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

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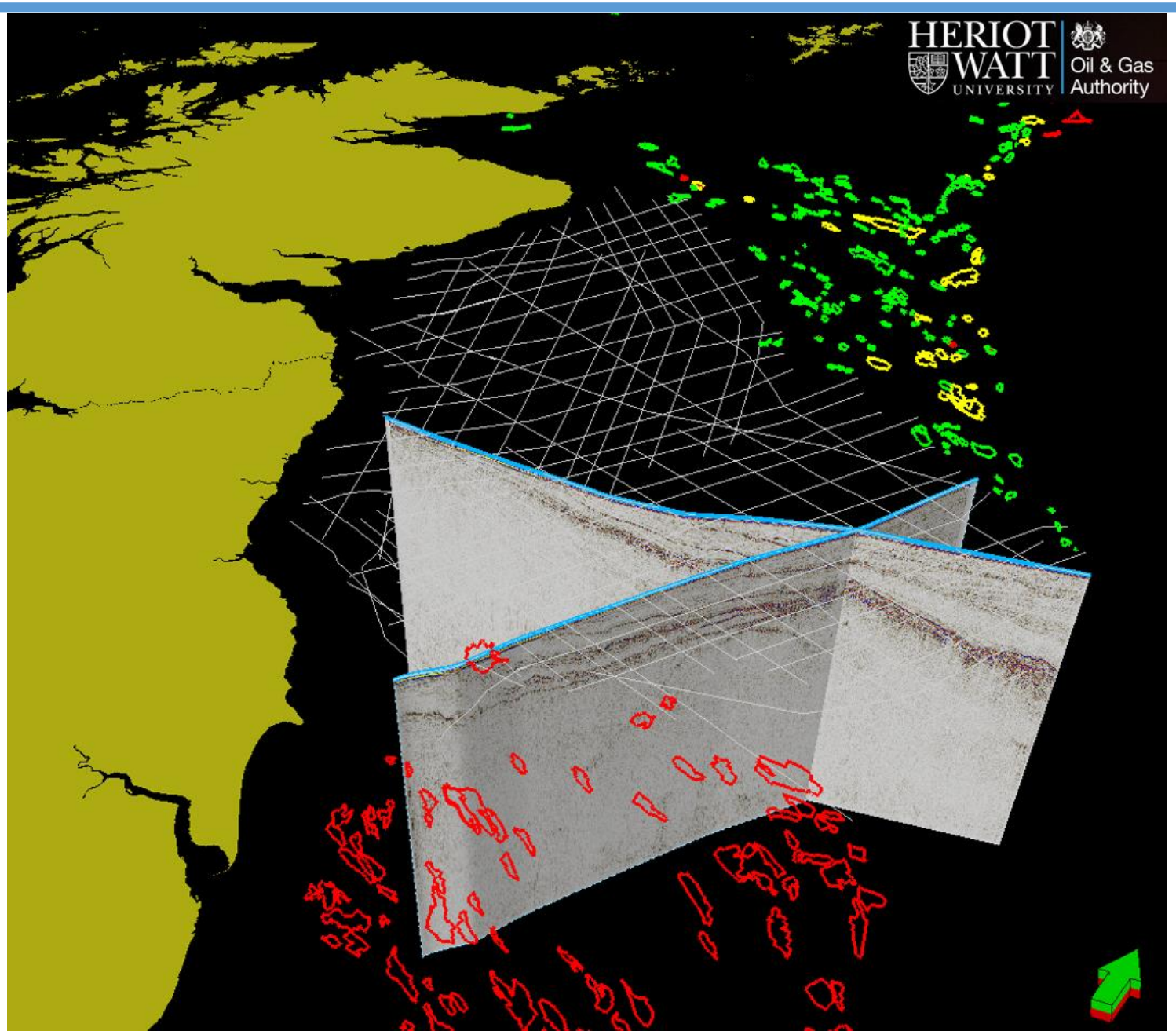
Outline:

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

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



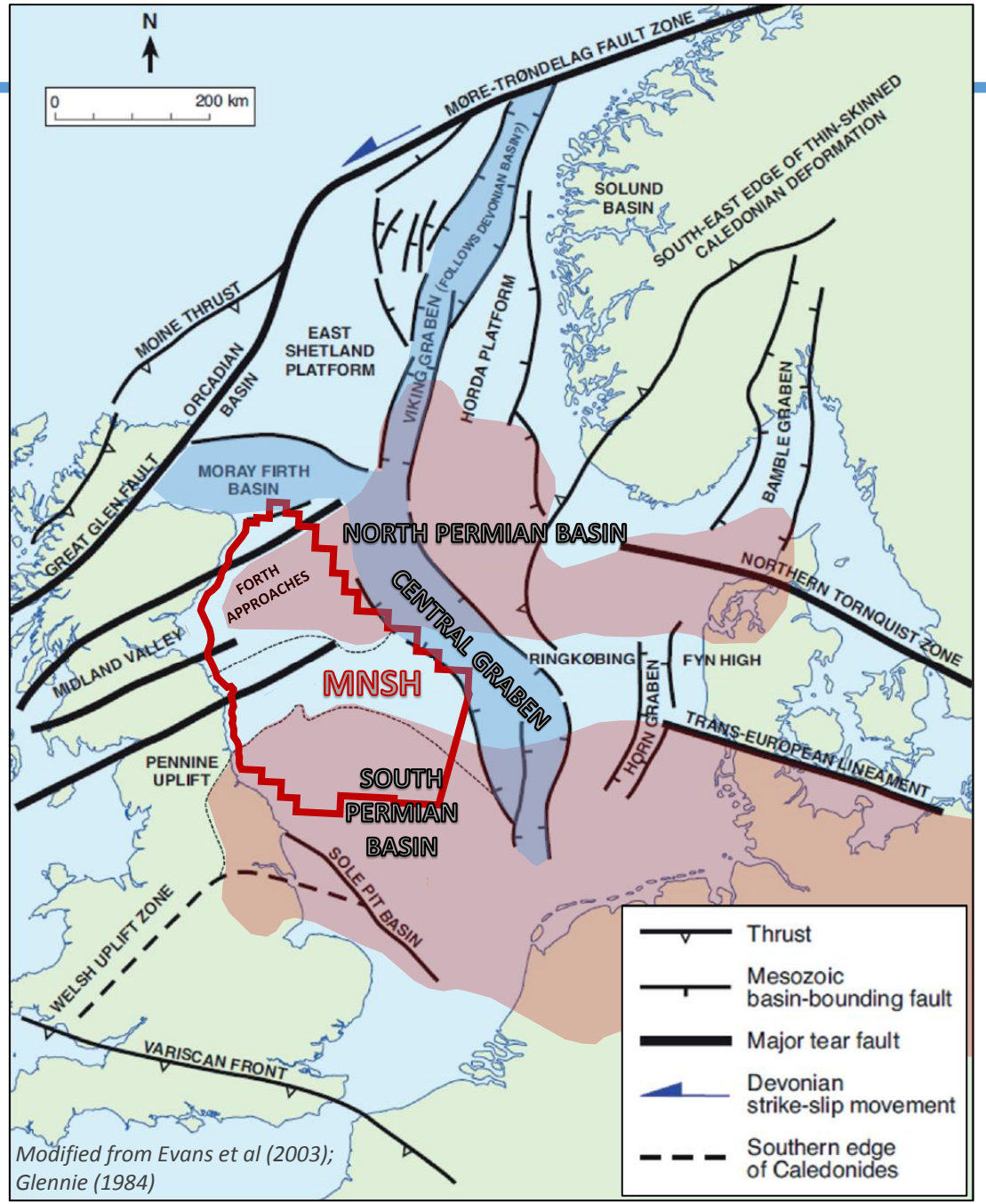
The Mid North Sea High

- Relative to the main structural features of the North Sea Basin, the Mid North Sea High (MNSH) lies between the Northern & Southern Permian Basins and is transected to the NE by the Jurassic Central Graben.

- This study focuses on the Greater MNSH region (highlighted in the red polygon), and examines how the High could be charged from:

  - the South Permian Basin Petroleum System – a gas basin sourced from numerous levels in the **Carboniferous**.
  - the Central Graben, a oil-bearing **Jurassic-sourced** system.

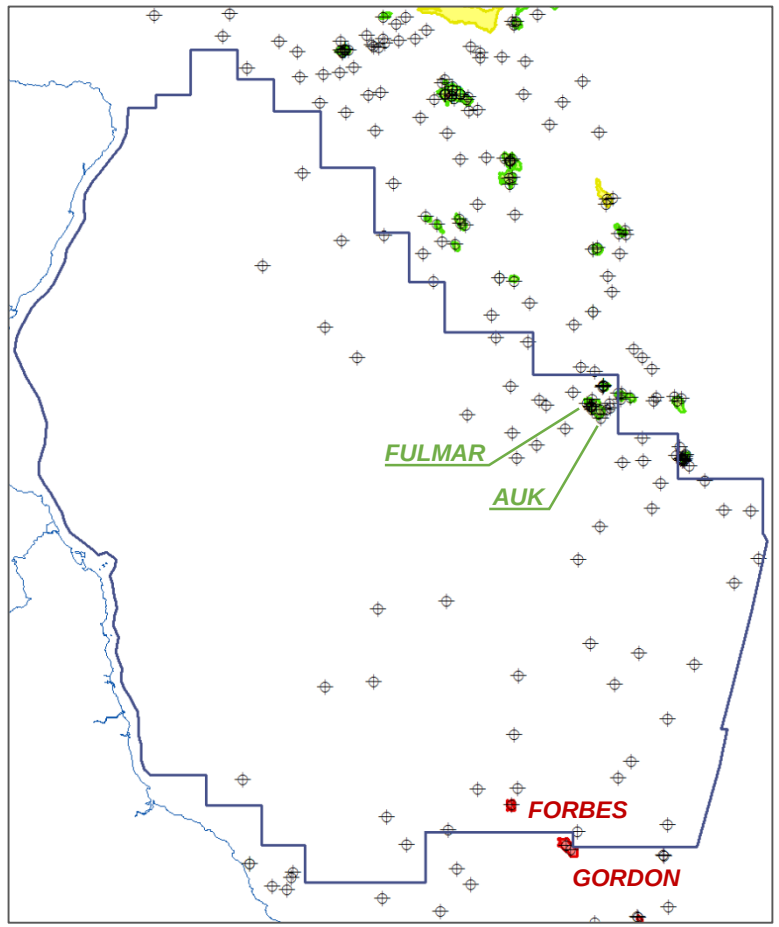
- The study area is defined by the 2015 OGA Frontier Basins seismic data coverage.



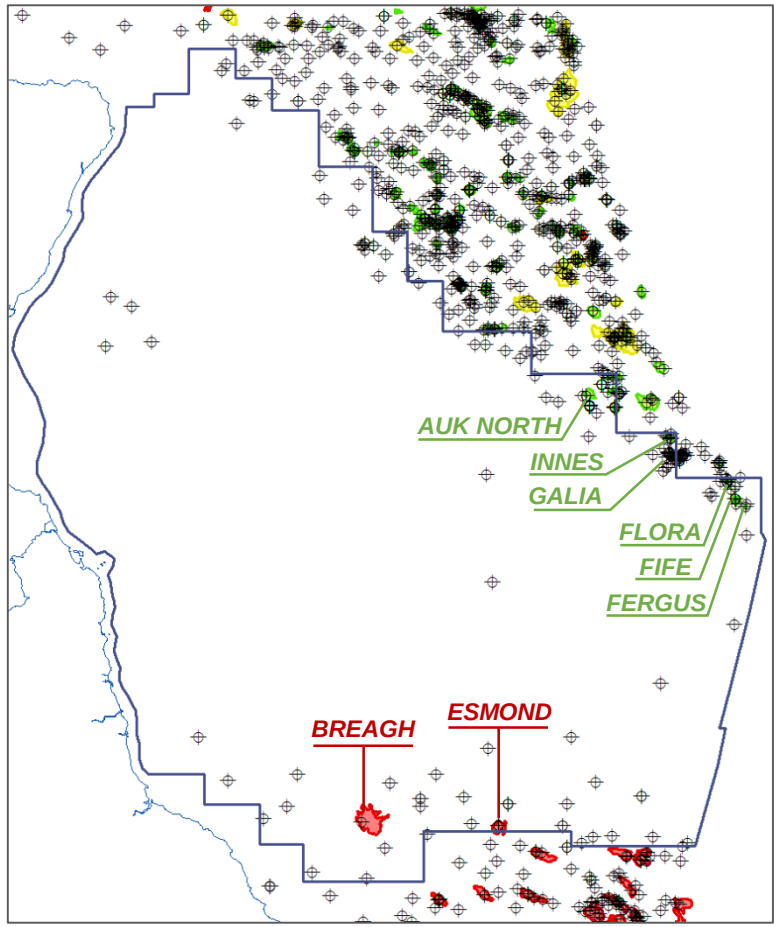
Project Rationale

- The Mid North Sea High is under-explored, and therefore poorly understood.

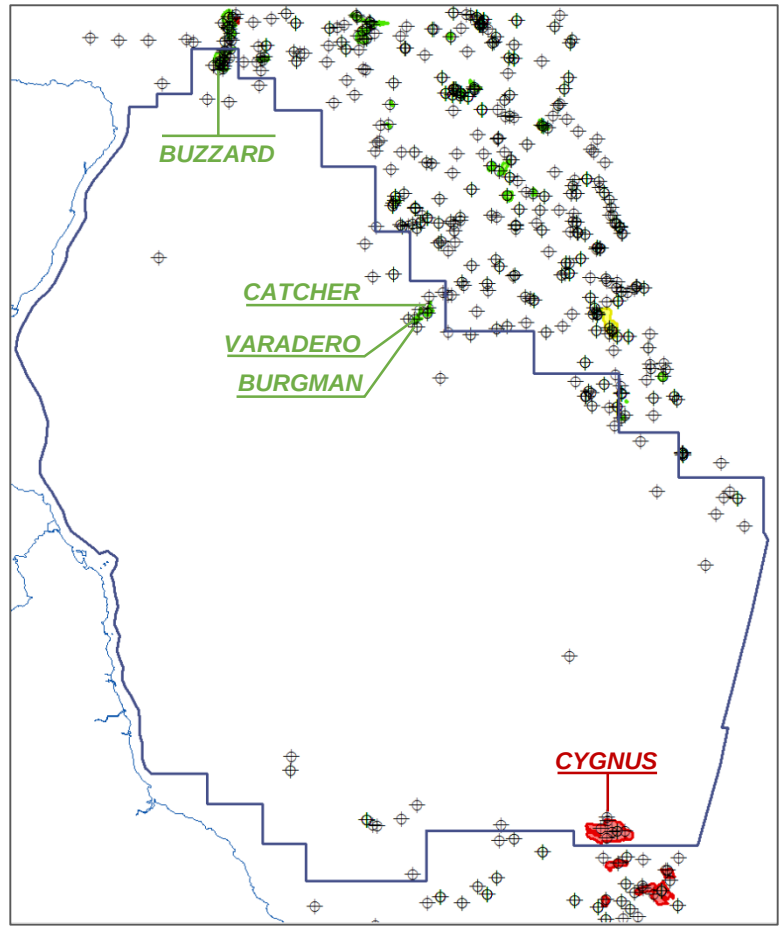
1960s – 1970s



1980s – 1990s



2000 - 2010s

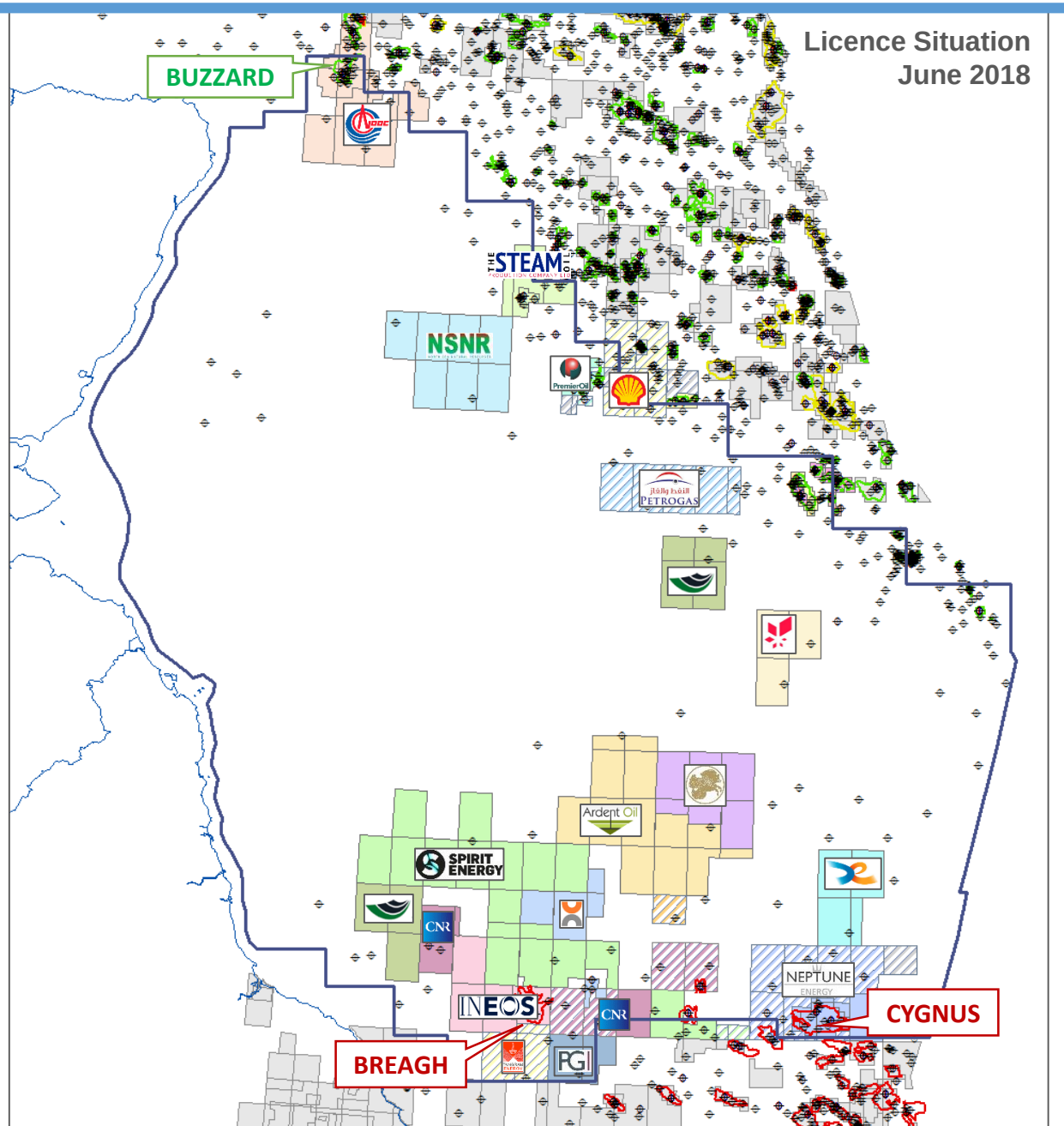


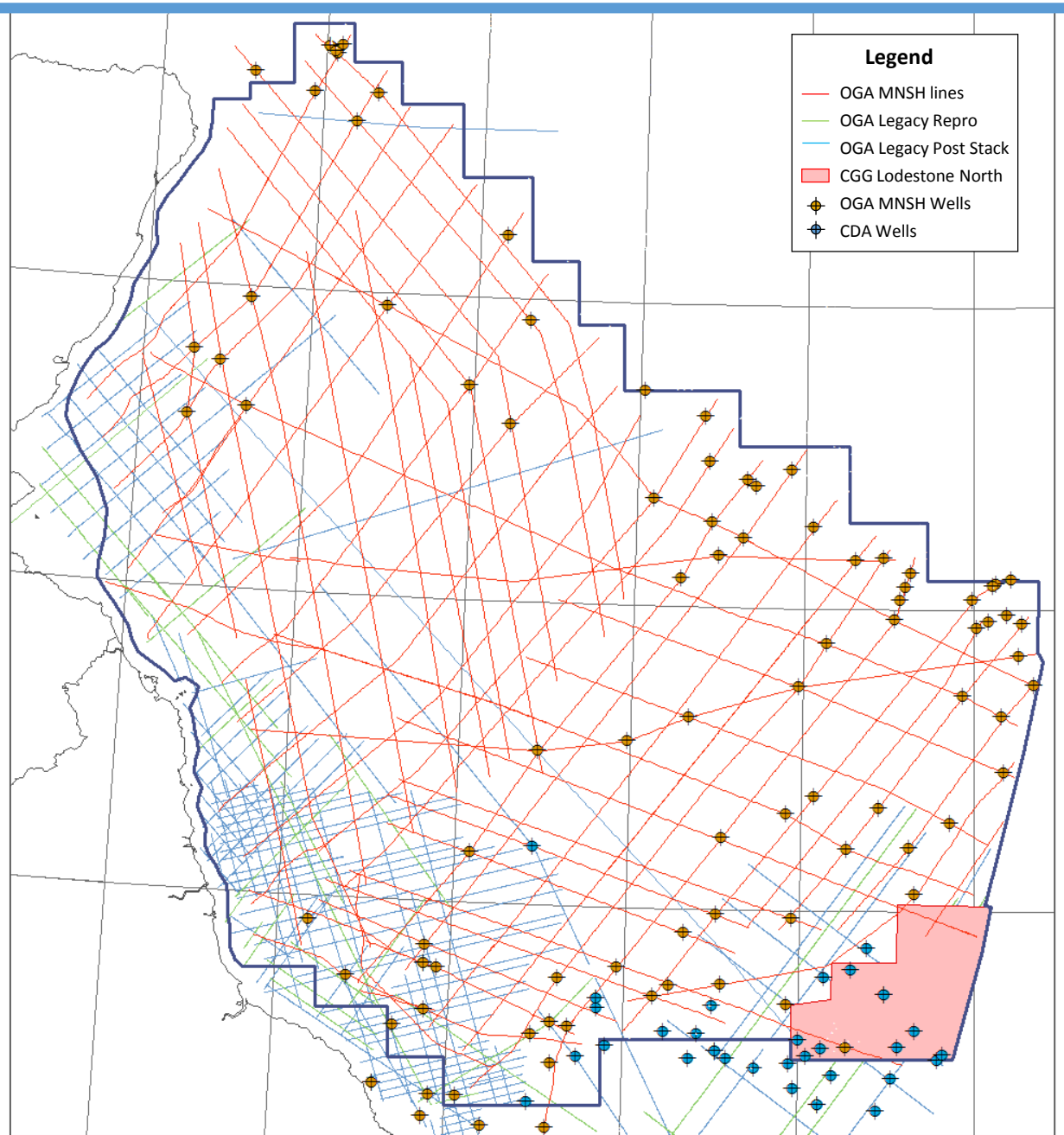
Brackenridge et al 2018. OGA Frontier Basins Research Workshop

Project Rationale

- Renewed exploration interest in recent years driven by:

1. Recent discoveries on on the margins of the Mid North Sea High.
2. Frontier-focused licensing rounds (29th and 31st Rounds).
3. OGA-sponsored acquisition of seismic data and release of legacy data over the region.





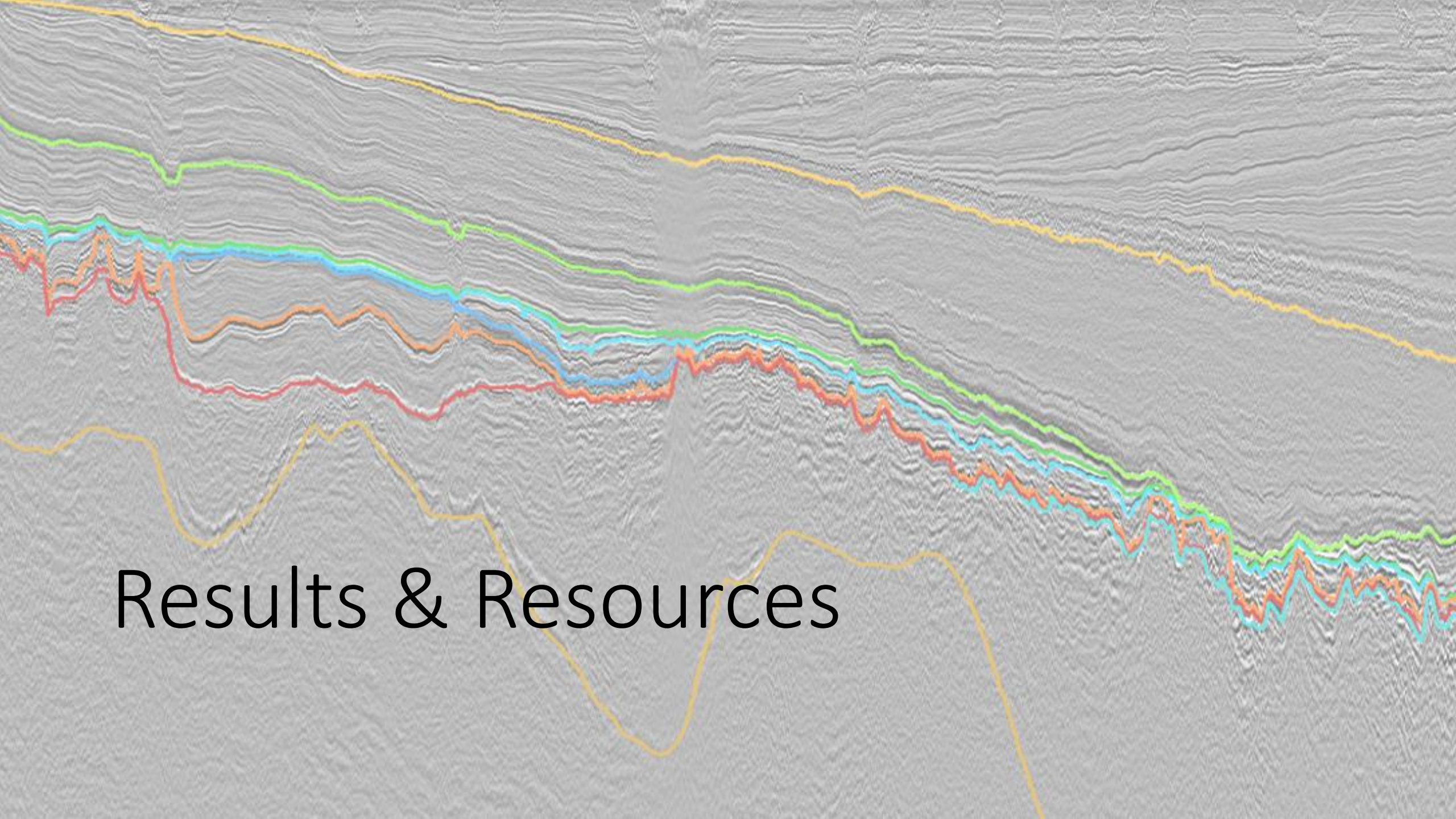
Data, Project Award & Aims

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 sequence stratigraphic framework for the region.
- Review the petroleum prospectivity of the region.

