The Valhall Miocene

An “out of the ordinary” Low-Mobility Reservoir

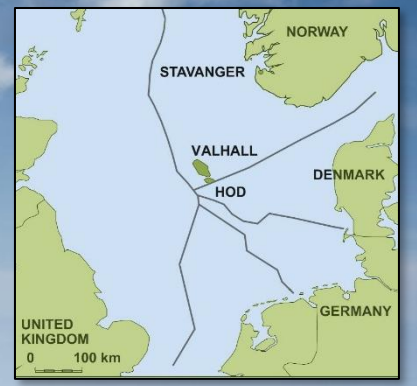
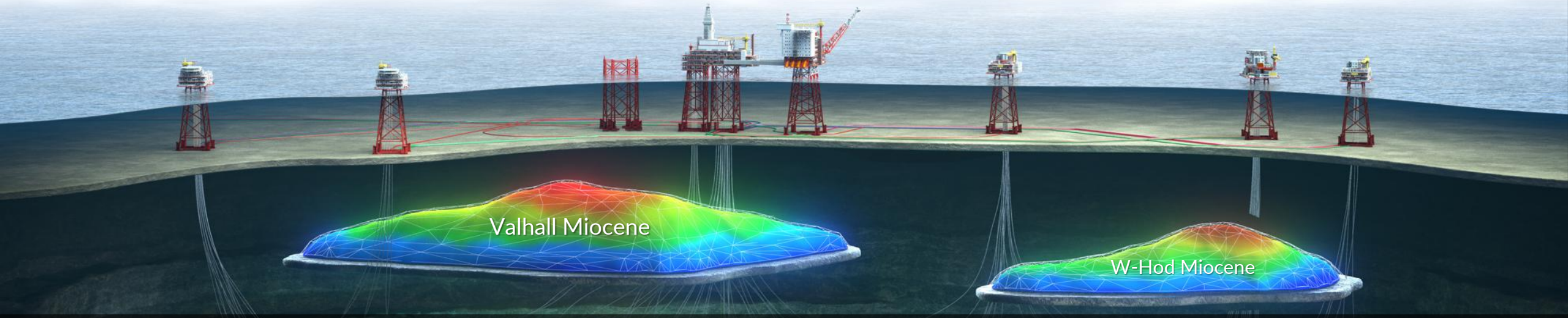
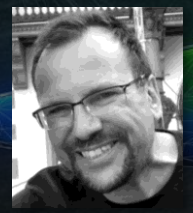


Figure courtesy of Golder Associates




Sigrun Mellemstrand Hetland


Niels Rameil


Ruth Synnøve Haga Pettersen


Yann Caline

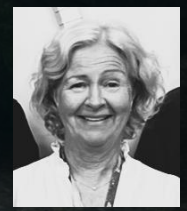

Søren Amdi Christensen


Mark Shahly


Eirik Stueland


Scott Tønnesen


Ole Vejbæk


Liv Torunn Vika

The Valhall Miocene

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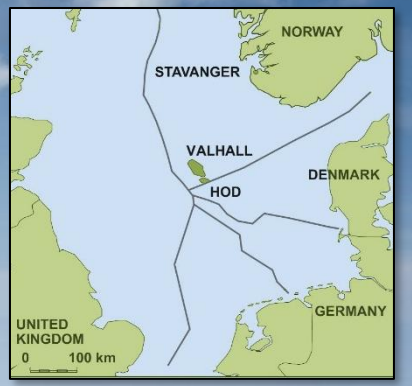


Figure courtesy of Golder Associates

Valhall Miocene

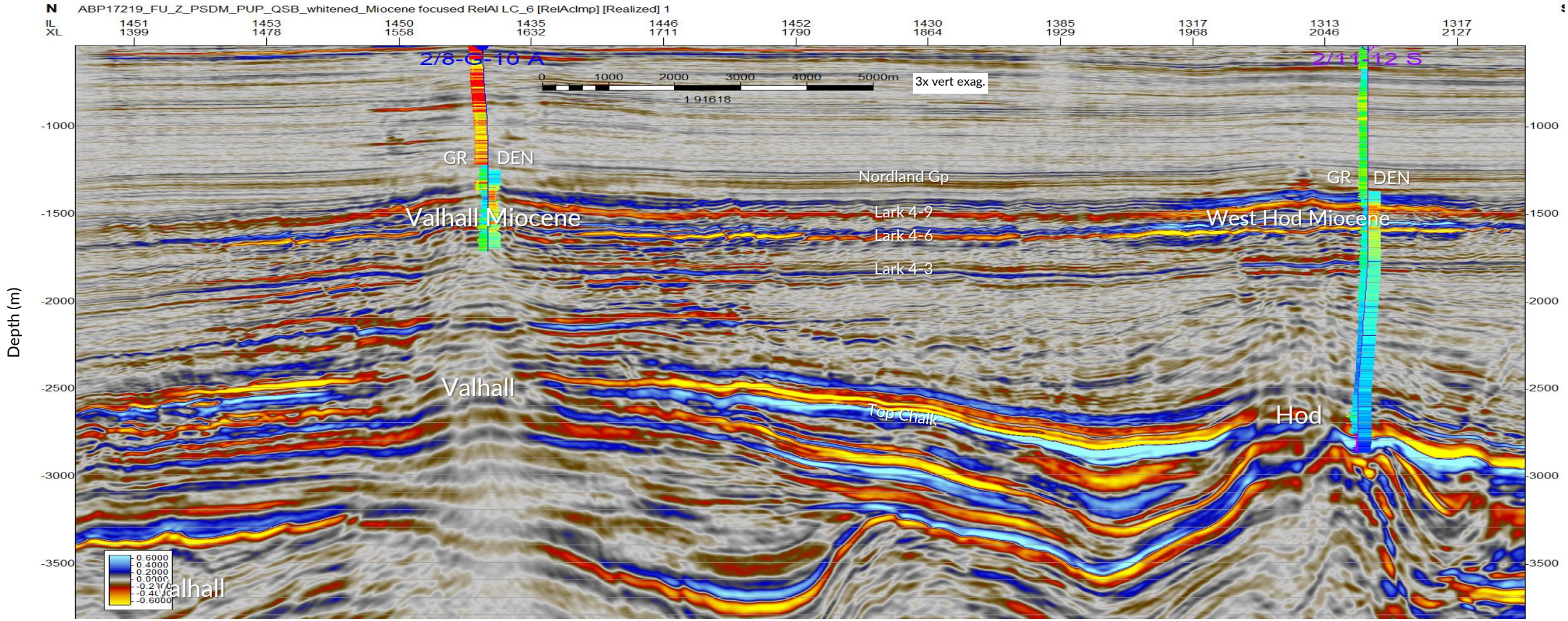
West Hod Miocene

Valhall

East Hod

W-Hod

The Valhall & Hod Miocene Lark Fm



- Relative acoustic impedance (AI), red/orange is soft/low AI
- Wells show GR (left) and density (right)

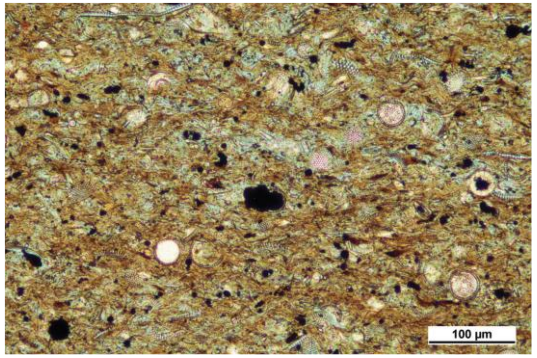
The Valhall & Hod Lark Fm

- Diatomaceous mudstones unconventional reservoir
  - STOOIP ~3 bn barrels
  - Porosity > 50 %
  - Permeability < 1 mD

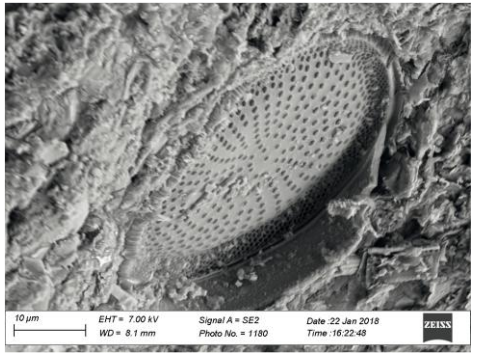
- Proven hydrocarbons since the 1980s
  - “Shallow hazard” until ~2016

