Next Generation Fluid Sampling on the Norwegian Continental Shelf

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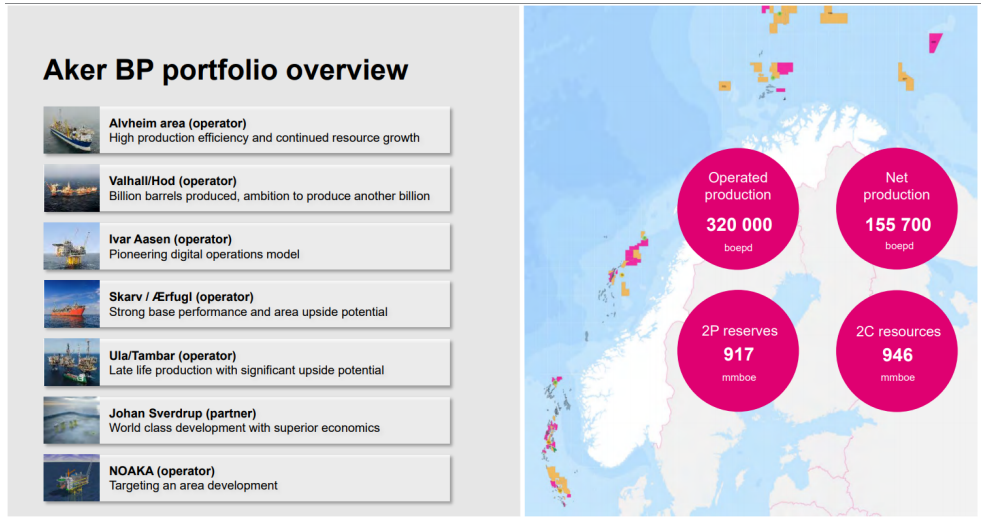
[1]Aker BP, [2]Schlumberger

Aker BP – Field tests of new technology



2019 Aker BP exploration program

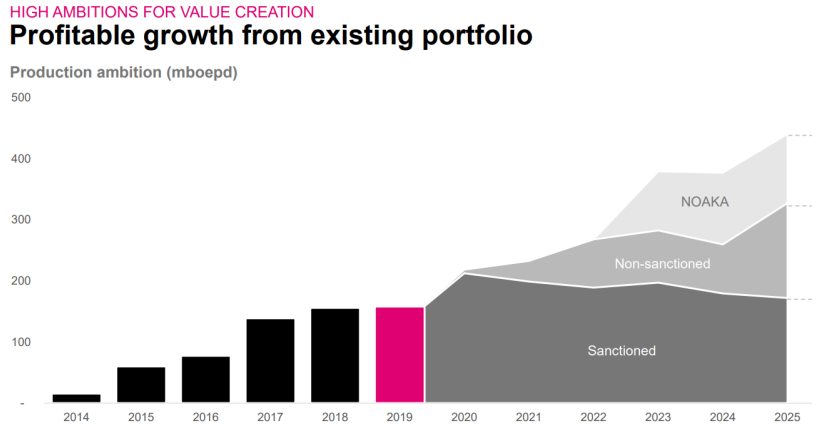
License	Prospect	Operator	Aker BP share	Est. spud	Pre-drill mmboe	Status
PL869	**Froskelår Main**	**Aker BP**	**60 %**	**Q1**	**45 - 153**	**Discovery 60-130 mmboe**
PL857	Gjøkåsen	Equinor	20 %	Q1	26 - 1427	Dry
PL033	Hod Deep West	Aker BP	90 %	Q1	2 - 22	Dry
PL869	**Froskelår NE**	**Aker BP**	**60 %**	**Q2**	**7 - 23**	**Discovery 2-10 mmboe**
PL916	JK	Aker BP	40 %	Q2	100 - 420	Dry
PL814	Freke-Garm	Aker BP	40 %	Q2	16 - 81	Dry
PL777	Hornet	Aker BP	40 %	Q2	14 - 137	Dry
PL502	Klaff	Equinor	22 %	Q2	50 - 372	Ongoing
PL869	Rumpetroll	Aker BP	60 %	Q2	45 - 148	Ongoing
PL442	**Liatårnet**	**Aker BP**	**90 %**	**Q2**	**39 - 331**	**Discovery 80-200 mmboe**
PL942	Ørn	Equinor	30 %	Q3	8 - 40	
PL762	Vågar	Aker BP	20 %	Q3	63 - 130	
PL782S	Busta	Conoco	20 %	Q3	54 - 199	
PL019C	Kark	Aker BP	60 %	Q3	15 - 48	
PL986	Nipa	Aker BP	30 %	Q3	35 - 115	NEW: Added in Q2
PL838	Shrek	PGNIG	30 %	Q4	10 - 22	
PL1008	Nidhogg	Aker BP	60 %	Q4	26 - 70	NEW: Added in Q2

Sampling challenges faced in atypical reservoirs

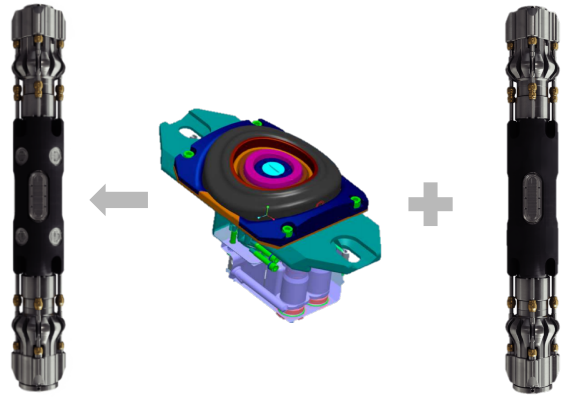
- Low permeability reservoirs (<1 mD)
- Flow rate control
- Complex NET
- Limited hydrocarbon inflow tolerance in very shallow reservoirs
- Limitation on flow rate when Mini-DST

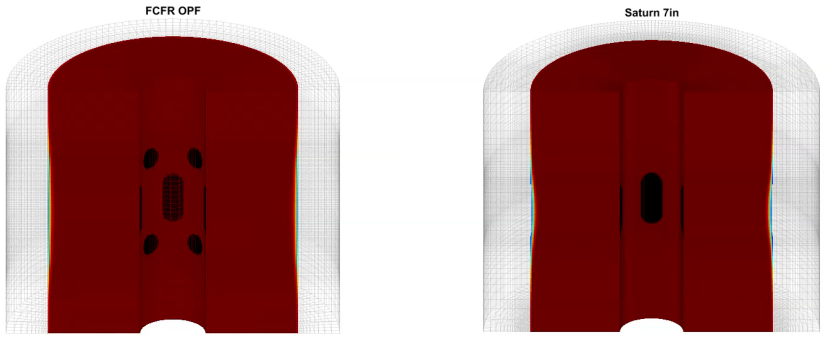
Case studies

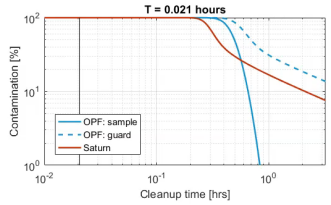
1. Very low perm sampling
2. Ora for Additional well in the RFG study on Ivar Aasen oil field
3. Conceptual test of the inflow management test system for Ora

