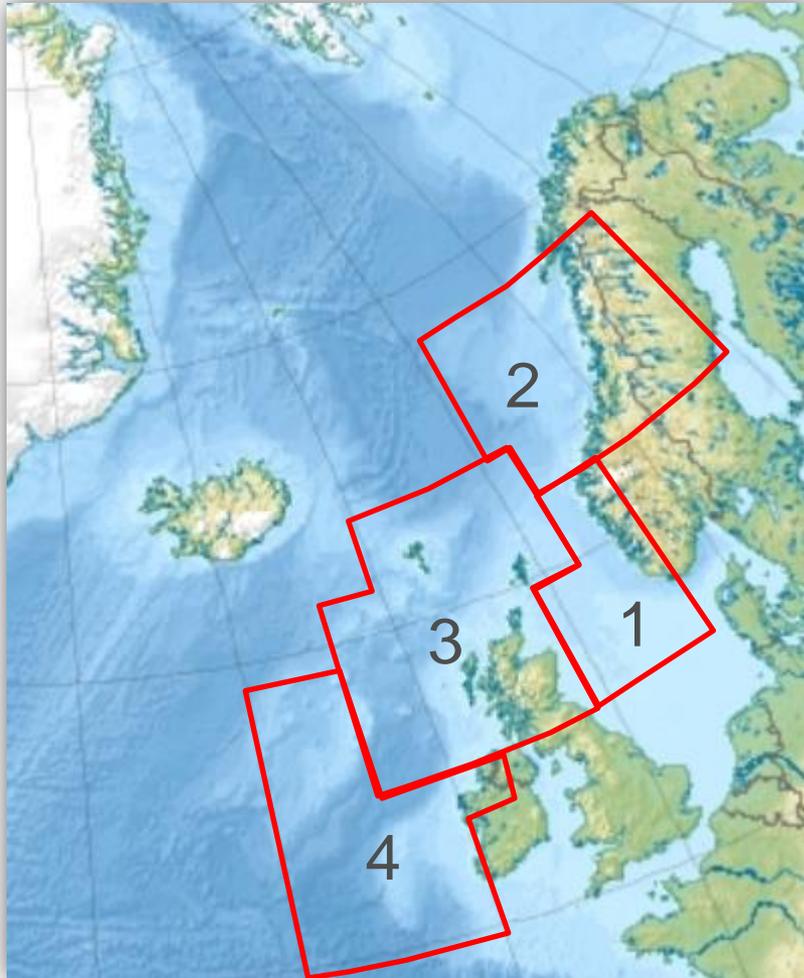


# Play fairway mapping in the Northeast Atlantic Margin Comparison between mature and immature basins



**David Mudge, Joanne Cranswick**

- Ternan
- North Sea
  - Play fairway mapping
  - Tertiary case study
- Northeast Atlantic
  - Database
  - Regional Geology
  - Plate Reconstructions
- Play Fairway Mapping
- Conclusion



