# A Simple Triassic–Cretaceous Regional Geological Model to Support Wells Drilled in Overpressured Central North Sea Sequences

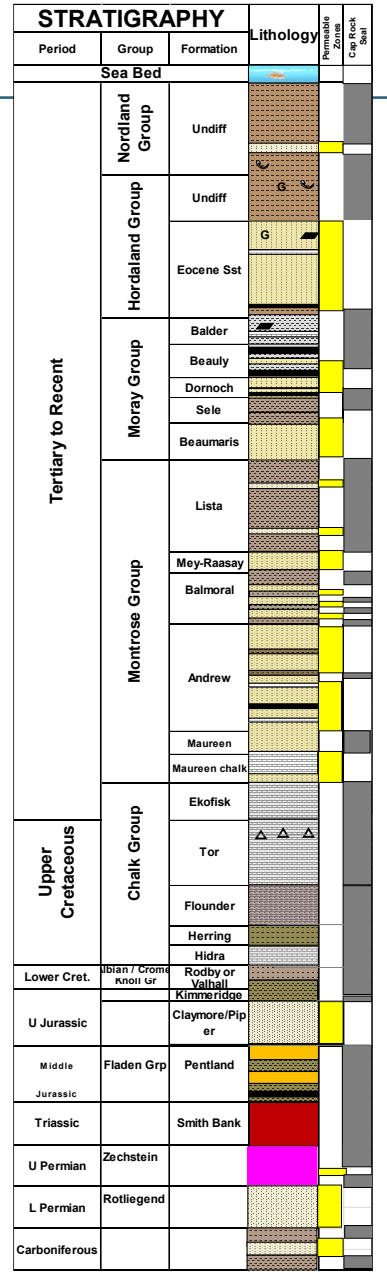
**SPE - Devex Conference** *Chester Hotel, Aberdeen - 29-30th April 2026*

Peter Evans – NEO NEXT+ Operations Geologist

# Objective and Summary

***Present the follow:***

- Cretaceous Flounder Marls - effective regional seal **juxtaposed** against Triassic/Pentland shales to provide lateral seal - creates discrete pressure cells - *cross sections*
- Elevated heat flow - **failed** Central Graben **rift** - combine with gas/condensate generation to further contribute to overpressures.
- Cretaceous **chalk** sequence generally a **cap rock** – though pressure data from Shaw Field indicates vertical **pressure transmission** from the overpressured Fulmar through to near top Cretaceous, in low-permeability Tor Fm underlying normally pressured Andrew Sandstone
- Rapidly deposited, undercompacted and **overpressured Tertiary shales** above
- Shale-rich basinal Tertiary succession acts as a **thermal insulator** - geothermal gradient twice that of sandy rift flanks
- Assessment uses **AI** techniques compares LOTs with **fracture pressures** - objective of reducing drilling losses and influx risk
- Simple regional geological models and methodology – provides a "**practical**" framework for assessing overpressure, shallow hazard risks, annular pressure development - informing **well design**, drilling execution, decommissioning in CNS.



# Methodology, Data Sources, Process Flow

*Science/Engineering → Curiosity → Inspection*

| | |
|---|---|
| Empirical data – LOT/FIT/DST/RFT/mud gas/ flows/kicks/cavings/losses | Prime in areas of rich well data |
| Undercompacted shale modelled – resistivity/ density/sonic | Works well in thick Tertiary claystone and scanty well data |
| Seismic and velocities | Used in exploration - also 3D/4D geomechanical field models large overpressured field) |
| Structural, sedimentology | Critical to consider "plumbing" |
| Pressure cells - models | Very important in Central North Sea below Flounder |
| Geothermal gradient | Important in Central North Sea – high heat flow in failed rift – shale insulator |
| Reservoir pressure - depletion/WI | "A given" – RE responsible - input from Ops Geo, Dev Geo etc ref WI etc |

- PPFG
- Integrated across disciplines
- Geological driven – plumbing/ architecture
- Temperature predictions