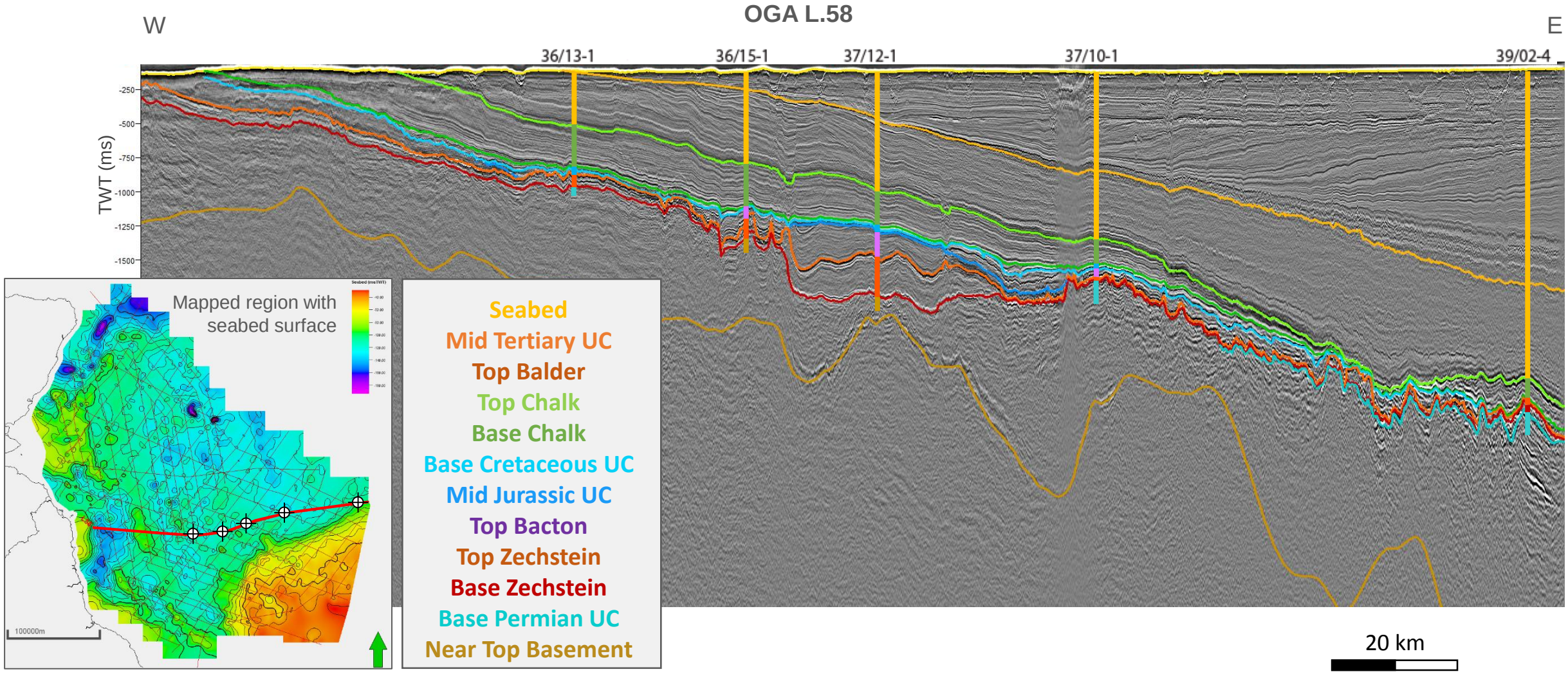
All results to be provided open access through the OGA data centre.



Results & Resources

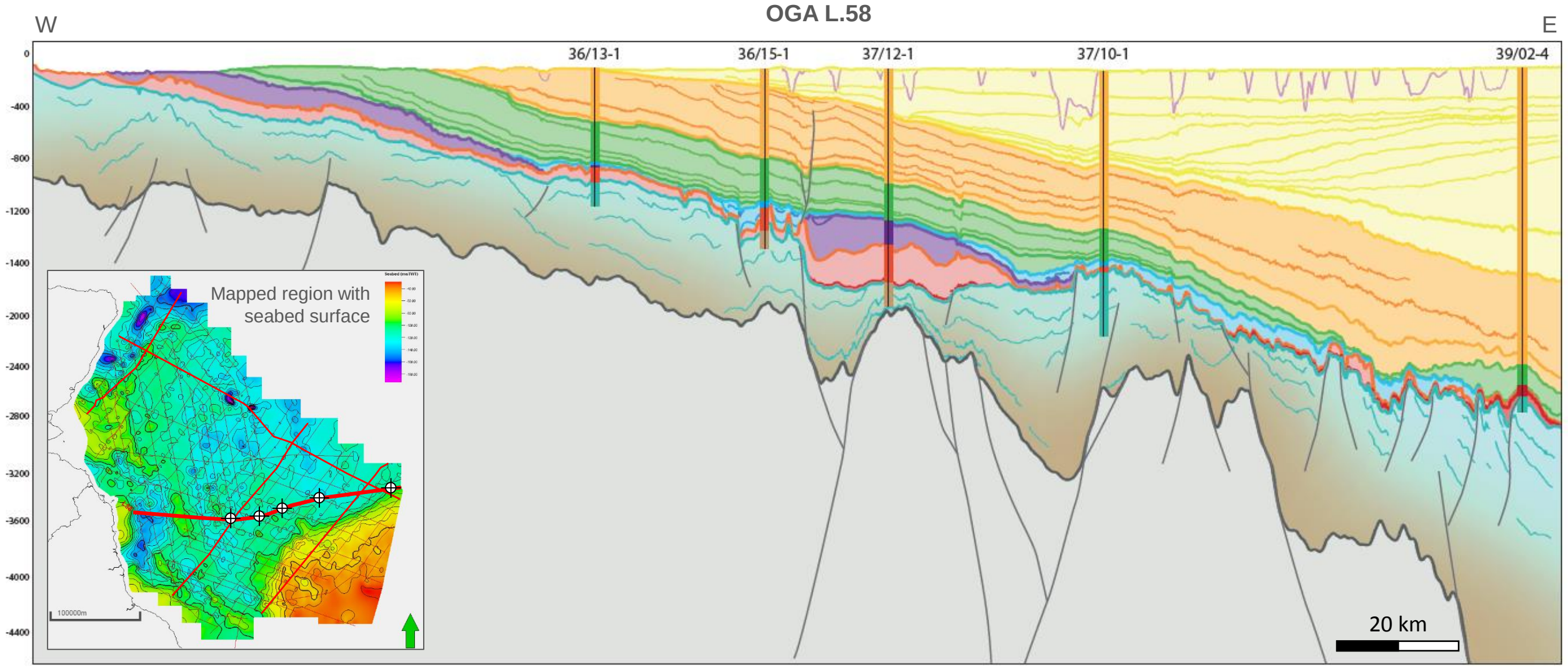
Results: Seismic Mapping

12 surfaces have been mapped regionally.



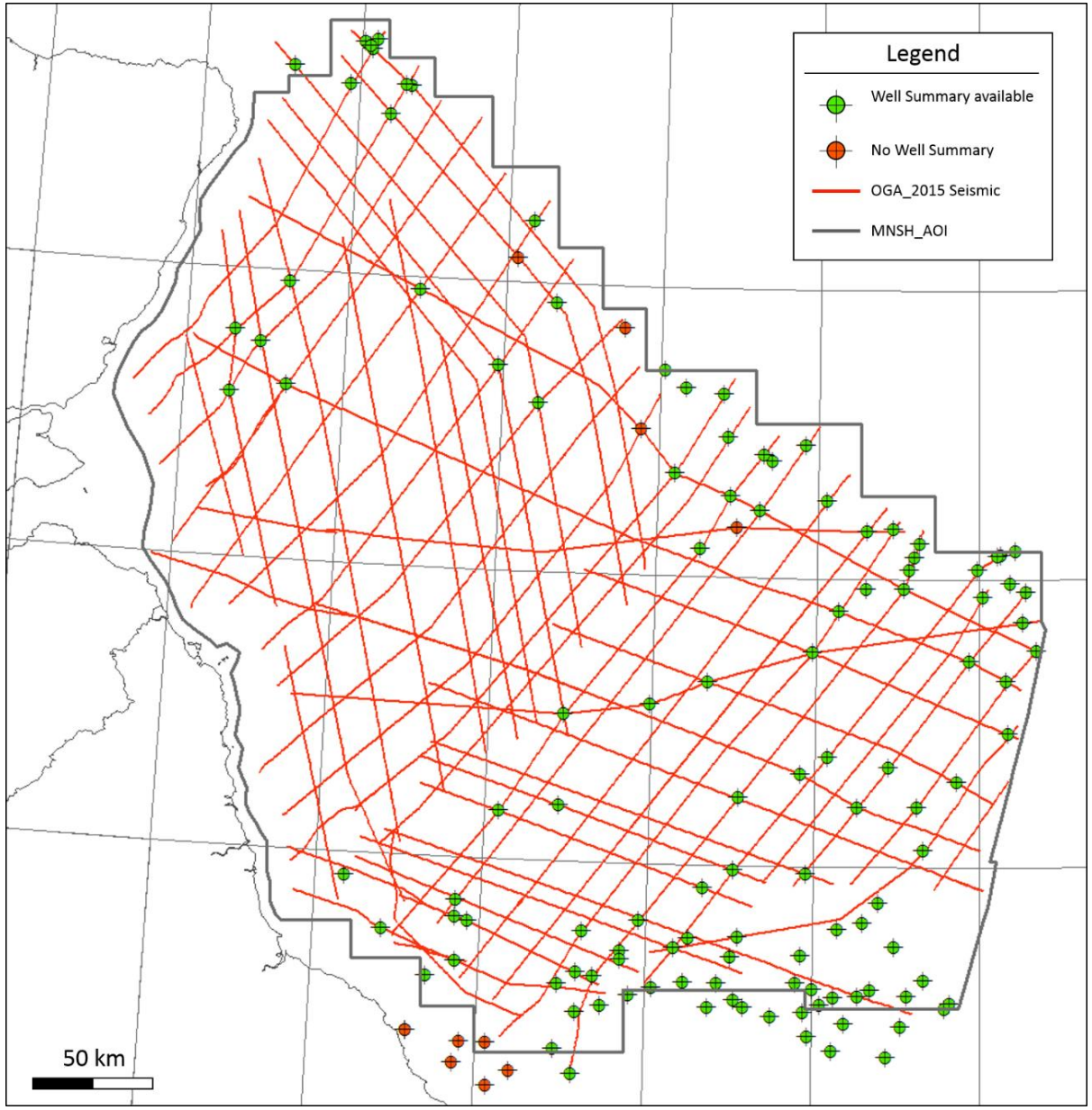
Results: Seismic Mapping

5 herolines have been chosen for detailed interpretation.



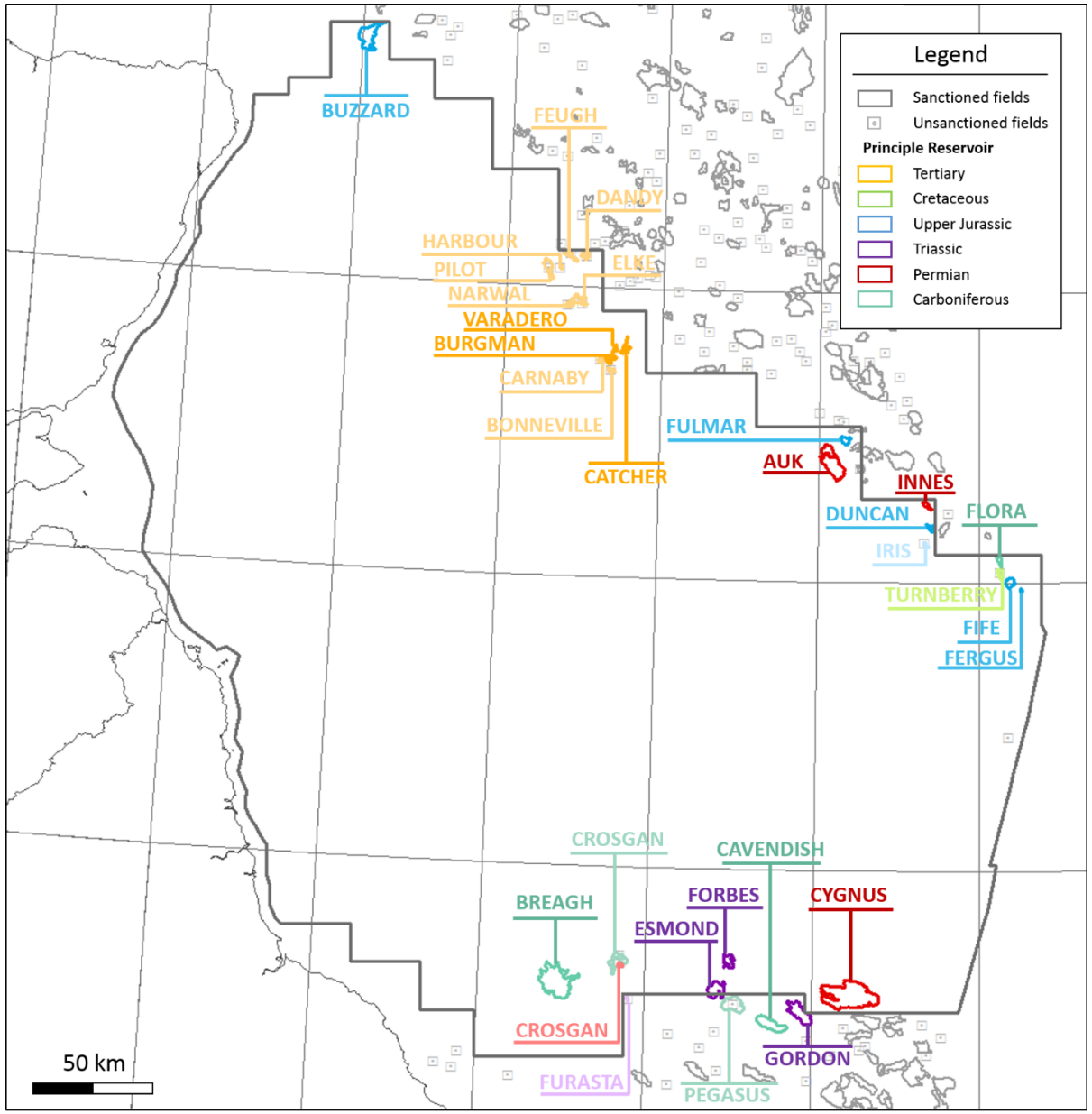
Results: Well Analysis

- Mapping has been informed by the wells drilled in the area.
- A single **Well Summary Sheet** was created for all wells on the MNSH and key marginal wells.
- > 120 well summaries to date.



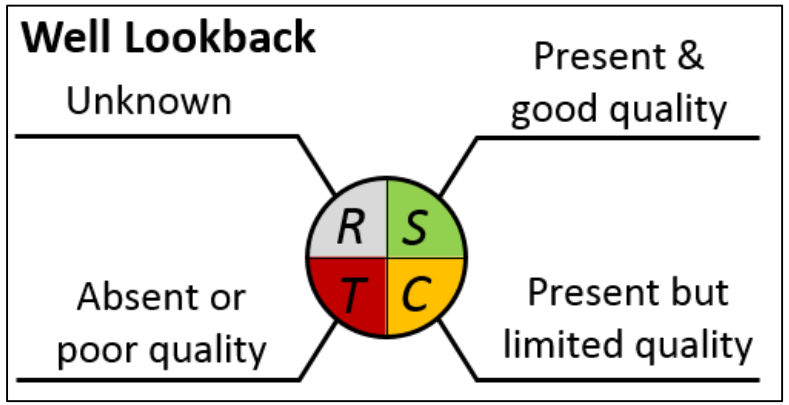
Results: Well Analysis

- Mapping has been informed by the wells drilled in the area.
- A single **Well Summary Sheet** was created for all wells on the MNSH and key marginal wells.
- > 120 well summaries to date.
- **Field Summary Sheets** also available.



Results: Well Analysis

- Example Well Summary Sheet.
- Aim to provide a quick-look resource for explorers.
- Have helped to define a regional stratigraphic framework
- This feeds into the **Well Look Back** or **Dry Hole Analysis** which summarises the reason for failure at each play level.



Well Name: 38/29-1

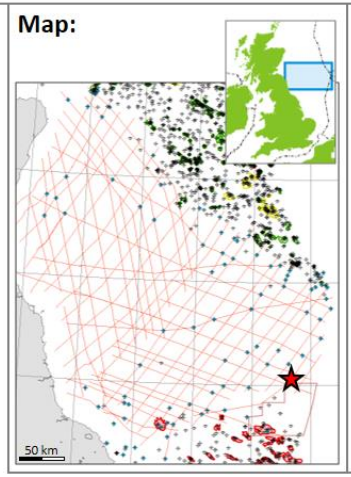
Reason for Failure: Lack of source rock (Carboniferous section absent, thus relying on long-distance migration).

Summary:

Location: **2°39'42.356"E 55°3'37.494"N**
Licence: **P.23**
Block: **Quadrant 38, Block 29**
Water Depth/Datum: **88 ft / KB 83 ft**
Spud Date: **Dec 1964**
Operator/Partners: **Phillips**

TD/Formation: **9,304 ft MD, Devonian Old Red Sandstone.**
Objectives: **Tertiary sst., Triassic Bunter sst., Permian carbonates and sst. and Carboniferous sandstones.**
Reservoir: **Zechstein dolomite, Devonian sandstone.**
Charge: **No HC shows encountered. Carboniferous SR absent.**
Seal: **Various.**
Structure: **Unknown.**
Results: **Dry, P&A.**

Map:



Tops:

Top	MD (ft)	TVDSS
Seabed	168	-88
Pliocene	2,252	-2,172
Miocene	2,387	-2,307
Oligocene	2,544	-2,464
Eocene	2,928	-2,848
Chalk	4,200	-4,120
Cromer Knoll	5,676	-5,540
Bacton	5,688	-5,608
Zechstein	6,215	-6,135
Devonian	8,142	-8,062
TD Driller	9,304	-9,224

DHA:

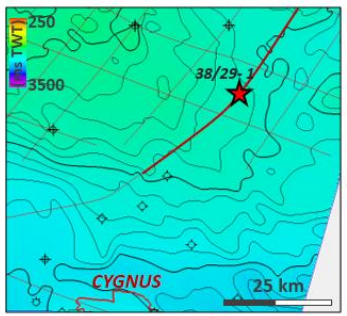
PLAY	R	S	C	T	Comments
Bunter	0	1	0	0	Bunter shales only.
Zechstein	1	1	0	-1	Porosities of 5-20%, no shows.
Rotliegend	0	-1	-1	-1	Absent.
Westphalian	0	-1	-1	-1	Absent.
Namurian	0	-1	-1	-1	Absent.
Diantian	0	-1	-1	-1	Absent.
ORS	1	1	0	-1	Porosities of 5-20%, no shows. Td-ed in Devonian: unknown total thickness.
Kyle	-1	-1	-1	-1	Td-ed in overlying Old Red Sandstone.

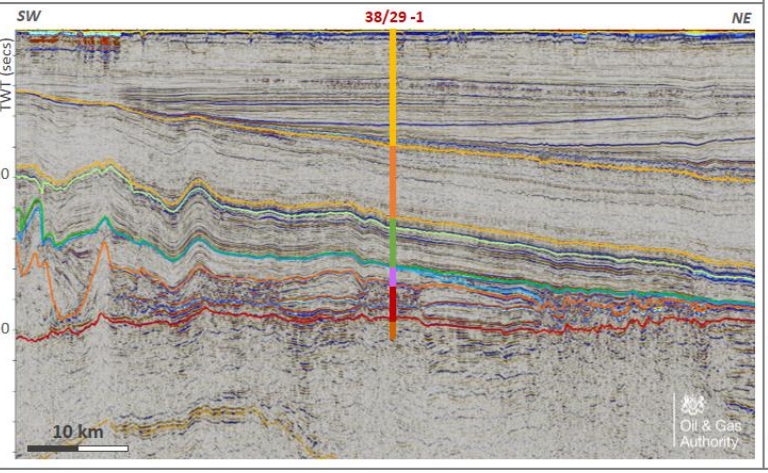
Geological Summary:

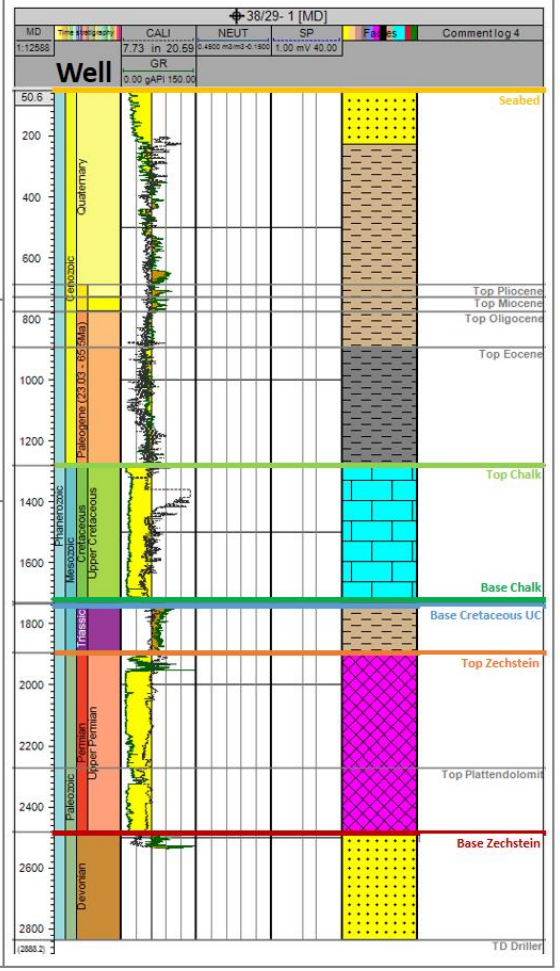
The 38/29-1 well's objective was to give a full understanding of the stratigraphy of this area – thus targeting all levels down through the Carboniferous. The **Triassic Bunter** sandstone was absent (shales only). On penetrating through the Permian Zechstein, Devonian sands and silts were encountered. Thus it is concluded that the **Permian Rotliegend** and **Carboniferous** are absent. The Devonian section was identified by spore analysis. Two reservoir layers were encountered: 1) **Zechstein** Oolitic Dolomite; and 2) **Devonian Old Red Sandstones**. Both reservoir units showed porosity ranges of 5-20%. No HC shows encountered (trace methane only). Given the lack of **Carboniferous** section, there is a resulting lack of source rock. For success, this well would rely on alternative source rocks or long-distance migration.

Seismic:

OGA_2015 L43 (TWT) with 38/29-1 well tied to seismic. Insert shows base Zechstein surface and nearby Cygnus field.



