Characterization of Fluid Composition While Drilling to Aid Well Placement

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Case study presented at AAPG ICE, 2018
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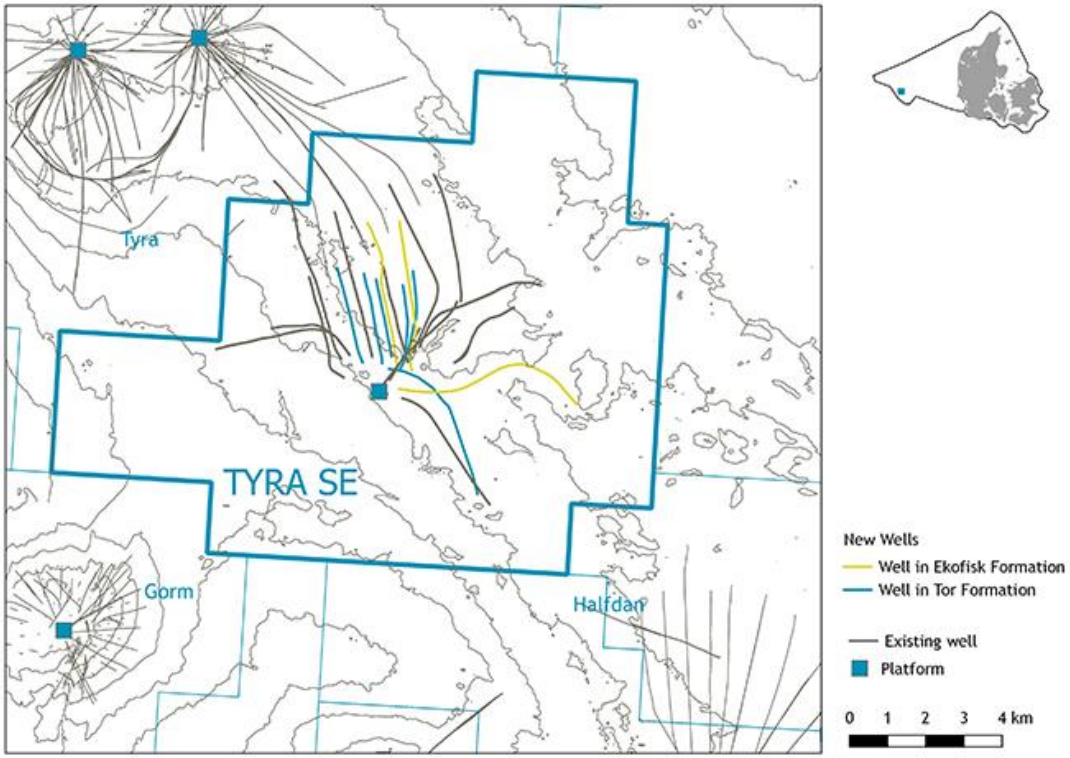
Reservoir setting

