Unconventional Petroleum Potential of the Gainsborough Trough, East Midlands, United Kingdom*

Francesco Palci[1], Alastair Fraser[1], Kate Parkin[2], Tom Wilson[2], Thomas Goode[2], and Martin Neumaier[3]

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Abstract

The Gainsborough Trough in the UK East Midlands has a long history of conventional exploration activity and its Carboniferous sequences have been important targets for hydrocarbon resources since the 1920's. The Gainsborough Trough has been considered a well-understood sedimentary basin – or so we thought. The development of technological advancements in horizontal drilling and hydraulic fracturing stimulation techniques has allowed the rapid exploitation of unconventional petroleum resources in the US and has led to a re-evaluation of the basin for its shale oil and gas potential. A Type II source rock was deposited during the Pendleian sub stage (Late Mississippian) known collectively as the Bowland Shale Formation; which is demonstrated to be thermally mature for both oil and gas generation and deposited in a relatively simple tectonic setting. A sophisticated petroleum systems model has been generated to provide an improved assessment of the unconventional petroleum resources in the basin. The petroleum systems modelling incorporates the burial and uplift history of the basin allowing the prediction of the generation and expulsion of the various hydrocarbons phases. Additionally, the breakdown of hydrocarbon accumulations within either the free or adsorbed phase was also possible. In-place volumes of shale oil and gas resources were estimated resulting in the production of unconventional hydrocarbon sweet spot maps consistent with the present day oil and gas conventional fields in the area. A total of 18 billion barrels of oil and 25 Tcf of gas in place have been estimated within the Bowland Shale Formation in the Gainsborough Trough. Critically, in terms of recoverable hydrocarbons, the natural fracture system present in the Bowland Shale is not fully understood due to the lack of direct well bore information and only future drilling and testing will allow explorers to fully understand the potential recoverable resources of the Gainsborough Trough.

Selected References

Andrews, I.J., 2013, The Carboniferous Bowland Shale gas study: geology and resource estimation: British Geological Survey for Department of Energy and Climate Change, London, UK.

Fraser, A.J., D.F. Nash, R.P. Steele, and C.C. Ebdon, 1990, A regional assessment of the intra-Carboniferous play of northern England: in J. Brooks (ed.), Classic Petroleum Provinces, Geological Society, London, Special Publications, 50, p. 417-440.

Kirby, G.A., H.E. Baily, R.A. Chadwick, D.J. Evans, D.W. Holliday, S. Holloway, A.G. Hulbert, T.C. Pharaoh, N.J.P. Smith, N. Aitkenhead, and B. Birch, 2000, The structure and evolution of the Craven Basin and adjacent areas: Subsurface Memoir of the British Geological Survey, London, Stationery Office, 130 p.

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Imperial College London

IGas Energy

Schlumberger

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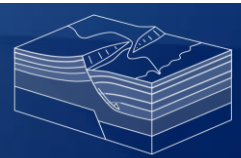

Outline

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- **Aims and objectives**
- **Background**
- **Interpretation**
- **Conclusions and learning**

Aims and objectives

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- Estimate the unconventional resource potential of the Gainsborough Trough

- Understand the burial history of the Gainsborough Trough
- Assess the thermal maturity of the Bowland Shale Formation
- Create sweet spot maps for shale oil and gas potential
- Comparison with the BGS/DECC study

Geological context

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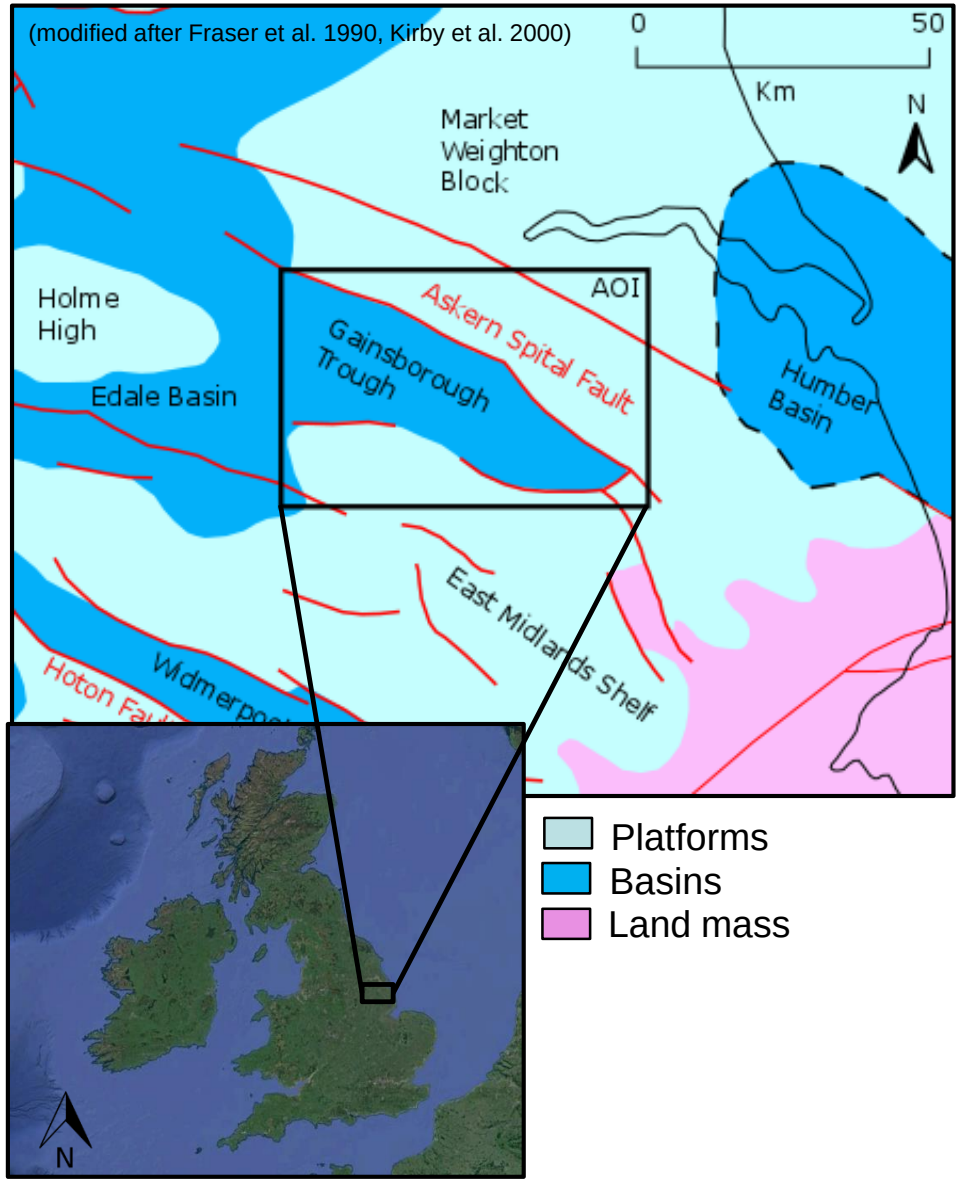
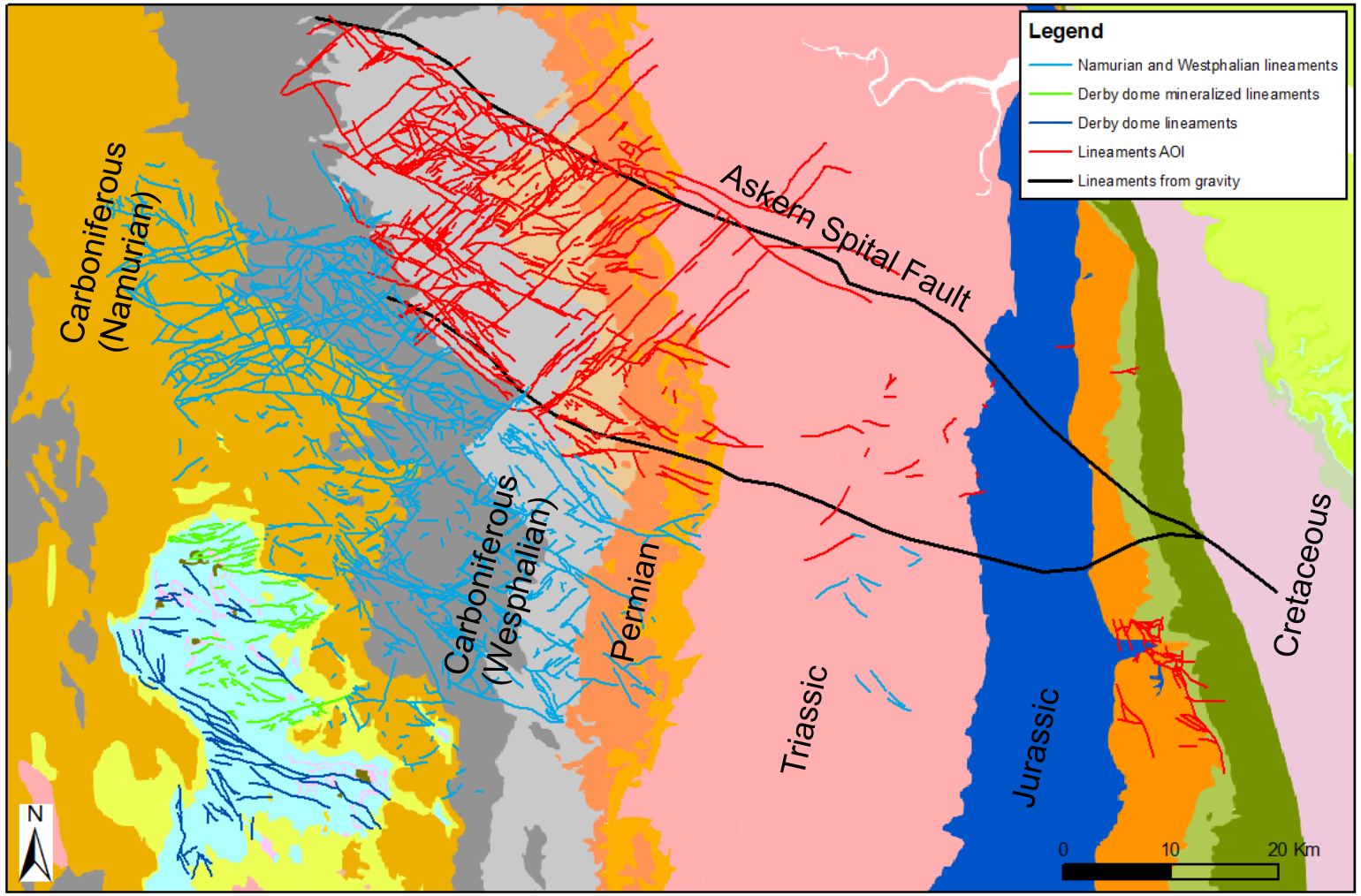
East Midlands Carboniferous basins and platforms