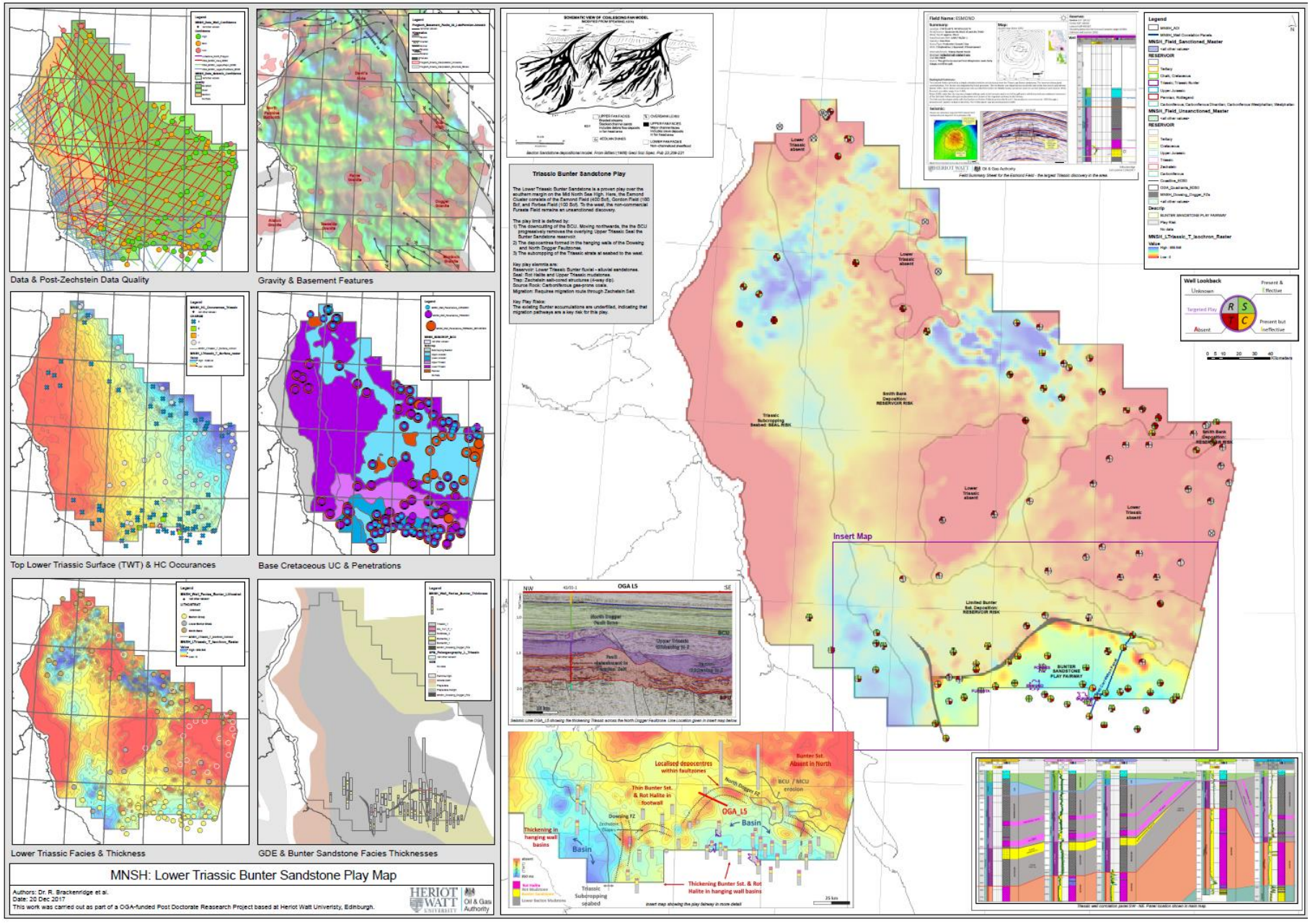


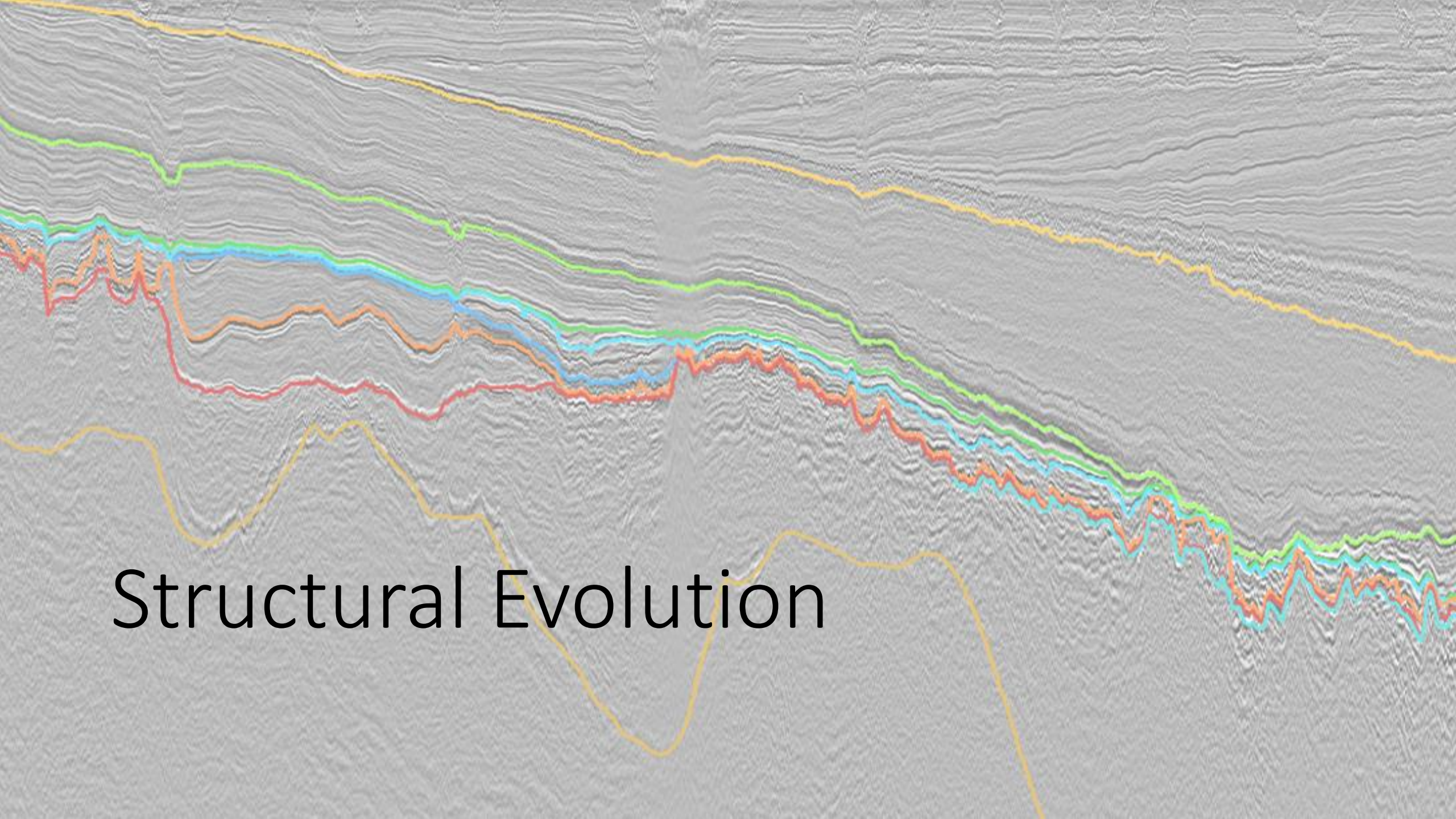


R.E.Brackenridge
Last updated 02/07/2018

Results: Play Mapping

- All results will feed into a final play map across the region.
- Example shows the Triassic Bunter Sandstone Play.





Structural Evolution

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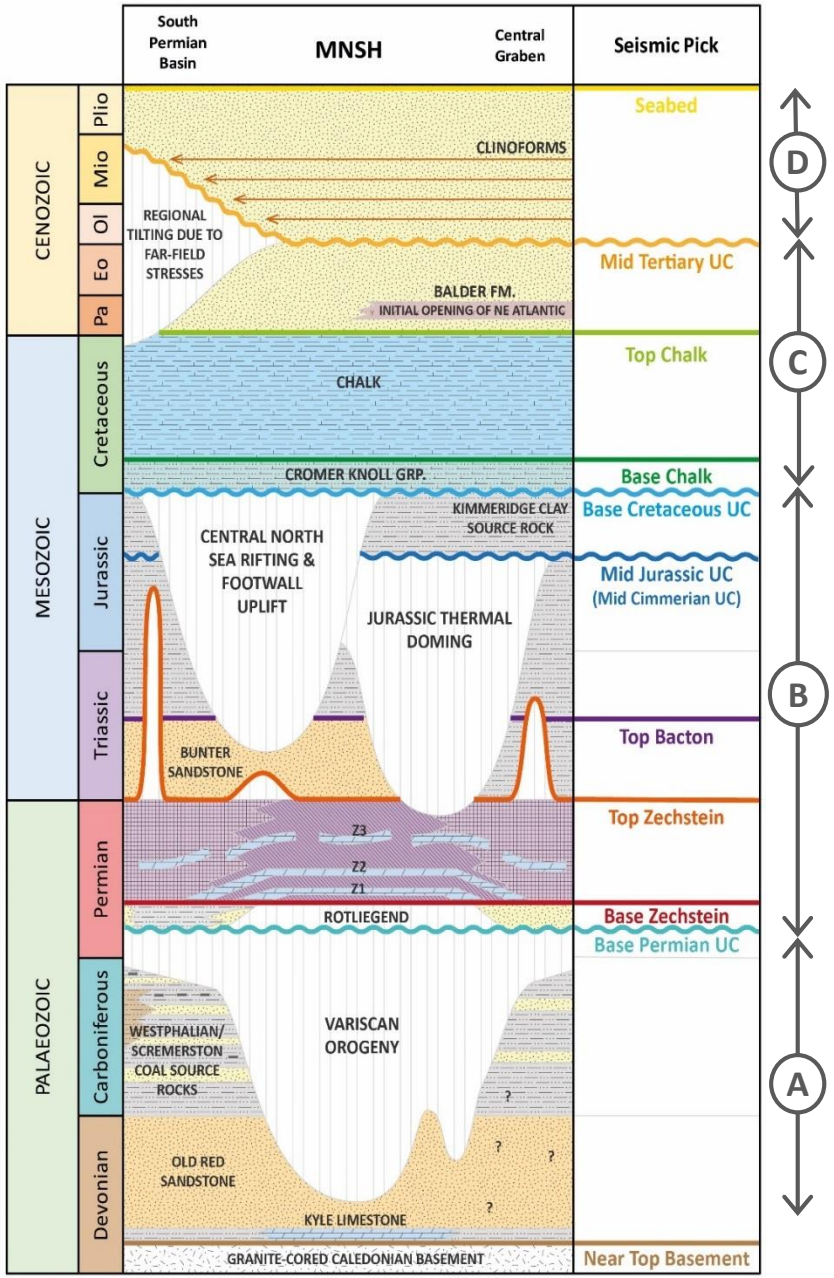
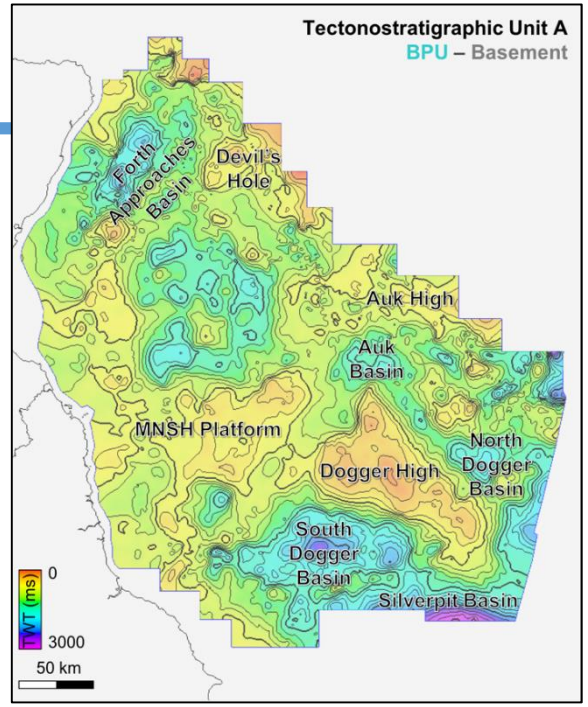
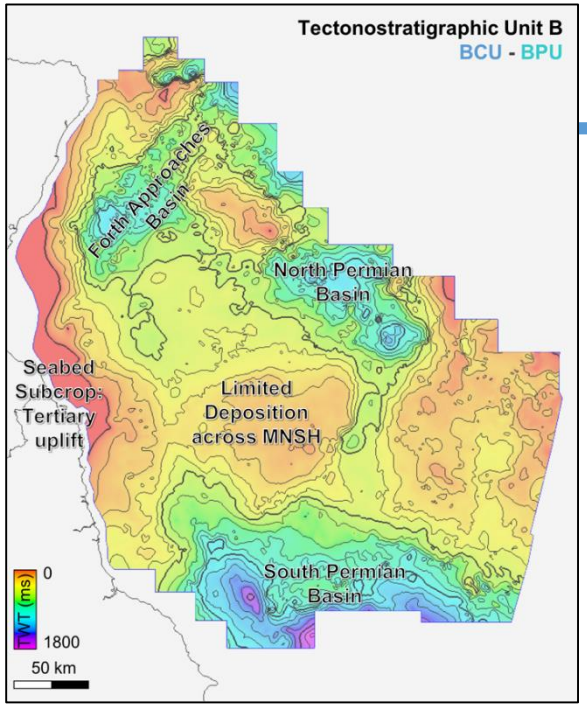
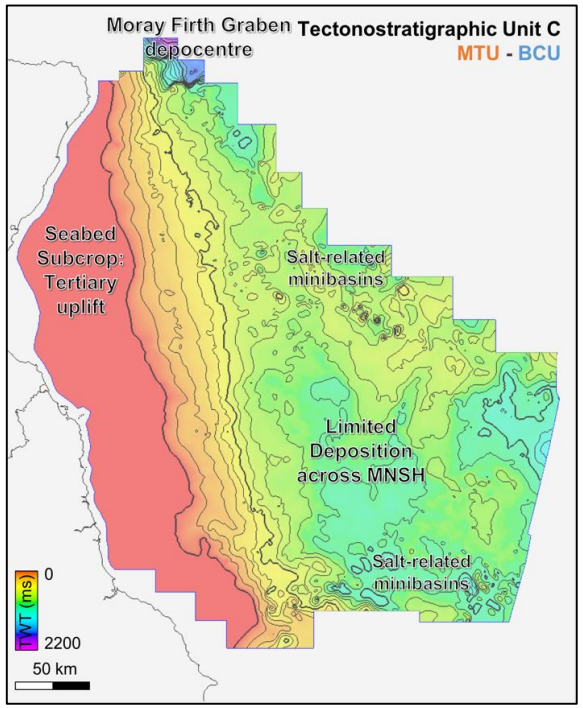
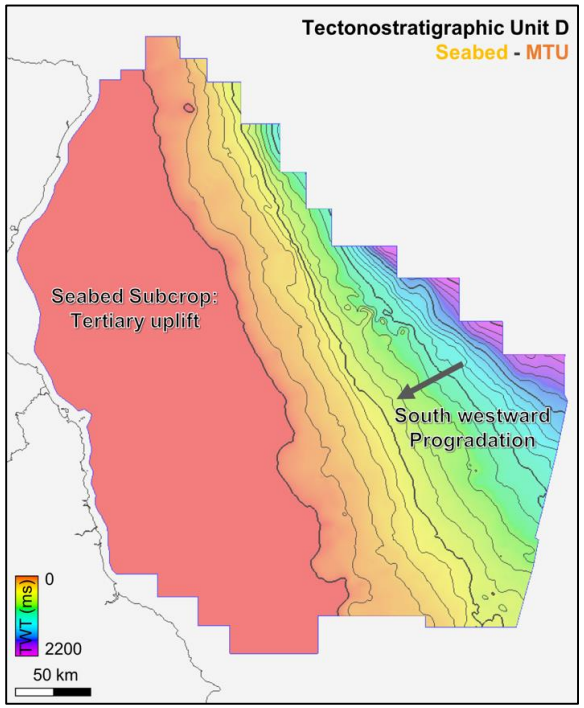


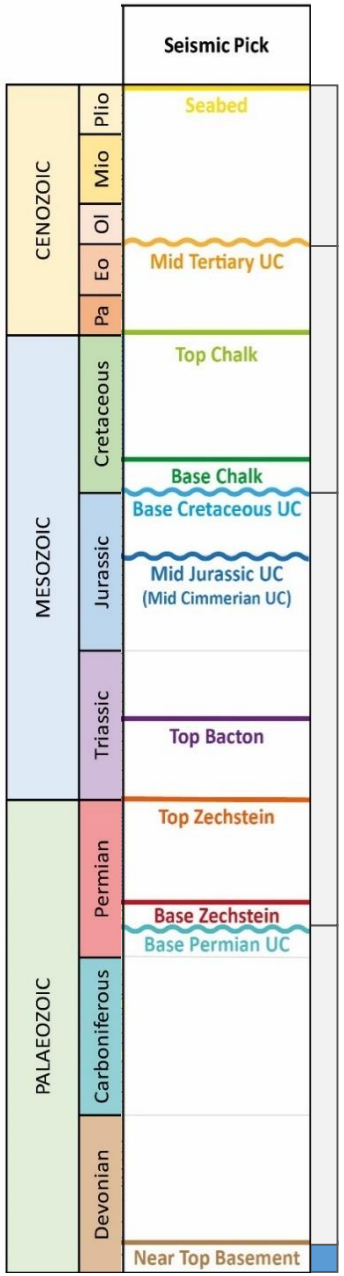
Four significant tectono-stratigraphic units identified.

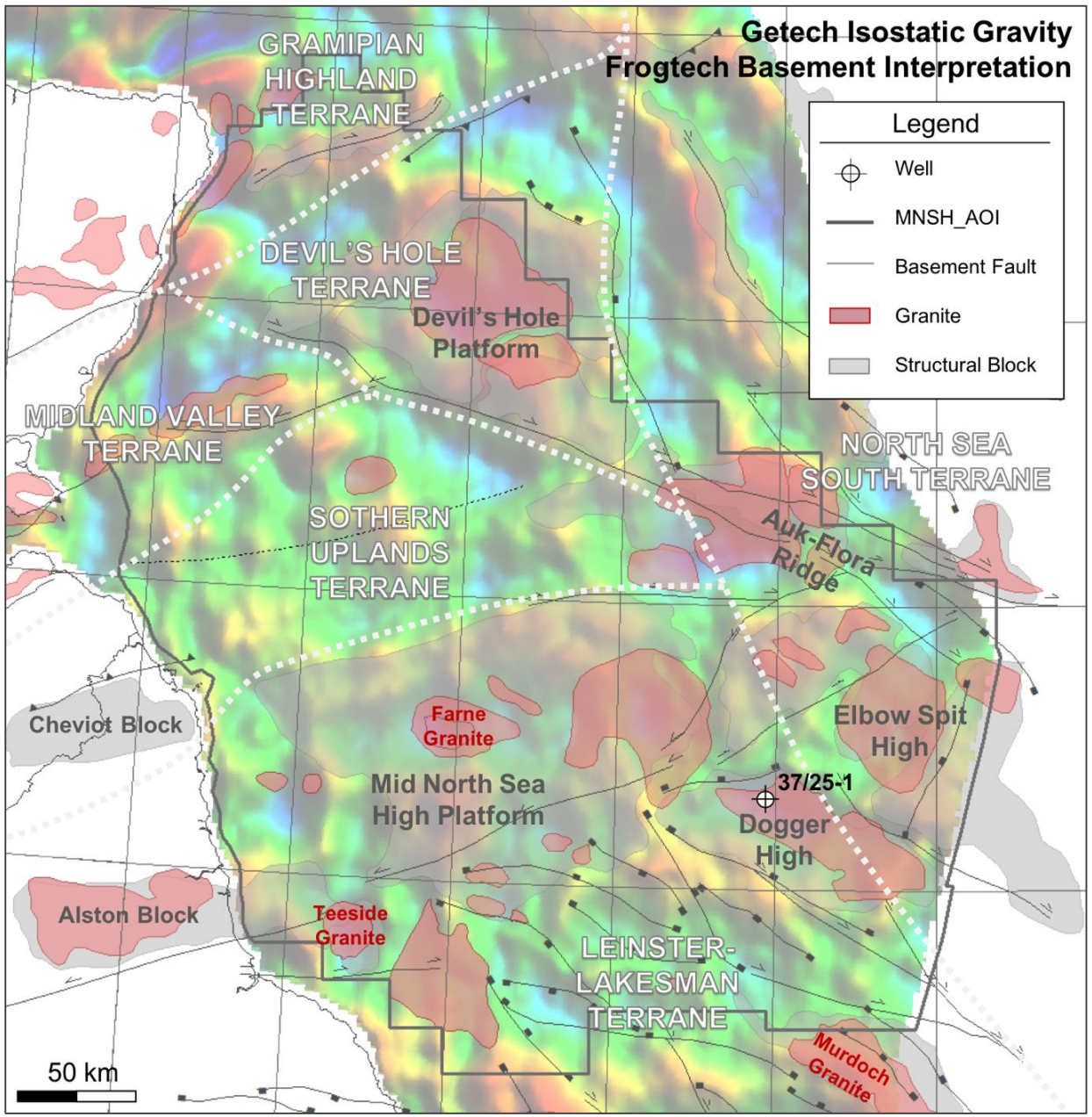










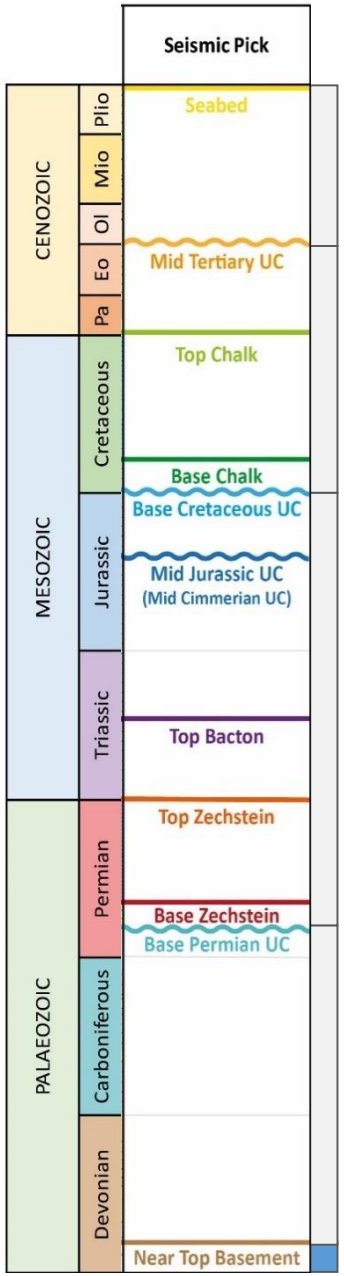


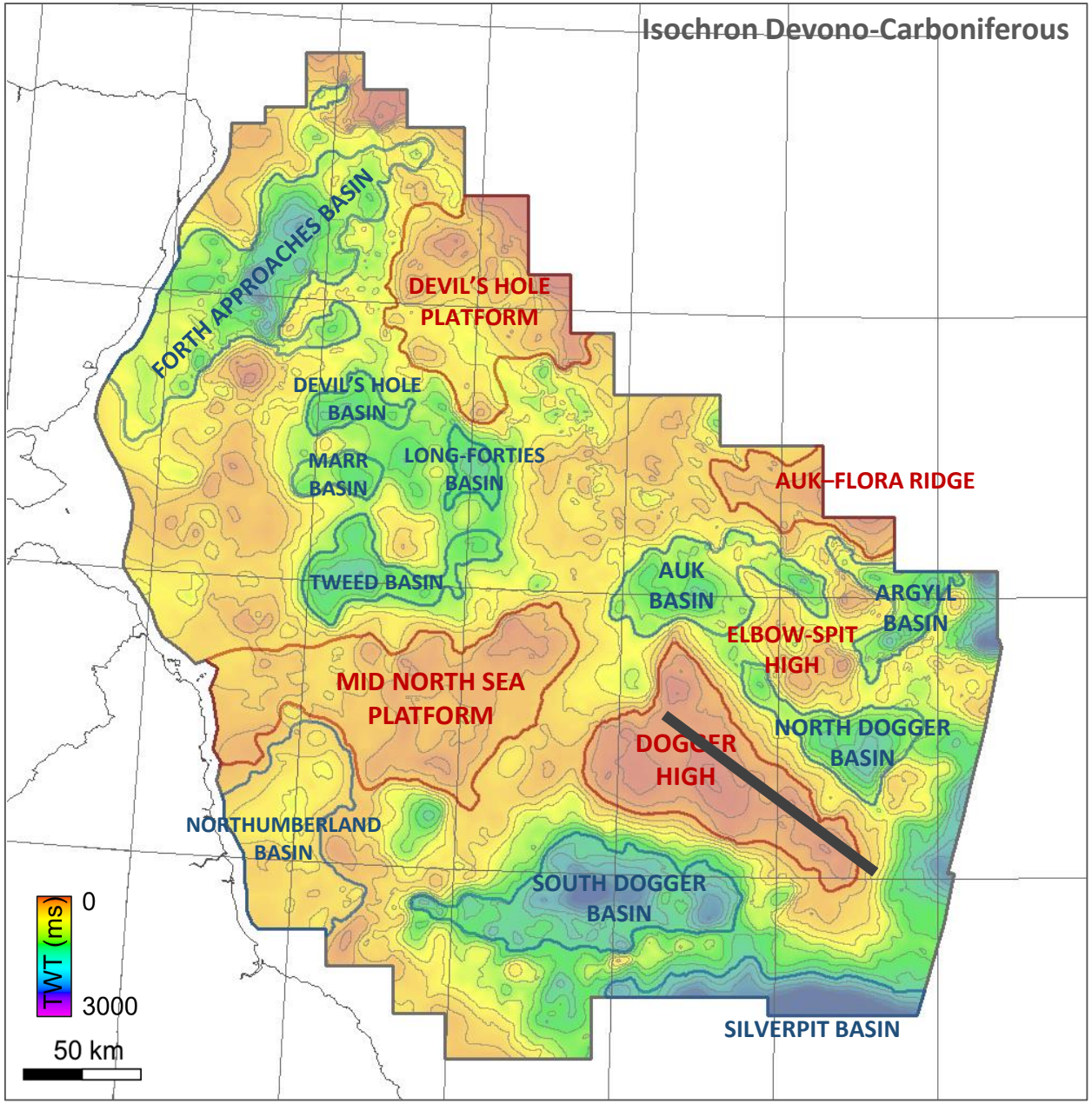
Basement

- Free Air Gravity data picks out granite features.
- Previous studies* have identified granite-cored Basement Highs and basement faults.
- Well 37/25- 1, drilled in 2009, encountered quartzite cuttings and a significant decrease in ROP as the drill string reached the basement.

** Previous Studies*

- *BGS 21st Century Roadmap*
- *Frogtech SEEBASE Study*



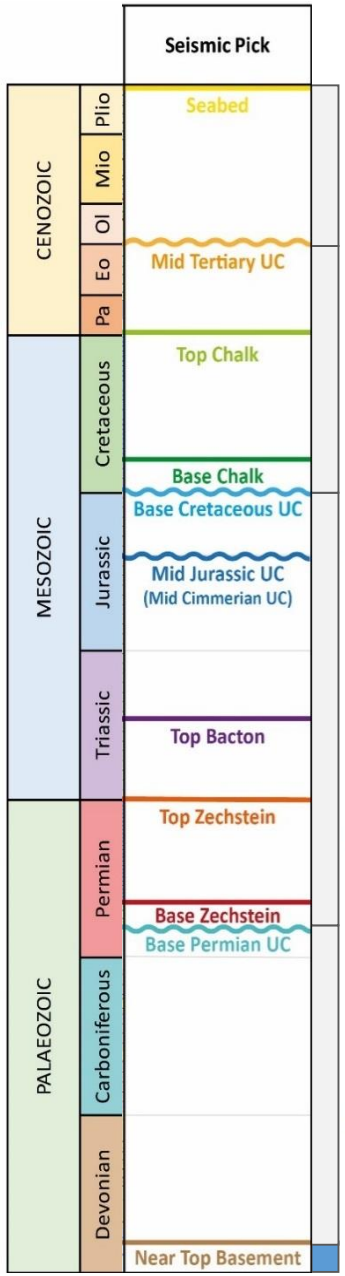


Basement

- Free Air Gravity data picks out granite features.
- Previous studies* have identified granite-cored Basement Highs and basement faults.
- Well 37/25- 1, drilled in 2009, encountered quartzite cuttings and a significant decrease in ROP as the drill string reached the basement.
- Fairly consistent with the interpretation in this study.

