Rift-Climax Deposition and Reservoir Architecture on the Hangingwall Dipslope of a Large Half-Graben; South Viking Graben, Northern North Sea*

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Abstract

The stratigraphic development of hangingwall depositional systems in rifts is poorly understood due to low preservation potential of associated deposits on low subsidence hangingwall dipslopes. In addition, boreholes tend to be located towards the footwall crests, updip of syn-rift hangingwall deposits. Existing tectono-stratigraphic models for rifts imply that; (i) hangingwall dipslopes are structurally simple during the late syn-rift (rift-climax) when activity focused on basin-bounding structures; and (ii) hangingwall depositional systems are characterised by shallow marine shorefaces fringing rotated fault blocks. In this study, subsurface data are used to investigate the controls on rift-climax turbidite systems on the hangingwall dipslope of a salt-influenced half-graben. During rifting, two normal faults developed on the hangingwall due to westwards tilting and gliding of cover strata above an underlying evaporite-rich detachment. Isochron mapping indicates; (i) initiation of activity along the central part of the easternmost fault, (ii) lengthening of the easternmost fault by lateral tip propagation and initiation of activity along the northern segment of the central fault, (iii) southwards propagation of the central fault and initiation of activity on the easternmost fault, and (iv) cessation of activity on all faults. Although seismic data is not of sufficient resolution to map individual depositional elements, well, core and biostratigraphic data are used to determine the control of gravity-driven normal faulting on syn-rift turbidite systems. Based on these data three main stratal units are identified, the oldest of which comprises thick, amalgamated turbidites, which are restricted to the hangingwall of the earliest, most basinward growth fault. The middle unit is more areally extensive than the underlying system, sealing the non-inactive basinward growth fault and extending upslope into the hangingwall of a now-active growth fault. The youngest unit is more sheet-like and was deposited when all growth faults were largely inactive and slope topography had been almost fully healed. This study demonstrates that changes in accommodation impact the distribution and architecture of syn-rift turbidite reservoirs. In addition, existing tectono-stratigraphic models of rift basin should be refined to recognise the importance of ductile detachment units at-depth and the impact these may have on hangingwall depositional systems.

Reference

Gawthorpe, R.L. and M.R. Leeder, 2000, Tectono-sedimentary evolution of active extensional basins: Basin Research, v. 12/3-4, p. 195-218.

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Acknowledgments:

Acknowledgments:

Talk Outline

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- Geological setting
- Syn-rift structural evolution
- Syn-rift sedimentology and hangingwall stratigraphic architecture
- Depositional system response to normal faulting
- Implications and conclusions

Rationale I – Rift basin models

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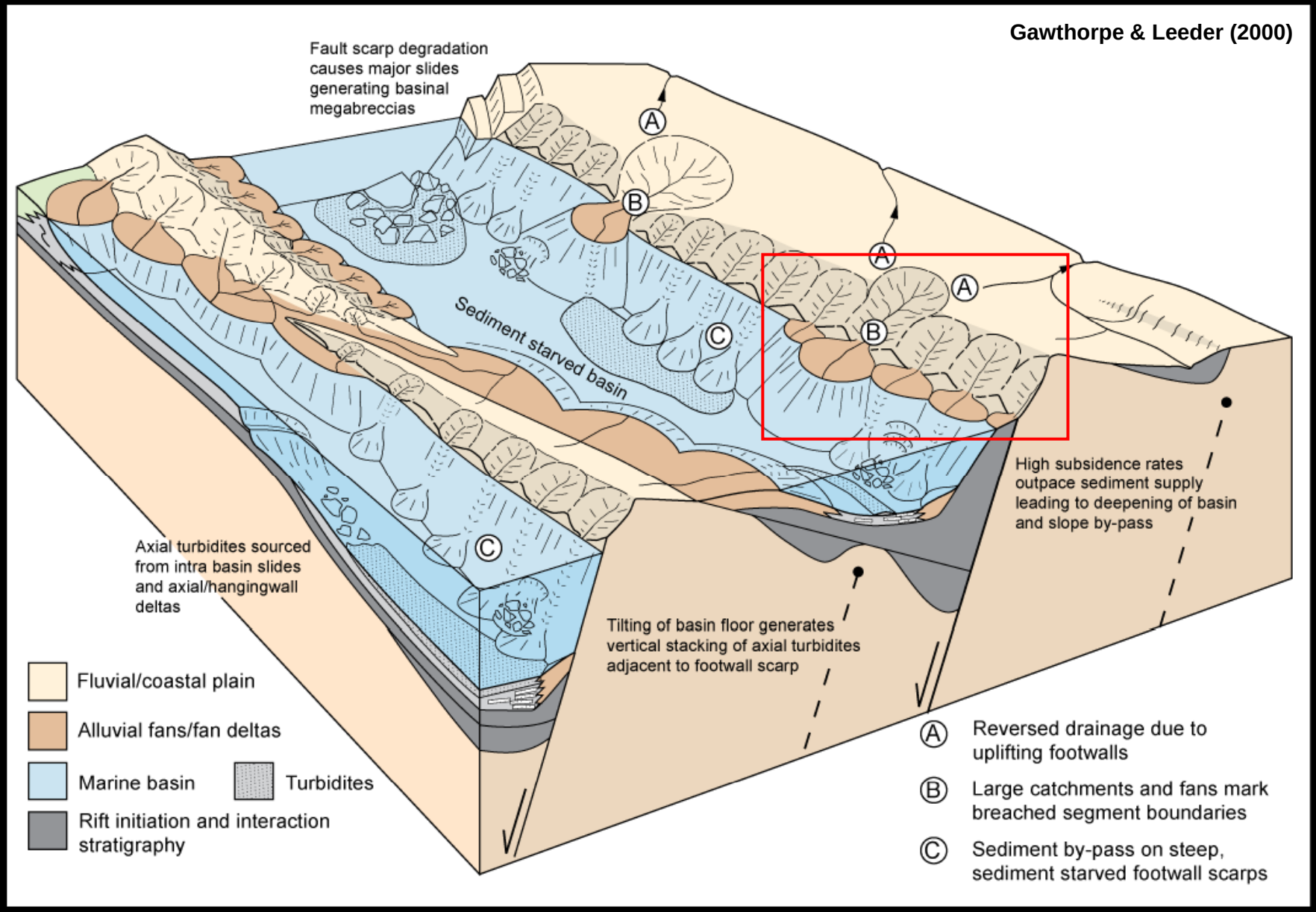

Rationale II - Footwall-derived depositional systems

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Badwater and associated fans, Death Valley, USA
(photos courtesy of Rob Gawthorpe)

Rationale III – Hangingwall dipslope systems

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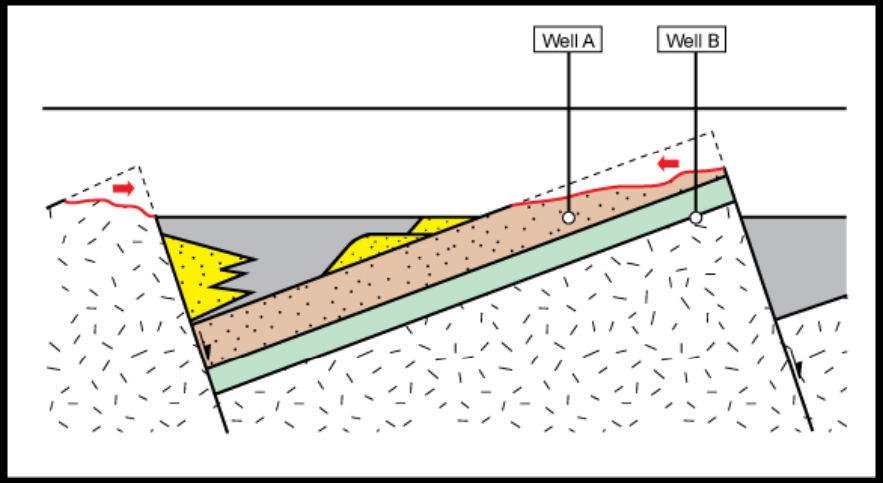
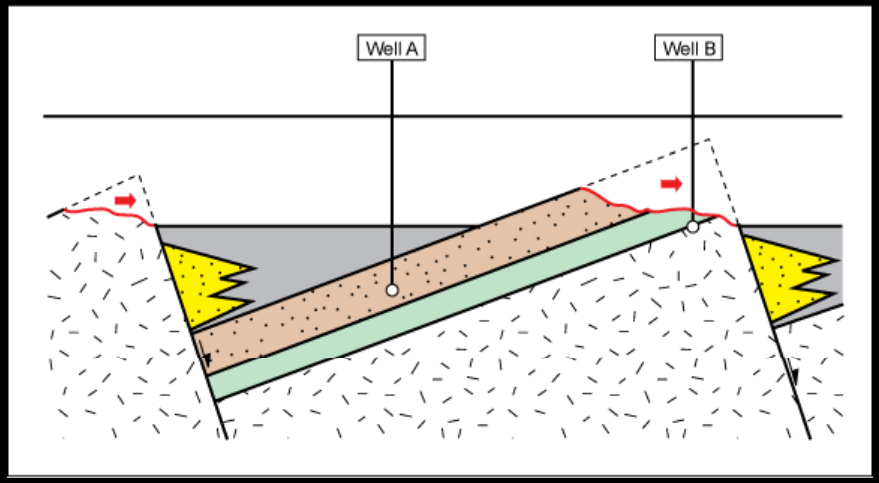
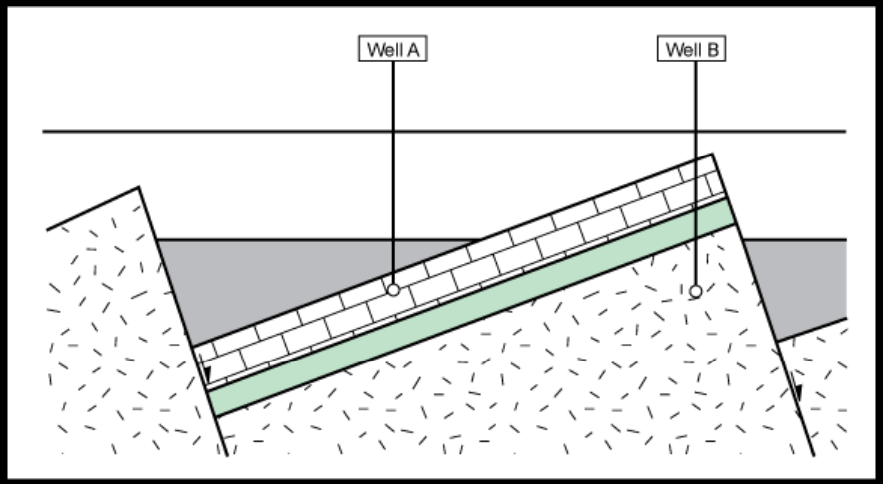
(i) Location of 'pre-rift focused' wells