- **Can we produce it economically?**

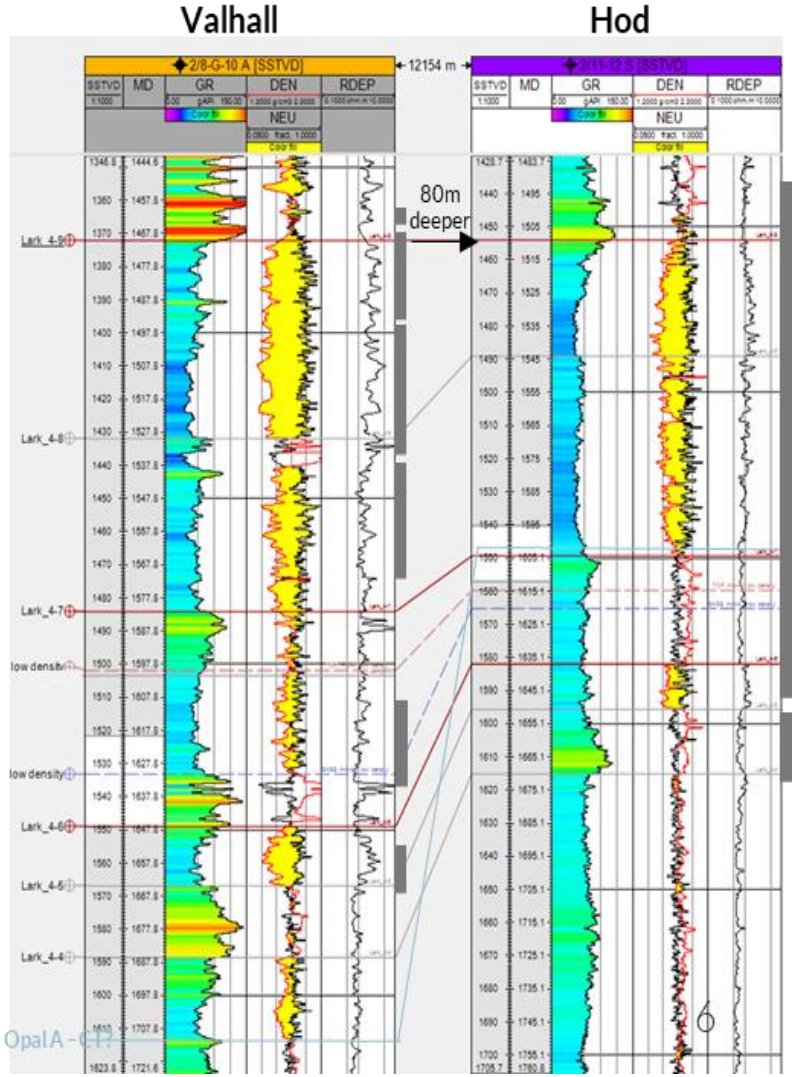
Fun fact: diatomites can float on water!



Thin section micrograph



SEM picture



Valhall & Hod Miocene – Appraisal History

2016
Volume of Oil Initially In Place (OIIP) Project

2016

2017
Valhall well Core and Data Acquisition

2018
Miocene Appraisal Initiated

2019
Valhall and West Hod wells Core & Data Acquisition

2019
WP Infrastructure Study

2020
Covid

Deferred
Miocene Test Producer (WP)

2022
Hod B platform

2022
Miocene Accelerated Appraisal Study (Hod B)

2022
PWP/Fenris PDO

2024

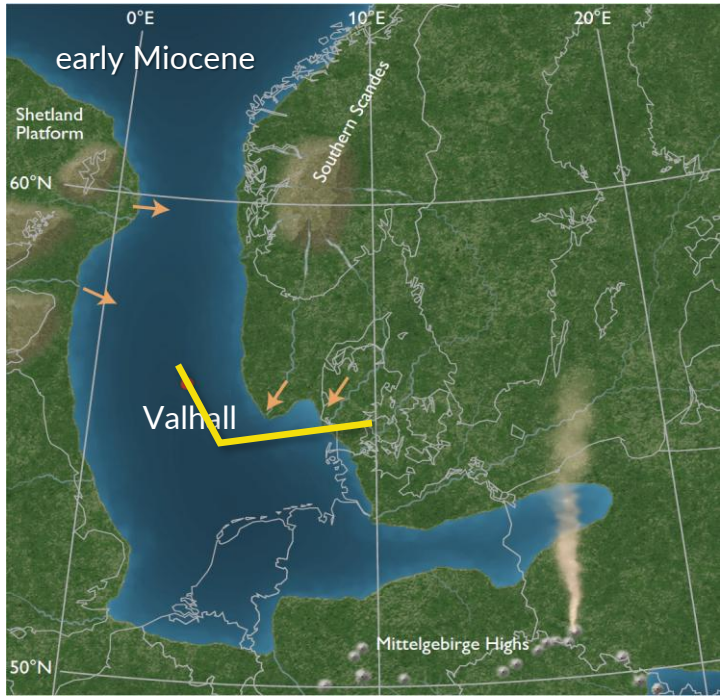
Miocene Test Producer and Development Project DG0 (PWP)

1982-2016
"Overburden Drilling Hazard"

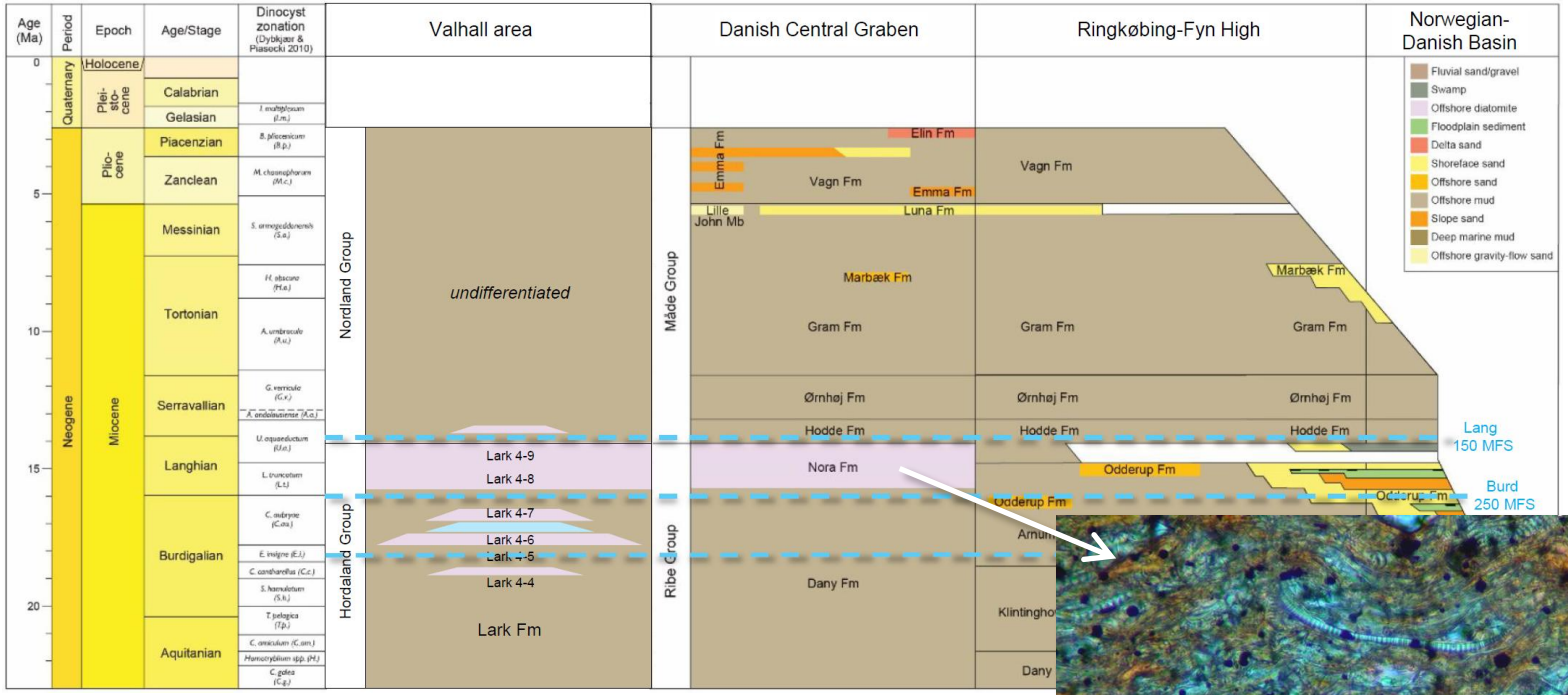
Reservoir Development Appraisal


Size does matter

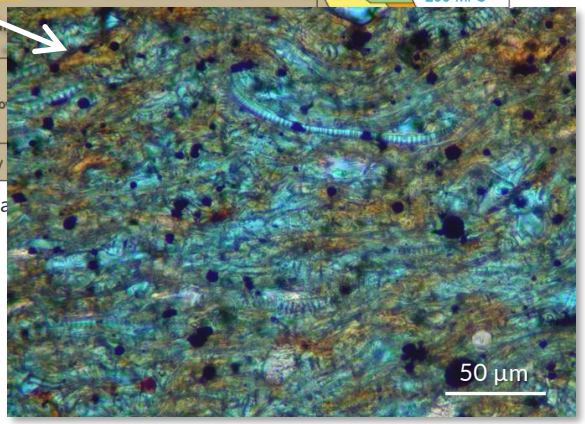
Geological Setting



GEUS 2021



Updated lithostratigraphic subdivision for the Neogene succession in the Danish sector of the North Sea, compa
Based on Rasmussen et al. (in prep.).

