Controls on the Prospectivity within the Elbow Spit Platform, Southern Permian Basin

Dr. Georgina Heldreich

Supervisors: Professor John Underhill & Dr. Rachel Jamieson

26th November 2019

LEADERS IN IDEAS AND SOLUTIONS

Presentation Outline

- Introduction
  - Background, project rationale and location of study area
- Dataset
  - Extent of 3D seismic surveys and location of wells
- Results
  - Seismic mapping
    - Regional herolines/tie-lines
    - Surfaces
    - Isopach maps
  - Well Analysis
  - Supracrop cross section from the BPU/Variscan UC
  - Rotliegend Play Fairway map/GDE map of Slochteren Fm
- Concluding remarks

Introduction & Project Rationale

- Lead on from Rachel Brackenridge's OGA Mid North Sea High (MNSH) project awarded to HWU
- Regional work on the entire stratigraphy & geological evolution of the area – part of this included the Rotliegend

HERIOT WATT UNIVERSITY | Oil & Gas Authority

Controls on the Structure, Stratigraphy and Prospectivity of the Mid North Sea High.

Rachel Brackenridge[1], Rachel Jamieson[1] & John Underhill[1]

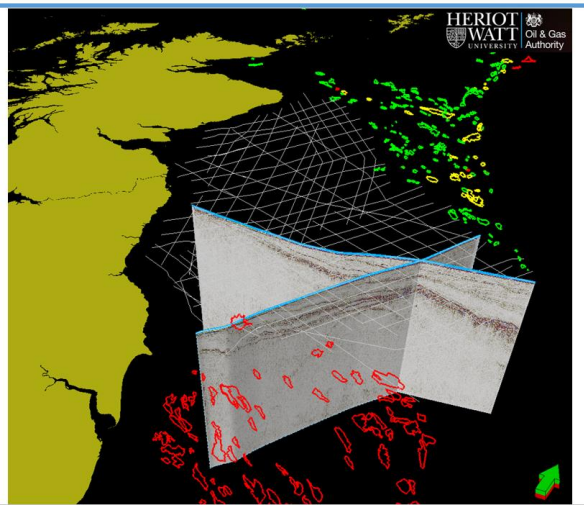
[1]R.Brackenridge@hw.ac.uk. Shell Centre for Exploration Geoscience, Heriot-Watt University, Edinburgh

Outline:

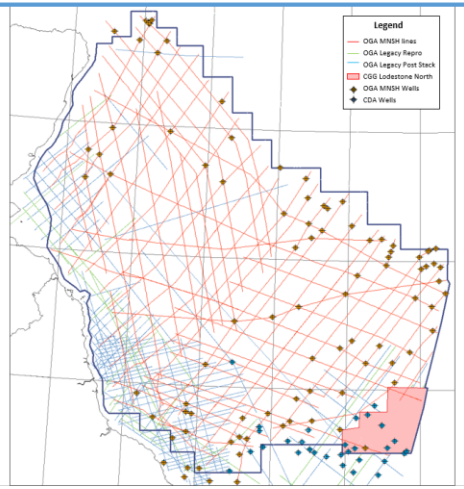
1) Rationale
2) Results and Resources
3) Structural Evolution & Prospectivity
4) Conclusions & Recommendations

PETEX | PESGB | PETROLEUM GROUP

PESGB / Geological Society Collaboration Showcase, PETEX Tues 27th Nov 2018



HERIOT WATT UNIVERSITY | Oil & Gas Authority



Data, Project Award & Aims

Two year postdoctoral project award was made to Heriot Watt University in 2016 to provide an independent academic view on the newly-released data-set.

The study aimed to:

- Define the structural features across the region and evaluate their geological evolution through time.
- Produce a robust seismic sequence stratigraphic framework for the region.
- Review the petroleum prospectivity of the region.

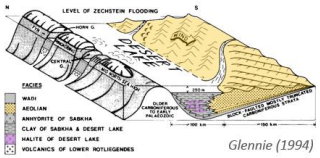
All results to be provided open access through the OGA data centre.

Brackenridge et al. PETEX 2018

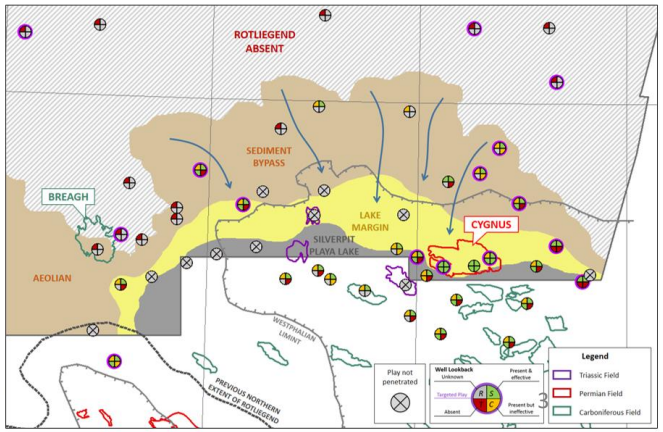
HERIOT WATT UNIVERSITY | Oil & Gas Authority

Permian: Rotliegend

- The resulting updated **Play Map** shows a **new play fairway** on the north margin of the South Permian Basin.
- Previous models do not show this fringing sandstone fairway (see Glennie 1994 figure).
- Rotliegend Facies appear to play an important role in the distribution of **Carboniferous** Fields.

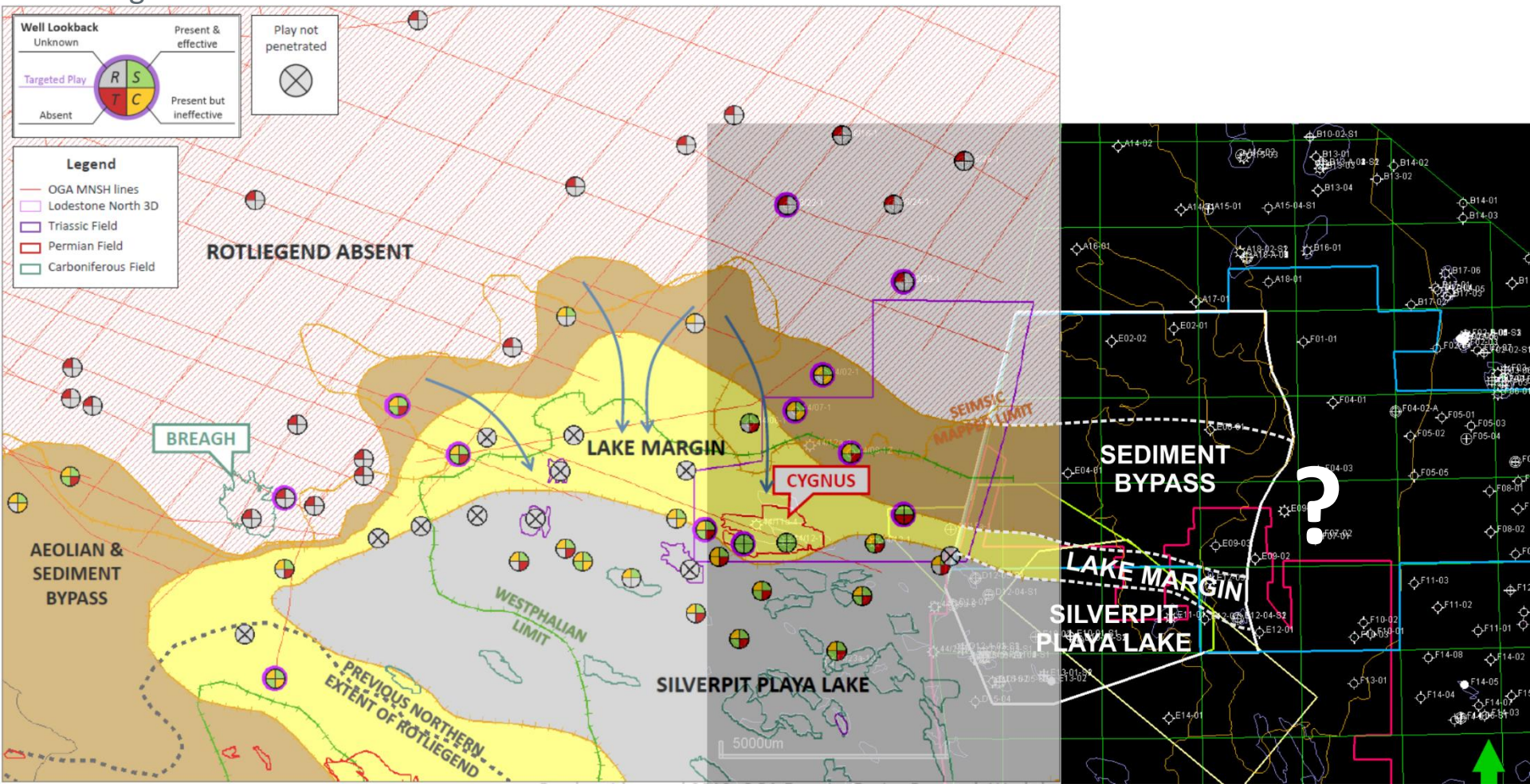


Glennie (1994)



Extending the Rotliegend Play Fairway

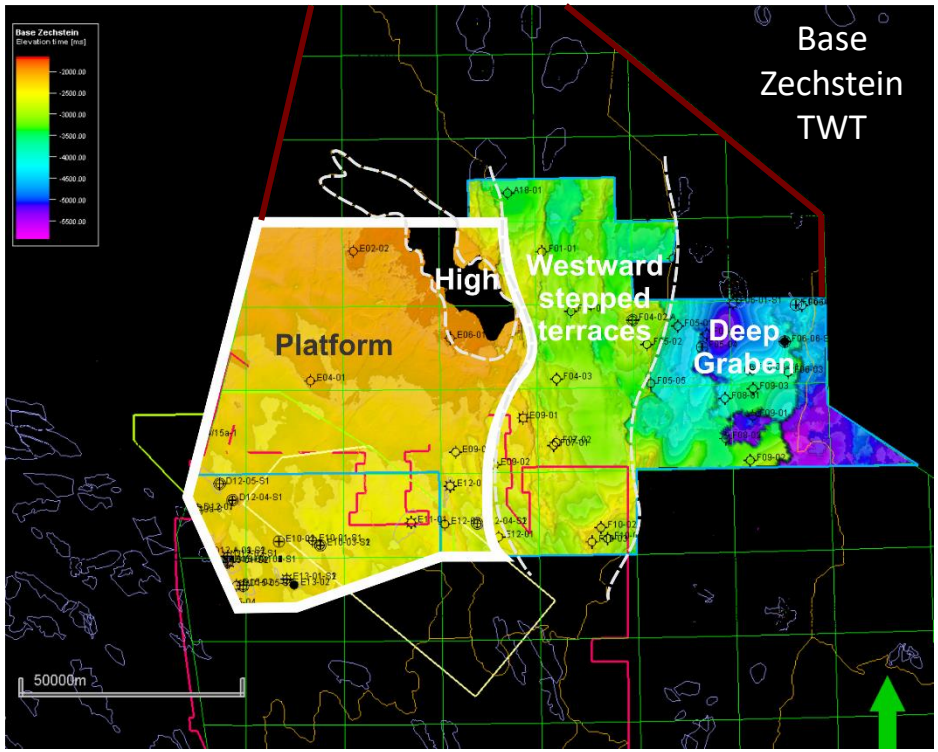
- Cygnus Field proves the presence of a prospective gas reservoir play fairway in the Leman Rotliegend sandstone along the northern fringe of the Southern Permian Basin
- This study focuses on the Permian section – chasing the Leman (UK)/ Slochteren (NL) Sst further to East from Mid North Sea High study into the northern Dutch offshore

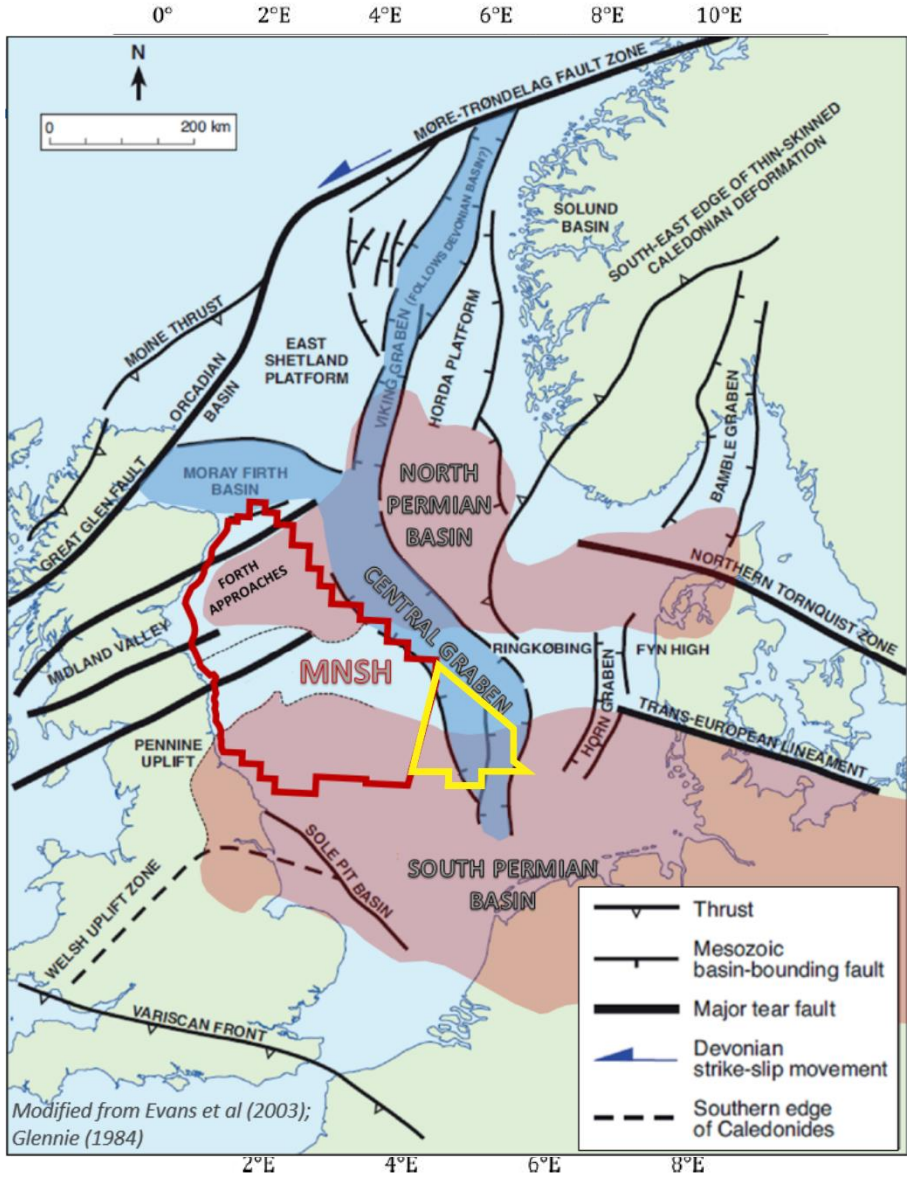


Regional Geology & Structural Domains

- Study area is situated along the northern margin of the Southern Permian Basin and lies between the MNSH to the NW and Central Graben to the East.

- Structural elements helped to define the AOI of this study
  - ➢ Focusing on the Elbow Spit Platform area – linking directly on from MNSH project area.





