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Advanced mud-gas analysis

Old data – New insights

T. Rognmo, W.A.H. Lekens, C. Kierdorf, E. Fugelli

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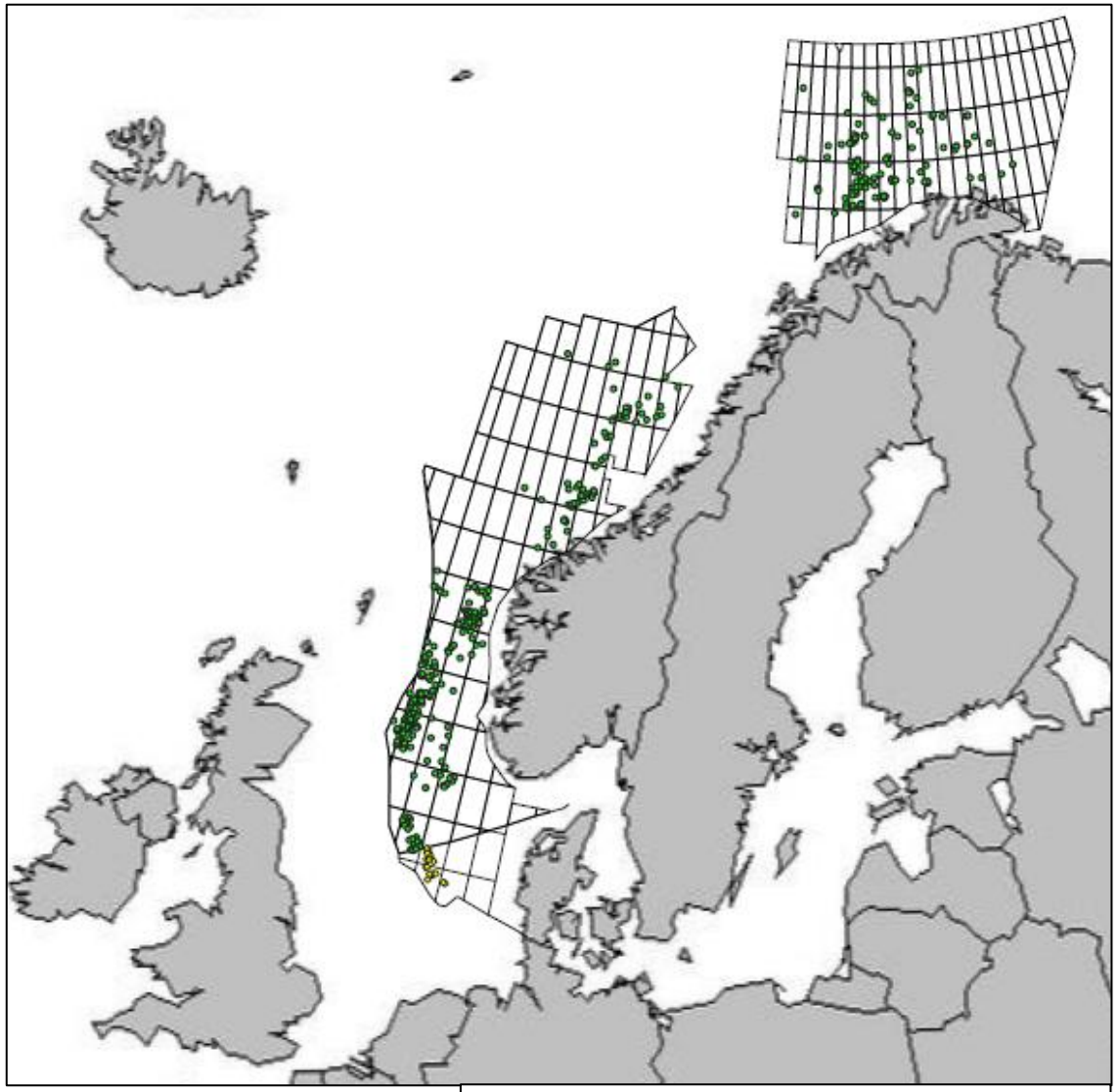
Outline:

- Mud gas Workflow
  - Mud gas QC
  - Analysis
  - Interpretation
- Practical use of mud gas data
  - Case study



Methodology tested on ~ 500 wells in Norway, UK & Denmark

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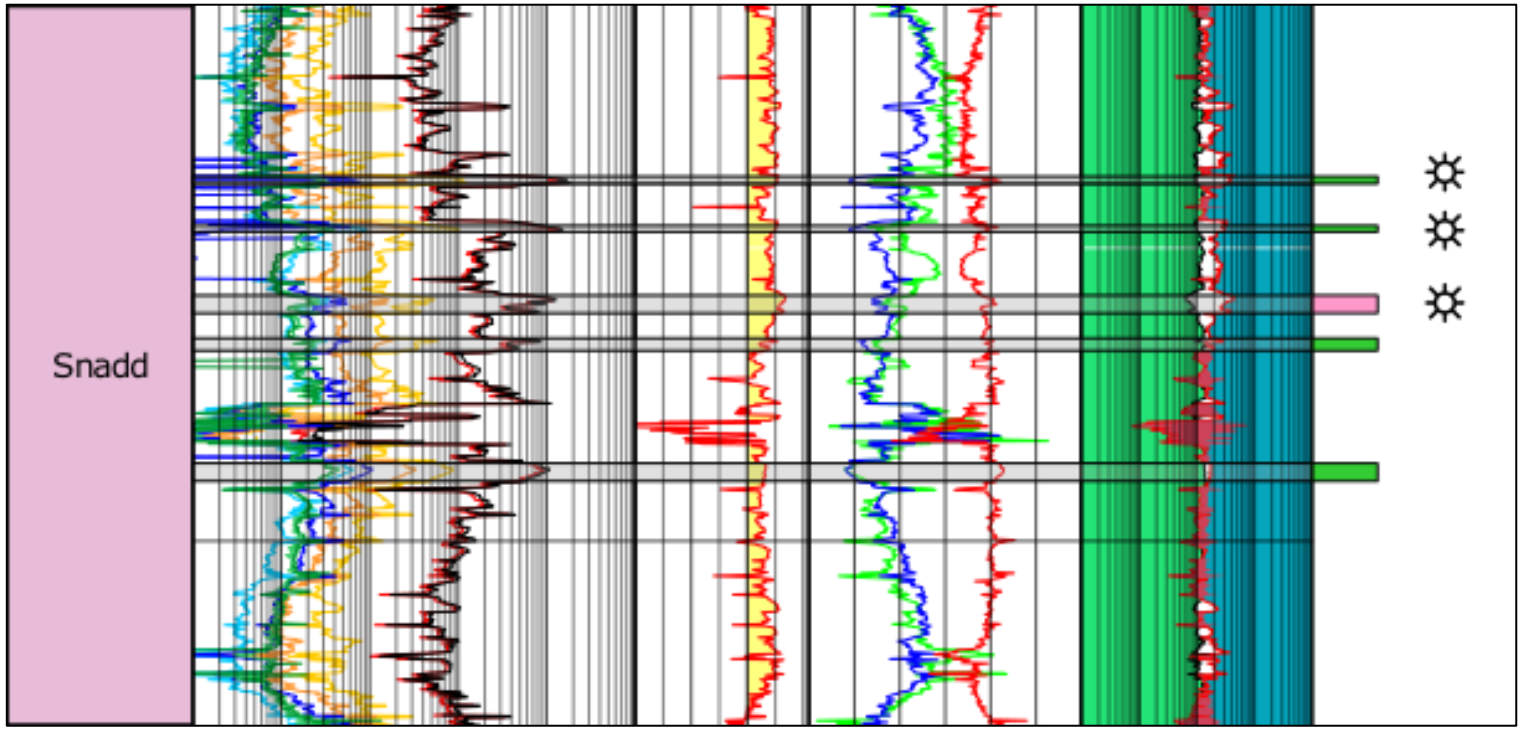
What are shows?

From Schlumberger Oilfield Glossary

"A surface observation of hydrocarbons, usually observed as florescent liquid on cuttings when viewed with an ultraviolet or black light (oil show) or increased gas readings from the mud logger's gas-detection equipment (gas show)."

A gas show is a gas reading that varies in magnitude or composition from the established background.



Reported gas shows and gas shows observed on the mud log data.

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Workflow

Standard workflow for evaluating mud gas data.

Hydrocarbon & Seal Evaluation Workflow

W.A.H. Lekens, A. Minovic, T. Rognmo

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Data sets:

- Surface Logging Data
- Geological Data
- Headspace Data

QC:

- Gas system/calibration
- Borehole factors
- Data quality

Analysis:

- Gas Ratios
- Gas Quality
- HC Type

Interpretation:

- Show intensity
- Potential HC zones
- Potential seals/barriers

Results:

- QC'ed raw data
- Evaluation Logs
- Comparison Plots
- Integration with seismic sections and displayed in mapview

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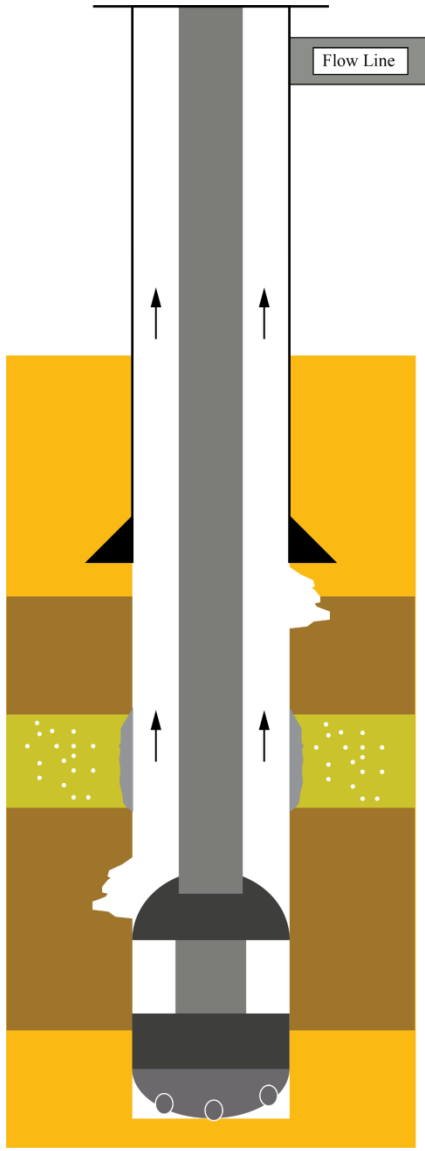
Mudgas QC

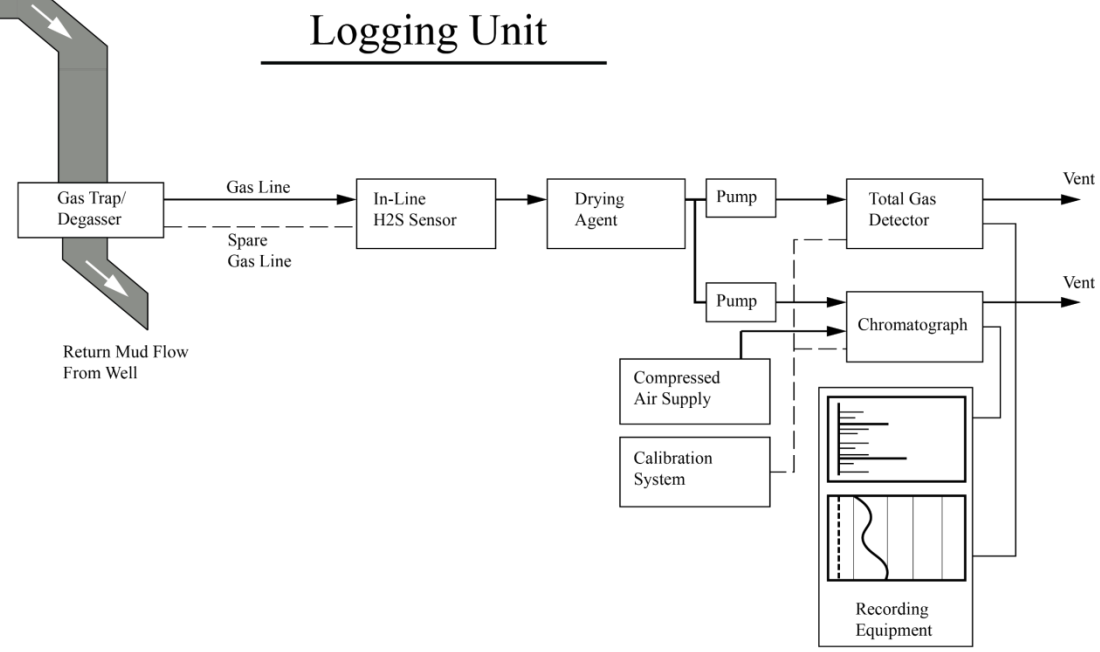
Downhole Influences

- Mud type & contaminations
- Recycling
- Overbalance
- Temperature

Surface Influences

- Flowline
- Gas system
- Analyser
- Calibration





Modified from Weatherford / ENI, SPE Talk, 2012

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Mudgas QC

Downhole Influences

- Mud type & contaminations
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Surface Influences