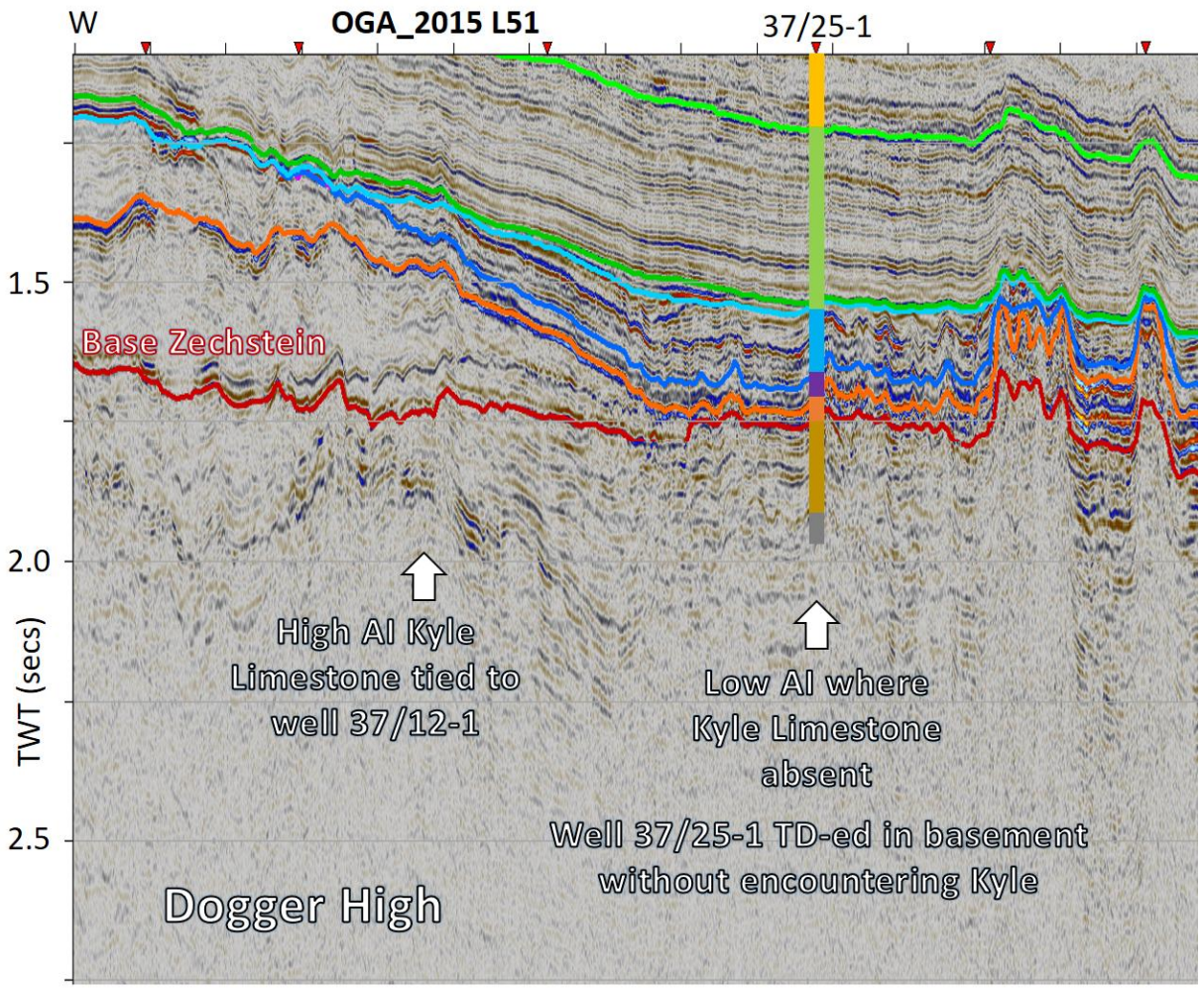
** Previous Studies*

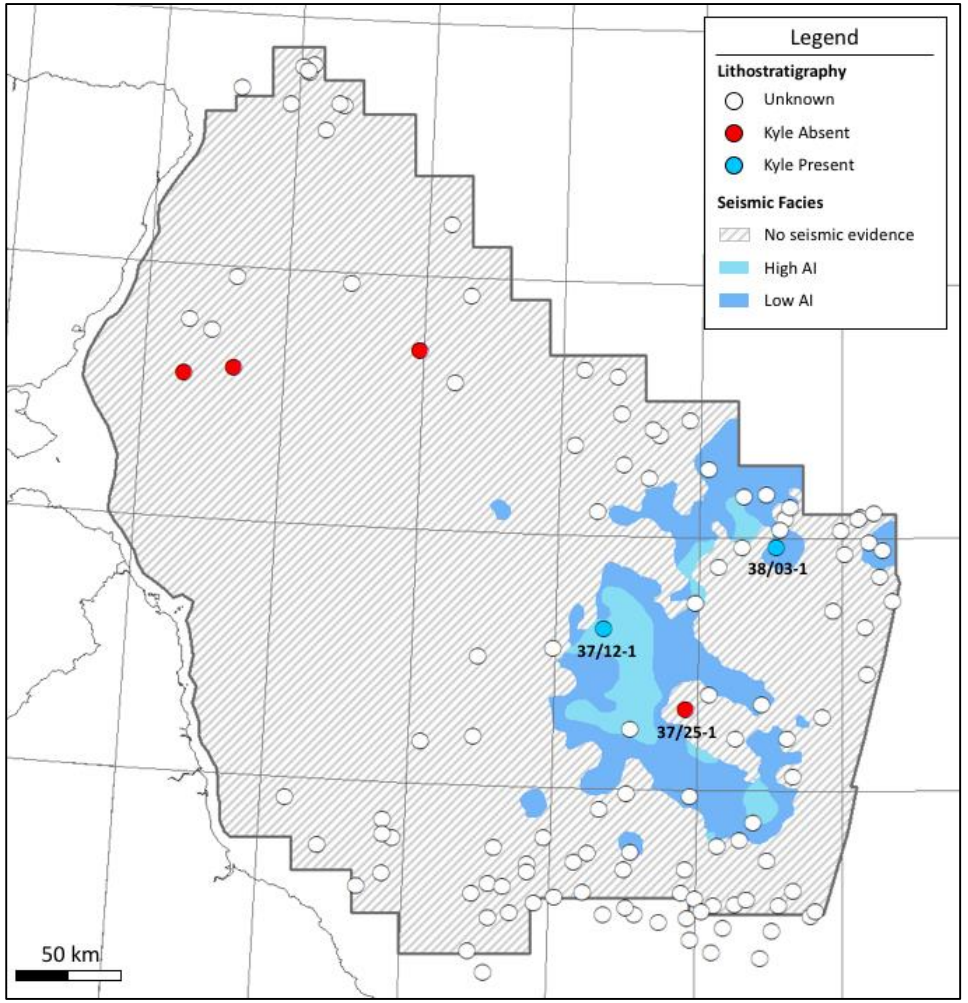
- *BGS 21st Century Roadmap*
- *Frogtech SEEBASE Study*

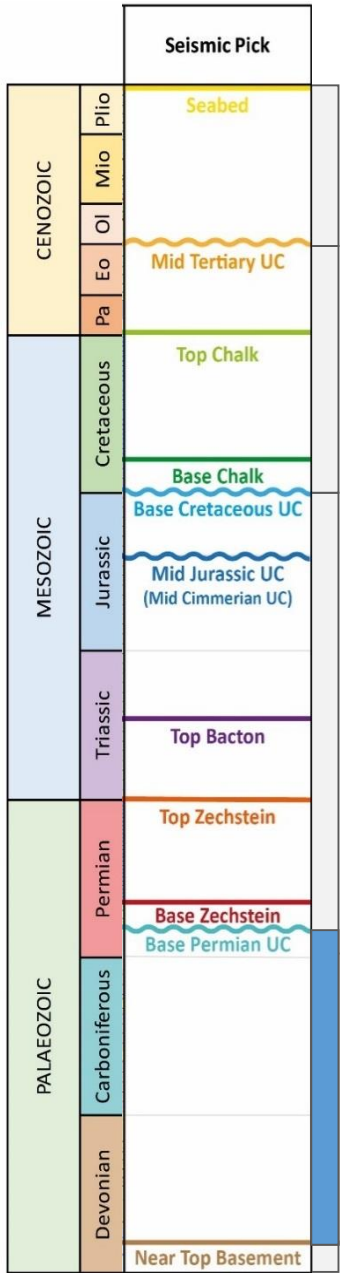


Devonian Kyle Limestone

- Devonian Kyle Limestone locally imaged on basement highs.
- Seismic Facies mapping indicates Structural Highs in the Devonian.

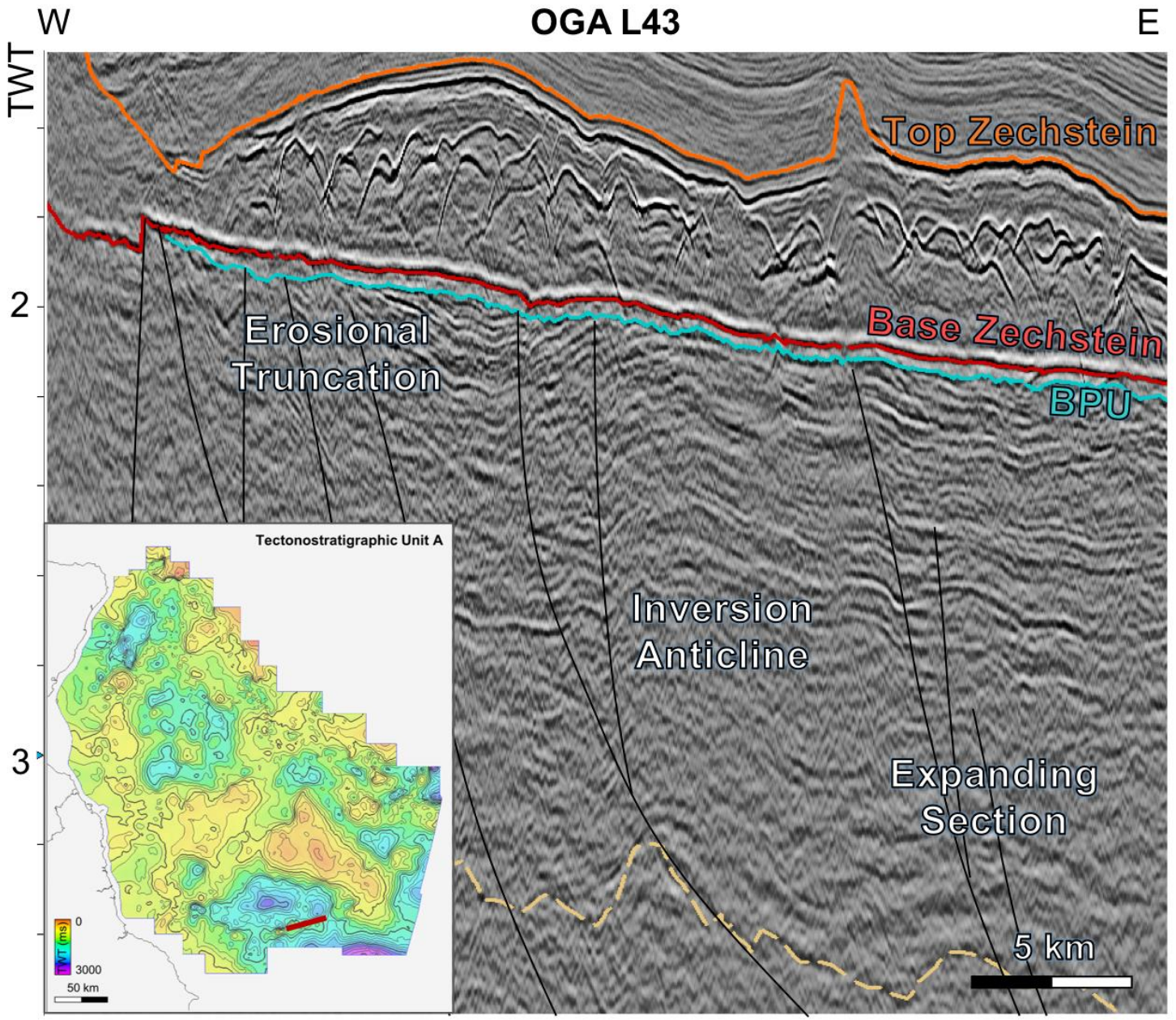


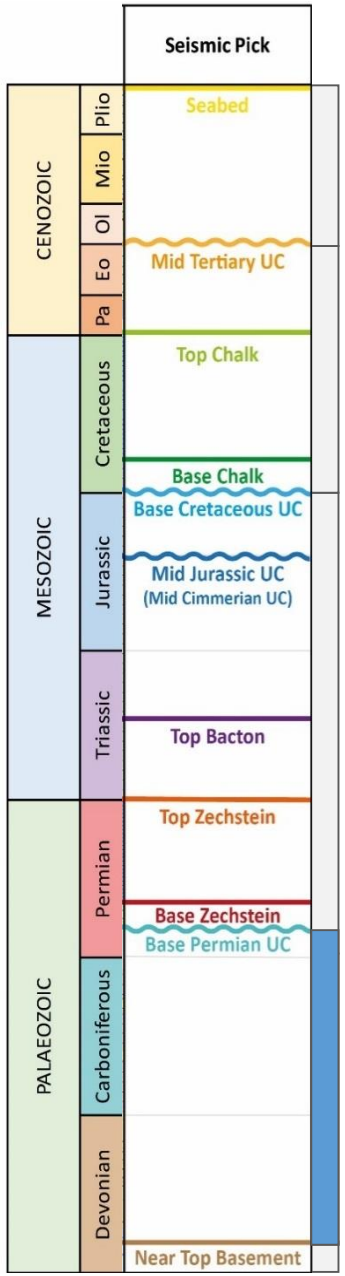




Devono-Carboniferous

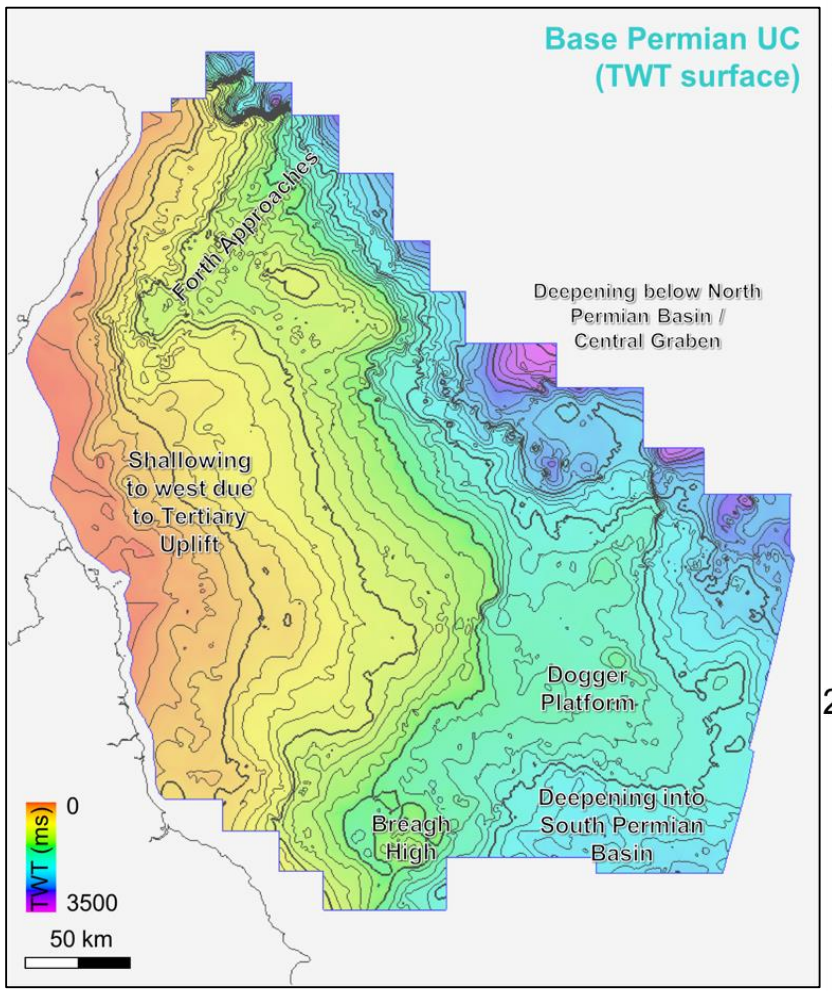
- Complex series of depocentres and highs.
- Evidence for multiple extensional and inversion events.
- Imaging is the key challenge.

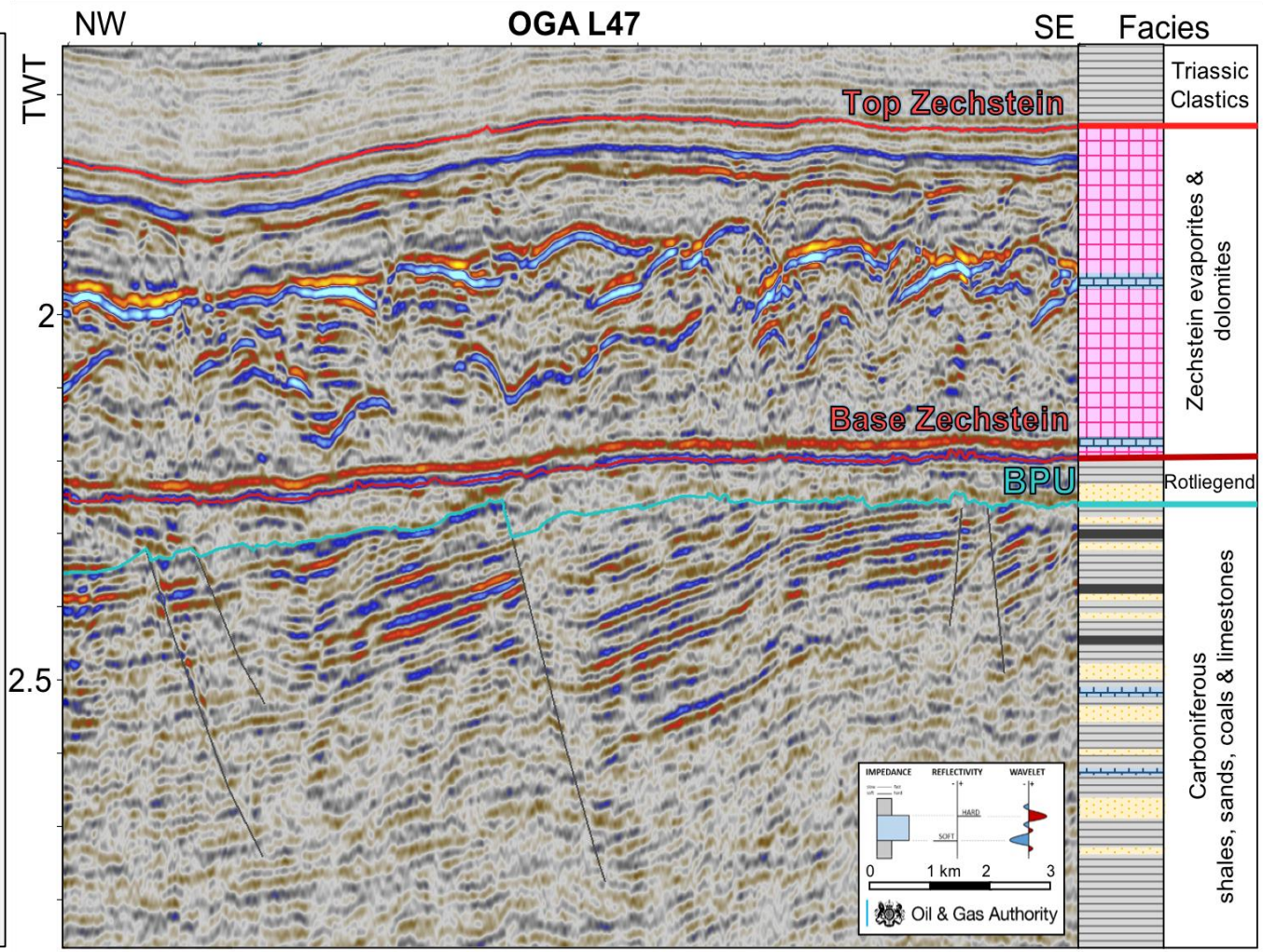




Base Permian Unconformity

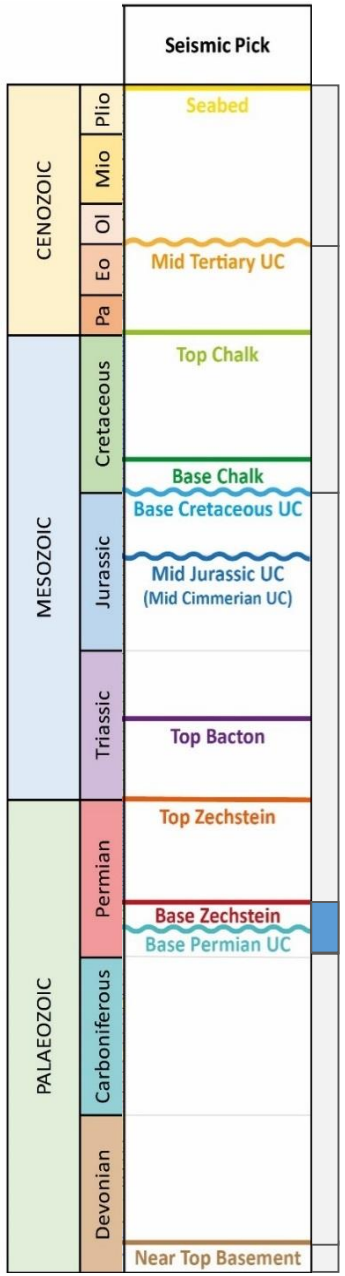
- Formed by the Variscan Orogeny.
- Extensive erosion across the Mid North Sea High.

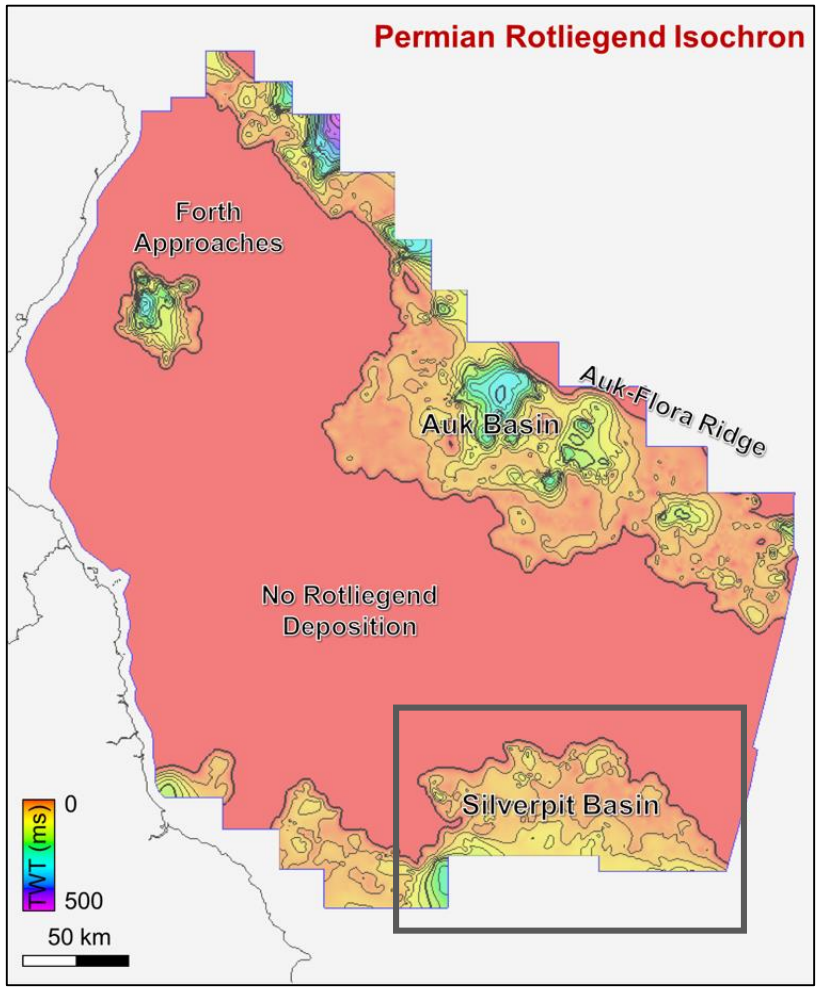


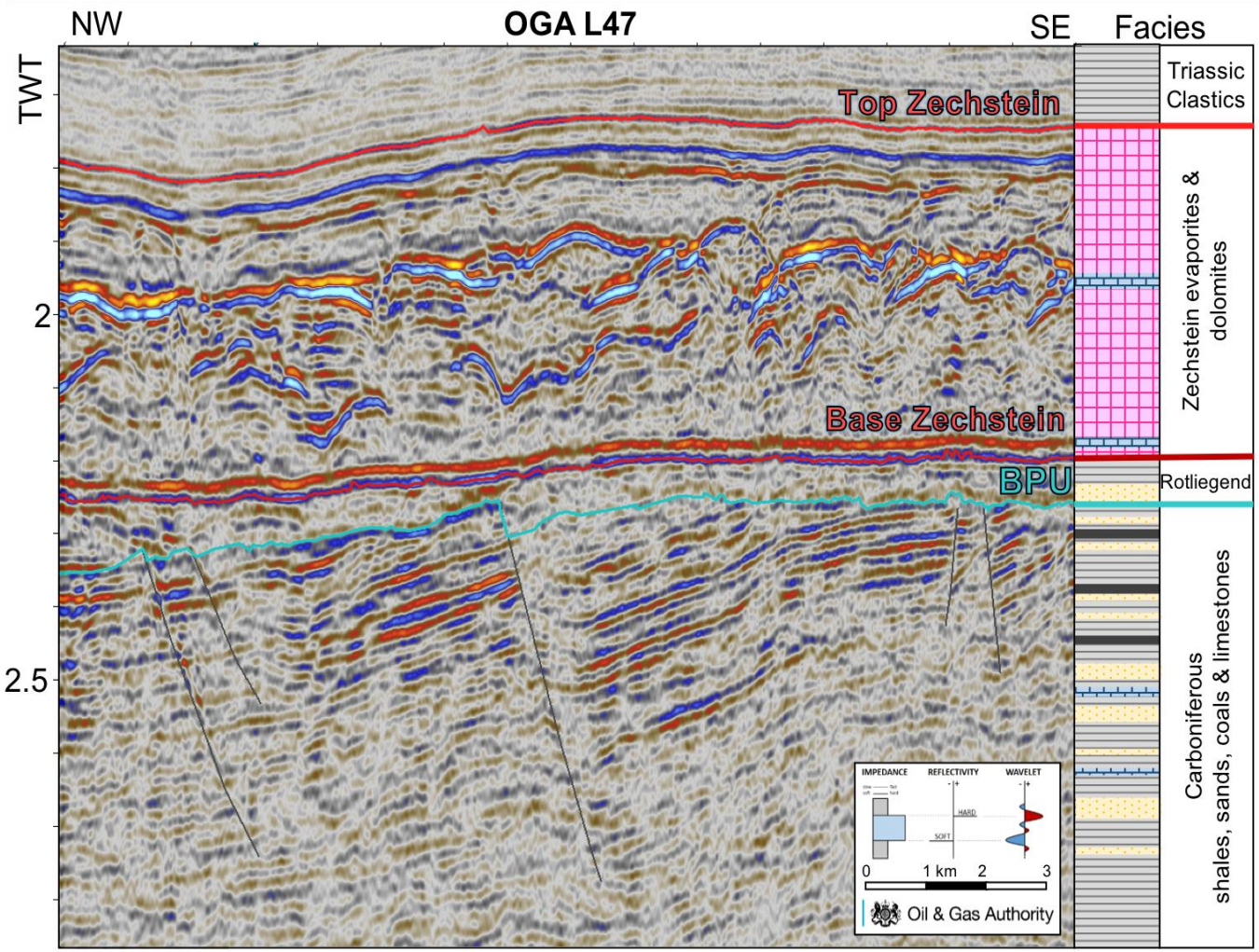


Permian: Rotliegend

- New Rotliegend play fairway opened up with the discovery of **Cygnus.**
- **Leman Sandstone** Reservoir pinches out onto the MNSH.
- Proven play also across the North of the MNSH (**Auk Field**).