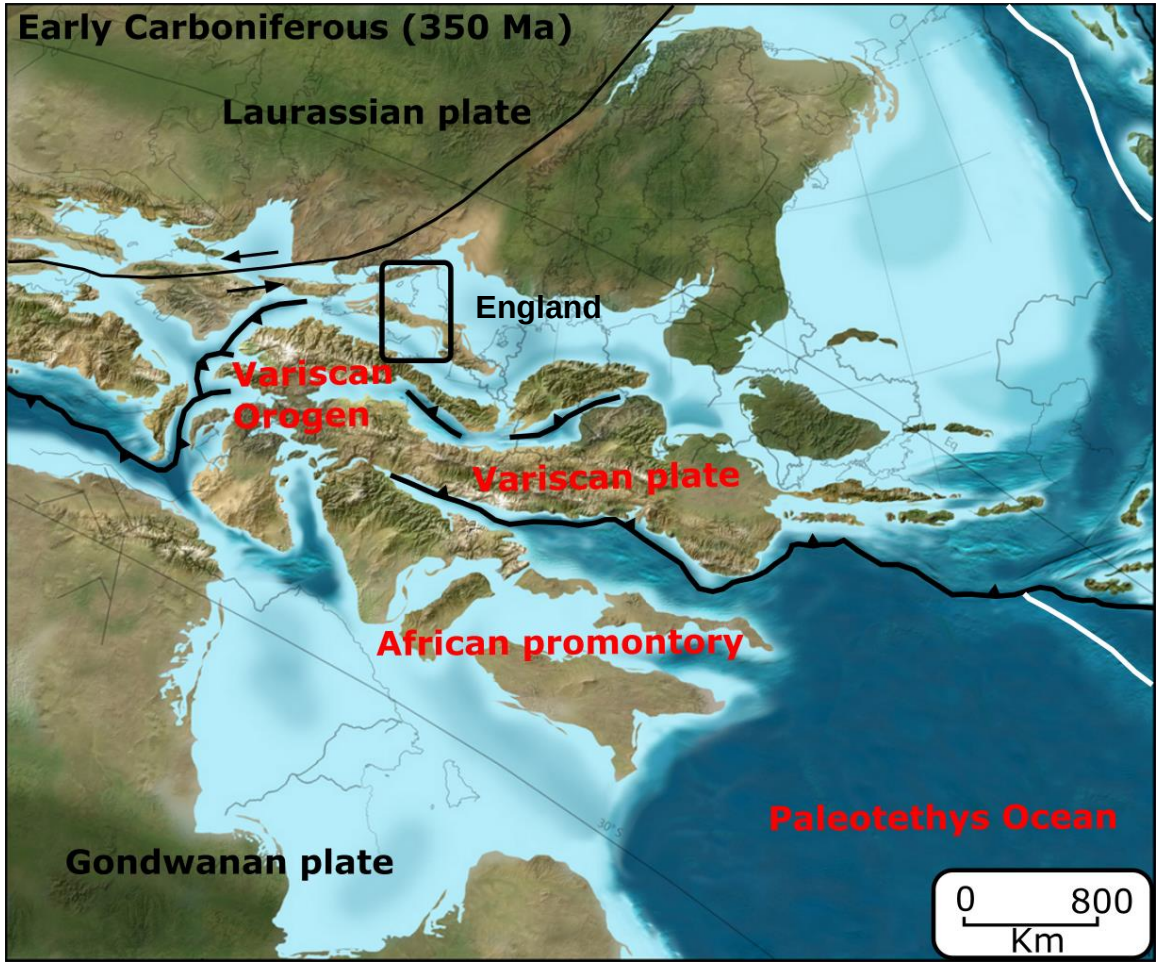


BGS surface geology and lineaments

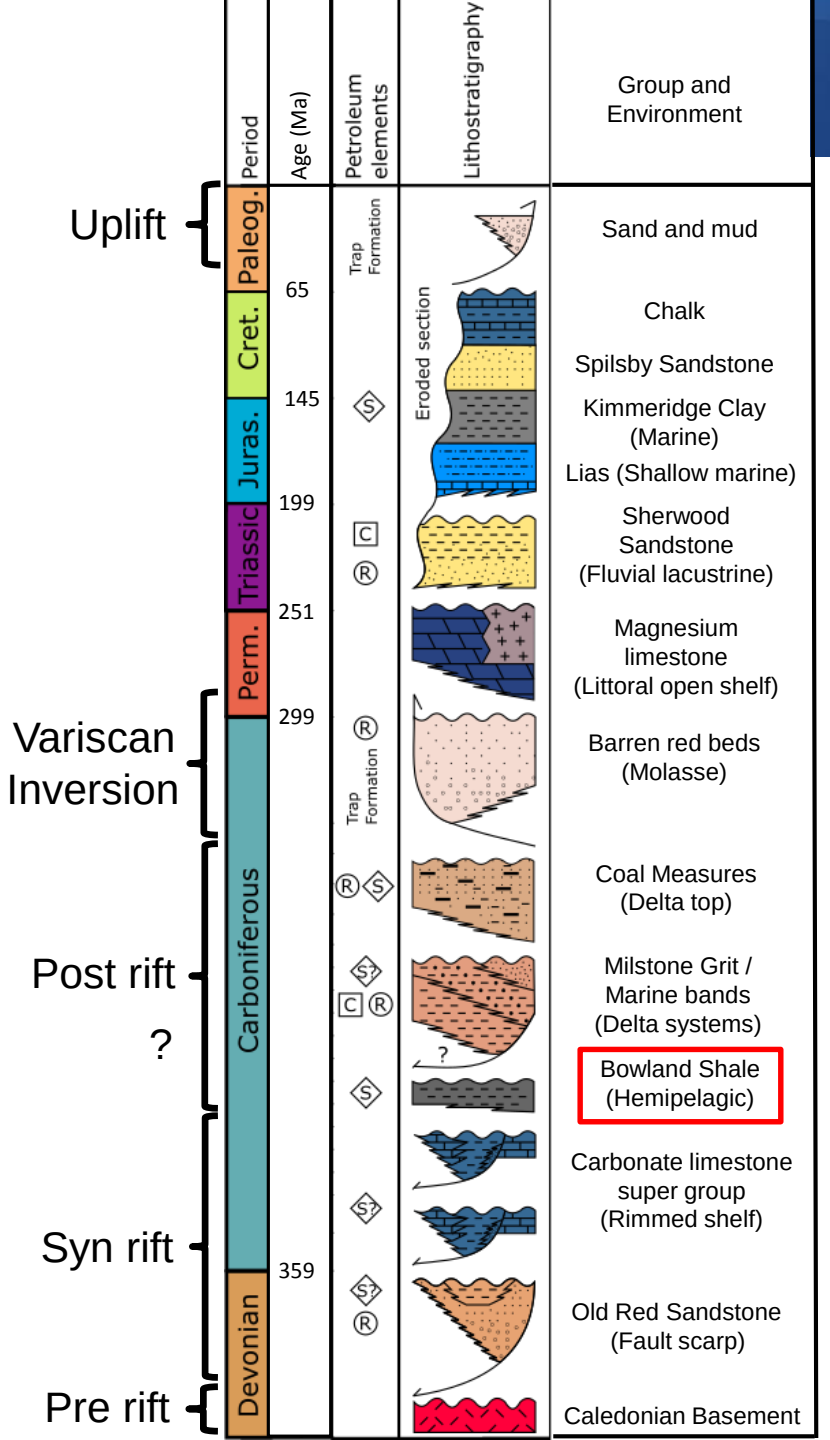


(BGS onshore digital geological map)

Tectonic evolution



(Blakey R. 2011)



(Modified After Fraser et al., 1990)

Bowland Shale Formation

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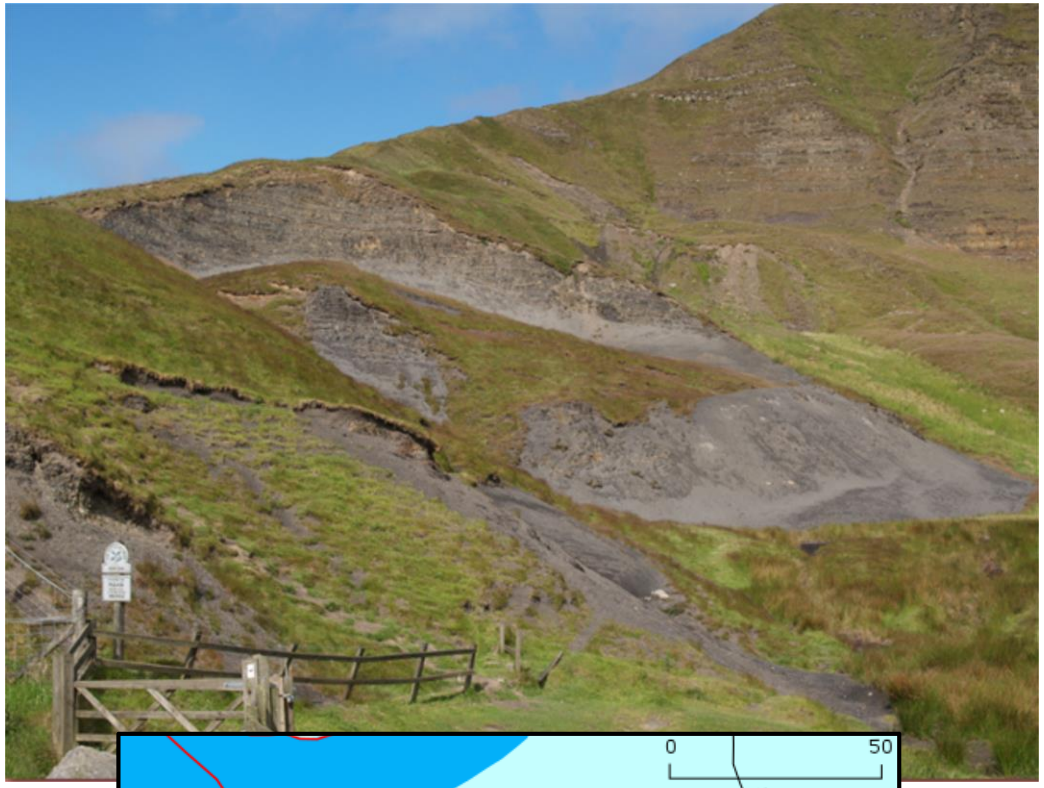
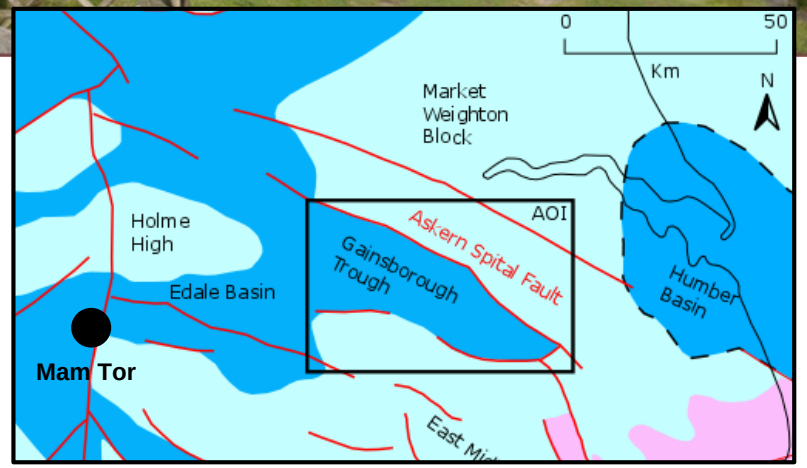
Mam Tor Bowland Shale Formation