- Flowline
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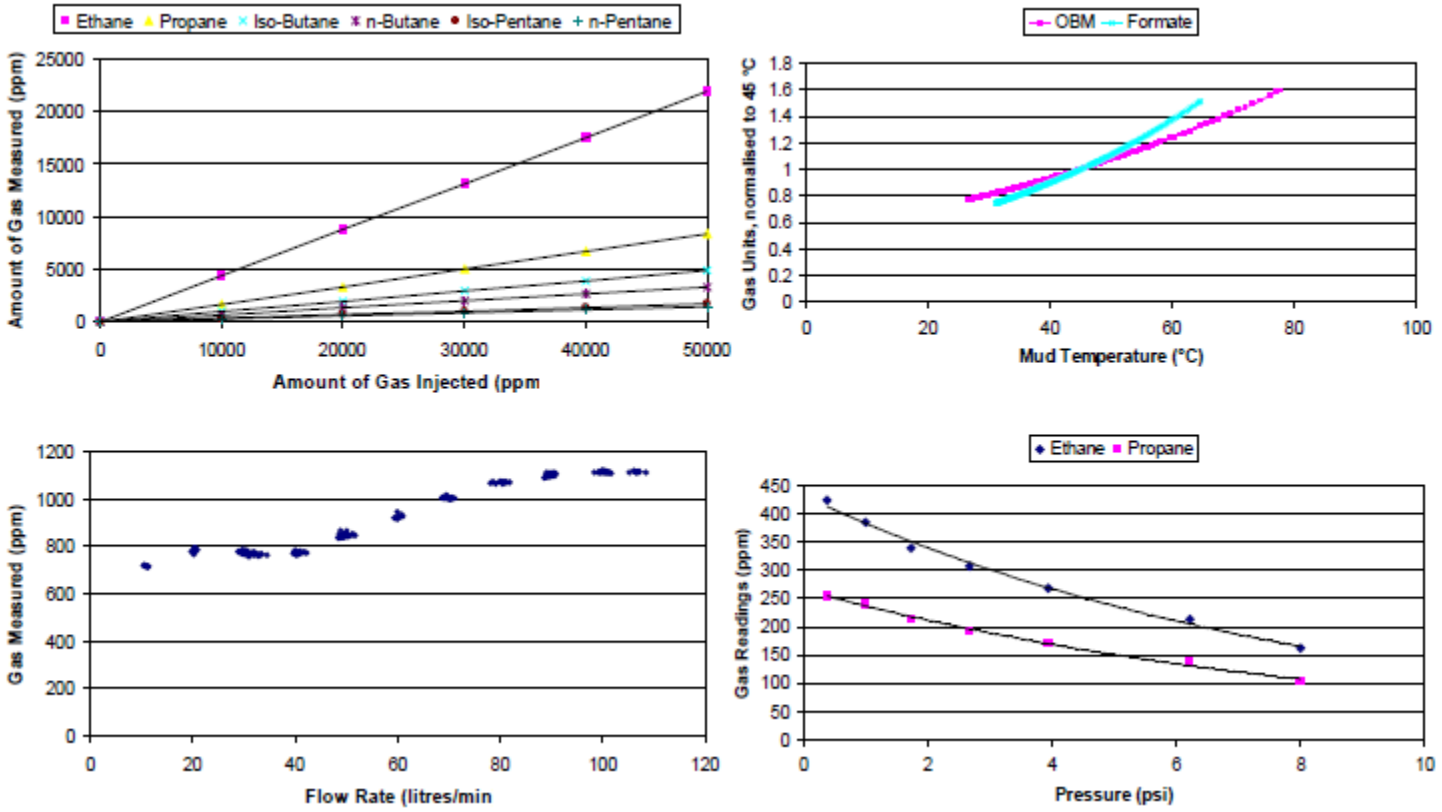

Weatherford study
Forber et al., 2009

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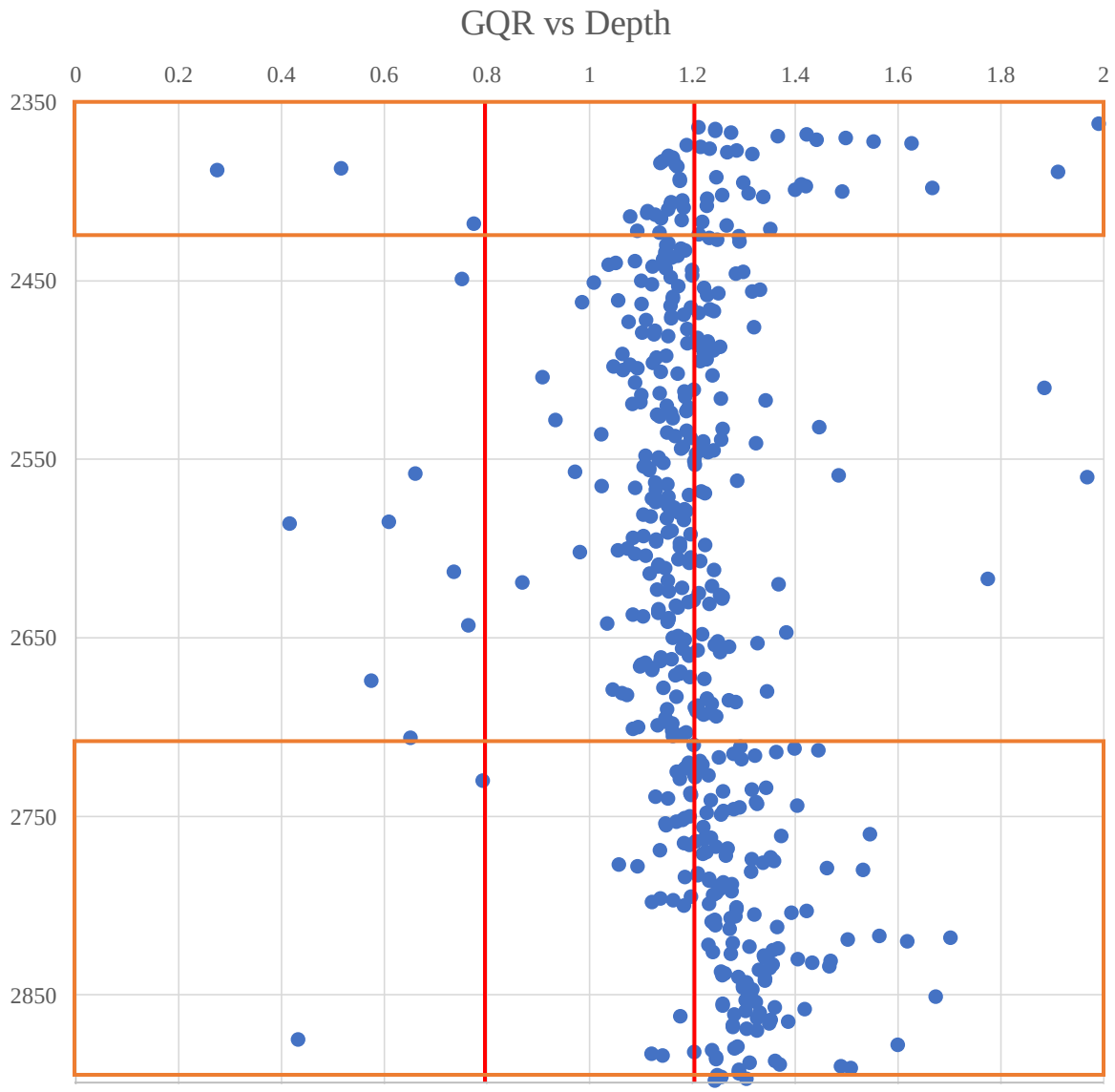
Mudgas QC

Gas Quality Ratio: TG /ΣCcorrected

TG (Total Gas) is to be from the Gas Detector

ΣC is taken from the Gas Chromatograph



GQR = TG / (C1 + 2*C2 + 3*C3 + 4*(iC4 + nC4) + 5*(iC5 + nC5))

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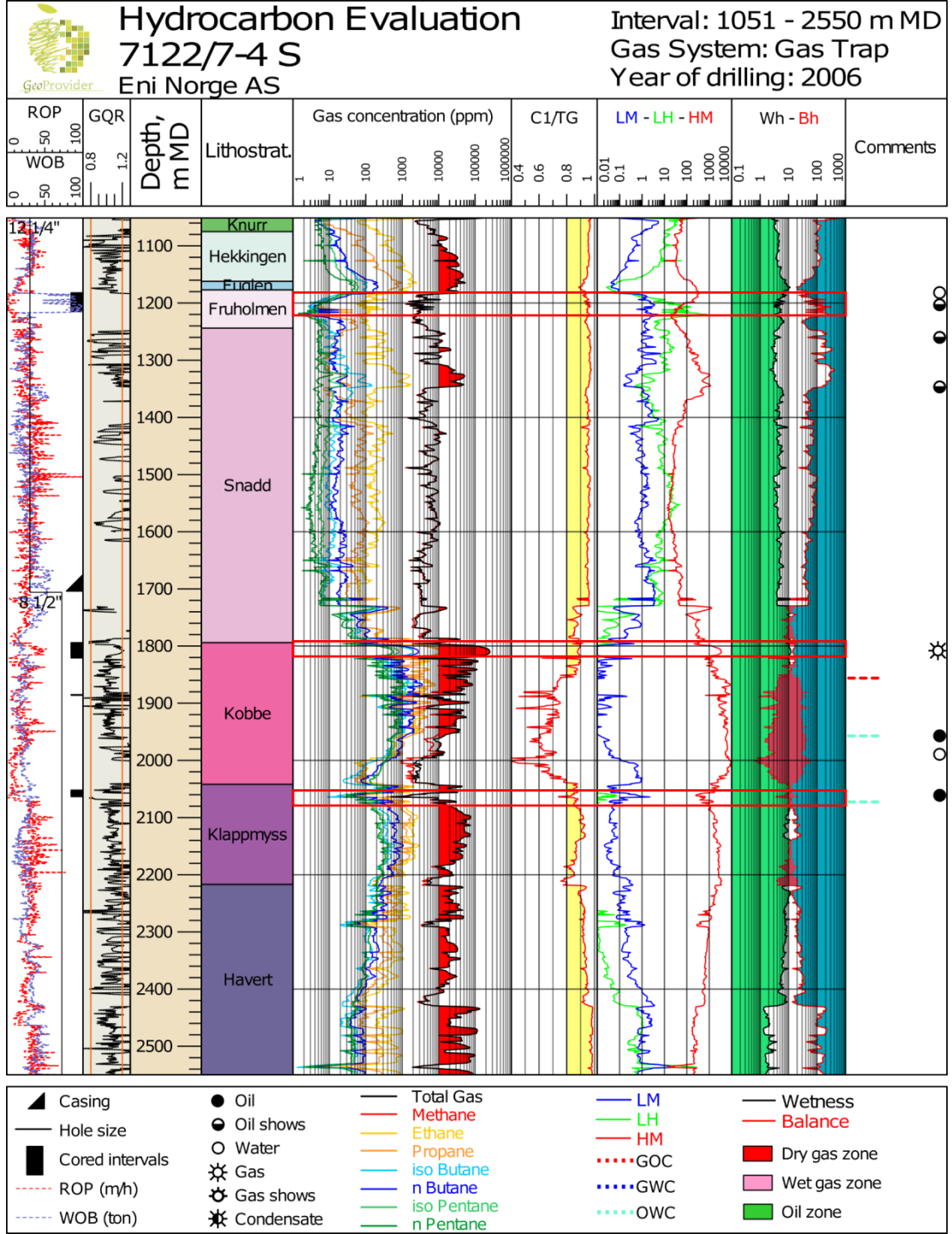
Mudgas QC

Important factors:

- Gas system (Gas trap, Headspace, etc.)
- Butane & Pentane in the 70s – 80s
- Cores and Casings
  - Low circulation
- OBM/Synthetic OBM
  - Contaminations
  - Low interactions between the formations and the borehole
- DBM
  - Generation of HC from SR or OBM



