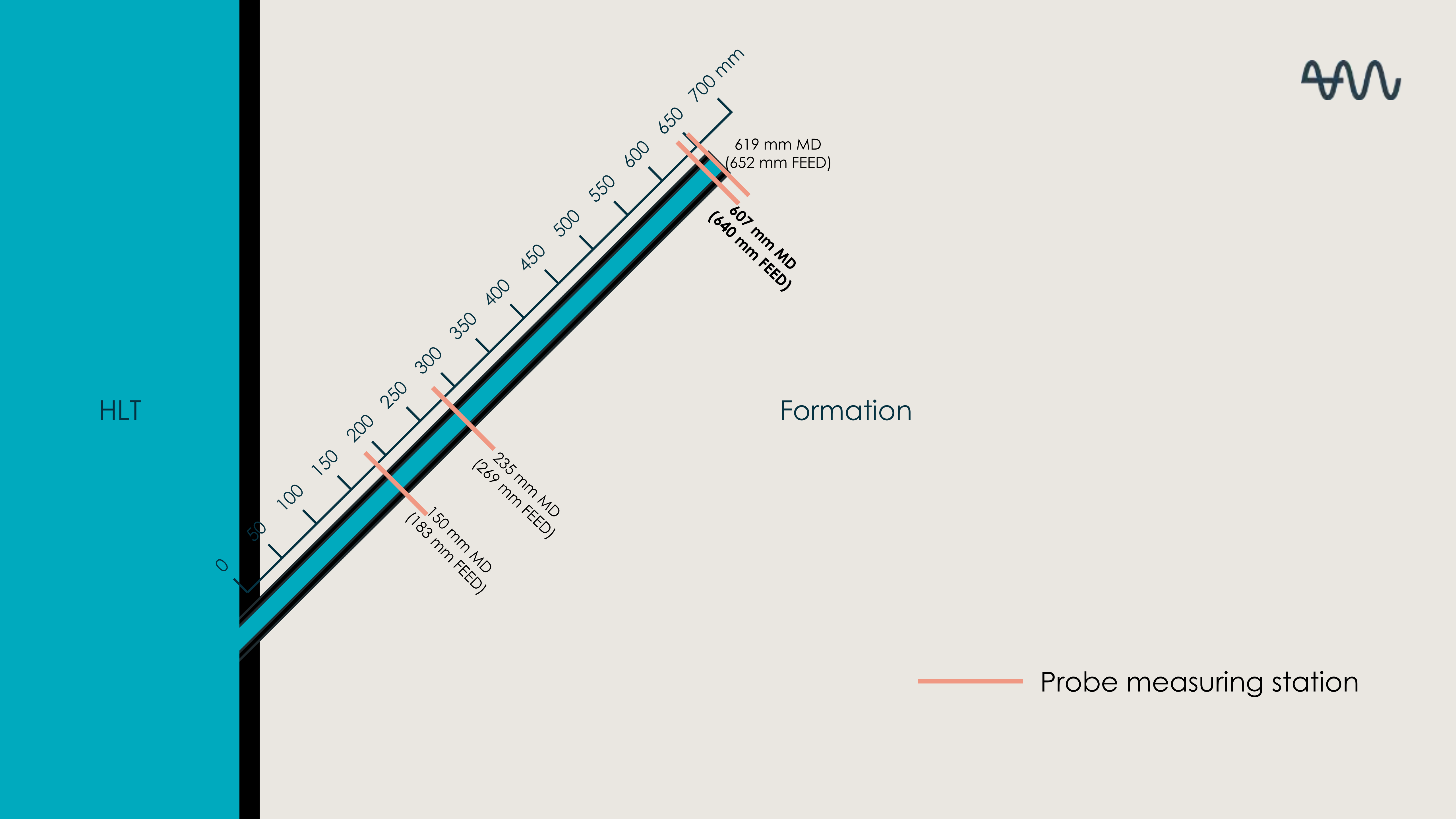


Temperature effects

Temperature effects


Drill Feed Motor
600 mm
400 mm
200 mm
0 mm
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Drill Feed RoP (mm/min)
Drill Feed Position (mm)