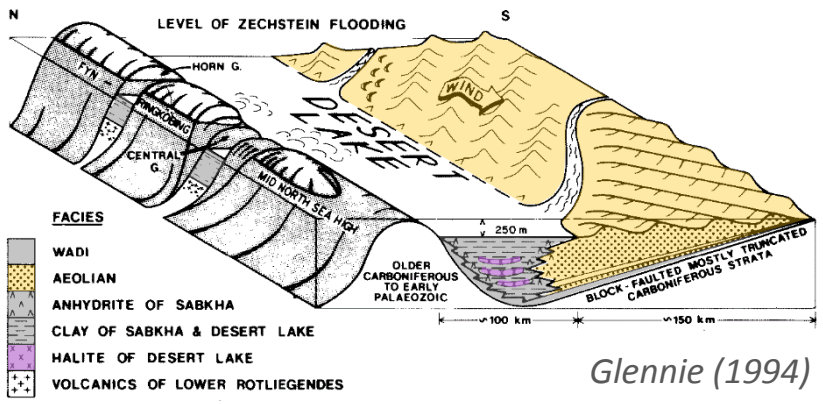




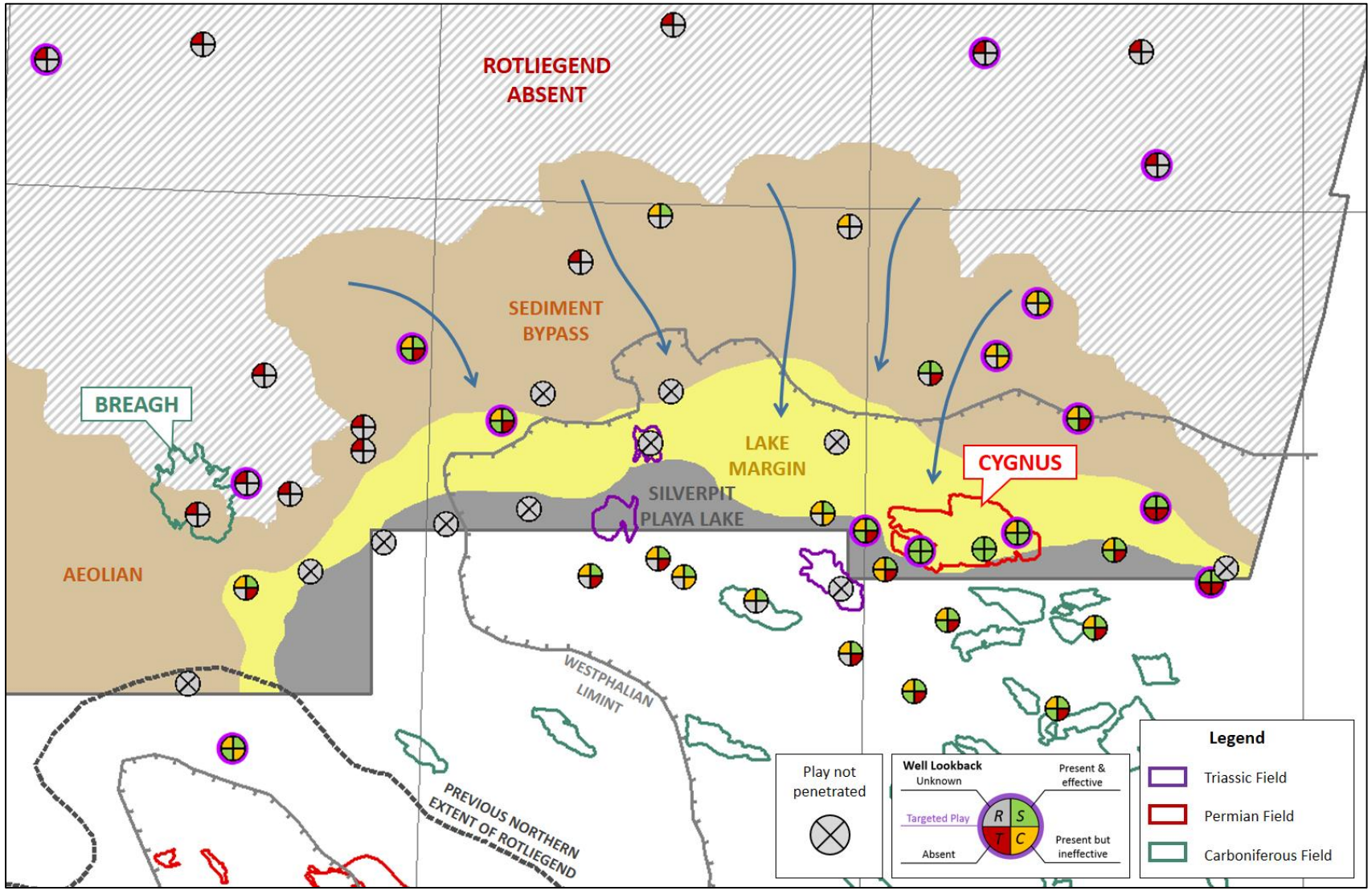


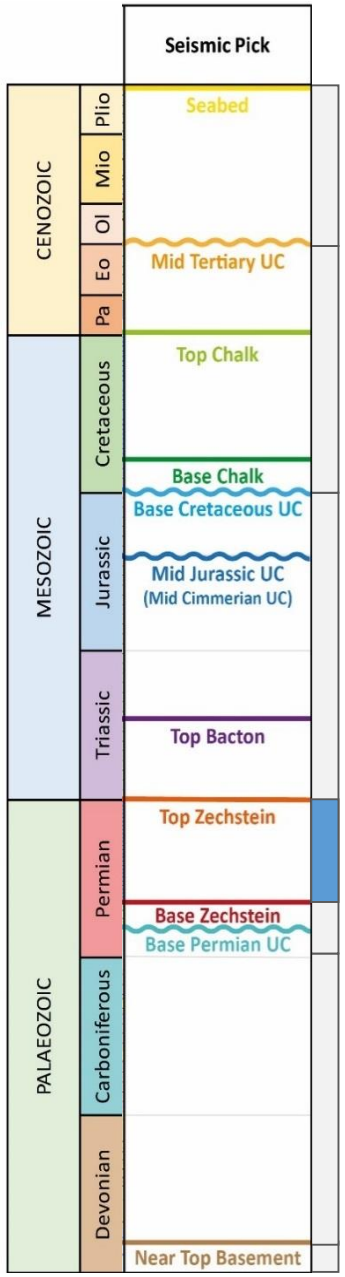
Permian: Rotliegend

- 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.



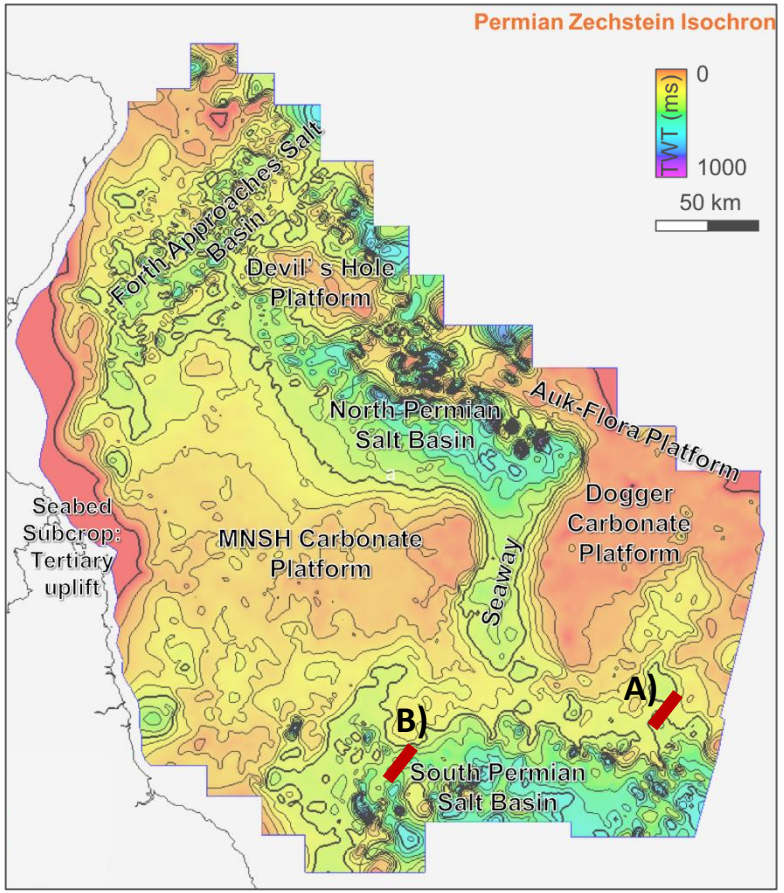
Glennie (1994)

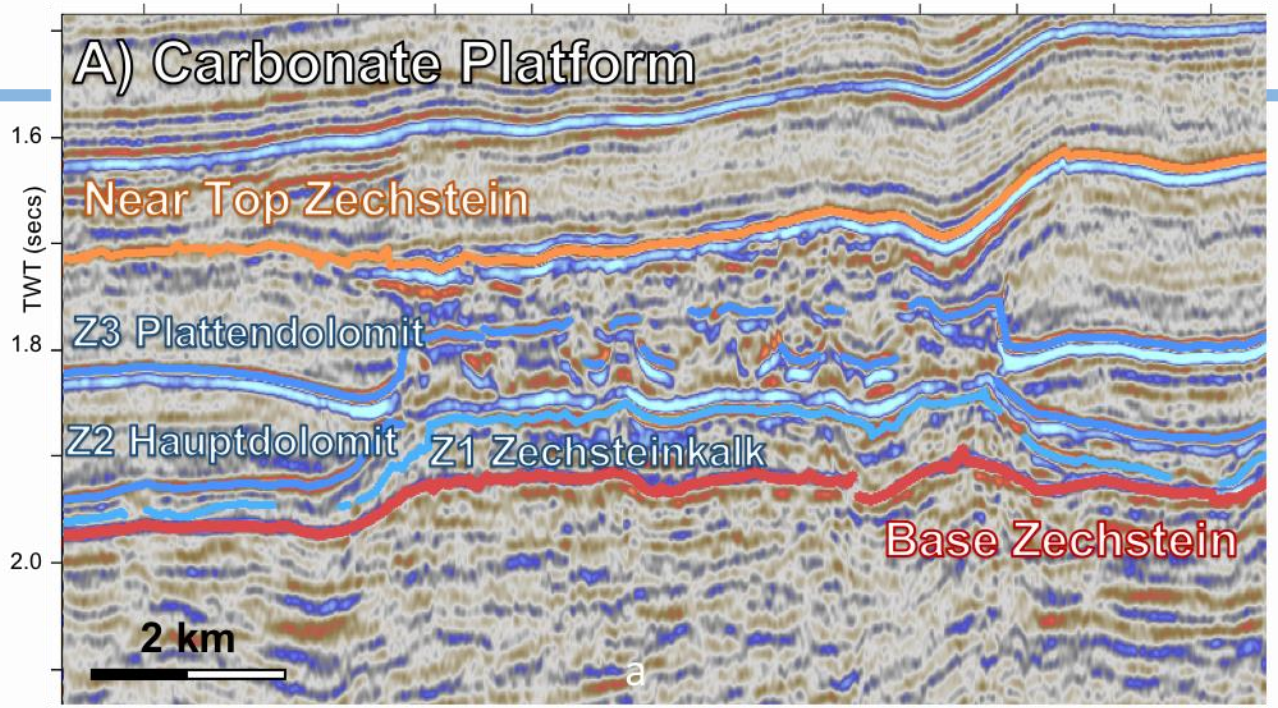


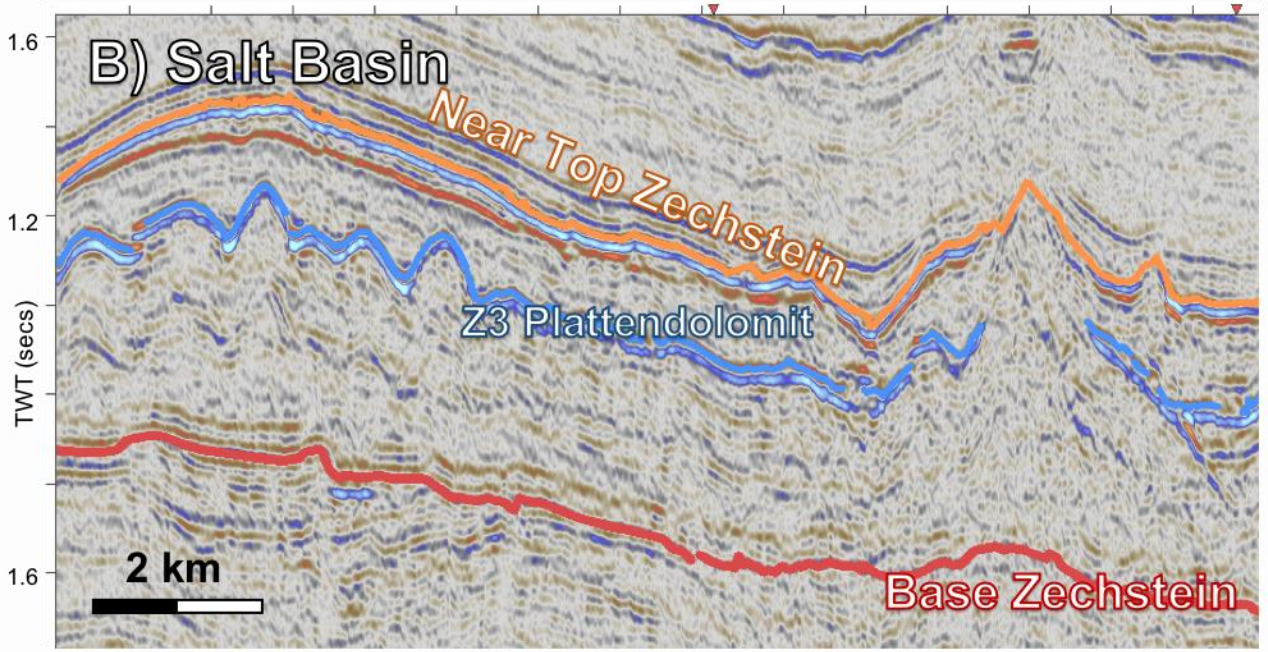


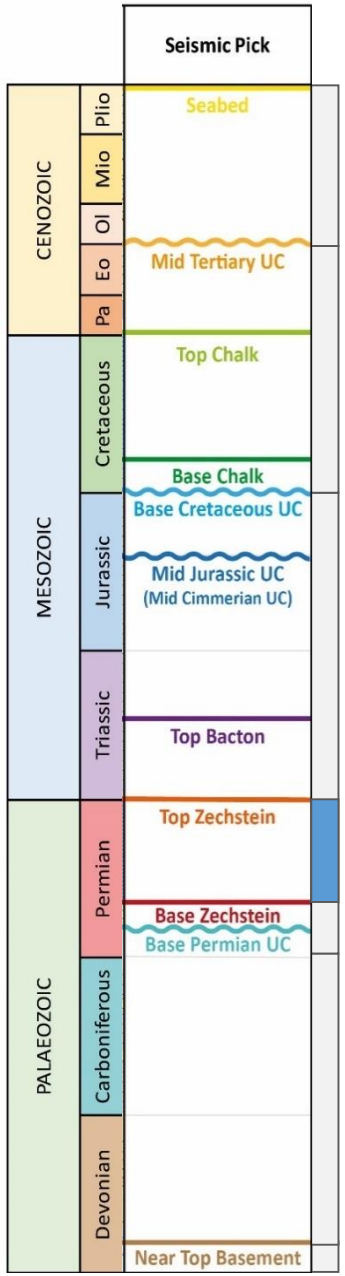
Permian: Zechstein

- Zechstein formed through repeated flooding and desiccation events
- Seismofacies show carbonate & evaporite deposition and subsequent halokinesis.



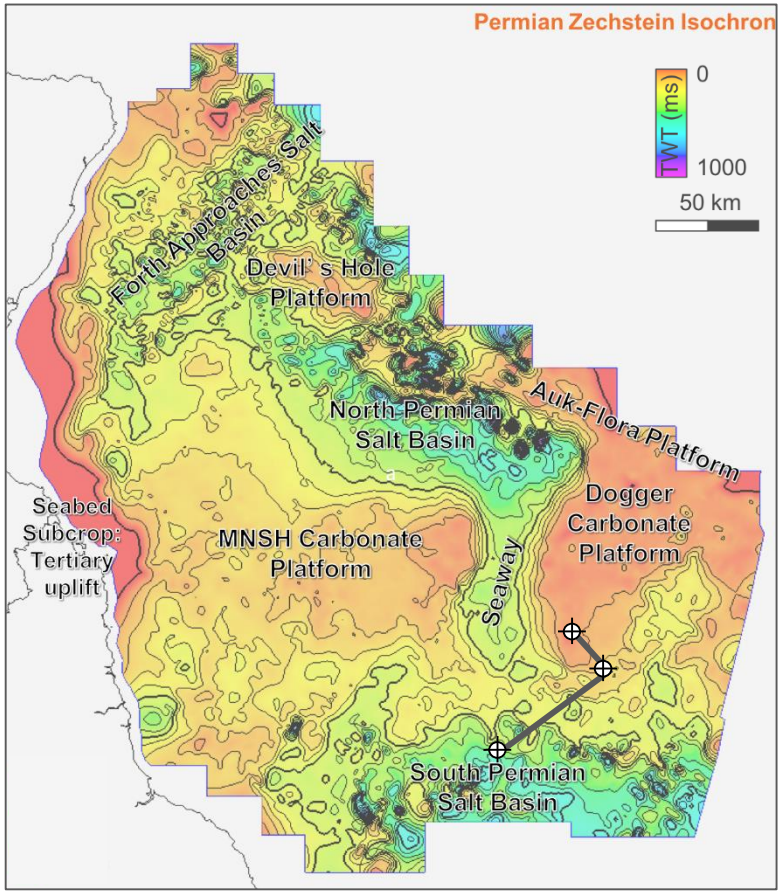


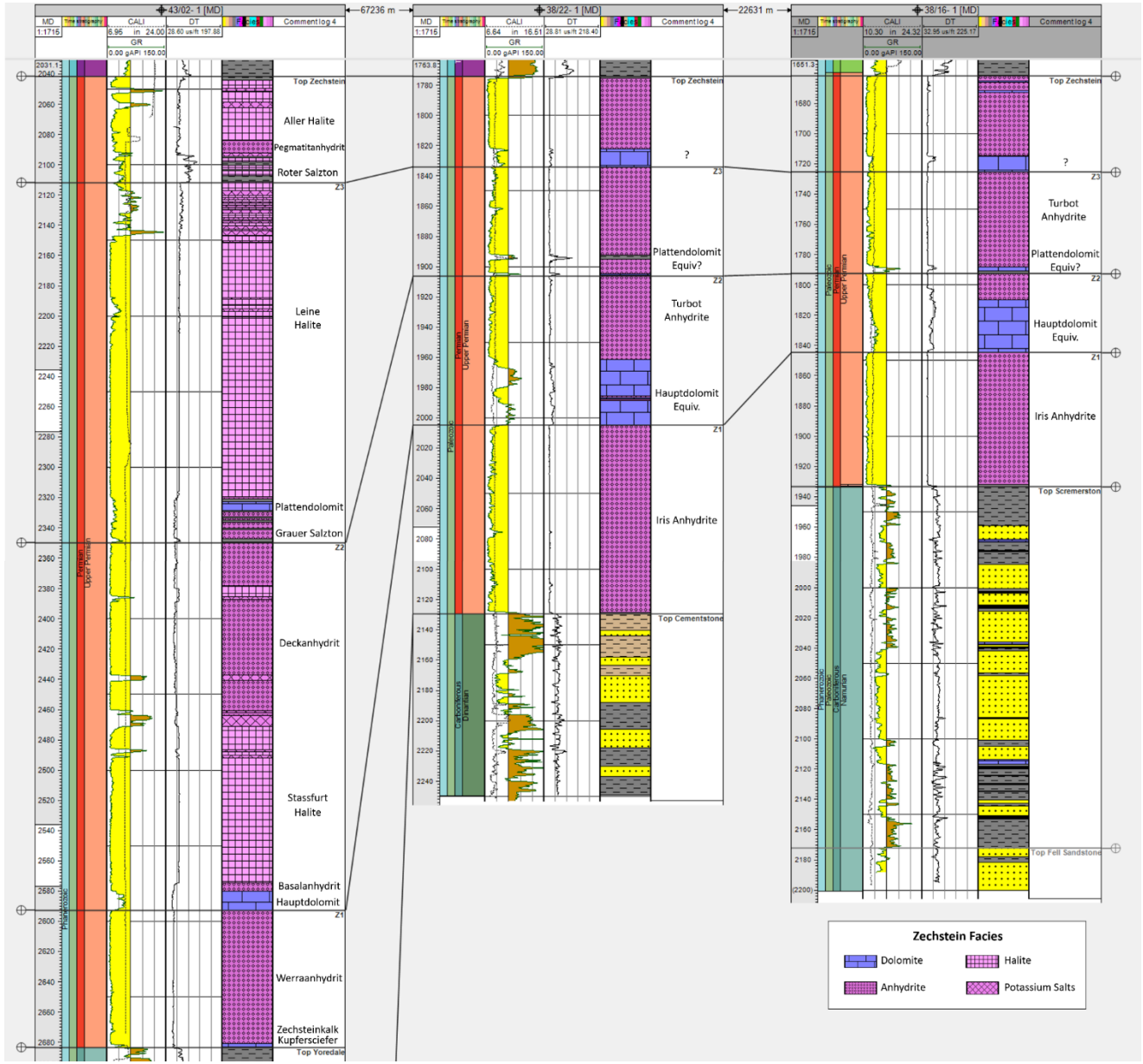


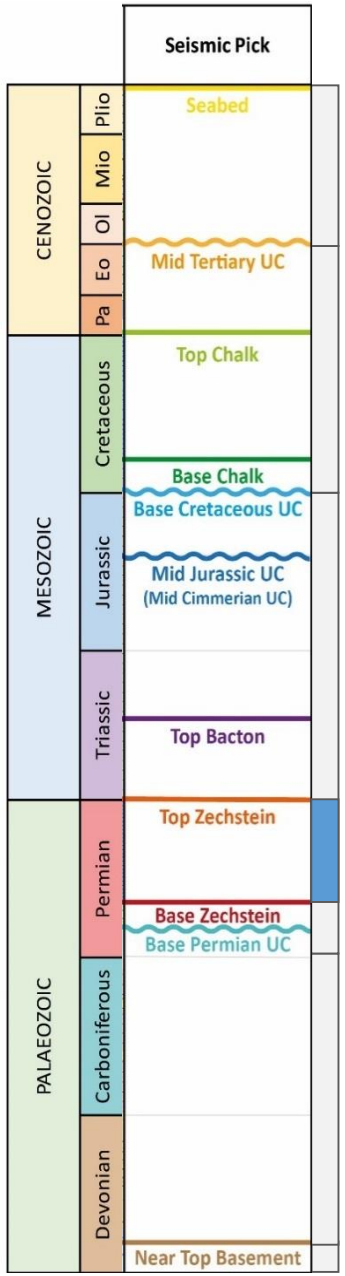


Permian

- Well data shows **anhydrite & dolomite** are deposited across the MNSH, with **halite** dominating the North and South Permian, and Forth Approaches Basin.