Taken from Ter Borgh et al., 2018

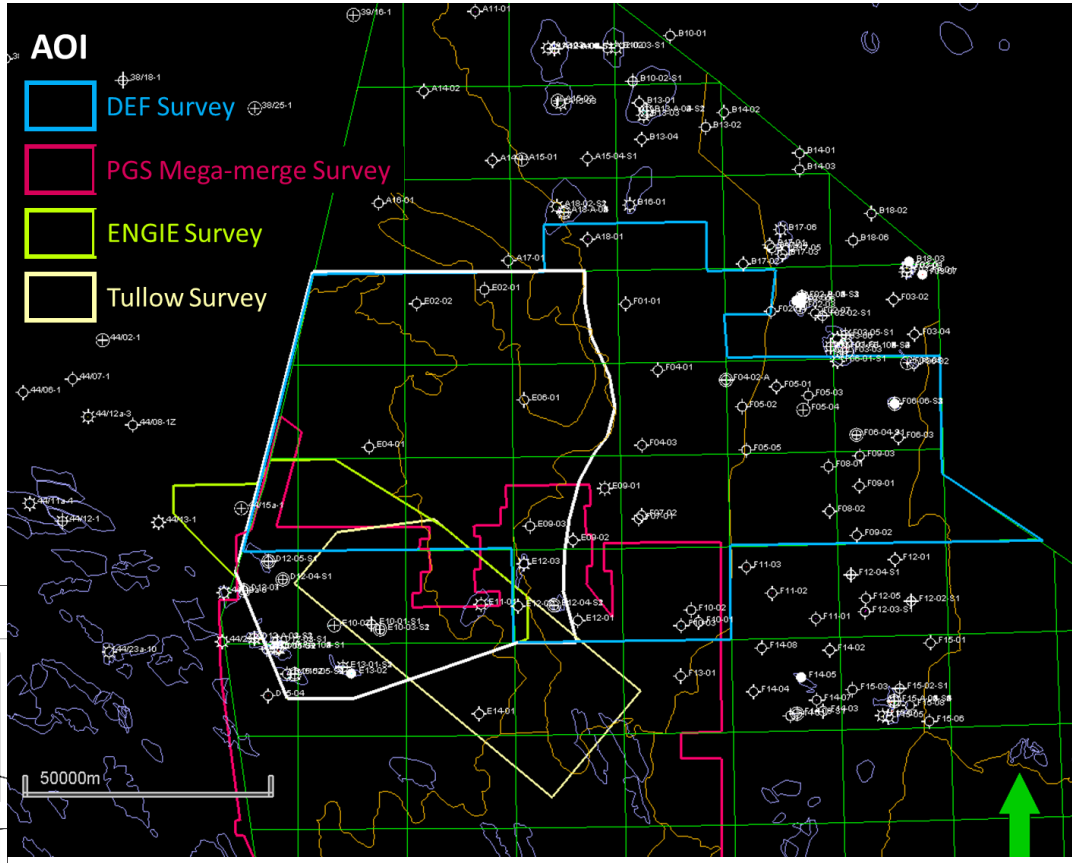
Dataset & AOI

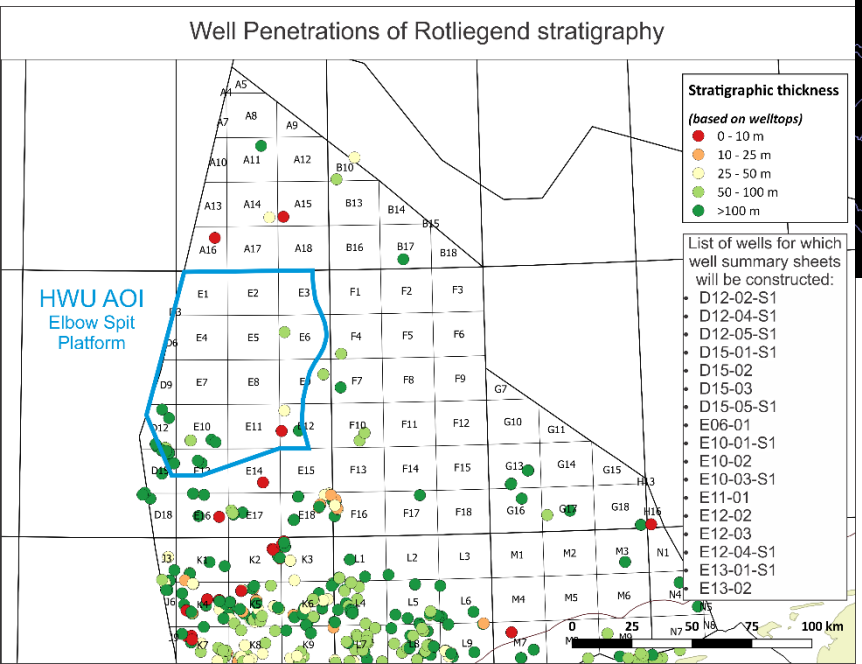
4 3D seismic surveys and wells

- DEF survey
- Tullow Oil survey
- Engie survey
- PGS mega-merge survey

Selected wells within the AOI which contain Rotliegend

- Rotliegend well penetration map





NLOG website for well information to construct well summary sheets:

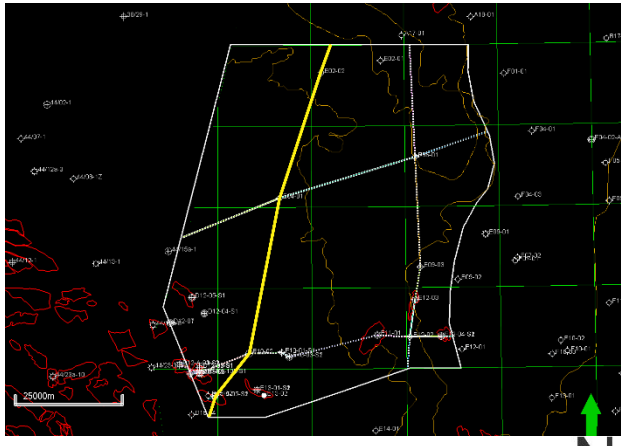
- well completion reports
- final well reports
- final geological reports
- relinquishment reports

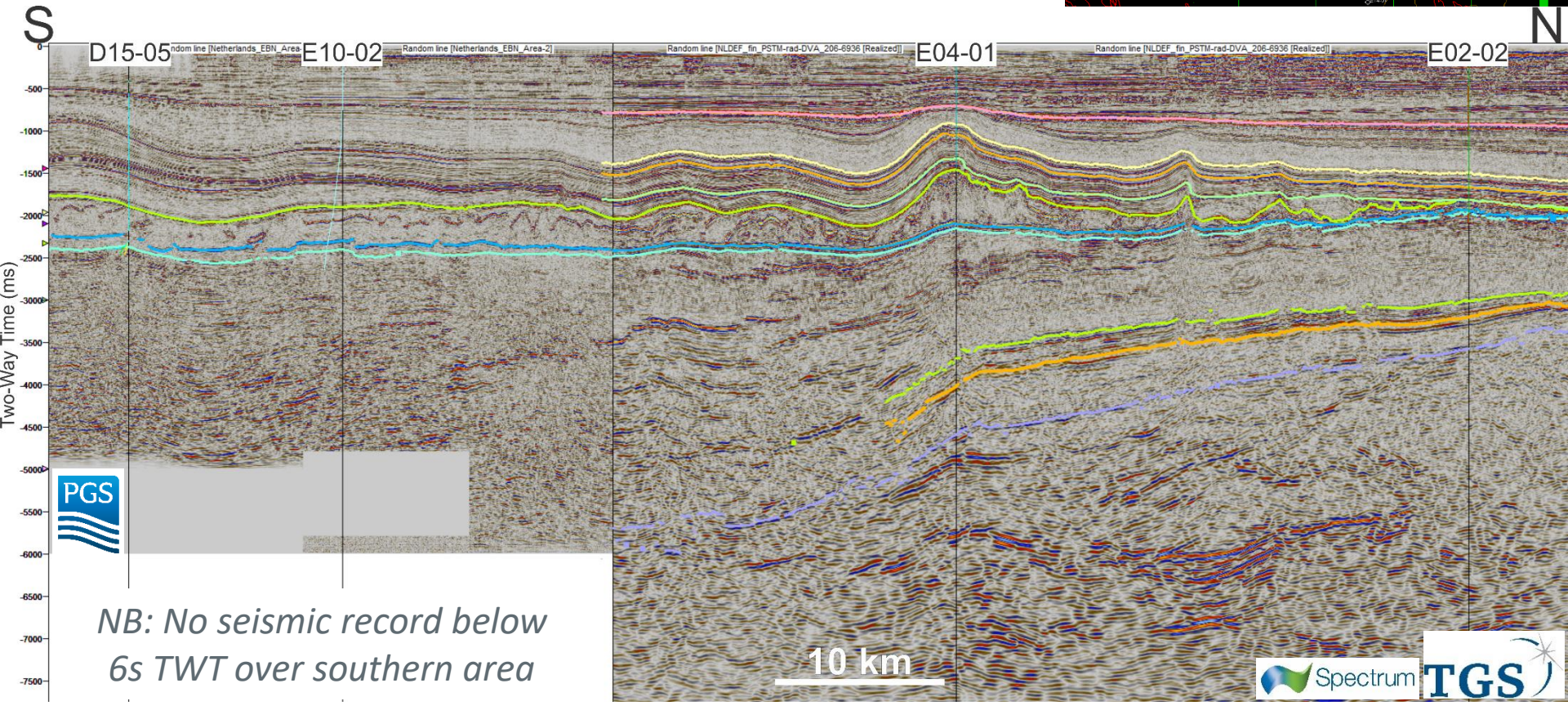
Results – Seismic Mapping

- Seismic Mapping
  - Regional herolines (tied to as many key wells as possible)
    - 2 N-S lines.
    - 1 E-W line linking MNSH line into the AOI.
    - 11 horizons/ surfaces mapped.
    - Isopach maps between key surfaces.
    - Schematic supracrop diagram from the BPU/Variscan UC.
      - N-S across AOI utilising corresponding well correlation panels/ herolines to inform the chronostrat diagram.
- Well Analysis
  - 18 wells which penetrate the Rotliegend interval – well summary sheets constructed for these.
- Rotliegend Play Fairway map/GDE map of Slochteren Fm
  - Linked on from the MNSH Permian Leman GDE map to provide an across boarder regional view of the play fairway along the northern margin of the Southern Permian Basin.

- Tertiary U/C
- Mid North Sea Group
- Top Chalk
- Base Chalk
- Near Top Zechstein
- Base Zechstein
- Base Rotliegend/BPU
- Pre-Variscan III
- Pre-Variscan II
- Pre-Variscan I

N-S Heroline tied to 4 wells: E02-02, E04-01, E10-02, D15-05.

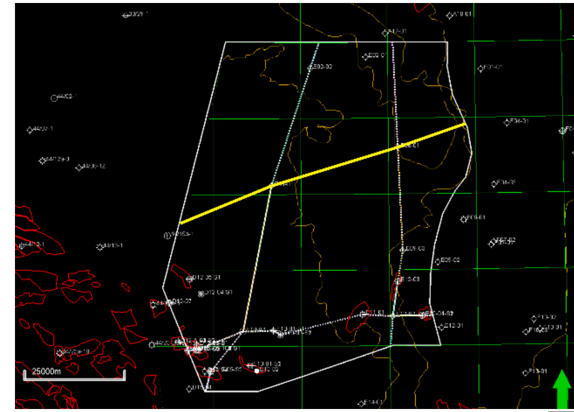


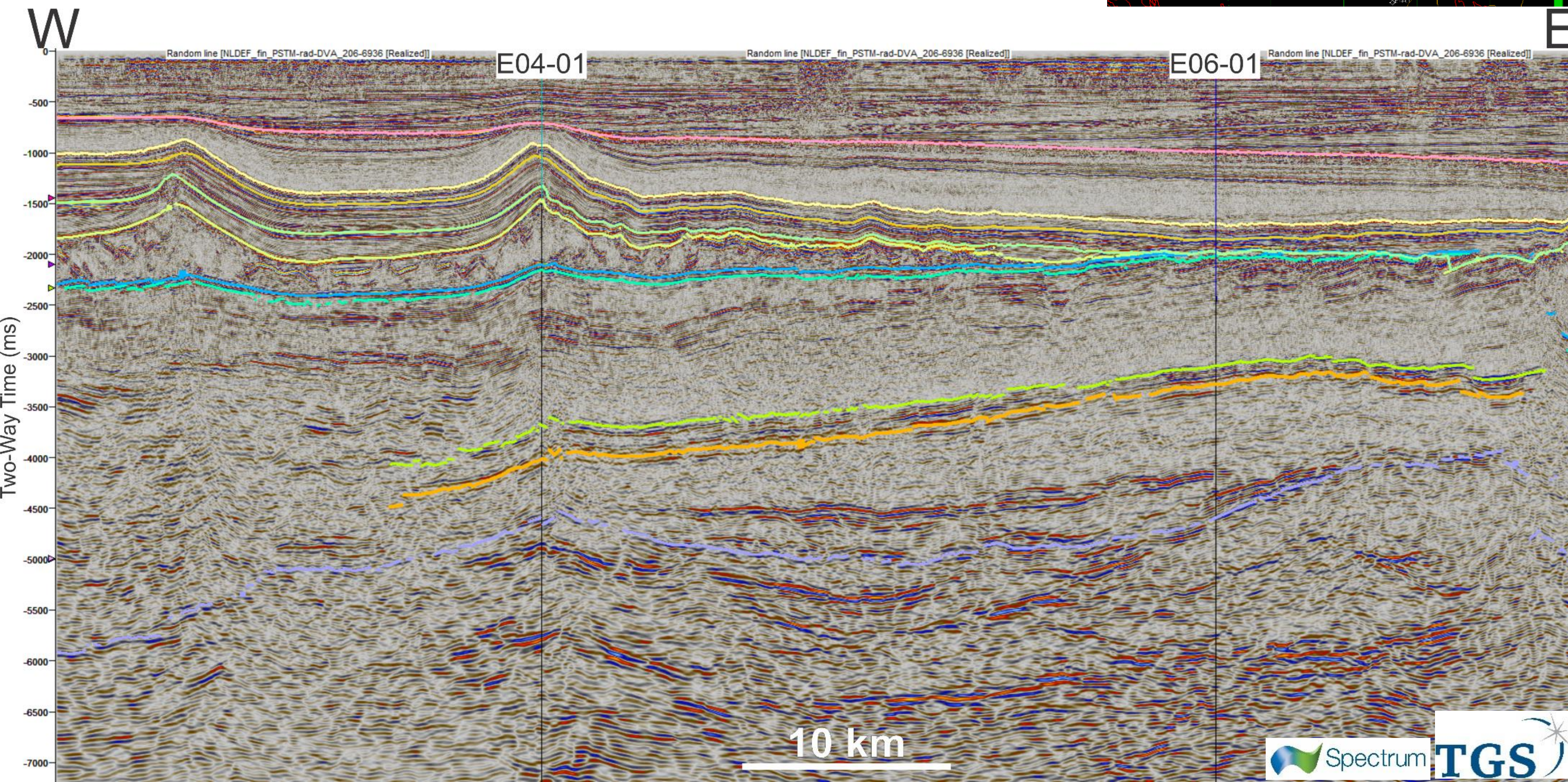


NB: No seismic record below 6s TWT over southern area

- Tertiary U/C
- Mid North Sea Group
- Top Chalk
- Base Chalk
- Near Top Zechstein
- Base Zechstein
- Base Rotliegend/BPU
- Pre-Variscan III
- Pre-Variscan II
- Pre-Variscan I

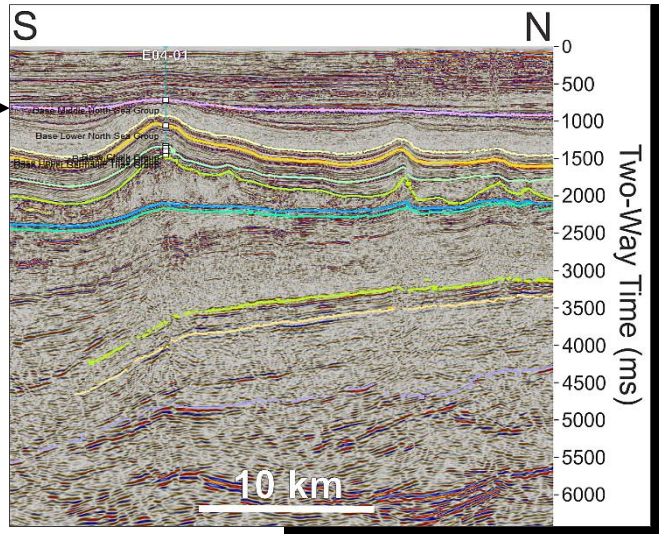
E-W Heroline tied to 2 wells: E04-01, E06-01.