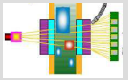
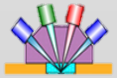
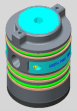


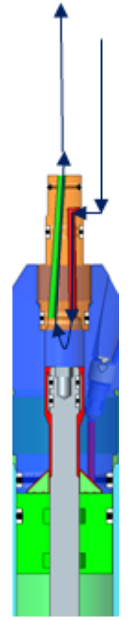
Formation Testing Next Generation – Ora







- 24 Channel Spectrometer 
- Fluorescence/Critical Fluids 
- Density / Viscosity 
- Broad Range Viscosity Sensor 
- Induction Resistivity Sensor 
- Annular & Flowing Pressure Gauges 

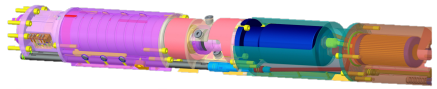


MDT

2 cc/s ⟷ 30 cc/s

Ora

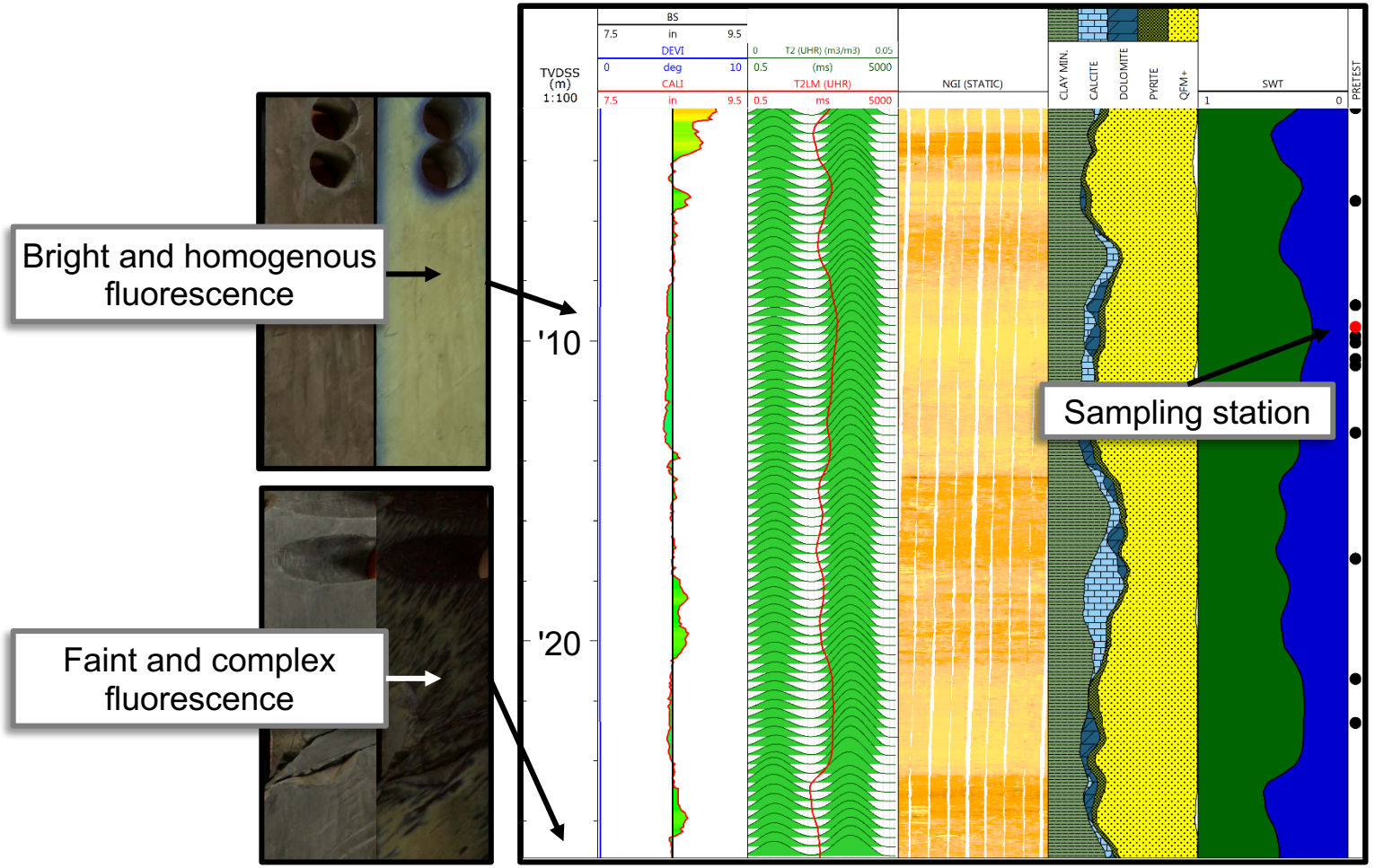
0.2 cc/s ⟶ **120 cc/s => 200cc/s**



1 motor, 2 pumps

Tight mudstone play fluid sampling

$$1\ \mu D < k_{h,w} < 3\ mD$$



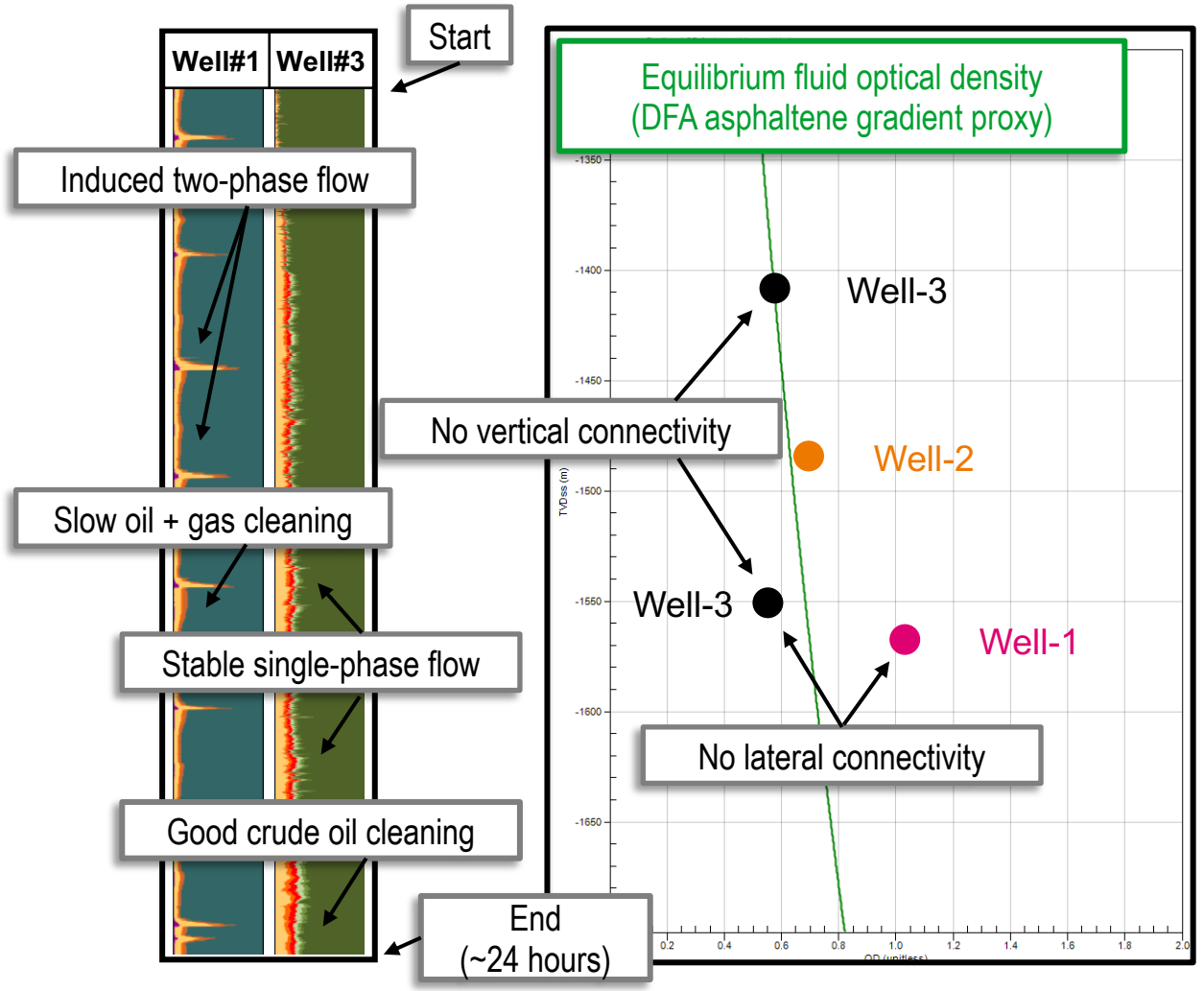
Successful oil sampling in tight, unconventional reservoir