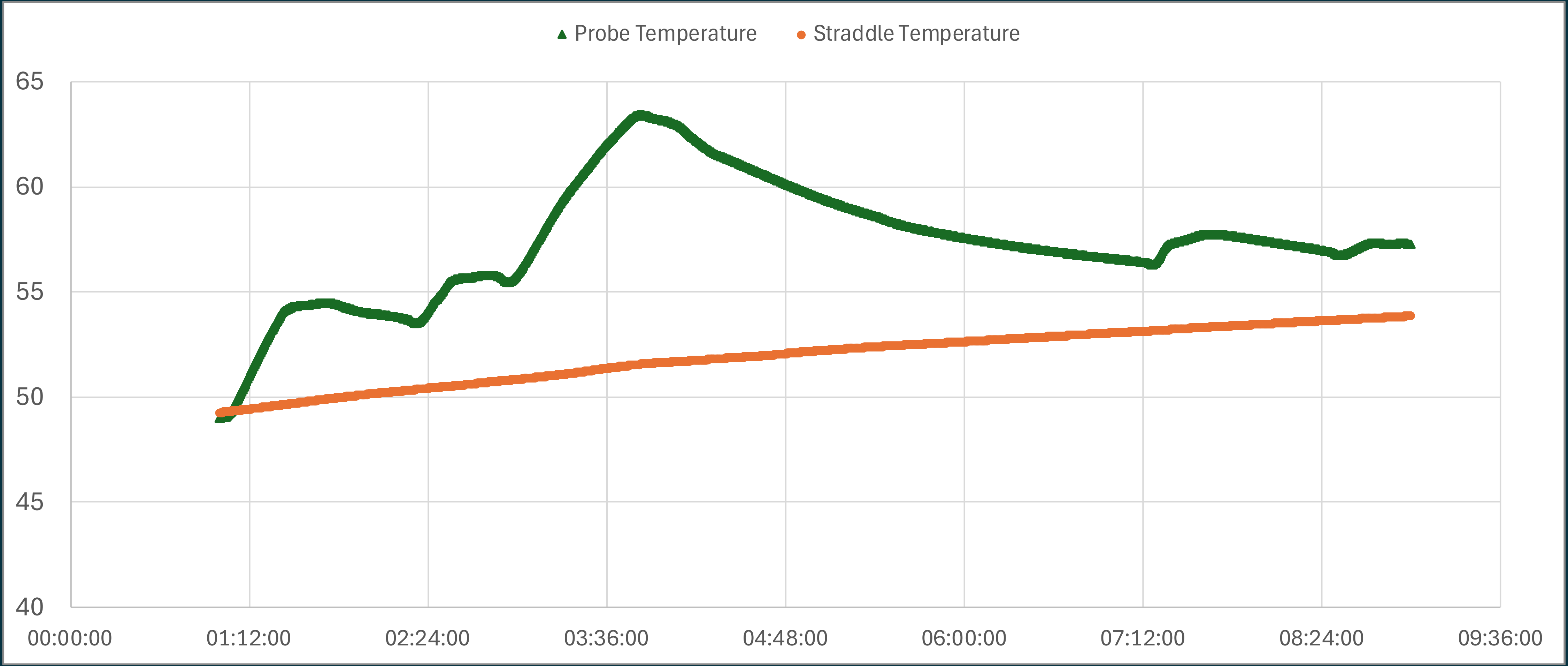

Probe and Straddle Measurements
65.00
60.00
55.00
50.00
°C
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
08:00
08:30
Probe Temperature
Straddle Temperature


HLT
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700 mm
619 mm MD
(652 mm FEED)
607 mm MD
(640 mm FEED)
235 mm MD
(269 mm FEED)
150 mm MD
(183 mm FEED)
Formation
Probe measuring station