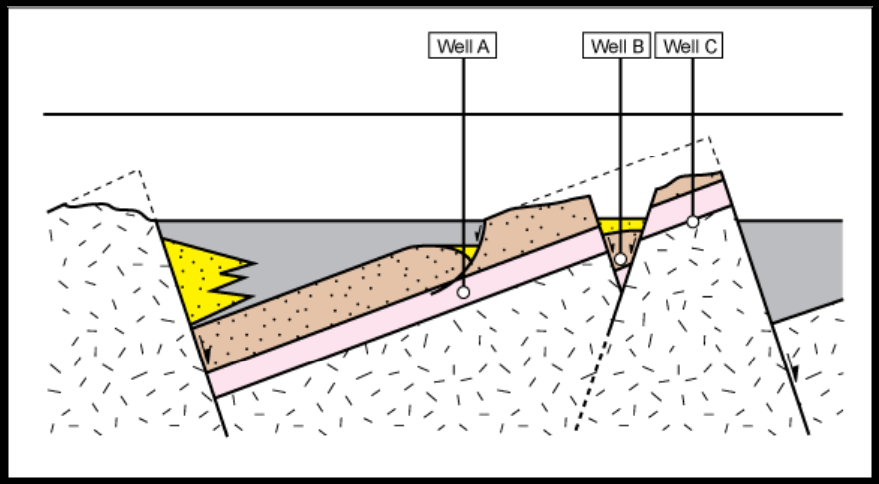
(ii) Preferential sediment supply to hangingwall



(iii) Low sediment yield due to pre-rift lithologies



(iv) Local sediment depocentres on hangingwall…



Structural Setting

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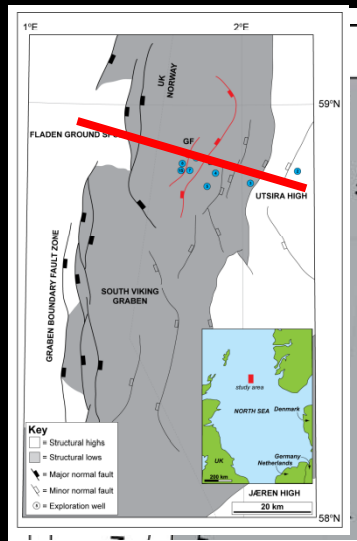

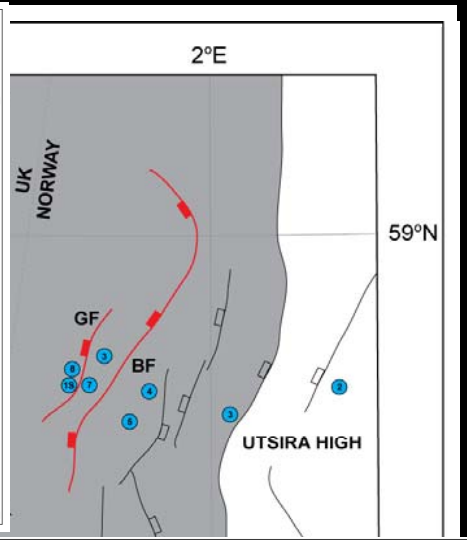

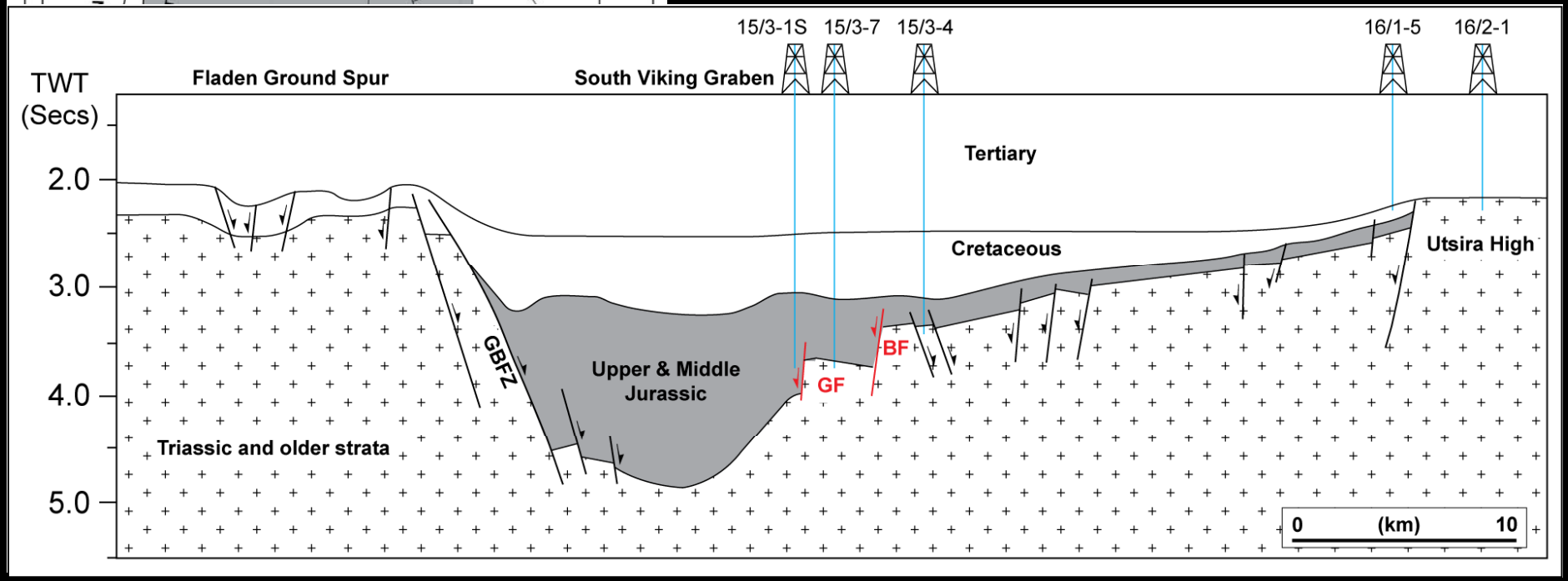

Stratigraphic Framework

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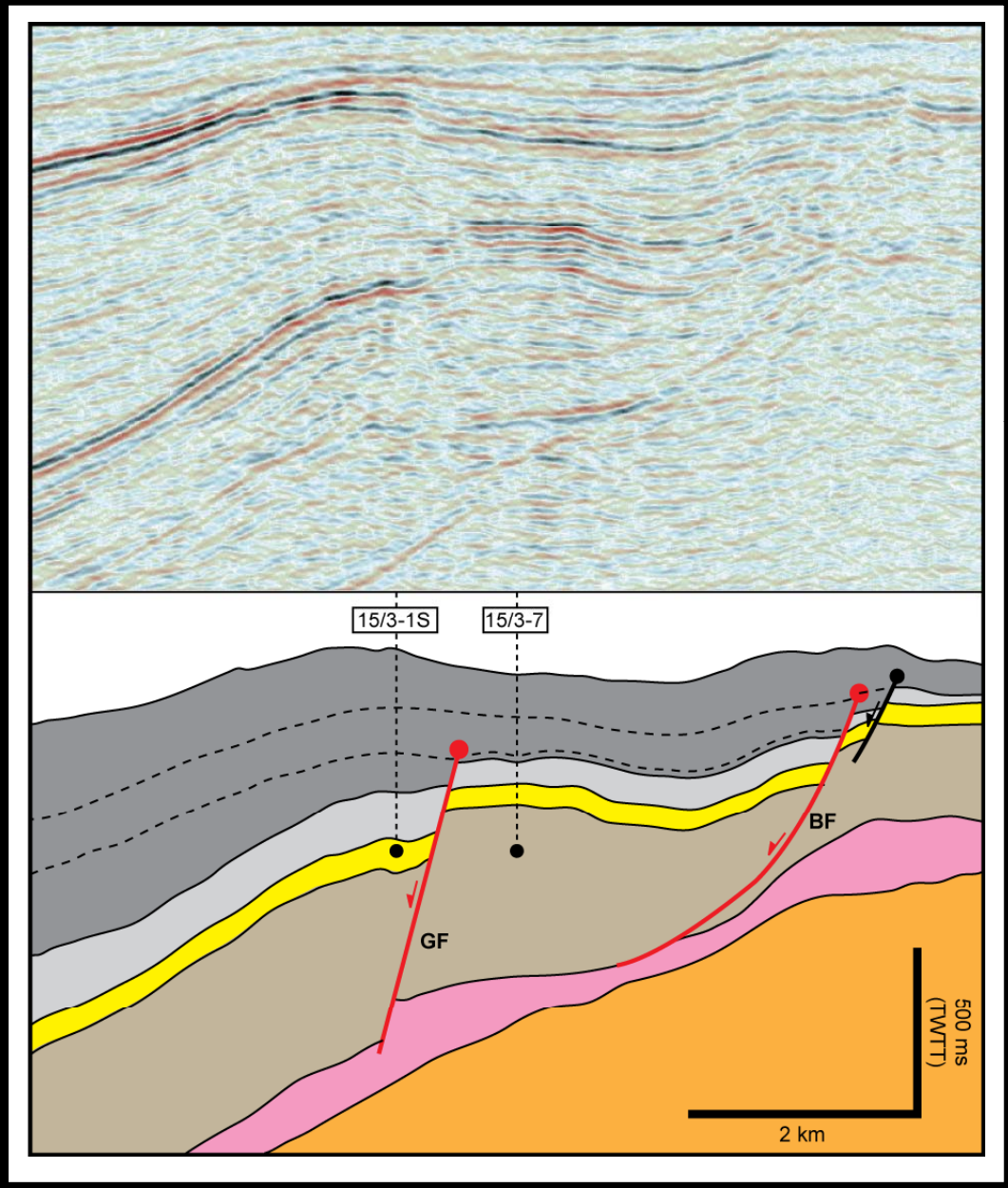
System	Series	Group	Formation	Tectono-stratigraphic significance	
Cret.	Upr.	Cromer Knoll	Rødby	post-rift	
			Sola		
	Lwr.		Åsgard		
Jurassic	Upr.	Viking	Draupne	syn-rift	Unit 3
			Heather		Unit 2
	Mid.	Brent	Hugin		Unit 1
			Sleipner	pre-rift	supra-detachment rafts
Triassic		Hegre	Skagerrak		
			Smith Bank		
Permian	Upr.	Zechstein			detachment
	Lwr.	Rotligendes	Auk		sub-detachment 'basement'



