Next Generation Fluid Sampling on the Norwegian Continental Shelf

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¹Aker BP, ²Schlumberger
Aker BP portfolio overview

- Aker BP (operator) - High production efficiency and continued resource growth
- Vitol (operator) - Medium to high production, assists in producing another oilfield
- Inter Asien (operator) - Pooring digital operations model
- Skar / Argo (operator) - Strong base performance and high upside potential
- Ula/Talker (operator) - Late life production with significant upside potential
- Jahann Sverdrup (partner) - World-class development with superior economics
- NOAkA (operator) - Targeting onsource development

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

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

2019 Aker BP exploration program

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<th>Est. Depth</th>
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Formation Testing Next Generation – Ora

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

1 motor, 2 pumps

MDT

Ora

120 cc/s => 200 cc/s

T = 0.214 hour

0.2 cc/s

2 cc/s

30 cc/s
CASE STUDY #1 – SAMPLING VERY LOW PERMEABILITY

Tight mudstone play fluid sampling

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

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**Equilibrium fluid optical density** (DFA asphaltene gradient proxy)

**Well #3**
- No vertical connectivity
- No lateral connectivity

**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

CASE STUDY #1 – SAMPLING VERY LOW PERMEABILITY

 Controlled drawdown (~20 bara) (flowing pressure above \( P_b \))

 Fluid density decreasing (cleaning up)

 Fluid density fairly stable (clean crude oil?)

 Bottles filled

 IPTT

 Pb Test

 Pump from the flowline with very low rate

 Onset of scattering

 \( P_b - 224.4 \text{bar} \)

 Decreasing Pressure

 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
CASE STUDY #1 – SAMPLING VERY LOW PERMEABILITY

Sample quality and results

Well - 3

- First station
- Second station

Security samples (eroding borehole wall)

Sample contamination [%wt.]

Elapsed time (pump active) [hours]

< 3%wt. contamination

- Security samples (eroding borehole wall)
- First station
- Second station

Sample quality:
- 0%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%

Graph showing sample contamination over elapsed time.
CASE STUDY #1 – SAMPLING VERY LOW PERMEABILITY

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?

Rw baseline <0.06 Ohm.m

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
CASE STUDY #2 - ORA FOR ADDITIONAL WELL IN THE RFG STUDY ON IVAR AASEN OIL FIELD

Field test results

Testing of the high pumping rates

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.

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

Maximum Flow rate: 5700l/s L1 and 3600l/s L2

Pumped 289 liters in 1.4h
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%

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<td>(l/min)</td>
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CASE STUDY #3 - CONCEPTUAL TEST OF THE INFLOW MANAGEMENT TEST SYSTEM FOR FGNT

First Worldwide FTWT/IPTT in Shallow Gas well

Sampling @25 cc/sec

1.3 m³ of gas pumped

IPTT BU

FTWT High Rate pumping 100 cc/sec

Dry gas

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.