Regional

↓

Field Wide

↓

Well data - analytics

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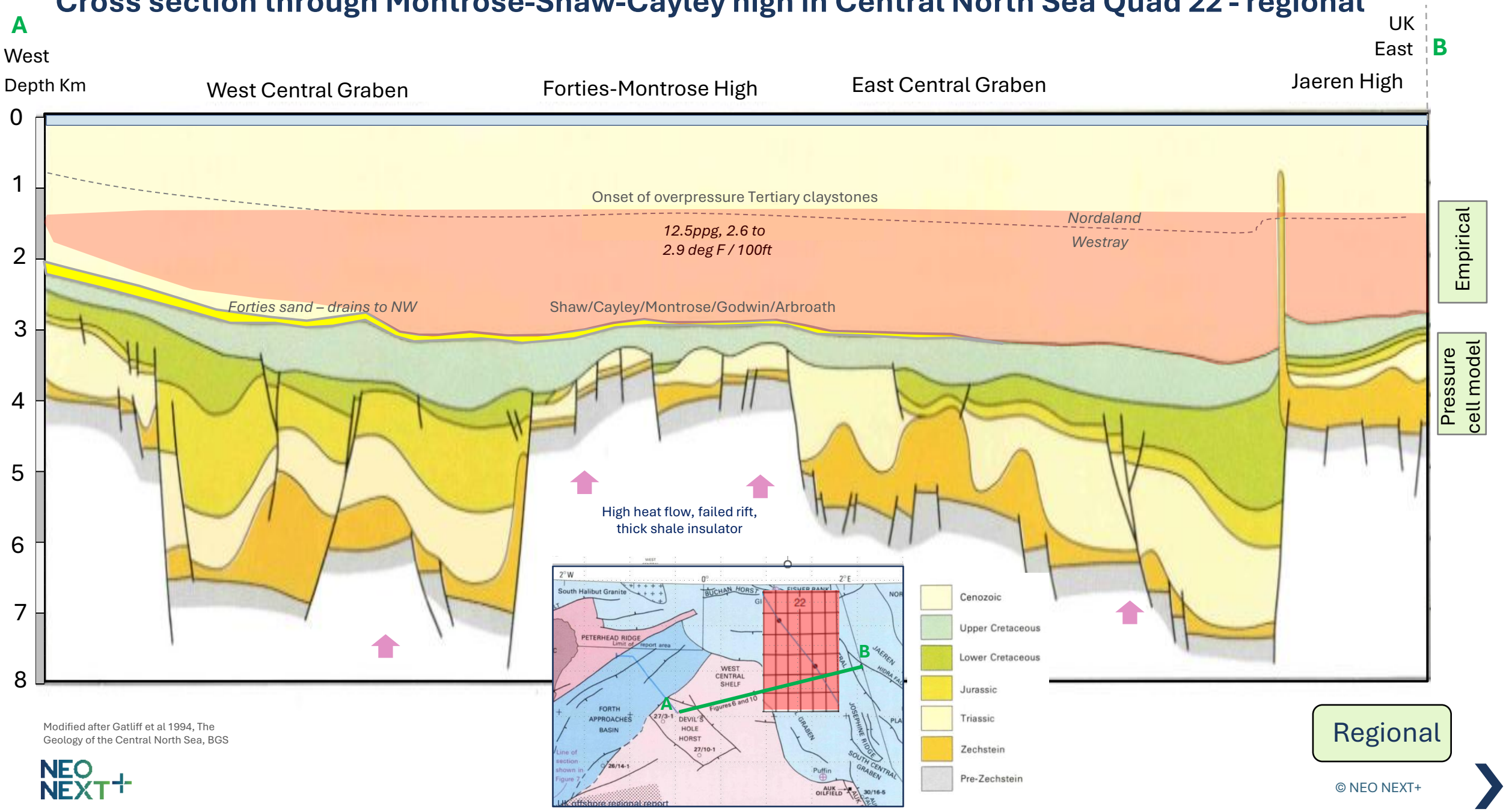
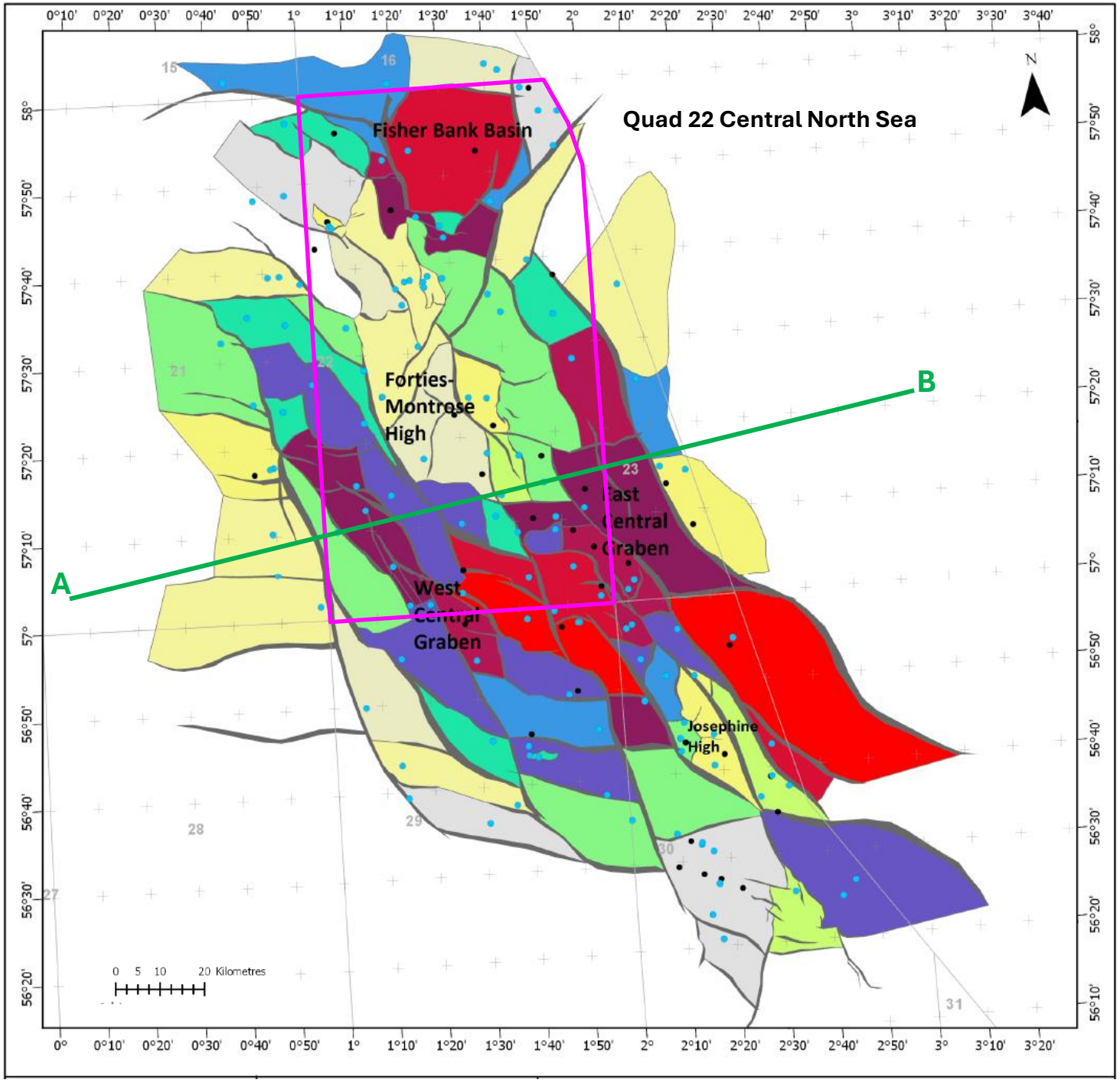
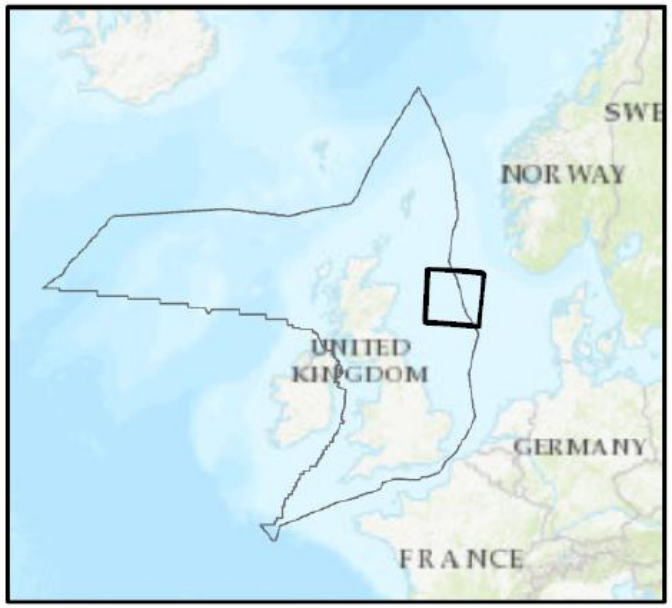
# Cross section through Montrose-Shaw-Cayley high in Central North Sea Quad 22 - regional




Modified after Gatliff et al 1994, The Geology of the Central North Sea, BGS

Regional




Legend

- Hydrocarbon Data Wells
- Aquifer Data Wells
- Pressure Cell Boundaries
- Quads_UKCS_offshore

Min Overpressure [psi]

- ≤1000
- ≤2000
- ≤3000
- ≤4000
- ≤4500
- ≤5000
- ≤5500
- ≤6000
- ≤6500
- ≤7000
- ≤7500
- ≤8000
- ≤9000