- **Field tested new fluid sampling tool (Ora)**
  - Aker BP first user outside Middle East and US
  - Two wells in two weeks (Wells 2 & 3)

- **Successfully sampled light crude oil from very tight formation**
  - 10 bottles from 2 stations
  - 0.2 mD/cP and 0.4 mD/cP (< 0.5 mD)
  - Among tightest ever successful oil sampling in OBM on NCS
  - Large radial probe with focused flow proved valuable with thin beds
  - High performance – alternative method would have taken almost twice as long, likely with lower sample quality

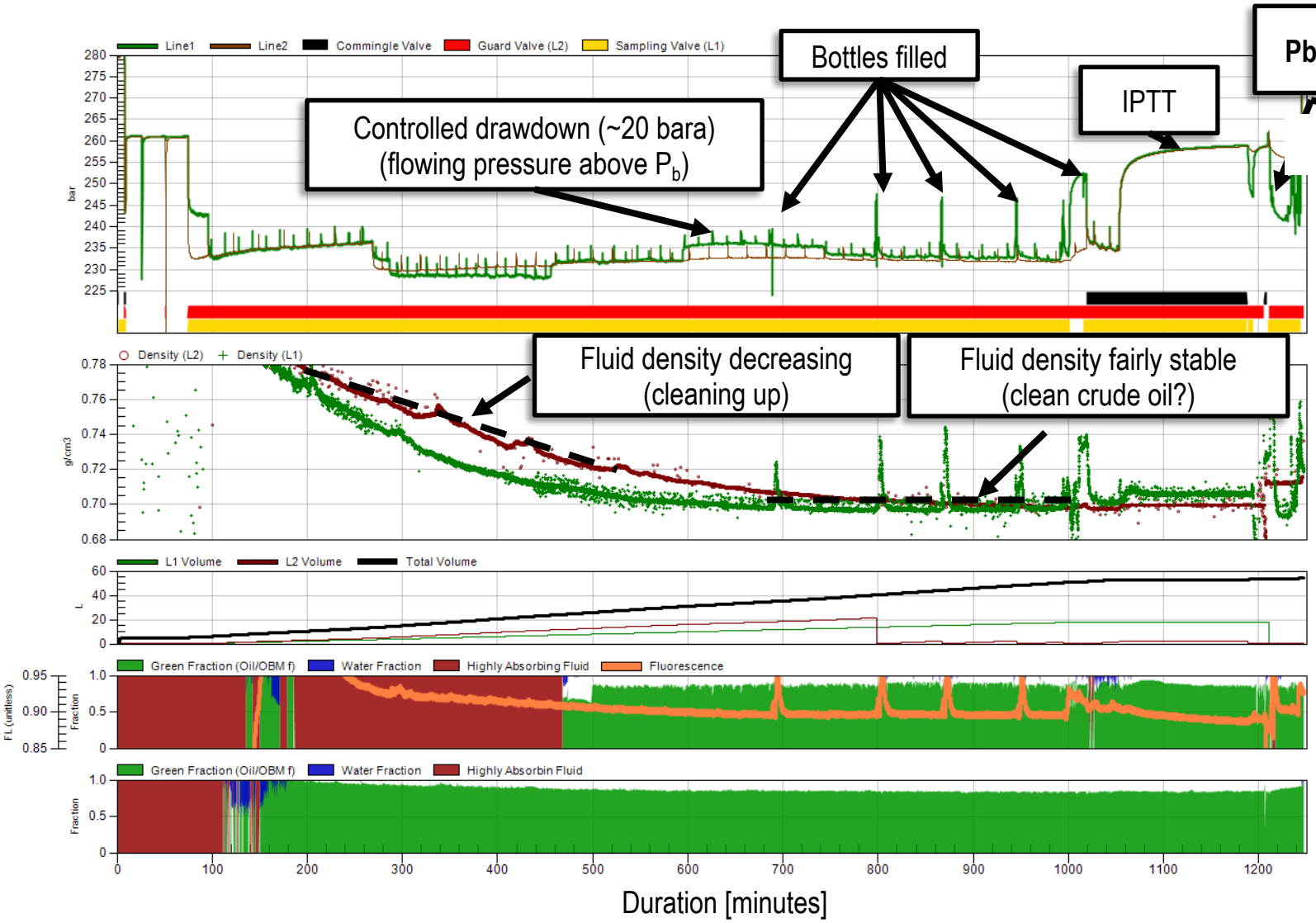
- **Low and controllable pressure drawdown ensured single-phase flow and maintained sample integrity**
  - Allows conclusive analysis and use of oil in core flooding studies
  - Enables good RFG to inform distribution of fluid quality in reservoir
  - Reduced risk of spending time sampling non-representative fluids