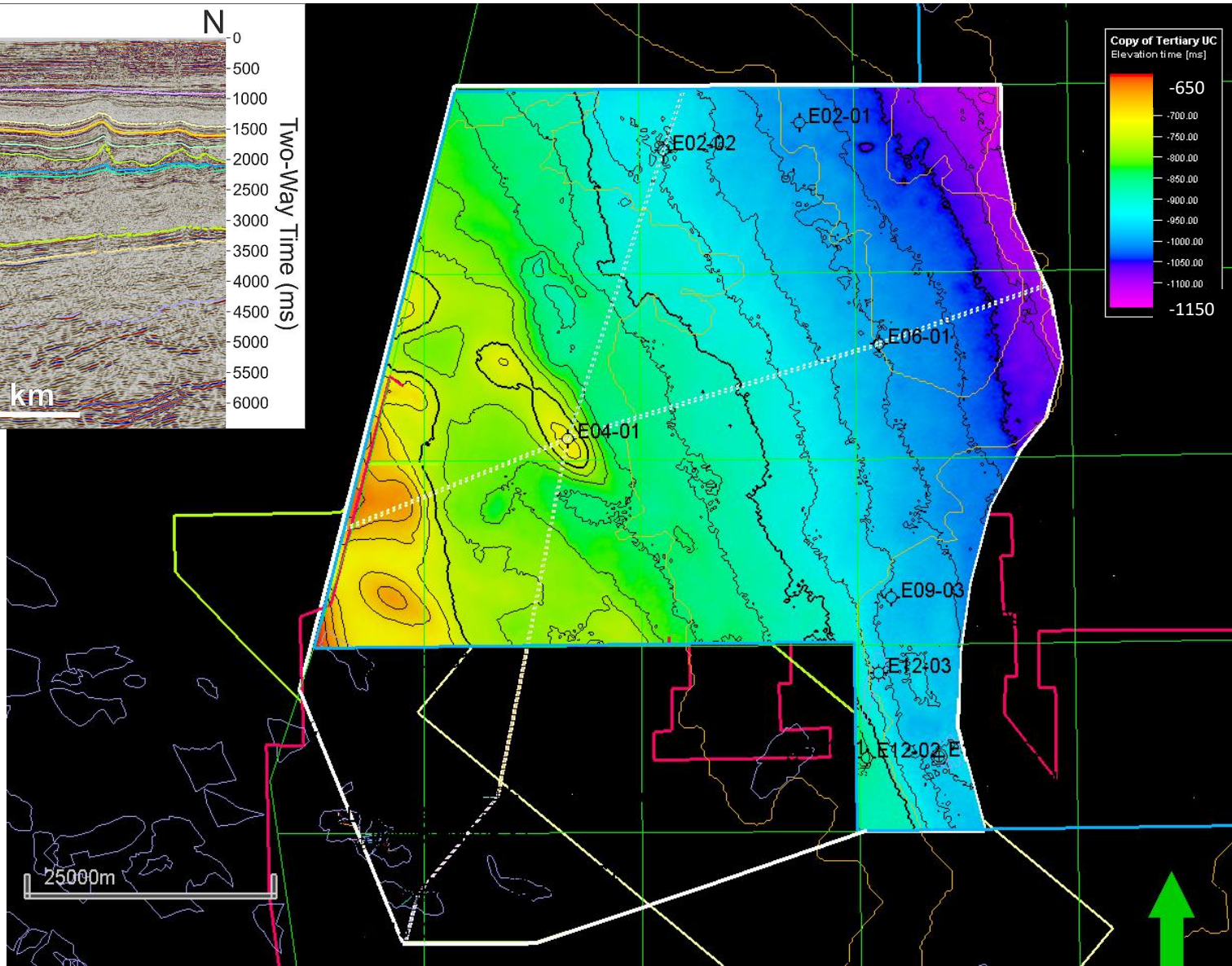




Regional Surfaces

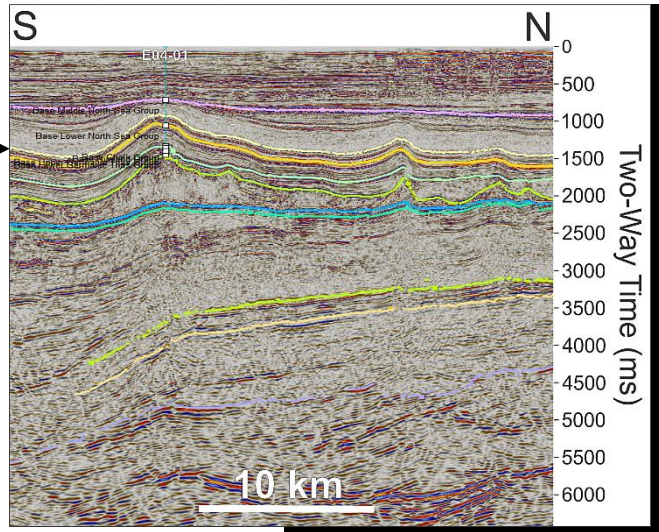
Tertiary (Miocene) Unconformity

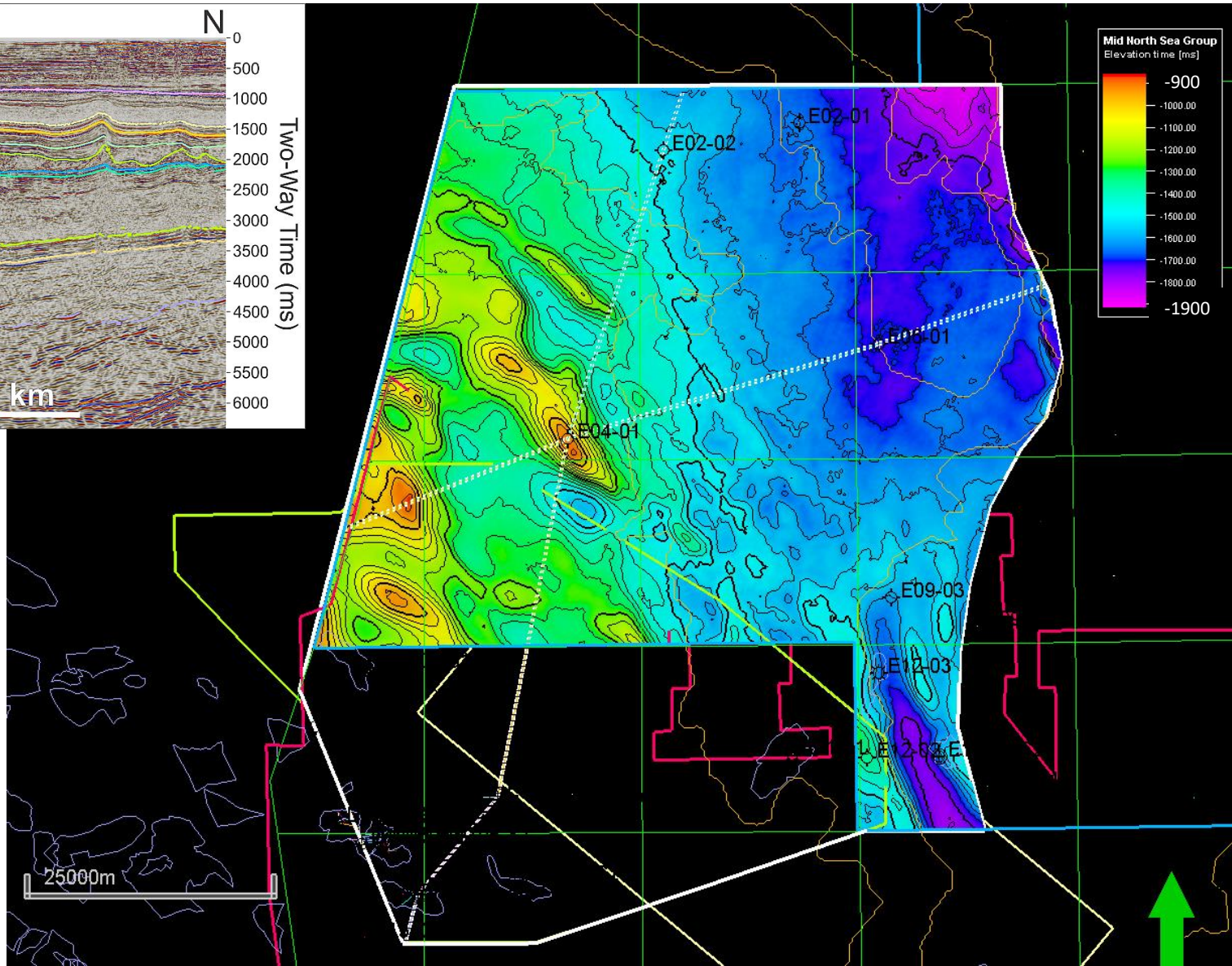




HERIOT WATT UNIVERSITY

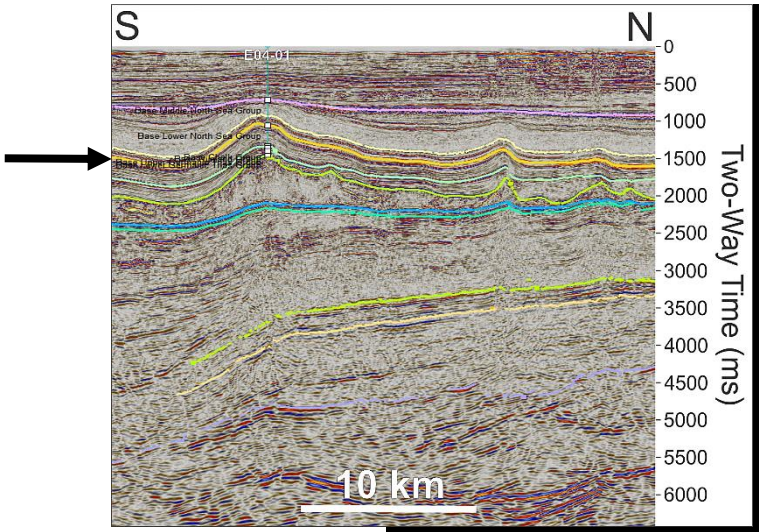
Top Mid North Sea Group

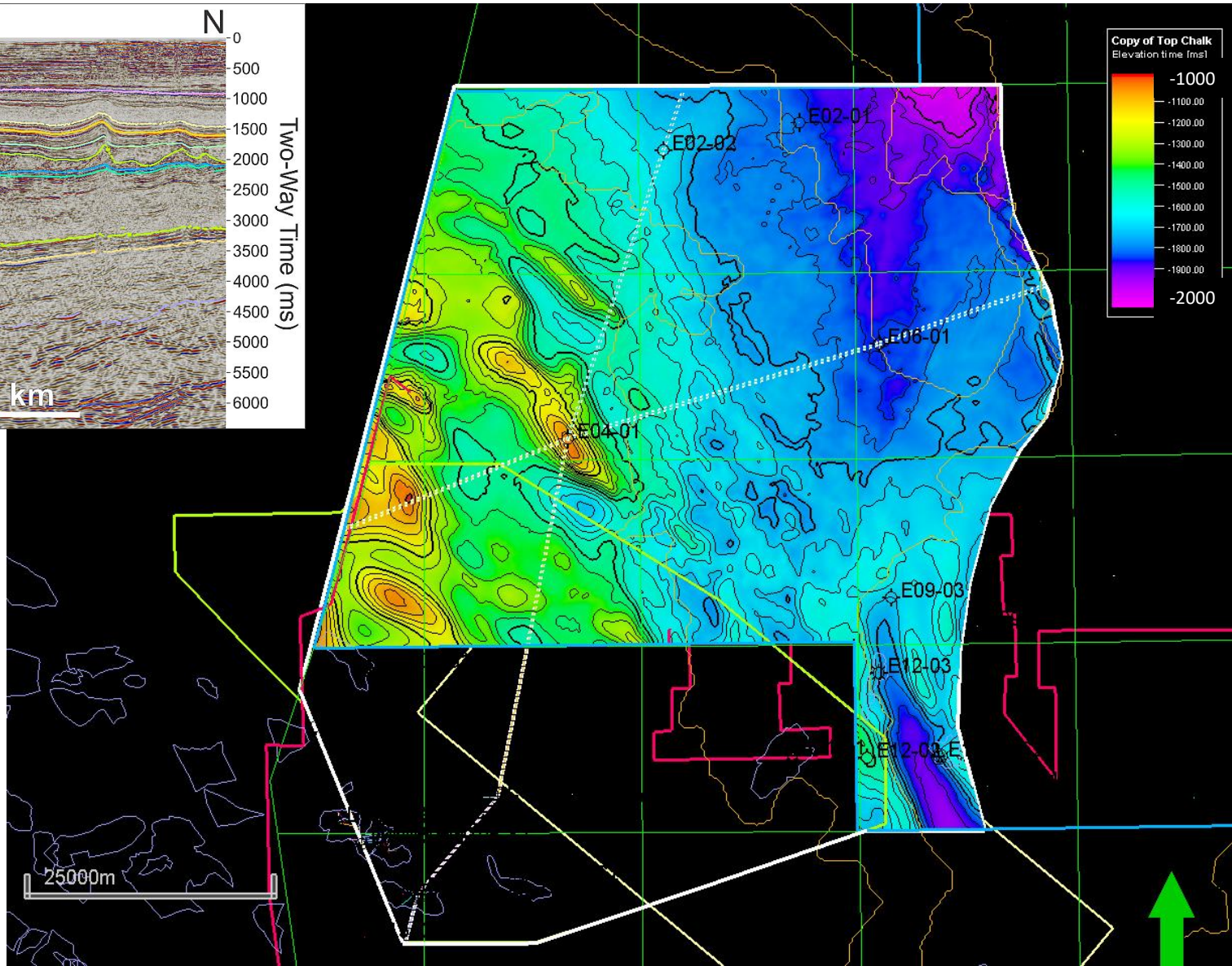




HERIOT WATT UNIVERSITY

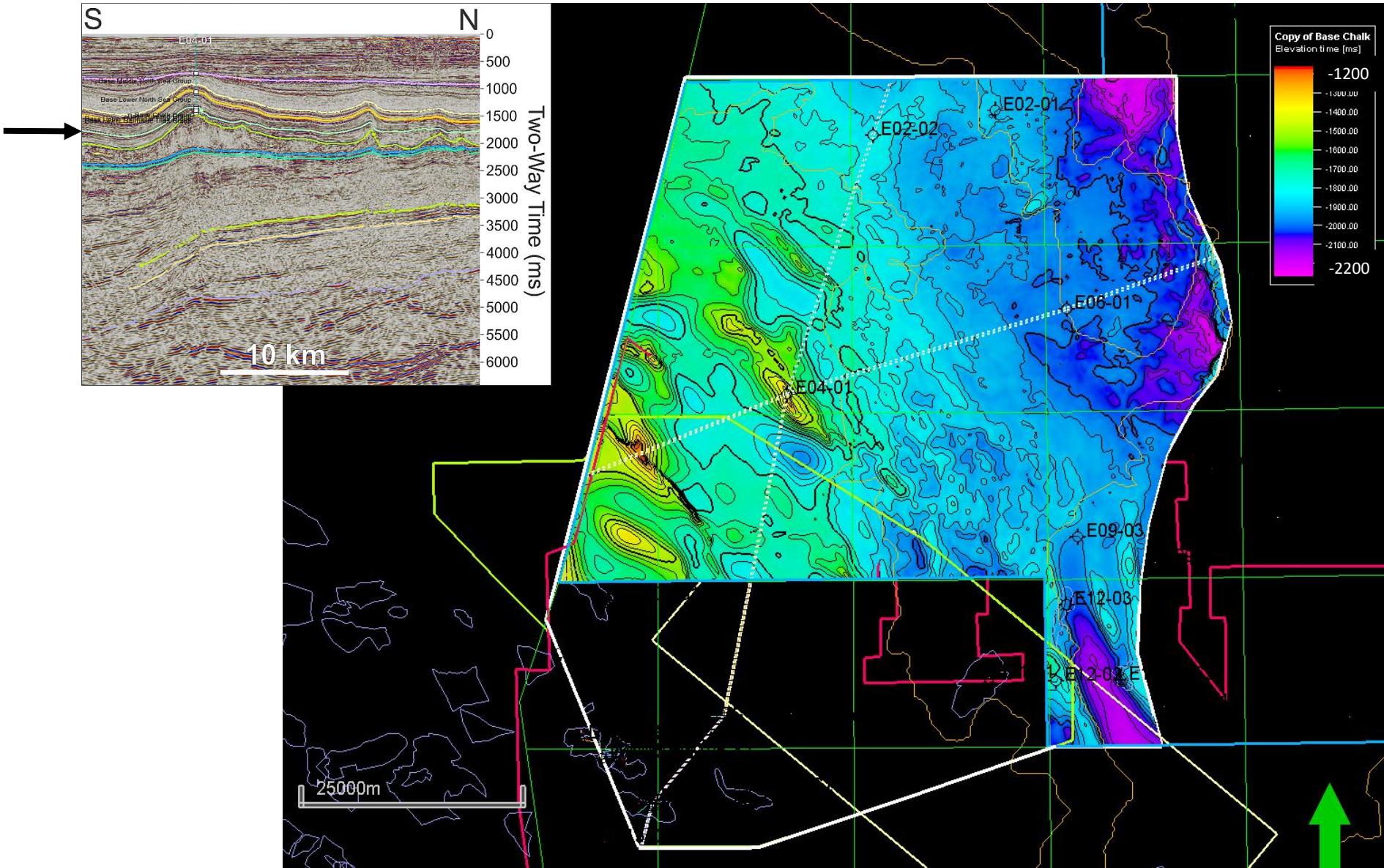
Top Chalk