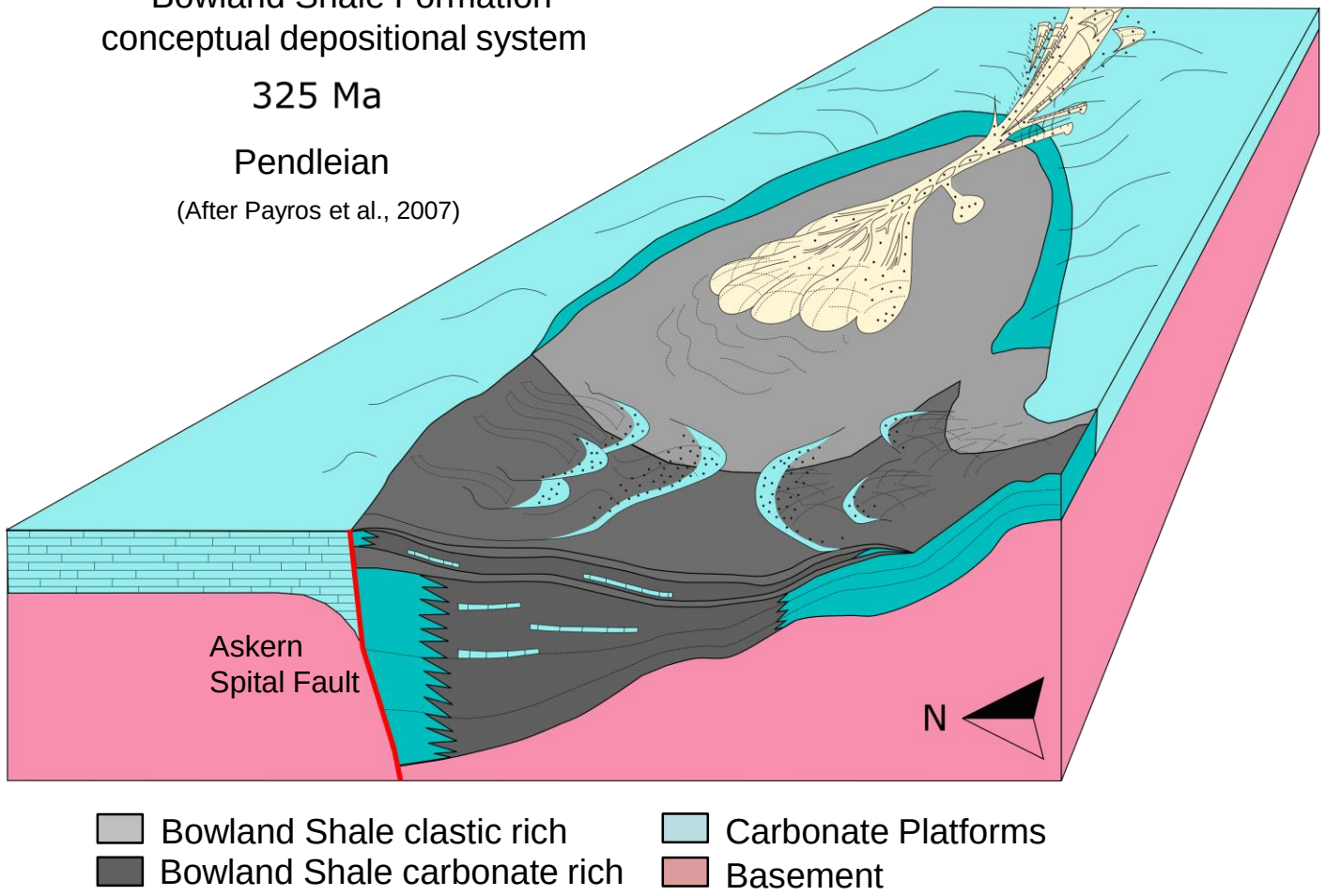


Bowland Shale Formation
conceptual depositional system

325 Ma

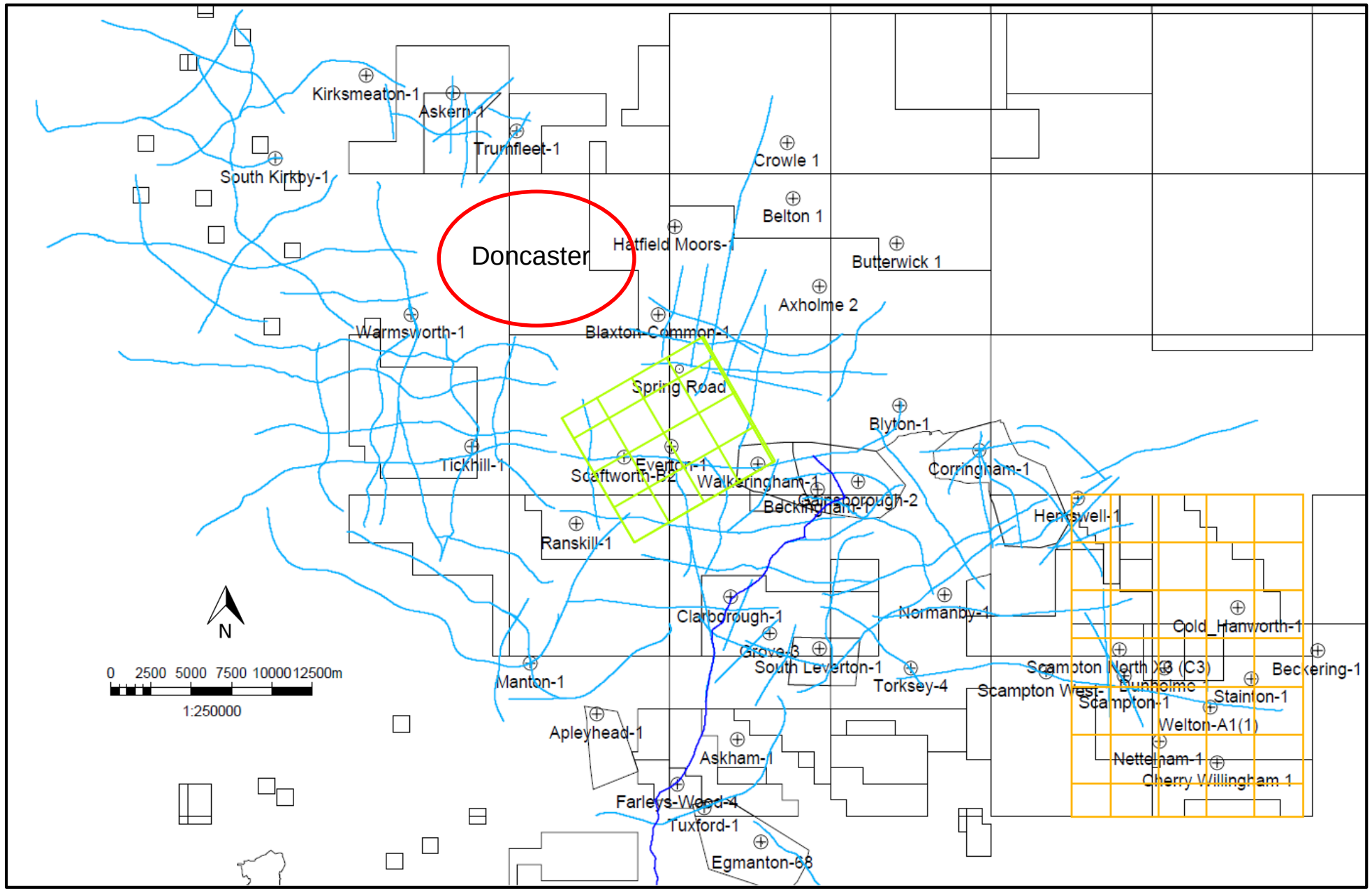
Pendleian

(After Payros et al., 2007)



(modified after Fraser et al. 1990, Kirby et al. 2000)

Dataset



3D seismic

3D seismic

2D seismic

Licences

Well

Proposed well

Seismic interpretation

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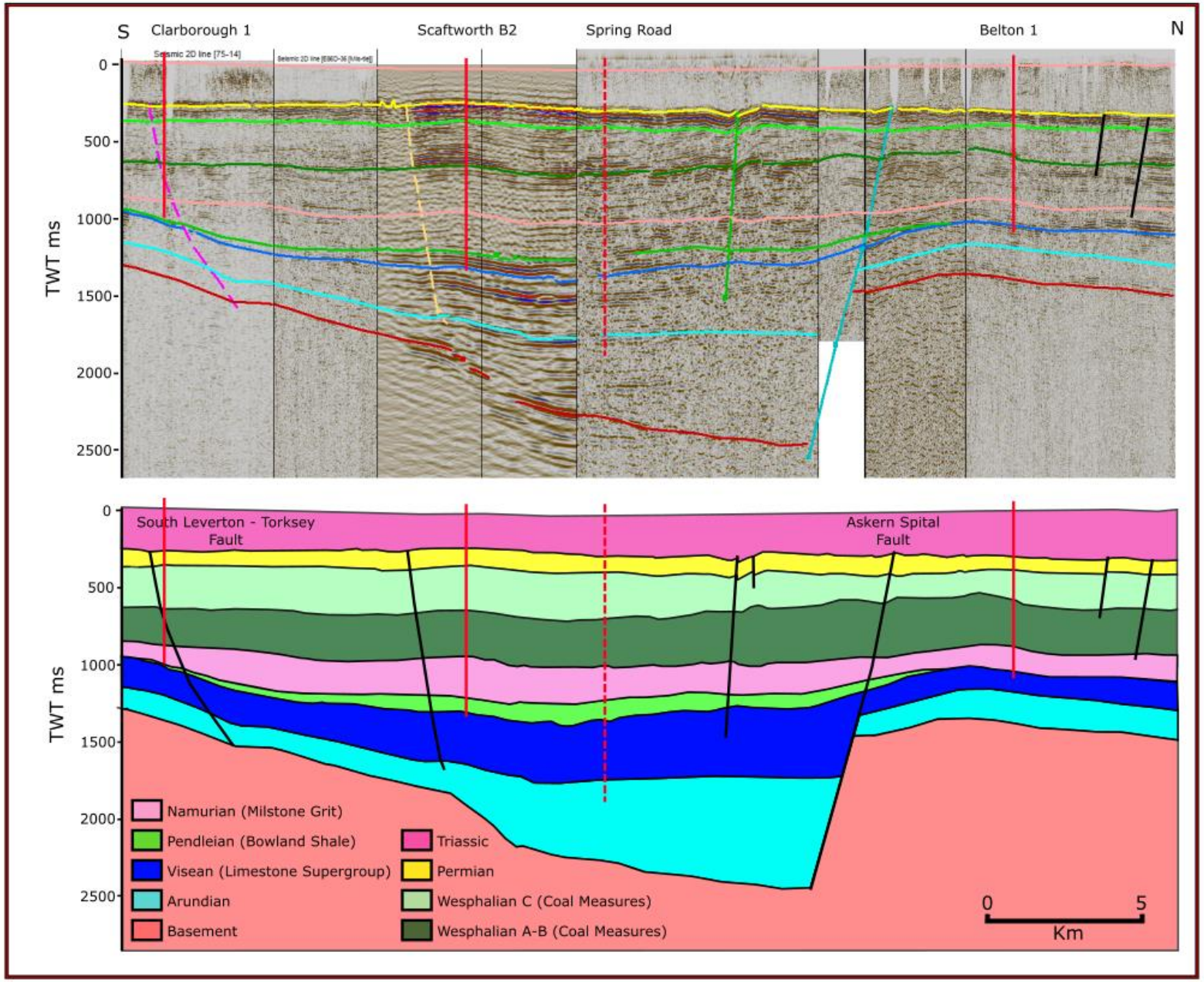
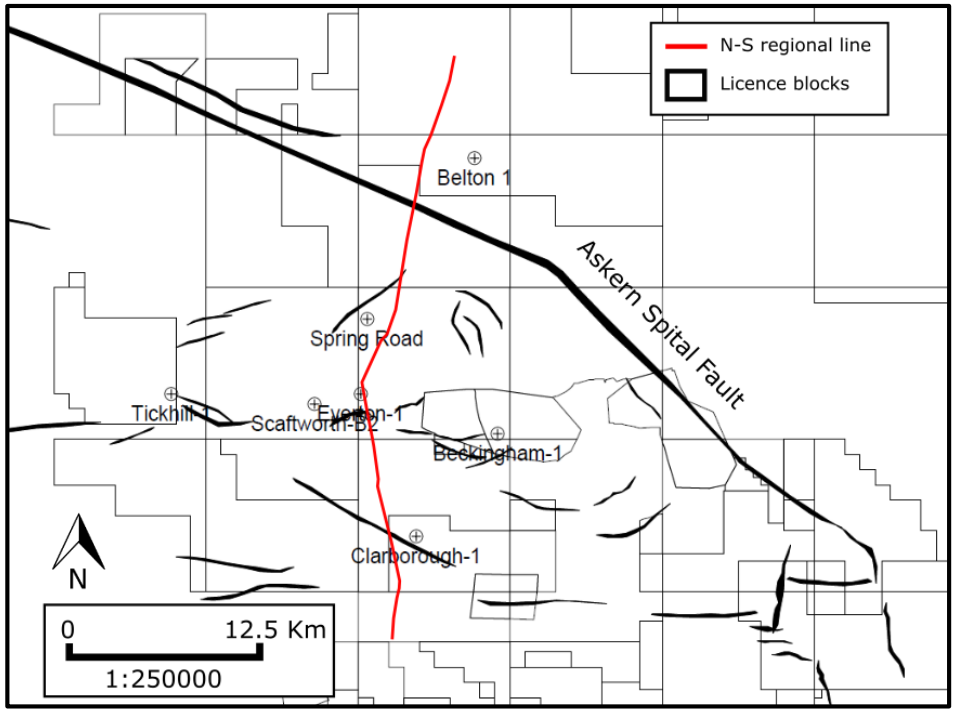