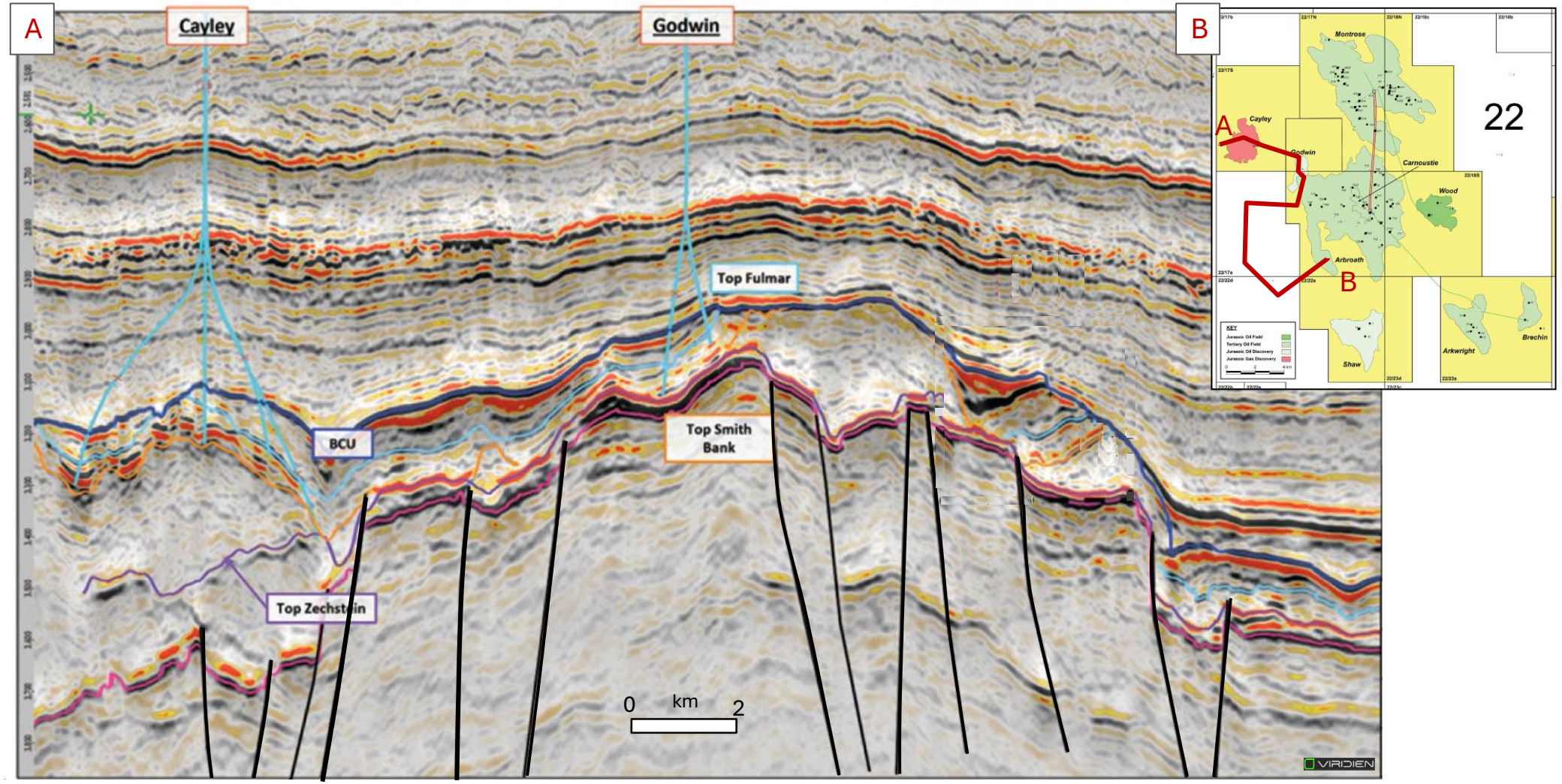
Oil & Gas Authority

Area of interest mainly 2000 - 5000 (on flanks up to 7000 psi overpressure)