7122/7-4S
Goliath Field
Barents Sea

Mudgas QC

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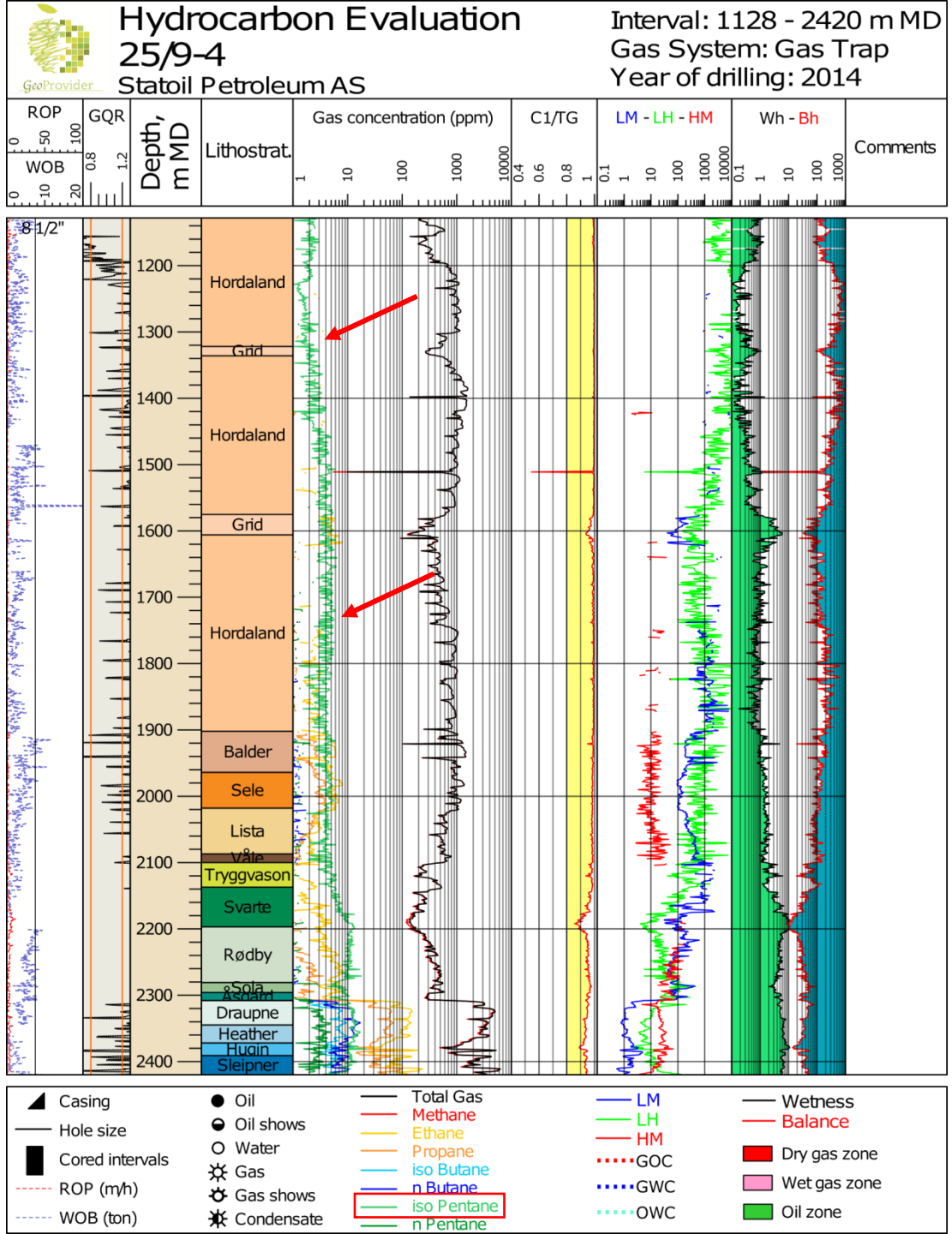


25/9-4
Stord Basin
North Sea

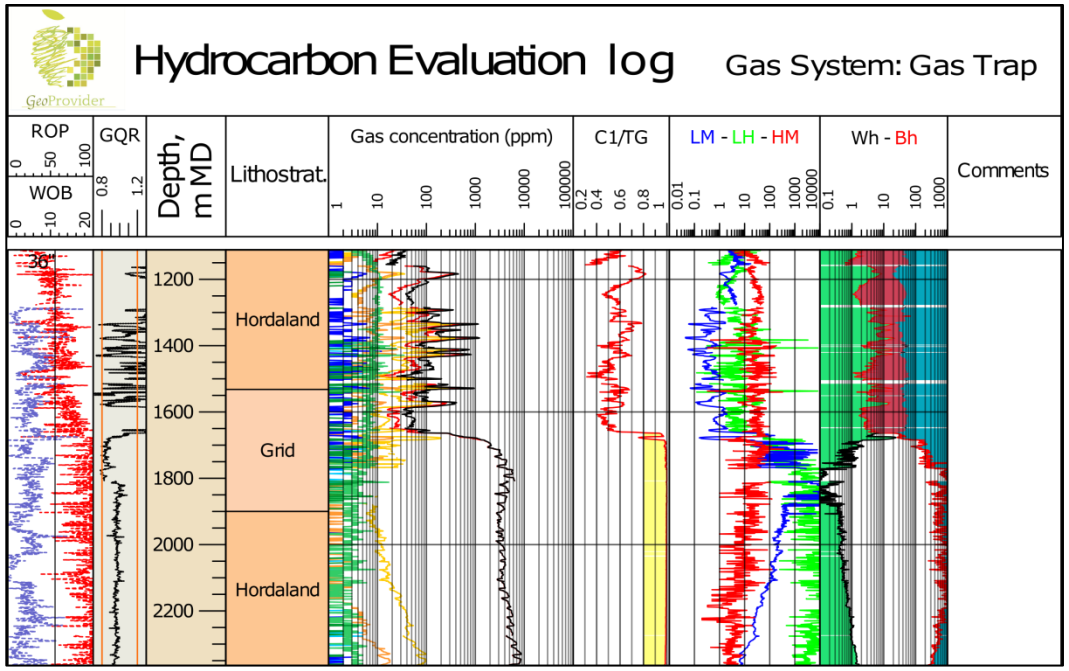
Analysis

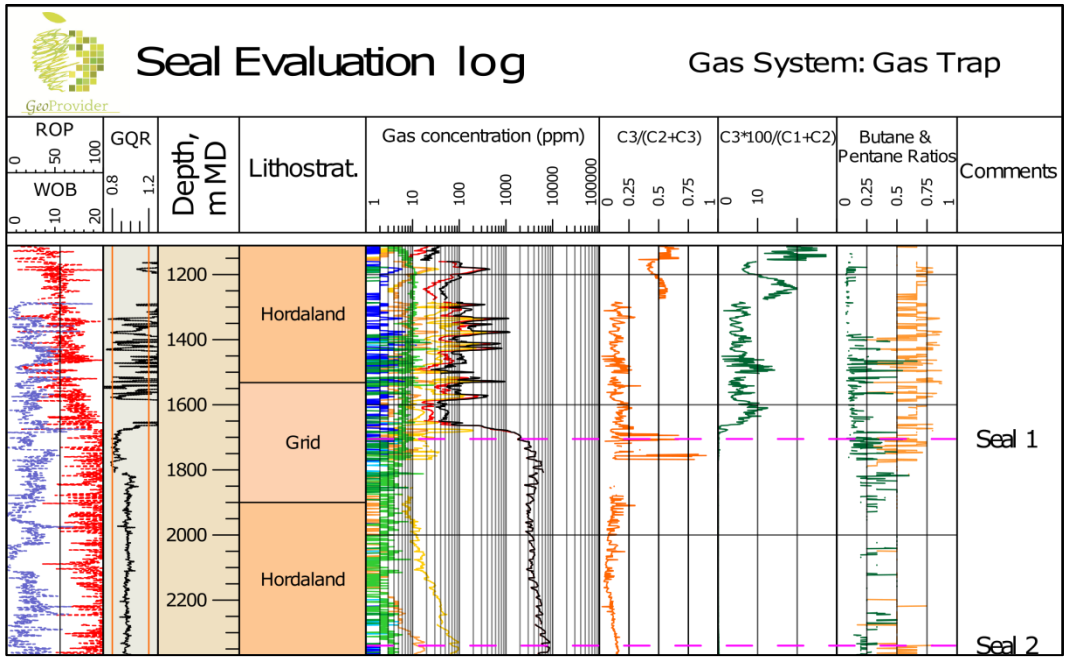
Hydrocarbon Evaluation Ratios

- Methane Content
- Wetness and Balance Ratios
- C1/C2
- LM-LH-HM

Seal Evaluation Ratios

- Prinzhofer Ratio
- Ten Haven Ratio
- Butane & Pentane Ratios





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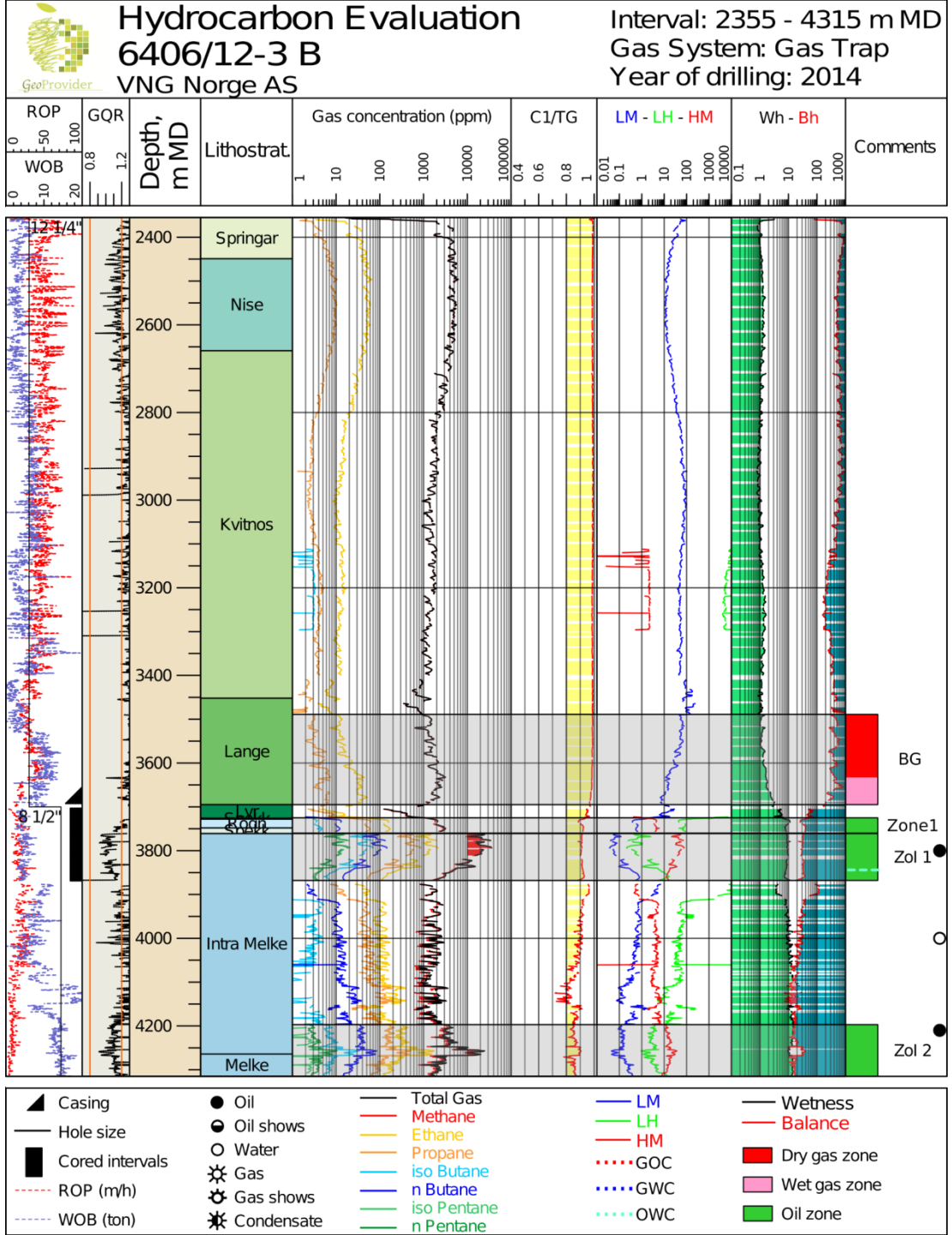
Hydrocarbon Evaluation

Background gas vs shows

- Gas shows calibrated against “outer factors”, can be seen as rapid increase in TG concentrations and with levels of C2+ above background.

- Background gas display continuous readings not affected by changes in the lithology.