- Top Triassic
- Upper Magnesium Limestone
- Base Permian Unc.
- Near Westphalian B
- Near top Yeadonian
- Near top Pendleian
- Near top Brigantian
- Near top Arundian
- Near top Basement



Basin and Petroleum system modelling

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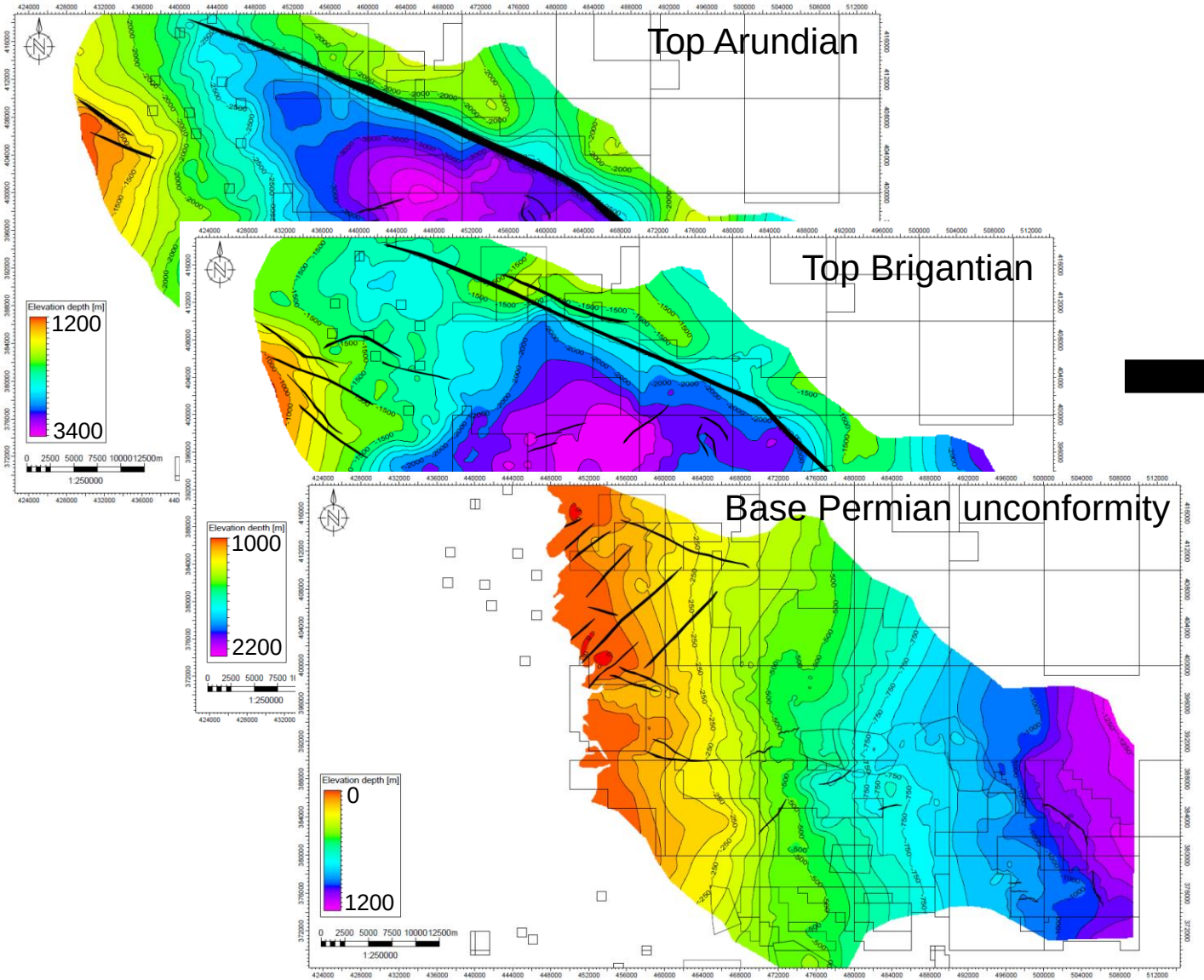
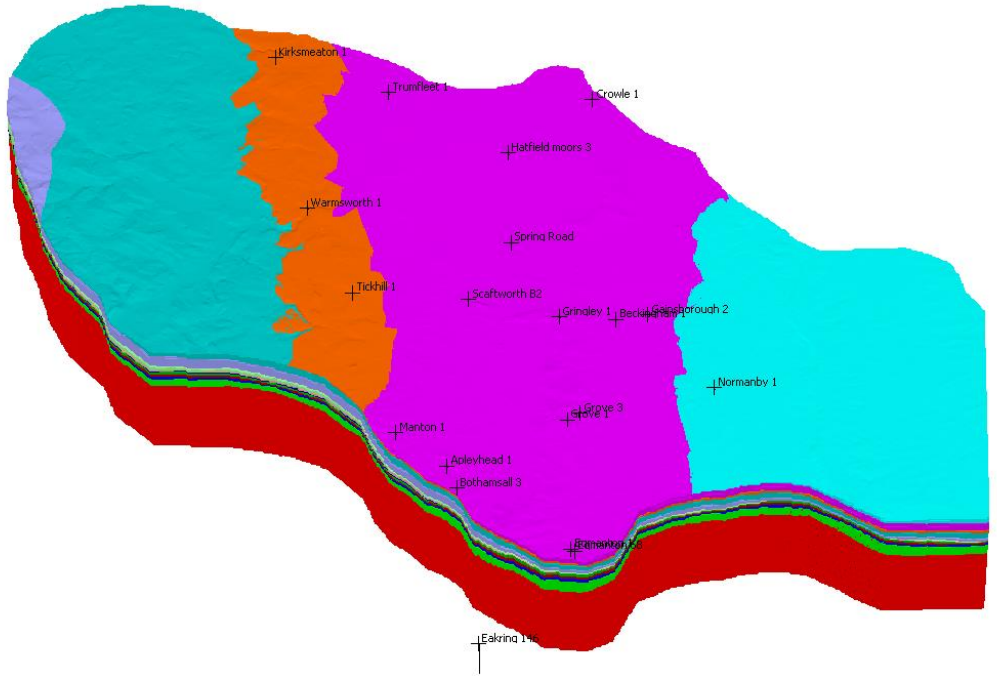
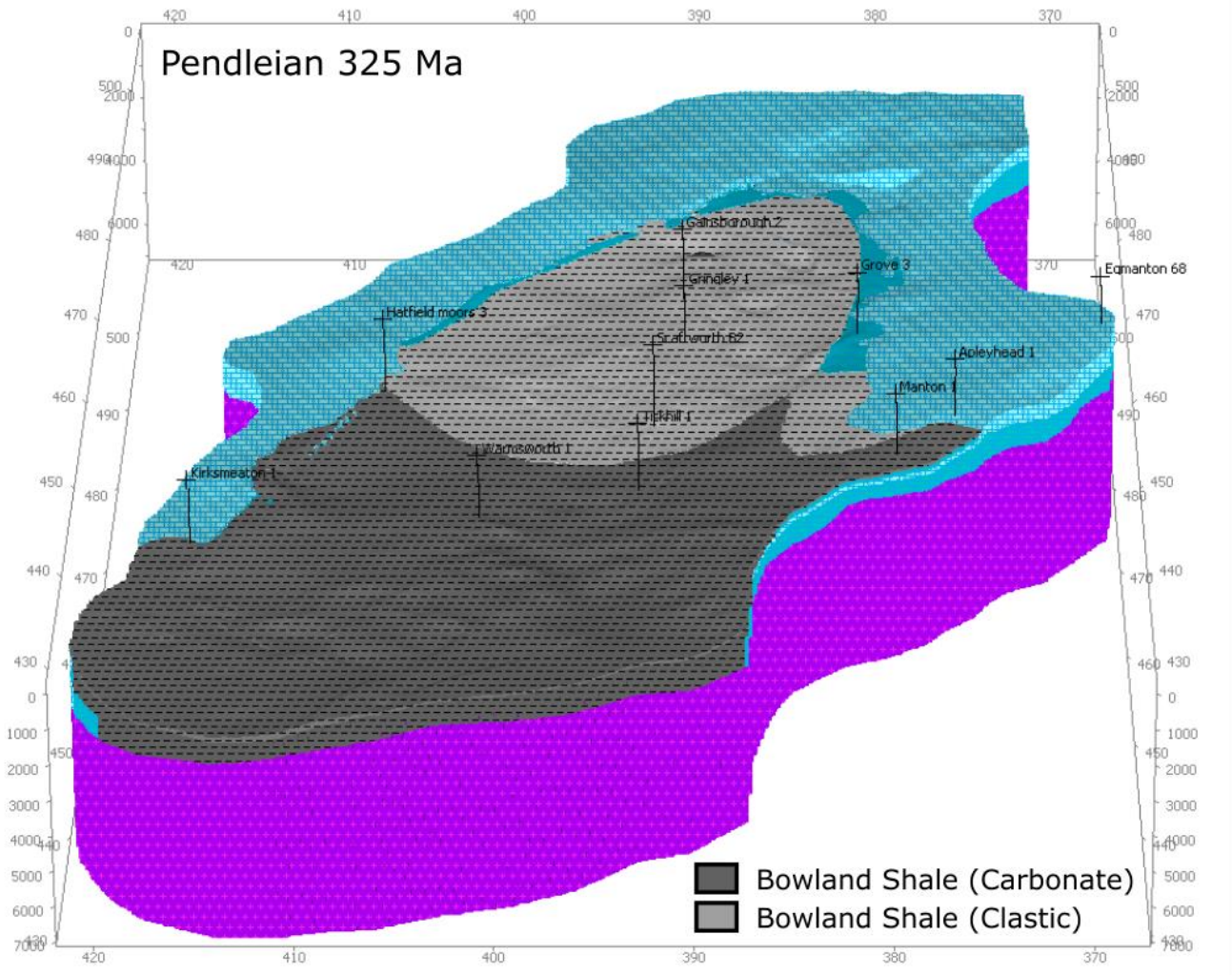
Depth maps (m)