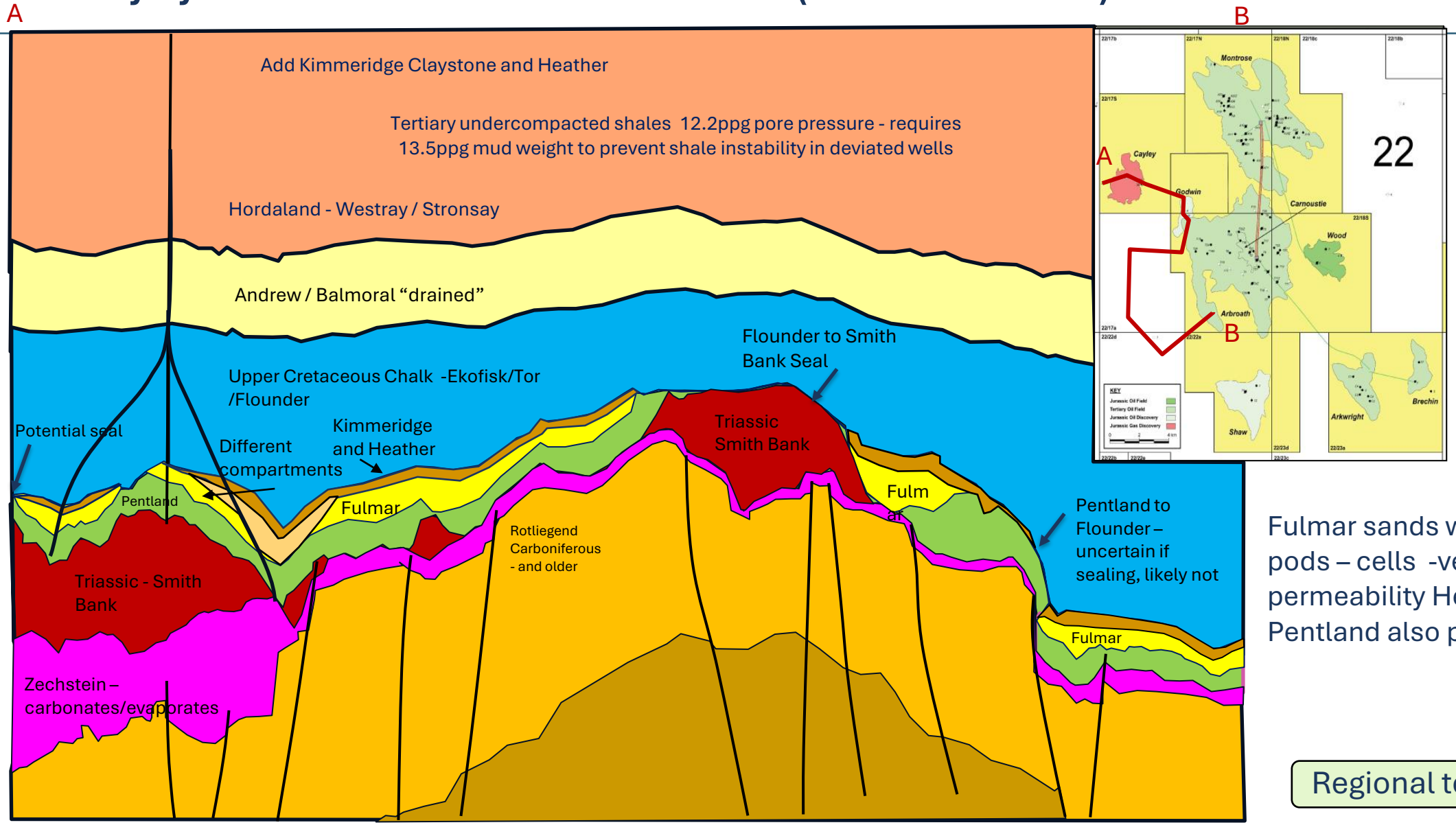
Regional

*Supported by Ikon Science*

# Cayley – Godwin - Shaw –Arbroath area – seismic section



# Cayley – Godwin - Shaw area cross section (south of Arbroath)

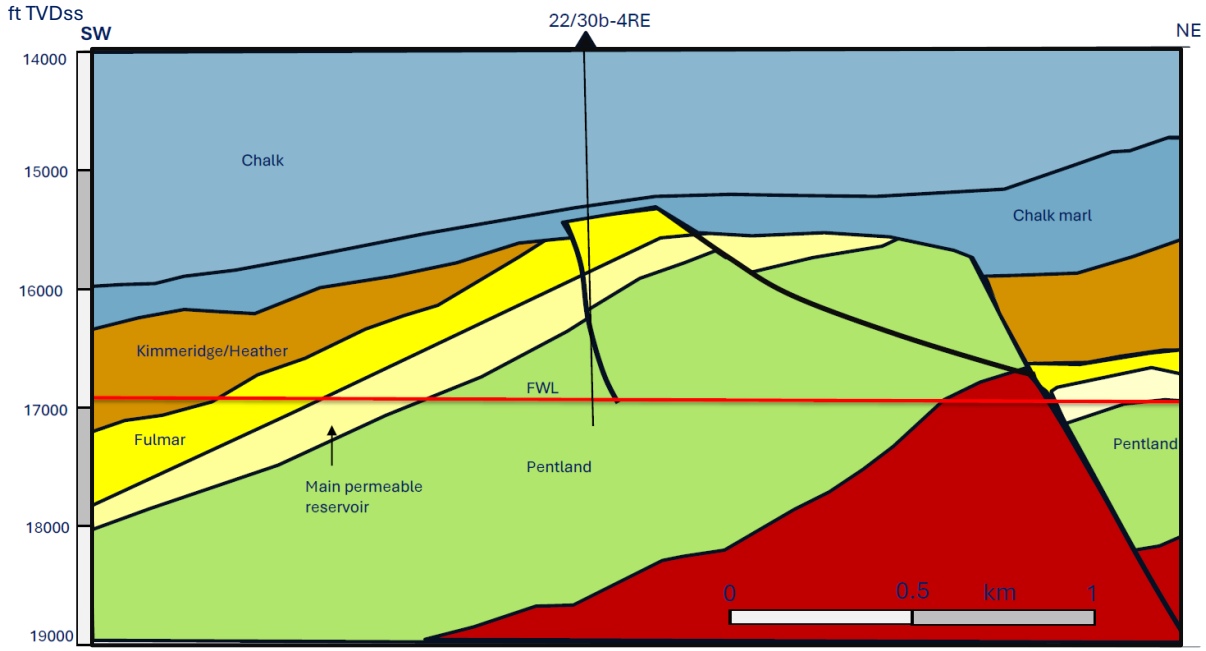



Fulmar sands within Triassic pods – cells -very thin low permeability Heather and Pentland also possible

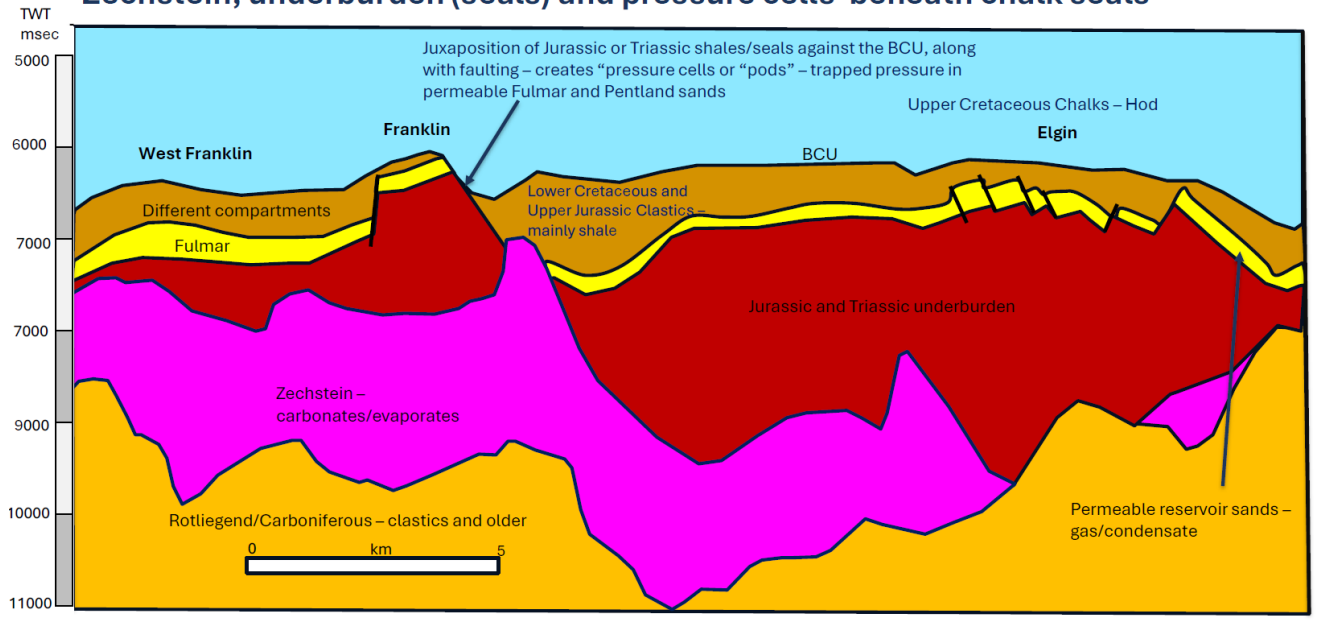
Regional to field wide

# Regional – flanks of Quad 22

## Shearwater Field



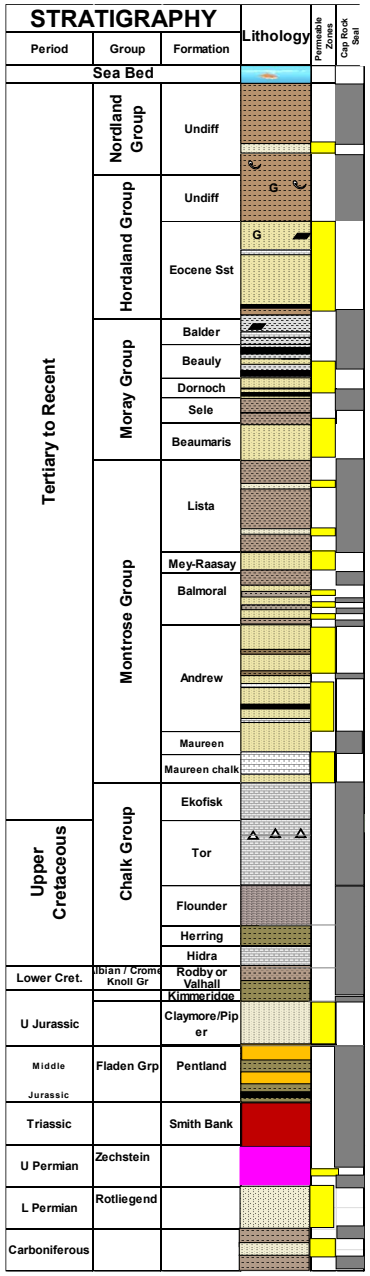

## Elgin – Franklin – schematic cross section – to illustrate the variable Zechstein, underburden (seals) and pressure cells beneath chalk seals



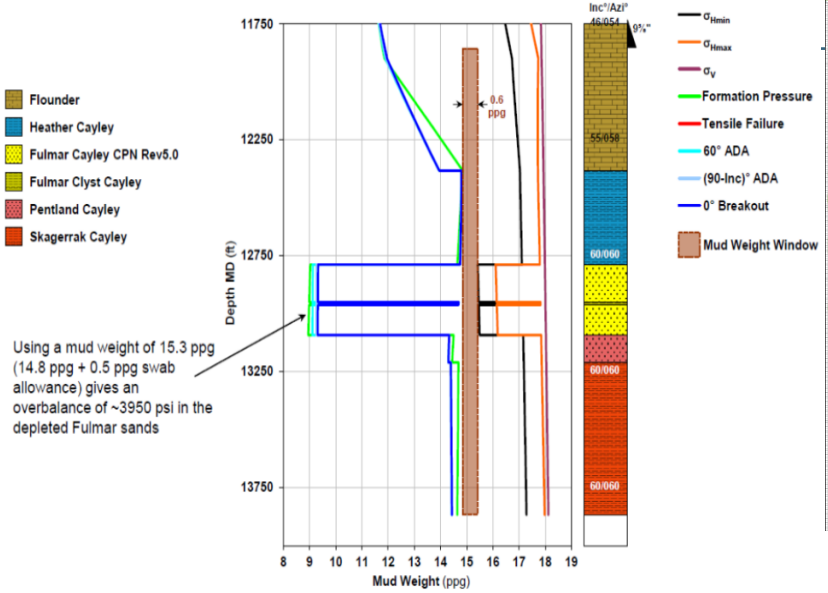

Pressure cells – Smith Bank/Pentland seal juxtaposed against tight Flounder/BCU – trapped "pressure cooker"