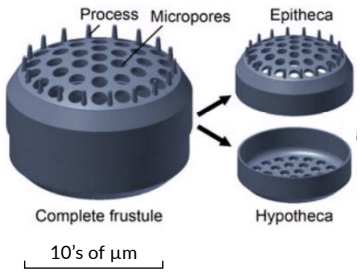


- Marginal sea, humid subtropical climate
- Basin centre → fine-grained, distal deep-water deposits (basinal muds & silts)
- progradation of large delta systems from the basin margins → **nutrient input!**

Diatom blooms *mixing* Background sedimentation

Diatomaceous mudstones

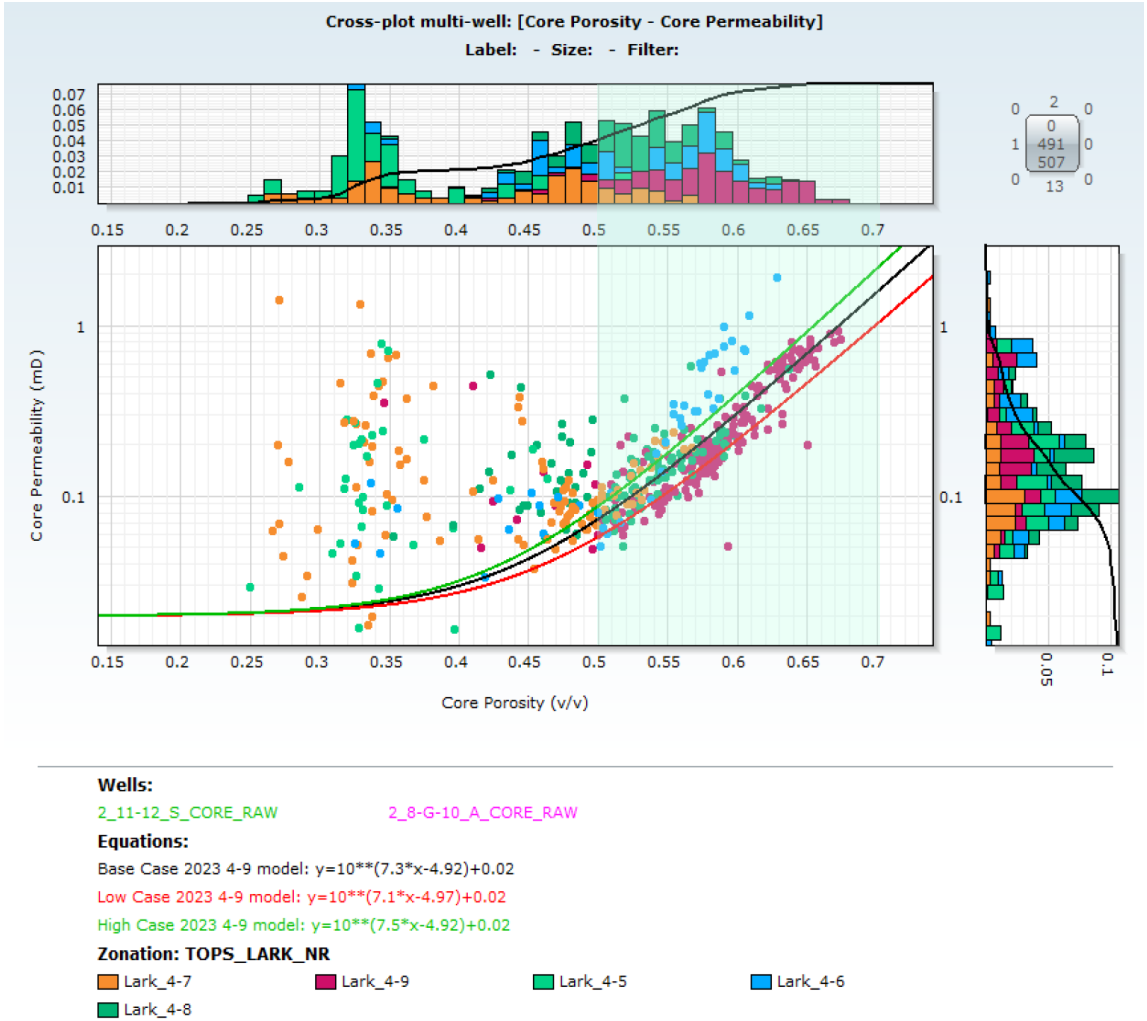
high-porosity / low permeability



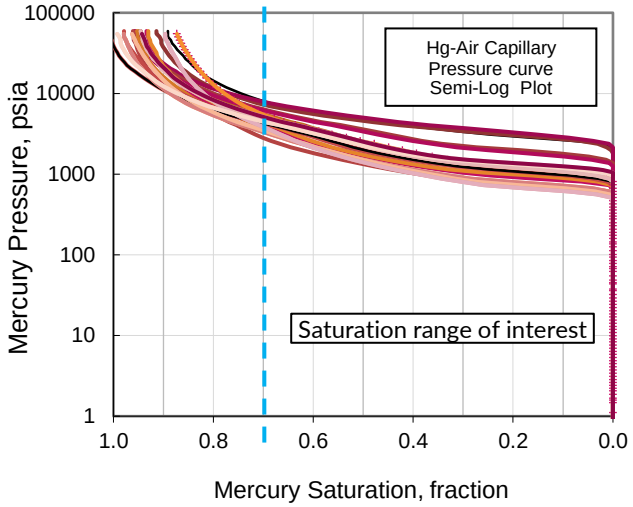
Petrophysical Fundamentals of the Lark Fm