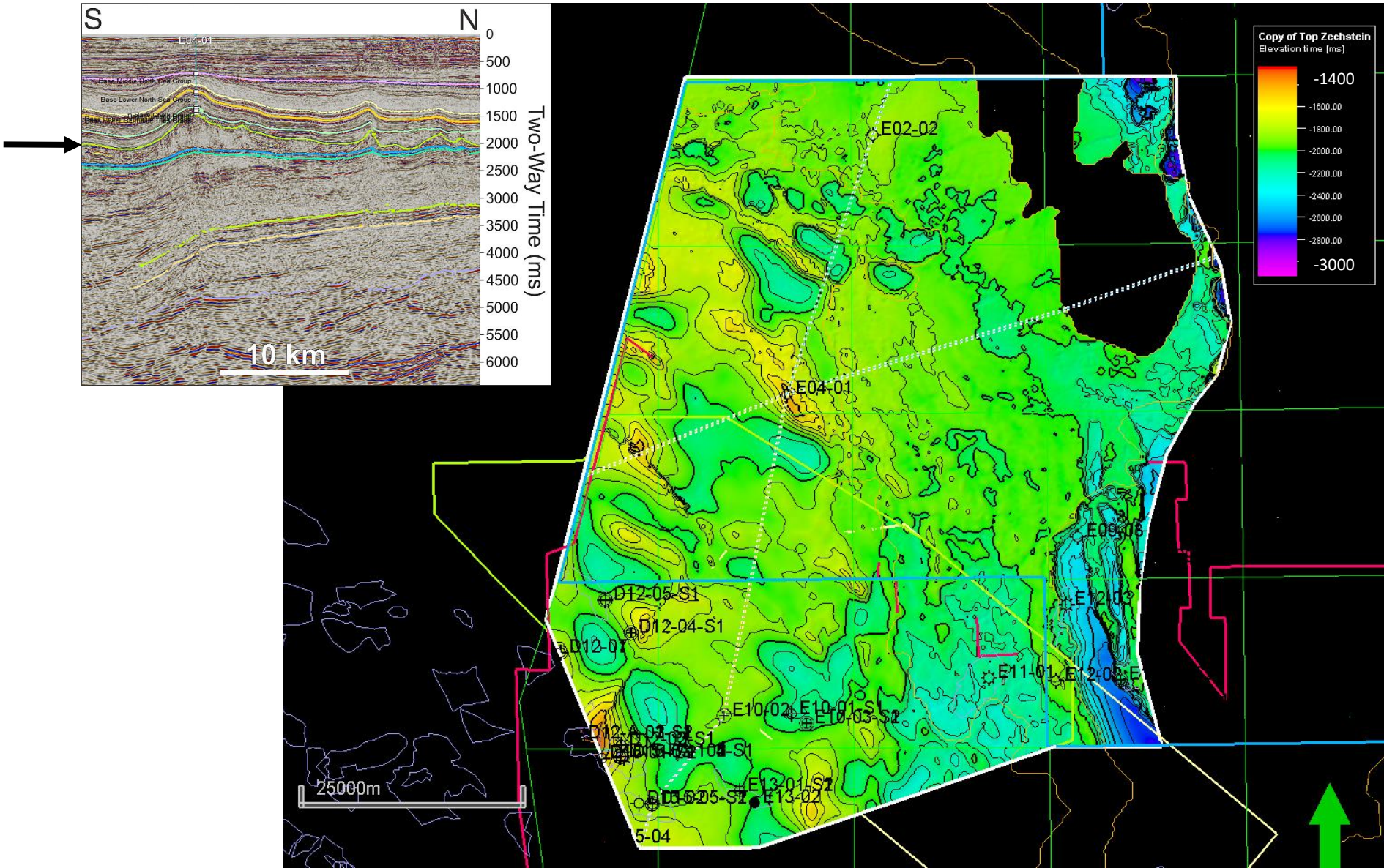
HERIOT WATT UNIVERSITY

Base Chalk



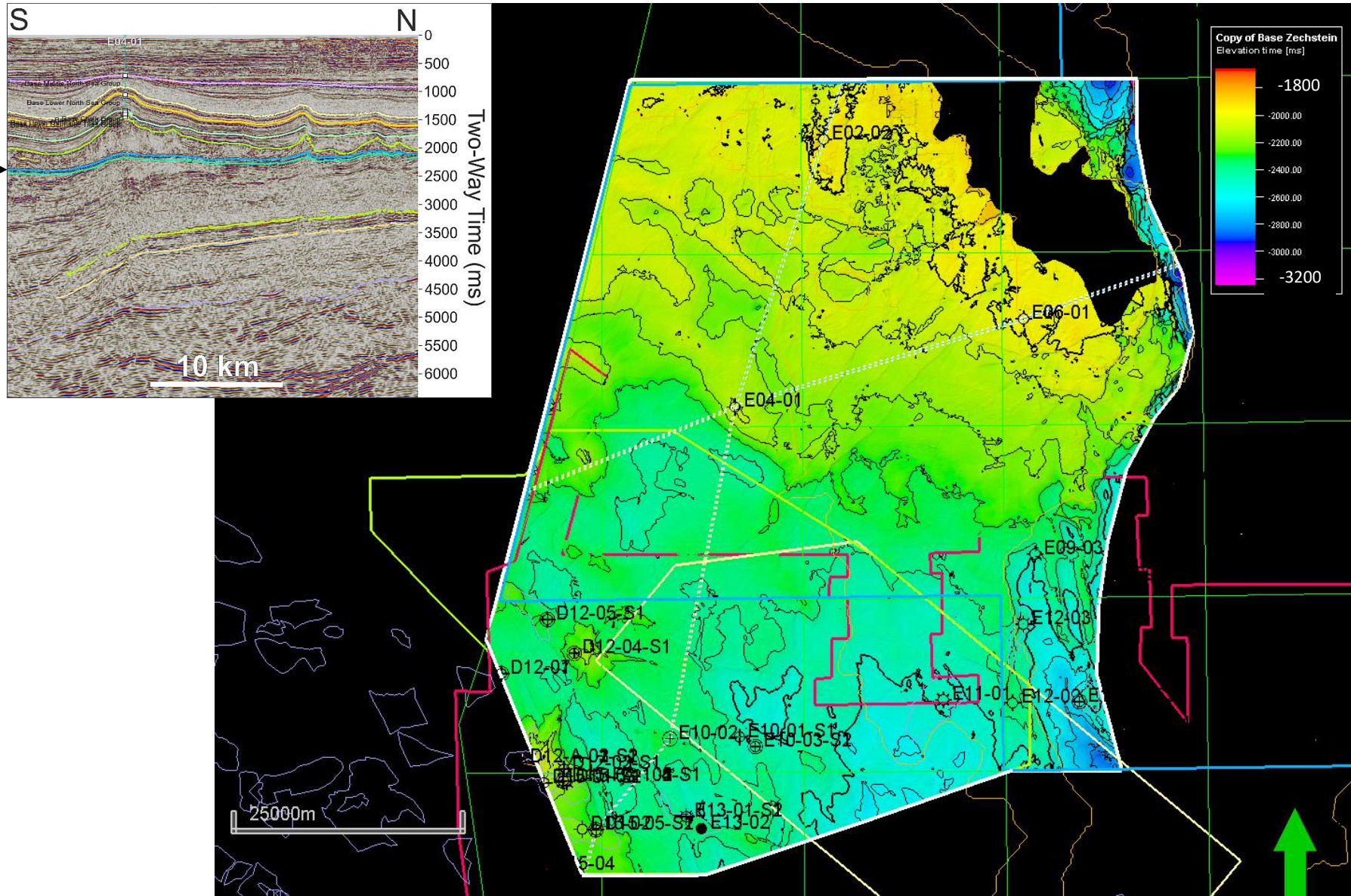
HERIOT WATT UNIVERSITY

Top Zechstein



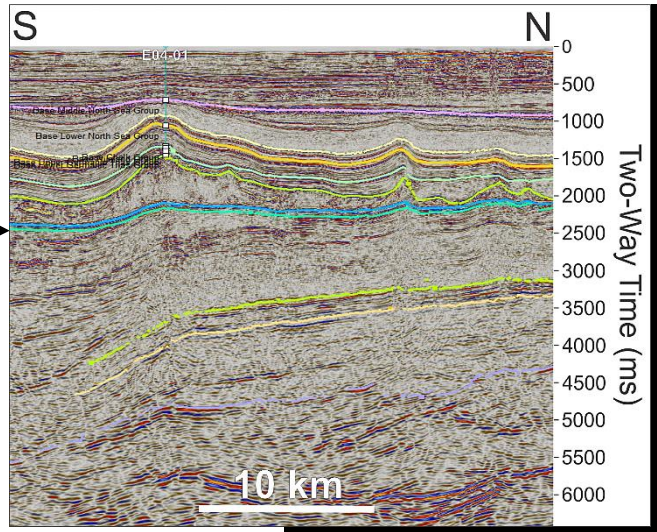
HERIOT WATT UNIVERSITY

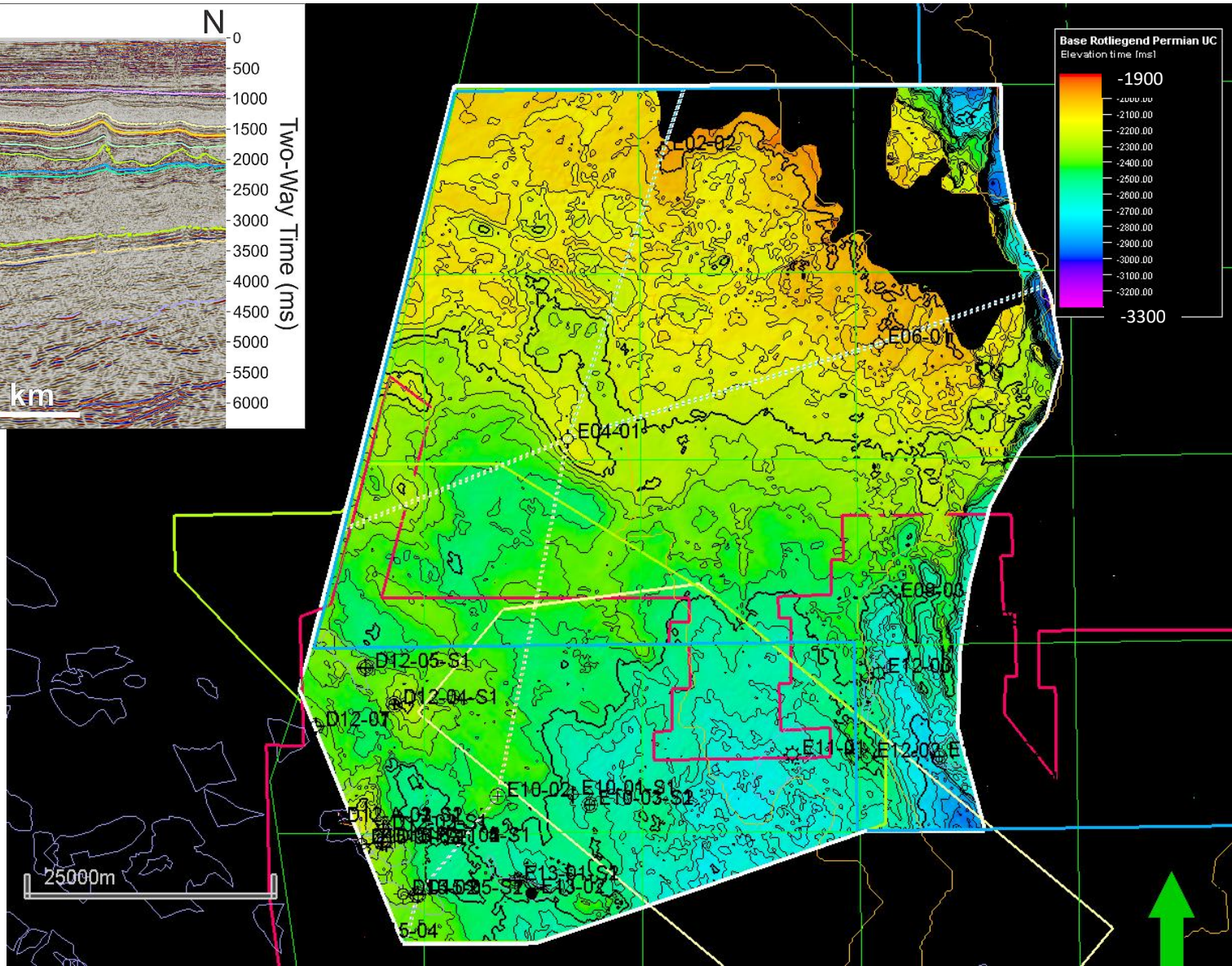
Base Zechstein



HERIOT WATT UNIVERSITY

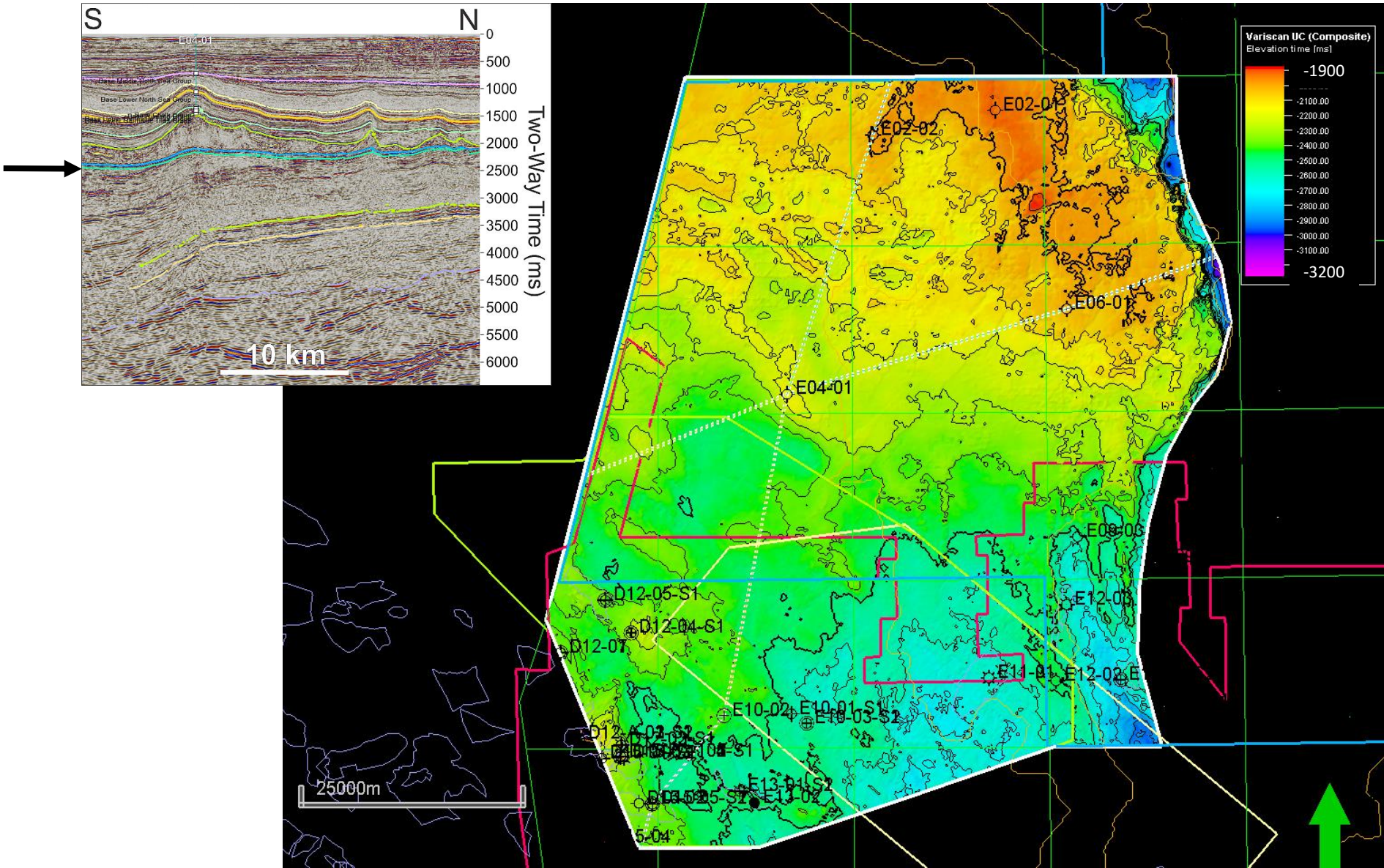
Base Rotliegend/ Permian Unconformity (BPU)