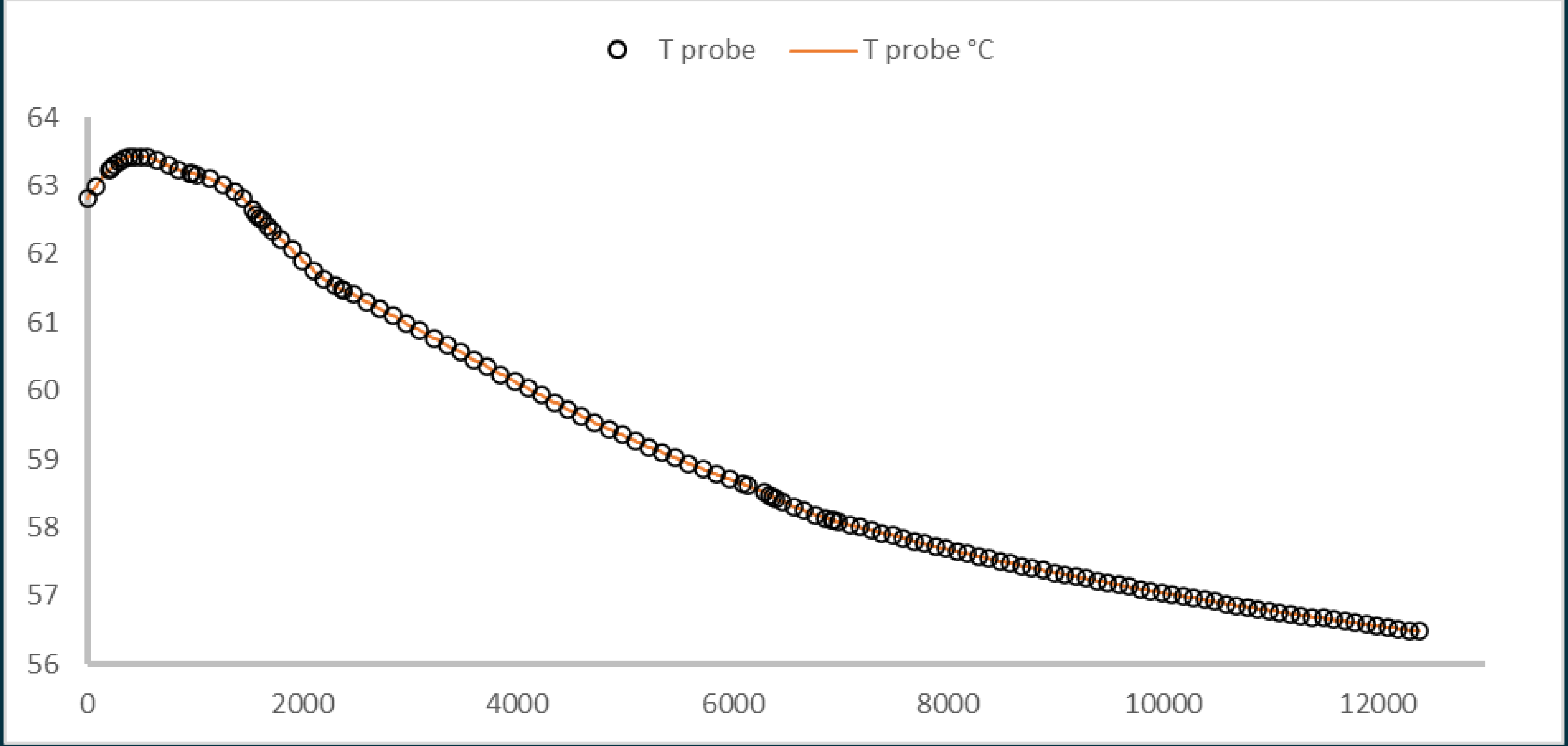
Temperature

- Input in simulation: average probe temperature
- The probe is a long tubing (2.5 m) with the sensor located at one end
- Initially, temperature in the well & tool is lower than the reservoir temperature.
- During drilling, heat is generated from the motor (~300 W), resulting in increased T at the probe sensor.
- Must assume significant T gradients (within the tool) and a different T development within the drilled side-well.