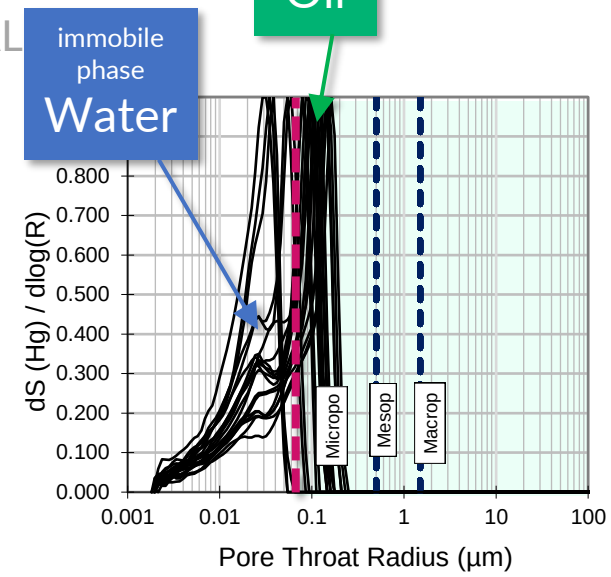
AkerBP

RCA data

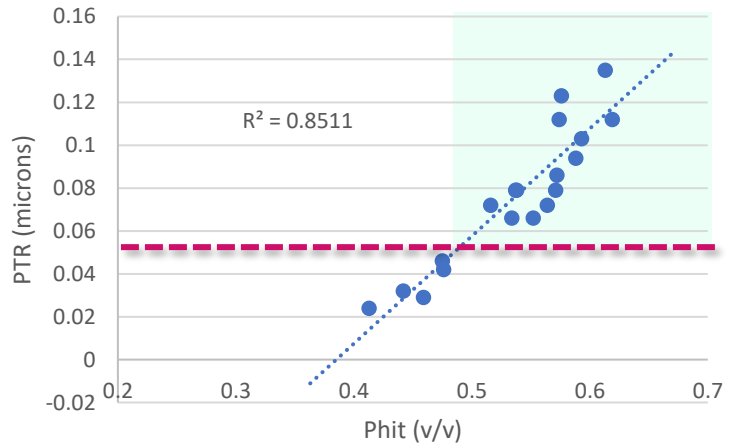


SCAL





Phit - PTR

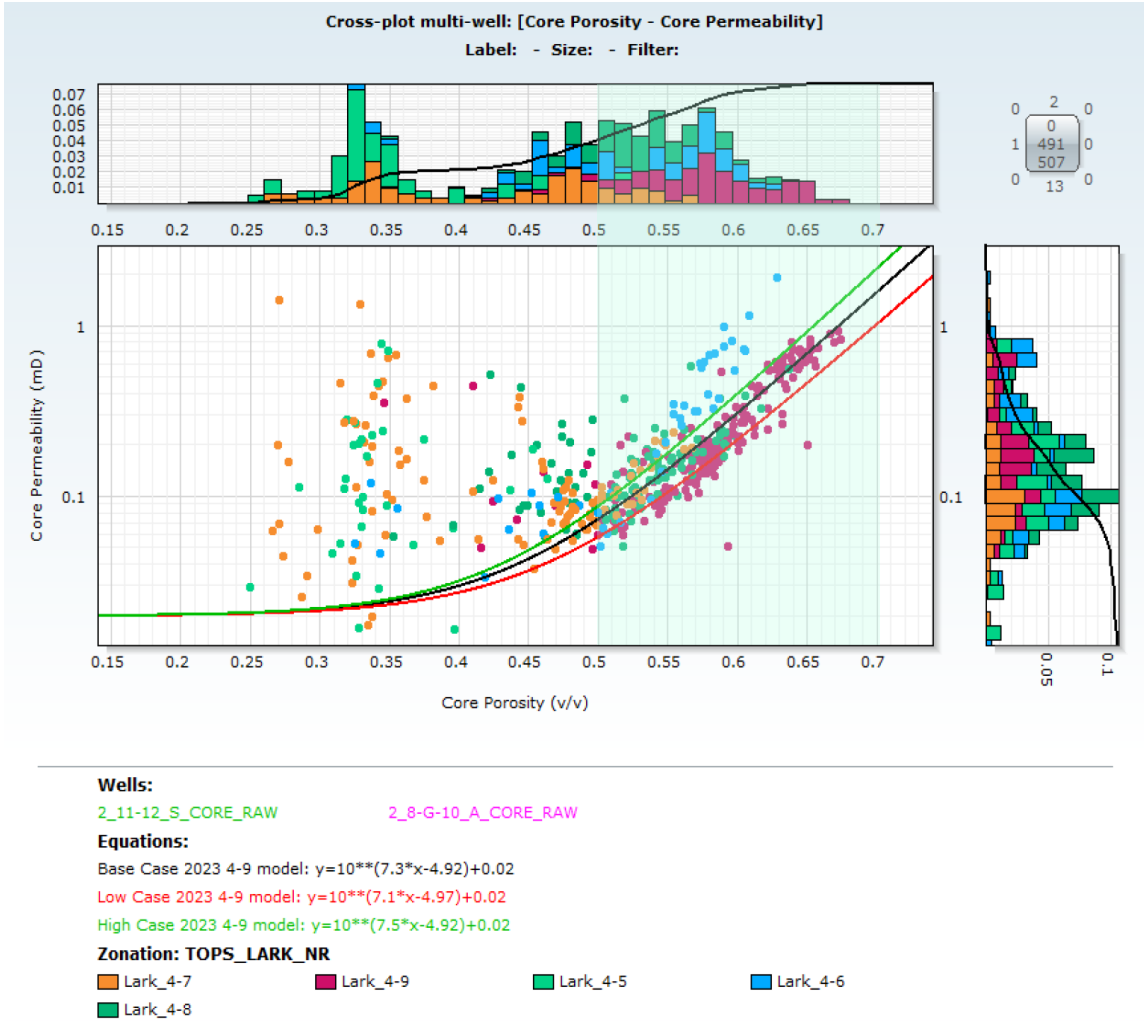


PTR range for pay 0.052 - 0.16 microns
PHIT range for pay ca. 50-70%

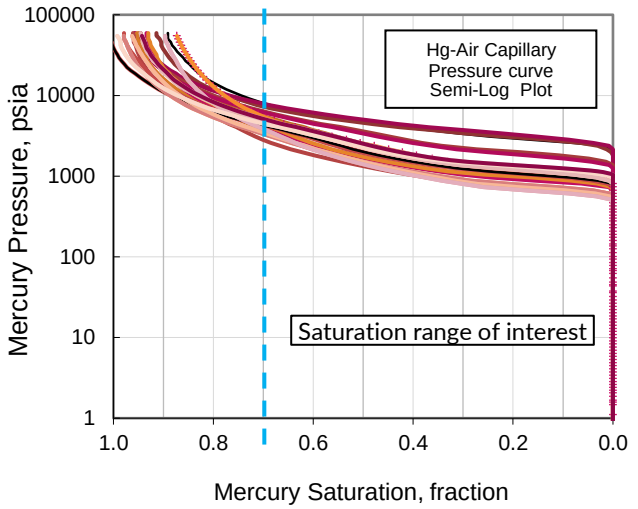
Petrophysical Fundamentals of the Lark Fm