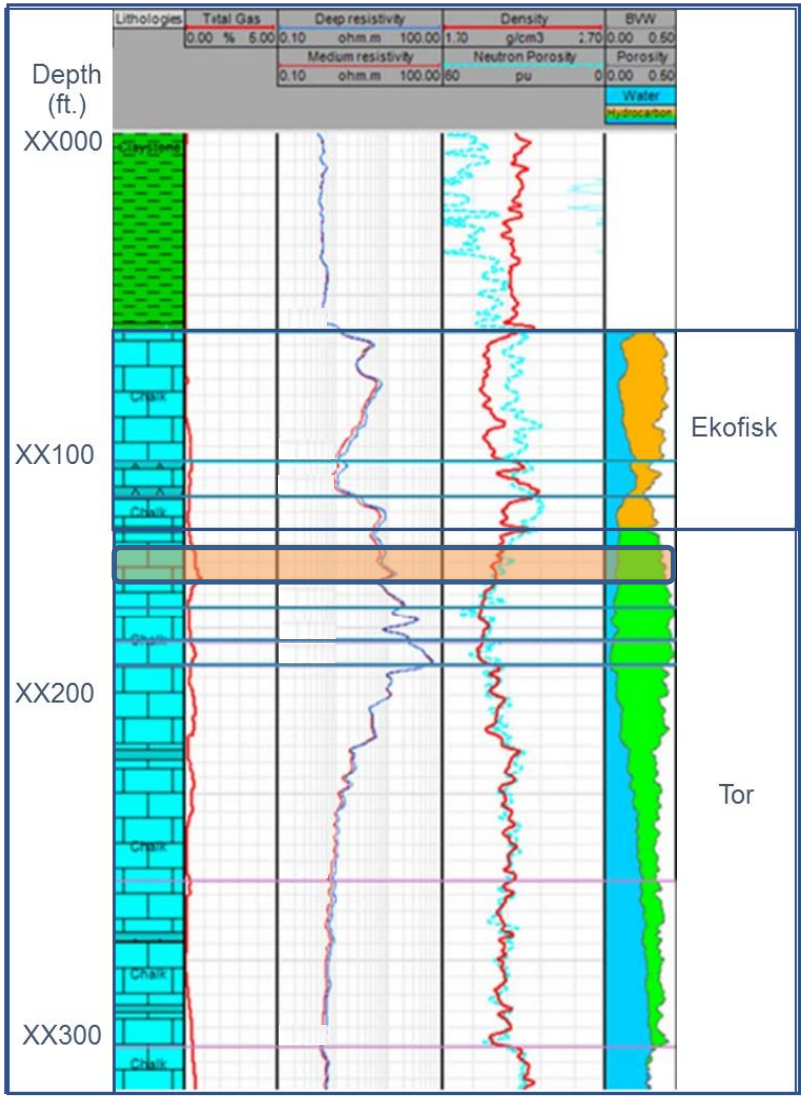
- 220 km West of Esbjerg
- Total E&P Denmark A/S
- Discovered: 1991
- Year on stream: 2002
- Reservoir depth: 2,050 m
- Reserves: 50 million BBOE

- *Source: Nordosfonden*



Development Challenge

- Oil & Gas production from Tor & Ekofisk
- Since 2002:
  - 11 wells drilled
  - 4 P&A
  - Poor well landing
  - Inconsistent exposure to desired hydrocarbons
  - Decreased production
  - Loss of revenue
- Well bore needs to be in target formation and phase



A New Approach

- Maximizing reservoir contact in the correct phase
- Place high in oil leg, maintains oil production due to migrating OWC and GOC
- Advanced Surface Fluid Logging (ASFL) was the key to provide well placement
- Geochemically steering the well = World 1st

Mud Gas Data

Extraction

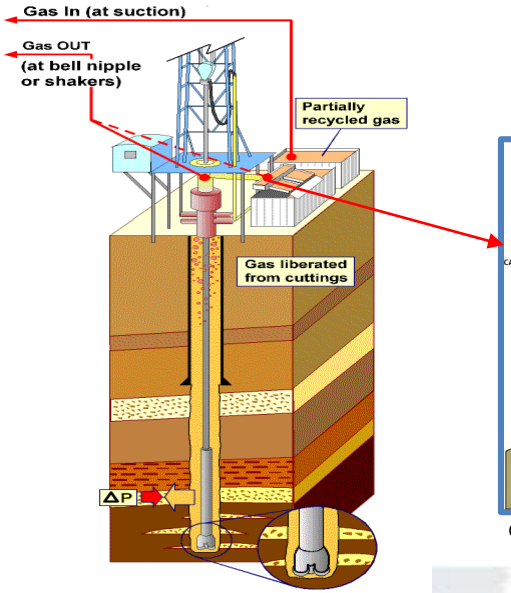
- Efficiency
- Reliability
- Repeatability
- Flexibility
- Maintenance