Regional to field wide

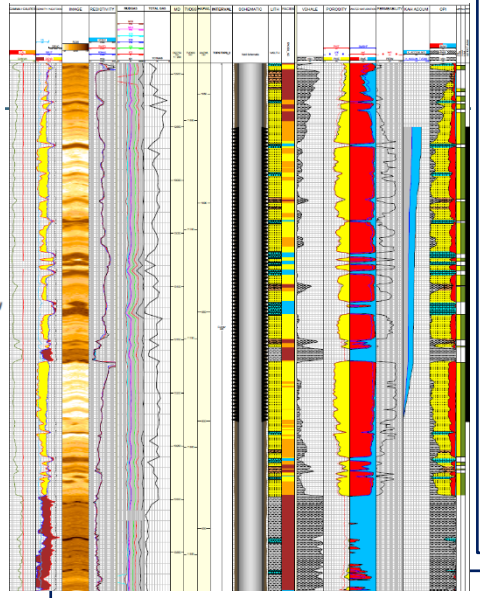
## Piper and Claymore – normal pressures “leaky-sandy-draining”



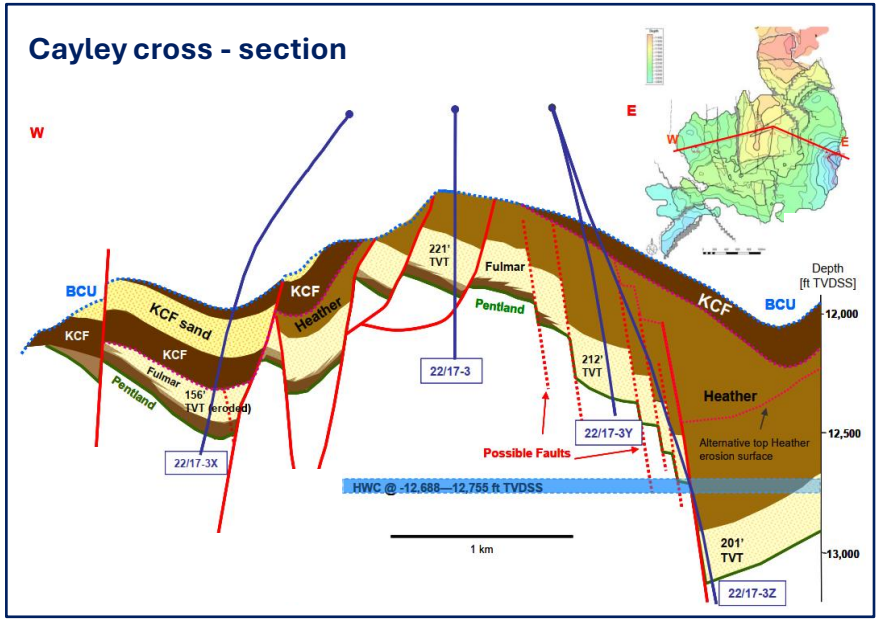

## Typical Cayley showing ramp up in pressure towards base Chalk - mud weight assessment , part of wellbore stability study