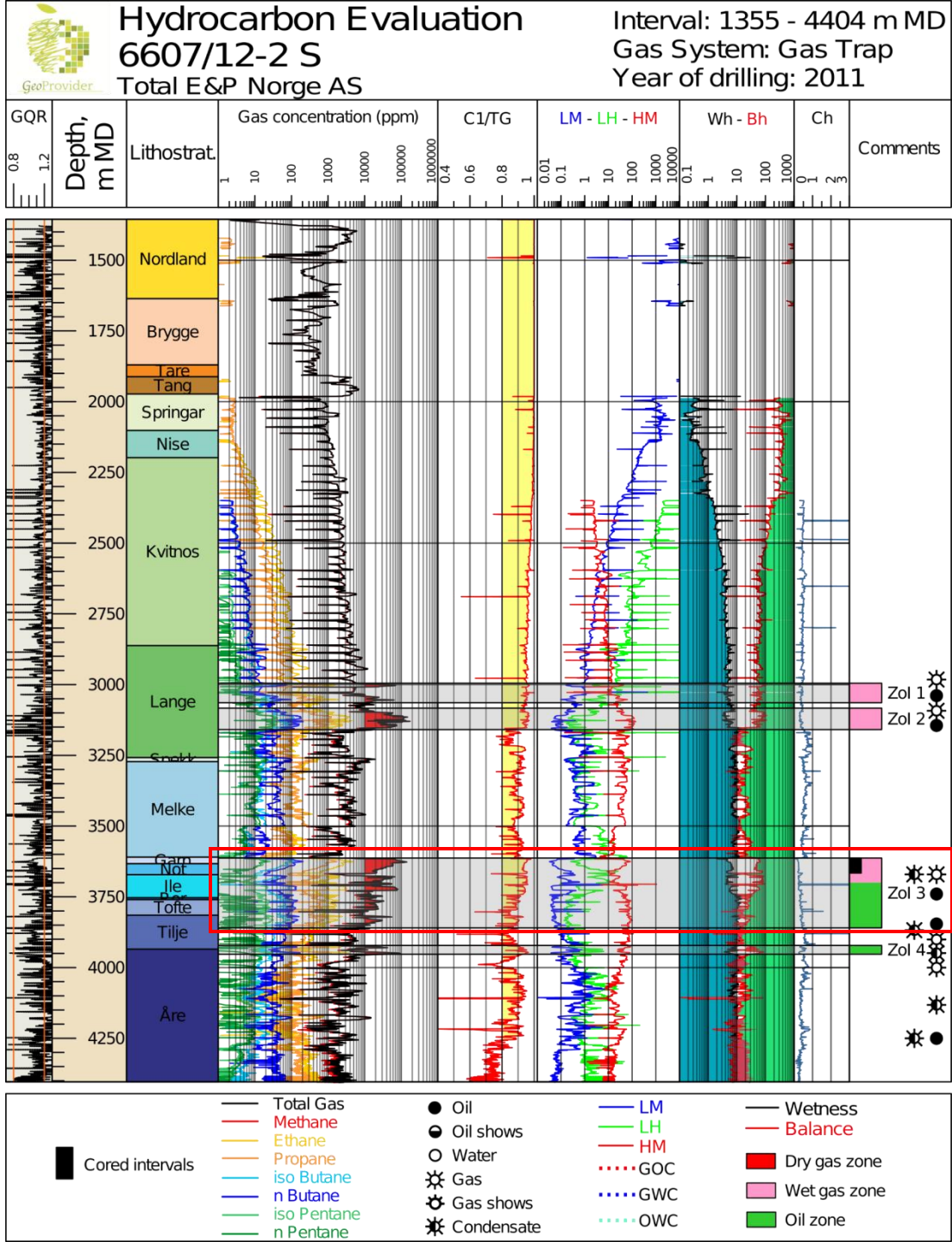


6406/12-3 B
Fenja Field
Norwegian Sea

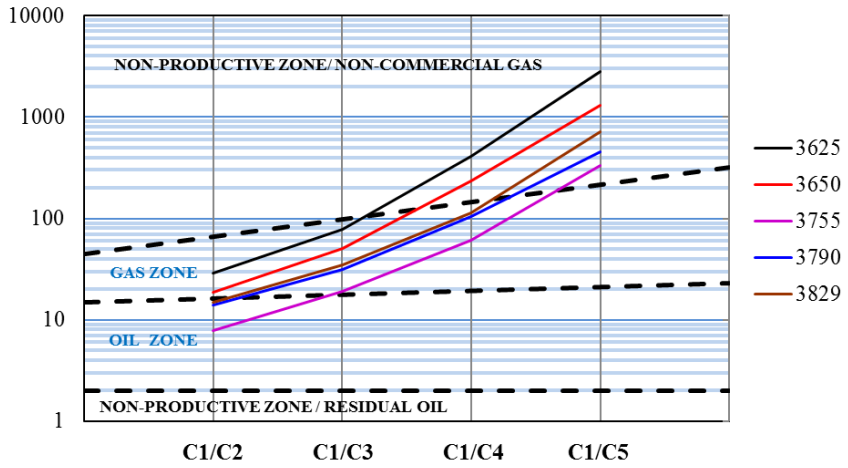
Hydrocarbon Evaluation

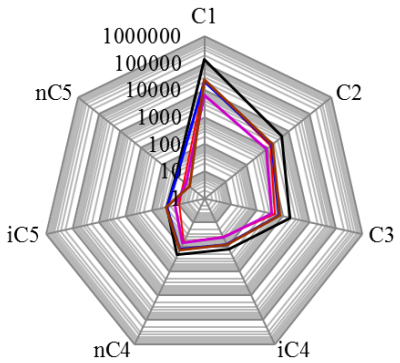
- Oil signature vs gas signature

6607/12-2 S
Alve Nord
Norwegian Sea



Zone of Interest 3

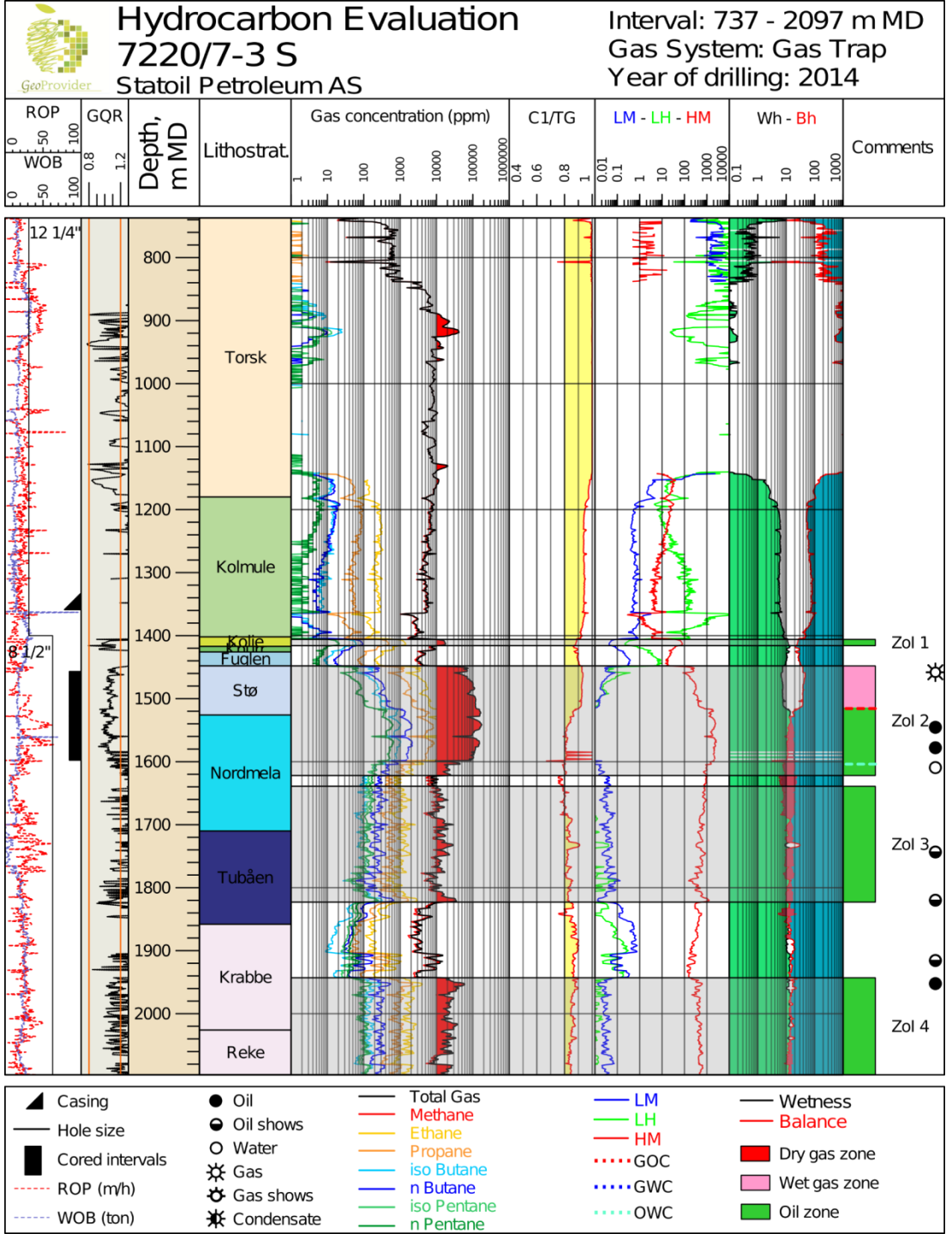




Example of two different discoveries

Shows can be subtle depending on the mud system and the borehole conditions.

Or they can be easy to pick up if the well conditions are correct.



7220/7-3 S
Drivis Discovery
Barents Sea

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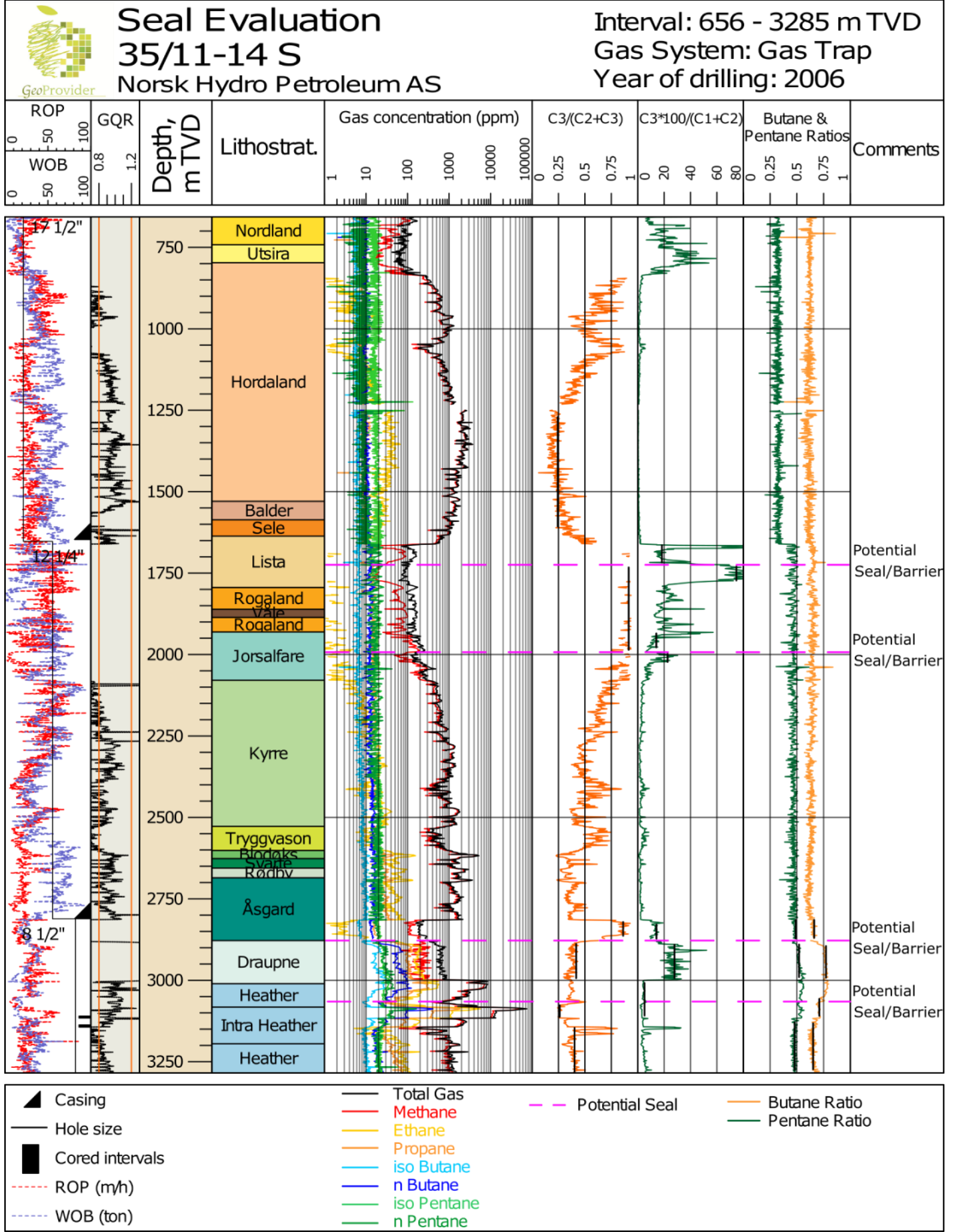
Seal Evaluation