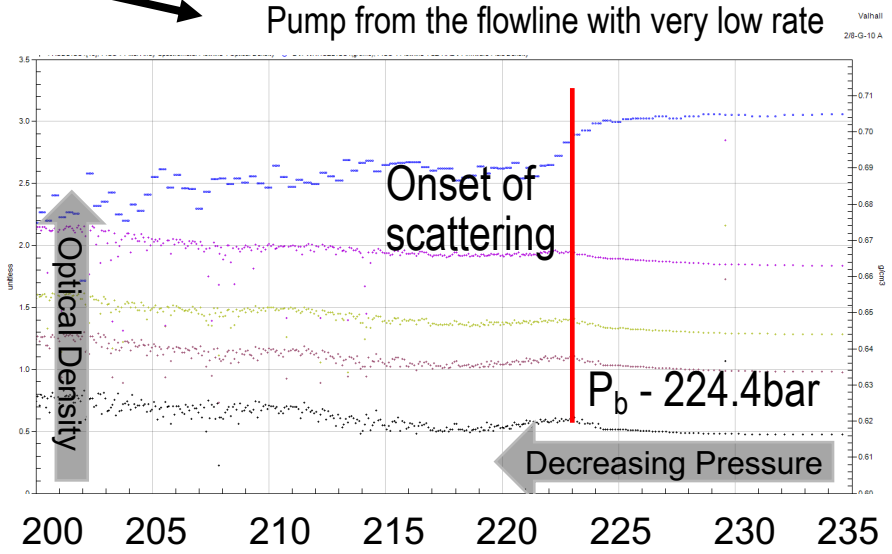
- **New capability that enables conclusive evaluation of complex tight oil plays, where reservoir fluid properties matter the most**
  - Also beneficial in unconsolidated/weak formations to avoid sanding



- Well 1: MDT, DD Mobility – 2.4mD/cP, Drawdown 165bar, Sampling Below Pb
- Well 3: Ora, DD Mobility <0.2 mD/CP, Drawdown 25 bar, Single Phase Sample

Well-3 flowline data & Pb test

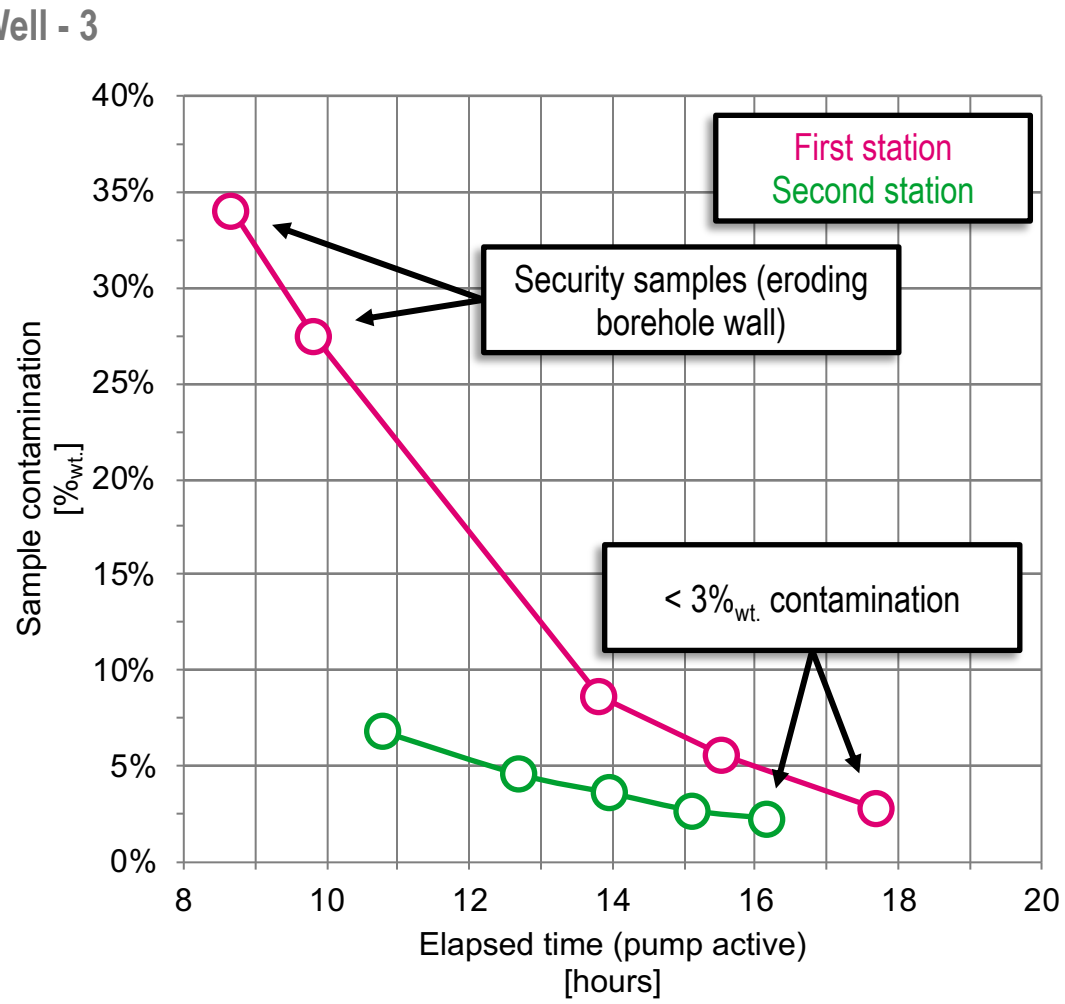




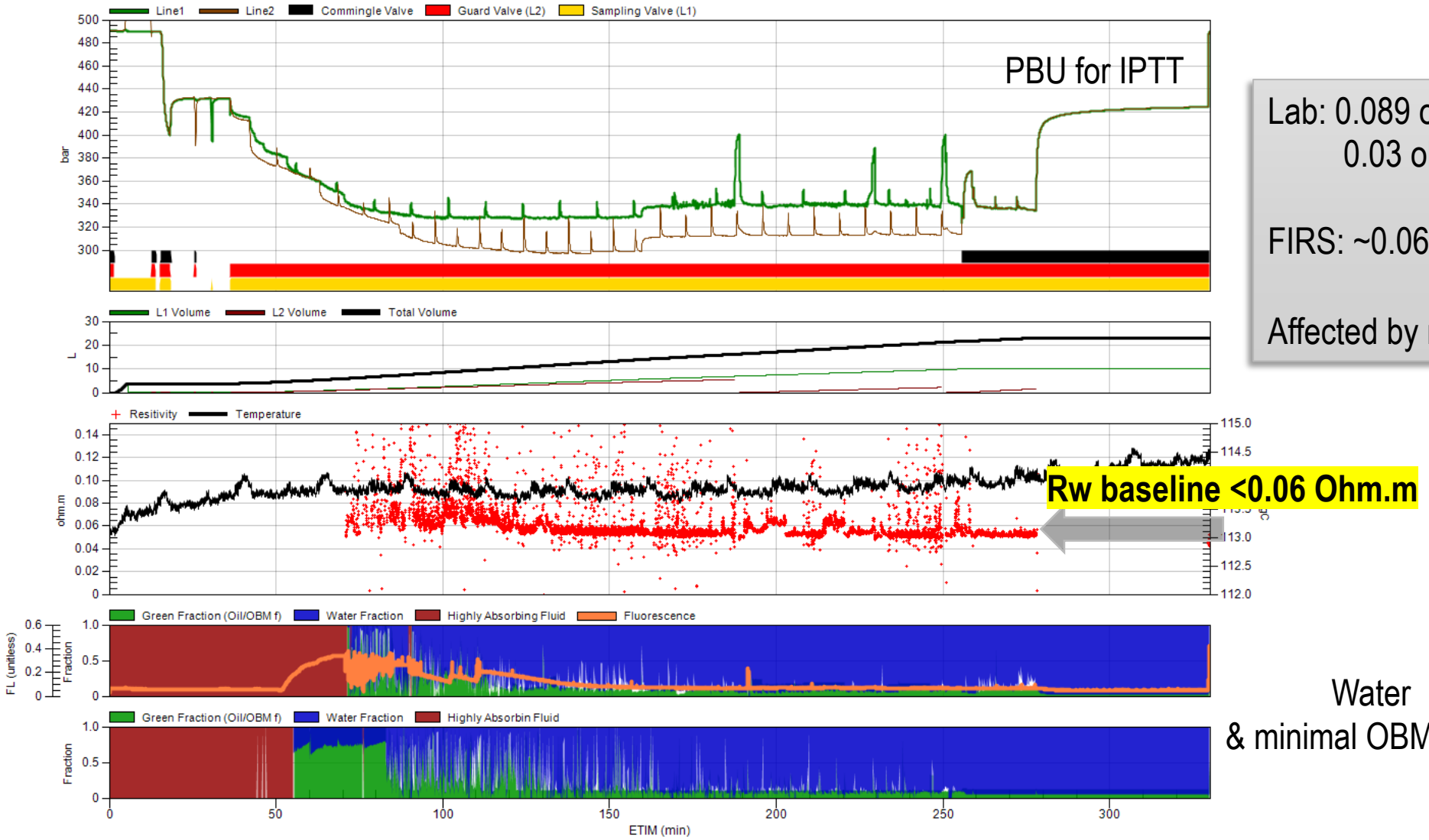
ODs start to shake as gas bubbles appear and migrate up in the flow line from 224.4bar.