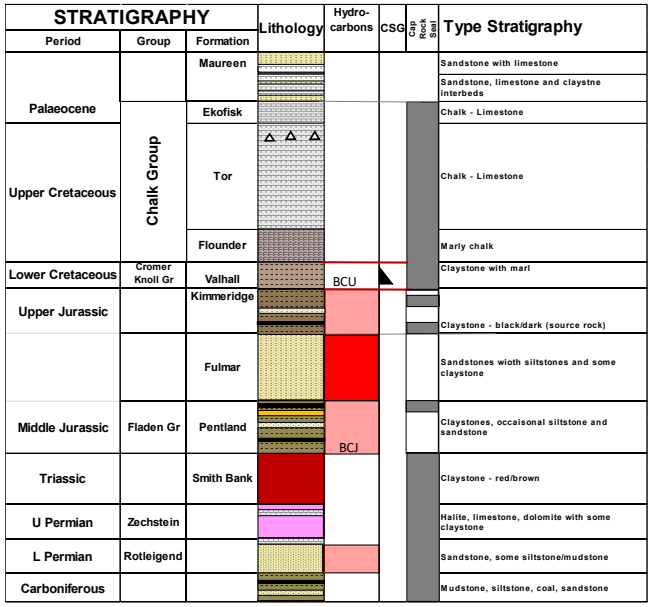

## Cayley J1 CPI



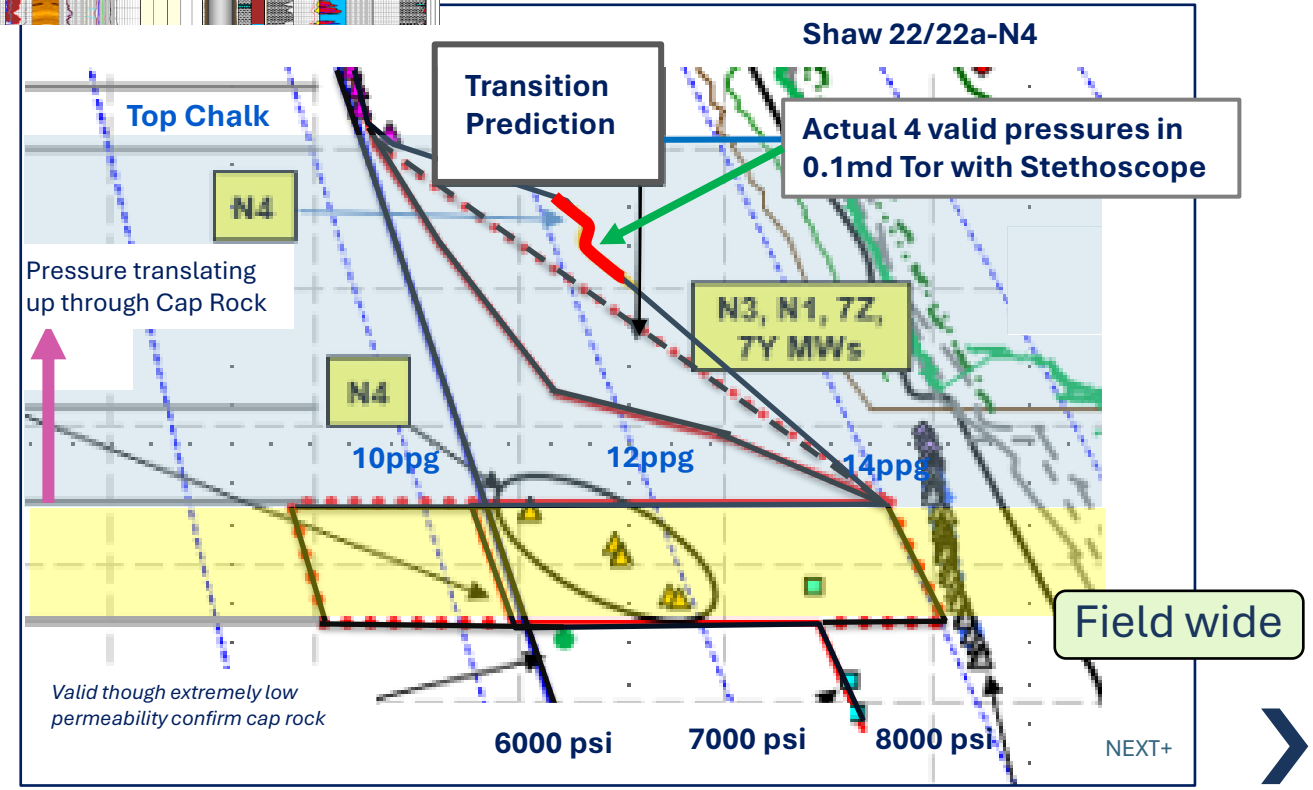
## Cayley cross - section




## Type log in over pressured Shaw/Cayley/Montrose area



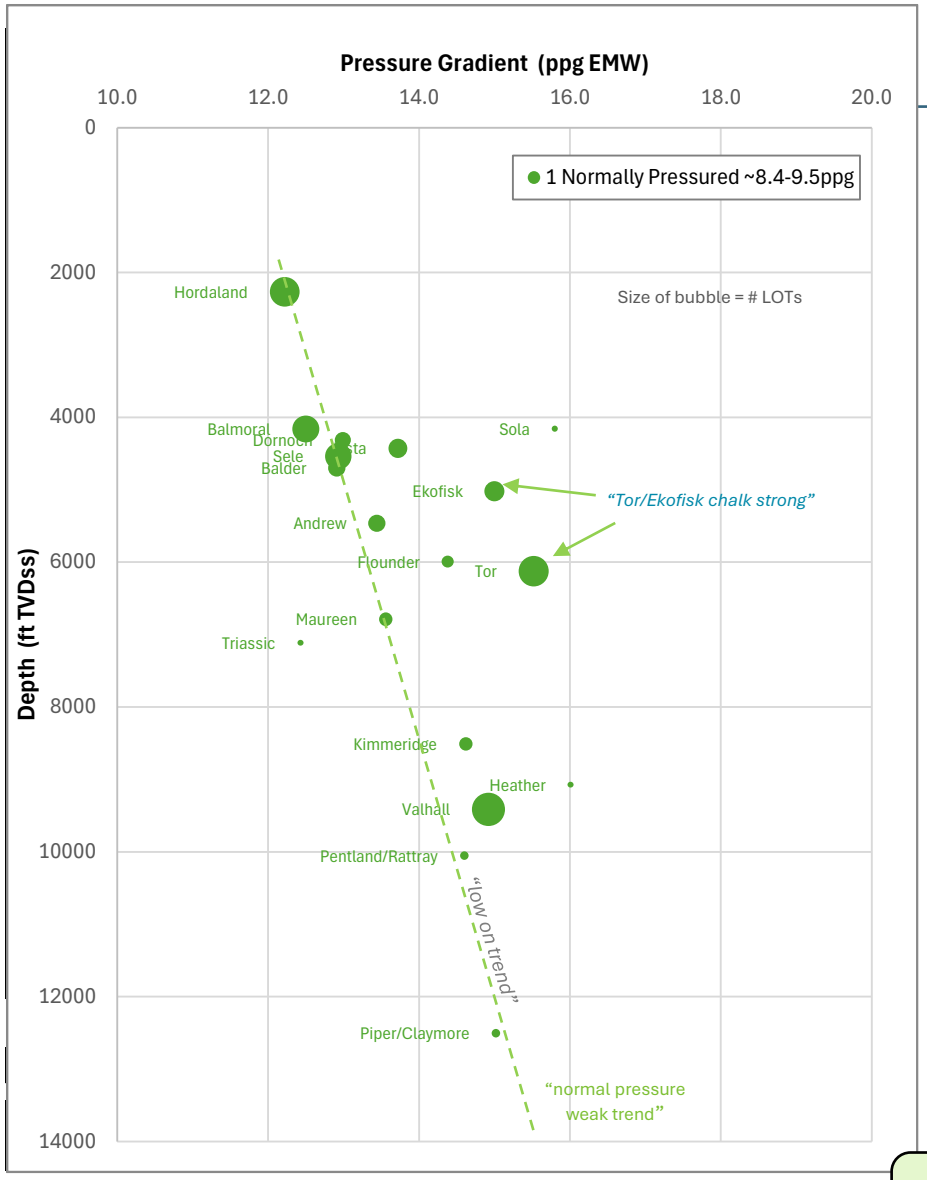

## Shaw 22/22a-N4



# Central North Sea - Geology and Fields - development, exploration and appraisal wells - per overpressured area - *NEO NEXT fields/areas*

## Fracture Pressure LOT Database - measured/empiricle well data

| Formation | 1 Normally Pressured ~8.4 - 9.5ppg | | | 2 Overpressured 9.5-11ppg | | | 3 Overpressured >11 -15ppg | | | Delta 2-1 | Delta 3-2 | Delta 3-1 (or 3-2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LOT ppg | No. | Depth Average ft TVDss | LOT ppg | No. | Depth Average ft TVDss | LOT ppg | No. | Depth Average ft TVDss | | | |
| Hordaland | 12.2 | 24 | 2267 | 14.6 | 81 | 5419 | 15.6 | 17 | 6975 | 2.3 | 1.0 | 3.4 |
| Westray | | | | 15.3 | 35 | 4714 | 14.7 | 14 | 5886 | | -0.6 | |
| Stronsay | | | | 14.8 | 7 | 6676 | 15.4 | 29 | 8134 | | 0.6 | |
| Balder | 12.9 | 8 | 4702 | 14.1 | 8 | 6000 | 14.2 | 22 | 8234 | 1.2 | 0.1 | 1.3 |
| Dornoch | 13.0 | 7 | 4313 | | | | | | | | | |
| Sele | 12.9 | 19 | 4538 | 16.0 | 1 | 8984 | 15.0 | 8 | 8102 | 3.1 | -1.0 | 2.1 |
| Lista | 13.7 | 10 | 4427 | 15.7 | 5 | 8089 | | | | | | |
| Balmoral | 12.5 | 20 | 4161 | | | | | | | | | |
| Andrew | 13.4 | 8 | 5463 | | | | 15.8 | 1 | 8550 | | | 2.4 |
| Maureen | 13.6 | 5 | 6788 | 13.5 | 4 | 6271 | | | | | | |
| Ekofisk | 15.0 | 11 | 5022 | 15.8 | 7 | 9567 | 15.2 | 5 | 9638 | 0.8 | -0.6 | 0.2 |
| Tor | 15.5 | 25 | 6125 | 15.1 | 10 | 8956 | 16.4 | 27 | 10325 | -0.4 | 1.3 | 0.9 |
| Hod | | | | 16.7 | 19 | 11558 | 16.9 | 3 | 11271 | | 0.2 | |
| Flounder | 14.4 | 4 | 5992 | | | | 17.1 | 7 | 10860 | | | |
| Sola | 15.8 | 1 | 4158 | | | | | | | | | |
| Valhall | 14.9 | 30 | 9415 | 17.4 | 18 | 11854 | 18.3 | 8 | 12953 | 2.5 | 0.9 | 3.4 |
| Kimmeridge | 14.6 | 5 | 8511 | 17.2 | 6 | 12015 | 18.9 | 4 | 13671 | 2.6 | 1.7 | 4.2 |
| Piper/Claymore | 15.0 | 2 | 12504 | | | | | | | | | |
| Pentland/Rattray | 14.6 | 2 | 10051 | | | | | | | | | |
| Heather | 16.0 | 1 | 9073 | | | | | | | | | |
| Triassic | 12.4 | 1 | 7113 | 16.3 | 1 | 11935 | | | | | | |
| Zechstein | | | | 17.5 | 1 | 7603 | | | | | | |
| Rotliegend | | | | 13.9 | 2 | 7712 | | | | | | |
| Average delta | | | | | | | | | | 1.7 | 0.3 | 2.0 |
| Average | 14.0 | 183 | 6368 | 15.6 | 205 | 8490 | 16.1 | 145 | 9550 | 1.6 | 0.5 | 2.1 |
| LOT vs Copilot | | | | | | | | | | | | |
| Pure chalk fms | | | | | | | | | | | | |