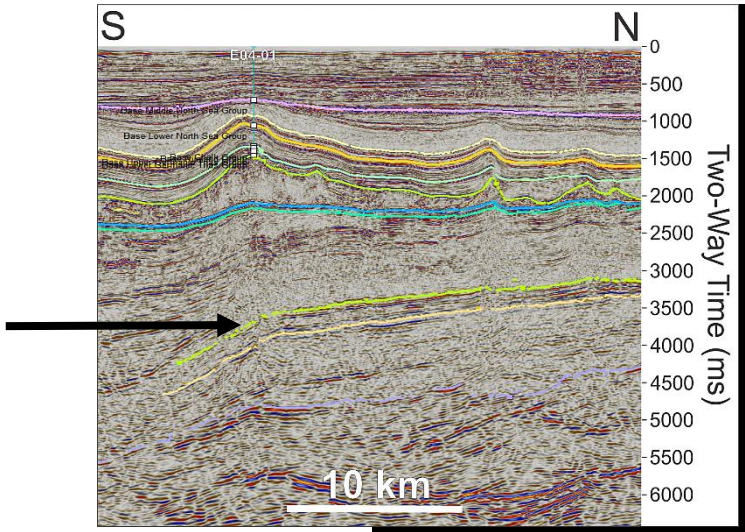


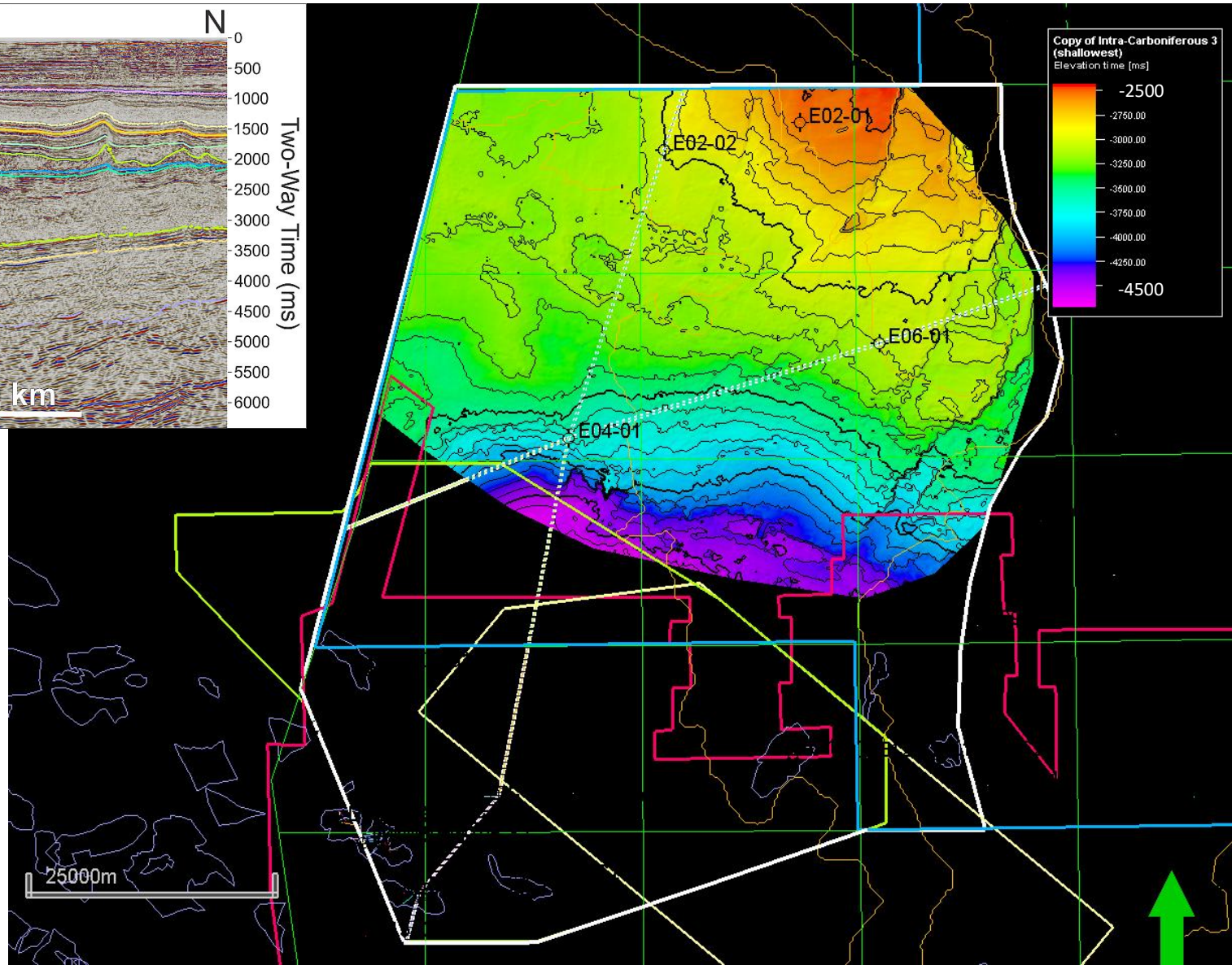
HERIOT WATT UNIVERSITY

Composite Variscan Unconformity

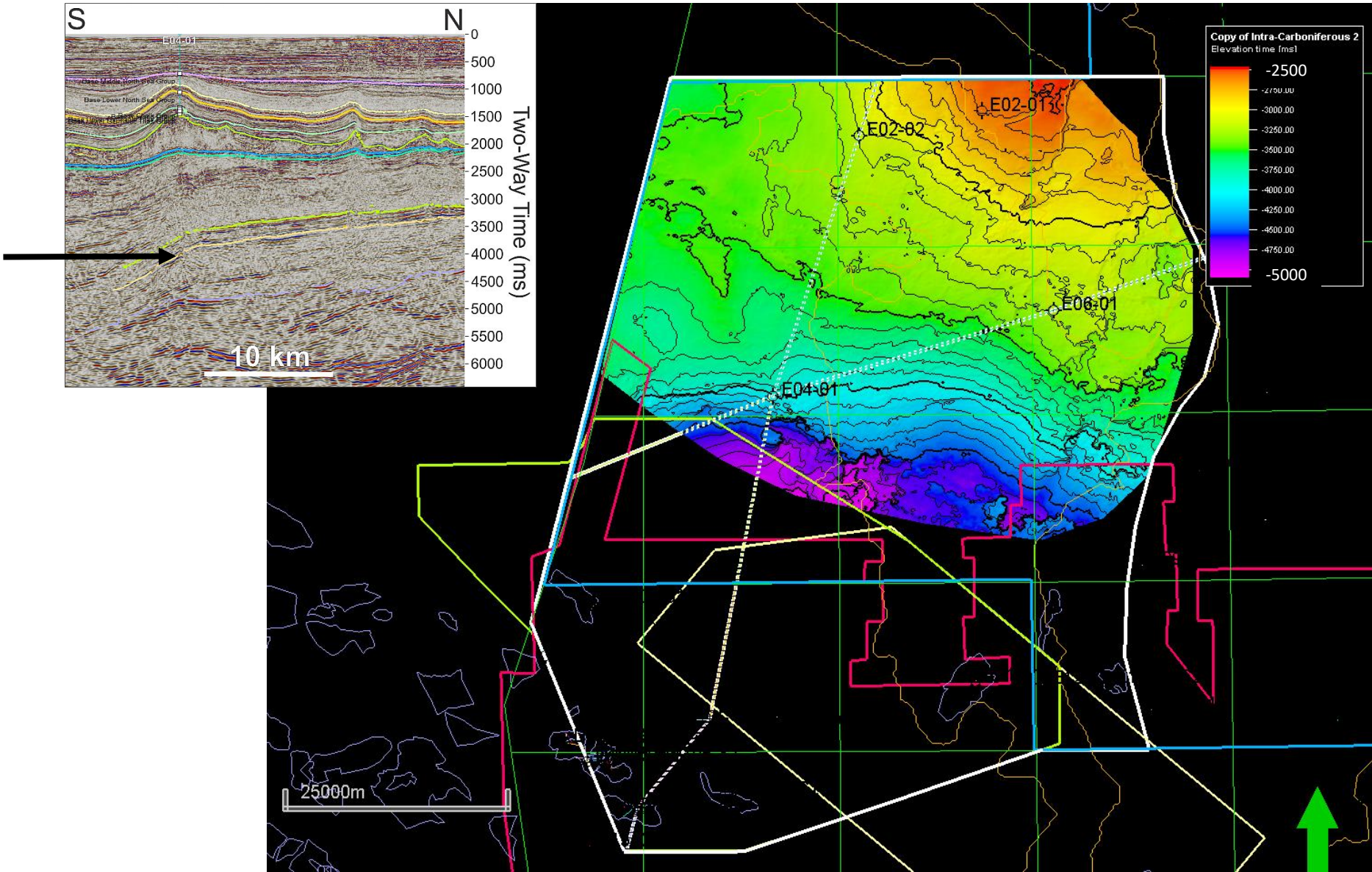


Pre-Variscan Upper Palaeozoic marker III (shallowest pick)

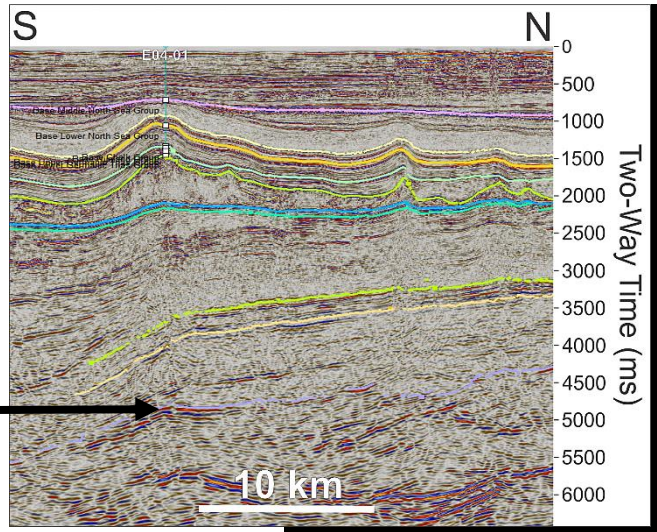


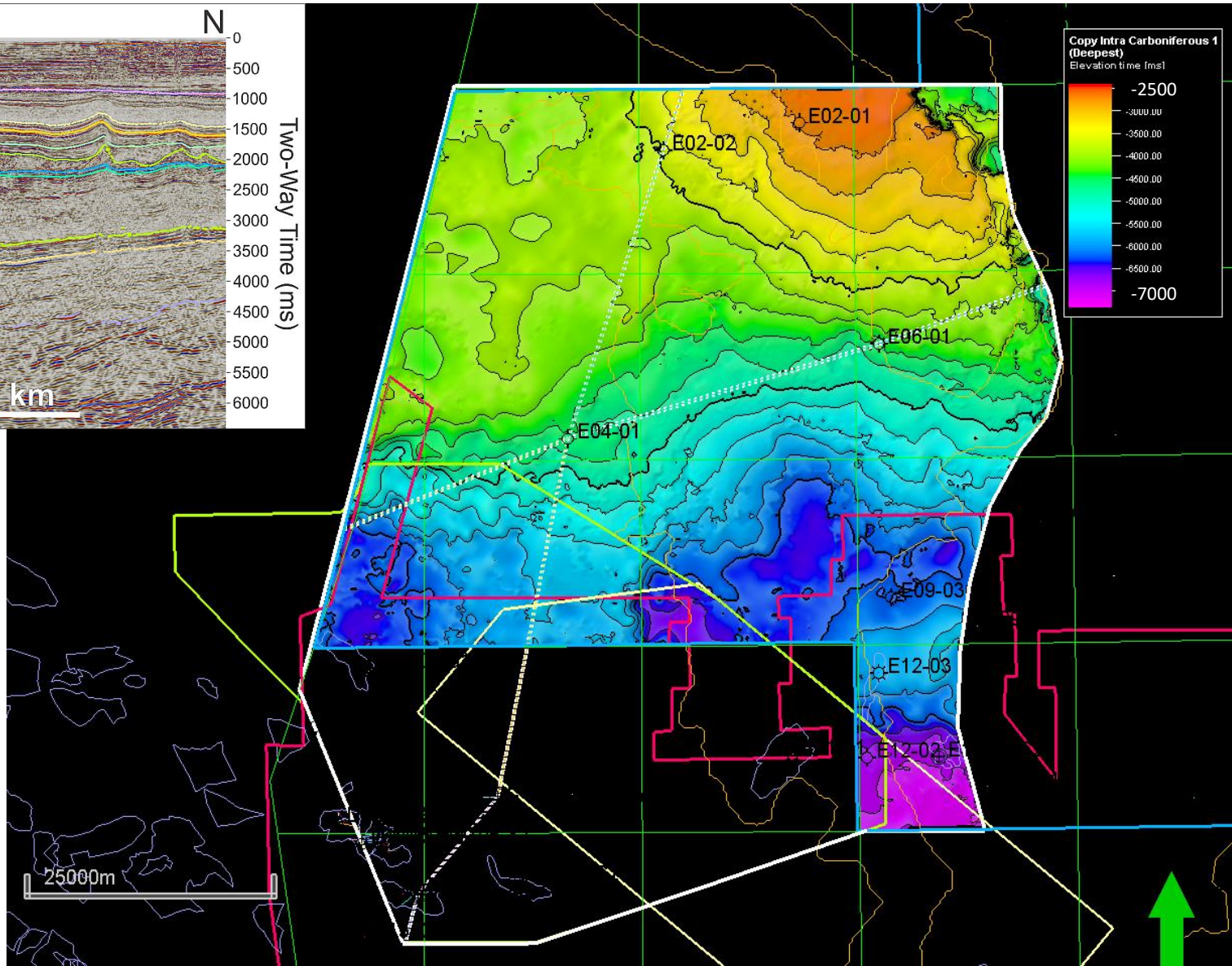


Pre-Variscan Upper Palaeozoic marker II (intermediate pick)



Pre-Variscan Upper Palaeozoic marker I (deepest pick)