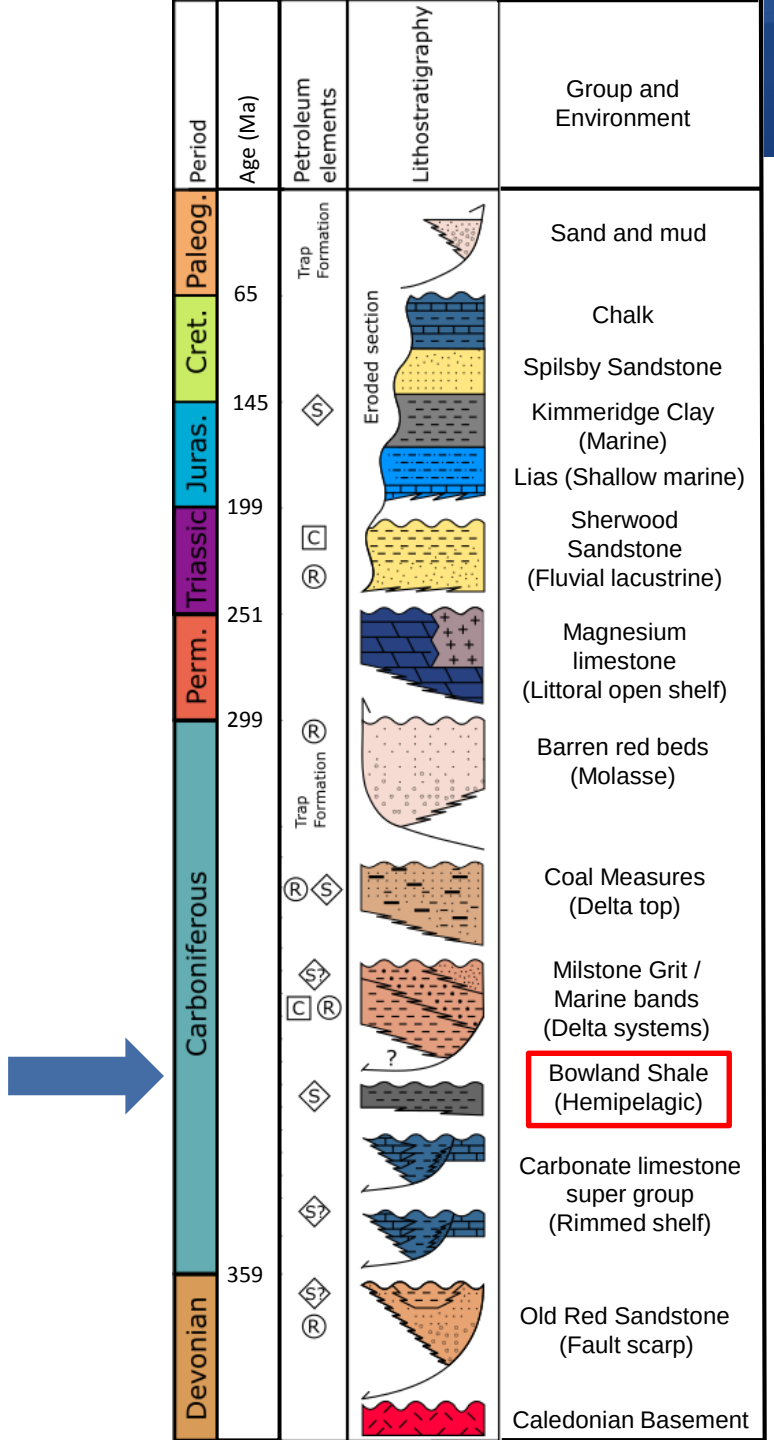


Grid cell size: 100 x 100 m
Horizons: 19
Layers: 18



Structural / Stratigraphic evolution





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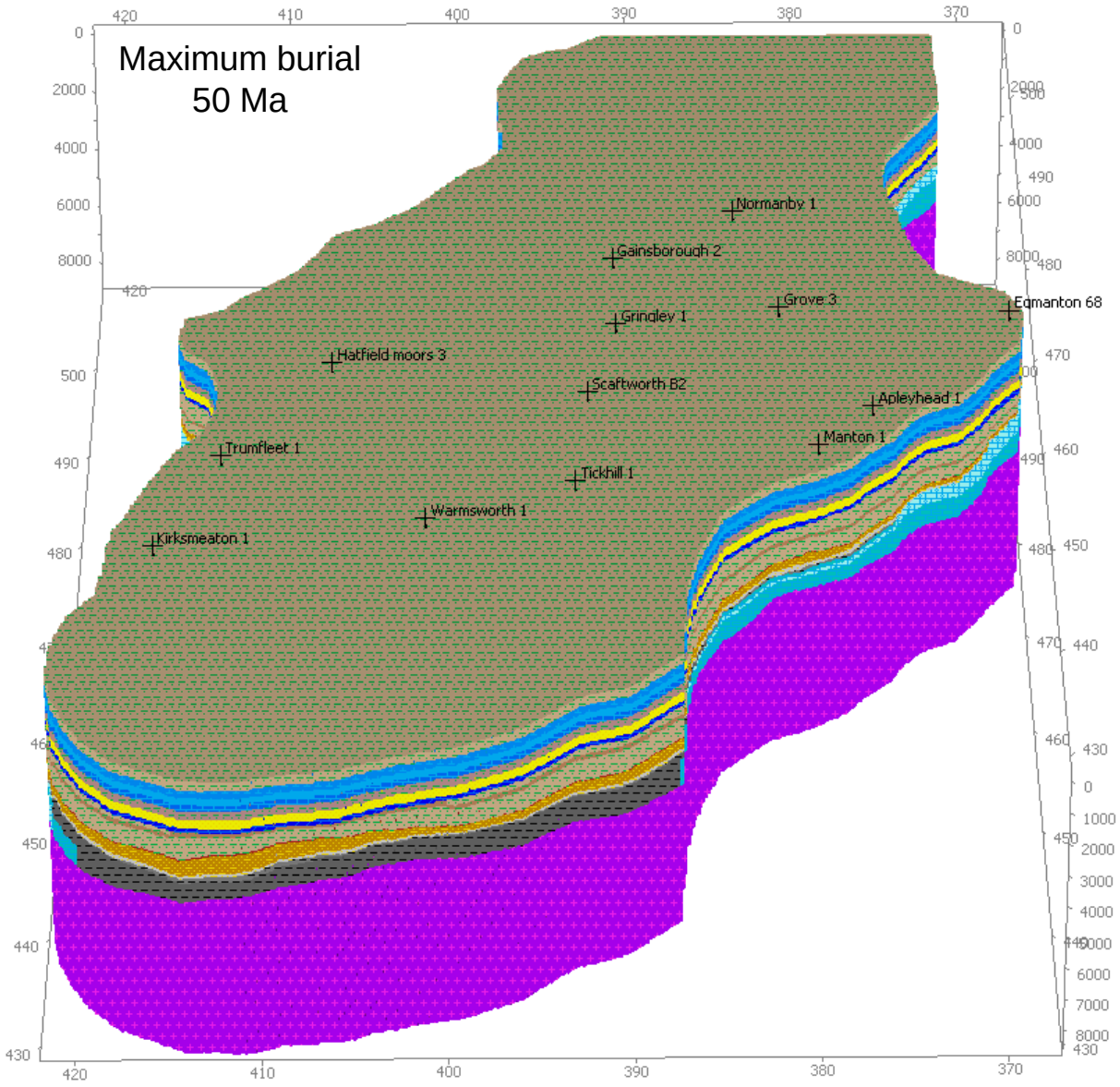
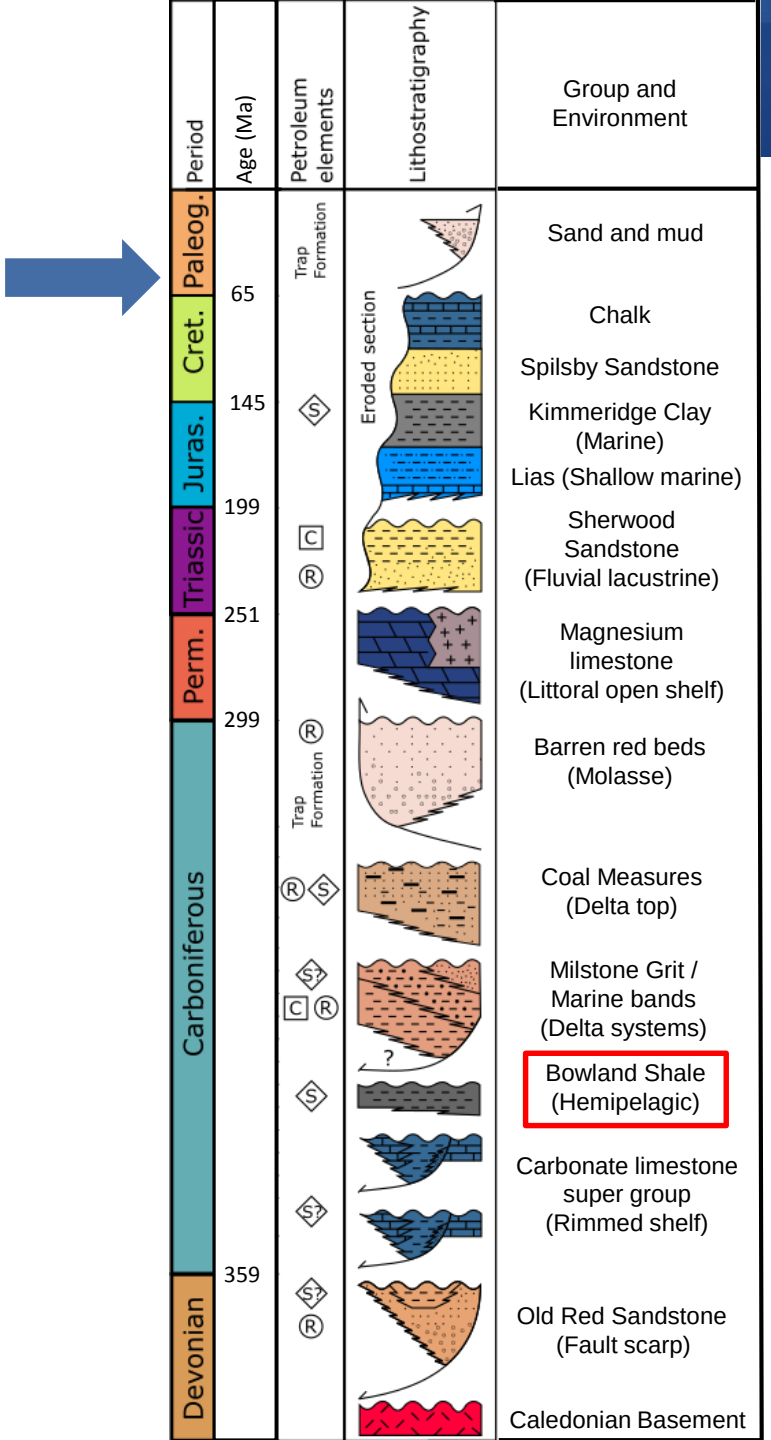
Structural / Stratigraphic evolution