Temperature



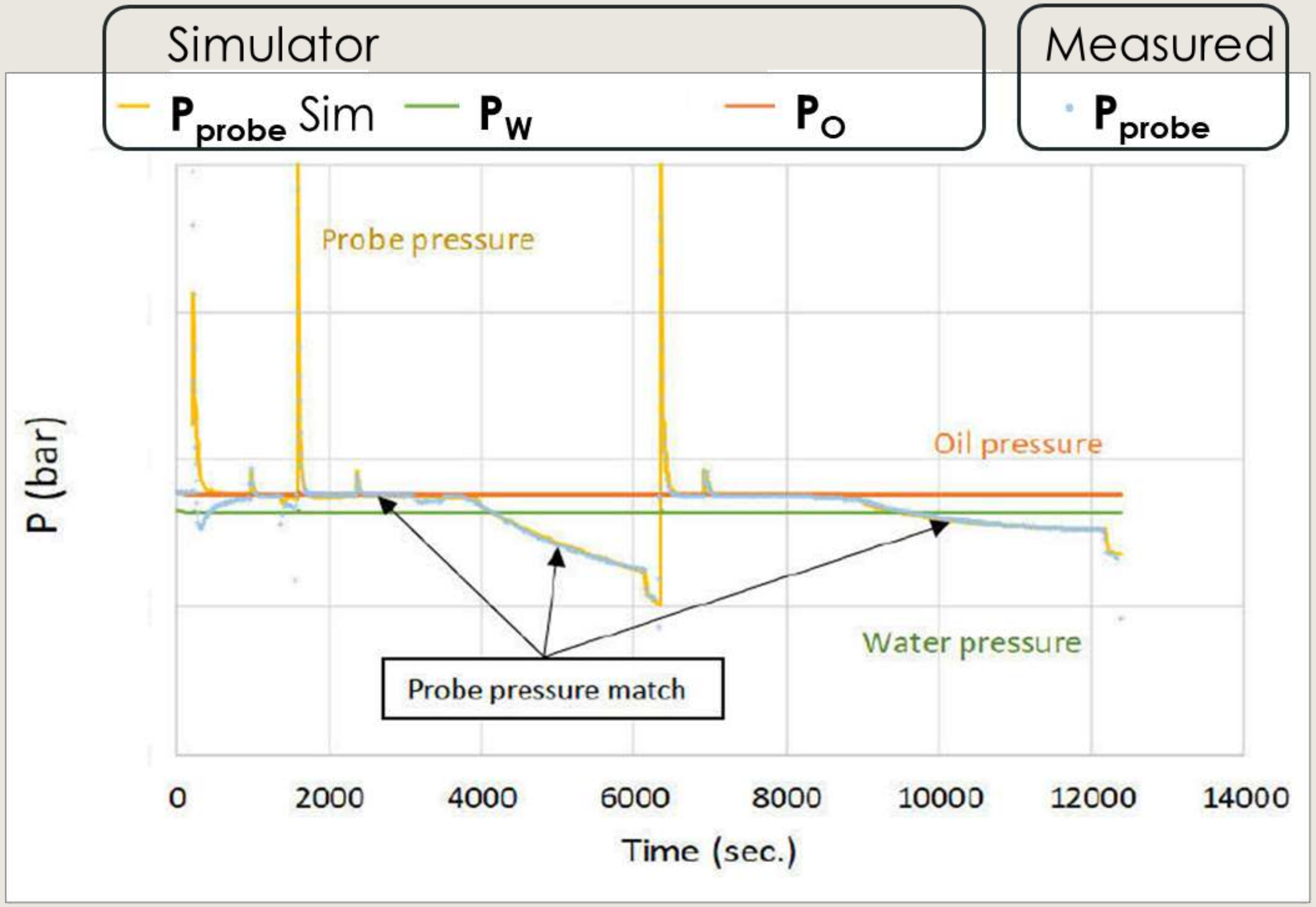
Modeling cooling effect



Including temperature

- Probe sensor temperature included
- Cooling effect reproduced
- Water pressure (P_w) near perfectly matched during the entire 200 minutes at the Main Measurement Station (607 mmMD)
- 3 probe valve closings
- 3 landings
- 3 lift-offs
- Oil pressure (P_o) input

- **$P_o - P_w$ = 0.64 bar**



Successful HLT Pilot
September 2024

Learnings

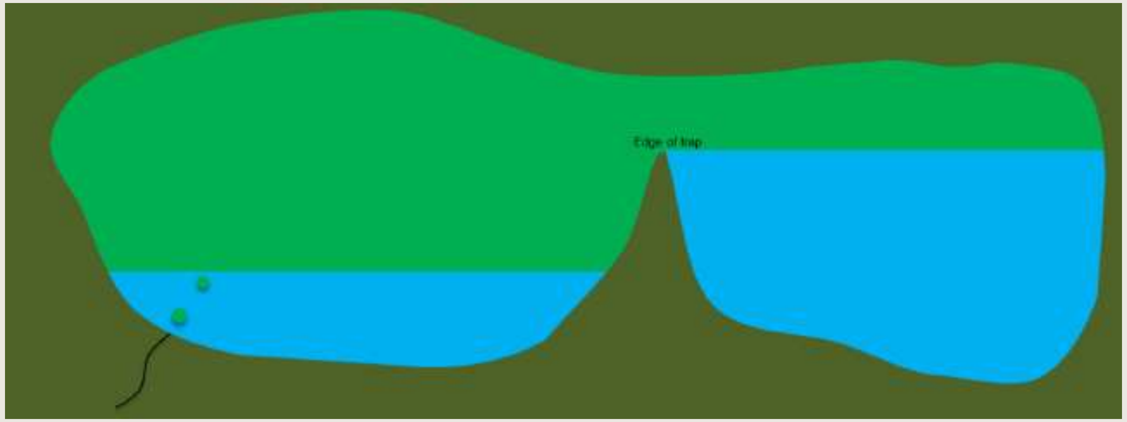
- Wait for tool to cool after drilling
- Wait for delayed pressure (low Kw)
- Check and quantify cooling effect after each Pw measurement
- Reproduce results with simulator
- Identified tool improvements opportunities
- Improved procedures