Unit 1 – Rift-Initiation

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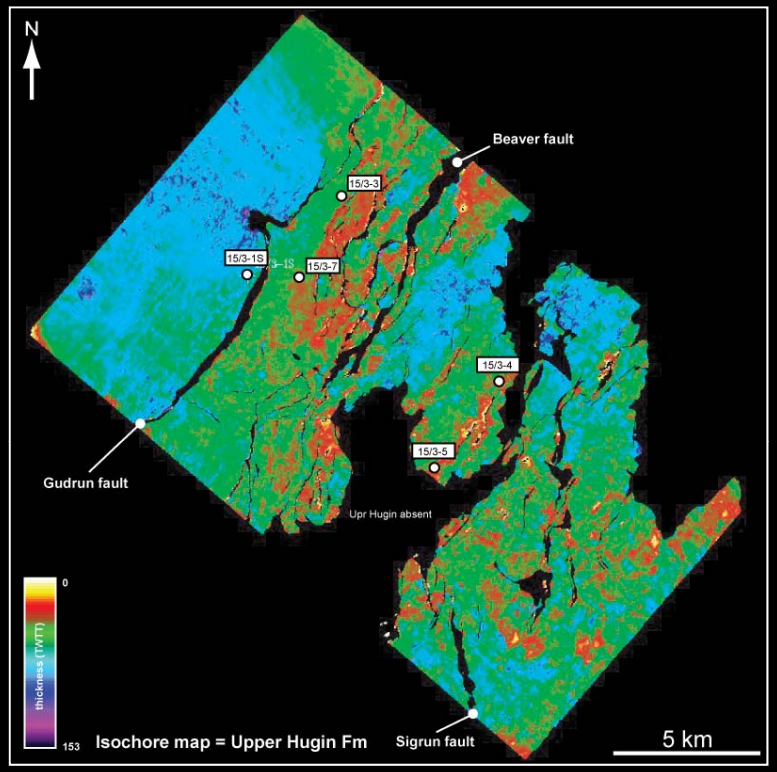

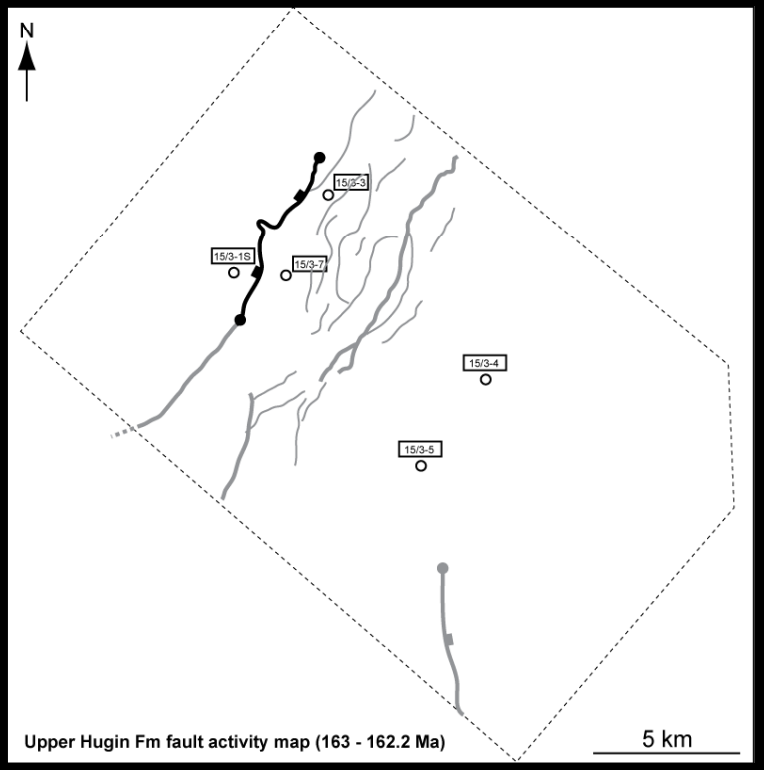

Stratigraphic Units	Significance
Shetland Gp	Post-rift
Draupne Fm	Late syn-rift
Heather Fm	
Hugin Fm	Early syn-rift
Sleipner Fm	Pre-rift "rafts"
Smith Bank & Skagerak Fms	
Zechstein Gp	Mobile detachment

Unit 2 – Lower Rift-Climax

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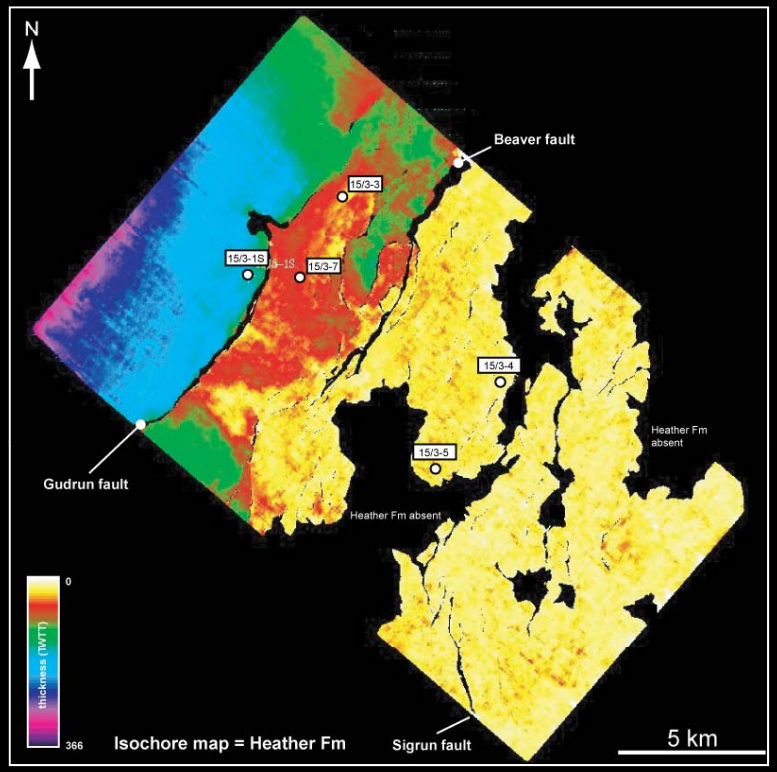

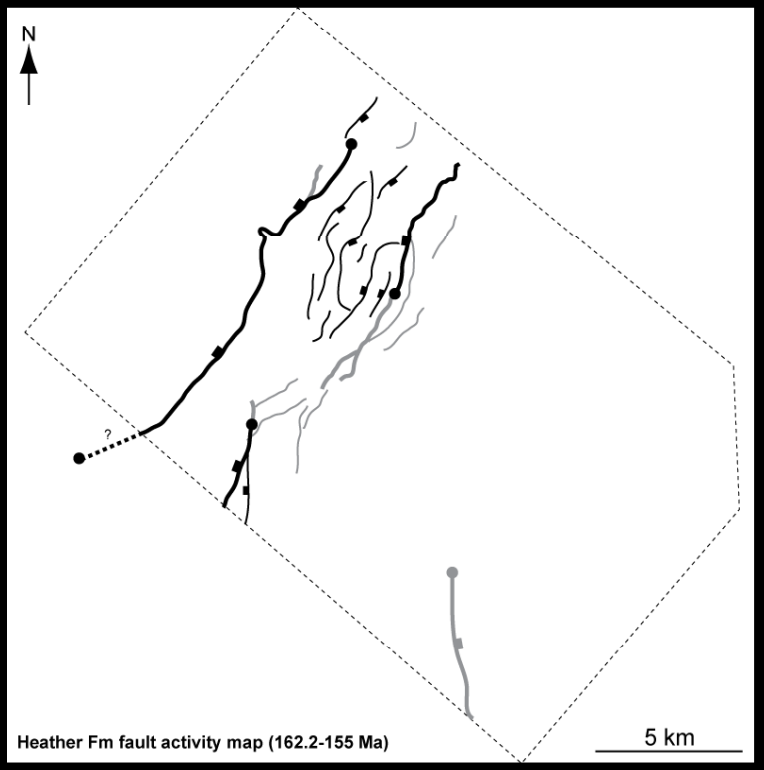

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Heather Fm	
Hugin Fm	Early syn-rift
Sleipner Fm	Pre-rift "rafts"
Smith Bank & Skagerak Fms	
Zechstein Gp	Mobile detachment