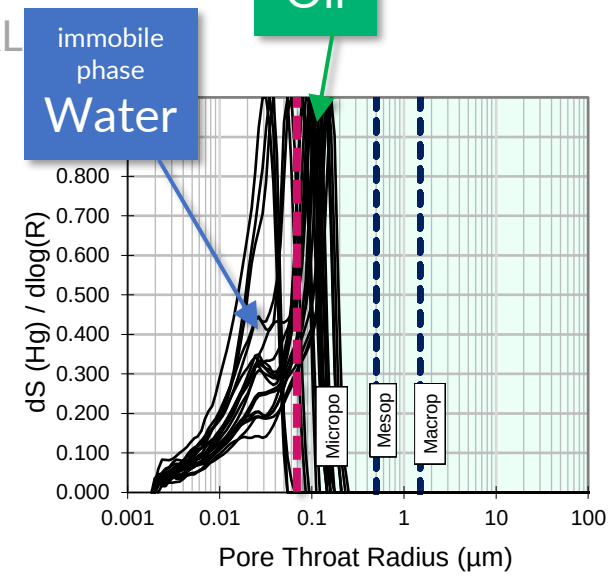
AkerBP

RCA data

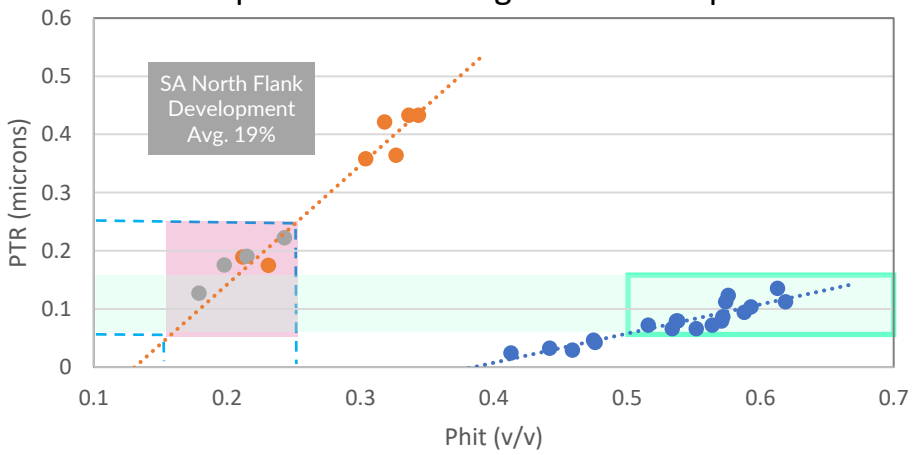


SCAL



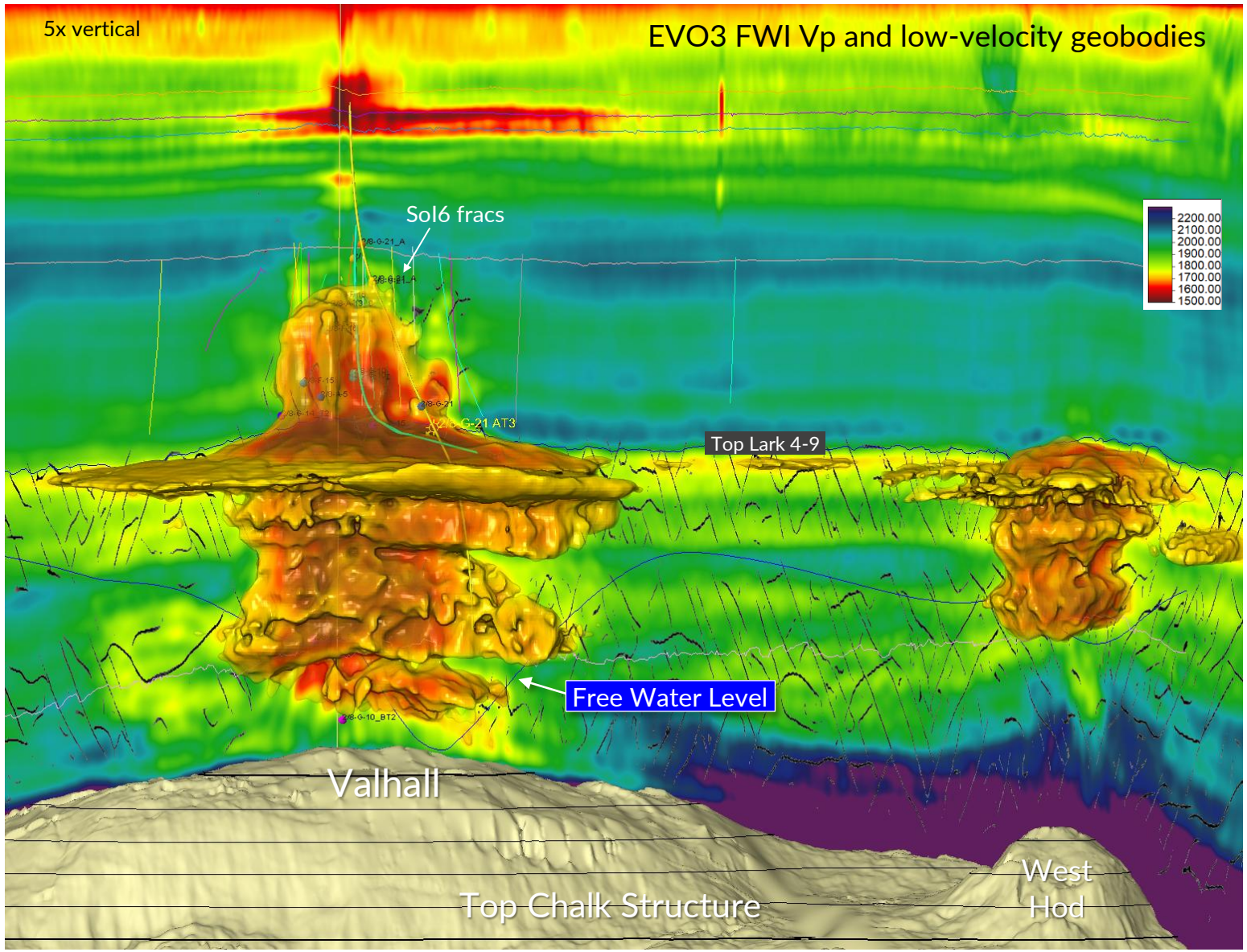


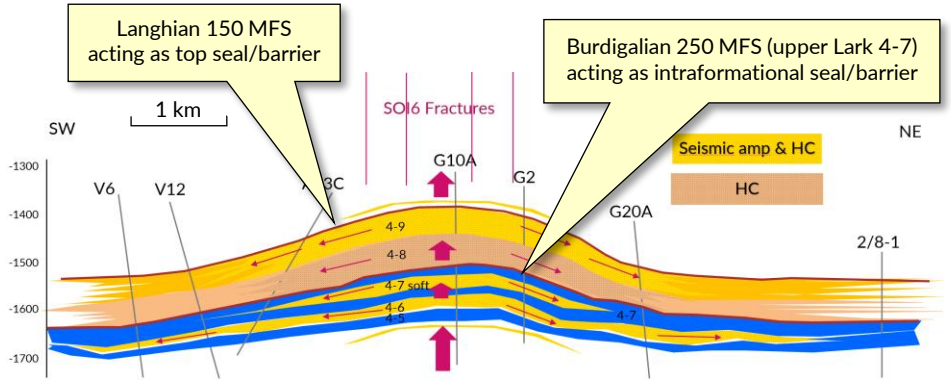
Comparison to existing chalk developments

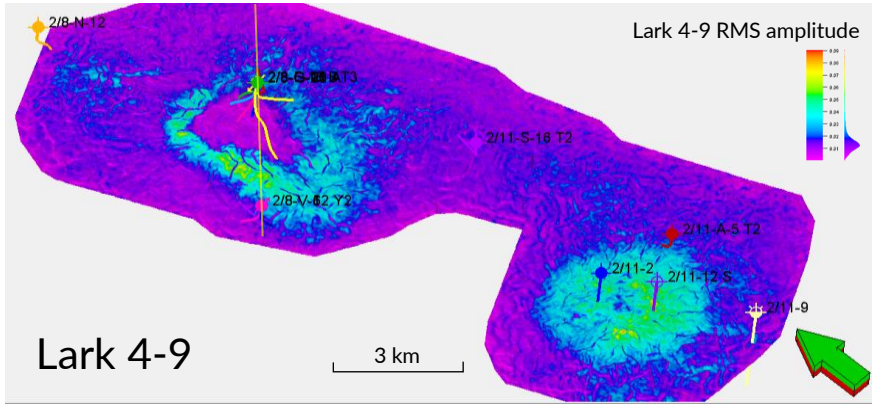


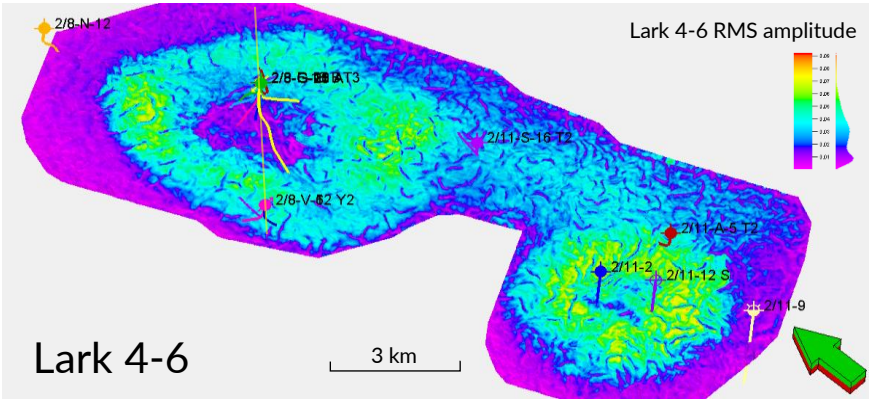
Chalk reservoirs with a PTR range close to the Valhall Miocene have already been successfully developed!