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*CoPilot likely measures a greater range of fields-area with a more mathematical approach. LOT comparison versus Copilot not calculated for LOTs number 5 or less (not statistically meaningful)*
*ppg = pounds per gallon equivalent mud weight - fracture gradient. Note: Chalk "rigid" not much variation with overpressures. Shales "flex" - significant strengthening as soon as into overpressured areas*
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| Balder | 12.9 | 8 | 4702 | 14.1 | 8 | 6000 | 14.2 | 22 | 8234 | 1.2 | 0.1 | 1.3 |
| Dornoch | 13.0 | 7 | 4313 | | | | | | | | | |
| Sele | 12.9 | 19 | 4538 | 16.0 | 1 | 8984 | 15.0 | 8 | 8102 | 3.1 | -1.0 | 2.1 |
| Lista | 13.7 | 10 | 4427 | 15.7 | 5 | 8089 | | | | | | |
| Balmoral | 12.5 | 20 | 4161 | | | | | | | | | |
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| Hod | | | | 16.7 | 19 | 11558 | 16.9 | 3 | 11271 | | 0.2 | |
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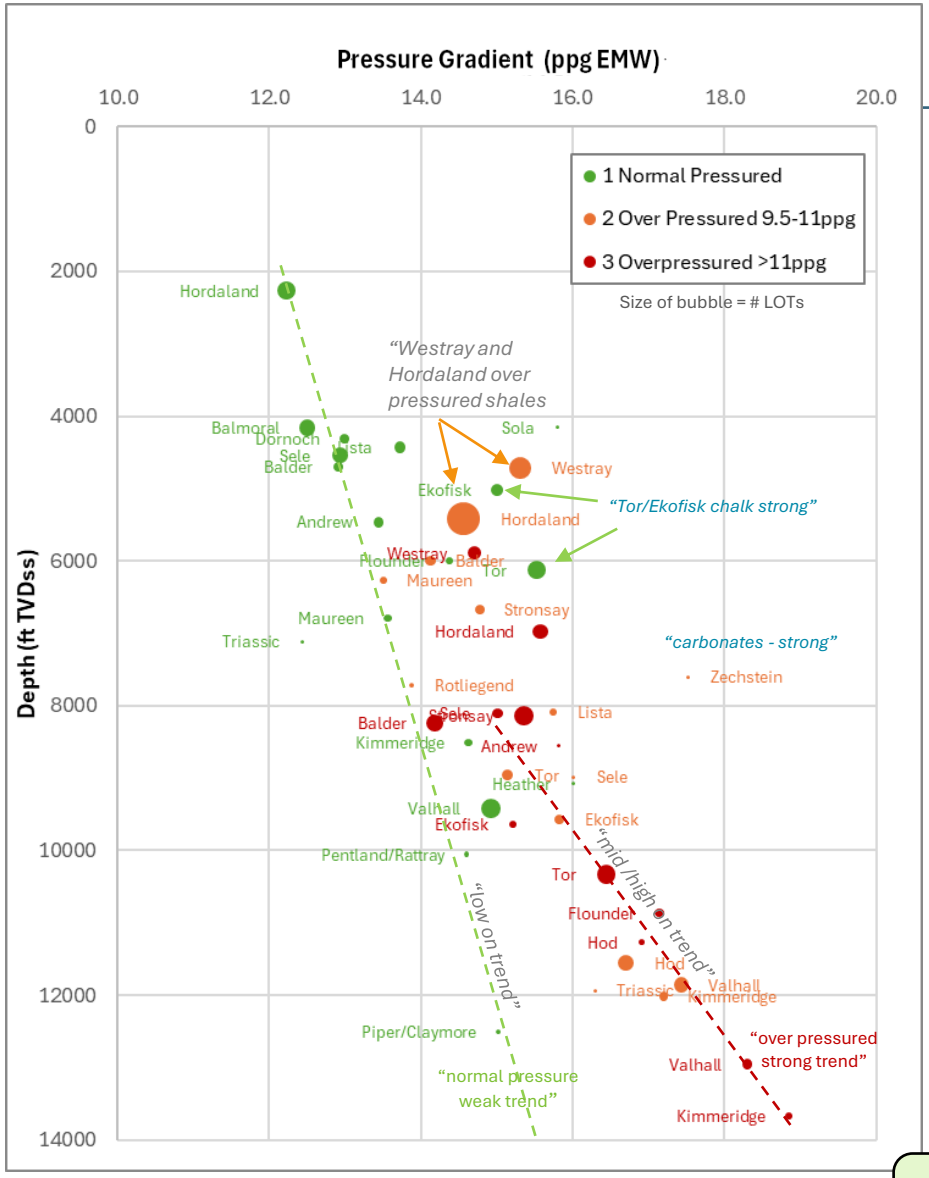
| Sola | 15.8 | 1 | 4158 | | | | | | | | | |
| Valhall | 14.9 | 30 | 9415 | 17.4 | 18 | 11854 | 18.3 | 8 | 12953 | 2.5 | 0.9 | 3.4 |
| Kimmeridge | 14.6 | 5 | 8511 | 17.2 | 6 | 12015 | 18.9 | 4 | 13671 | 2.6 | 1.7 | 4.2 |
| Piper/Claymore | 15.0 | 2 | 12504 | | | | | | | | | |
| Pentland/Rattray | 14.6 | 2 | 10051 | | | | | | | | | |
| Heather | 16.0 | 1 | 9073 | | | | | | | | | |
| Triassic | 12.4 | 1 | 7113 | 16.3 | 1 | 11935 | | | | | | |
| Zechstein | | | | 17.5 | 1 | 7603 | | | | | | |
| Rotliegend | | | | 13.9 | 2 | 7712 | | | | | | |
| Average delta | | | | | | | | | | 1.7 | 0.3 | 2.0 |
| Average | 14.0 | 183 | 6368 | 15.6 | 205 | 8490 | 16.1 | 145 | 9550 | 1.6 | 0.5 | 2.1 |
| LOT vs Copilot | | | | | | | | | | | | |
| Pure chalk fms | | | | | | | | | | | | |

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*For areas up top 15ppg LOTs and Copilot very close - breaks down in high case likely because Copilot assessing HTHP datasets (not valid for Cayley-Shaw-Montrose)*