Bubble point pressure validated with the standard lab Volume/Pressure experiment as 224bar

Sample quality and results



Focused Sampling of Formation Water @ 0.1mD/cP, 95 bar Drawdown



Lab: 0.089 ohm.m (89ppk) @ 22 degC
0.03 ohm*m @ 115degC (chart)

FIRS: ~0.06 ohm*m (35-40 ppk) @ 114degC

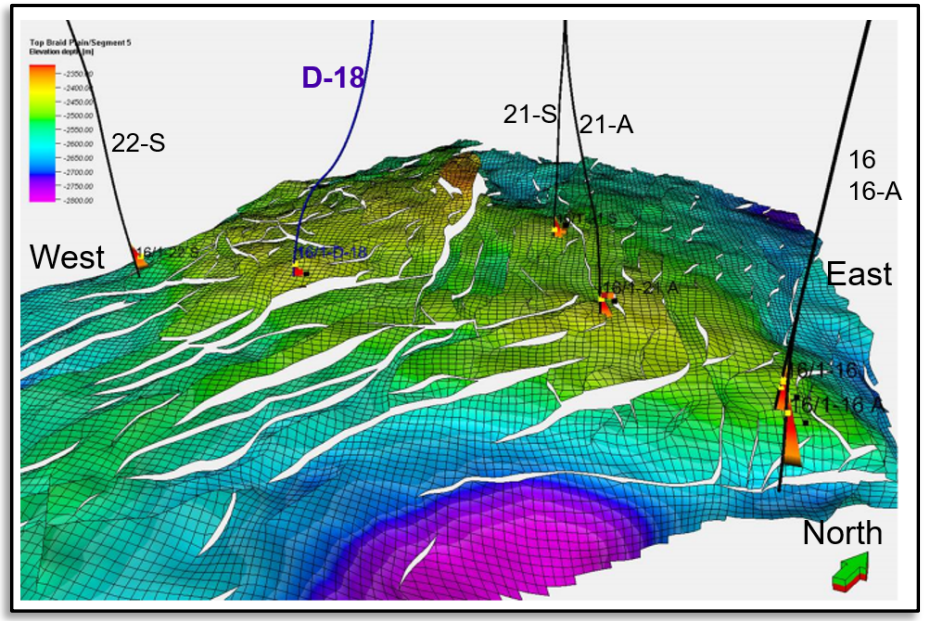
Affected by remaining filtrate or residual oil?

Water
& minimal OBM filtrate

Ivar Aasen D-18

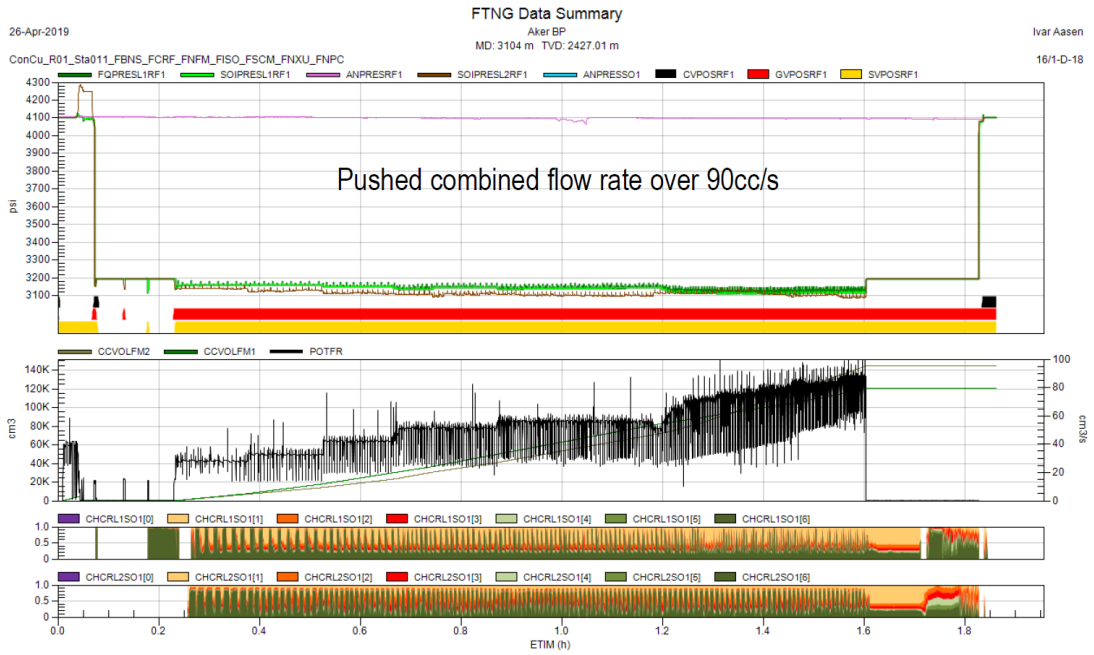
Summary

- Oil & Gas Sampling, DFA data to evaluate connected HC volume to assess vertical and lateral connectivity, delineate the Gas Oil Contact (GOC). Reservoir not at virgin conditions (depleted due to production)
- Three sampling stations at 3177.3m, 3162.2m, 3117.4m all oil close to Psat
- Three DFA stations at 3113.5m (oil), 3107.8m (oil) and 3104m (gas+ oil)
- Tested maximum combined flow rate to about 92cc/s