Main principles in seal interpretation

- Gas Segregation
- Abrupt changes in gas signatures

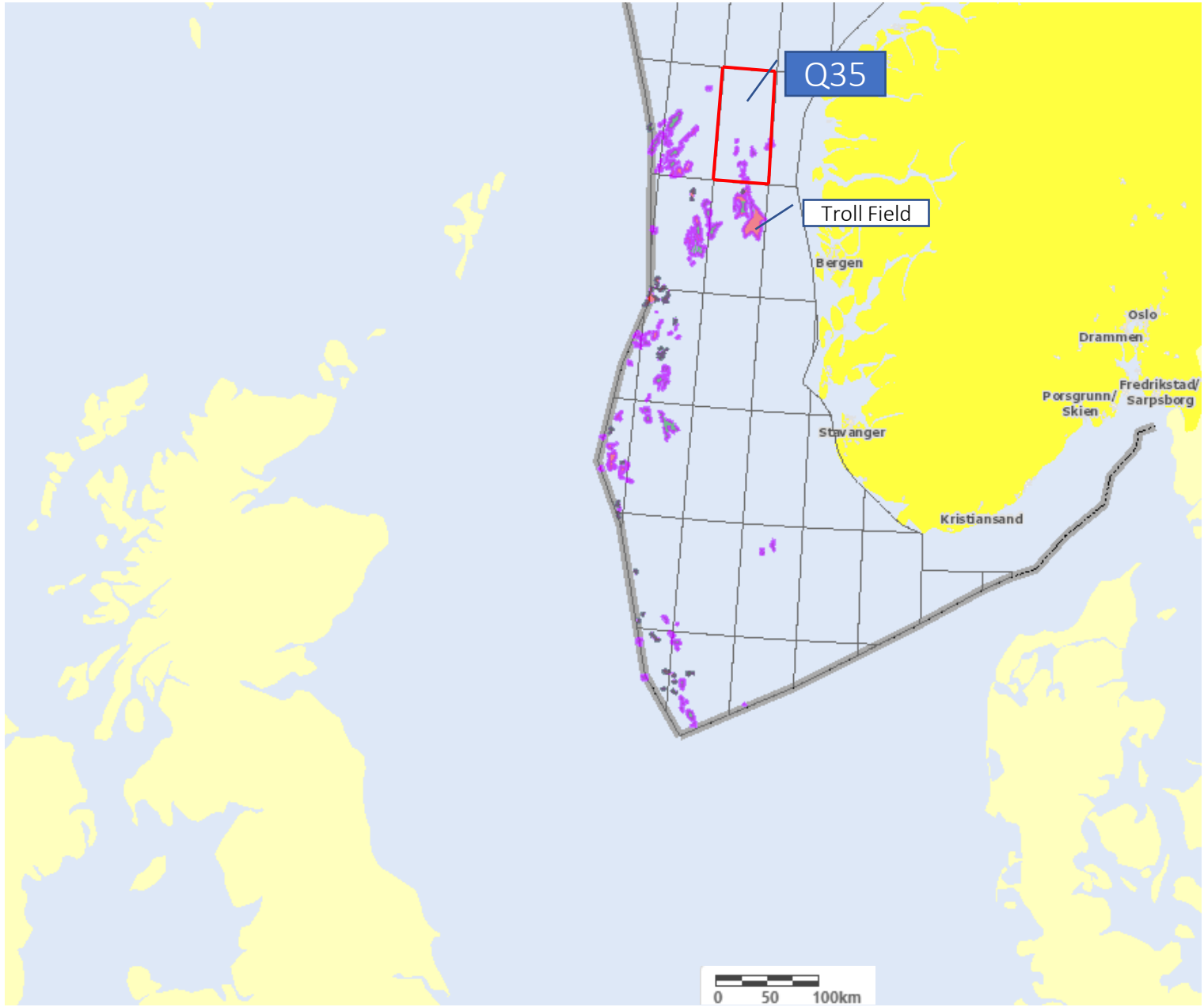
Prinzhofer Ratio
Ten Haven Ratio
Butane & Pentane Ratios



35/11-14S
Byrding Field
North Sea

Quadrant 35 – Play study

- Q35 is located in the Northern North Sea north of the Troll Field
- In total 59 Exploration wells have been analysed.
- Wells from 1987 to 2017



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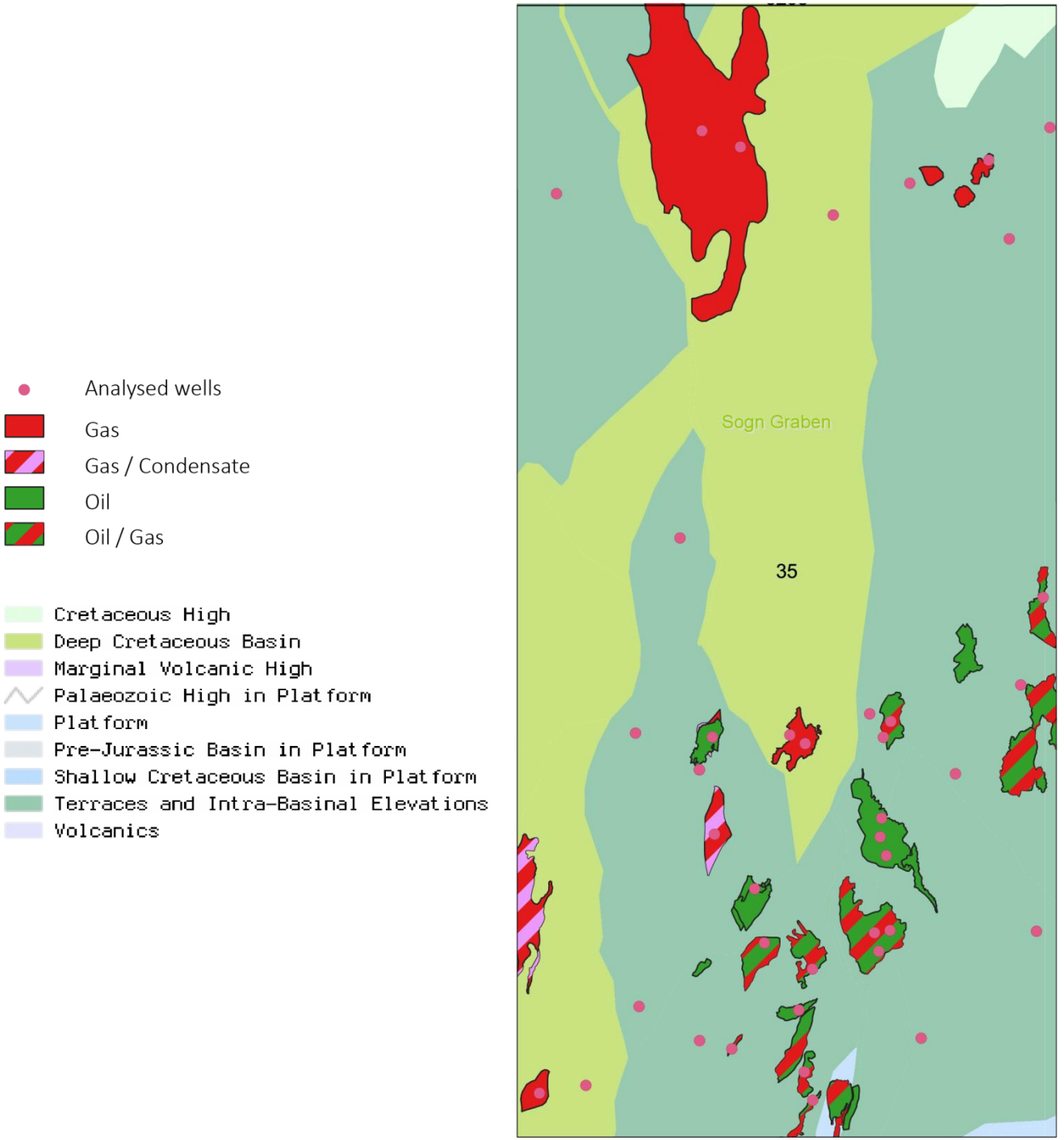
Quadrant 35 – Case study

- Mature area
- More recent discoveries include Nova (Skarfjell), Duva (Cara) & Grosbeak
- Jurassic plays in the south and Cretaceous plays to the east



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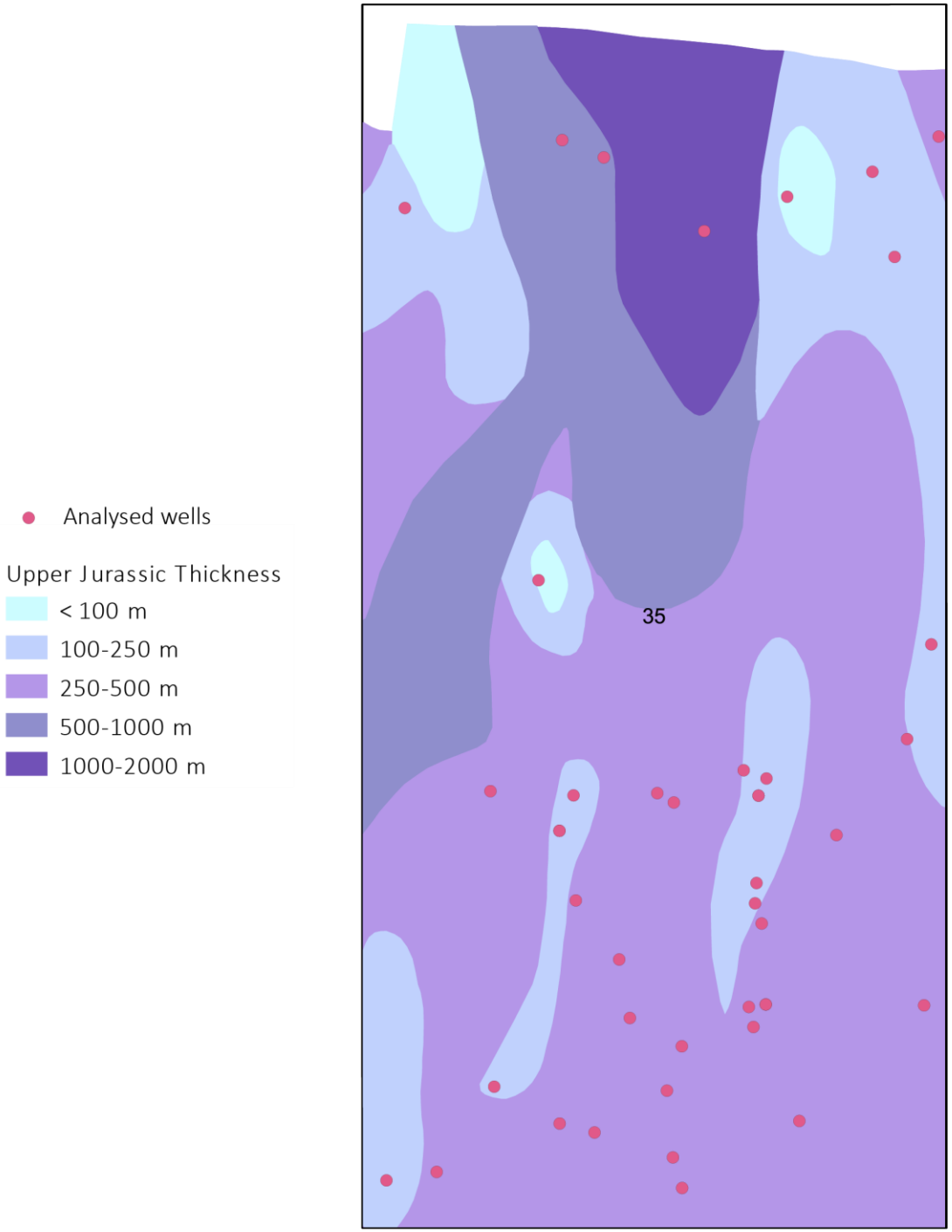
Quadrant 35 – Case study

- Jurassic play model
- Thickness map modified from The Millennium Atlas (2003)
- 53 analysed wells and wellbores penetrating the Jurassic