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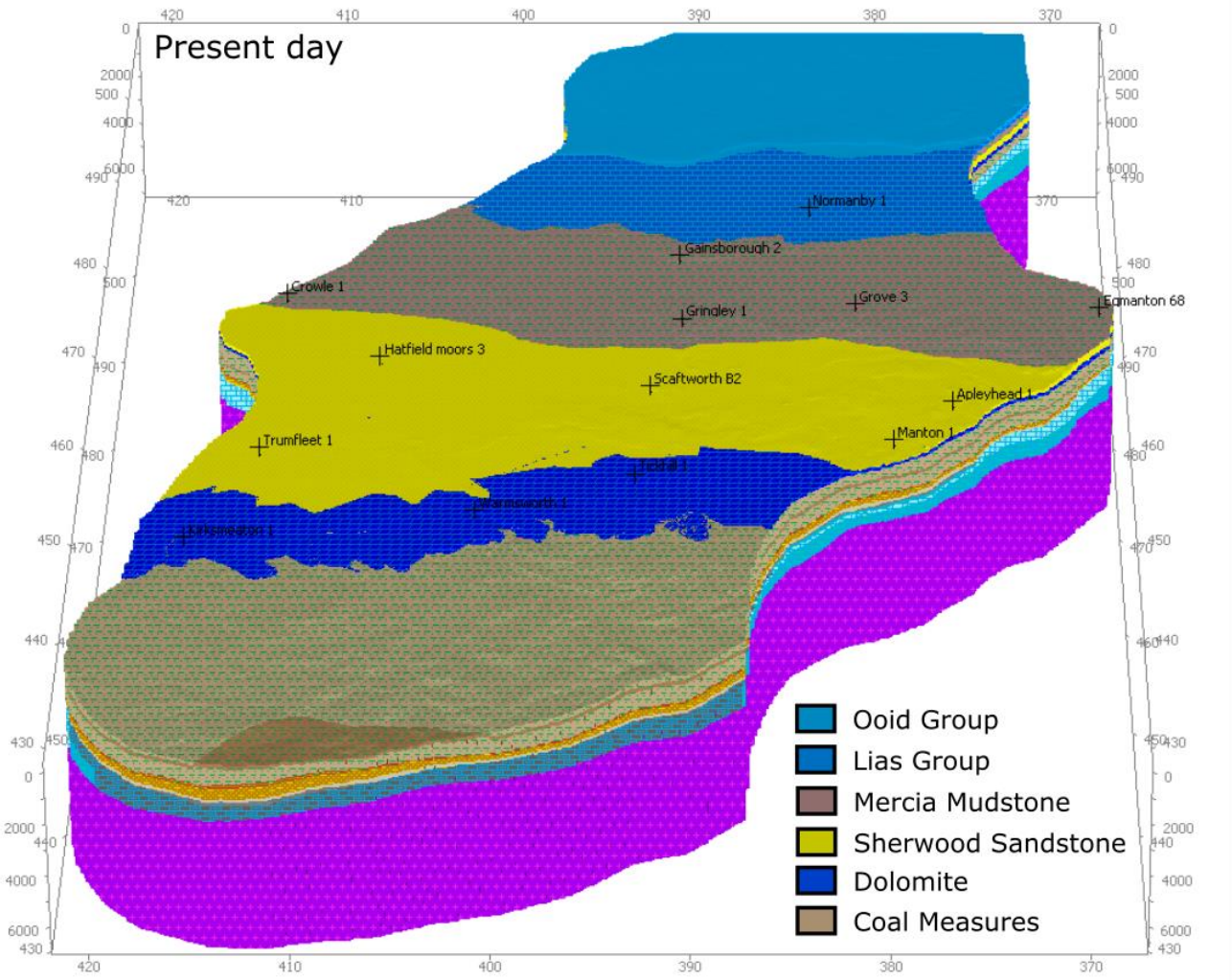
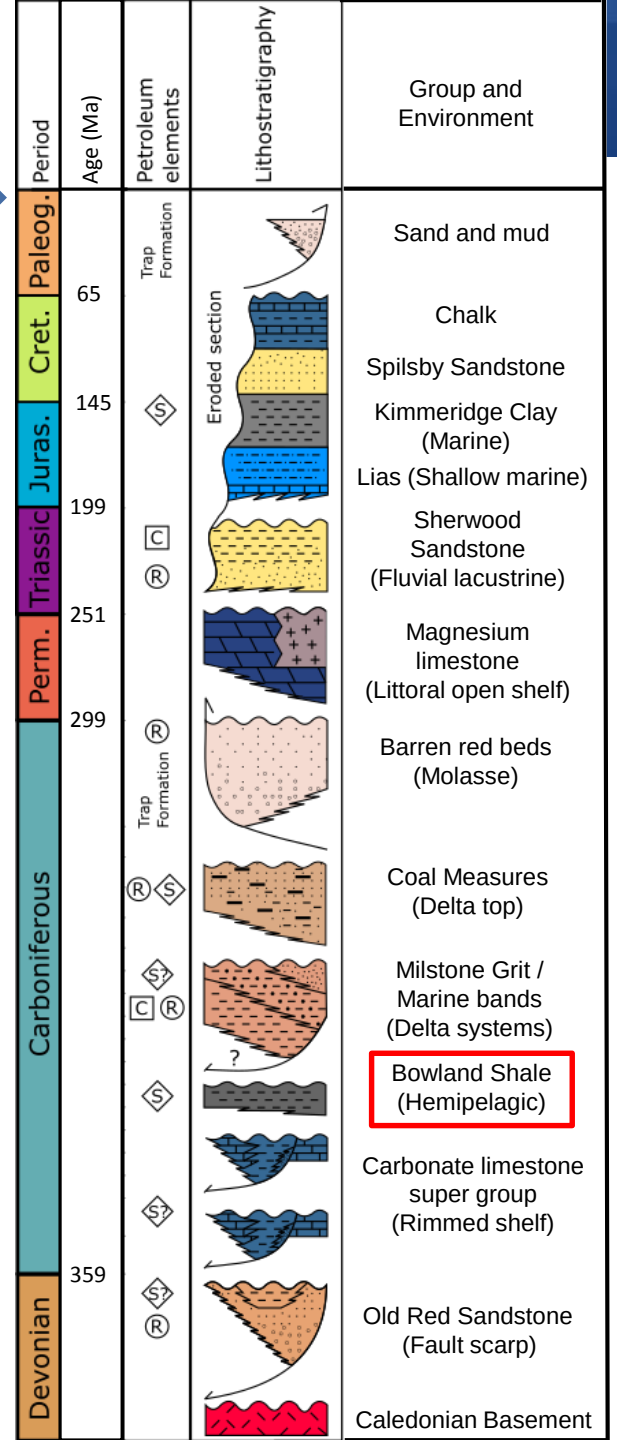
Structural / Stratigraphic evolution





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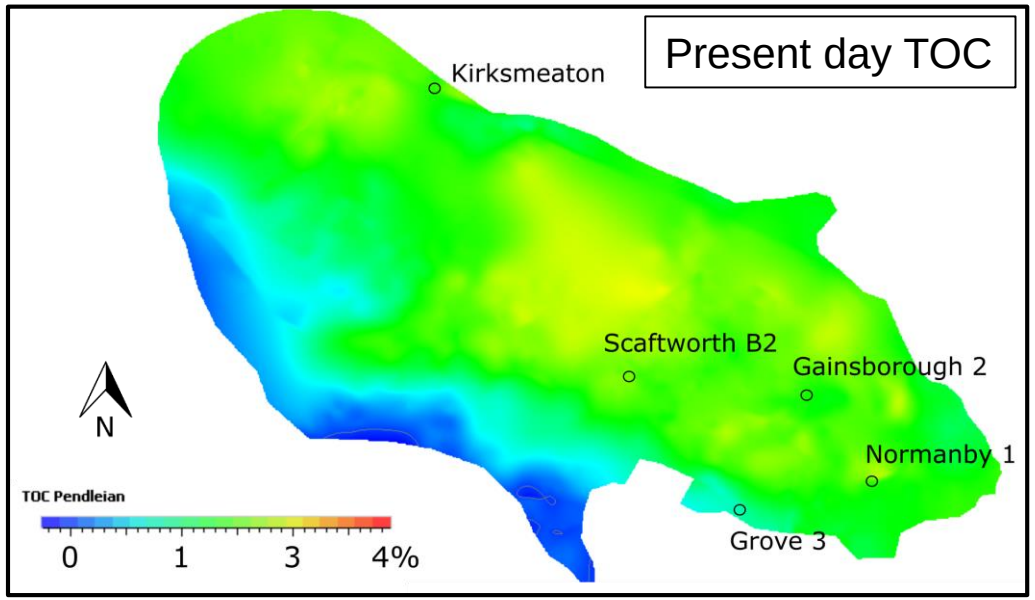
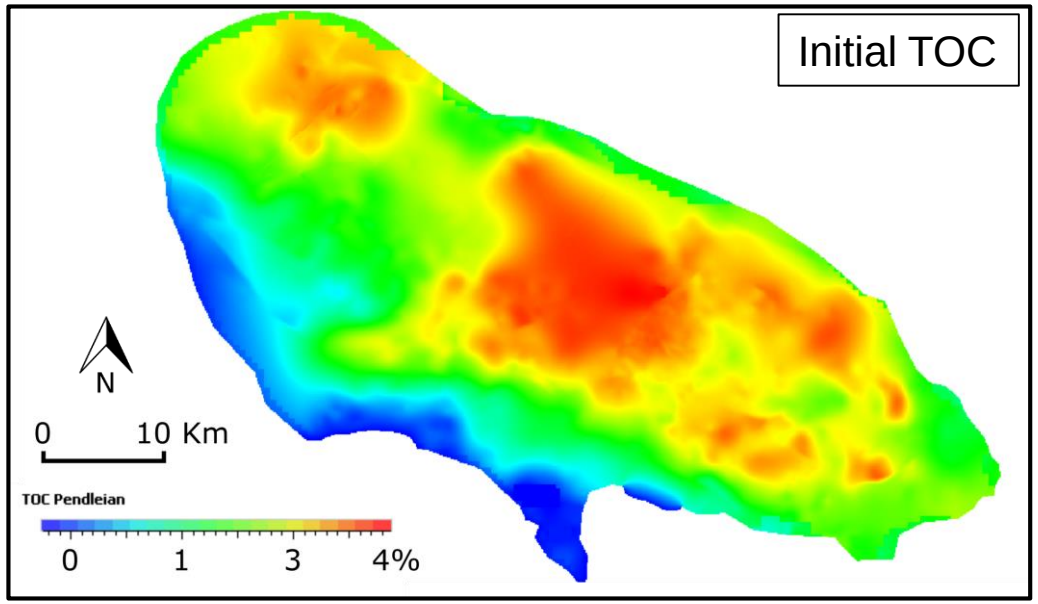
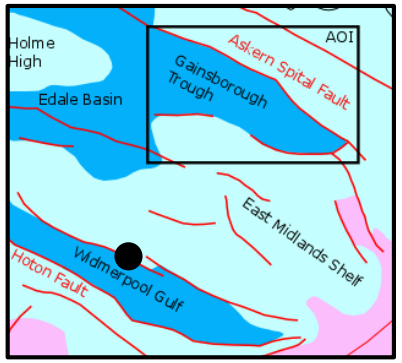
Source rock properties