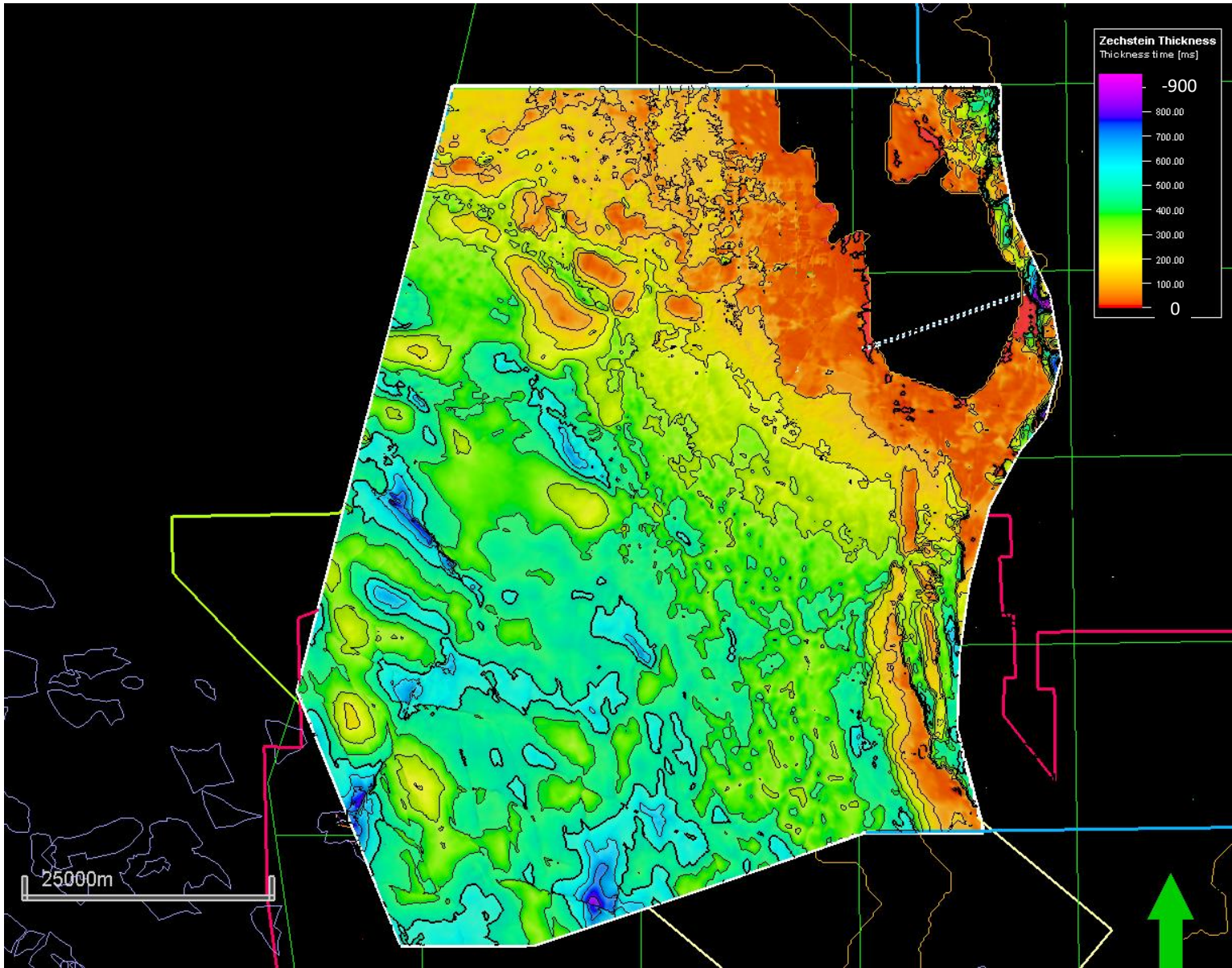




HERIOT WATT UNIVERSITY

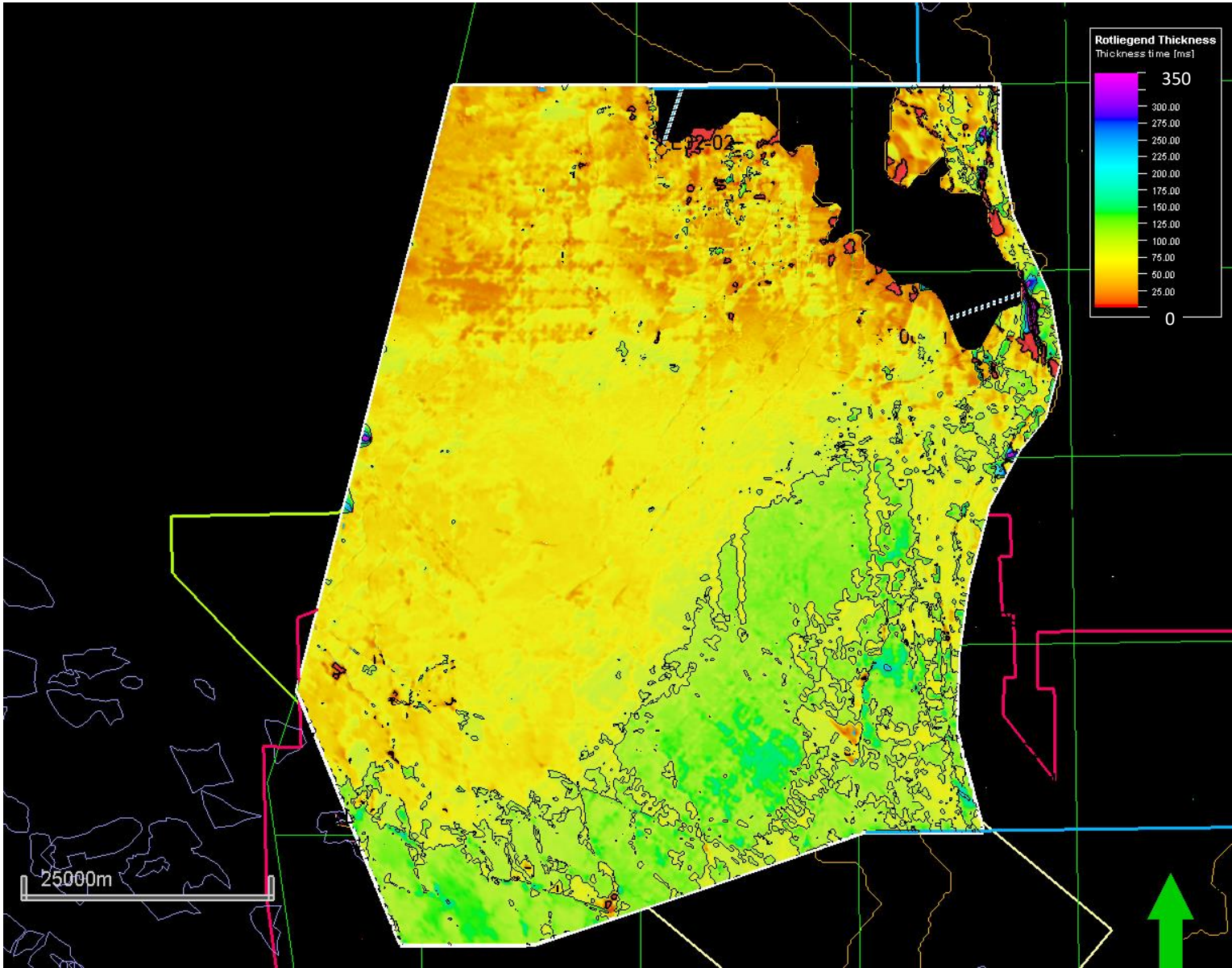
Isochron maps

Zechstein TWT Thickness Map

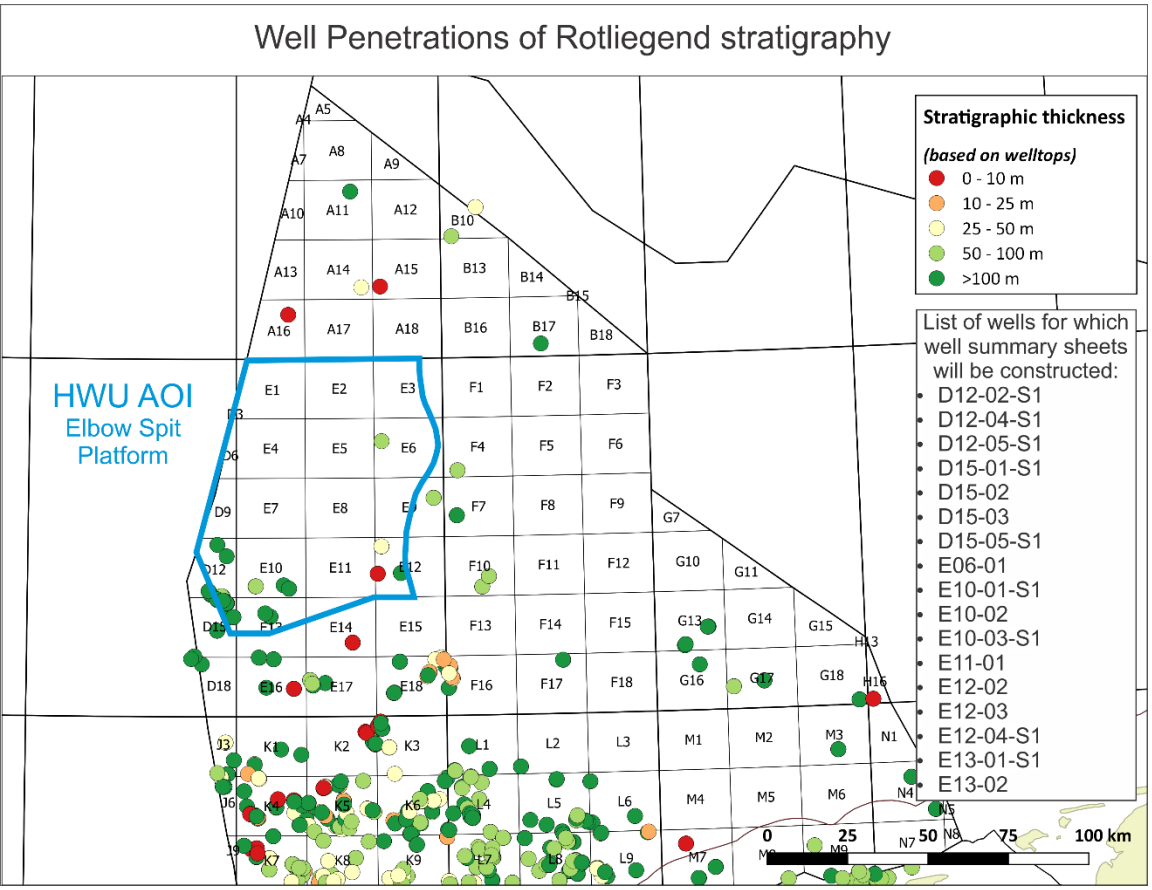


HERIOT WATT UNIVERSITY

Rotliegend TWT Thickness Map



Results – Well Analysis



- 18 wells within the AOI penetrate Rotliegend stratigraphy
- Well correlations of key wells and corresponding seismic herolines help develop chronostratigraphic cross section across the AOI

Well Name: E02-02

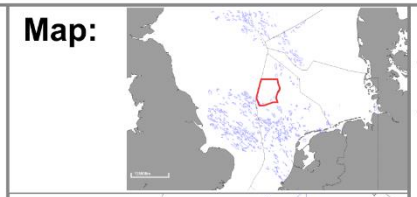
Reason for Failure: Reservoir intervals very tight. No hydrocarbon generation.

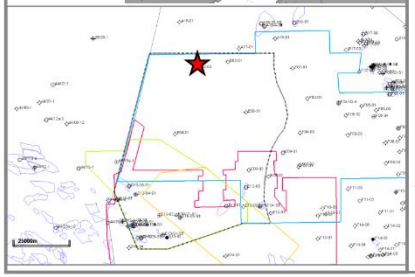
Summary:

Location: **3°22‘14.5631"E 54°56‘38.5276"N**
Block: **Quadrant E, Block 2**
Water Depth/Datum: **37.6 m / 35.63 m (KB)**
Spud Date: **20.10.1990**
Operator/Partners: **Mobil**

TD/Formation: **2647.5 m MD (2,611m TVDSS) / Farne Gp**
Objectives**: Zechstein Carbonates**
Reservoir: **Zechstein Carbonates & Yoredale sands**
Charge: **Carboniferous Coals, but no HC shows**
Seal: **Various**
Structure: **Fringing carbonate facies along Elbow Spit High?**
Results: **Dryhole, P&A**

Map:





Tops:

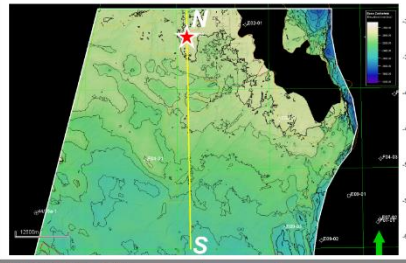
Top	MD (m)	TVDSS
Seabed	73.2	37.6
Chalk Group	1,665	- 1,629
Rijnland Group	1,958	- 1,922
Zechstein Group	1,978	- 1,942
Rotliegend Group	2,342	- 2,306
Farne Group	2,351	- 2,315
TD Driller	2,647	- 2,611

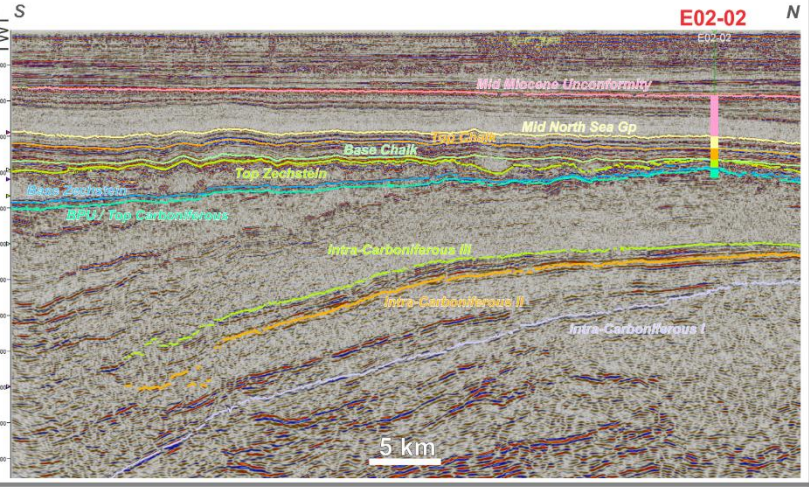
Geological Summary:

- The objective was to drill a wildcat exploration well to target the Zechstein carbonates along the SE edge of the Elbow Spit high.
- Thin ~10 m section of Rotliegend consisted of light brown to brown, soft to firm, silty in parts and slightly dolomitic/calcareous claystones of the Silverpit Claystone Formation.
- There is a significant unconformity separating the Late Permian and Carboniferous with the entire Silesian section absent. The Carboniferous section consists of Visean Yoredale and Elleboog Formations dominated by light grey to dark grey limestone; dark grey silty claystones and fine-medium grained well sorted sandstones. Four thin coal seams were present at 2464m, 2521m, 2551m and 2595m. No hydrocarbon gas shows in sandstones or limestones.
- Geochemical source rock analysis of the Carboniferous interval (2398 - 2637m) suggests there is good potential for gas generation, limited oil-prone material and is mature for oil generation, but immature for gas generation.

Seismic:

NLDEF Xline 2981 (TWT) with E02-02 well tied to seismic. Insert shows base Zechstein map with cross line & well location

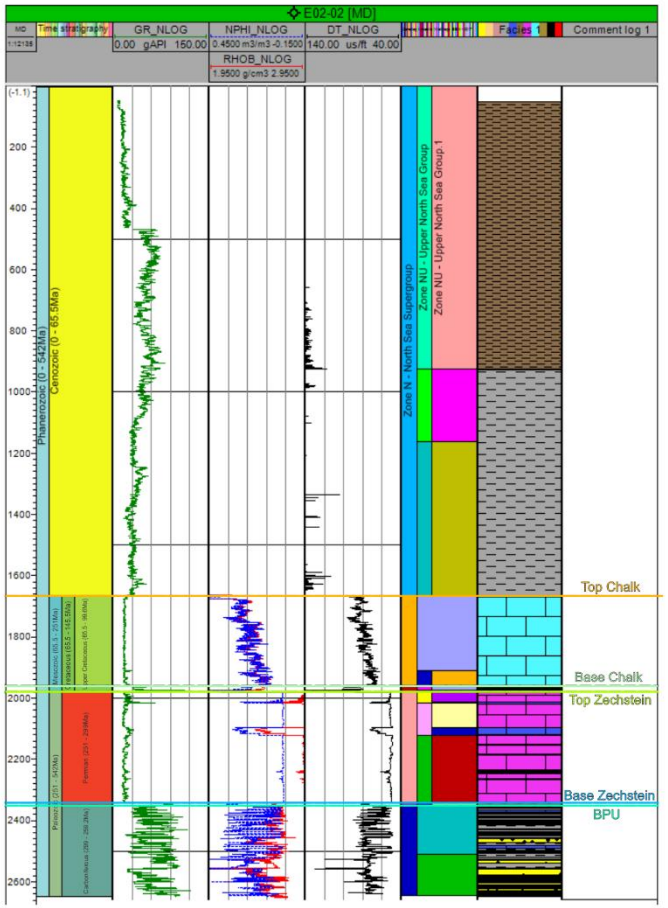




DHA:

PLAY	R	S	C	T	Comments
Upper Jurassic					
Triassic					No reservoir sections.
Zechstein					No porosity/permeability information on dolomites. Poor to good visible mirco-vuggy porosity in upper part of the succession.
Rotliegend					No reservoir sections.
U. Carboniferous					No information on porosity/permeability of sands or limestones? Source rock analysis indicates good gas generation potential but the interval is immature for gas generation
L. Carboniferous					Absent?

Well:



Author: G. Heldreich. 2019
Template modified from R. Brackenridge, OGA Mid North Sea High Project, 2018

Well Name: E13-01 (S1 & S2)

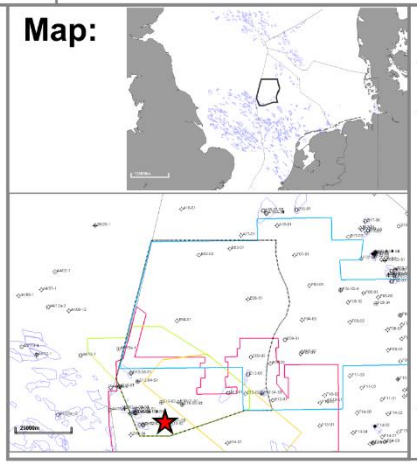
Reason for Failure: No significant hydrocarbon accumulations

Summary:

Location: **3°08'18,1"E 54°17'29,7"N**
Block: **Quadrant E, Block 13**
Water Depth/Datum: **47m / 35m (KB)**
Spud Date: **13.12.1983**
Operator/Partners: **Pennzoil.**

TD/Formation: **4277m MD (4232m TVDSS) / Limburg**
Objectives**: Carboniferous Westphalian A sandstones**
Reservoir: **Westphalian A sandstones**
Charge: **Carboniferous Coals. HC shows**
Seal: **Various**
Structure: **Structural/ Stratigraphic trap beneath BPU.**
Results: **Hydrocarbon shows. Suspended gas well. P&A.**

Map:



Tops:

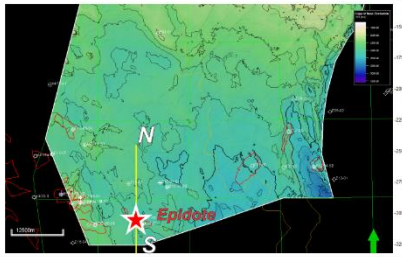
Top	MD (m)	TVDSS
Seabed	82	- 47
Chalk Group	1,313	- 1,277
Rijnland Group	1,866	- 1,829
Lower Germanic Trias Group	1,980	- 1,943
Zechstein Group	2,390	- 2,352
Rotliegend Group	3,287	- 3,244
Limburg Group	3,568	- 3,524
TD Driller	4,277	- 4,232

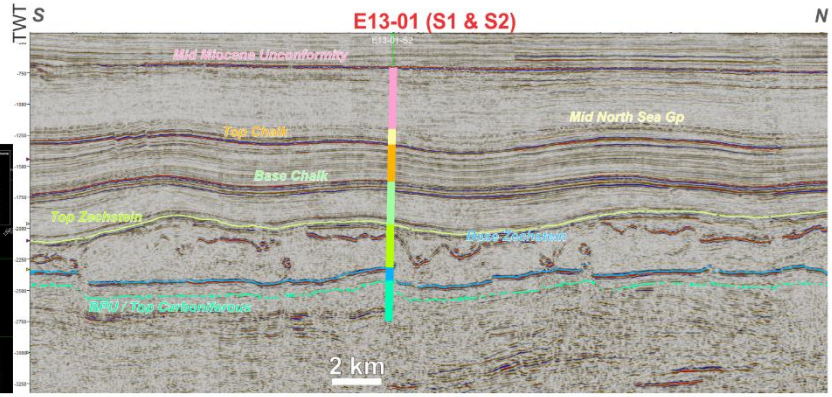
Geological Summary:

- The E13-01 (plus side tracks S1 and S2 due to technical failures) were drilled to target the Carboniferous Westphalian sandstones of a tilted fault block bound to the north by an WNW-ESE trending normal fault. The Carboniferous succession is tilted down towards the NW, sub-cropping the BPU to the east, potentially providing a stratigraphic trap. Potential structural closure at the BPU at 3661m.
- The basal Zechstein limestones and dolomites contain oil shows.
- The Rotliegend succession consists of interbedded claystone, siltstone and halite at this location.
- The Carboniferous succession is comprised of interbedded sandstone, siltstone, shales/ claystones and coal beds.
- Six conventional cores were taken from the Carboniferous succession. Reservoir porosities range from <1 - 19.9%. Horizontal permeabilities range from 0.01 - 660 mD and vertical permeabilities ranging from 0.04 - 290 mD. Gas shows in the upper sandstones.
- Gas bearing Westphalian D sands 3582 - 3600m = 10% av. porosity and from 3630 - 3693.5m = 12% av. porosity. Water bearing Westphalian D sands 3711 - 3827m = 11.5% av. porosiy, and Westphalian A-B sands 7 - 20% av. porosity.