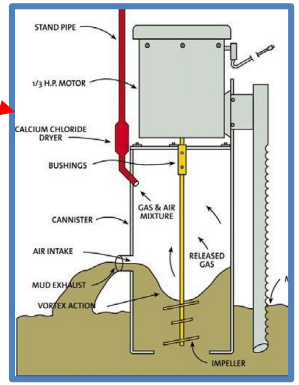
Analysis

- Detection Limit
- Components
- Principle
- Analysis time

Interpretation

- Data Analysis
- RT Transfer
- Integration





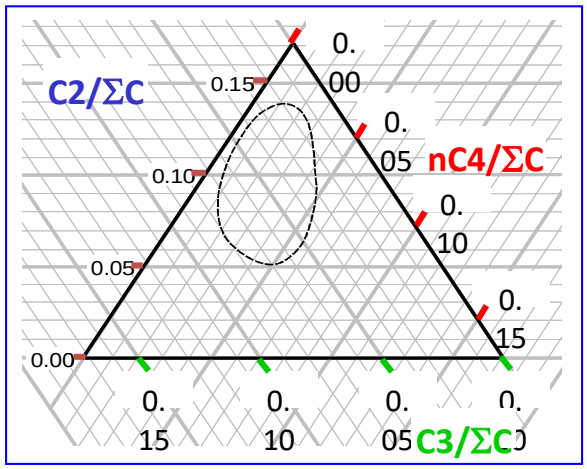
Graphic from: Geosearch Logging Inc

Evaluation needs

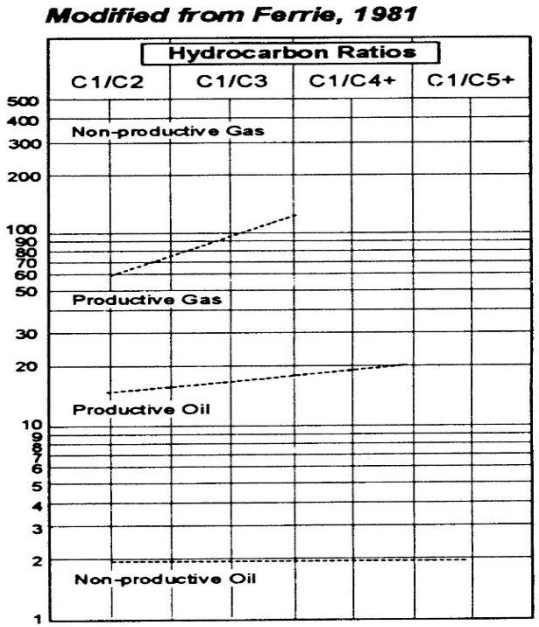
- Improve reservoir fluid evaluation along the entire well
- Accurate fluid characterization in challenging drilling environment

Mud Gas Data Interpretation – Fluid Typing

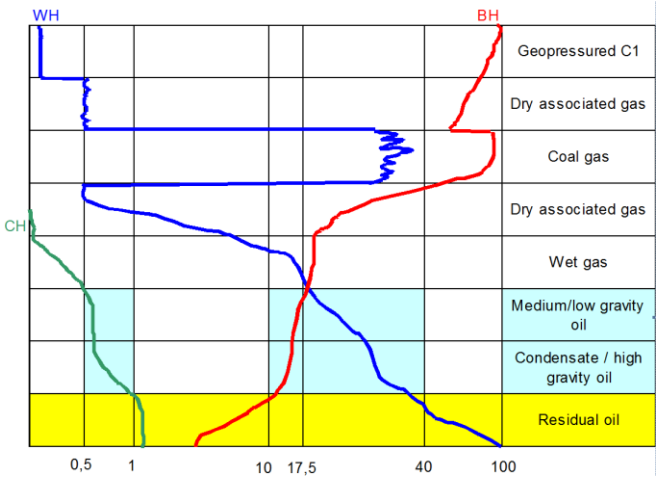
Triangle Method



Pixler ratios



Haworth ratios

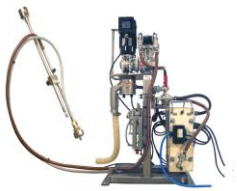


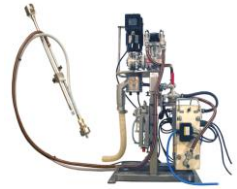
Challenges

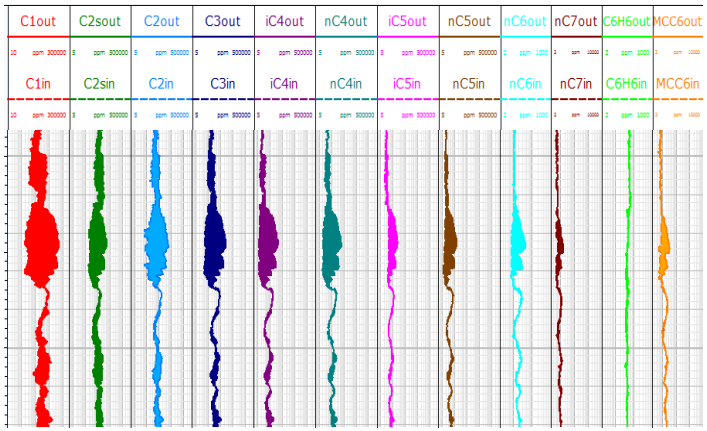
- Fluid type is not only conditioned by the fluid components but also by the reservoir conditions
- Only the composition of light fluid fraction is accessible to gas measurements
- The composition of the gas extracted from the mud is different from the composition of the reservoir fluid