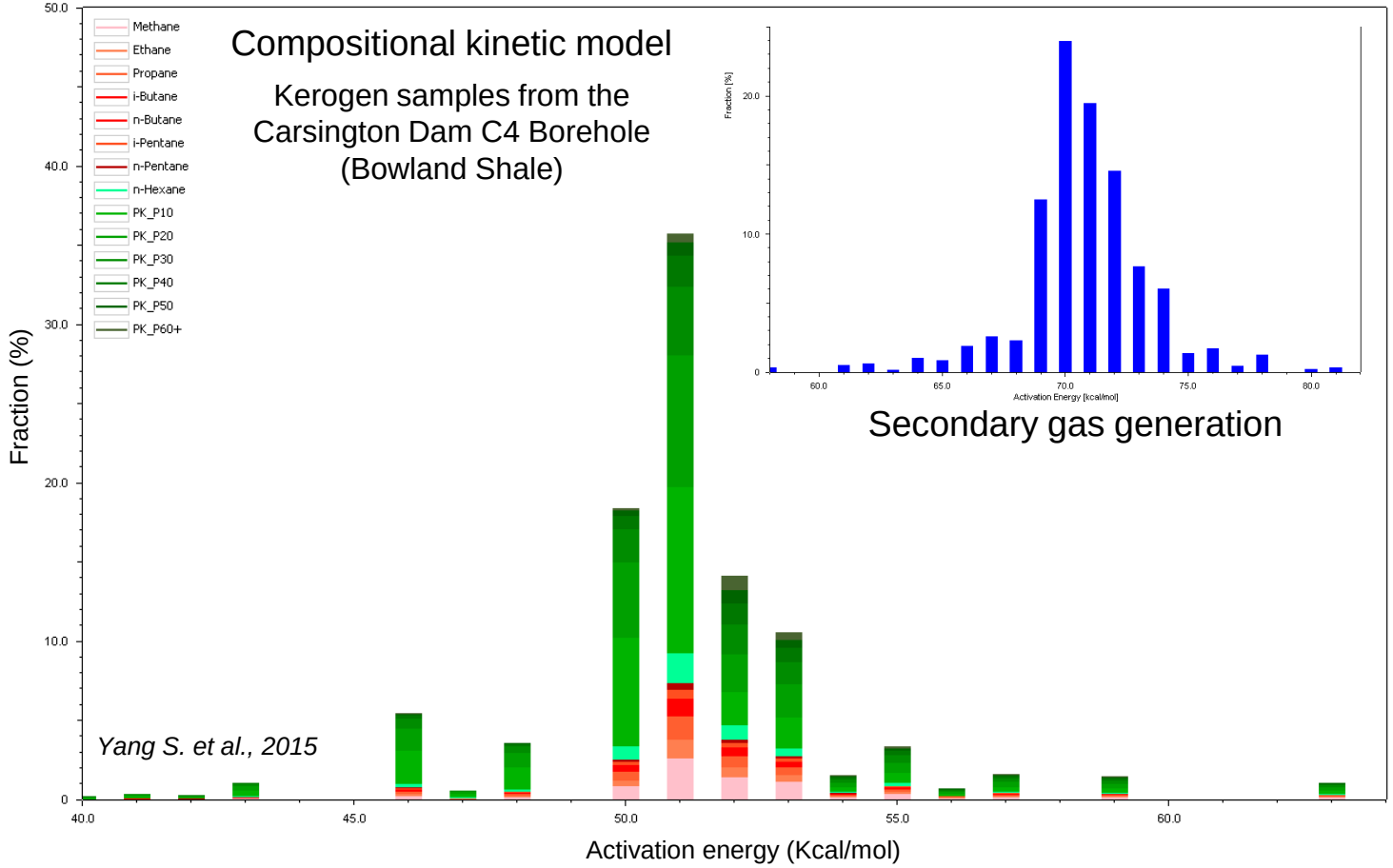


$$TOC\_0 = TOC/(1 - W * (HI/(1 - TR) - HI))$$ (Hantschel)

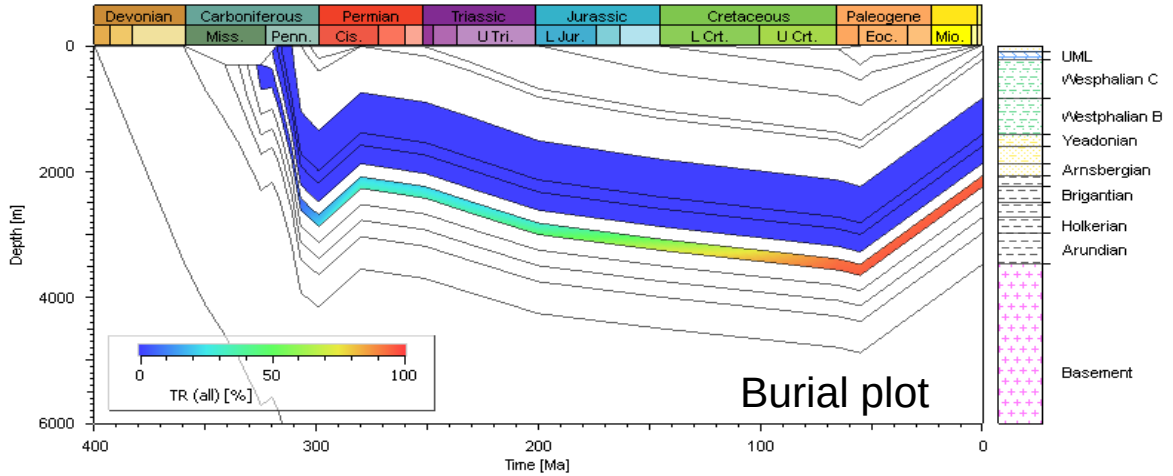
TOC_0 = initial TOC
TOC = Present day TOC
W = W factor (W=0.75 for Type II kerogen)
HI = Hydrogen index
TR = Transformation ratio

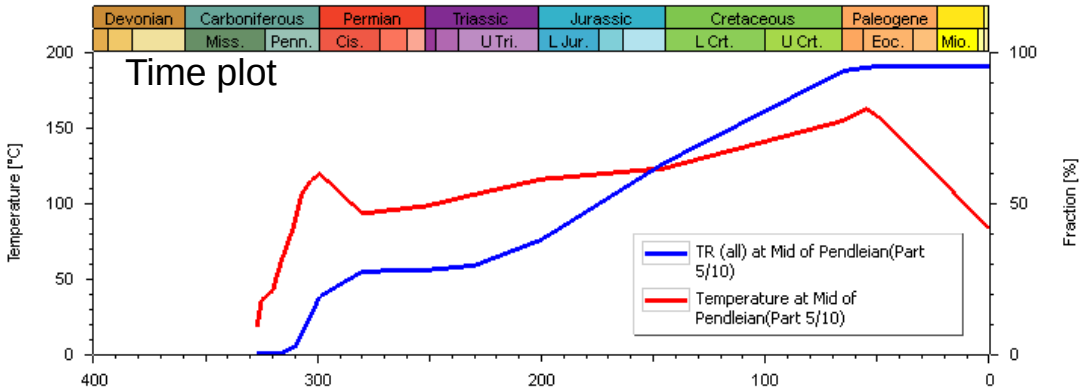


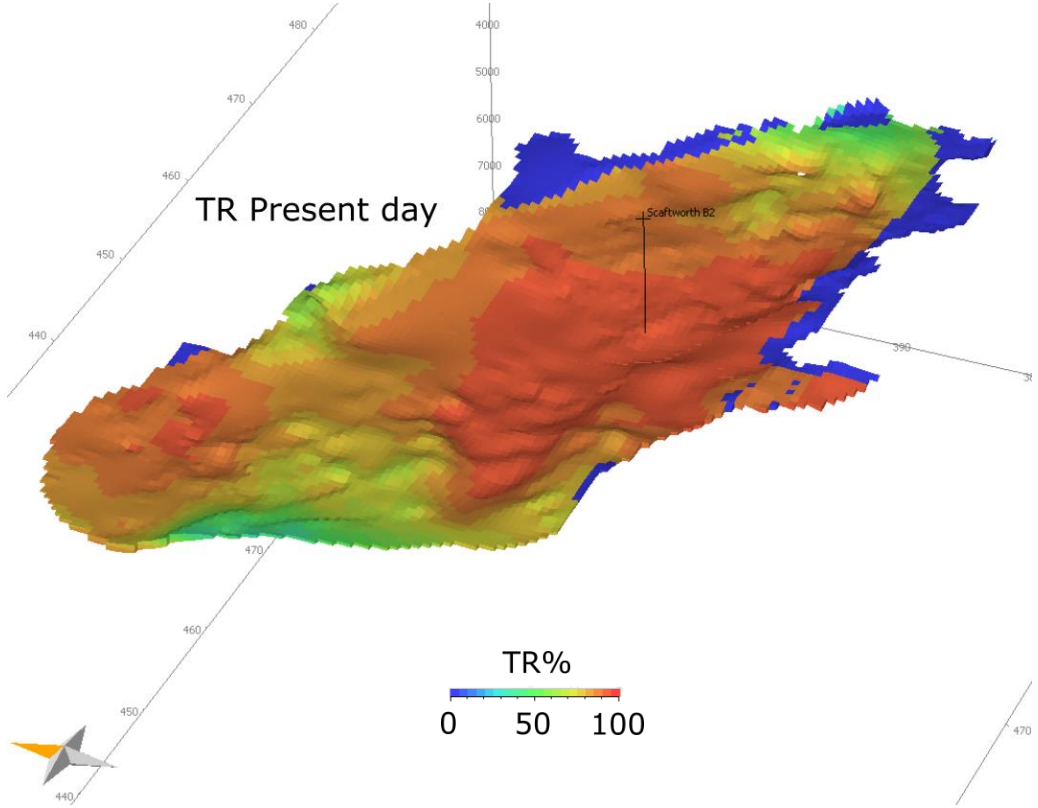
(modified after Fraser et al. 1990, Kirby et al. 2000)



Base case results (Bowland Shale Formation)







Oil (Billion barrels)			
Generation balance	**Accumulated in source rock**	**Free oil**	**Adsorbed oil**
24.20	**18.27***	**18.27**	**0.14**
Gas (Tcf)			
Generation balance	**Accumulated in source rock**	**Free gas**	**Adsorbed gas**
32.18	**25.45***	**23.45**	**1.89**