Unit 3 – Upper Rift-Climax

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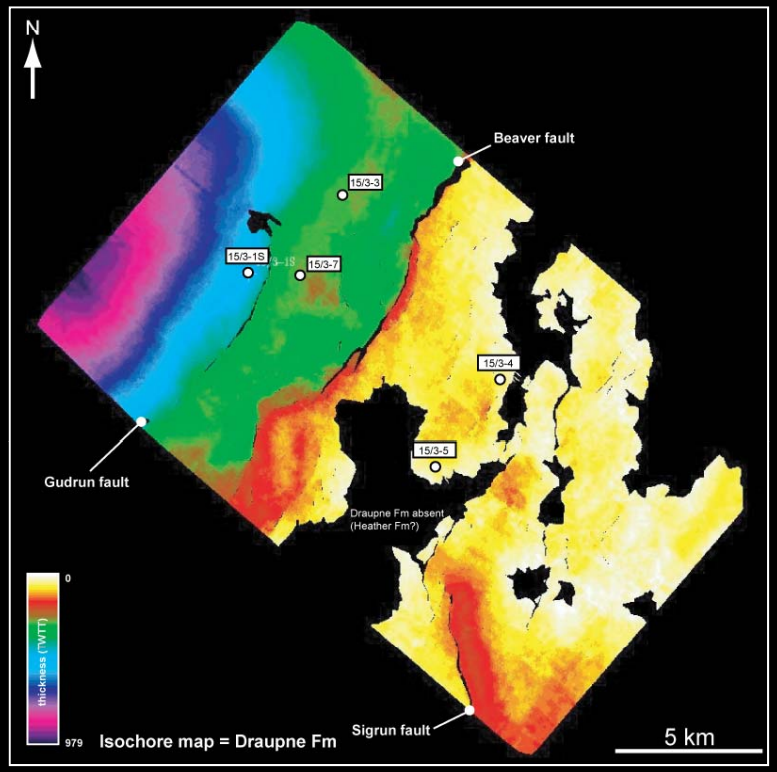

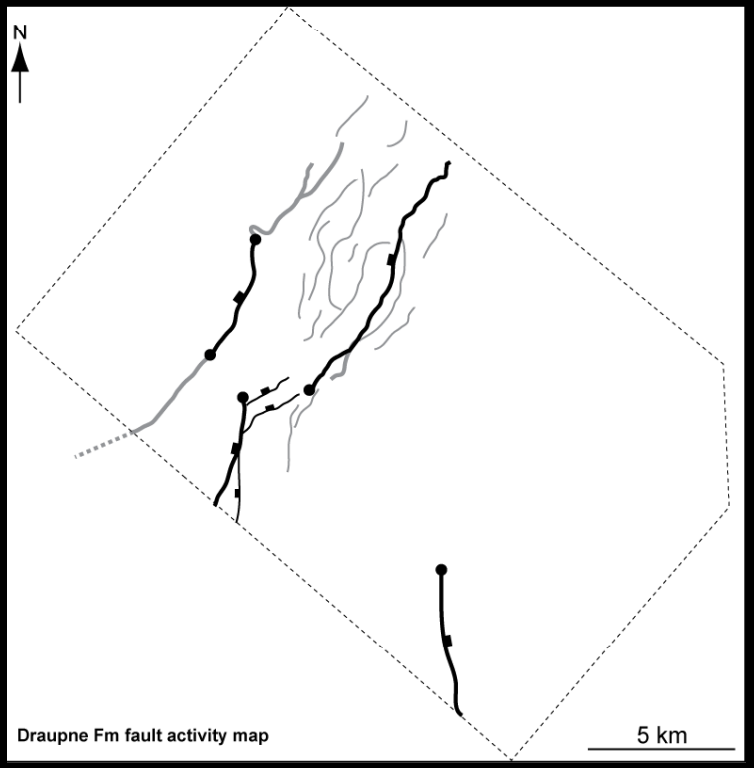

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Sleipner Fm	Pre-rift "rafts"
Smith Bank & Skagerak Fms	
Zechstein Gp	Mobile detachment

Structural evolution

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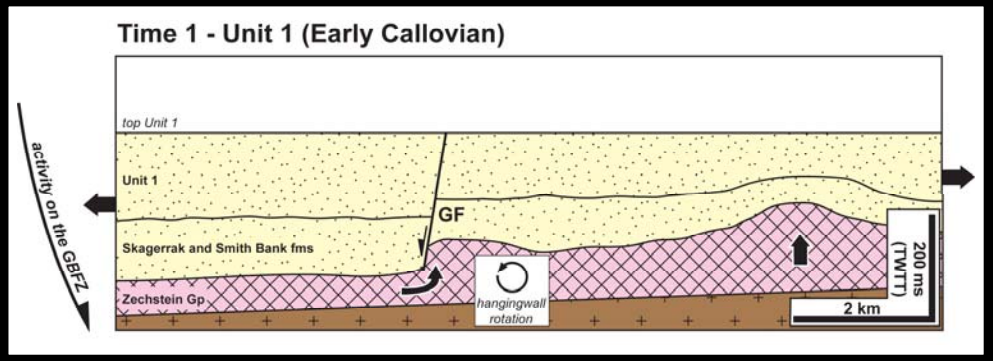

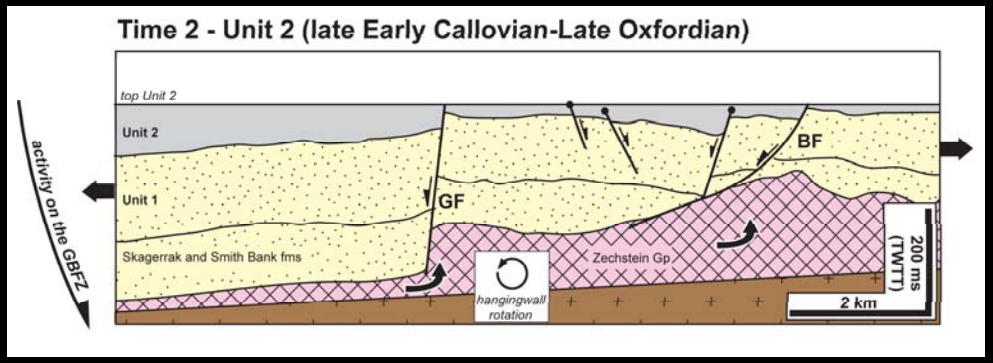

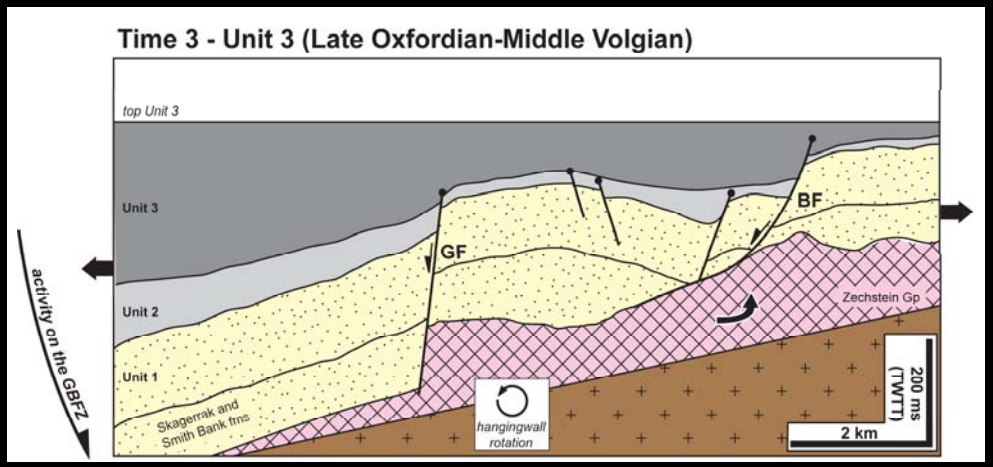

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Triassic		Hegre	Skagerrak		
			Smith Bank		
Permian	Upr.	Zechstein			detachment
	Lwr.	Rotliegendes	Auk		sub-detachment 'basement'

Syn-Rift Stratigraphic Architecture

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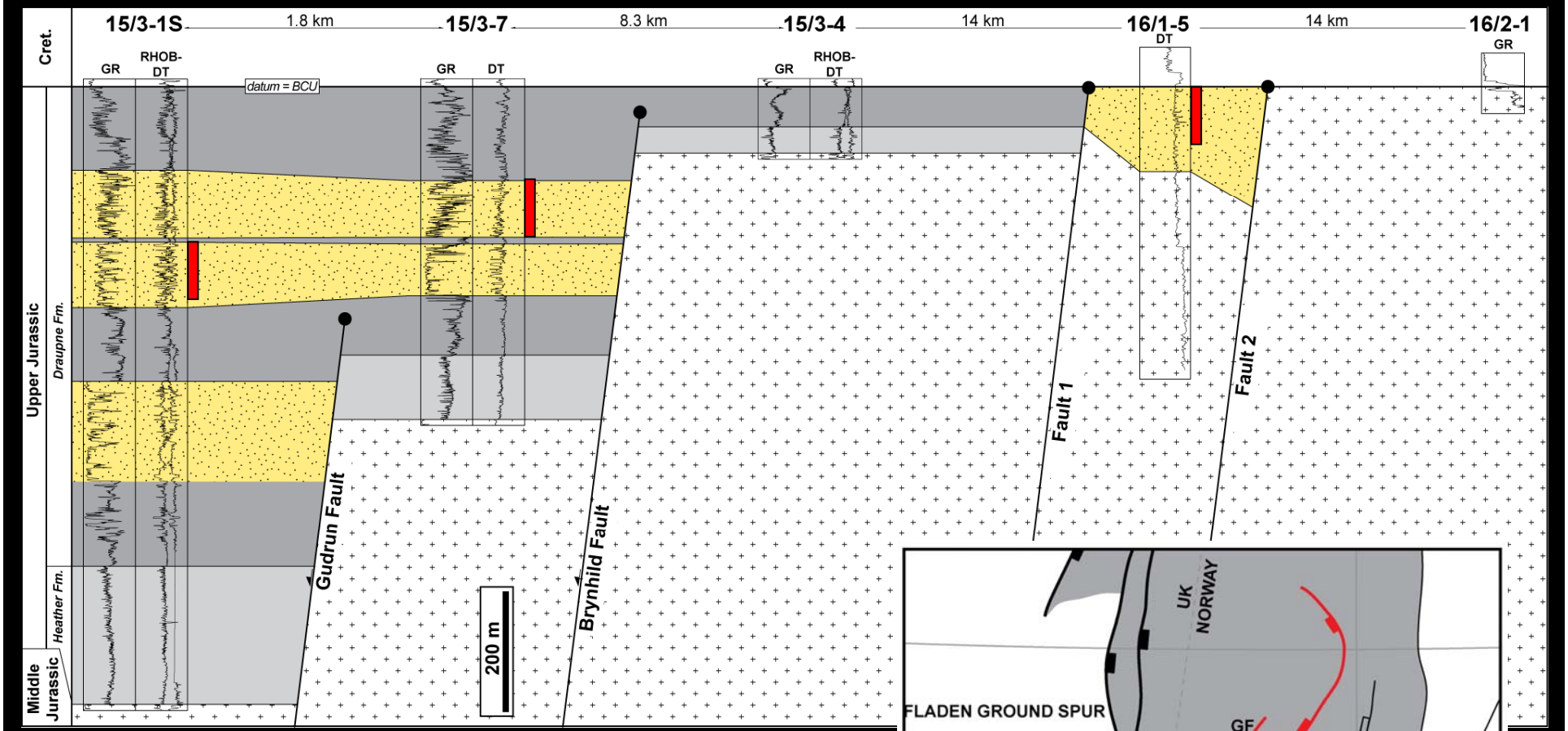