Perched Water

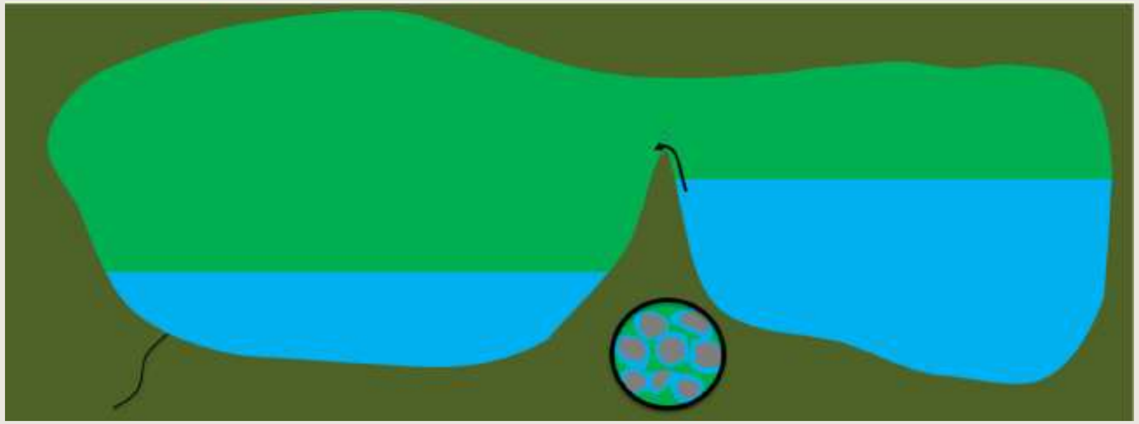
- Which water level will the HLT detect?