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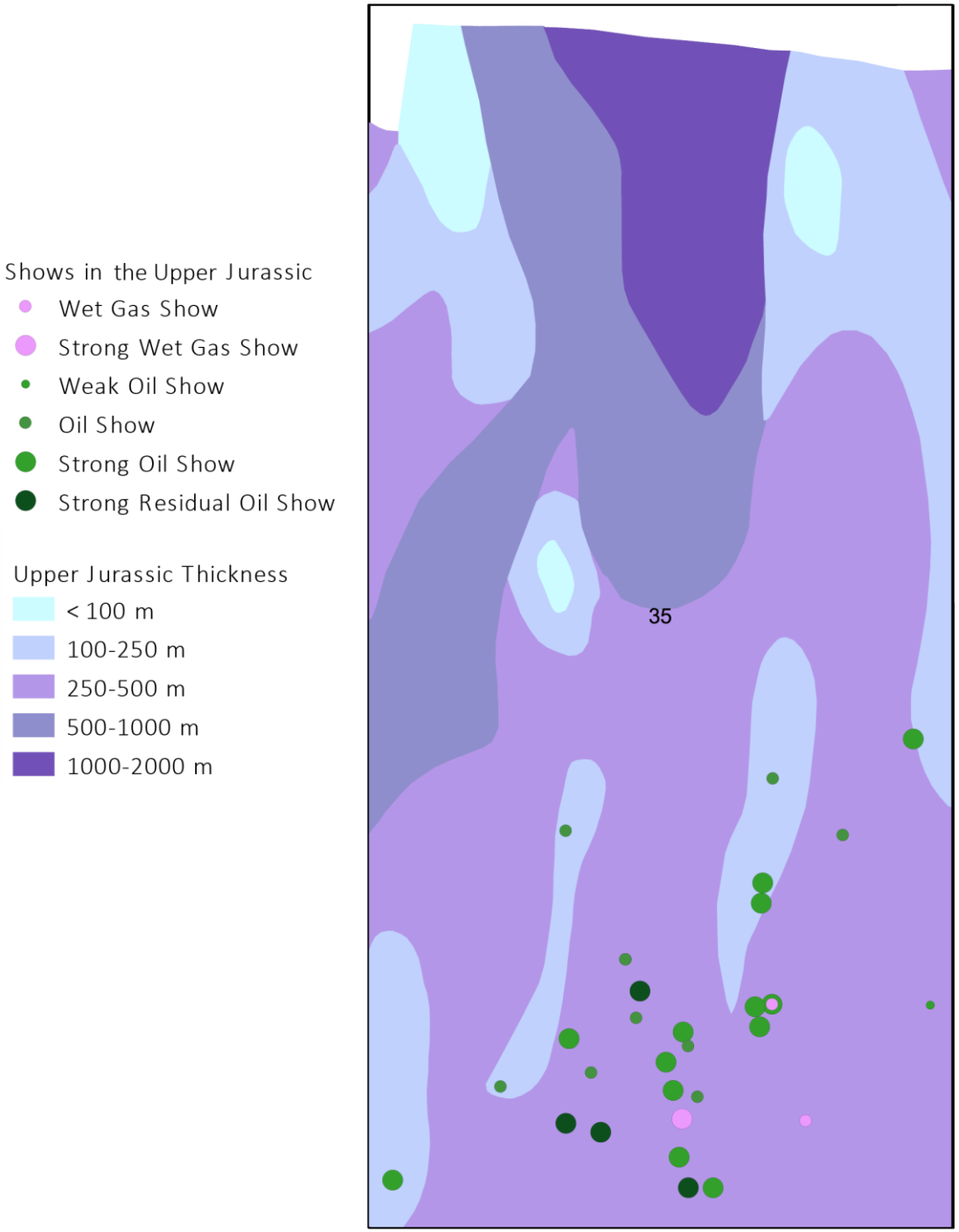
Quadrant 35 – Case study

- Jurassic play model
- 44 wells with shows in the Upper Jurassic



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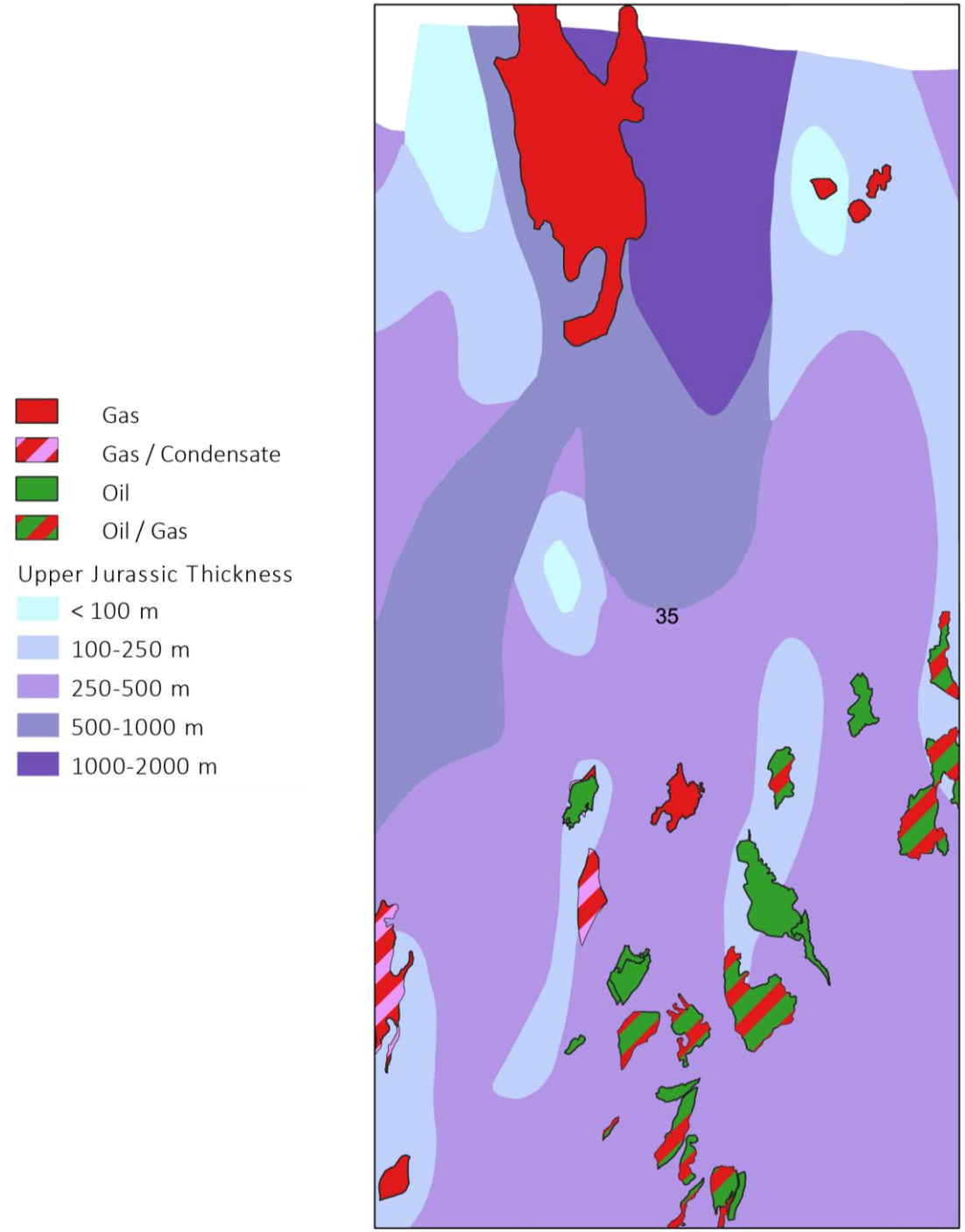
Quadrant 35 – Case study

- Jurassic play model
- 44 wells with shows in the Upper Jurassic
- Match with fields and discoveries in the Jurassic



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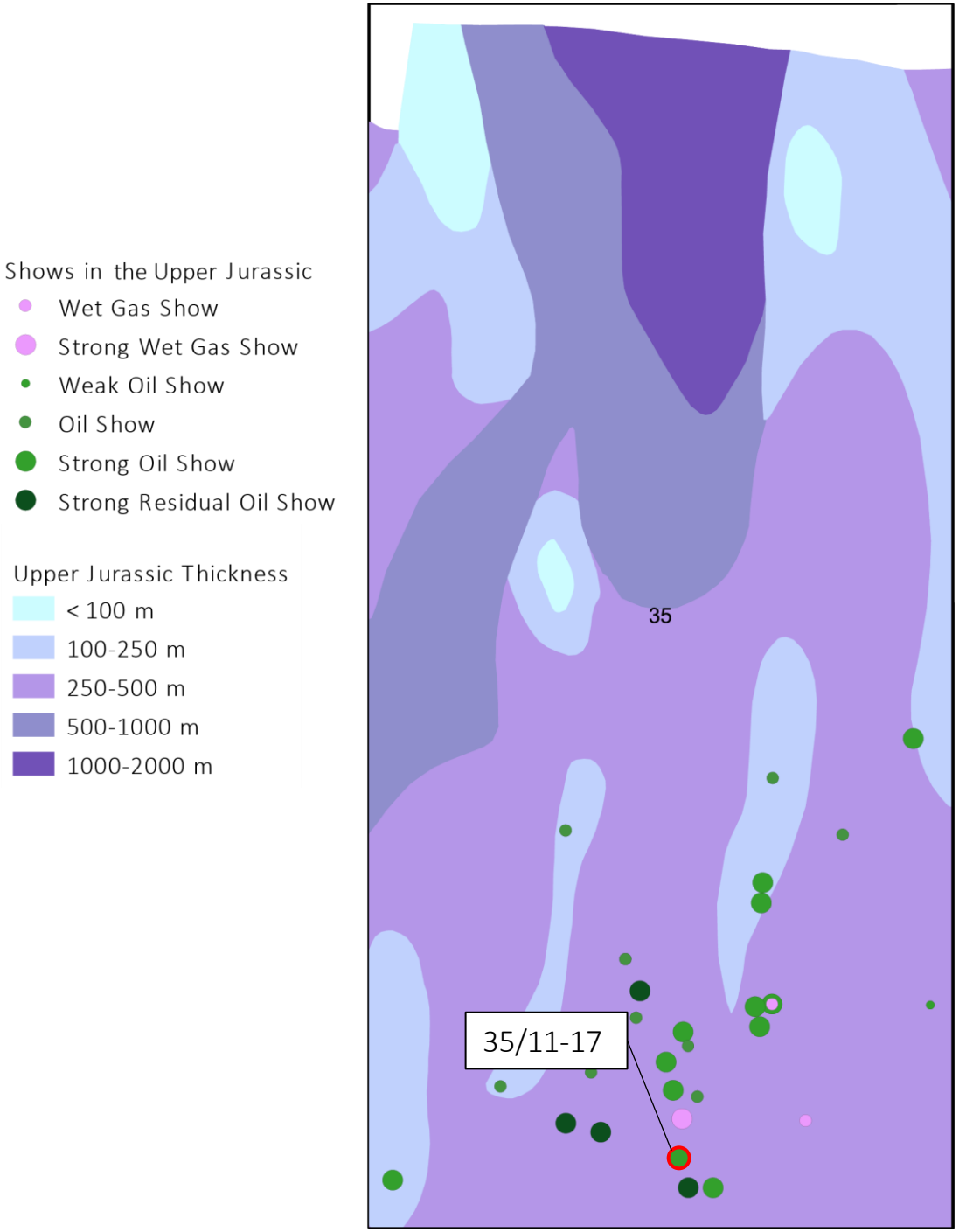
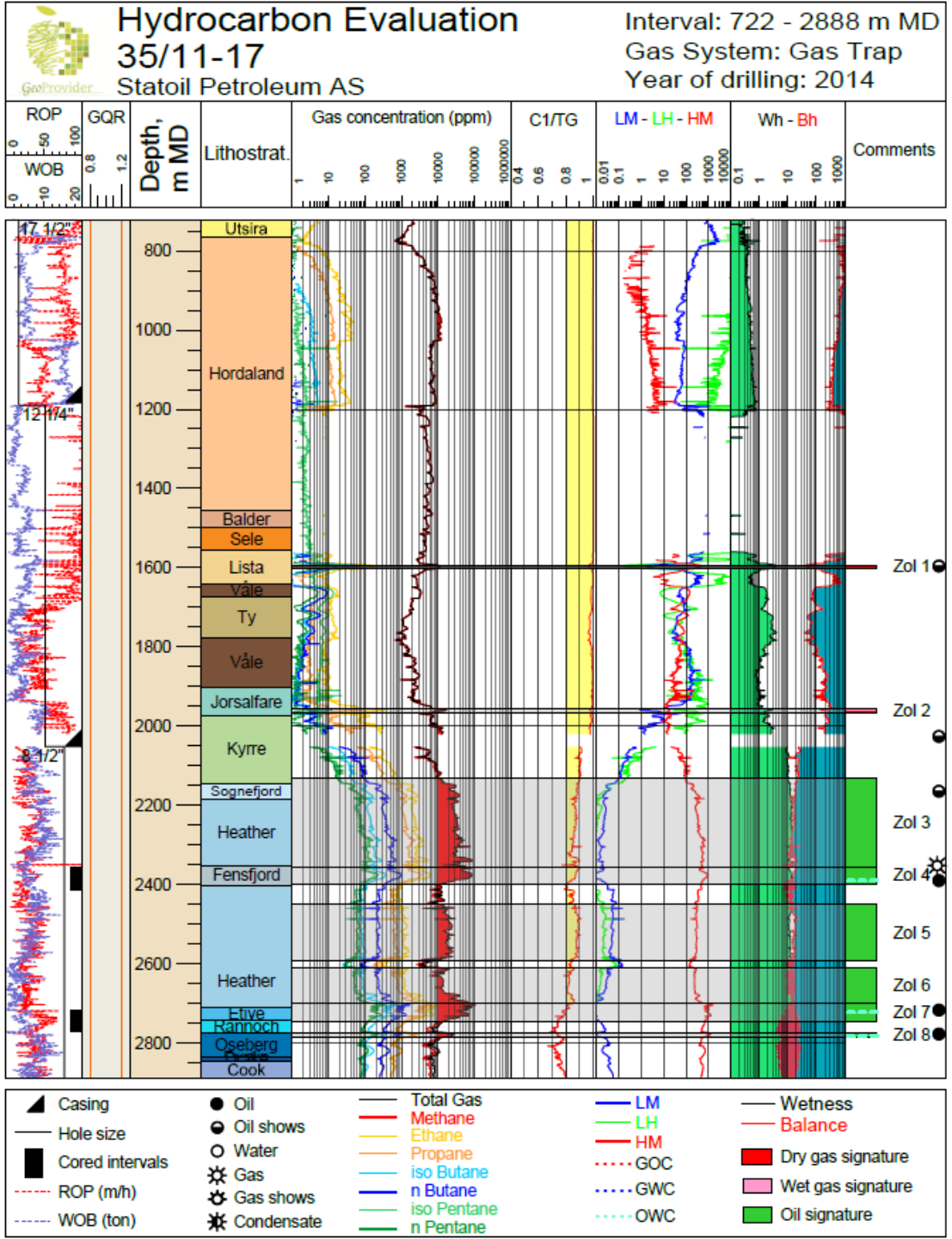
Quadrant 35 – Case study