Field test results

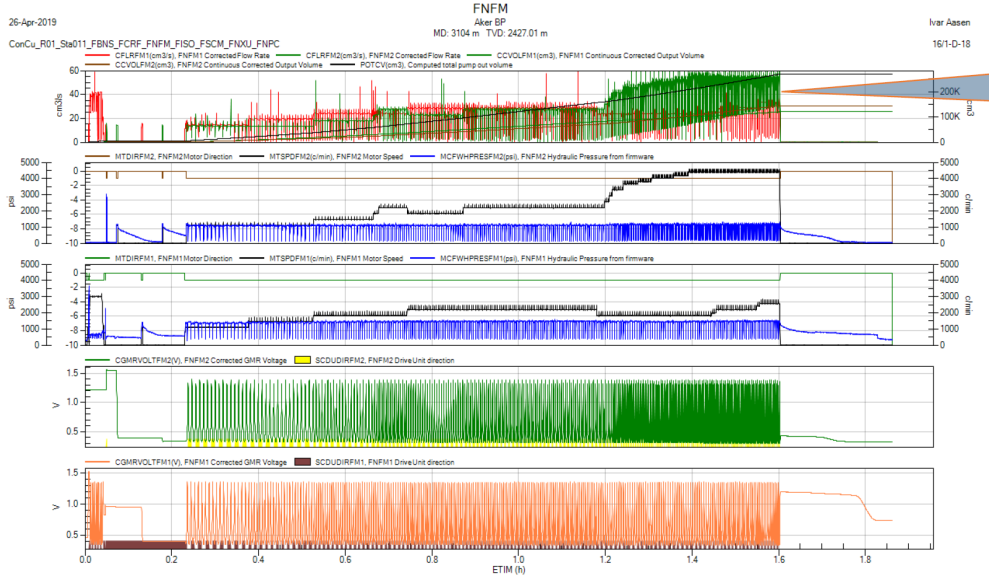
Testing of the high pumping rates



Important part of this job was to test the maximum achievable flow rate, within the available power limits of the 18AWG cable

Losses below Single Packer

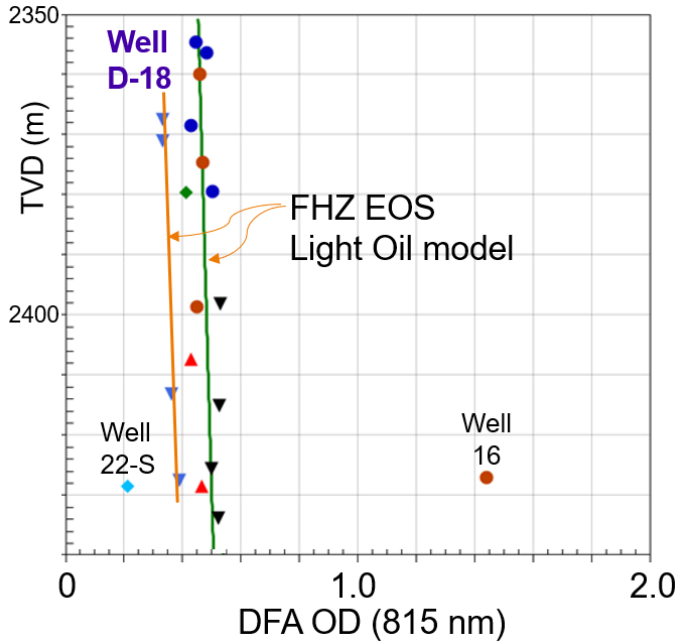
- Ora OPF has higher capacity to handle drilling fluid losses through the bypass lines.
- Handling losses has previously been an issue in Ivar Aasen and prevented from straddled packer tools in some cases.
- No bypass plugging observed, despite reports of mud losses before the job up to 300l/h.

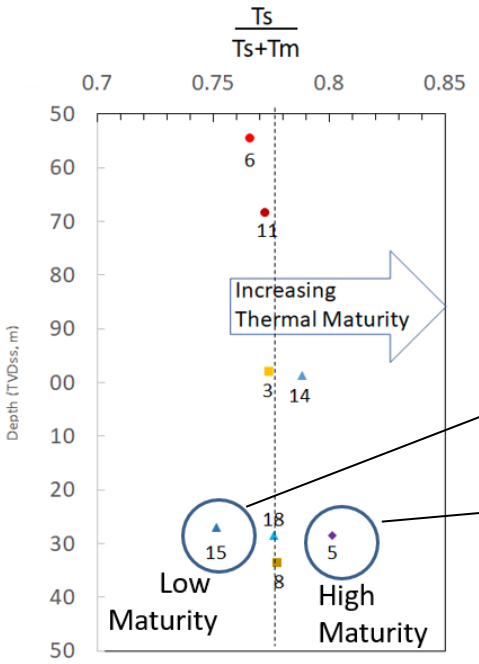


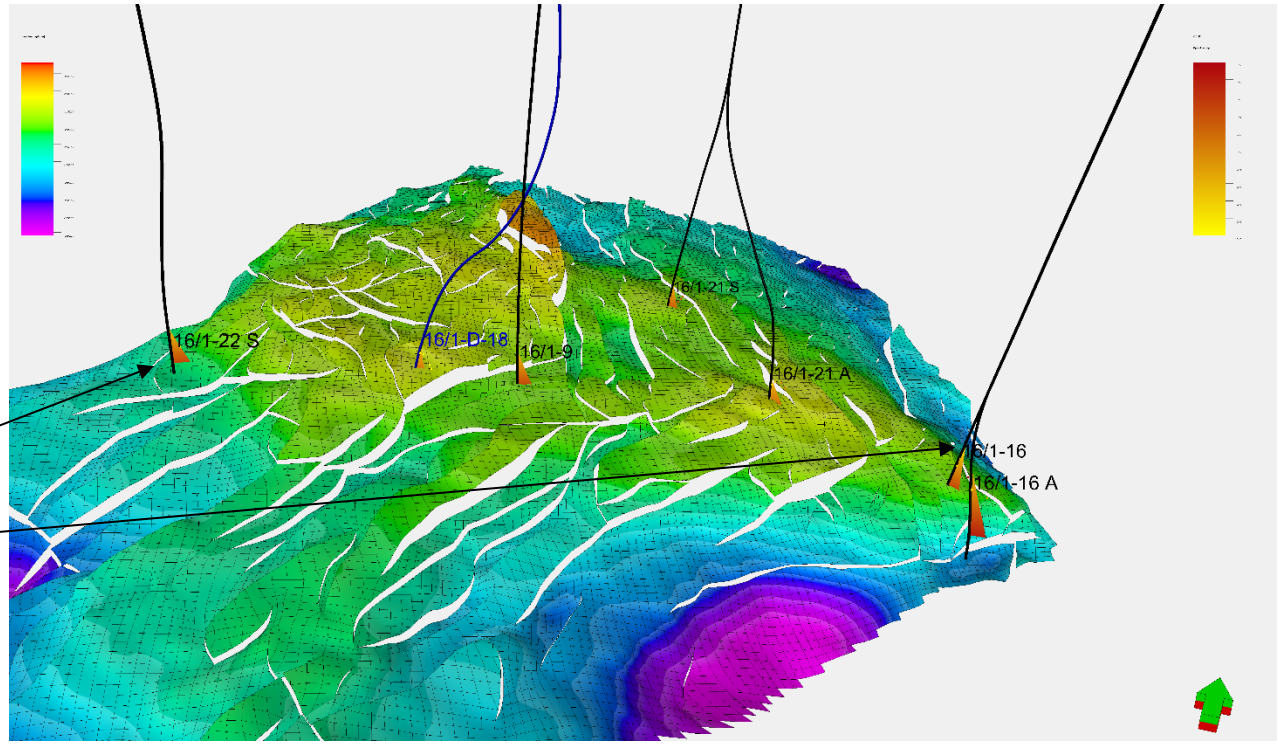
Maximum Flow rate:
57cc/s L1 and 35cc/s L2