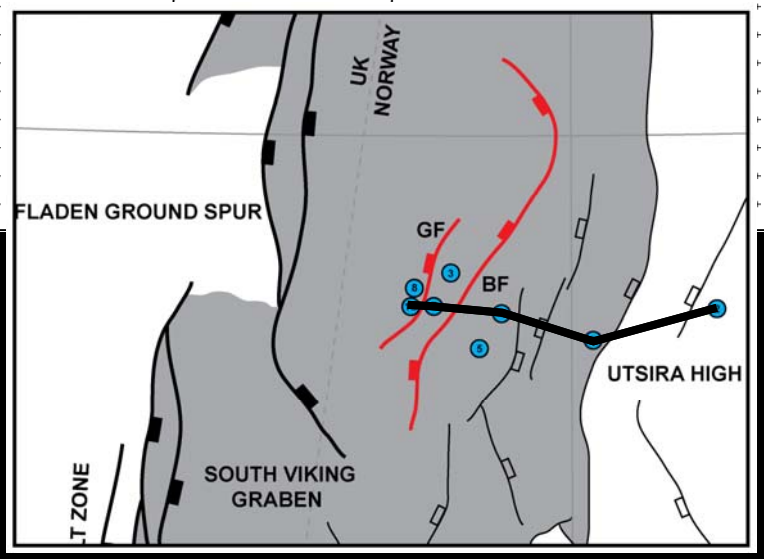

Updip Syn-rift Sedimentology

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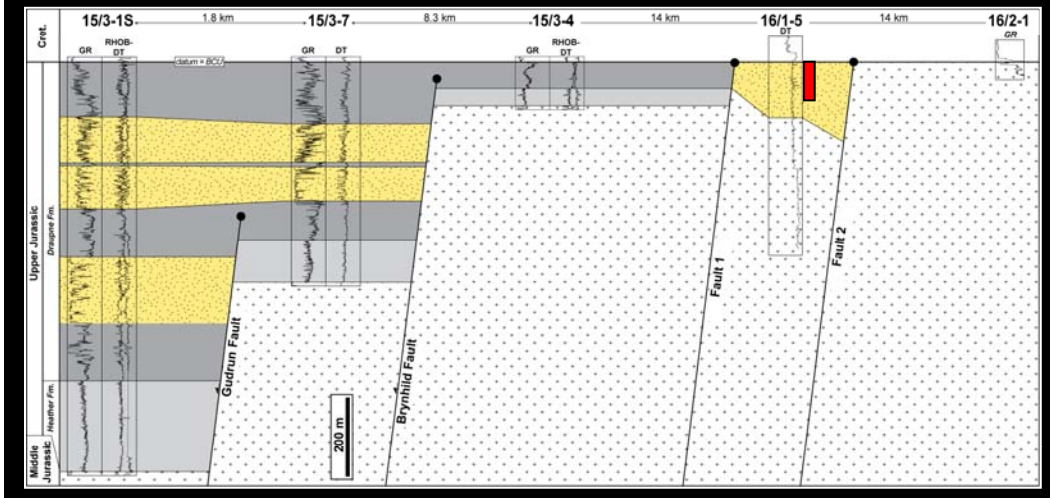

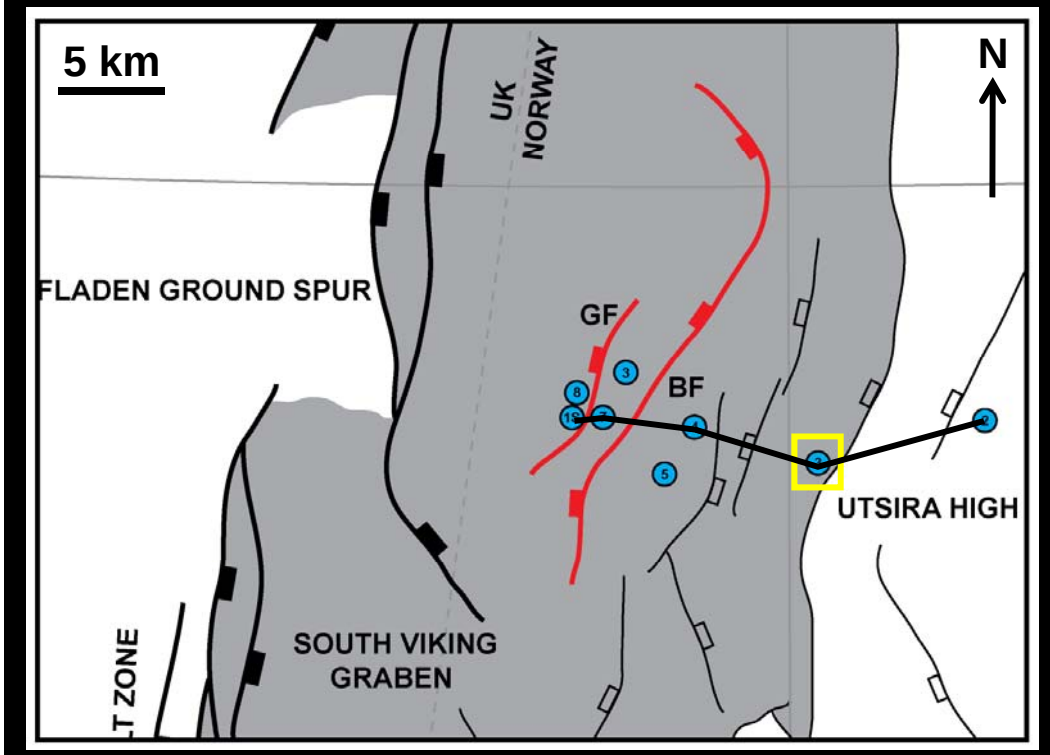

Downdip Syn-rift Sedimentology

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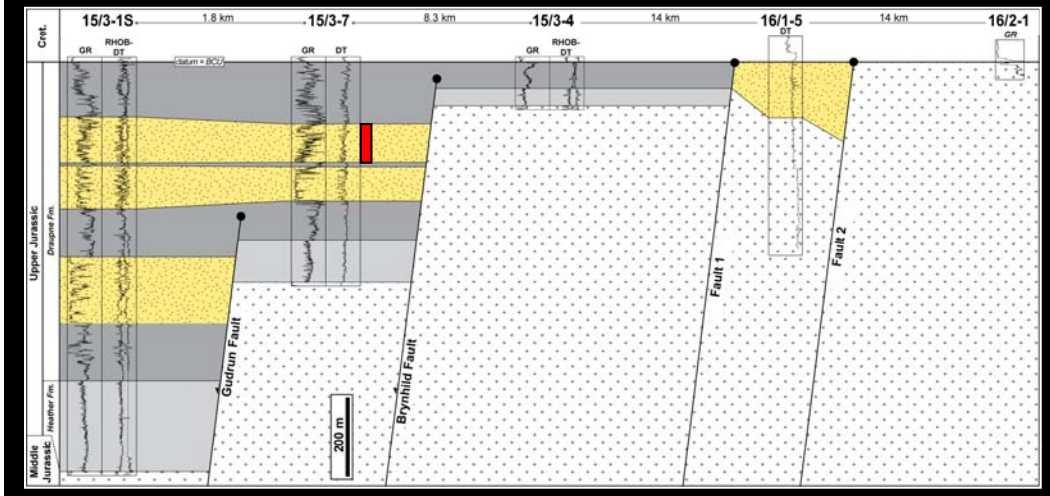