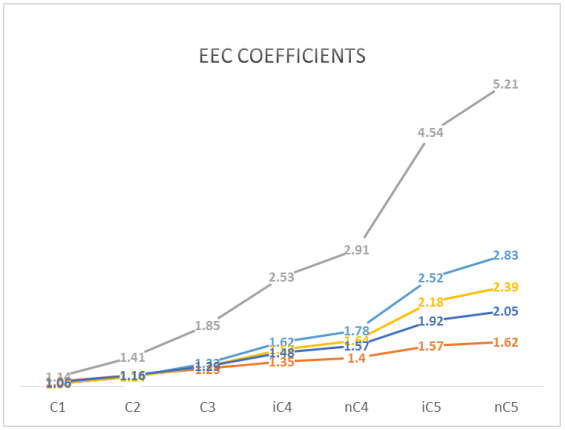
From ‘gas data analysis’ to ‘Fluid Logging’

- Constant and repeatable conditions of extraction
- Remove surface contamination due to gas entrained in mud
- Account for variable extraction efficiency
- Calibrate with known composition from field
- Create continuous fluid/ fluid facies log

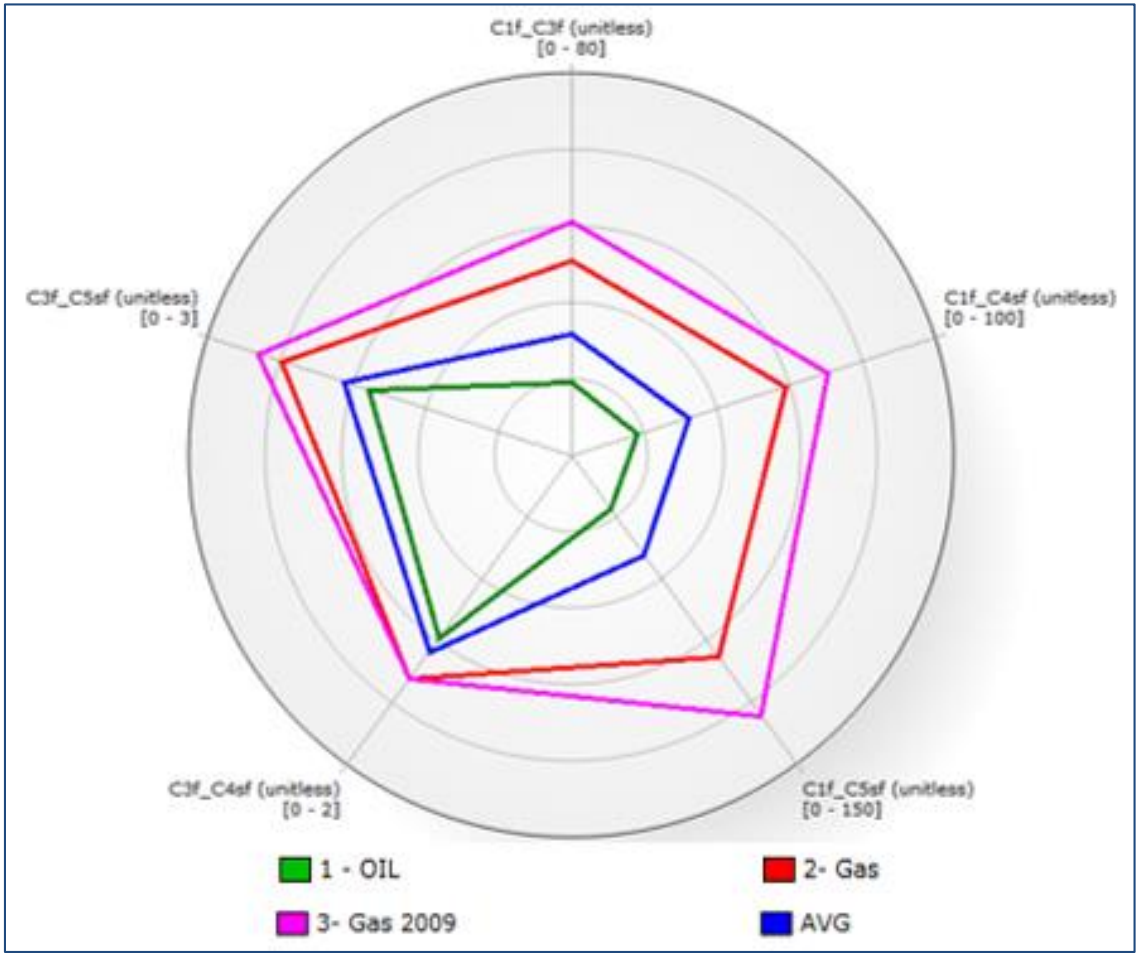




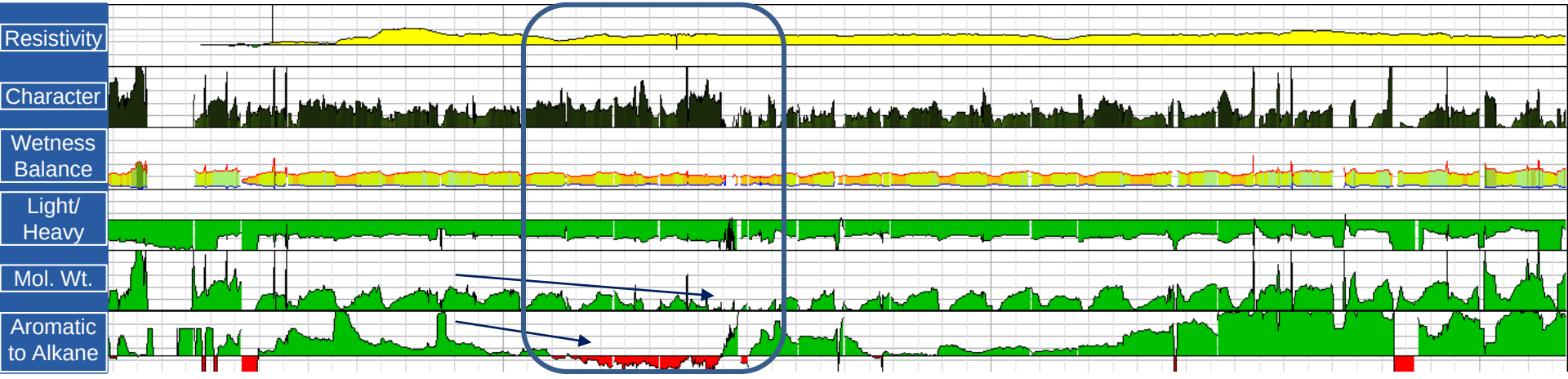


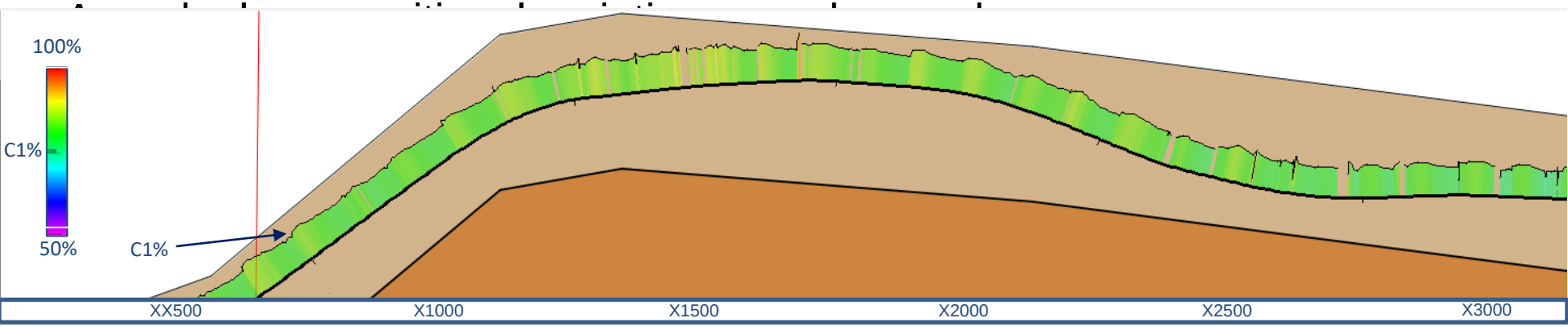