Perched Water Tester

Injection sand with perched water

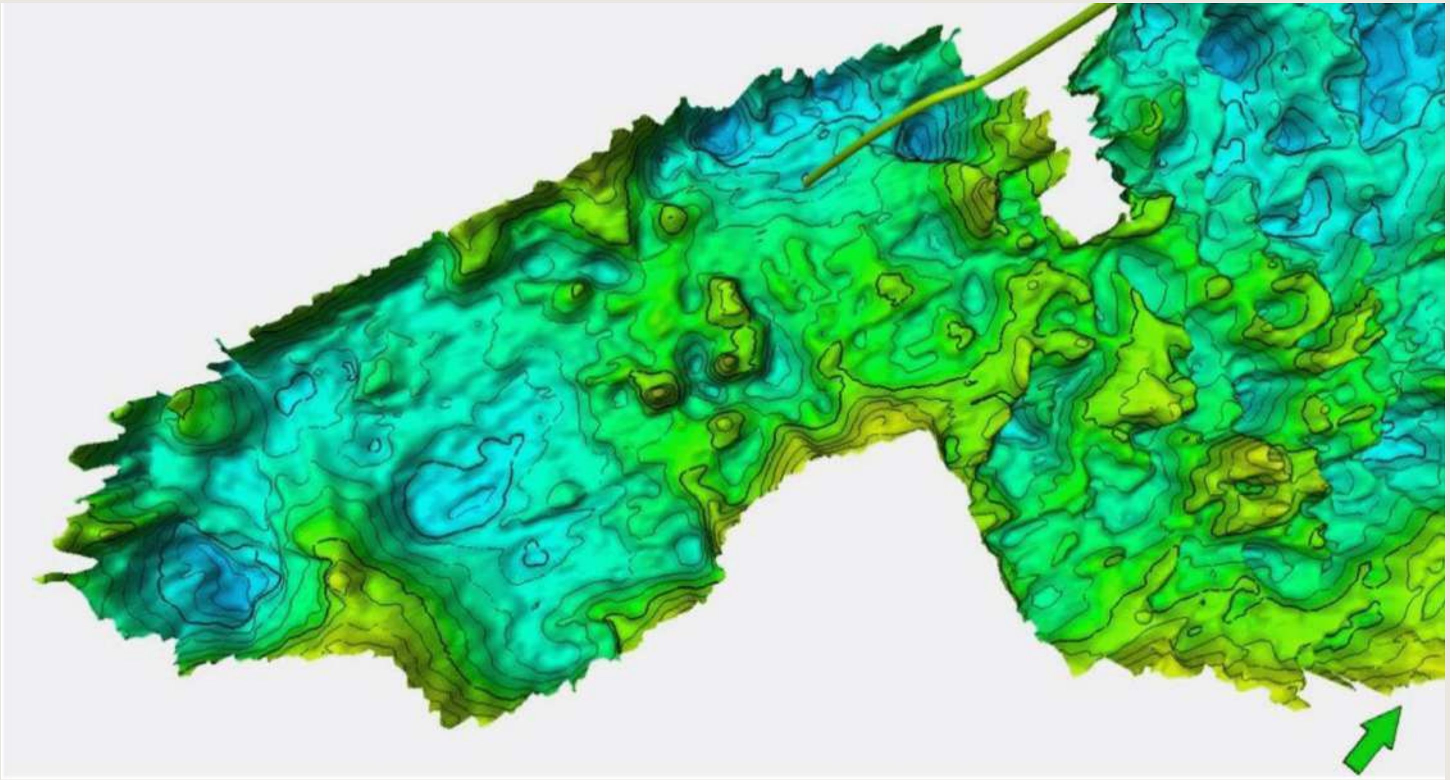


Migration of oil starts to interfere with the base of the reservoir



Migration of oil completed. The invasion of oil has pushed some of the water out of the trap through the continuous film of water on the water wet sand grains.

Grane Perched Water

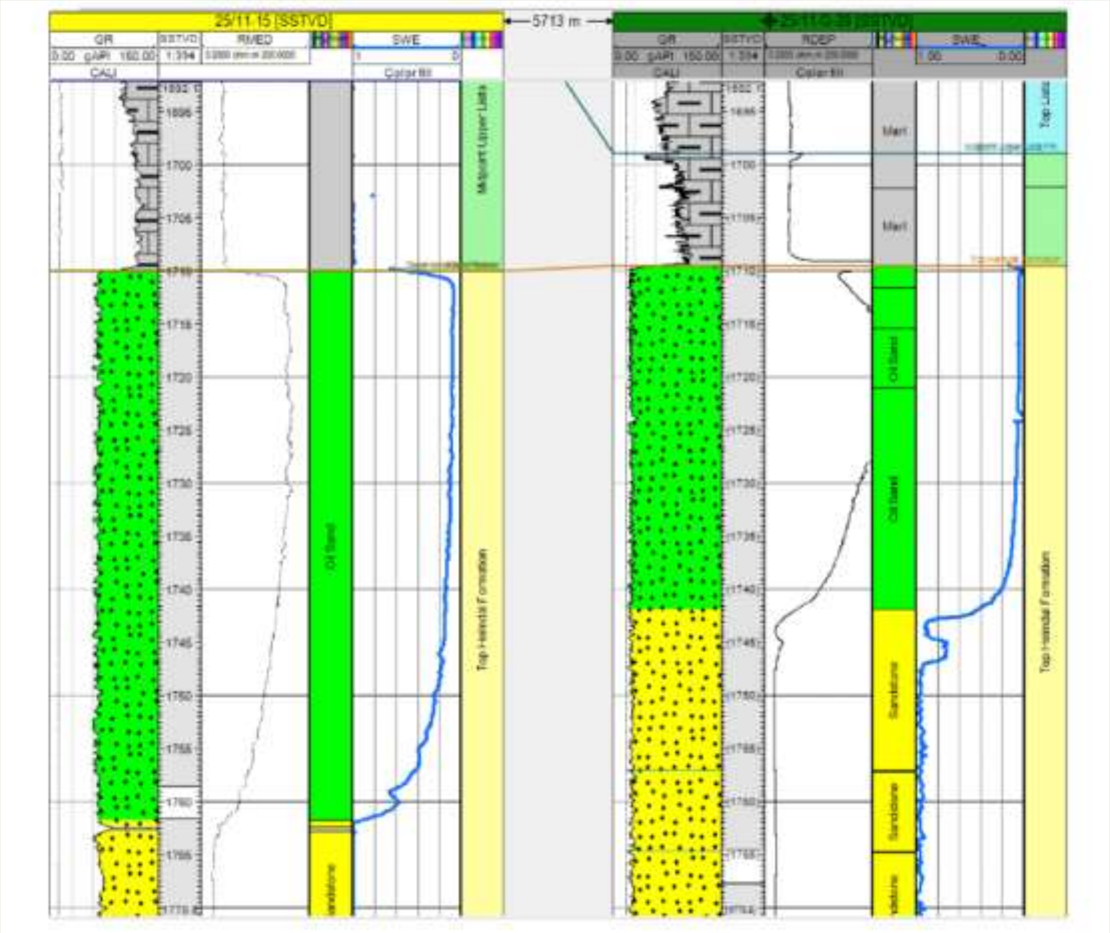


The base of the Grane reservoir is not flat – it undulates and local pools of water, laterally separated from each other, have been formed. The well shown over the base reservoir map is one of the branches of G39 towards the southern part of Grane.