Pumped 269 liters in 1.4h

Ora - RFG results





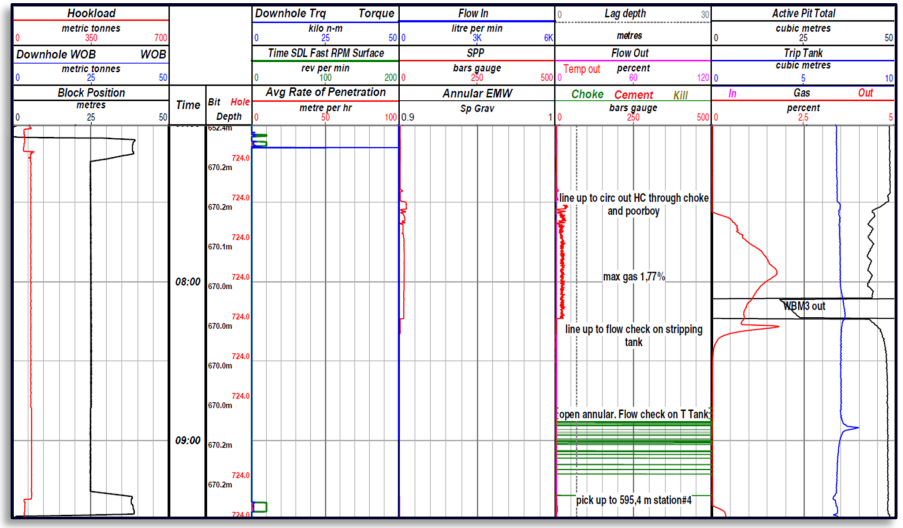


- The Ora evaluation in Well D-18 shows that the asphaltenes are equilibrated vertically over the 80 meter oil column.
- The Ora evaluation shows that well D-18 fluids are vertically equilibrated and slightly offset to lower asphaltene (in lower color) than the oils in the East. This is exactly expected given the charge model of increasing maturity fluids charging from the West as time progresses. This color offset in the West is consistent with the higher saturation pressure for the oils in the West as obtained from the deeper GOC in the West.
- Results are consistent with all pressure and production data from this field.

Continuous circulation of gas while sample clean up

- Formation depth 570m MD, water depth 345m MD → overburden 225 m
- Simulation allowed for only 65 l gas in wellbore, insufficient for cleanout
- FTWT system allowed for continuous circulation of pumped out hydrocarbons
- Cement pumps used to circulate, with returns to well test facilities
- Very little gas observed during job. Max reading = 1.77%

	Mud	Gas	
Molar mass	0.018	0.016	Kg/mol
	55.6	62.5	mol/Kg
Pumping rate	1000	6	l/min
Vol Ratio		**0.006**	
Density (water)	1	0.1	Kg/l
Pumping rate in Kg	1000	0.6	Kg/min
Pumping rate in mole	55556	38	mol/min
Molar ratio		**0.0007**	