Creating the signature



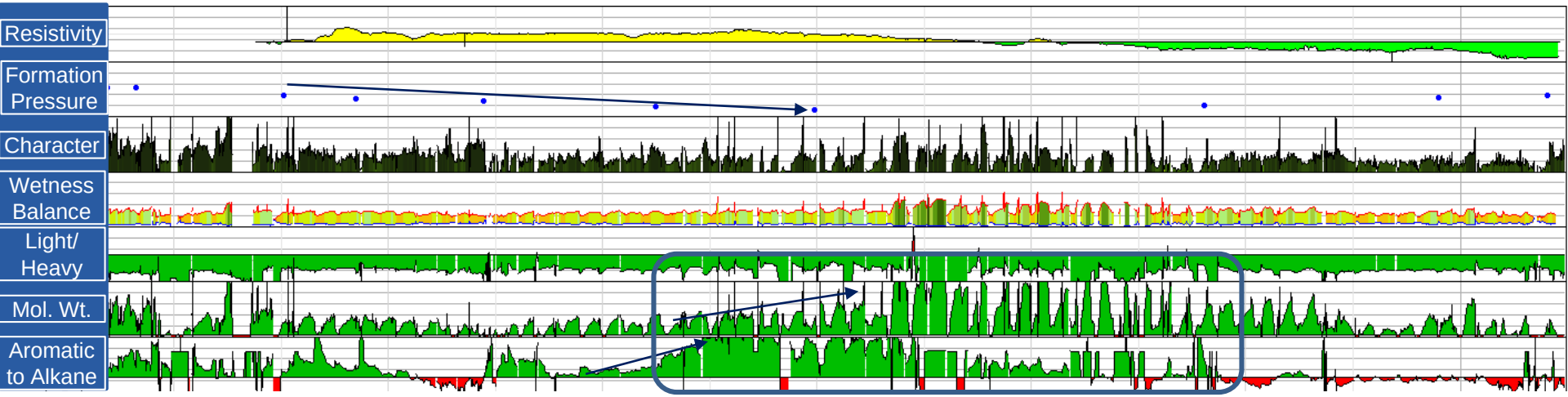
Drilling the Well - Landing

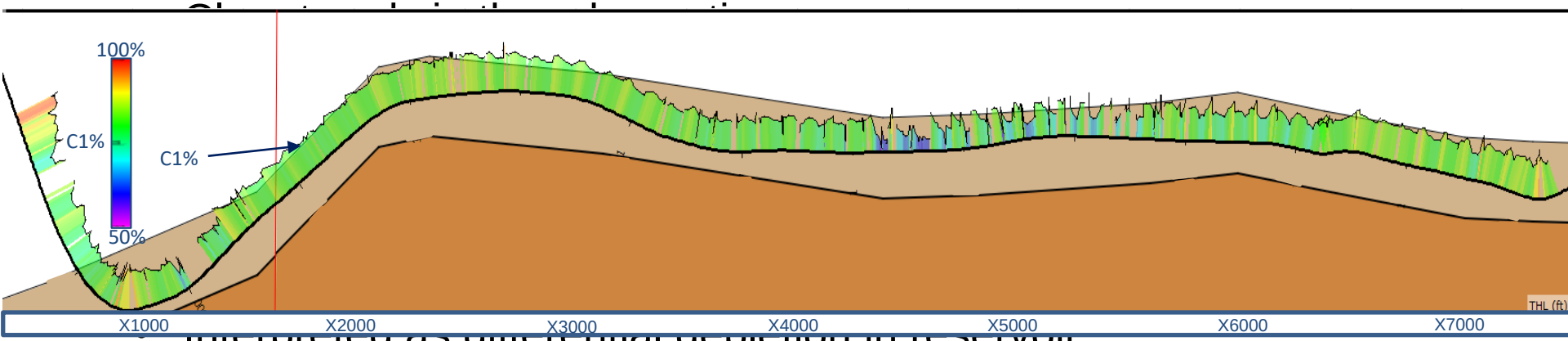




- Overall clear oil signature at the control point

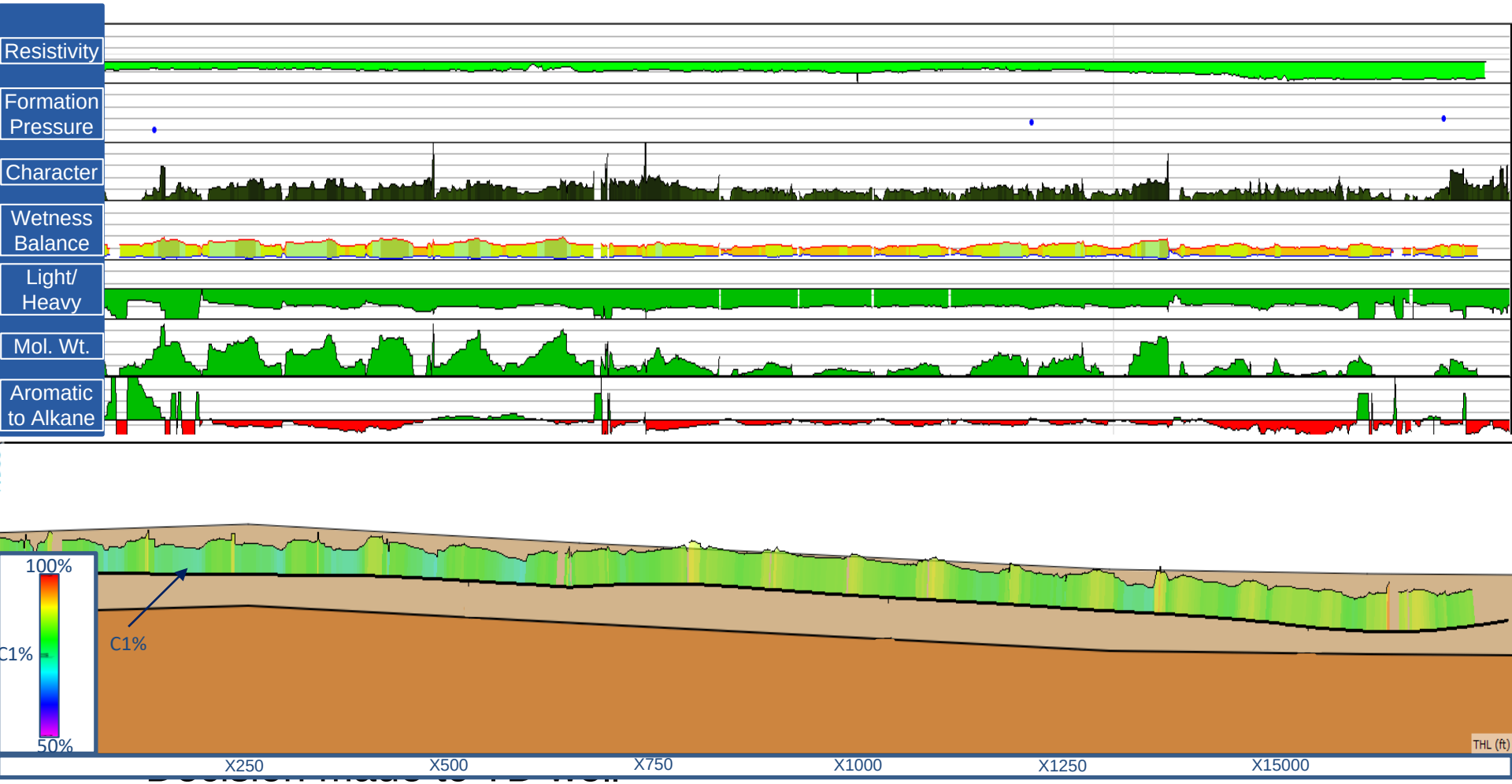
Drilling the Well – Steering ahead





interpreted as differential depletion in reservoir

Drilling the Well - TD

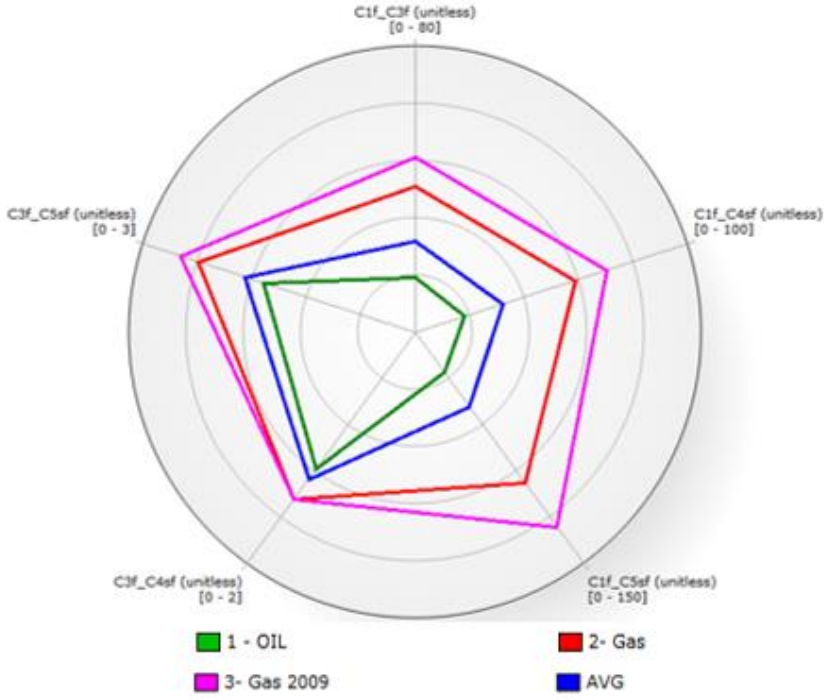


Observations

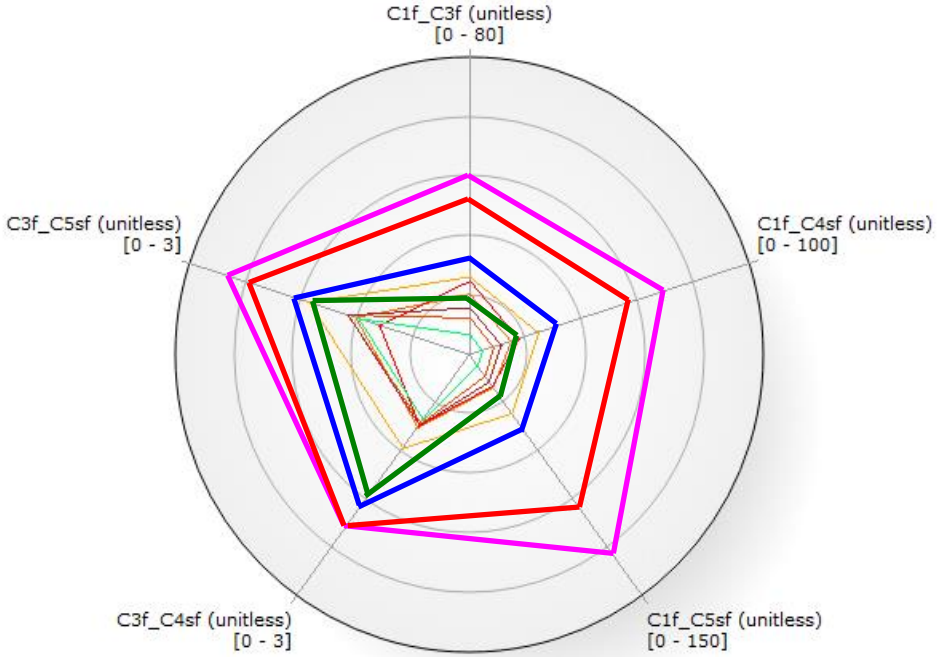