- Jurassic play model
- 44 wells with shows in the Upper Jurassic
- Strongest shows found in the south



Quadrant 35 – Case study

- Exploration well 35/11-17
- Fram Vest discovery well
- Upper Jurassic brightening up with gas
- Strong oil signatures



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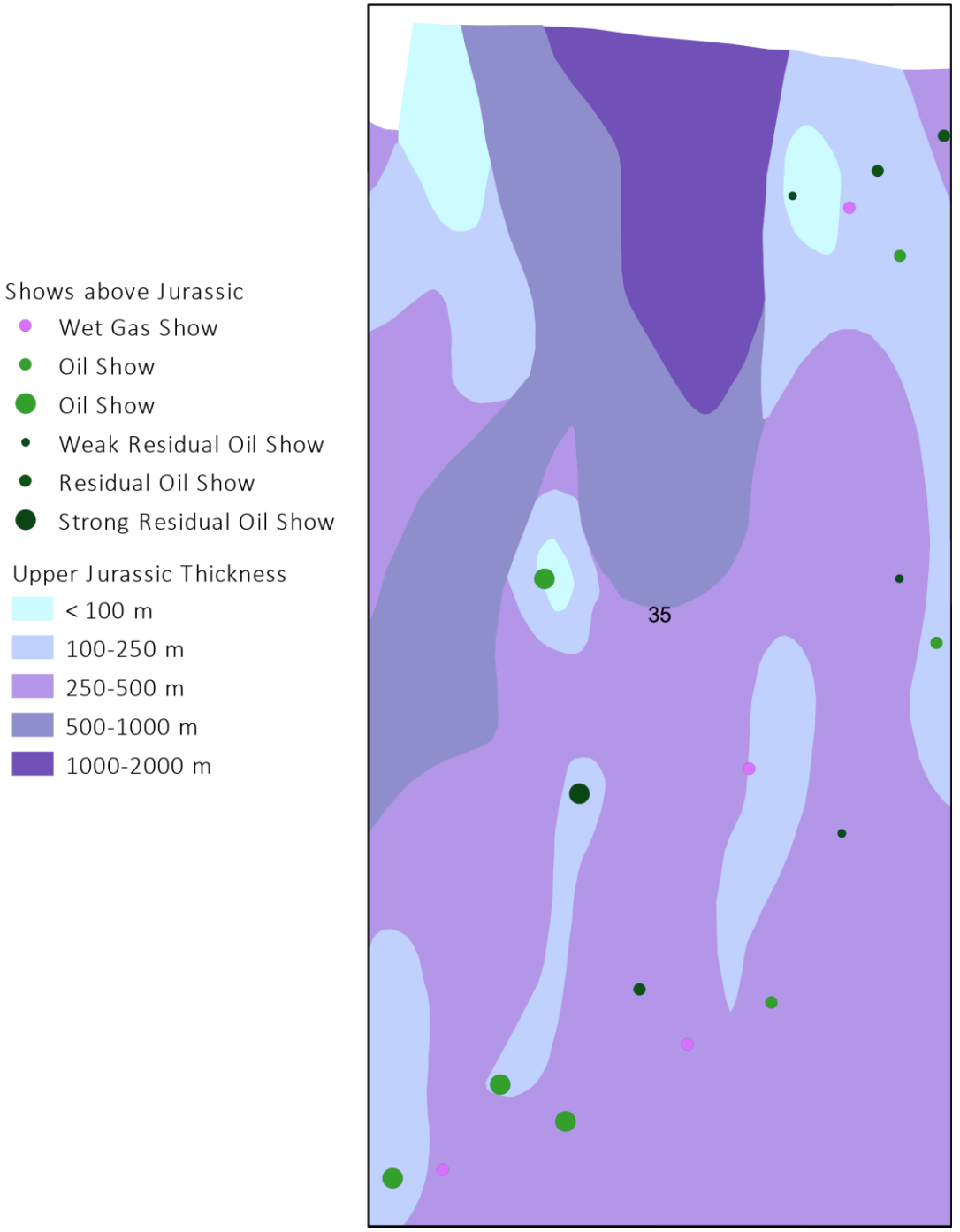
Quadrant 35 – Case study

- 17 wells with shows above the Jurassic
- Mainly seen where the Upper Jurassic is the thinnest



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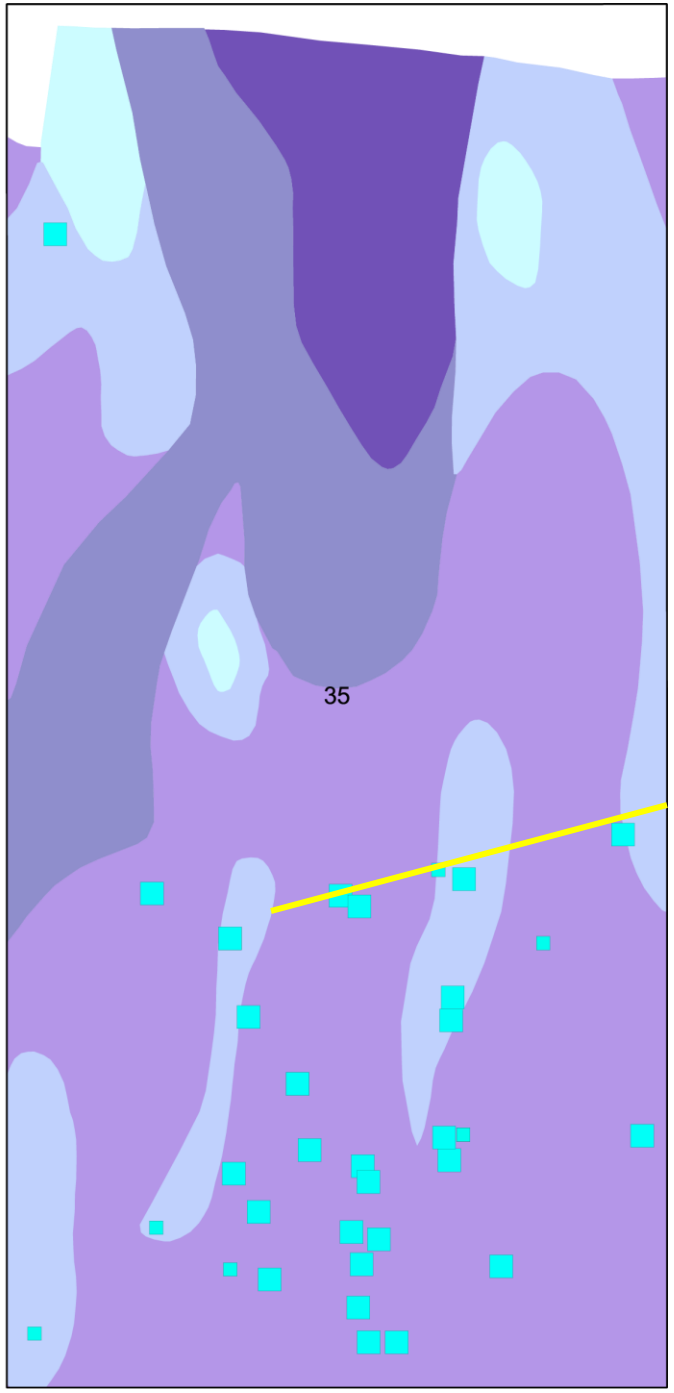
Quadrant 35 – Case study

- Wells with clear change in gas signatures and multiple sealing responses are plotted as “Strong Indications of sealing”
- Wells with some sealing responses or have shows above Upper Jurassic are plotted as “Weak Indications of sealing”



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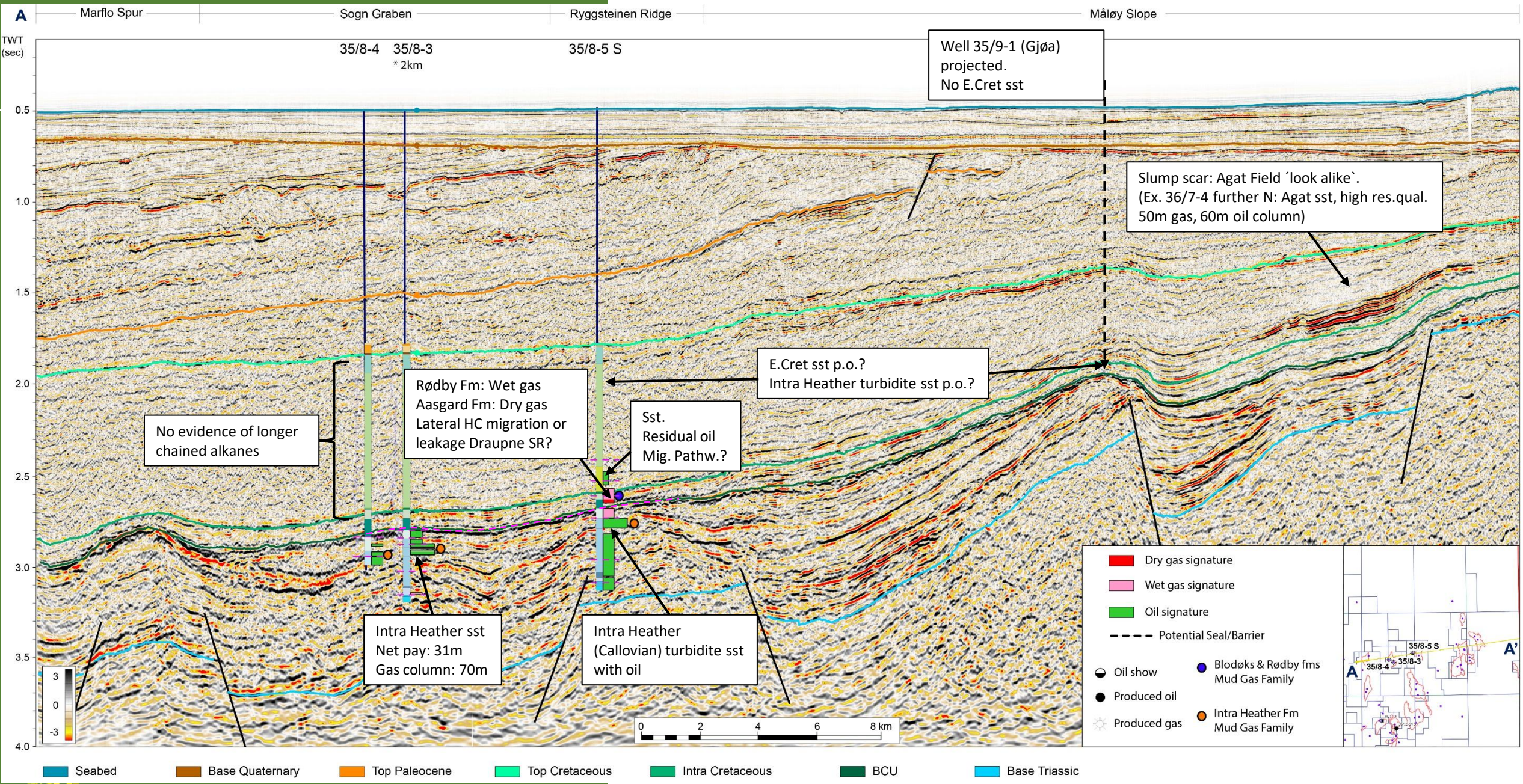