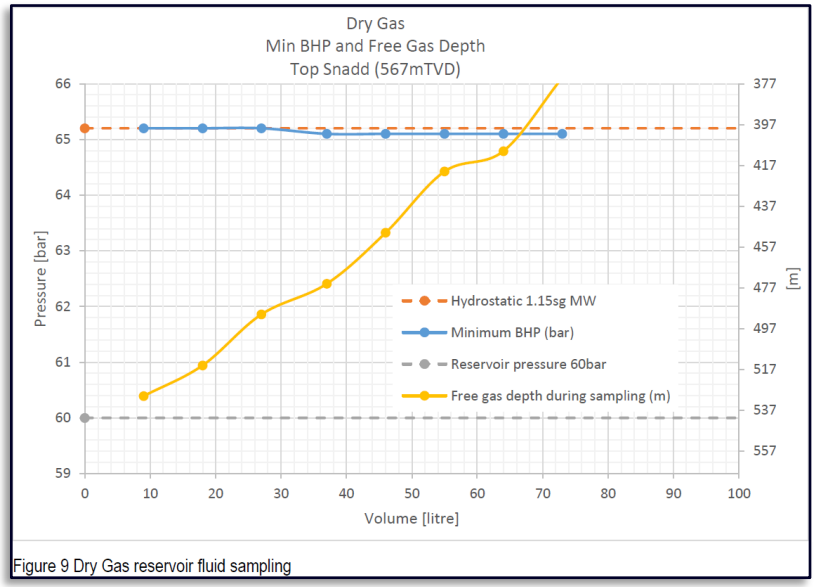
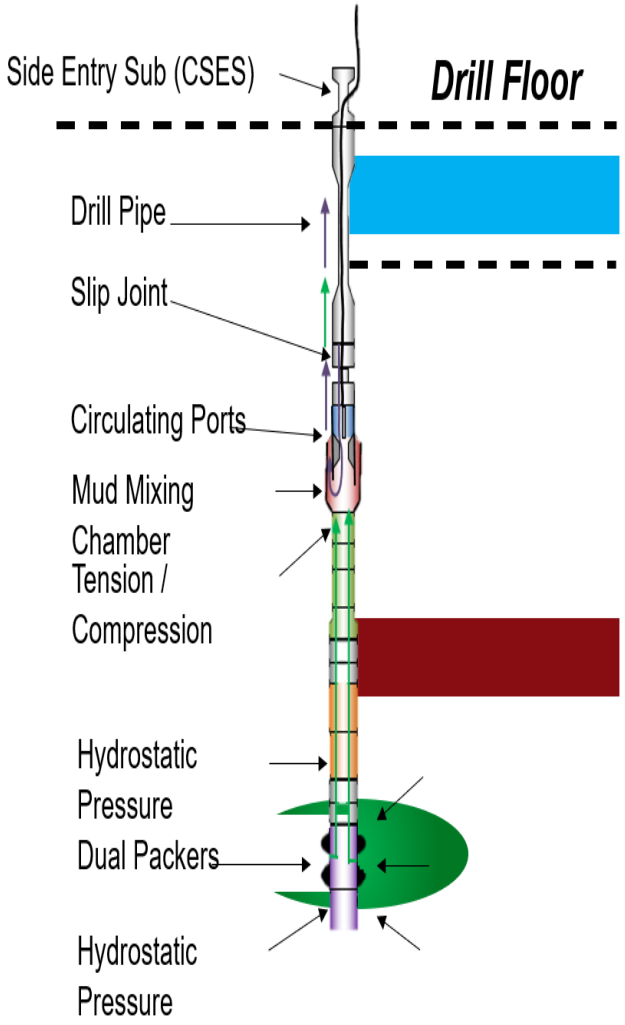
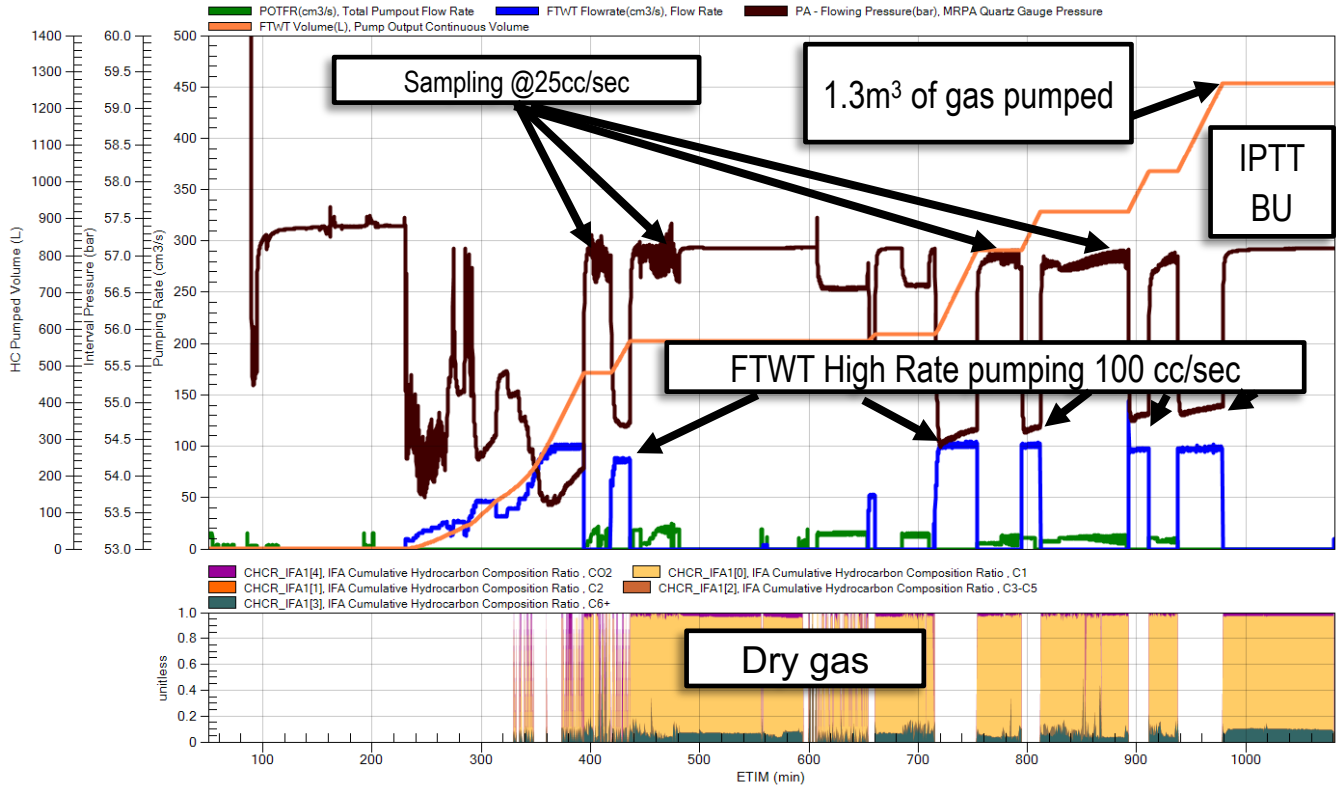


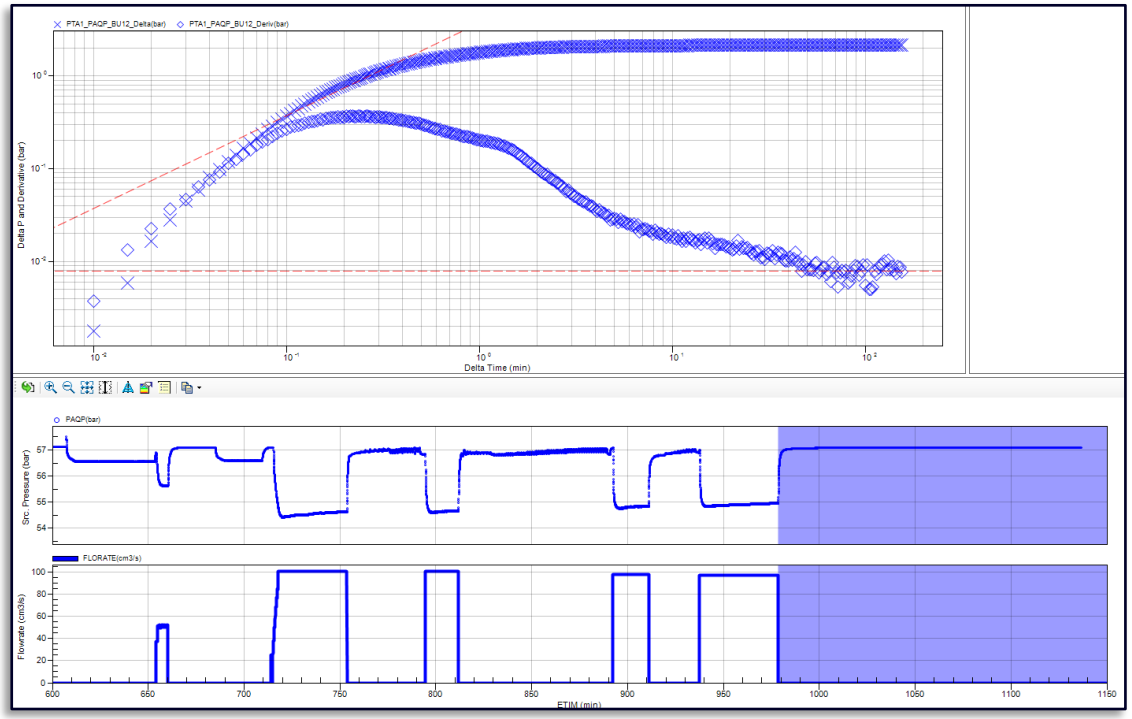
Figure 9 Dry Gas reservoir fluid sampling



First Worldwide FTWT/IPTT in Shallow Gas well



Up to 3 bar Flowing Pressure Drawdown in Dry Gas of 200 mD/cP allowed to estimate permeability flow the pressure transient data although significant amount of data smoothing



Achievements

- ✓ Representative sample in very low permeability reservoirs (<1 mD)
- ✓ Flow rate control
- ✓ Limited hydrocarbon inflow tolerance in very shallow reservoirs
- ✓ Limitation on flow rate when Mini-DST
- ✓ Complex NET
- ✓ Continuous hydrocarbons circulation & higher downhole pumping rates allow to acquire large volume samples of light oil and gas in shallow wells and estimate producibility.

SPIRIT ENERGY

PANDION ENERGY

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