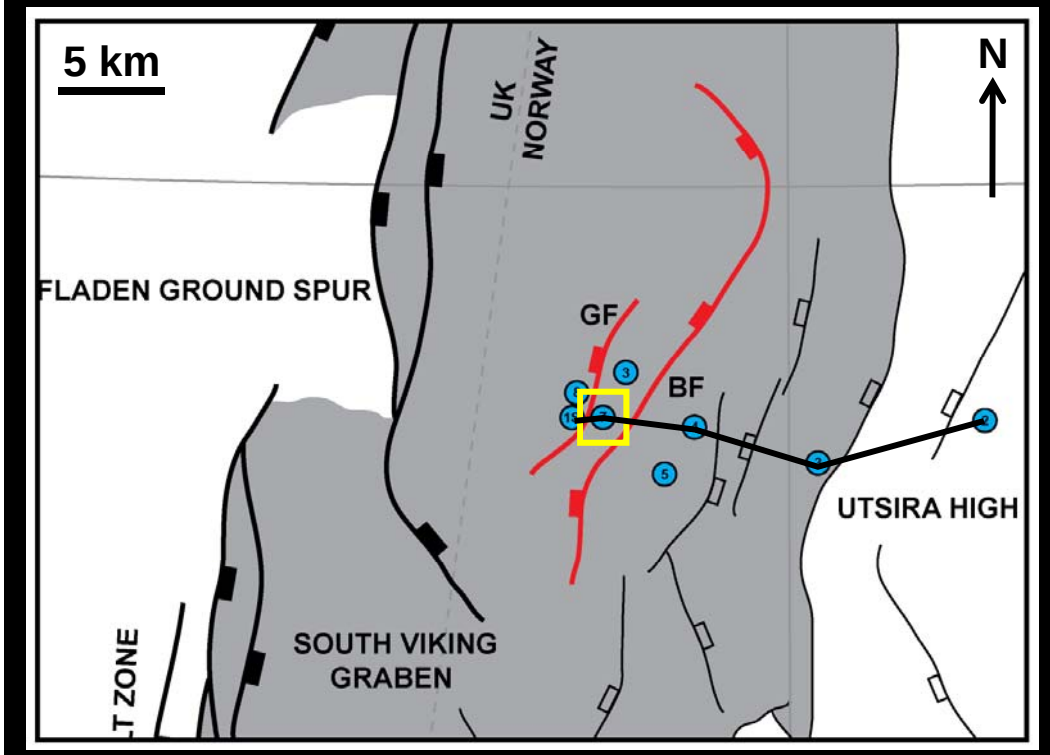

Syn-rift Architecture and Seismic Expression

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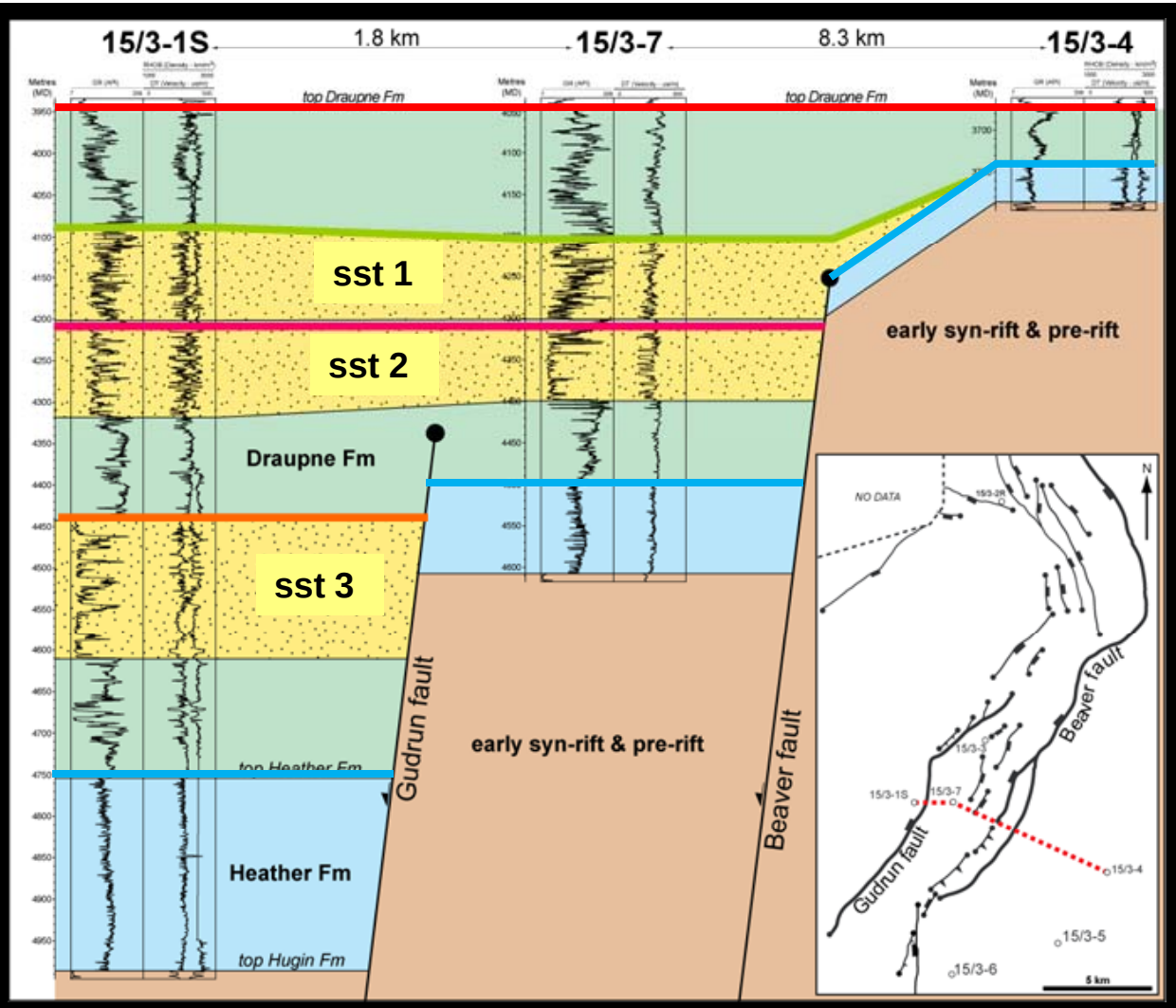

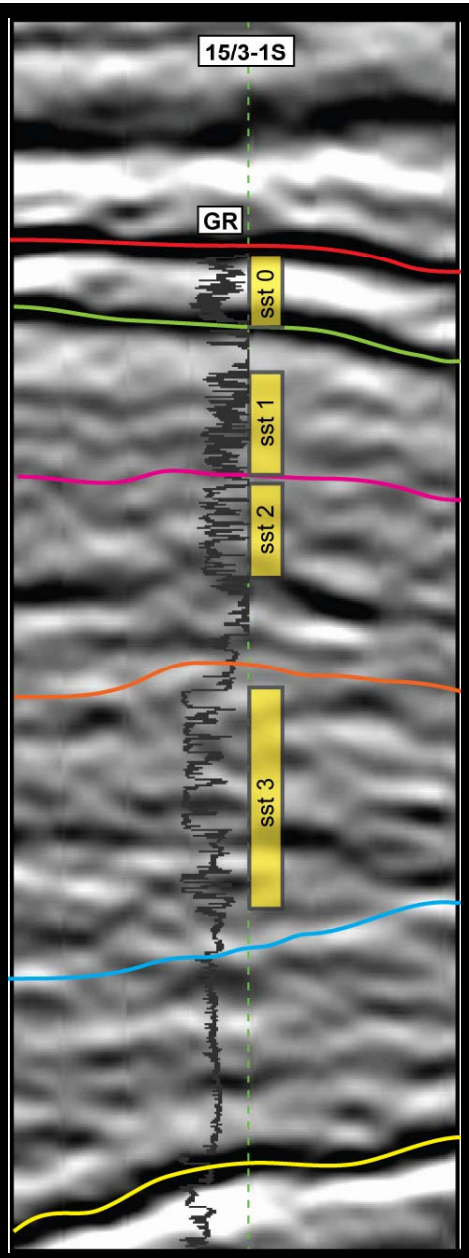

Palaeogeography I - Callovian

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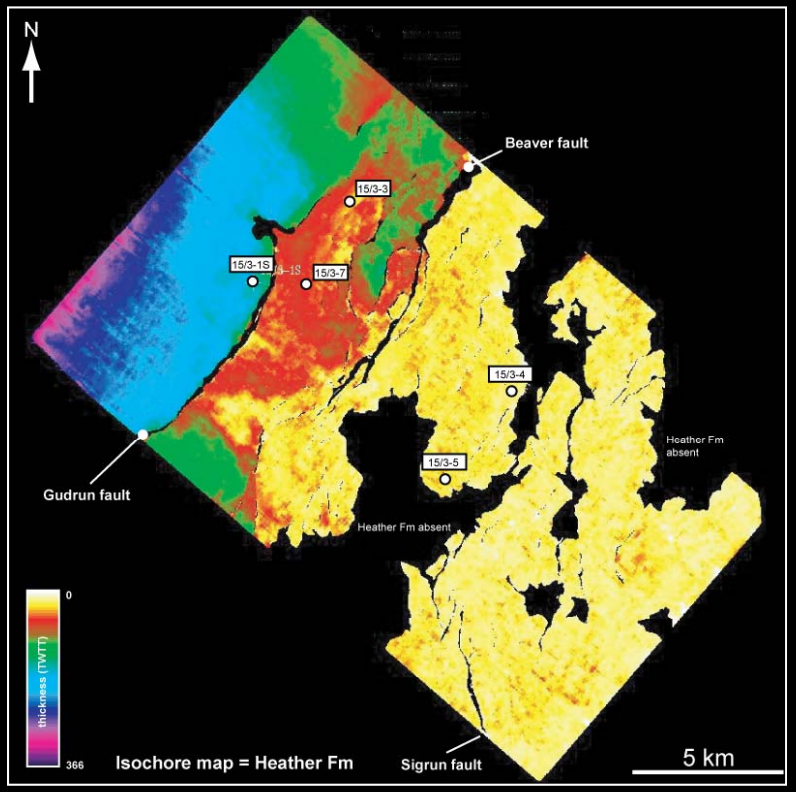