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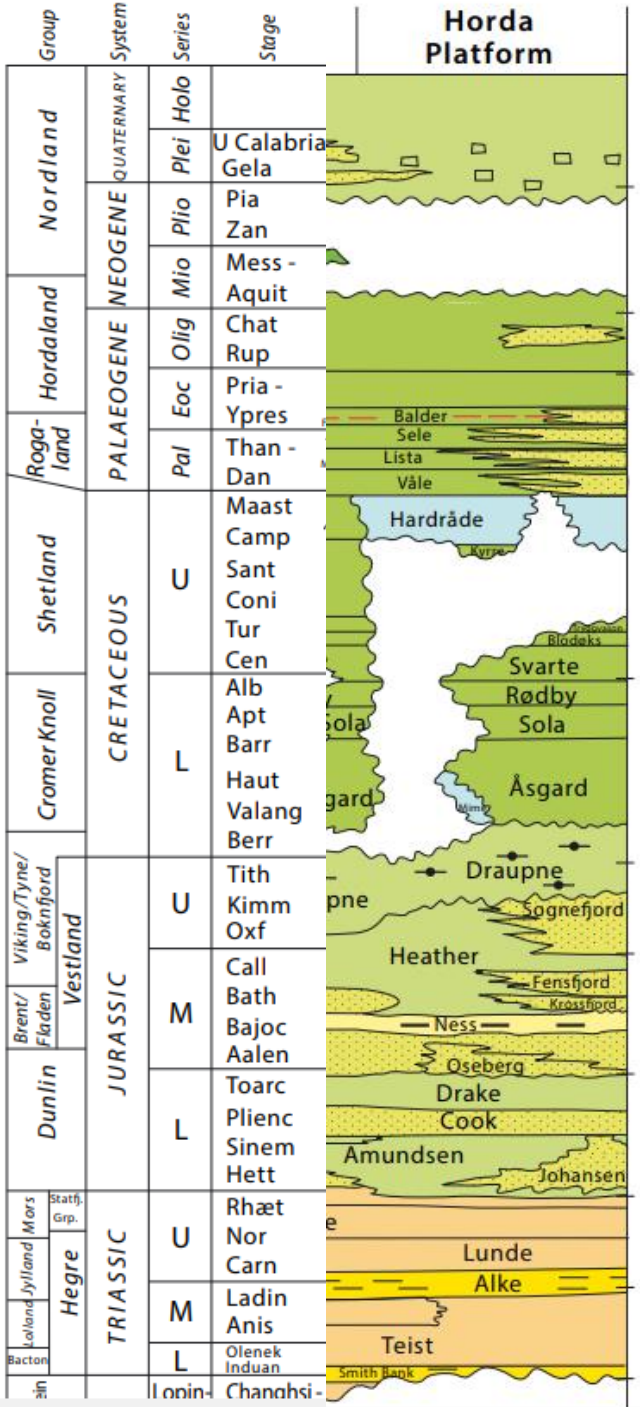
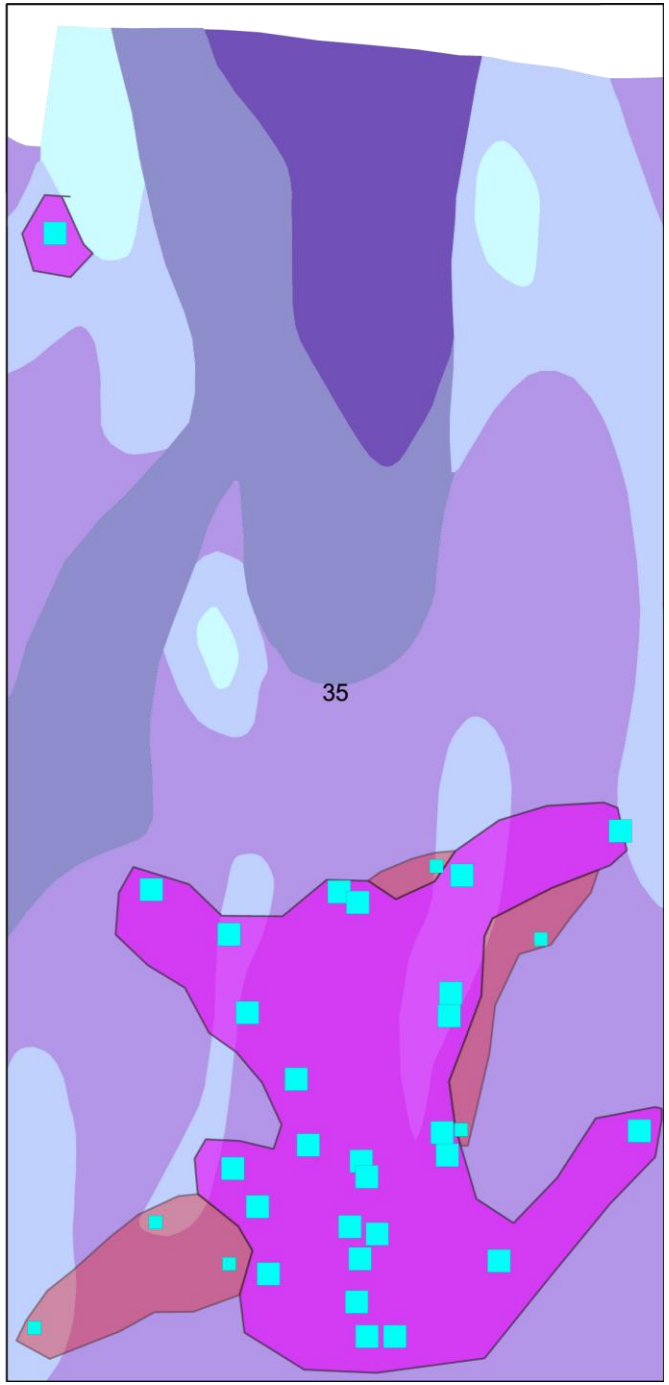
Quadrant 35 – Case study

- Wells with clear change in gas signatures and multiple sealing responses are plotted as “Strong Indications of sealing”
- Wells with some sealing responses or have shows above Upper Jurassic are plotted as “Weak Indications of sealing”
- Polygons are created based on the sealing indications from the wells





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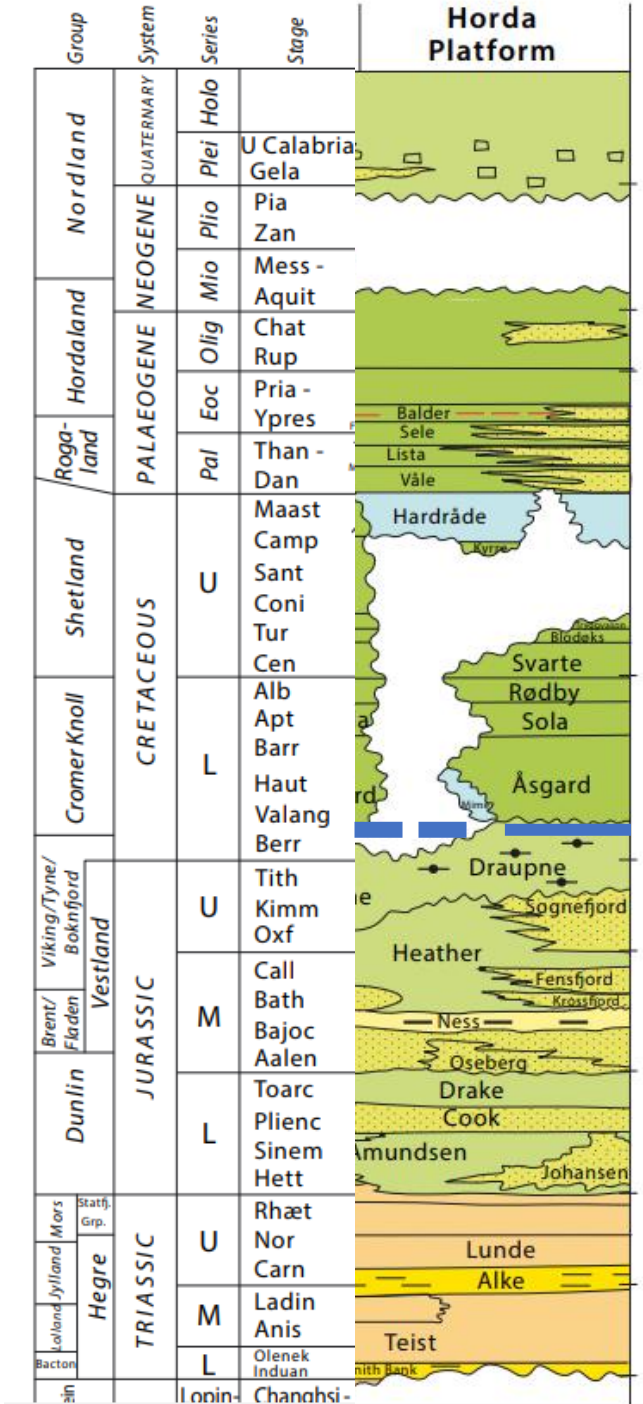
Quadrant 35 – Case study

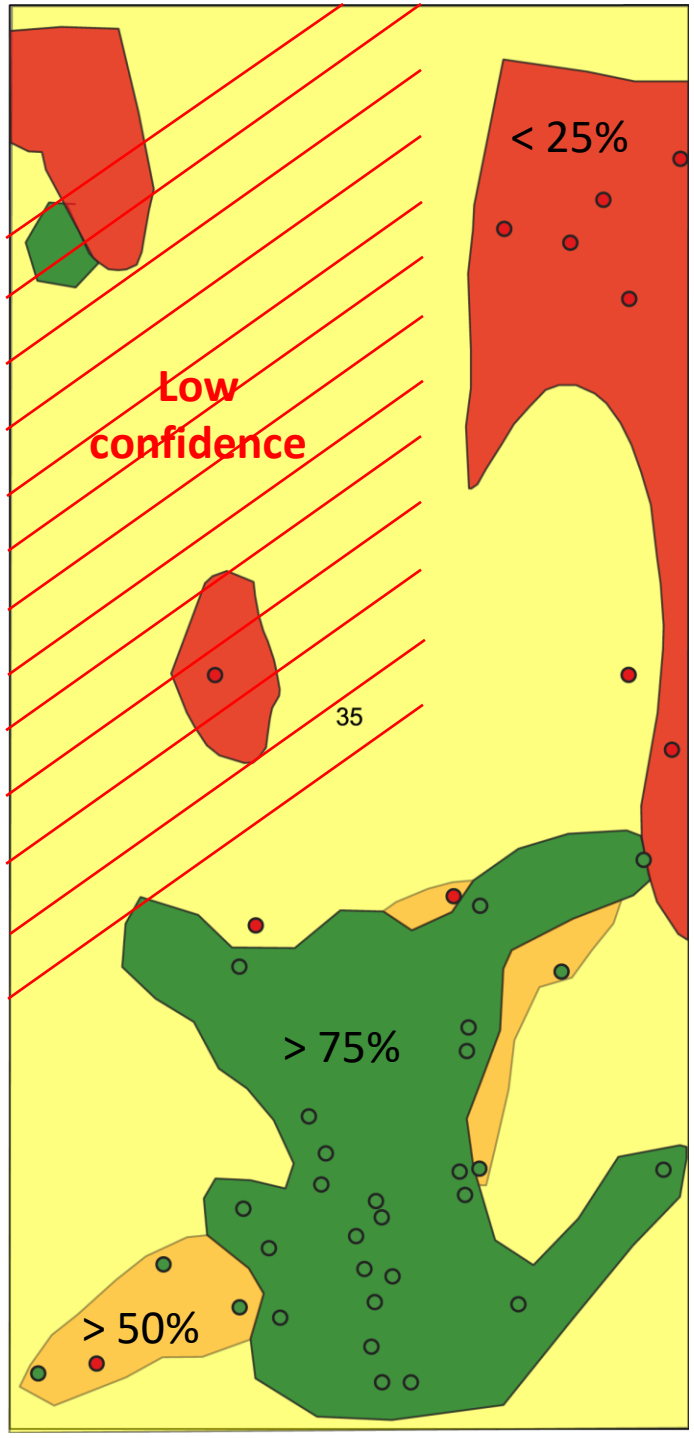
Prior assumptions in this area:

- Top seal and charge are no problem
- Reservoir, trap and containment are the main issues
- Upper Jurassic and Cretaceous plays considered independently

New upper Jurassic Common Risk Segment map indicates:

- Distribution of Jurassic discoveries seems to be determined by presence of good top seal as indicated by the positive wells are those with strong shows in the Upper Jurassic
- Areas with shows above the Upper Jurassic have Lower Cretaceous sands and discoveries. So far unclear why
- Large areas with little data suggest there is scope to learn and find more





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Conclusions

- Mud gas analysis is a reliable and powerful tool for:
  - Regional screening, basin modelling and play analysis
  - Derisking prospects and volumetrics
  - Near field exploration and field development
- Systematic methodology is key
- Mud gas data available for the majority of wells in the North Sea, data can be compared through time due to consistent use of TGA and GC