Grane Perched Water

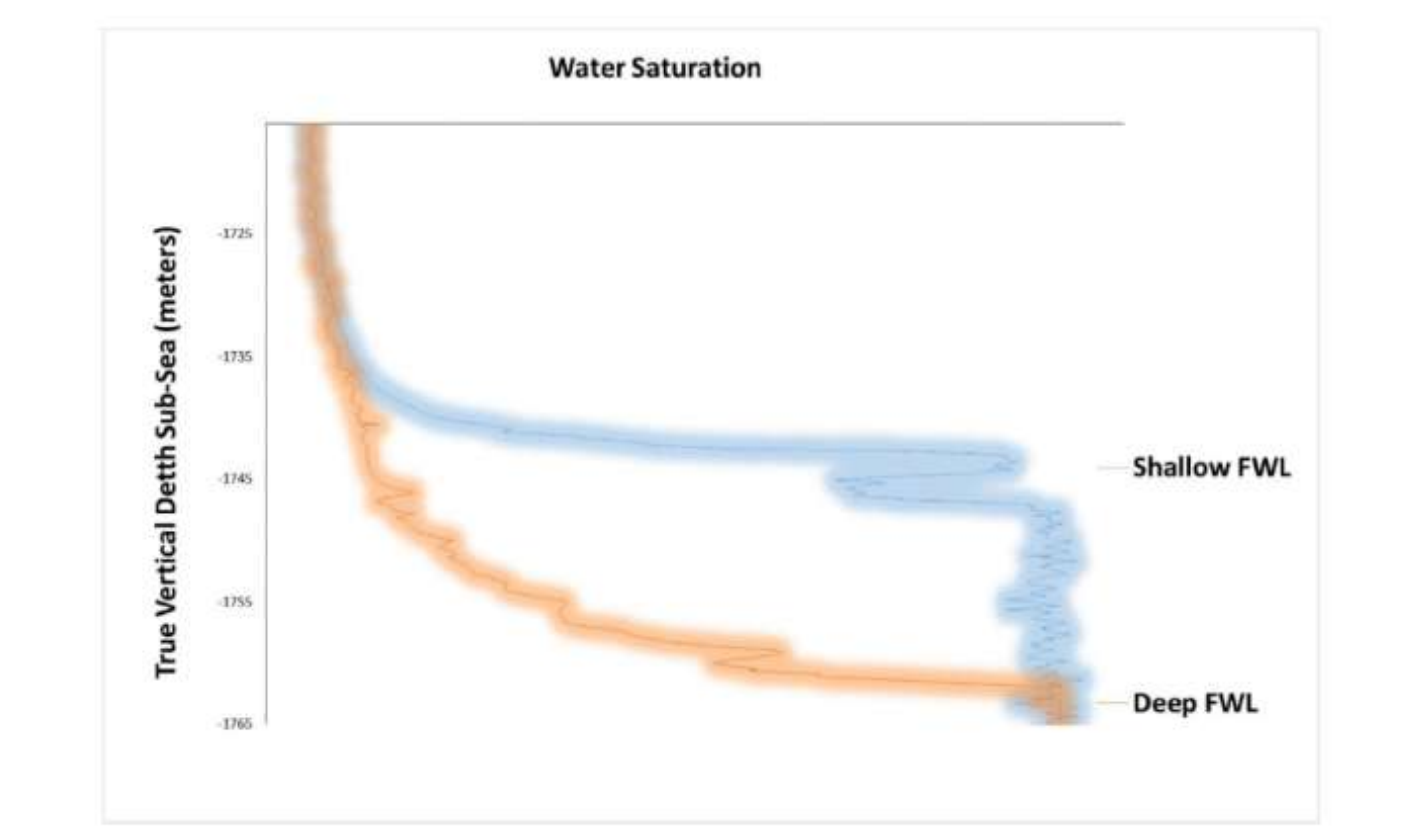
These two logs are from the Grane Field in the North Sea. The Grane reservoir is an almost homogeneous sandstone with multi-Darcy permeability in all directions. Well 25/11-15 is the 1992 discovery well, which found FWL @ 1763 mTVDSS. Producer G39 was drilled towards the southern tip of the field where it found perched water and a shallow FWL @ 1743 mTVDSS.