** Assuming 100% net to gross*

Uncertainties and sensitivity

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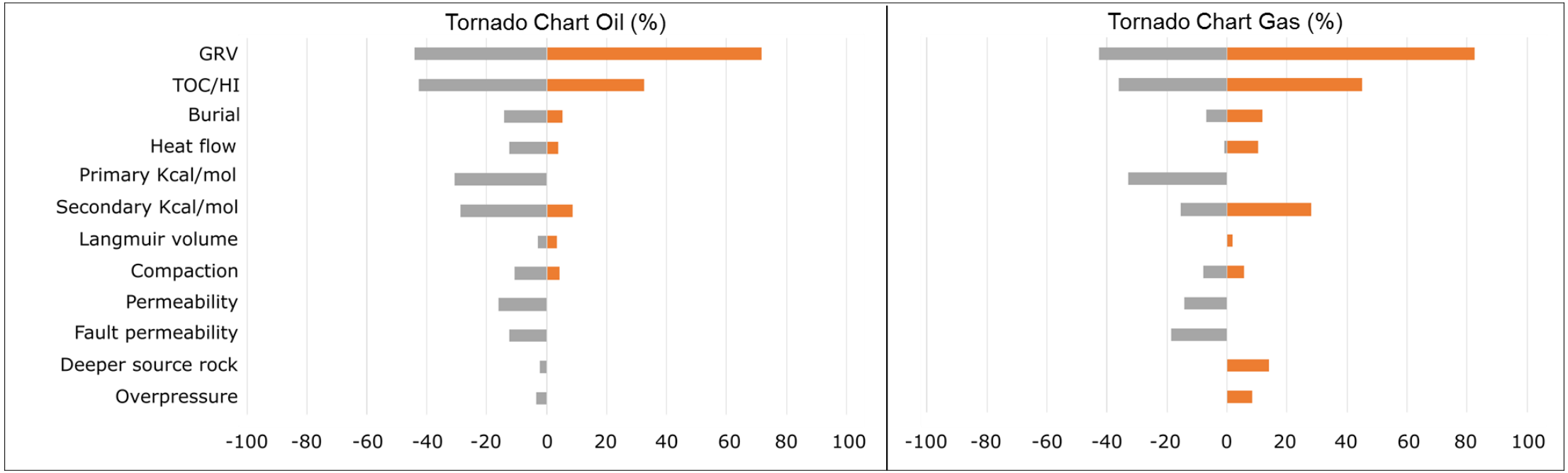
Kerogen amount			TR (primary/secondary gas)			Adsorbed gas				Liquid/vapour saturation		
GRV	TOC	HI	Burial	Heat flow	Kinetic reaction	Langmuir Volume (scf/ton)	Adsorbed component	Langmuir Pressure (MPa)	Adsorbed adjustment factor	Compaction	Permeability/ Mineralogy	Fault permeability

Deep source contribution	Overpressure

Parameters impacting on oil and gas accumulated within the source rock



- 3D data key to better define the GRV
- TOC/HI targeted core sampling programme
- Run kinetics on Gainsborough Trough Bowland Shale samples
- Bowland Shale Langmuir parameter

Sweet spot maps

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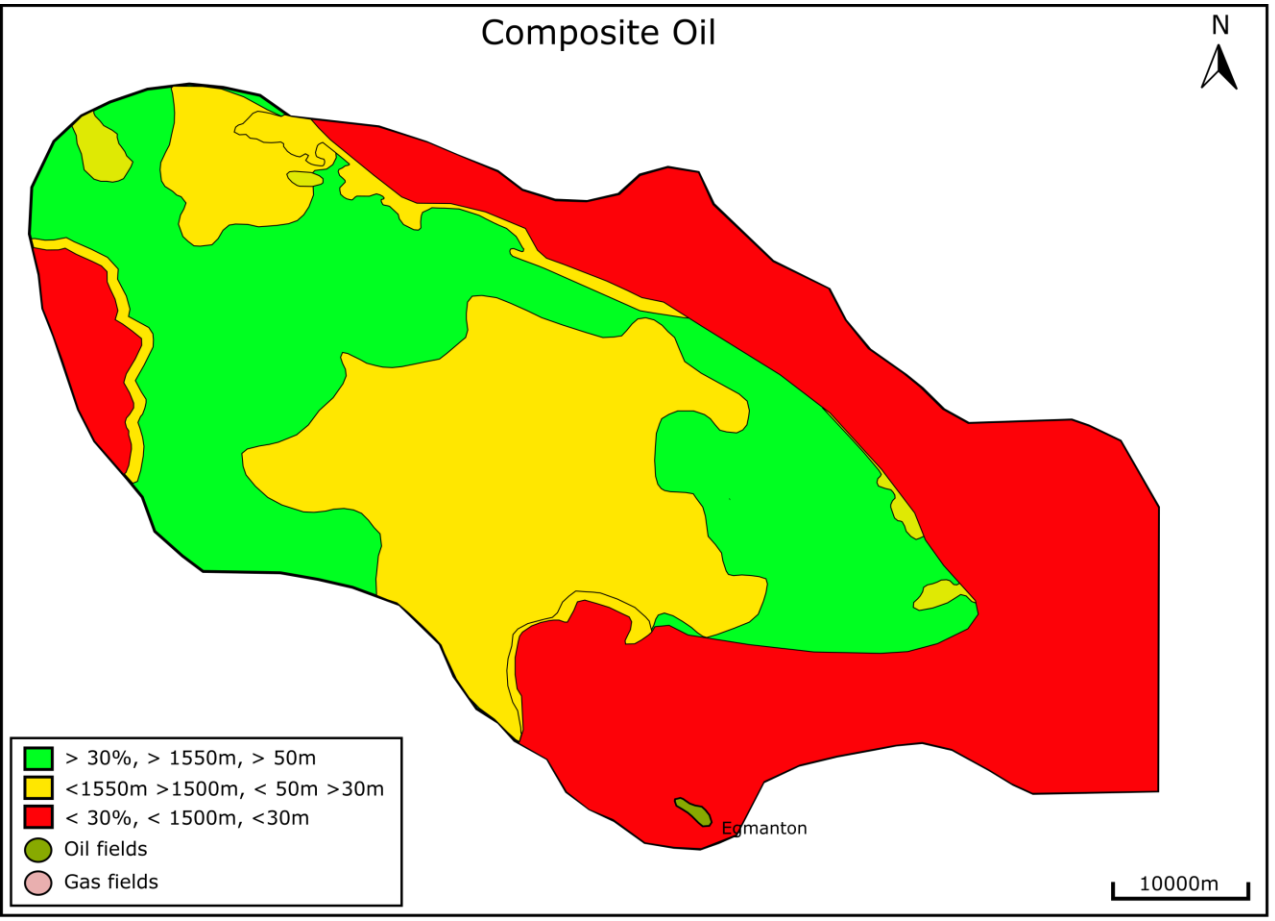

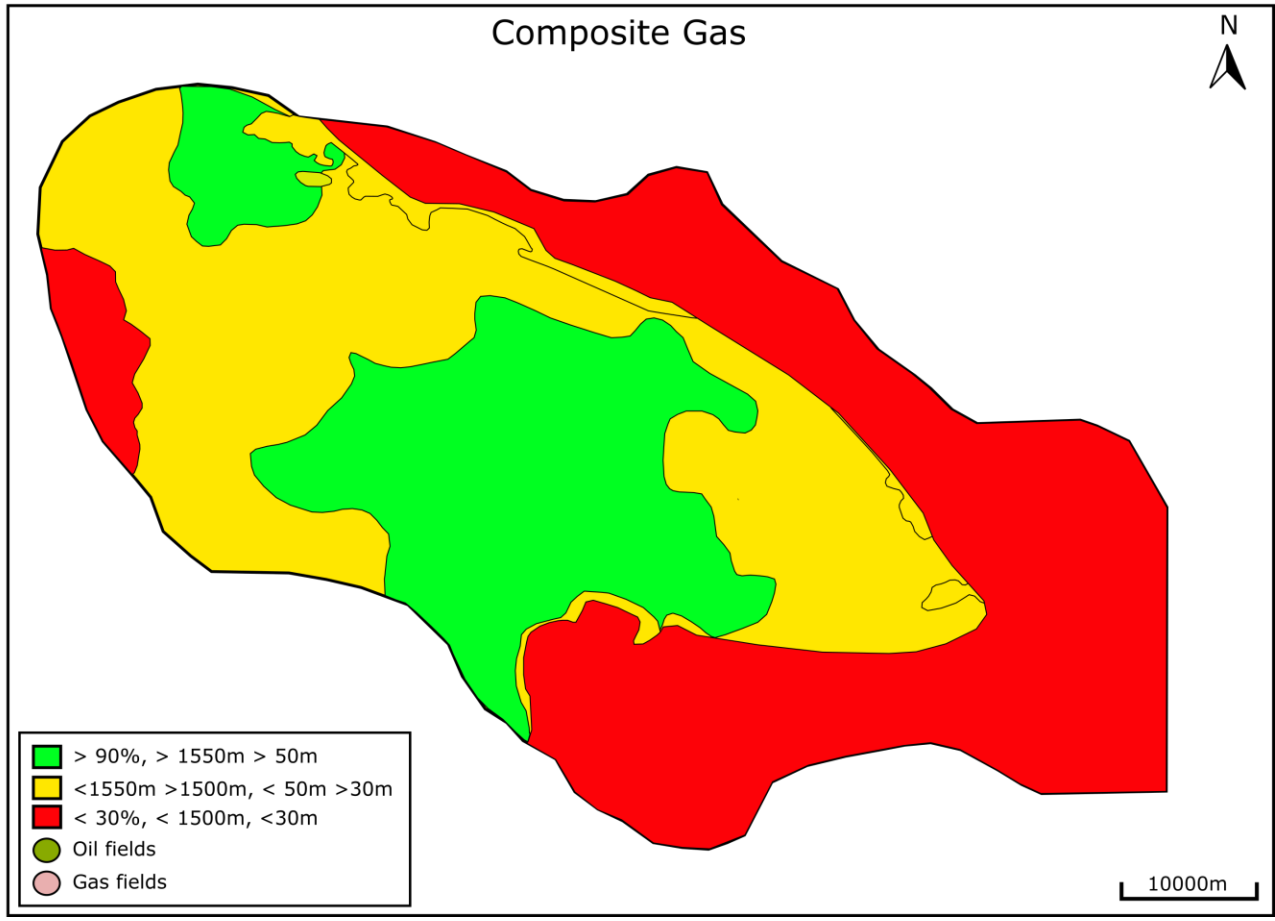

Note: Lateral migration up-dip beyond the eastern part of the Gainsborough Trough

Conclusions and learning

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Previous study (Andrews, BGS DECC 2013)

- The Gainsborough Trough was depicted as a shale gas system. No shale oil volumes assessed
- Modelled as a dry gas system historically
- Volume assessment made on standard static modelling

3D basin and petroleum system model

- The Gainsborough Trough yields potential for either shale oil and gas
- Better understanding of the hydrocarbon phase distribution within the source rock
- Better understanding of key parameters impacting on oil and gas accumulation and expulsion within the source rock

Future study

- Revise GRV based on future seismic
- Geochemical analysis on Gainsborough Trough Bowland Shale core samples
- High resolution sequence stratigraphy and facies analysis of the Bowland Shale
- Fracture system poorly understood due to the lack of core and borehole imaging data