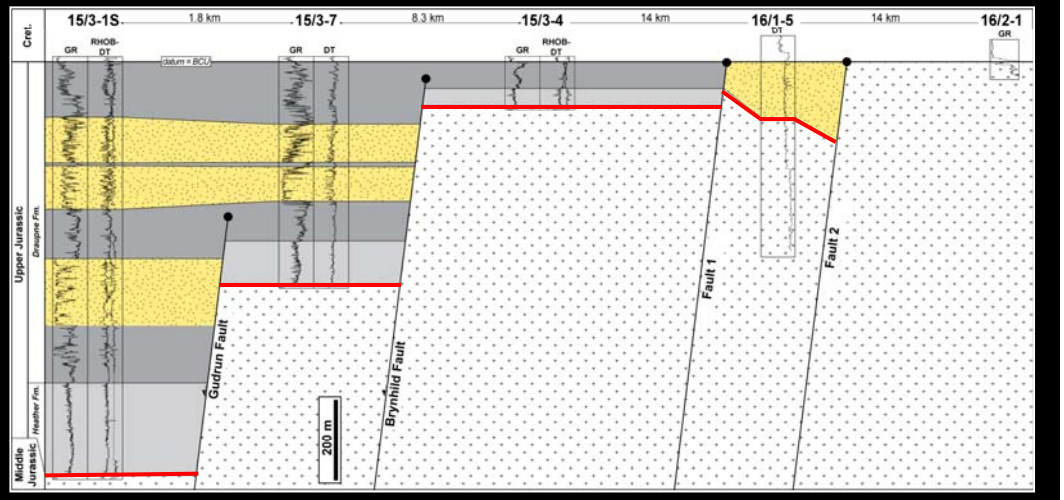

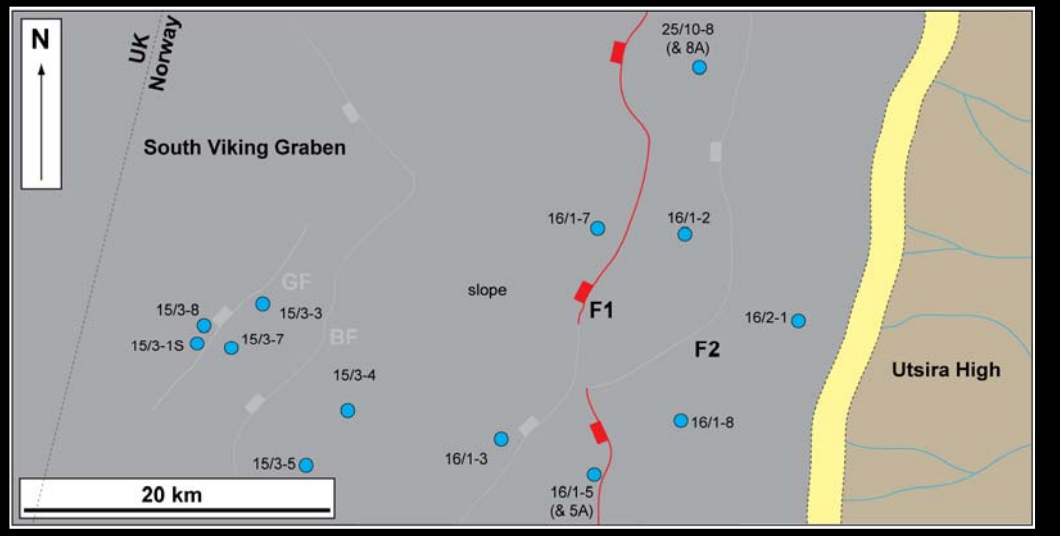

Palaeogeography II - Oxfordian

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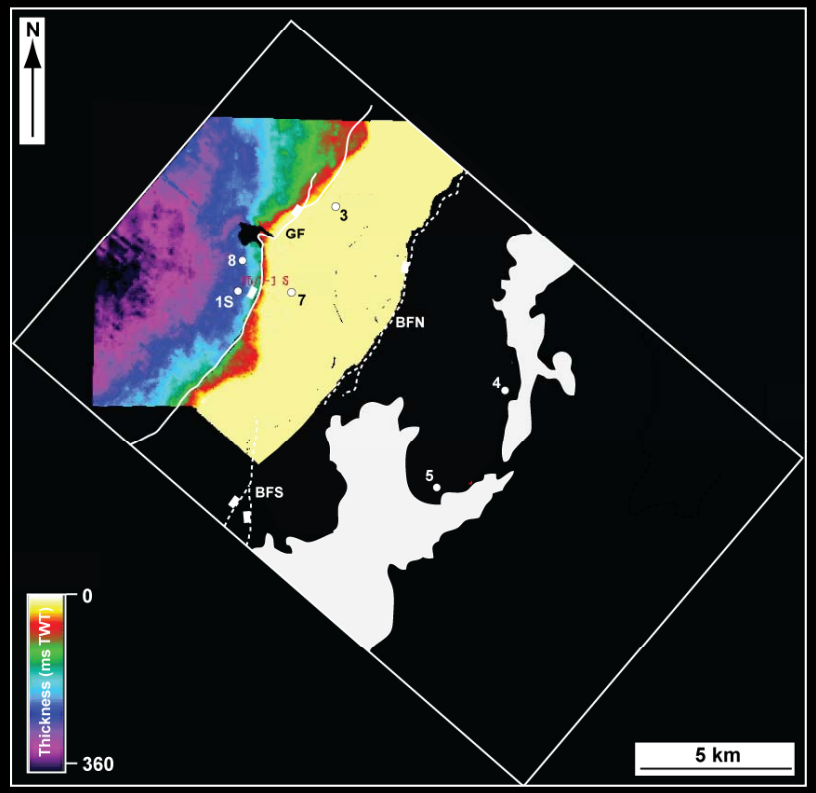

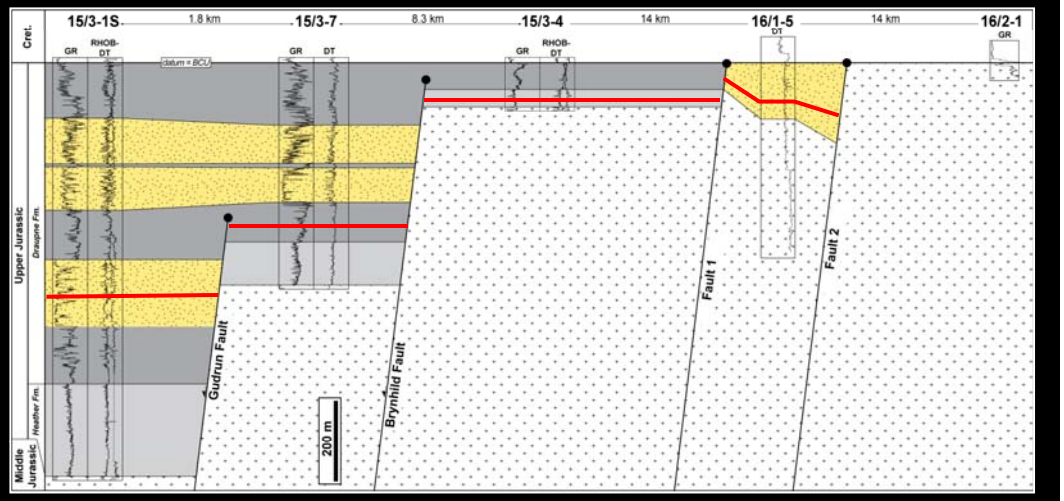

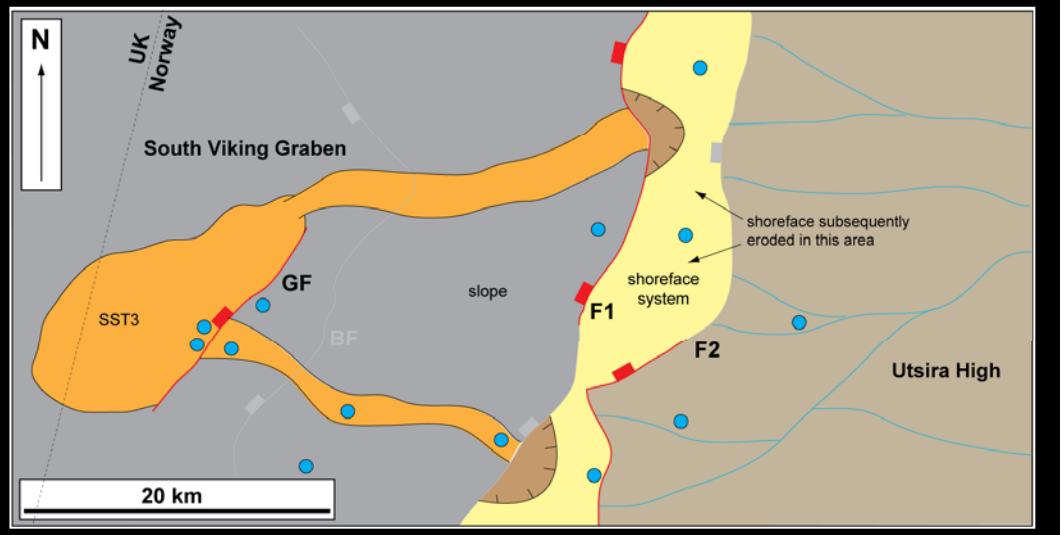

Palaeogeography III - Kimmeridgian

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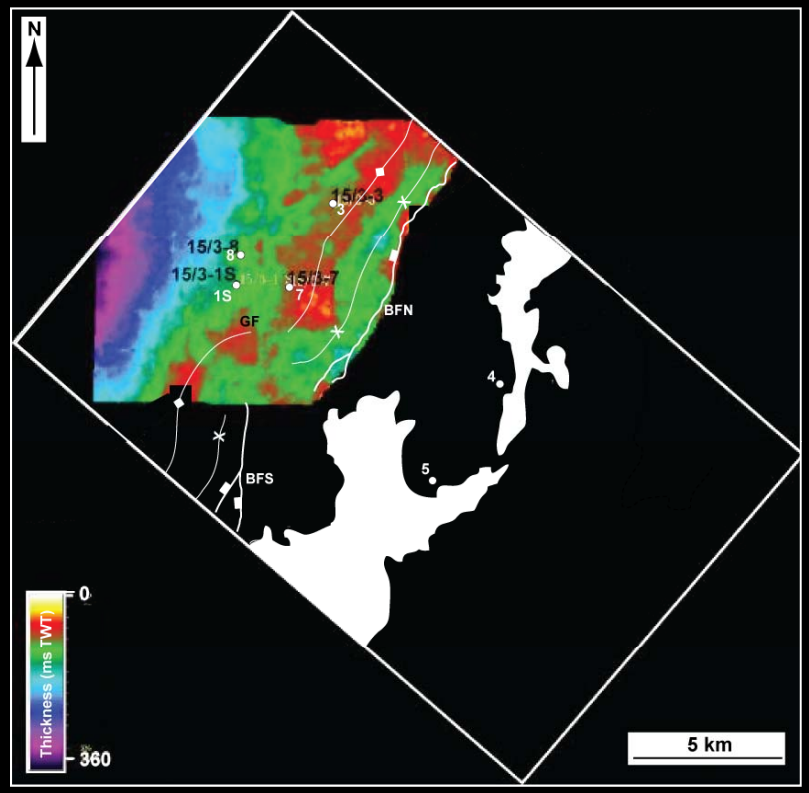