- Six fluids identified, with five similar to the original OIL PVT signature
- The heaviest oil Fluid indicates a composition with 55-56% C1
- The lightest oil Fluid indicates a composition with 79-80% C1.

Fluids	0% 20% 40% 60% 80% 100%	%C1	%C2	%C3	%iC4	%nC4	%iC5	%nC5
1a		82.50	7.90	3.92	1.16	2.23	1.22	1.07
1b		77.29	8.78	4.74	1.91	3.35	2.09	1.84
1c		69.38	9.93	6.96	2.94	5.27	2.89	2.62
1e		73.16	9.99	5.77	2.37	4.24	2.37	2.10
1d		79.06	8.32	3.97	1.65	2.89	2.08	2.02
2a		56.09	11.75	10.32	4.21	8.69	4.63	4.31

Observations



Modelled signature



Measured signature

Lightest

Heaviest

Observations

Ratio	Prejob Model Cut-off	Post Job Refined cut-off		
		Gas	Undifferentiated	Oil
Mol. Wt.	19	<19.5	19.5 to 21.5	>21.5
Light to Heavy	5	>5	3.5 to 5	<3.5
Aromatic to Alkane	0.5	<0.4	0.4 to 0.5	>0.5

- Nearly all cut offs were refined
- THC Norm use with caution
- Tends to over-estimate hydrocarbon content

Conclusions

- Fluid logging provides a means to obtain continuous fluid printing with calibrated compositional data
- Delivered the primary objective & increased net reservoir by 15%
- Verified a compositional trend with Formation Pressure While Drilling
- Confirmed an increase in Sw with reduction in component volumes
- Cut offs derived from ASFL refined the petrophysical model

Thank you, Any Questions?