G39

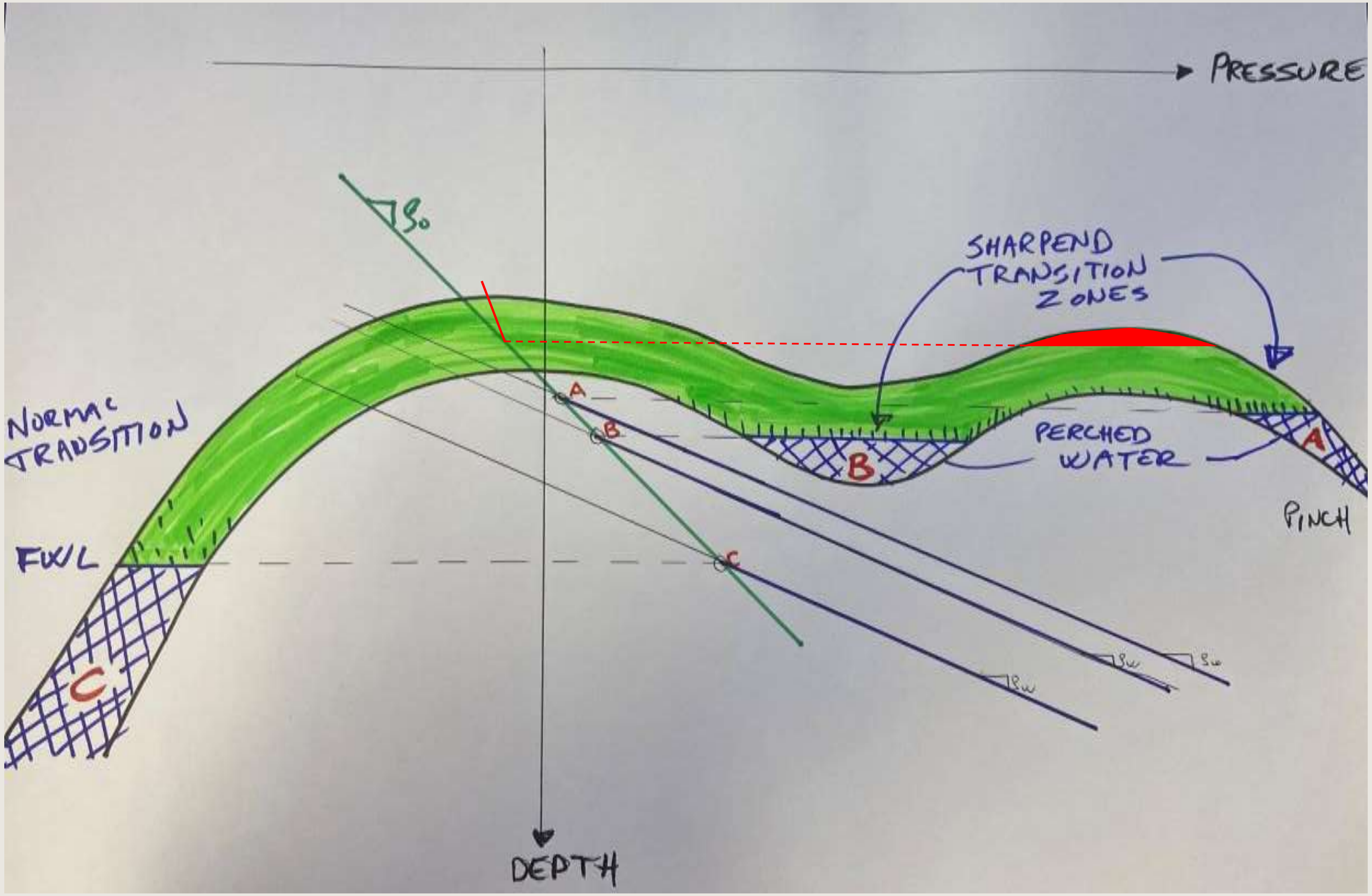


Grane Perched Water

Approx. 30 meters of transition from the deep FWL compared with approx. 10 meters from the shallow FWL.



Injection sand with perched water



The HLT will most likely detect the deepest FWL


Hydrophilic
INNOVATION

Offshore Team from Aarbakke Innovation

www.hydrophilic.no

New site from November 6th 2025