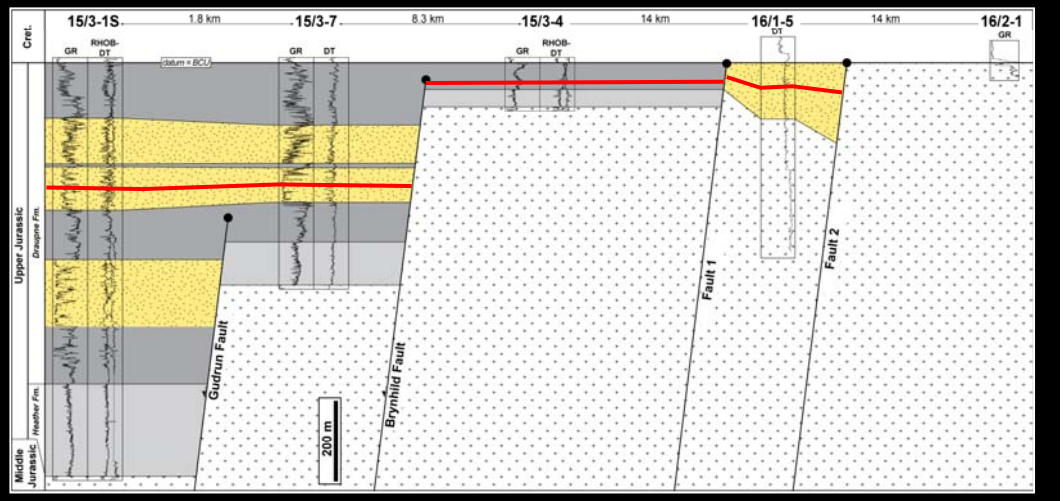

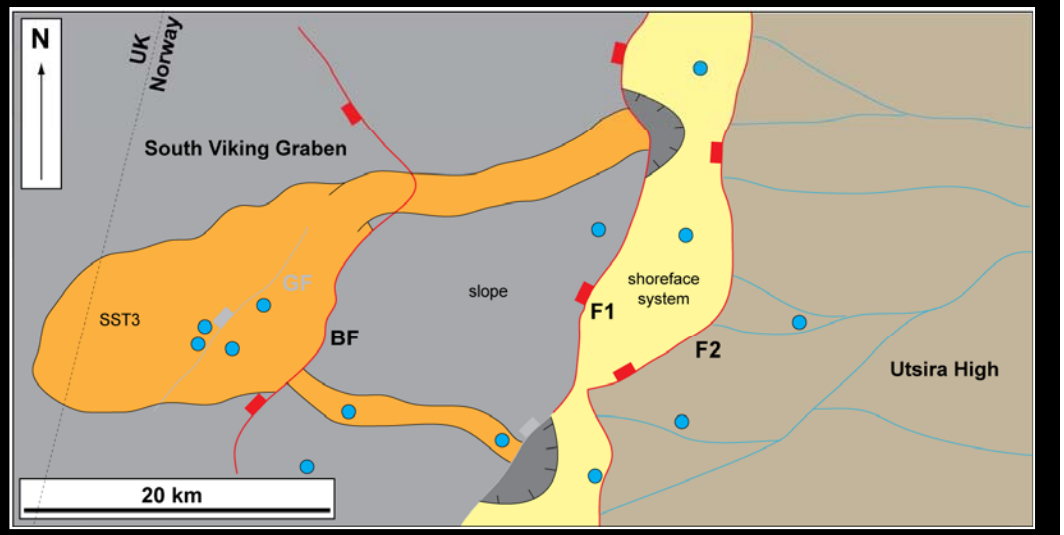

Palaeogeography IV - Volgian

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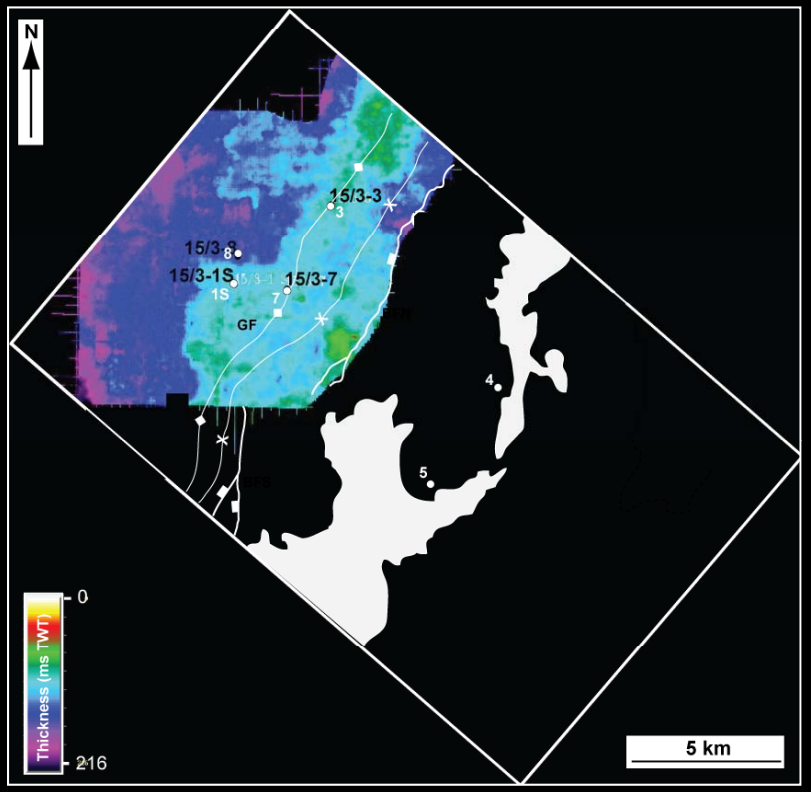

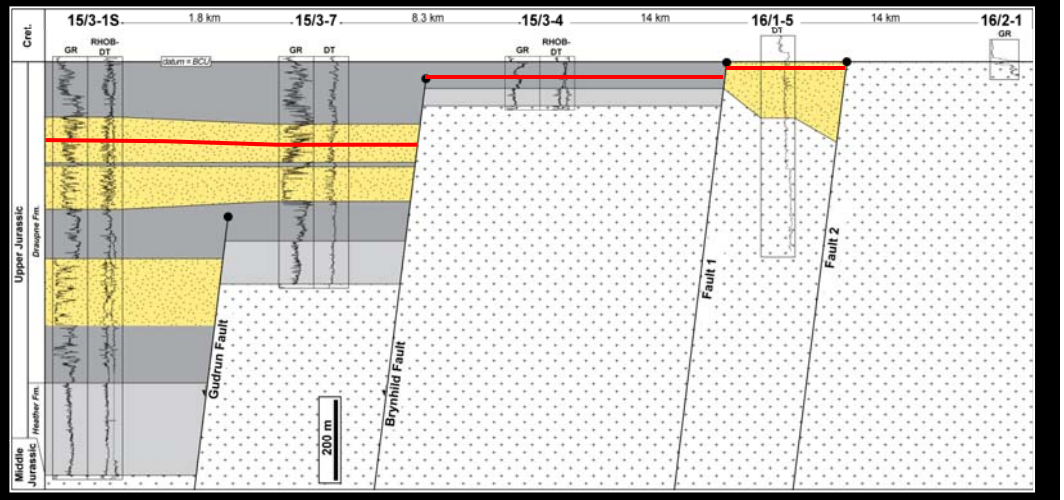

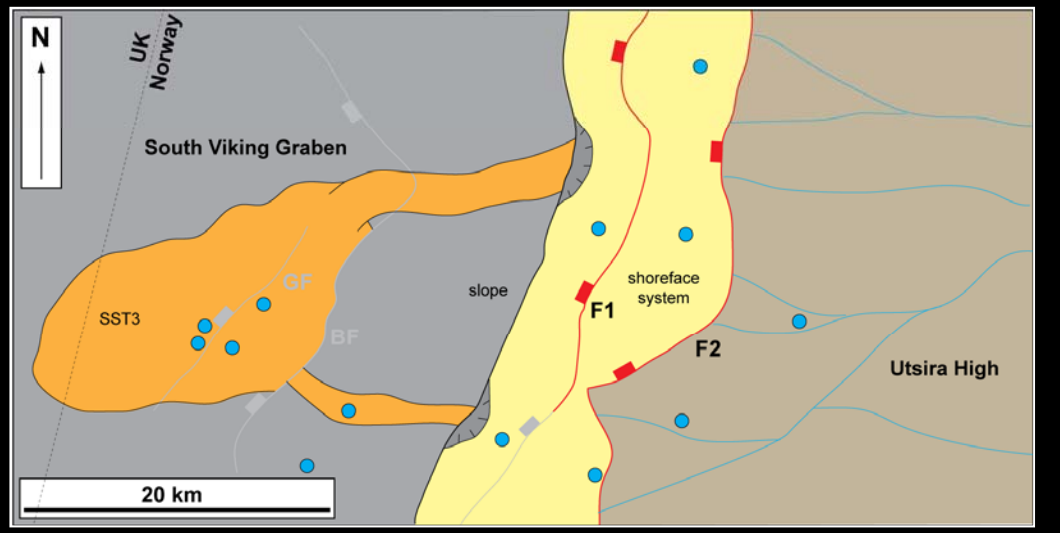

Conclusions

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- Sand-rich, gravity flow-dominated depositional systems can develop downdip of hangingwall shoreline/deltaic systems in rifts; these systems can be volumetrically significant and constitute important reservoir-prone units
- Gravity-driven (thin-skinned) normal faulting may control the spatial distribution (and preservation), sedimentology and stratal architecture of syn-rift hangingwall turbidite systems
- Faulting and sediment supply input pathways control the thickness, facies and reservoir properties (e.g. net-to-gross ratio, stratigraphic compartmentalisation; porosity, permeability, etc) of syn-rift hangingwall turbidite reservoirs
- It is critical to integrate various data types (e.g. seismic, electrical, etc) when attempting to understand the temporal and spatial development of syn-rift turbidite depositional systems