Hydrocarbon Migration from Valhall into the Overburden

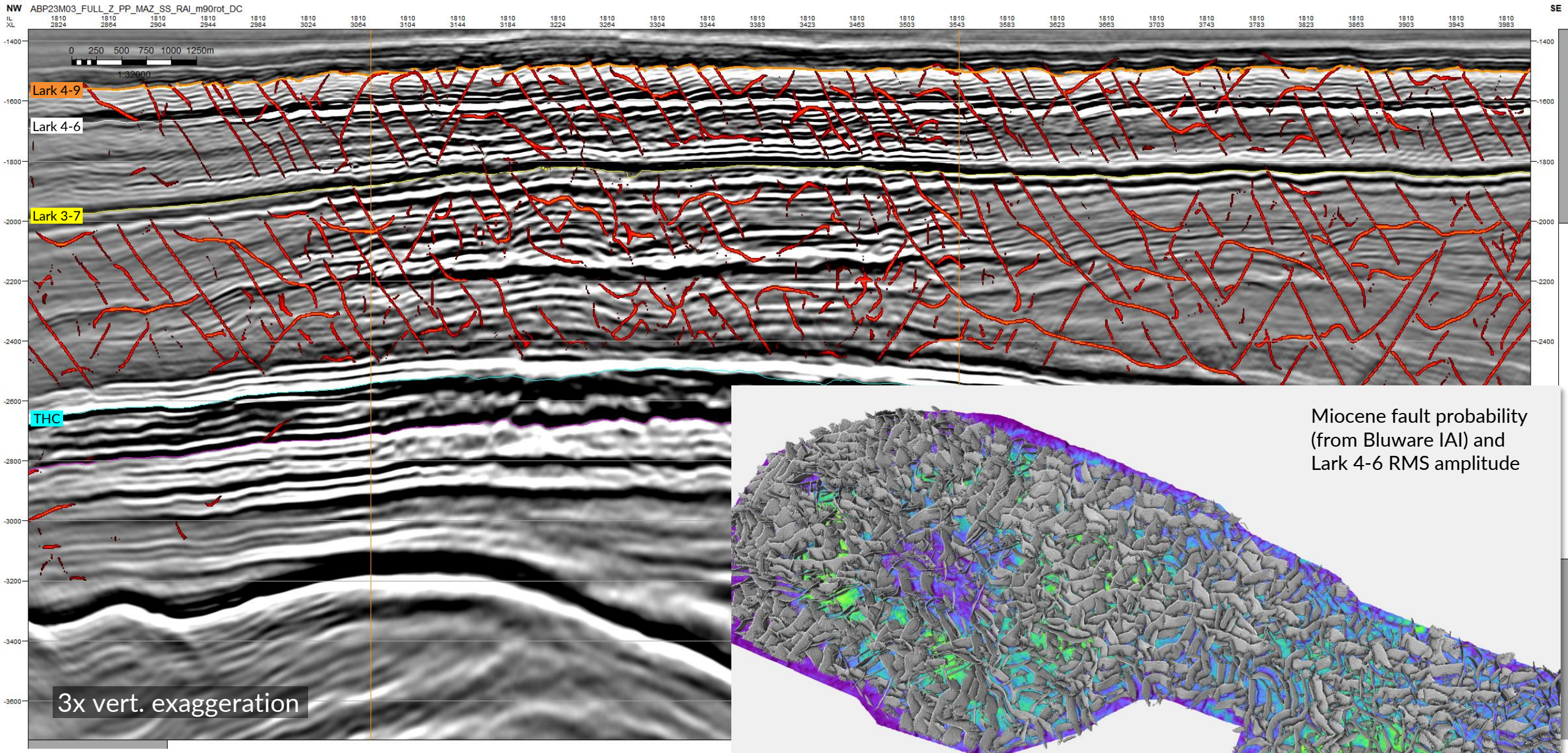






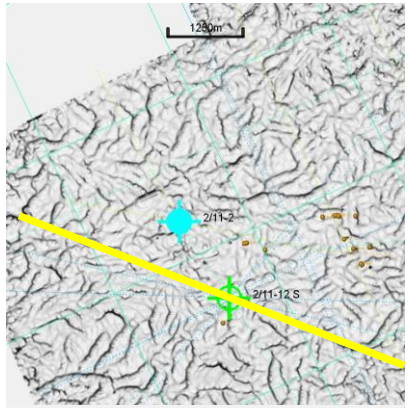


Polygonal Faults in the Valhall Overburden



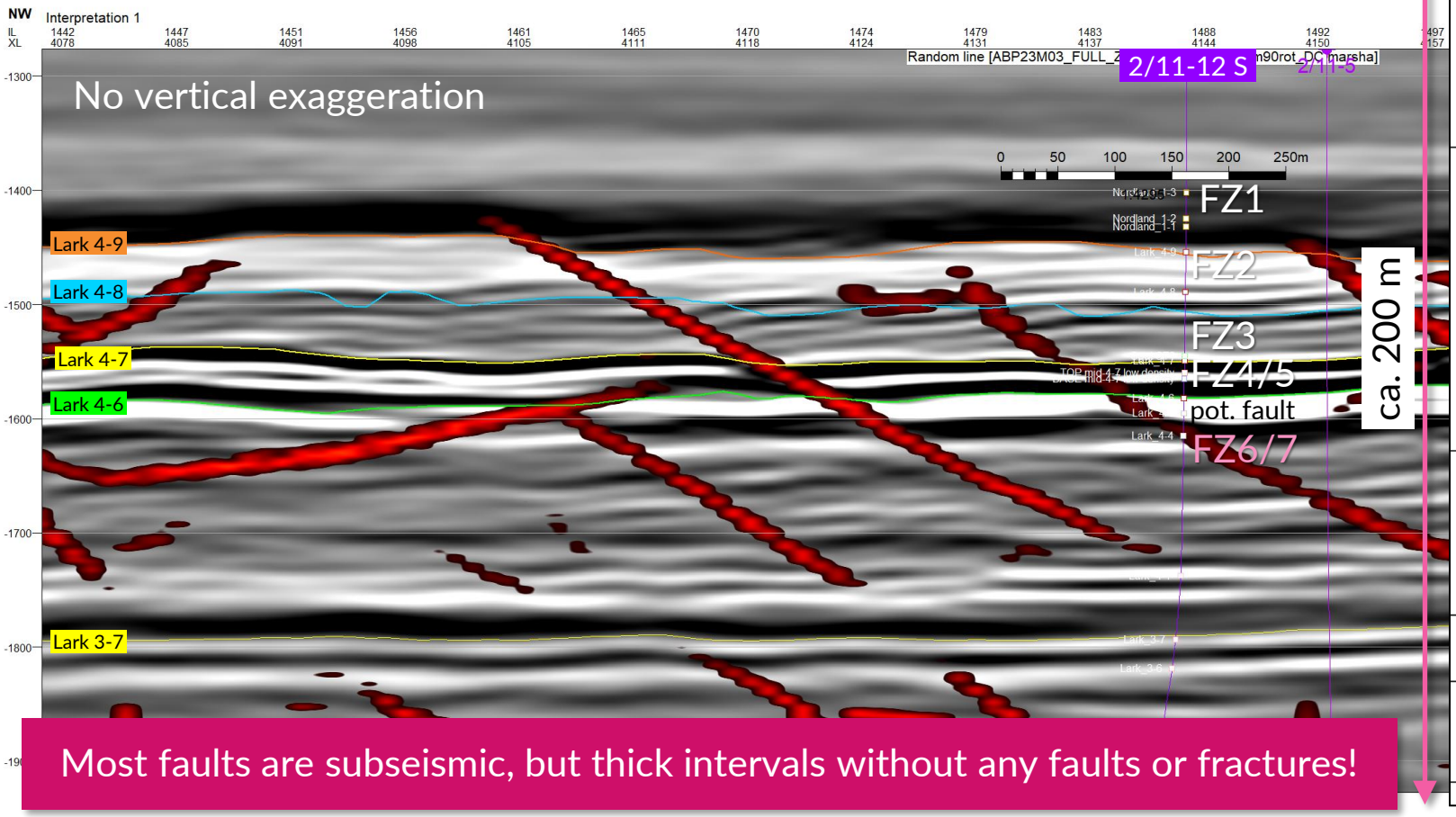
West Hod 2/11-12S

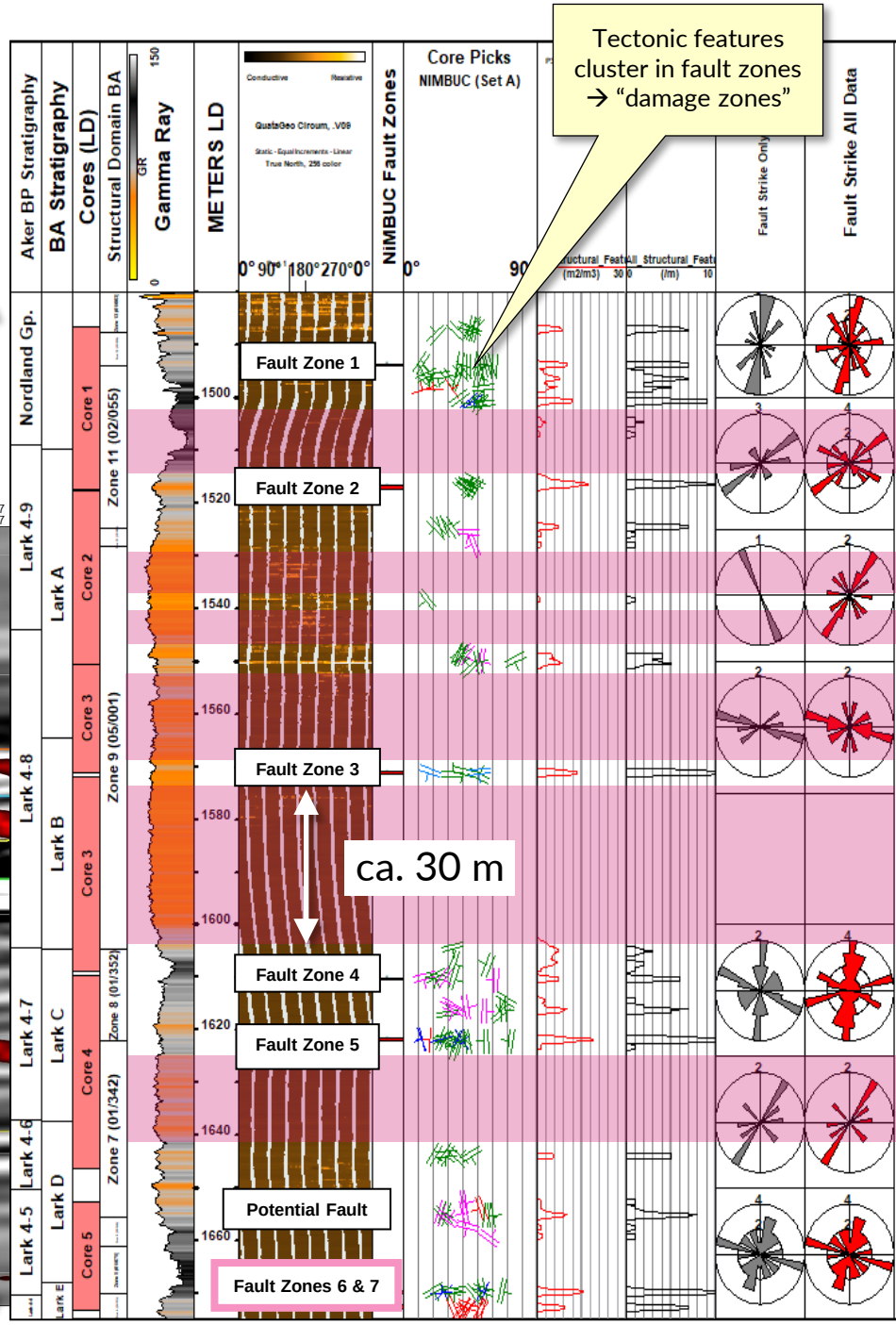
Seismic vs well & BHI observations



Max curvature Lark 4-9

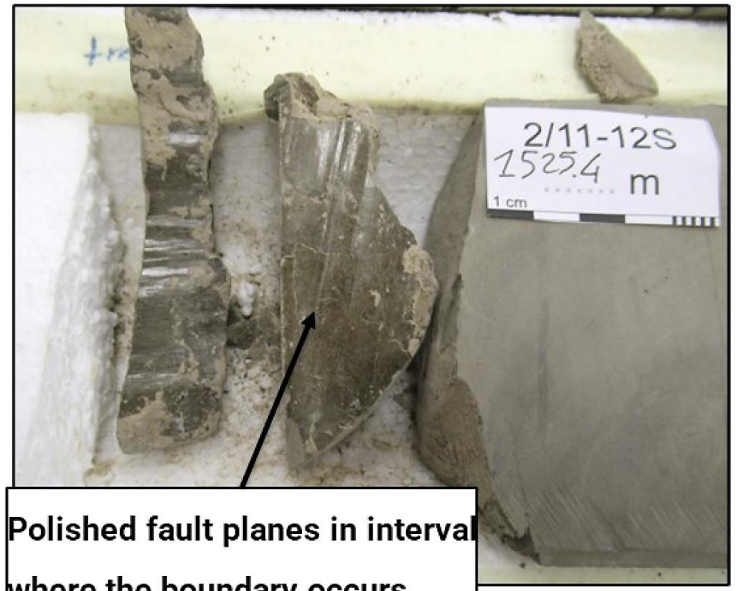
Fracture
Microfault
Fault
Fault Plane (FP)
Joint (J)
Mirror-like Fault Plane (MirFP)
Non-planar fracture
Low-confidence fault