Well data - analytics

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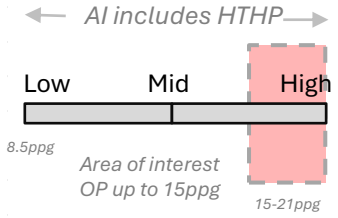
**Fracture Pressure LOT Database - measured/empiricle well data**

| Formation | 1 Normally Pressured ~8.4 - 9.5ppg | | | 2 Overpressured 9.5-11ppg | | | 3 Overpressured >11 -15ppg | | | Delta 2-1 | Delta 3-2 | Delta 3-1 (or 3-2) | Fracture Pressure - CoPilot Outputs - | | | | Variance LOT vs Copilot Pressure | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LOT ppg | No. | Depth Average ft TVDss | LOT ppg | No. | Depth Average ft TVDss | LOT ppg | No. | Depth Average ft TVDss | | | | ppg Low | ppg Mid | ppg High | Depth ft TVDss | ppg Low | ppg Mid | ppg High | Av depth ft |
| Hordaland | 12.2 | 24 | 2267 | 14.6 | 81 | 5419 | 15.6 | 17 | 6975 | 2.3 | 1.0 | 3.4 | 13.5 | 15.4 | 17.3 | 5900 | 1.3 | 0.8 | 1.7 | 1013 |
| Westray | | | | 15.3 | 35 | 4714 | 14.7 | 14 | 5886 | | -0.6 | | 13.8 | 15.4 | 17.3 | 8530 | | 0.1 | 2.6 | 3230 |
| Stronsay | | | | 14.8 | 7 | 6676 | 15.4 | 29 | 8134 | | 0.6 | | 15.0 | 16.5 | 18.3 | 10330 | | 1.7 | 3.0 | 2925 |
| Balder | 12.9 | 8 | 4702 | 14.1 | 8 | 6000 | 14.2 | 22 | 8234 | 1.2 | 0.1 | 1.3 | 13.5 | 15.4 | 17.3 | 7200 | 0.6 | 1.3 | 3.1 | 888 |
| Dornoch | 13.0 | 7 | 4313 | | | | | | | | | | 15.4 | 17.3 | 19.3 | 4300 | 2.4 | | | -13 |
| Sele | 12.9 | 19 | 4538 | 16.0 | 1 | 8984 | 15.0 | 8 | 8102 | 3.1 | -1.0 | 2.1 | 13.5 | 15.4 | 17.3 | 4900 | 0.6 | -0.6 | 2.3 | -2308 |
| Lista | 13.7 | 10 | 4427 | 15.7 | 5 | 8089 | | | | | | | 13.5 | 15.4 | 17.3 | 8500 | -0.2 | -0.3 | | 2242 |
| Balmoral | 12.5 | 20 | 4161 | | | | | | | | | | 15.4 | 17.3 | 19.3 | 7000 | 2.9 | | | 2839 |
| Andrew | 13.4 | 8 | 5463 | | | | 15.8 | 1 | 8550 | | | 2.4 | 14.5 | 17.3 | 19.2 | 8000 | 1.1 | | | 994 |
| Maureen | 13.6 | 5 | 6788 | 13.5 | 4 | 6271 | | | | | | | 15.4 | 17.3 | 18.3 | 9200 | 1.8 | 3.8 | | 2671 |
| Ekofisk | 15.0 | 11 | 5022 | 15.8 | 7 | 9567 | 15.2 | 5 | 9638 | 0.8 | -0.6 | 0.2 | 15.4 | 17.3 | 19.3 | 10000 | 0.4 | 1.5 | 4.1 | 1924 |
| Tor | 15.5 | 25 | 6125 | 15.1 | 10 | 8956 | 16.4 | 27 | 10325 | -0.4 | 1.3 | 0.9 | 13.5 | 16.4 | 19.3 | 10500 | -2.0 | 1.3 | 2.9 | 2031 |
| Hod | | | | 16.7 | 19 | 11558 | 16.9 | 3 | 11271 | | 0.2 | | 14.8 | 16.0 | 17.1 | 11500 | | -0.7 | 0.2 | 86 |
| Flounder | 14.4 | 4 | 5992 | | | | 17.1 | 7 | 10860 | | | | 14.4 | 16.4 | 18.3 | 11200 | 0.0 | | 1.2 | 2774 |
| Sola | 15.8 | 1 | 4158 | | | | | | | | | | 13.5 | 15.4 | 17.3 | 10000 | | | | |
| Valhall | 14.9 | 30 | 9415 | 17.4 | 18 | 11854 | 18.3 | 8 | 12953 | 2.5 | 0.9 | 3.4 | 14.4 | 16.4 | 18.3 | 10000 | -0.5 | -1.0 | 0.0 | -1407 |
| Kimmeridge | 14.6 | 5 | 8511 | 17.2 | 6 | 12015 | 18.9 | 4 | 13671 | 2.6 | 1.7 | 4.2 | 13.5 | 15.5 | 17.3 | 10000 | -1.1 | -1.7 | -1.6 | -1399 |
| Piper/Claymore | 15.0 | 2 | 12504 | | | | | | | | | | 16.4 | 17.3 | 19.3 | 9000 | | | | -3504 |
| Pentland/Rattray | 14.6 | 2 | 10051 | | | | | | | | | | 16.4 | 17.3 | 19.3 | 10000 | | | | -51 |
| Heather | 16.0 | 1 | 9073 | | | | | | | | | | 16.3 | 17.7 | 19.2 | 11650 | | | | 2577 |
| Triassic | 12.4 | 1 | 7113 | 16.3 | 1 | 11935 | | | | | | | 17.7 | 19.2 | 21.2 | 14100 | | | | 4576 |
| Zechstein | | | | 17.5 | 1 | 7603 | | | | | | | 11.5 | 15.4 | 19.2 | 6000 | | | | -1603 |
| Rotliegend | | | | 13.9 | 2 | 7712 | | | | | | | 16.4 | 18.3 | 20.2 | 10700 | | | | 2988 |
| Average delta | | | | | | | | | | 1.7 | 0.3 | 2.0 | | | | | 0.55 | 0.51 | 1.77 | 1067 |
| Average | 14.0 | 183 | 6368 | 15.6 | 205 | 8490 | 16.1 | 145 | 9550 | 1.6 | 0.5 | 2.1 | 14.7 | 16.6 | 18.5 | 9066 | | | | |
| LOT vs Copilot | | | | | | | | | | | | | 0.65 | 0.98 | 2.41 | | | | | |
| Pure chalk fms | | | | | | | | | | | | | 11.5 | 15.4 | 19.2 | | | | | |




| | |
|---|---|
| 2.8 | LOT High to Low |
| 3.0 | Cop Mid-High to Low |

Well data - analytics

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# Key Insights

- **Thoughtful methodology** to overpressure and fracture pressure prediction is required depending on formations and region and data quality/coverage
- **Wellbore stability studies** per well important for optimal mud weights selection - de-risk losses / shale instability
- **LOT analysis** (assisted by **Copilot**) demonstrate increase in fracture pressure strength related to overpressures – in 16 different formation (2067 FIT/LOT **- 533 LOTs**)
- **Chalk "rigid"** - not much variation with overpressures. **Shales "flex**" - significant strengthening as soon as within overpressured areas – 2.7 ppg average increase in fracture pressure from 533 LOTs in all formations – Copilot estimates 3.0ppg - good match (though mid point between mid and high reflecting AI also includes HTHP datasets)
- **Pressure transmits** up through very tight **Chalk** in Shaw – verified by formation pressures in tight cap rock
- LOT database/summation can be used to **reduce losses/influx risk** in Central North Sea in study area with overpressures to 15ppg

*Thank you, partners Ithaca Energy, SPE Devex and attendees*