Seismic:

PGS Mega-merge inline 14372 (TWT) with E13-01(S1 & S2) well tied to seismic. Insert shows base Zechstein map with cross line & well location

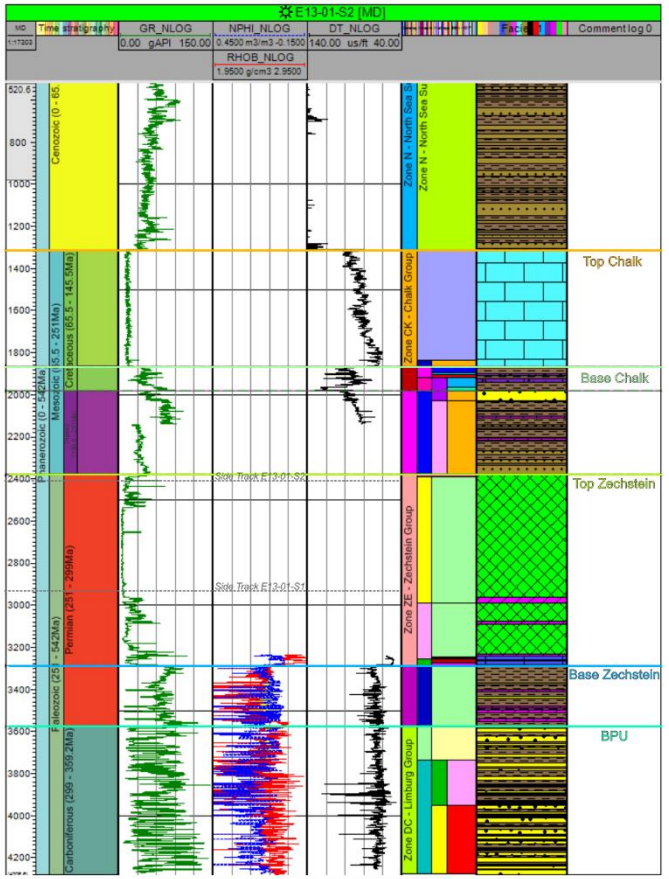




DHA:

PLAY	R	S	C	T	Comments
Upper Jurassic					No reservoir sections.
Triassic					No reservoir sections.
Zechstein					Basal Dolomitic limestone succession. Oil shows.
Rotliegend					Dominantly claystone, halite and anhydrite. No reservoir section.
U. Carboniferous					Reservoir porosities ranging <1 - 19.9% and KH ranging 0.01 - 660 mD, and KV ranging from 0.04 - 290 mD. Gas shows in the upper part of the succession.
L. Carboniferous					Absent

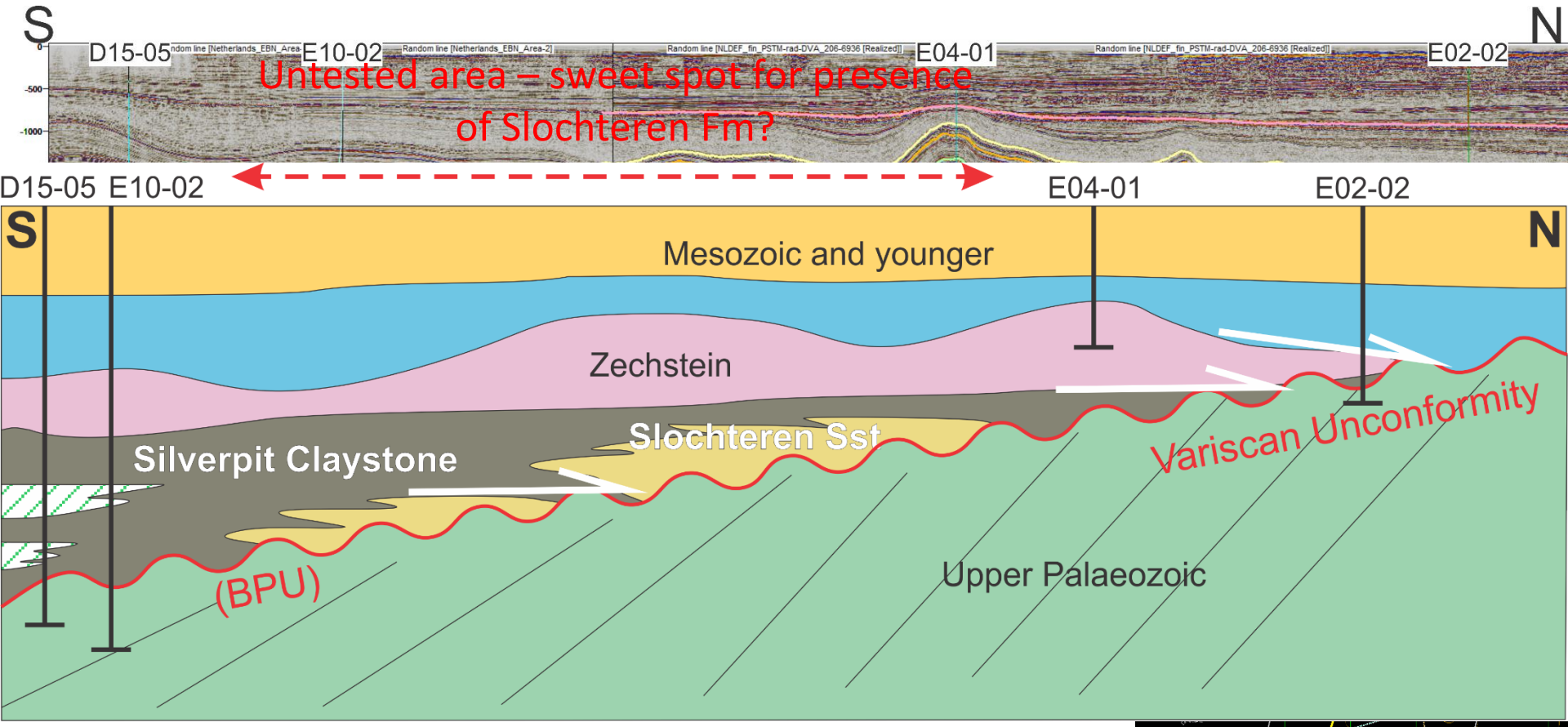
Well:

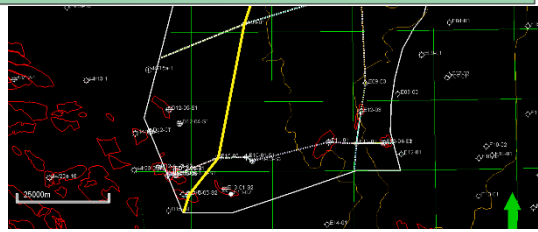


Author: G. Heldreich. 2019
Template modified from R. Brackenridge, OGA Mid North Sea High Project, 2018

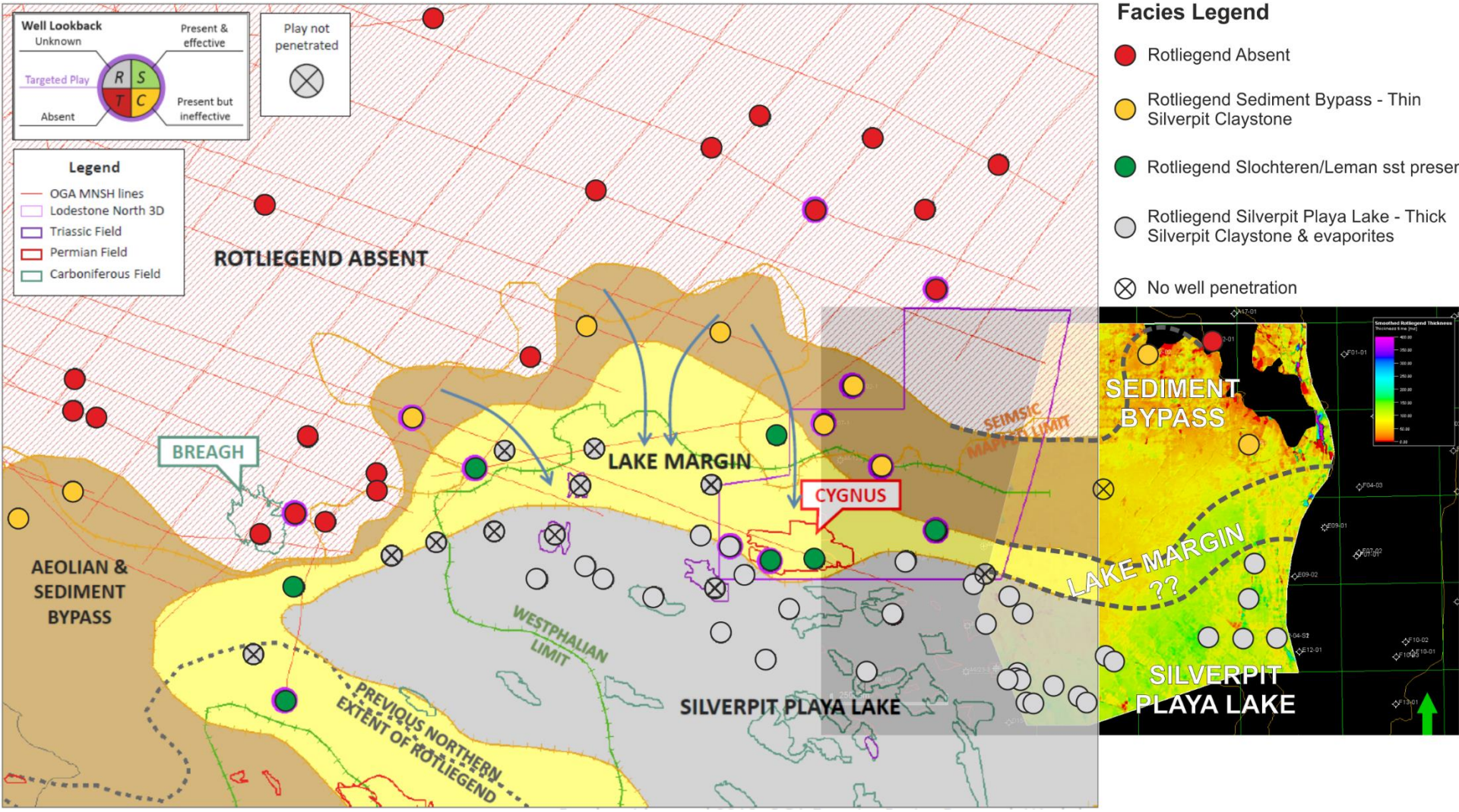
HERIOT WATT UNIVERSITY

Supra-crop cross section on BPU/Composite Variscan Unconformity surface



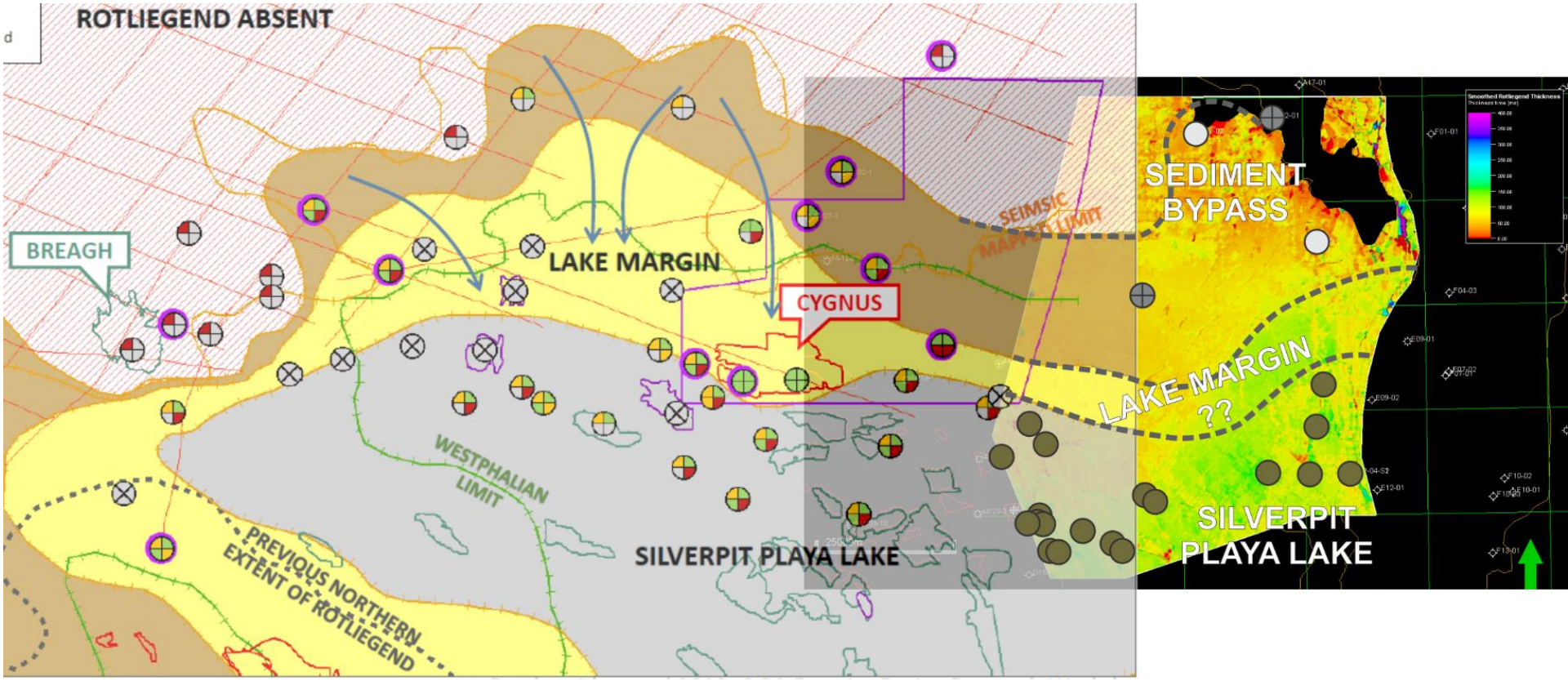


Results – Rotliegend Play Fairway Map



HERIOT WATT UNIVERSITY

E-W trending central area between northern and southern well penetrations remain untested – potential for Rotliegend sands here?



- Potential NE –SW trend of Slochteren play fairway on a local scale?
- Similar patterns/variability observed in the UK offshore
- Controlled by underlying Carboniferous highs?

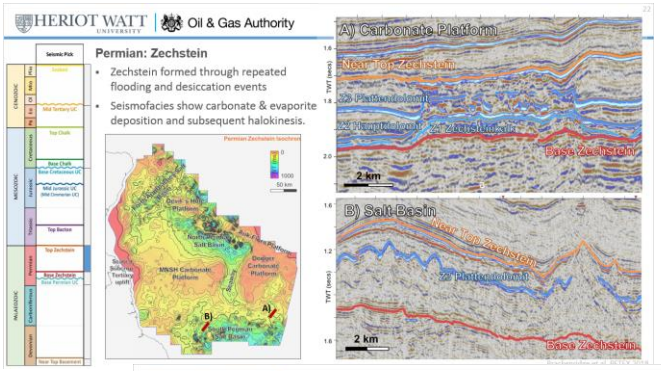
Conclusions

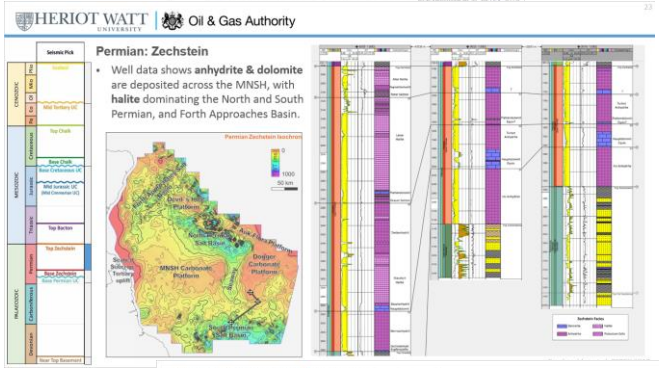
- Report out of results arising from a 6-month EBN-funded PDRA project based at Heriot-Watt University (HWU).
- Project was an eastward extension of an OGA-funded precursor also undertaken at HWU.
- Elbow Spit high (and eastern flank of Elbow spit platform) remained a structural high during deposition of Permian section.
  - Evidence of early rift flank uplift on proto-Central Graben?
- Post Permian stratigraphic successions deepen and thicken towards the east
  - Latest Mid Tertiary unconformity shallows to the west – thus indicating the effects of relatively late (Miocene) uplift seen in the UK OGA MNSH study also affect the Elbow Spit Platform area.
- Still potential to test presence of Slochteren sandstones in central belt
  - Thin Silverpit Claystone in northern wells
  - Thick Silverpit Claystone and evaporite successions in southern wells
  - Missing lake margin play fairway in between?

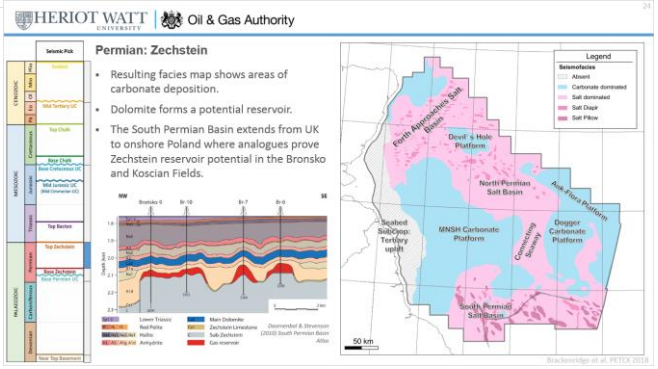
Elbow Spit Platform Workshop Teaser….