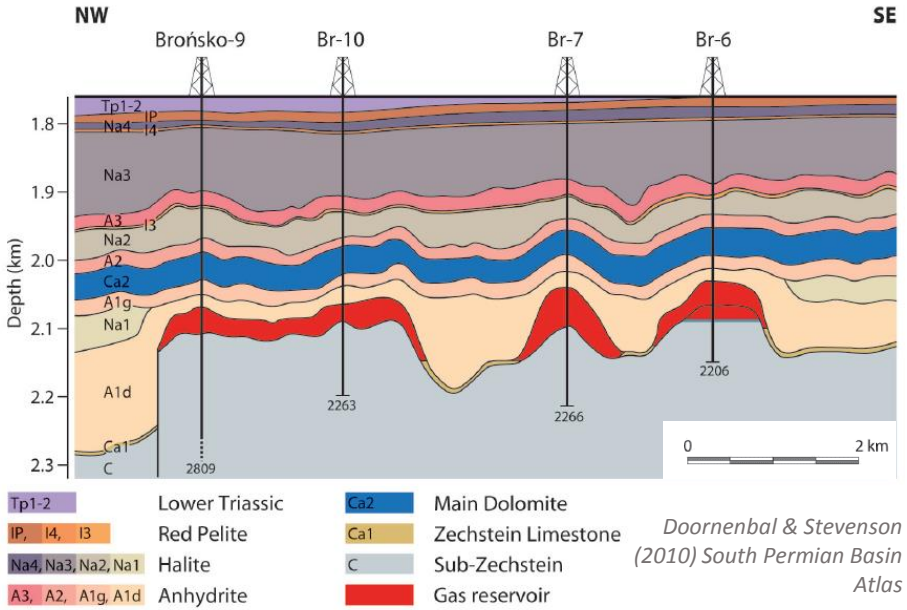




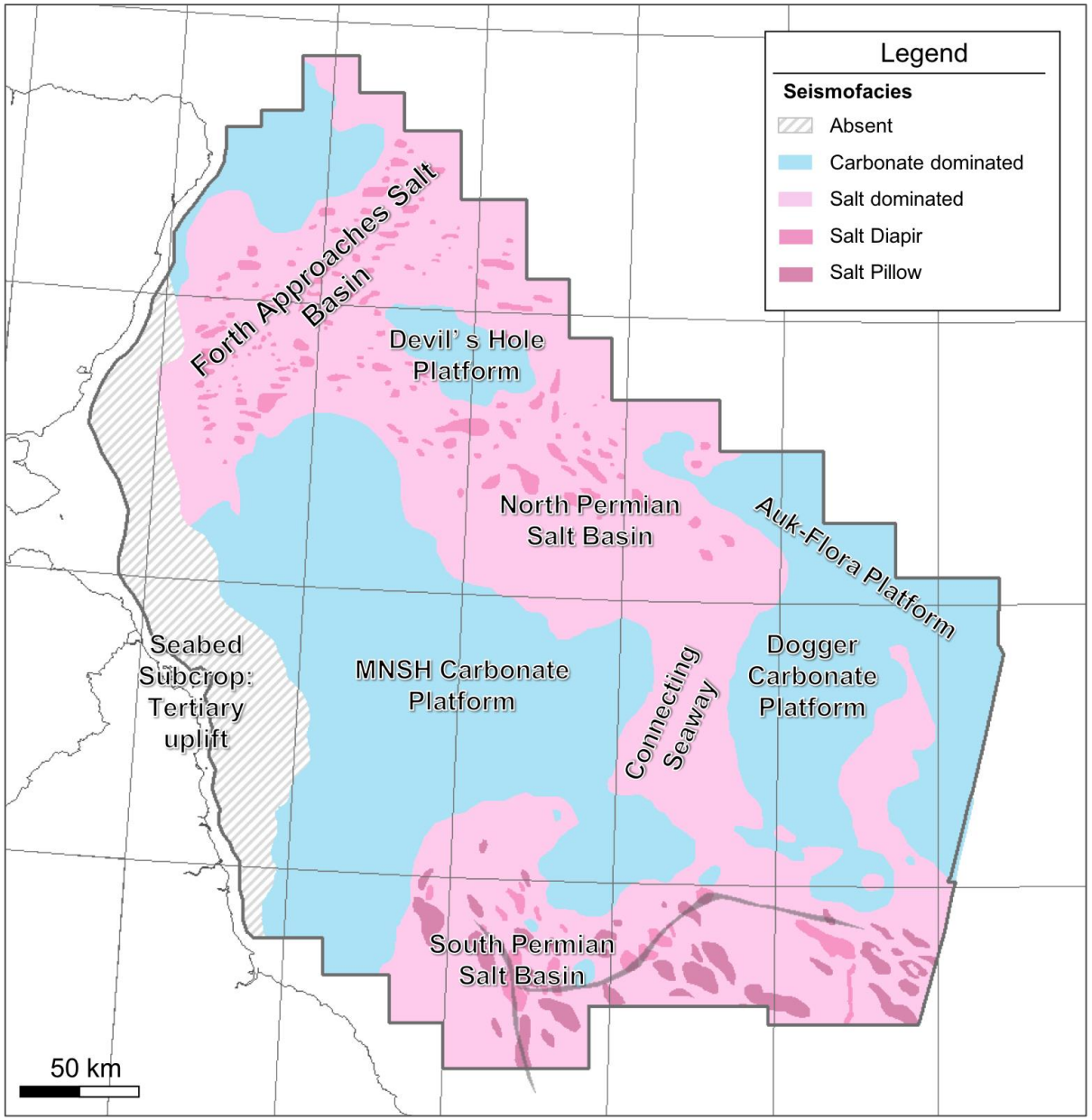


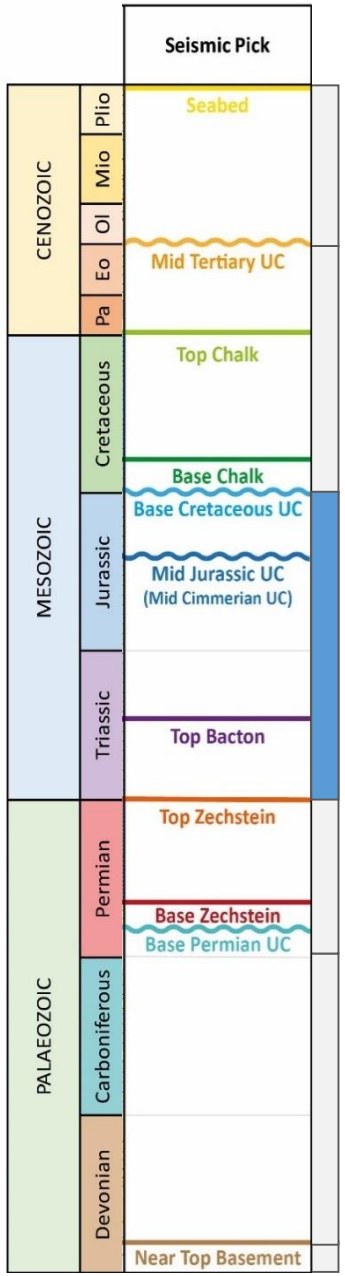
Permian

- Resulting facies map shows areas of carbonate deposition.
- Dolomite forms a potential reservoir.
- The South Permian Basin extends from UK to onshore Poland where analogues prove Zechstein reservoir potential in the Bronsko and Koscian Fields.



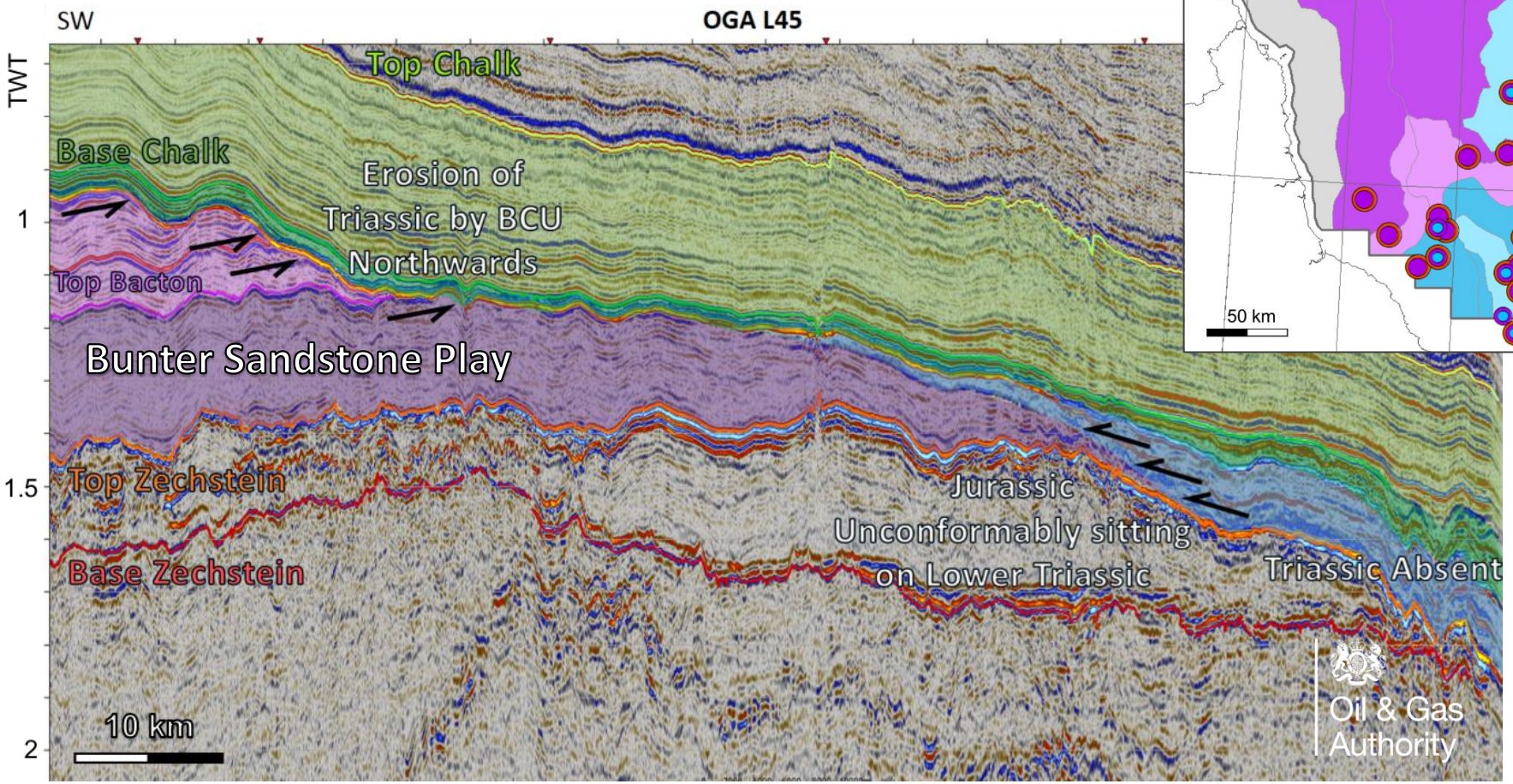
Doornenbal & Stevenson (2010) South Permian Basin Atlas

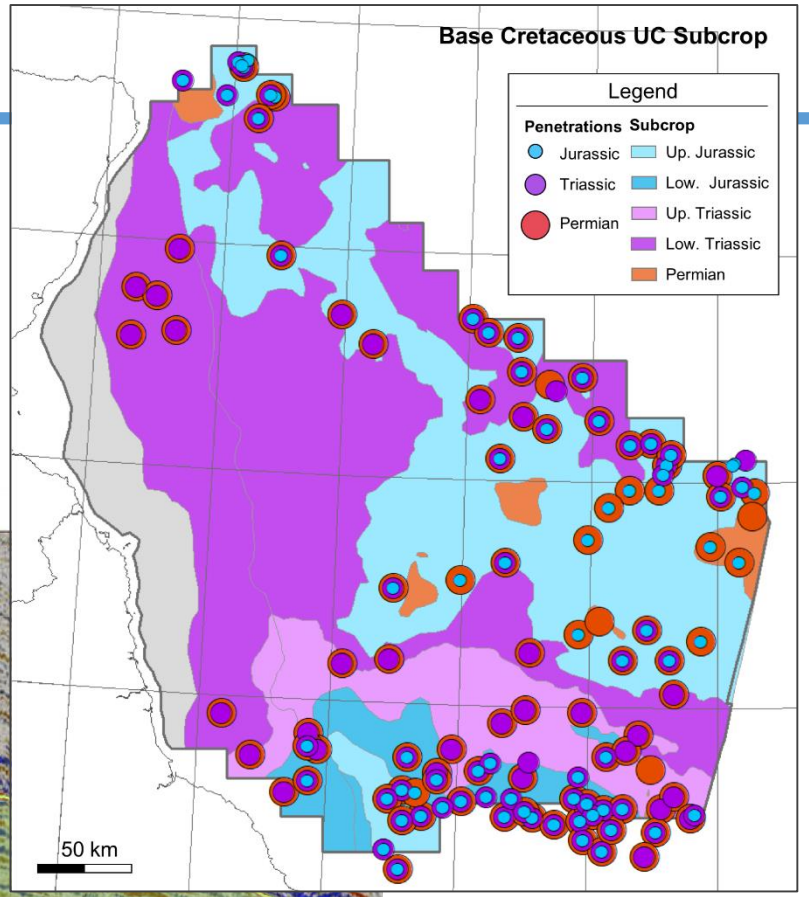


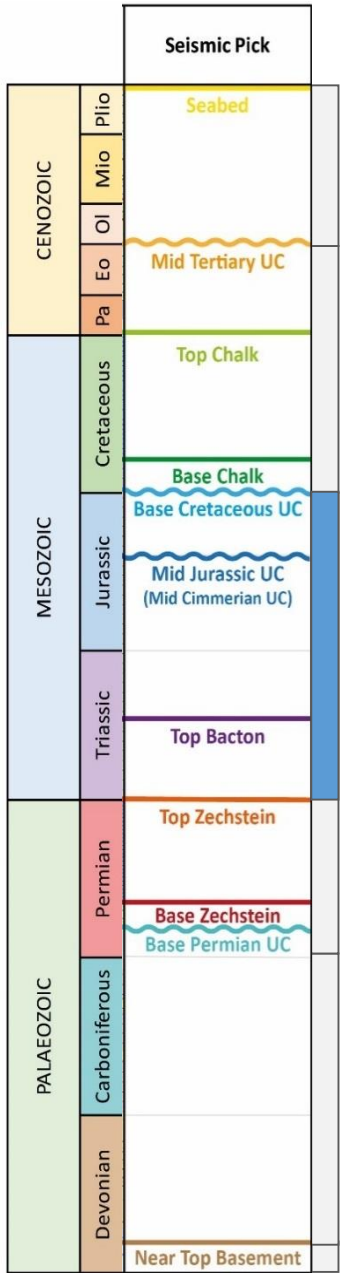


Mesozoic

- To the North, there is interaction between the Mid Jurassic and Base Cretaceous Unconformities.
- This generates a complex Base Cretaceous Subcrop.

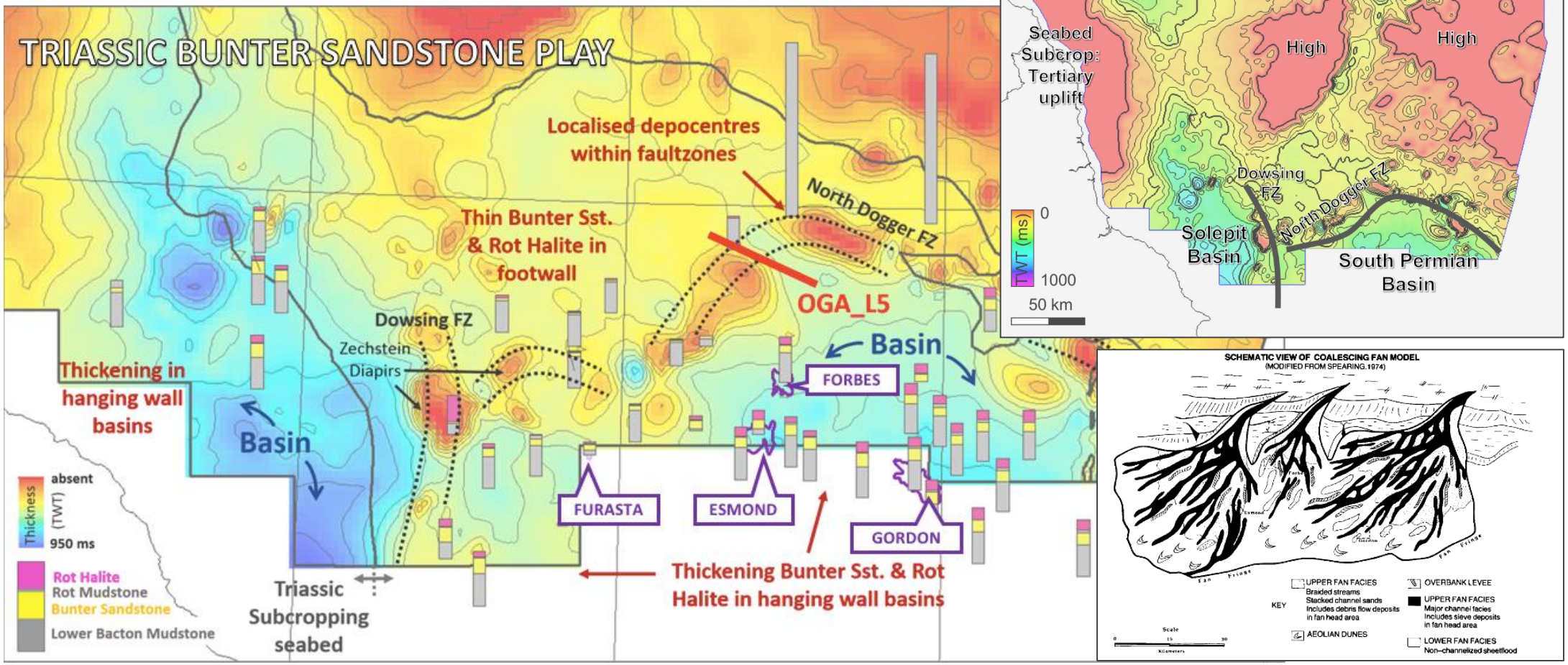


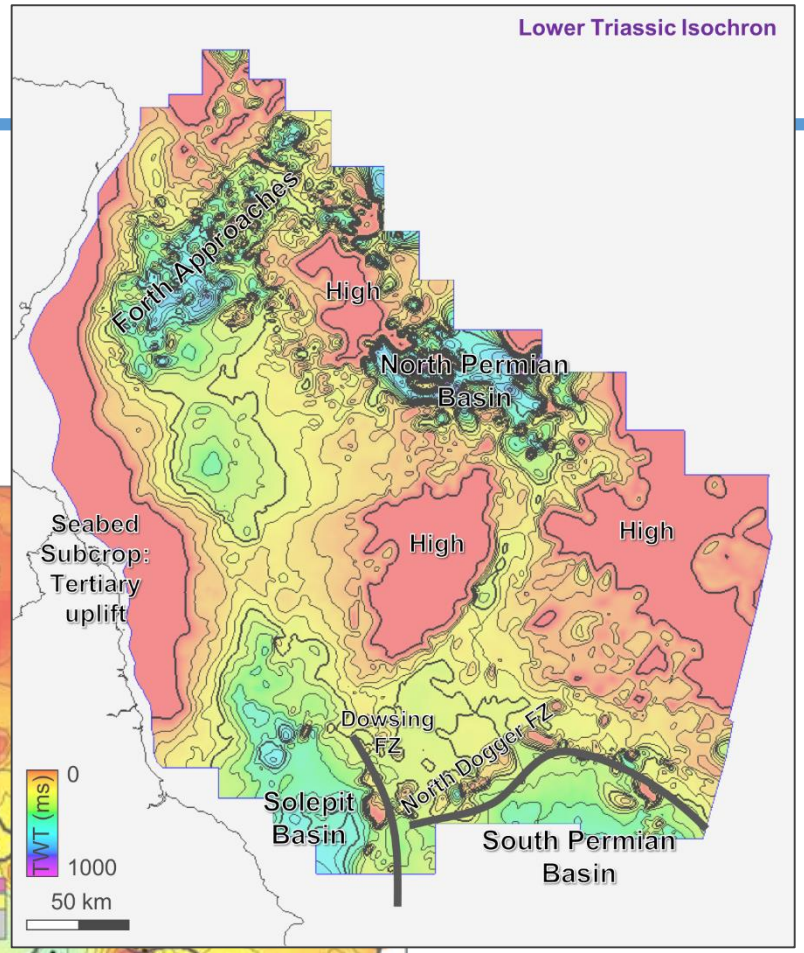


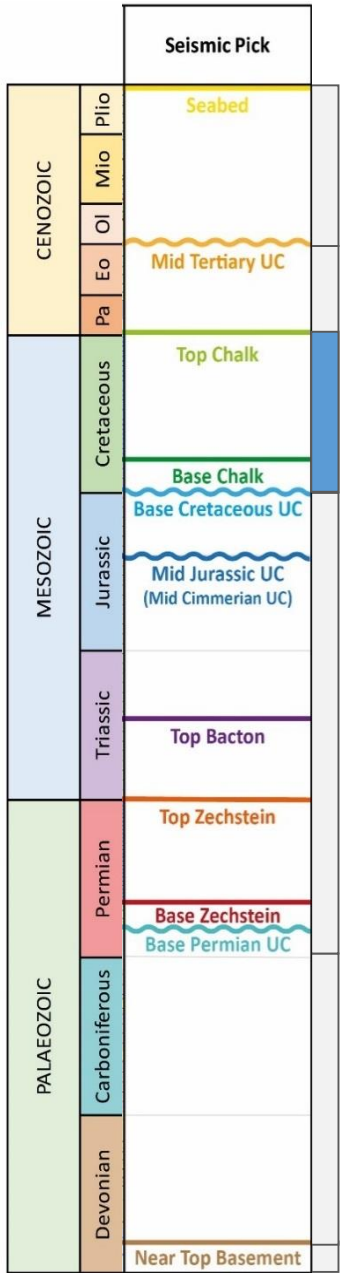


Mesozoic

- Lower Triassic Deposition is controlled by Zechstein halokinesis in the North Permian and Forth Approaches Basins.
- The Dowsing & North Dogger Fault Zones define the Triassic Play Fairway in the South

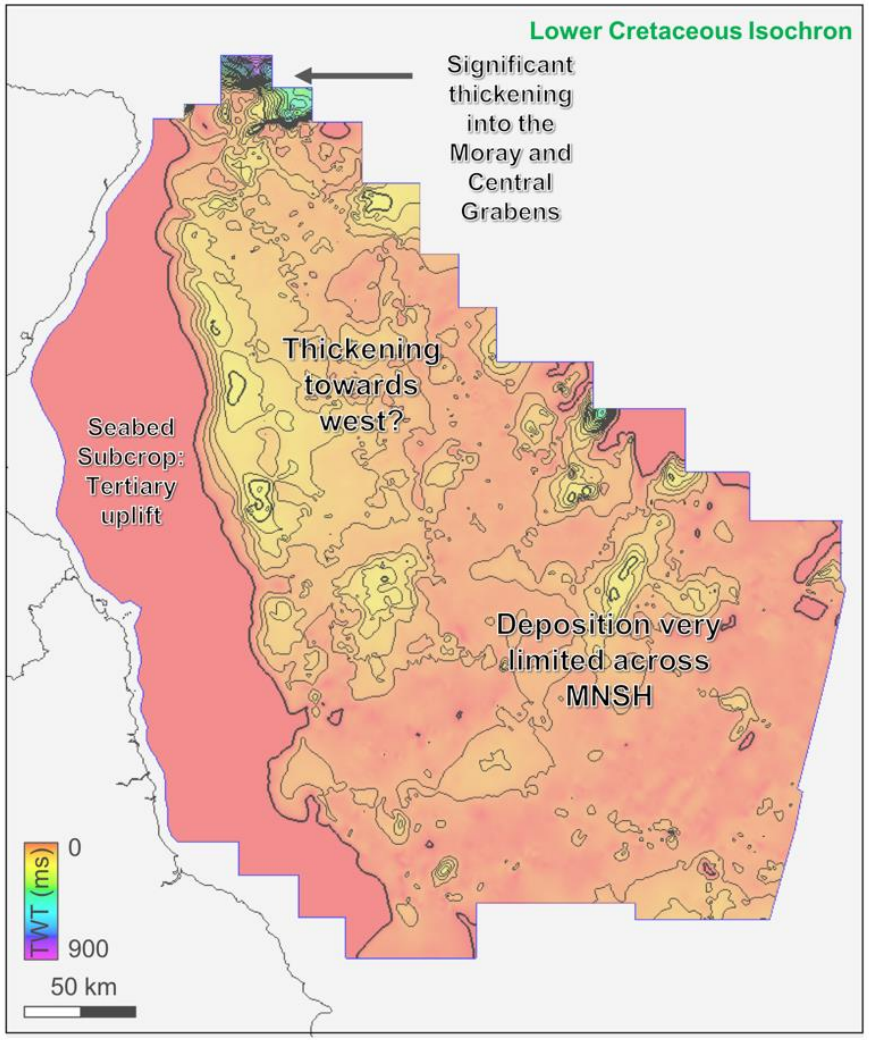


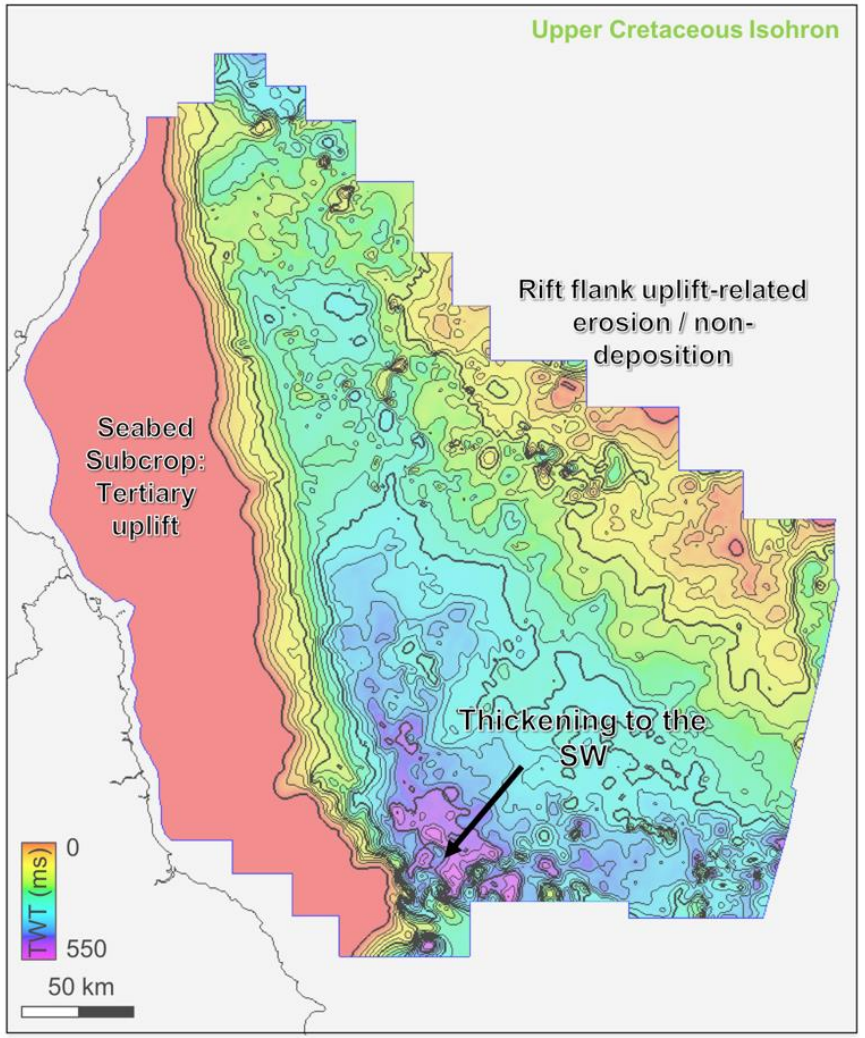


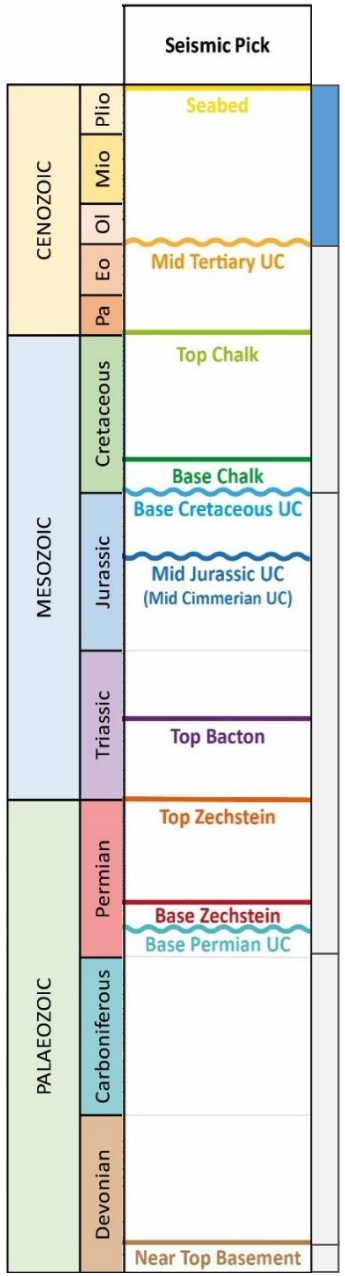


Cretaceous

- Relatively quiet time in the evolution of the region.