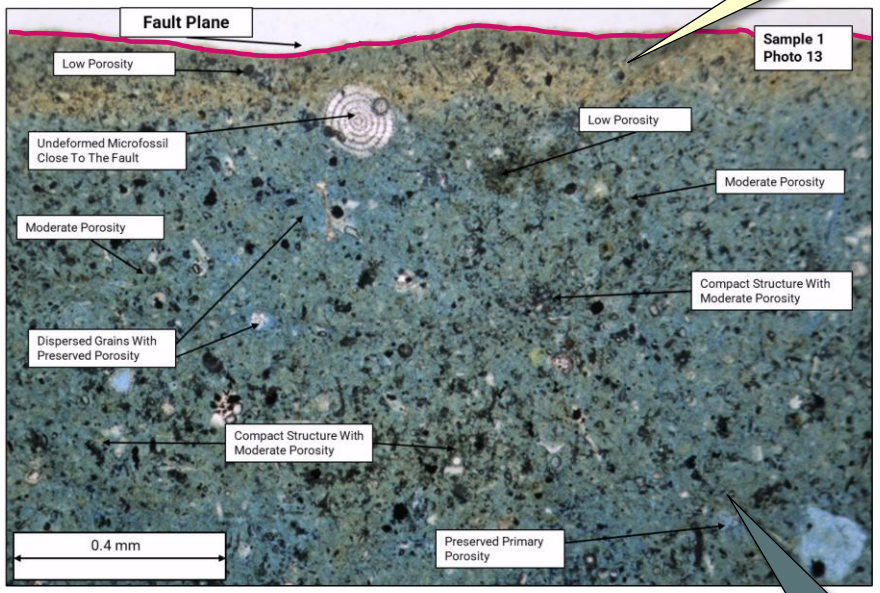


Most faults are subseismic, but thick intervals without any faults or fractures!

Polished Fault Planes

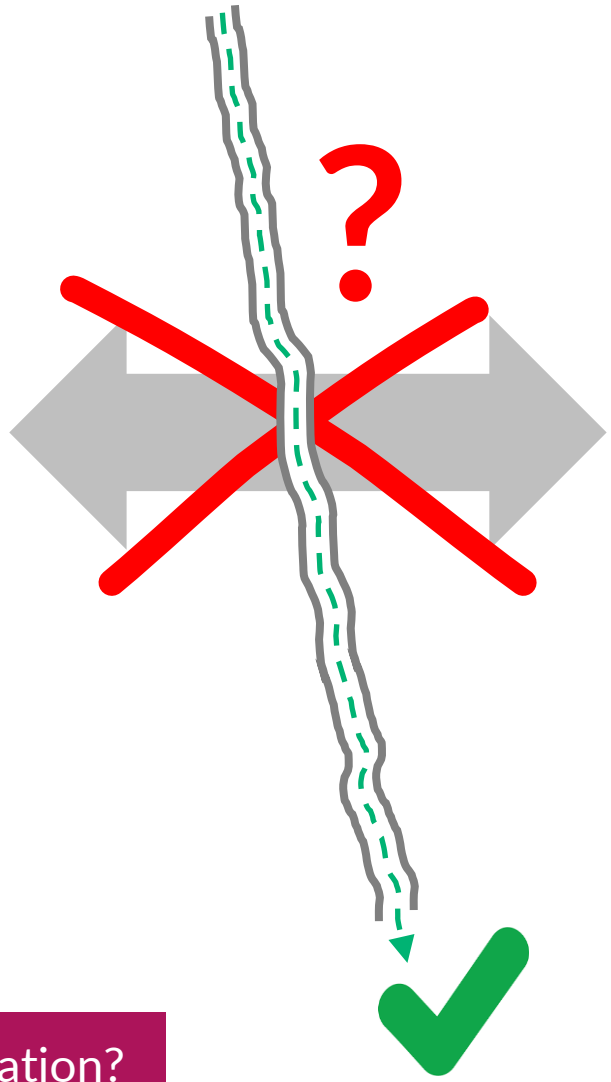


Polished fault planes in interval where the boundary occurs.



Blue resin does not enter

Pore space invaded by blue resin



- No mineralized fractures (e.g., calcite) observed
- Some fault planes are oil-stained → role for charge / fluid migration!
- Fault planes have polished & striated surfaces. It appears that small slip movements are enough to produce these → no “normal” fractures

What does this imply wrt fluid movement across faults / possible compartmentalization?

What now ???

The Challenge

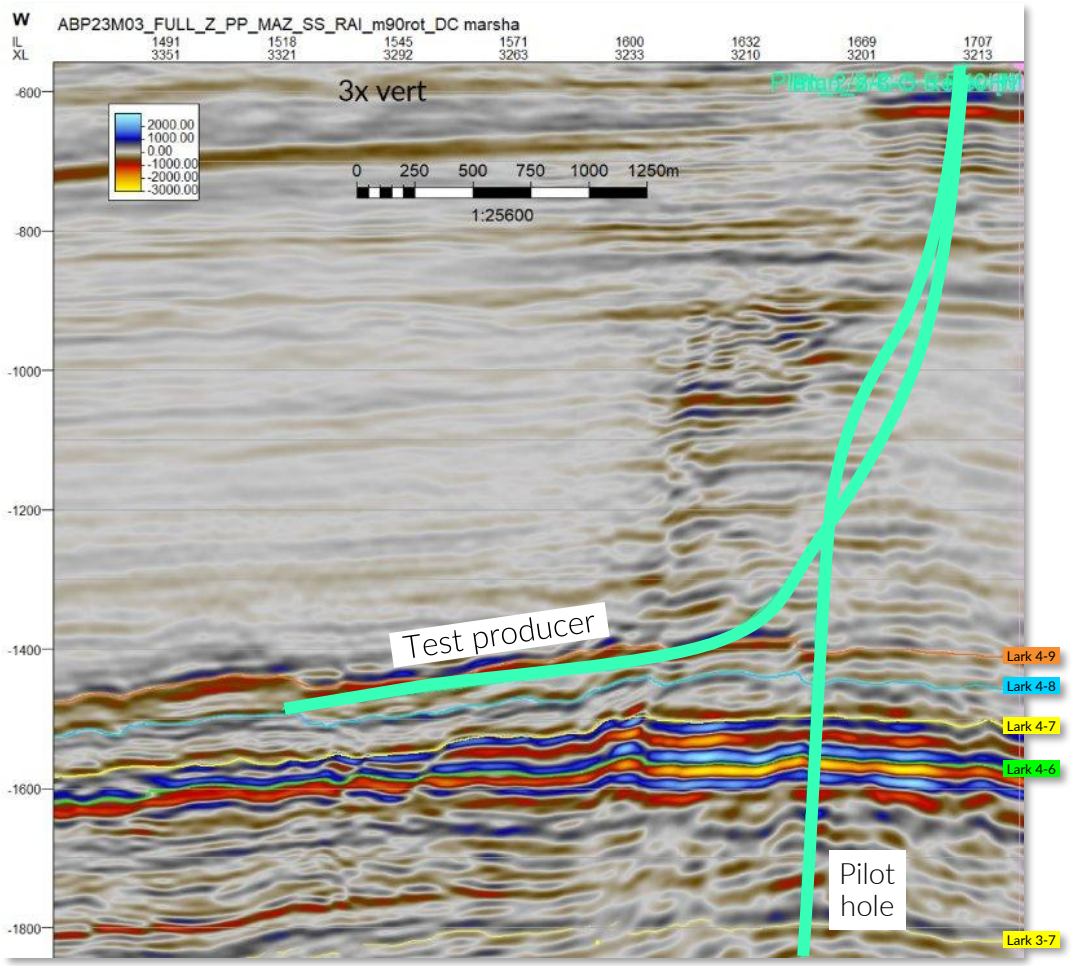
Unlock an unconventional, yet economic development offshore

- Static appraisal ✔ (however, less data than you'd think)
- Next step: Dynamic appraisal
- How to optimally DRILL, STIMULATE and PRODUCE the Miocene?