More information on:

- Across boarder integration of UK onshore, UK offshore and Dutch offshore regional geology
  - Carboniferous NW-SE (Tornquist) structural trend
  - Permian E-W (Southern Permian Basin) structural trend
- Chasing the Slochteren Sst play fairway further east - constrained by wells and seismic data within the AOI
- Integration of structural analysis (coherency maps) and Rotliegend well penetrations to identify potential structural traps/ inversion features
- Identification of other potential opportunities within the area…….
  - Carboniferous – display different thickness trends to the Permian interval
  - Examples where Zechstein may work outwith a Westphalian subcrop.







Join us and find out more on 26th November 2019!

Acknowledgements

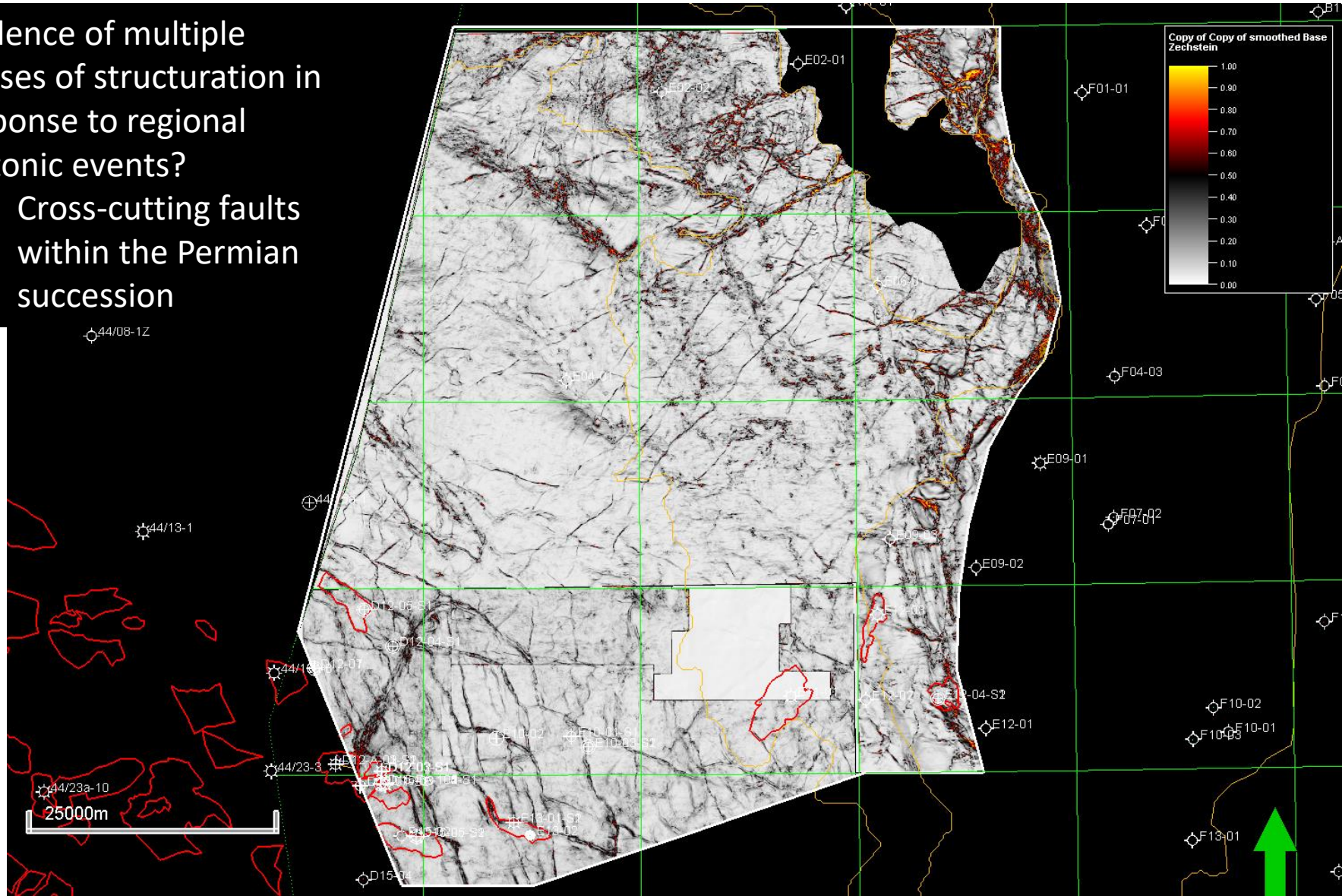
- EBN for sponsoring and funding the 6 month project
  - In particular Kees van Ojik, Marloes Kortekaas, Eric van Ewijk & Sabine Korevaar for support and technical input during progress meetings
- Data providers: Spectrum/TGS, PGS, Engie and Tullow Oil
- OGA and Rachel Brackenridge for access to results and learnings from their MNSH study
- Schlumberger for academic software licences
- HWU IT support (Alan Brown)

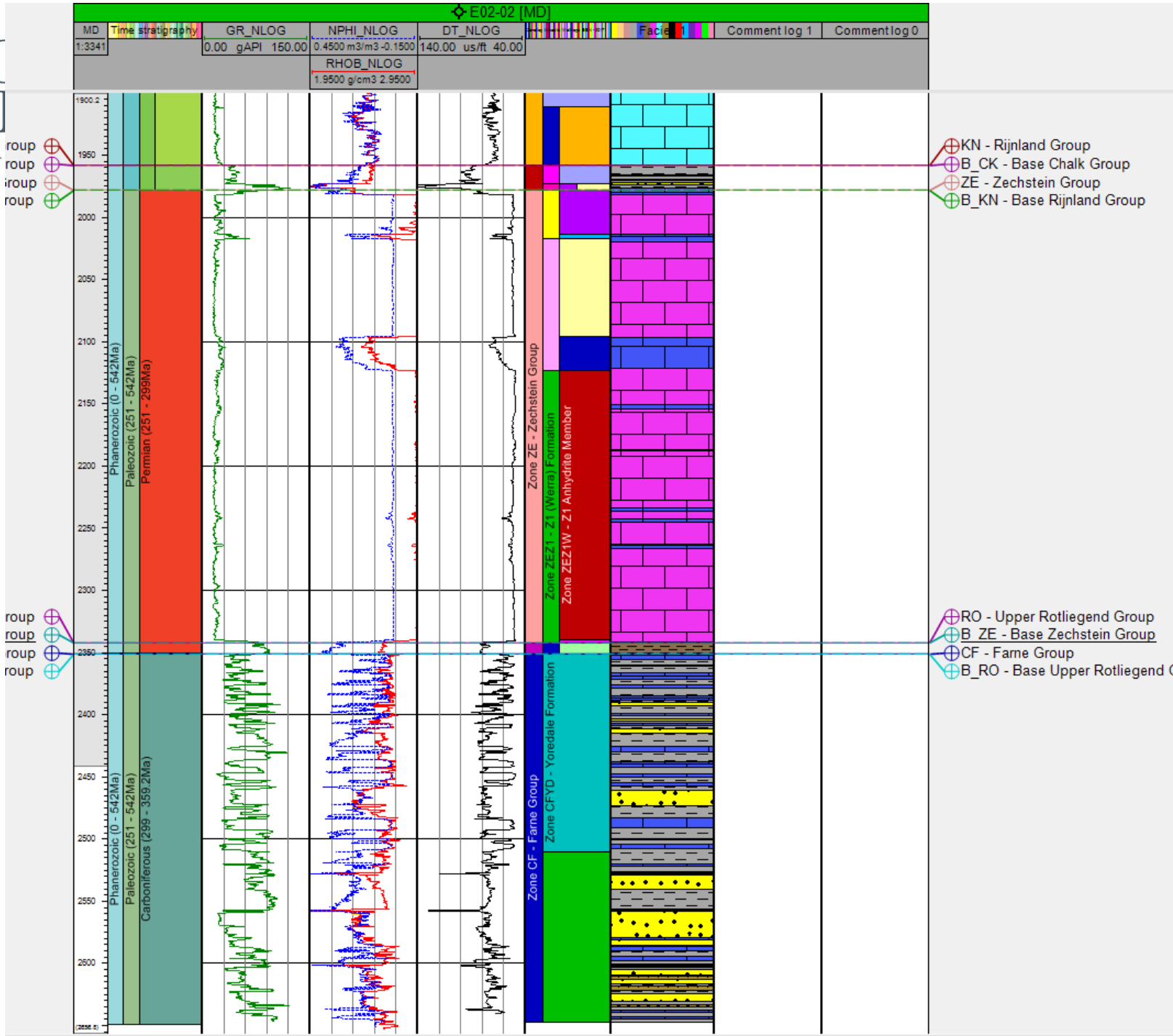
Thank you for listening

Structural Analysis

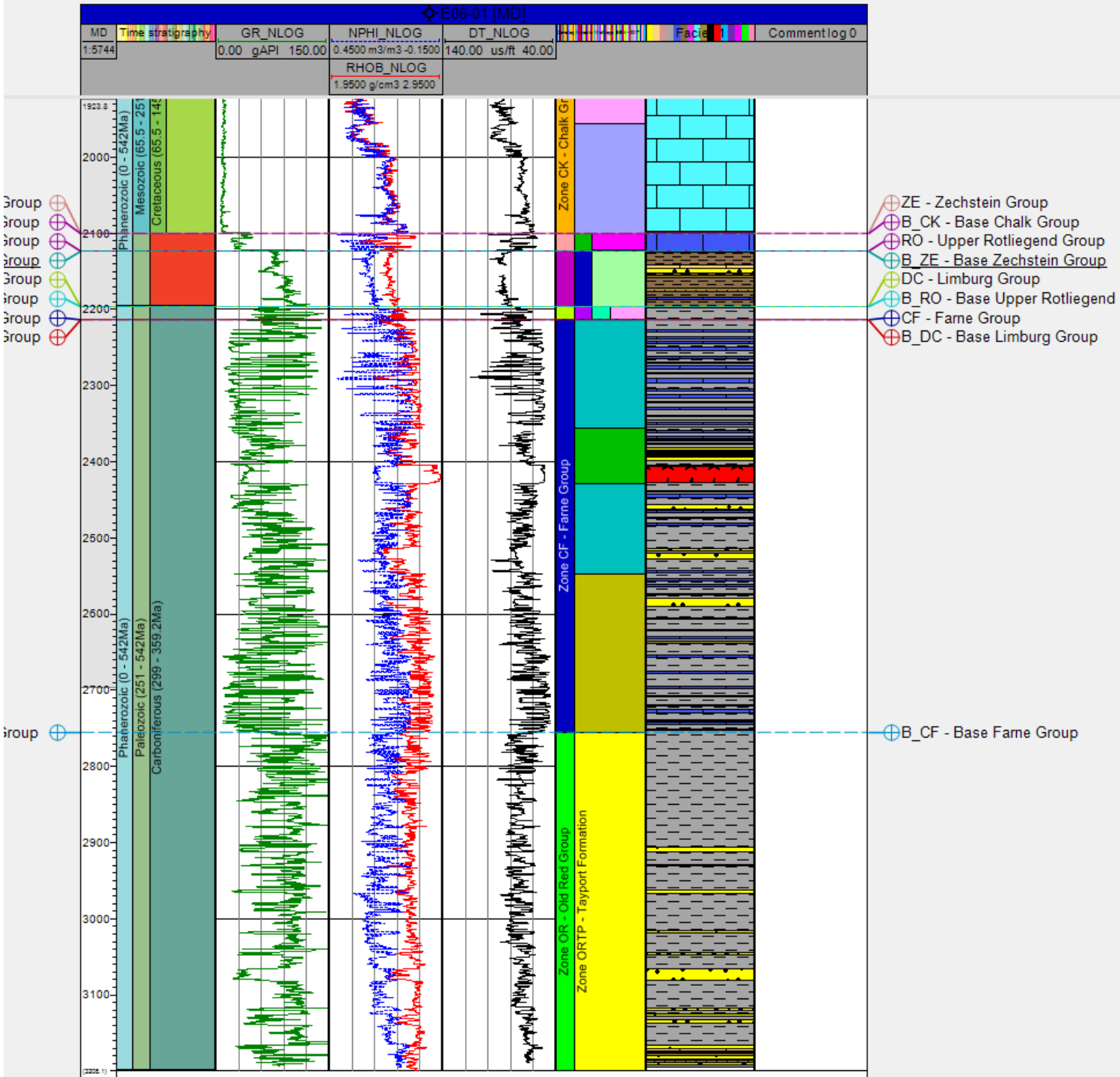
Base Zechstein Variance Map

- Evidence of multiple phases of structuration in response to regional tectonic events?
  - Cross-cutting faults within the Permian succession

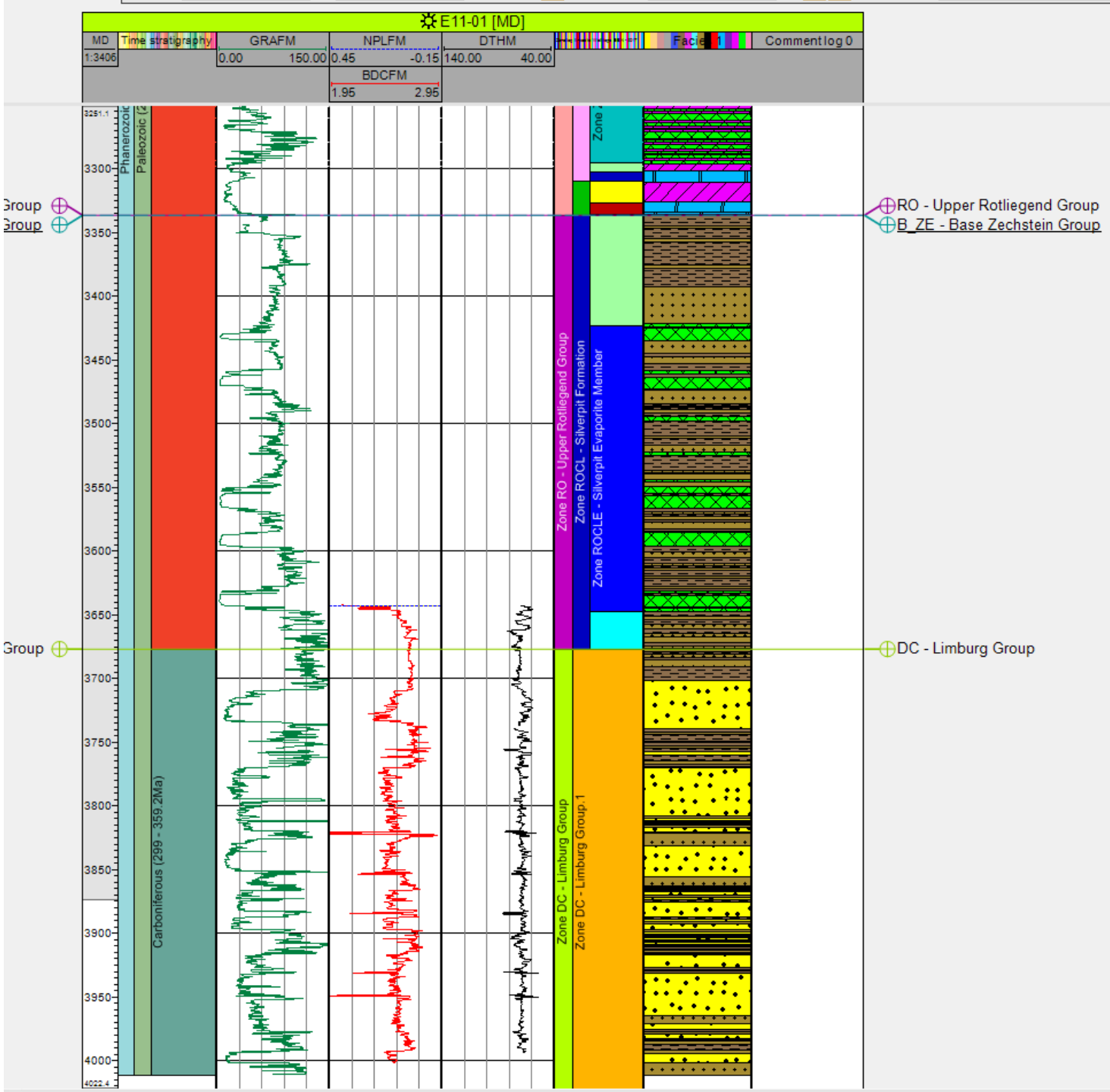



E02-02 [MD]
MD
1:3341
Time stratigraphy
GR_NLOG
0.00 gAPI 150.00
NPHI_NLOG
0.4500 m3/m3 -0.1500
RHOB_NLOG
1.9500 g/cm3 2.9500
DT_NLOG
140.00 us/ft 40.00
Facies
Comment log 1
Comment log 0
Phanerozoic (0 - 542Ma)
Paleozoic (251 - 542Ma)
Permian (251 - 299Ma)
Carboniferous (299 - 359.2Ma)
Zone ZE - Zechstein Group
Zone ZEZ1 - Z1 (Werra) Formation
Zone ZEZ1W - Z1 Anhydrite Member
Zone CF - Farne Group
Zone CFYD - Yoredale Formation
KN - Rijnland Group
B_CK - Base Chalk Group
ZE - Zechstein Group
B_KN - Base Rijnland Group
RO - Upper Rotliegend Group
B_ZE - Base Zechstein Group
CF - Farne Group
B_RO - Base Upper Rotliegend

HERIOT WATT UNIVERSITY



HERIOT WATT UNIVERSITY



HERIOT WATT UNIVERSITY