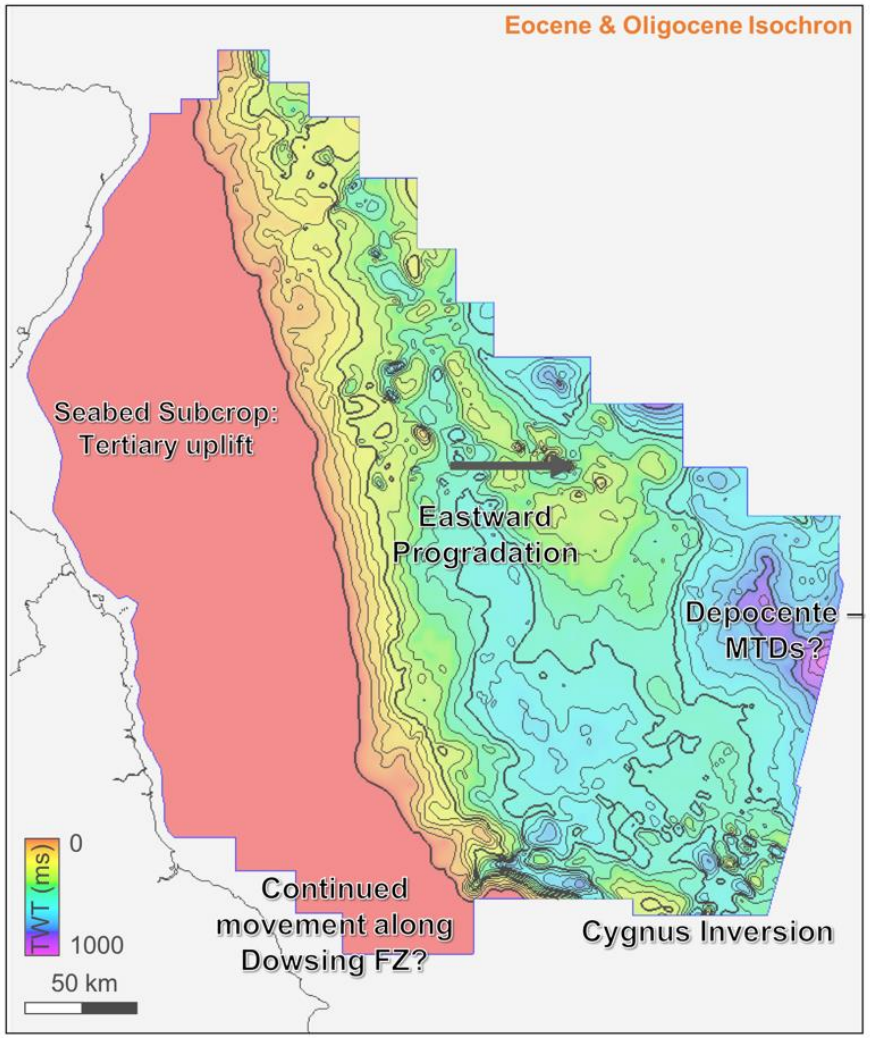


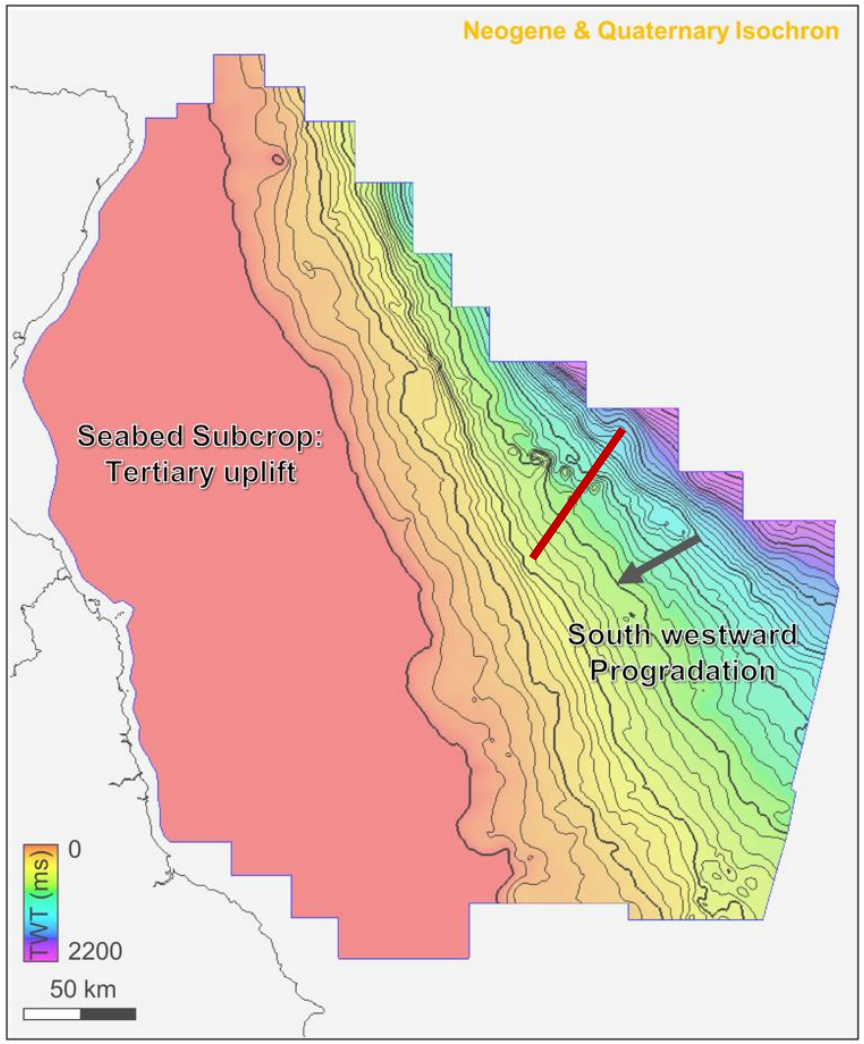


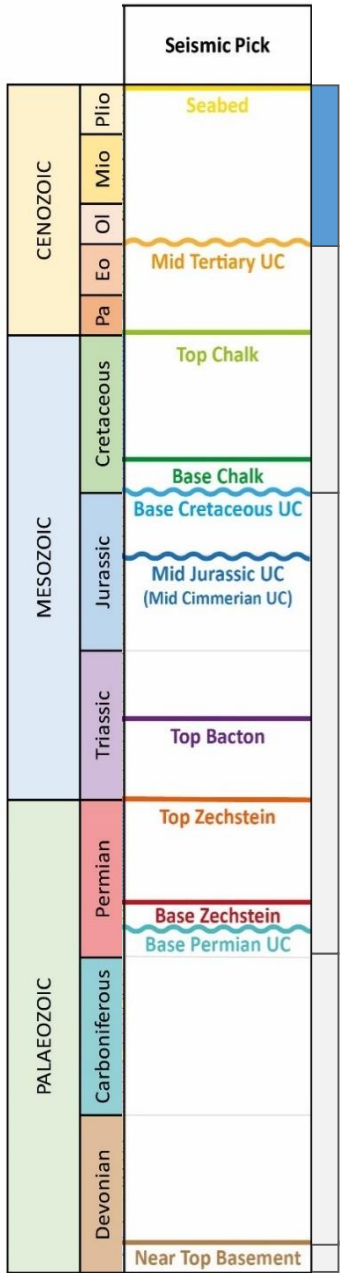


Mid-Tertiary- Recent

- Challenging to date the Mid Tertiary UC accurately: very few well tops.
- Significant Mid Tertiary tectonic reorganisation of the region.







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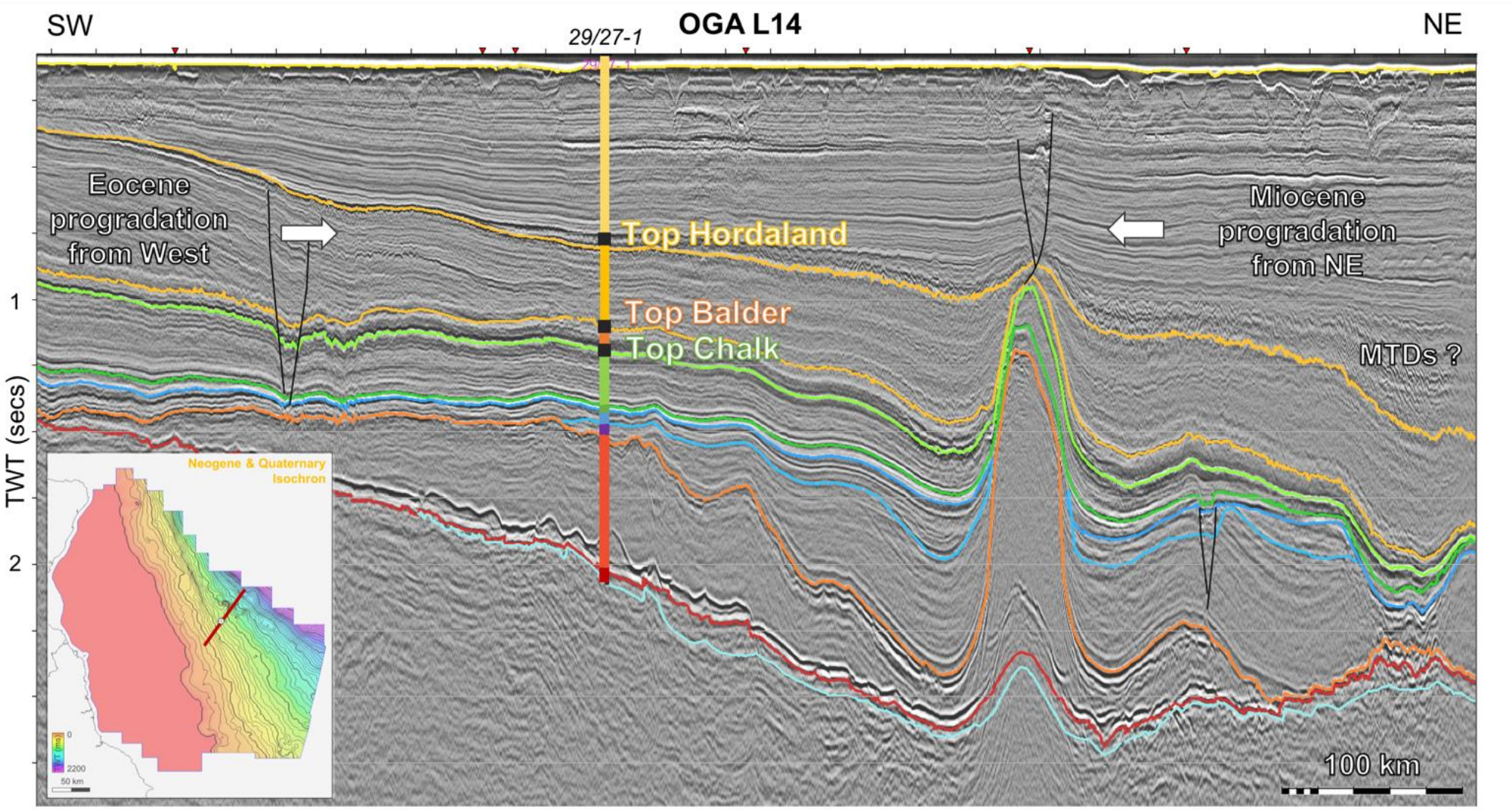
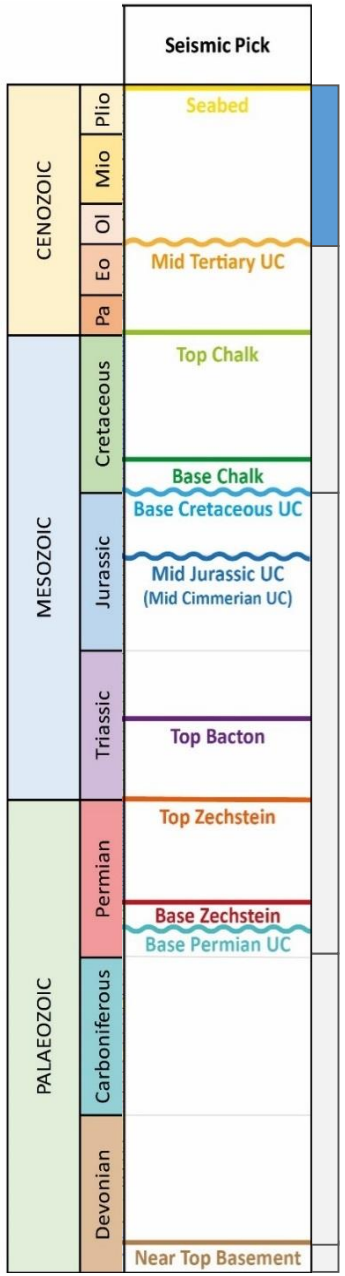
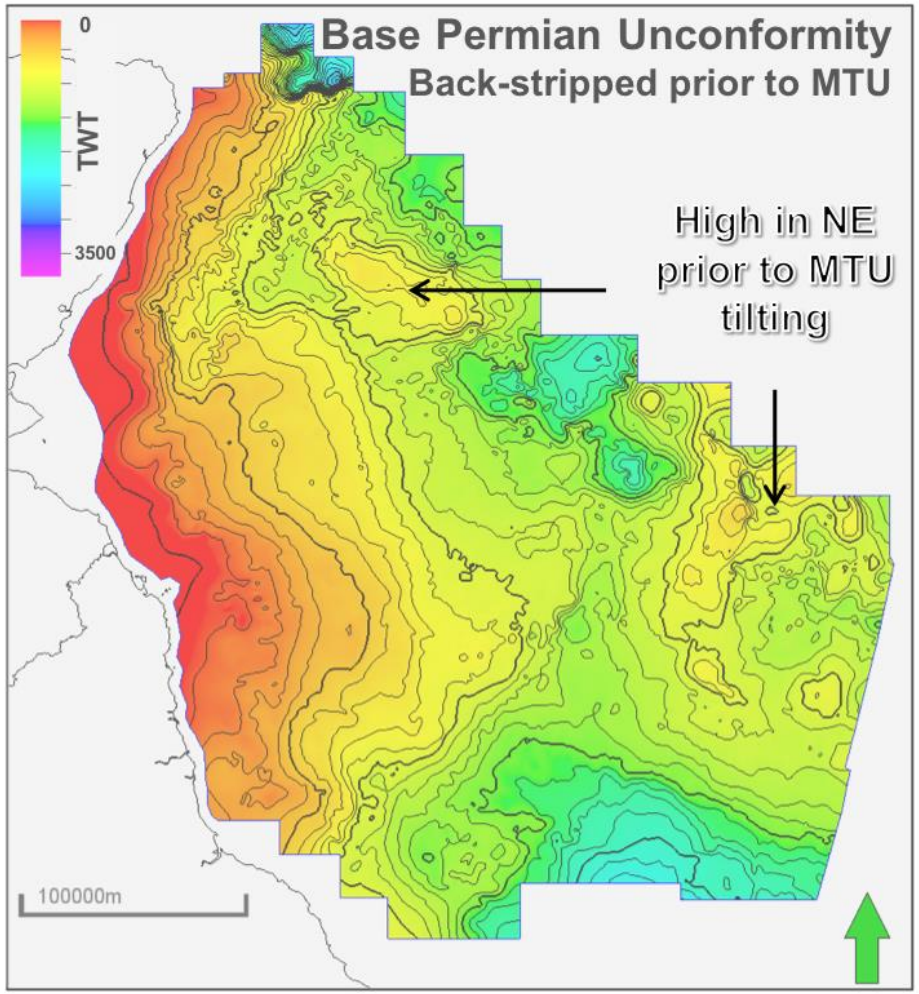


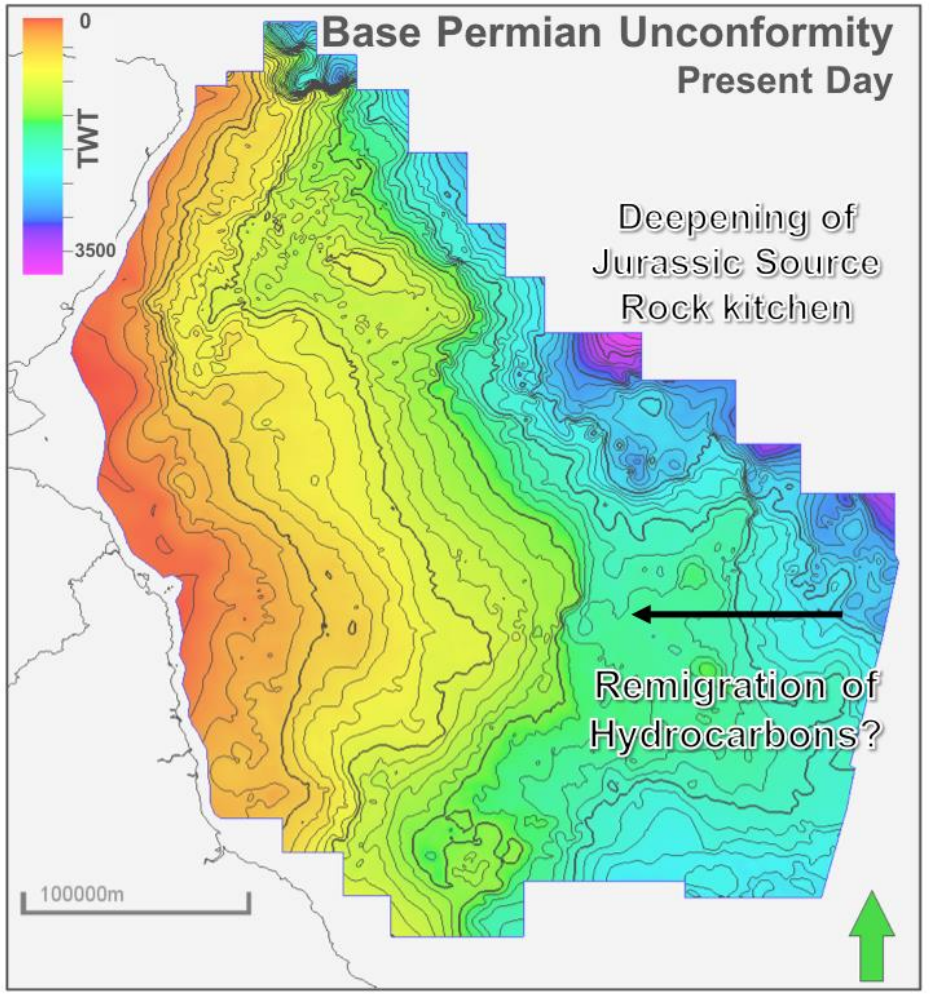


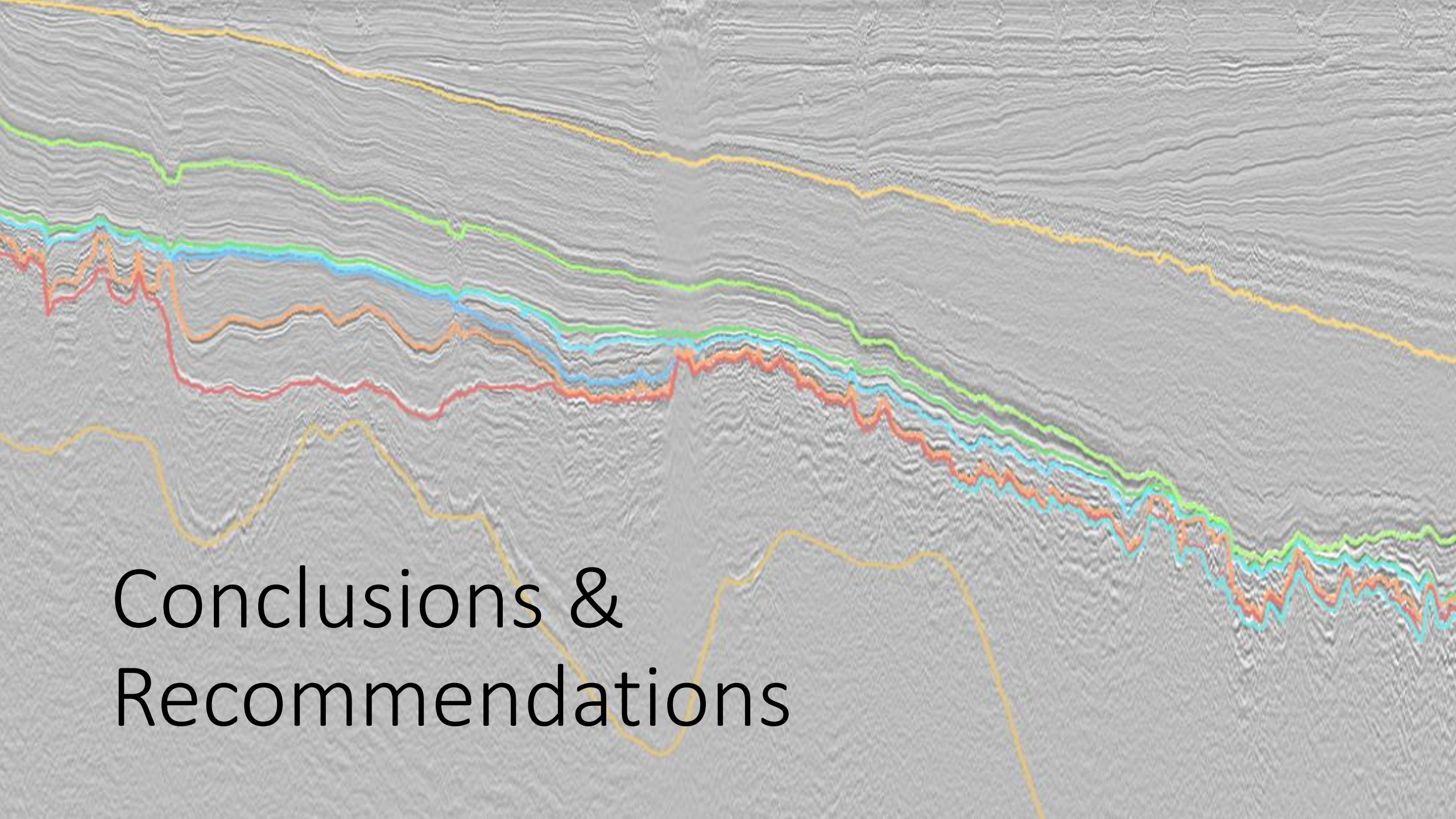
Mid-Tertiary- Recent

Understanding the importance of uplift events on:

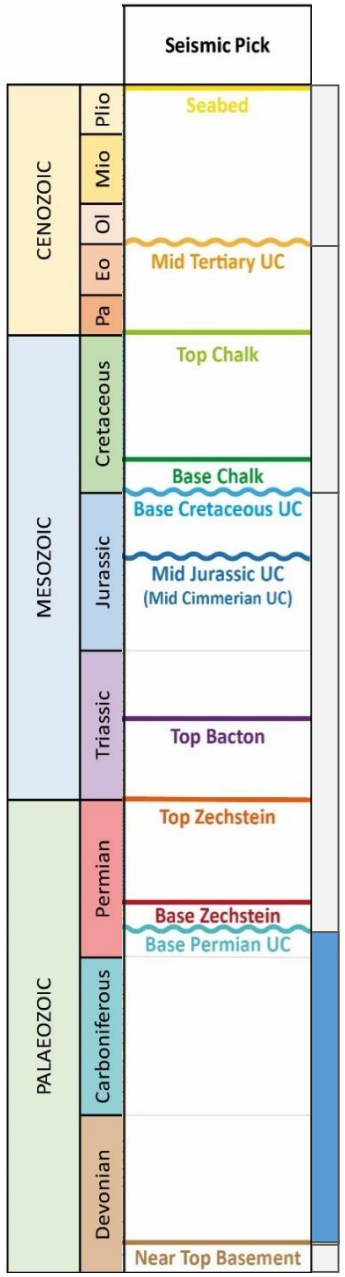
- Source Rock generation.
- Hydrocarbon re-migration.