Miocene Test Producer

- Key objectives
  - Confirm horizontal drilling
  - Confirm producibility
  - Static and dynamic reservoir characterization

- Tentative well concept
  - Vertical pilot for data acquisition
  - Horizontal test producer
    - Evaluating stimulation

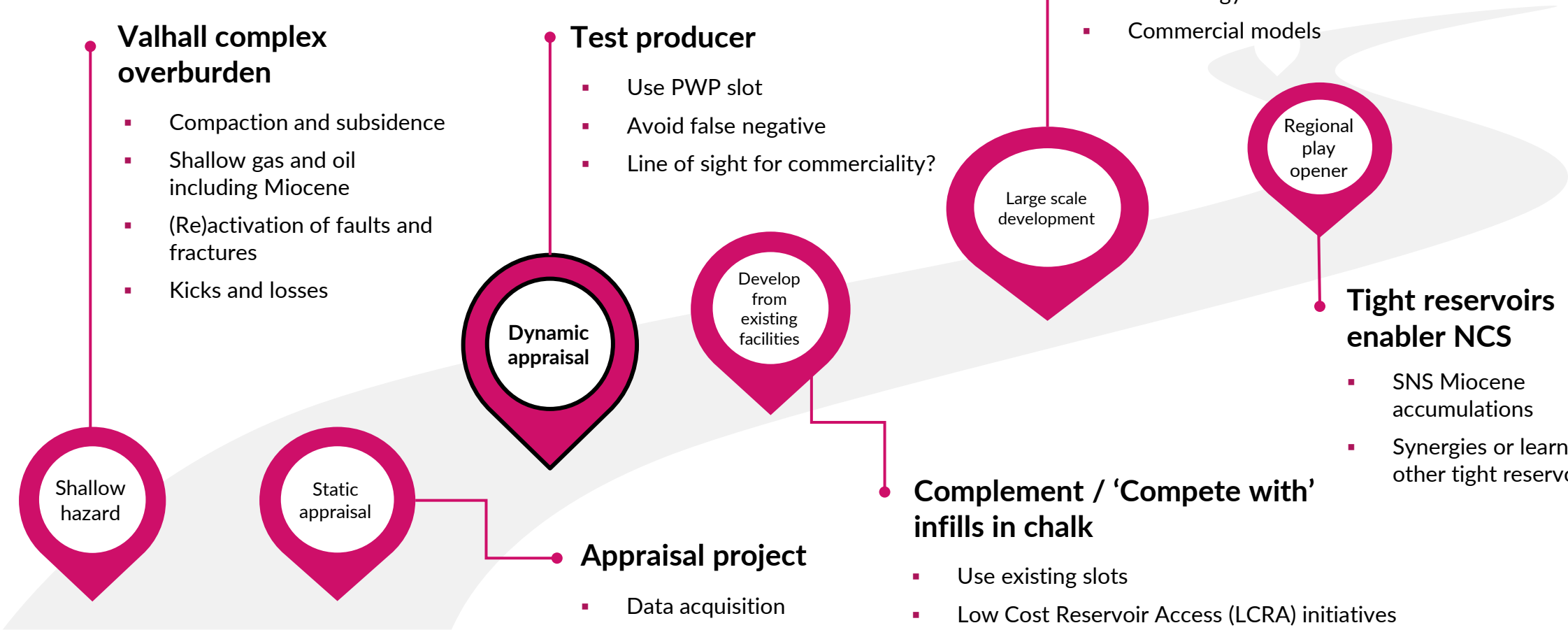


Relative acoustic impedance (RAI), red/orange is soft/low AI

**Limited acquisition in horizontal because of simple bottom hole assembly due to narrow PPFG window*

Phased Development

Step-by-step learning curve



Valhall complex overburden

- Compaction and subsidence
- Shallow gas and oil including Miocene
- (Re)activation of faults and fractures
- Kicks and losses

Test producer

- Use PWP slot
- Avoid false negative
- Line of sight for commerciality?

Appraisal project

- Data acquisition
- Res char & studies
- Model build
- Analogues

Complement / 'Compete with' infills in chalk

- Use existing slots
- Low Cost Reservoir Access (LCRA) initiatives
  - MLT, campaign driven, 'deep' sidetracks etc

Extend lifetime of Valhall & Hod

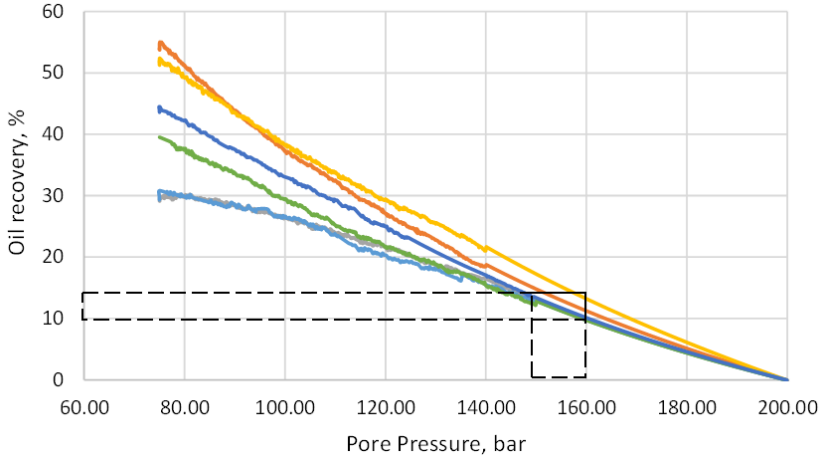
- Infrastructure
- Technology
- Commercial models

Tight reservoirs enabler NCS

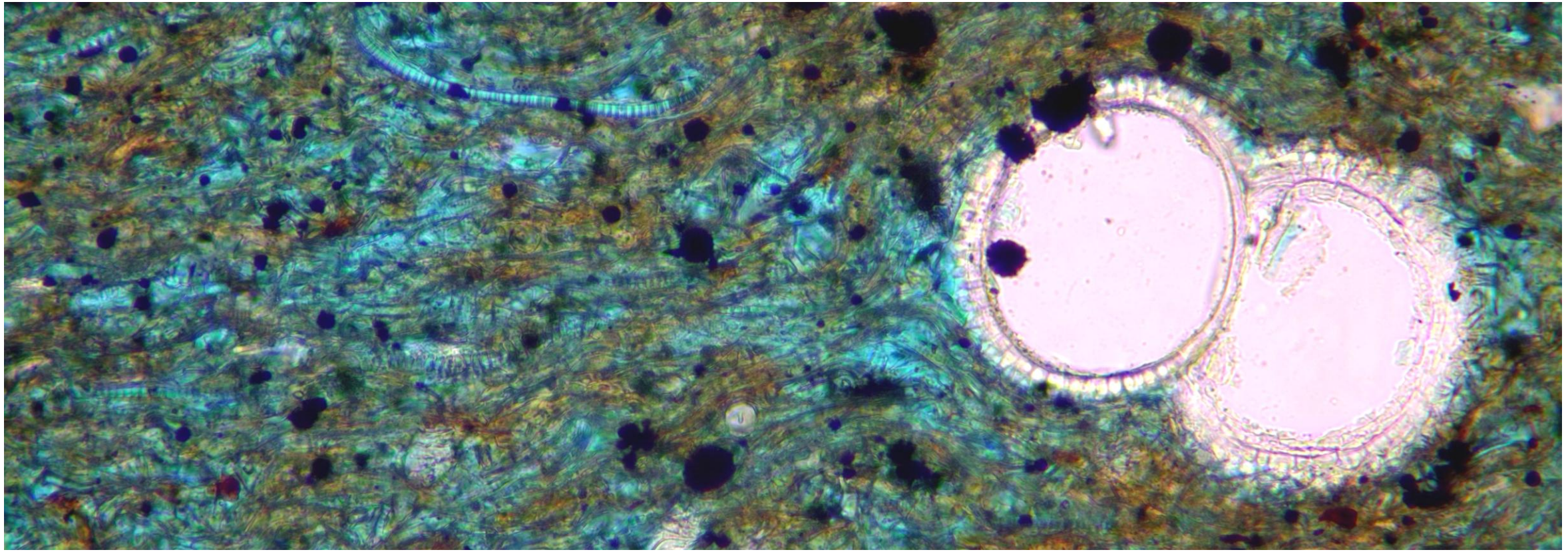
- SNS Miocene accumulations
- Synergies or learnings to other tight reservoirs

Summary

- Stepwise approach
  - Geohazard → development opportunity
- Challenging barrels
  - High porosity low permeability
  - No direct analogues
  - Maximize reservoir contact
- Think out-of-the-box
  - Innovation and technology
- Big prize
  - 3 bill barrels of oil → 1 % oil recovery = 30 mill barrels of oil!
  - 10 bar pressure drop → 3 % oil recovery increase



Thank you for your attention!



Acknowledgements

PANDION ENERGY

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