Conclusions & Recommendations



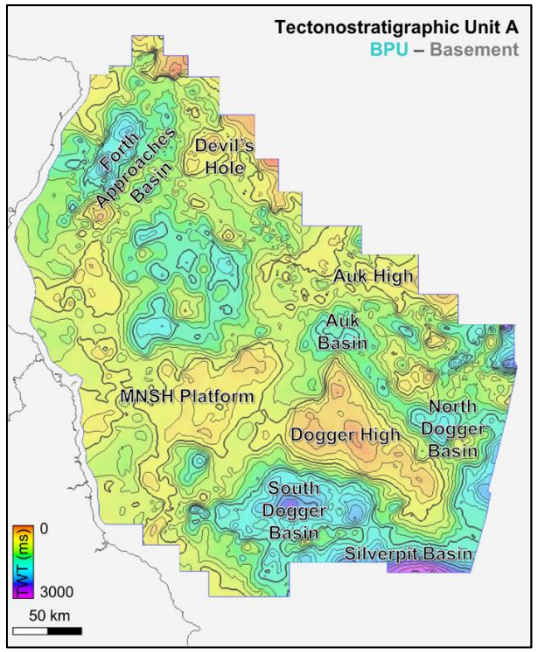
Conclusions

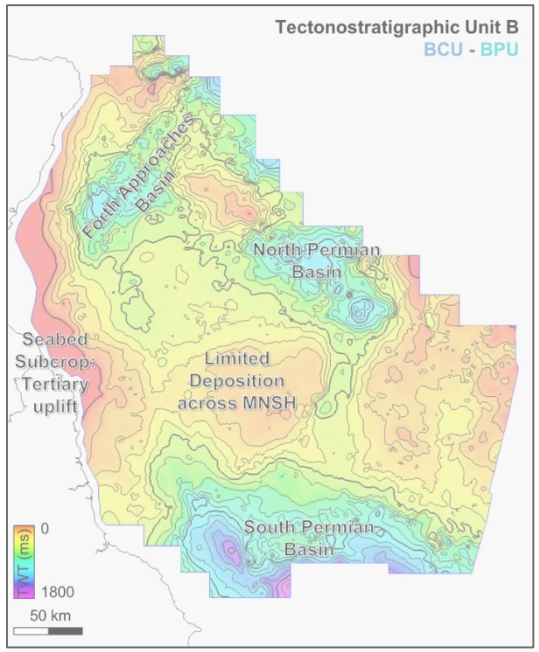
Upper Tertiary – Recent:

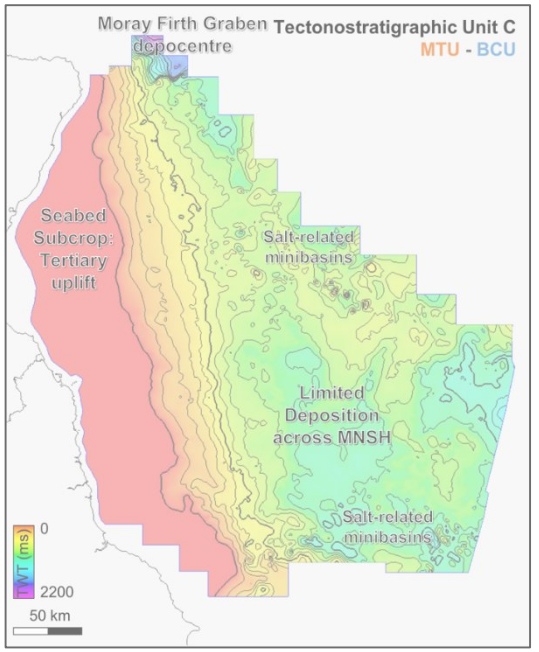
Cretaceous – Lower Tertiary:

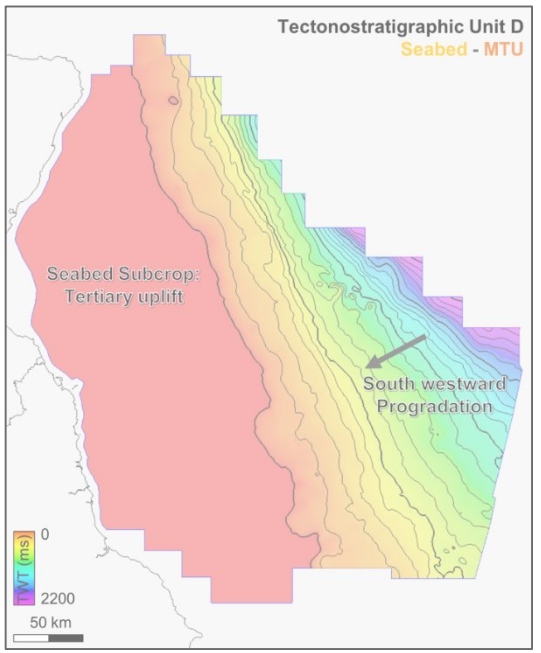
Permian - Jurassic:

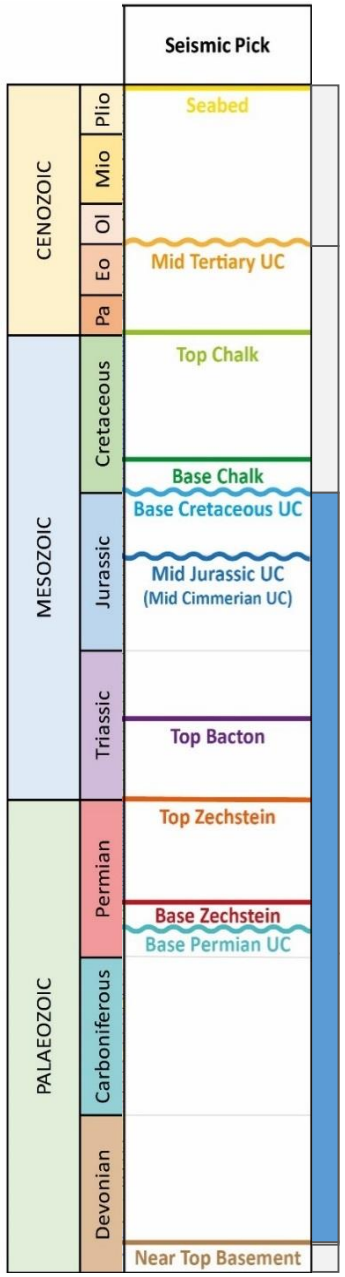
Devonian – Carboniferous: Isolated granite-cored highs and intra-basins.











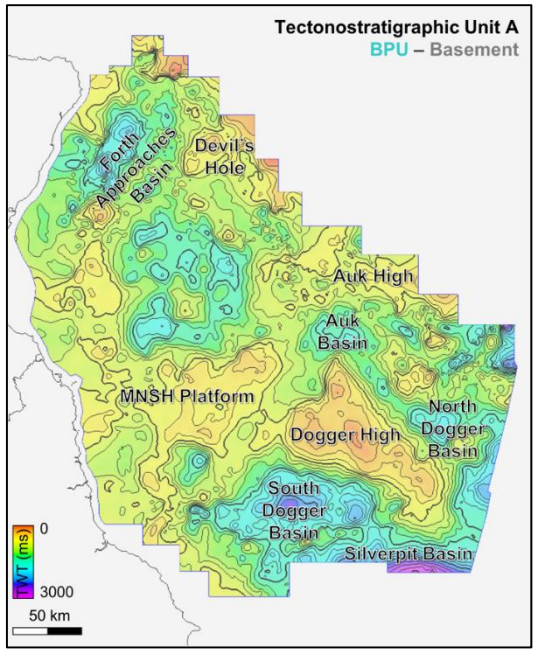
Conclusions

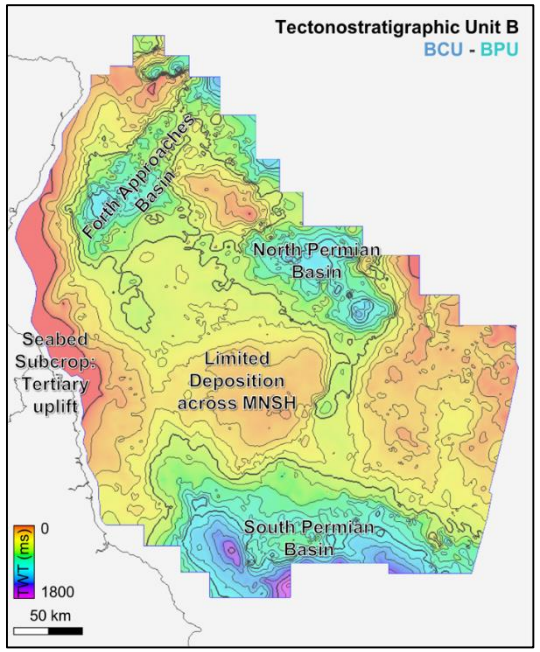
Upper Tertiary – Recent:

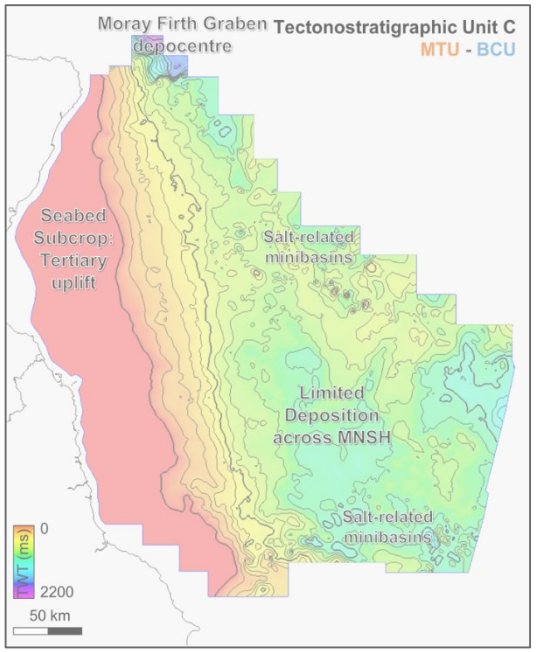
Cretaceous – Lower Tertiary:

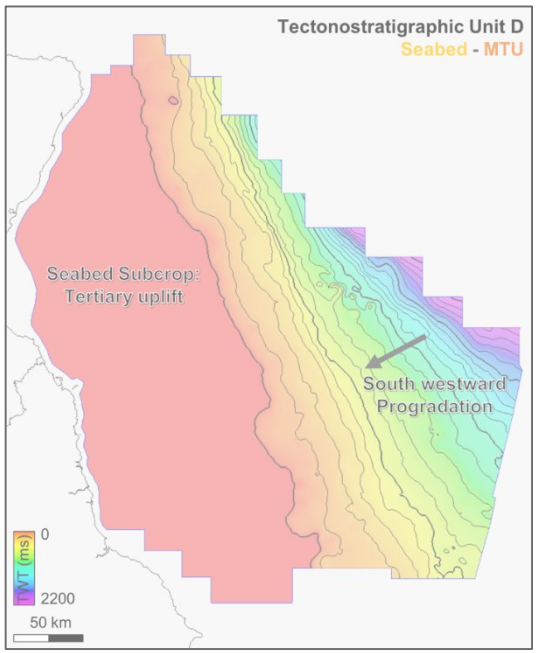
Permian - Jurassic: More regionally-extensive Permo-Triassic High, including the Dogger-Auk High
Non-deposition over much of the region despite Upper Jurassic rifting to NE.

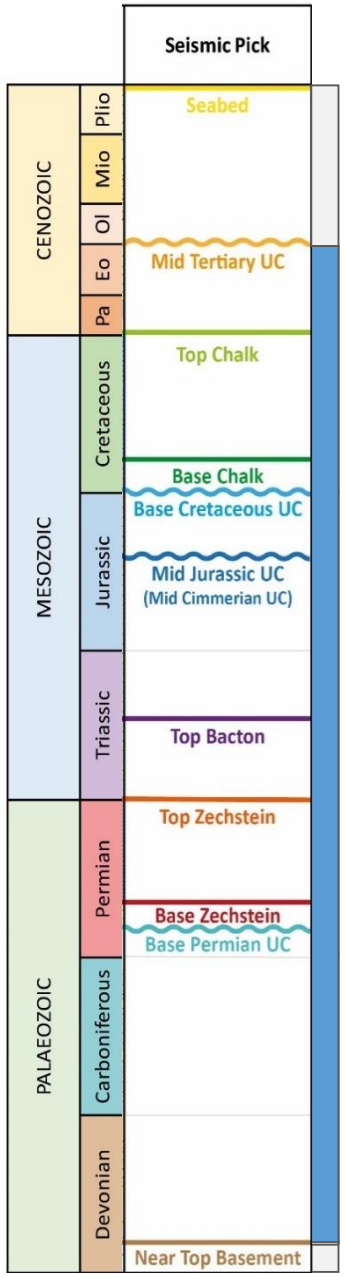
Devonian – Carboniferous: Isolated granite-cored highs and intra-basins.











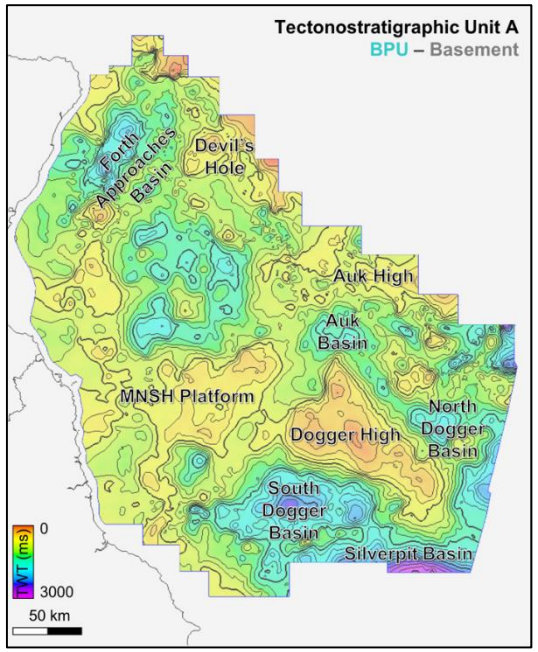
Conclusions

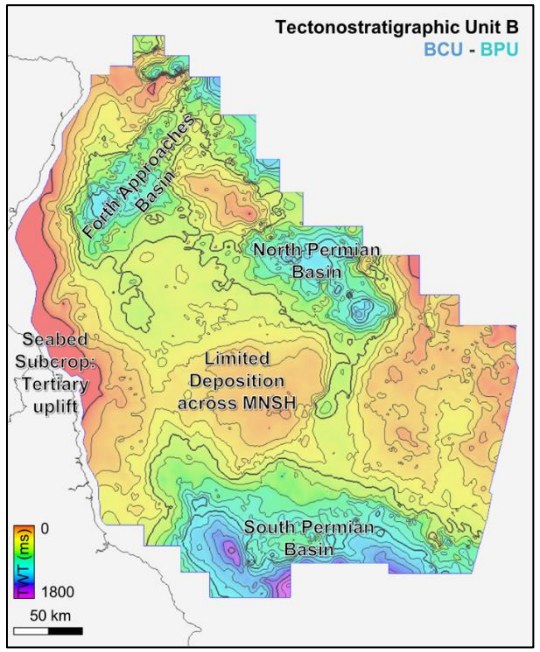
Upper Tertiary – Recent:

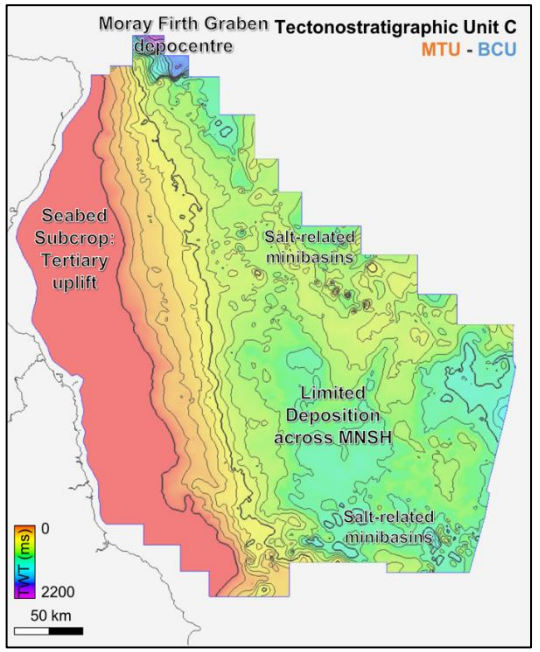
Cretaceous – Lower Tertiary: Post-rift thermal subsidence. Footwall flank of Central Graben high.

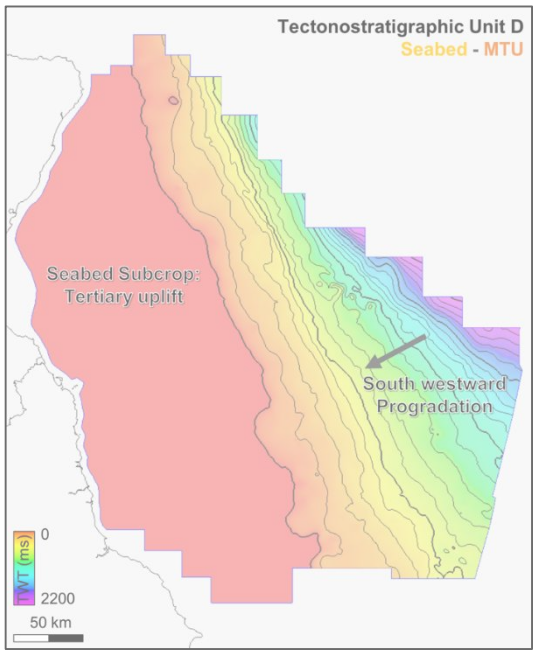
Permian - Jurassic: More regionally-extensive Highs, including the Dogger-Auk High in the East. Non-deposition over much of the region.

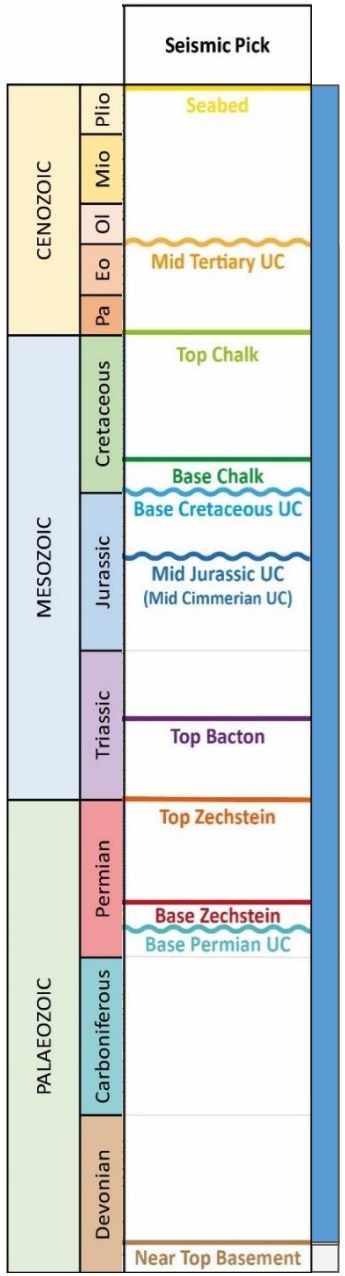
Devonian – Carboniferous: Isolated granite-cored highs and intra-basins.











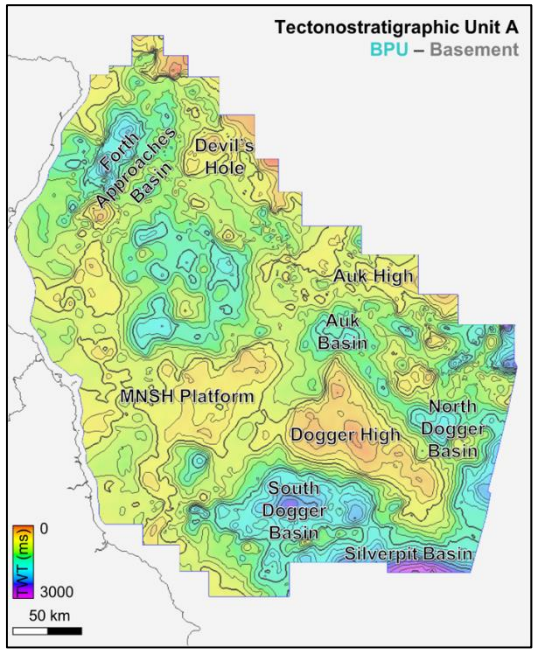
Conclusions

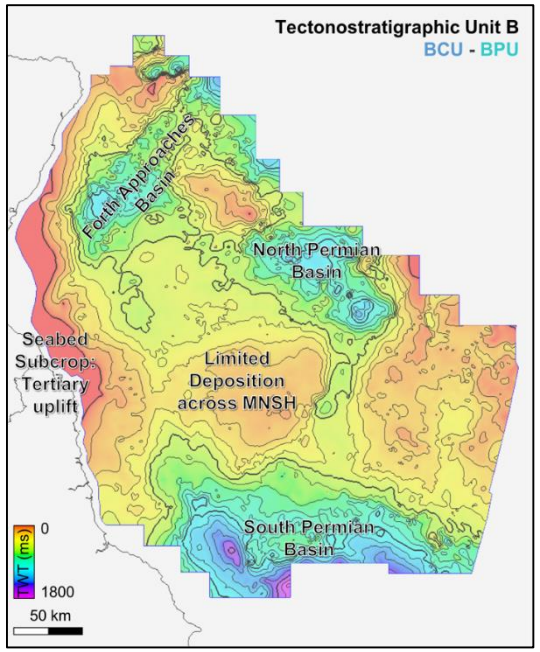
Upper Tertiary – Recent: Tectonic reorganisation through regional tilting.

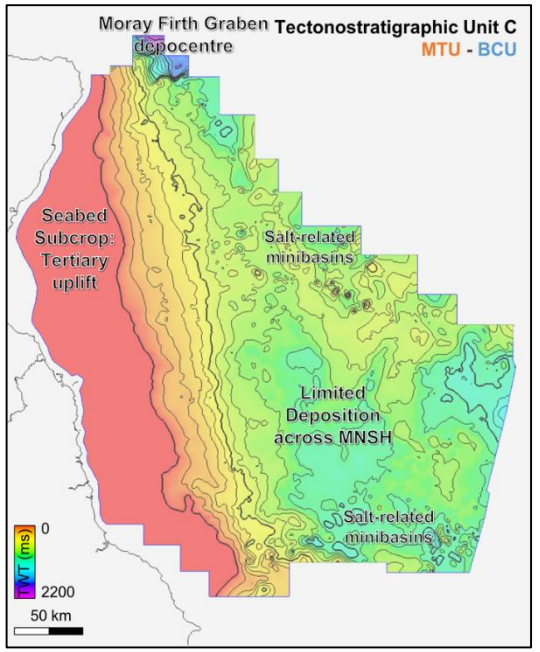
Cretaceous – Lower Tertiary: No significant tectonic activity. Footwall flank of Central Graben high.

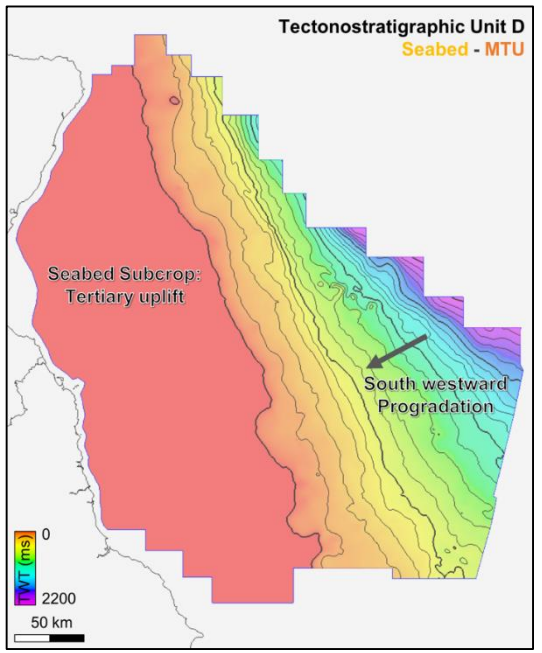
Permian - Jurassic: More regionally-extensive Highs, including the Dogger-Auk High in the East. Non-deposition over much of the region.

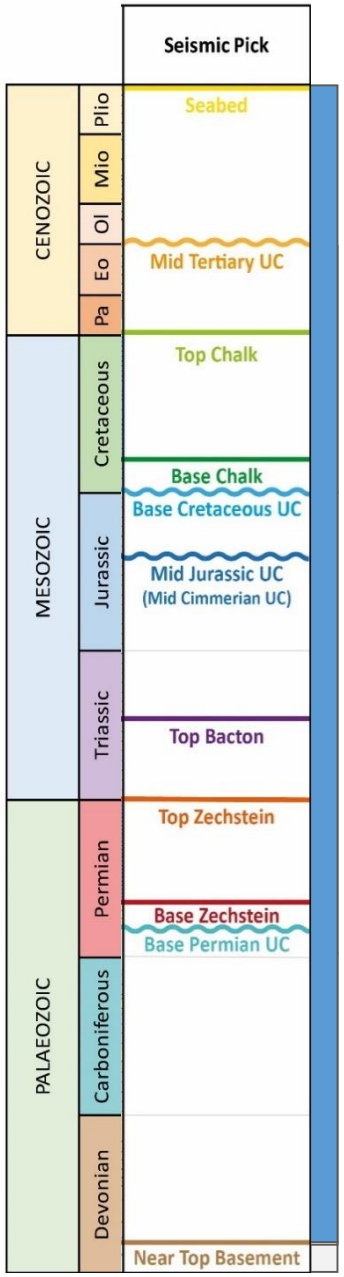
Devonian – Carboniferous: Isolated granite-cored highs and intra-basins.











Conclusions

- OGA data has allowed for a better definition of the Mid North Sea High and an understanding of its evolution through time and space.
- Regionally-significant tectonic events have been identified, all of which have implications for the petroleum systems.
- All results from this study are now available for download via the OGA Data Centre.