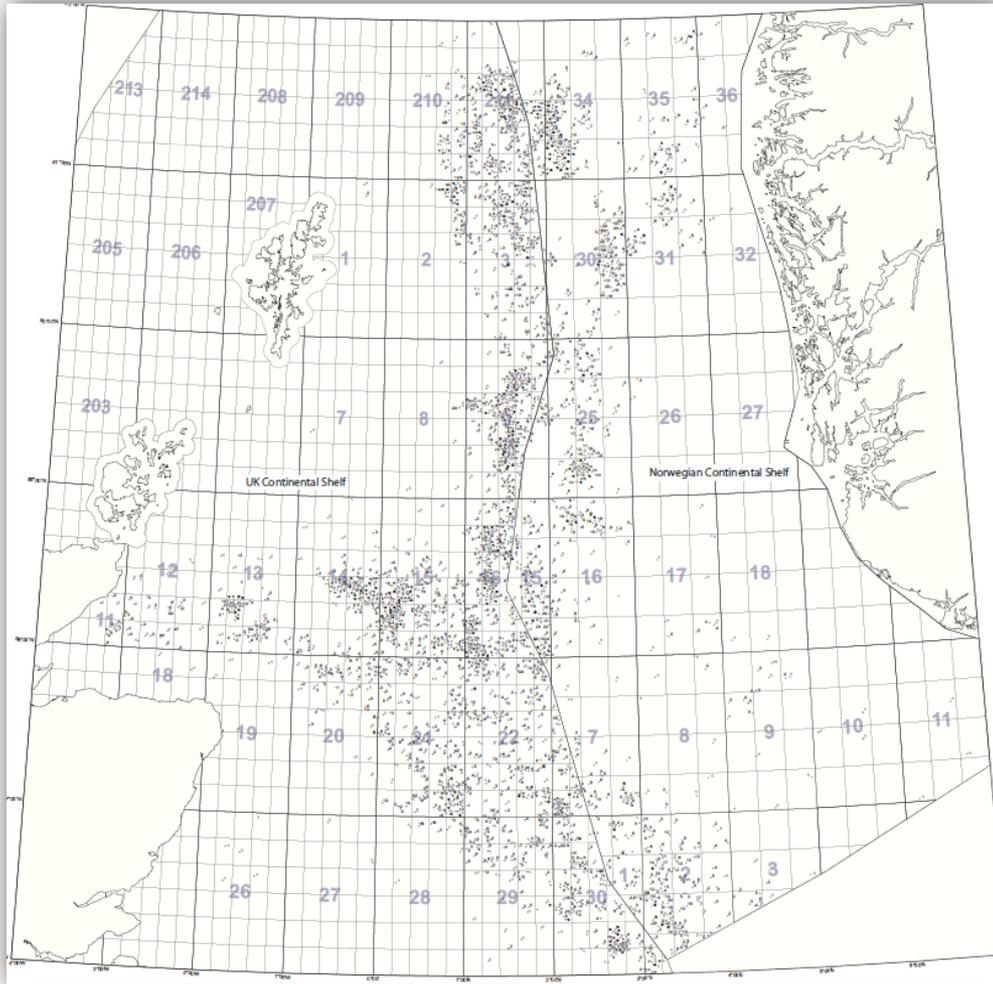
## Ternan Regional Multi-Client Reports

1. UK & Norwegian North Sea
2. Norwegian Sea
3. UK Atlantic Margin
4. Atlantic Ireland

## North Sea Reports:

- UK Central North Sea
- UK Northern North Sea
- Norwegian North Sea
  
- 2015 Integrated North Sea

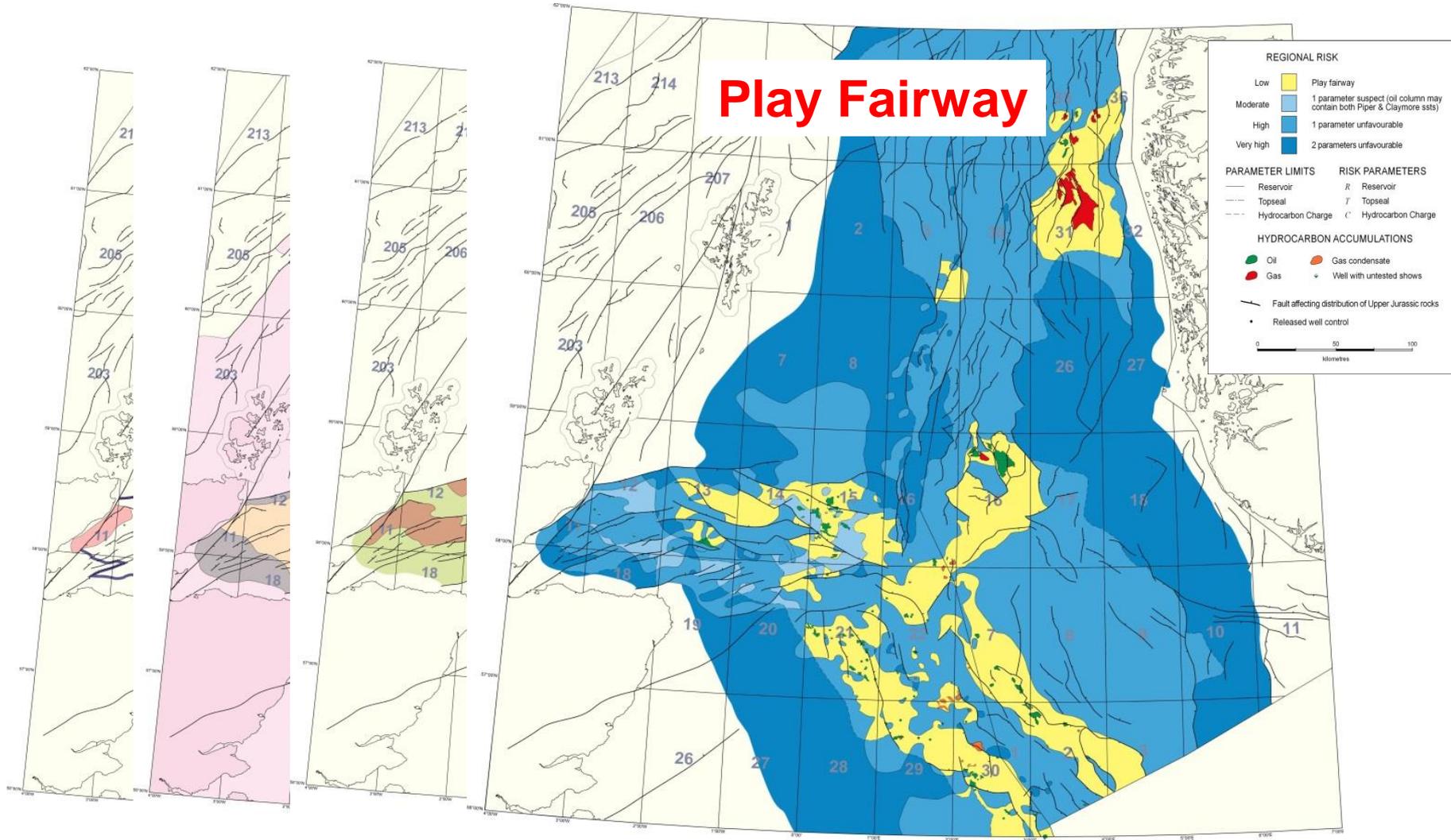
# North Sea Interpreted Well Database



UK Northern North Sea	581
UK Central North Sea	1270
Norwegian North Sea	793
Total Database	2644

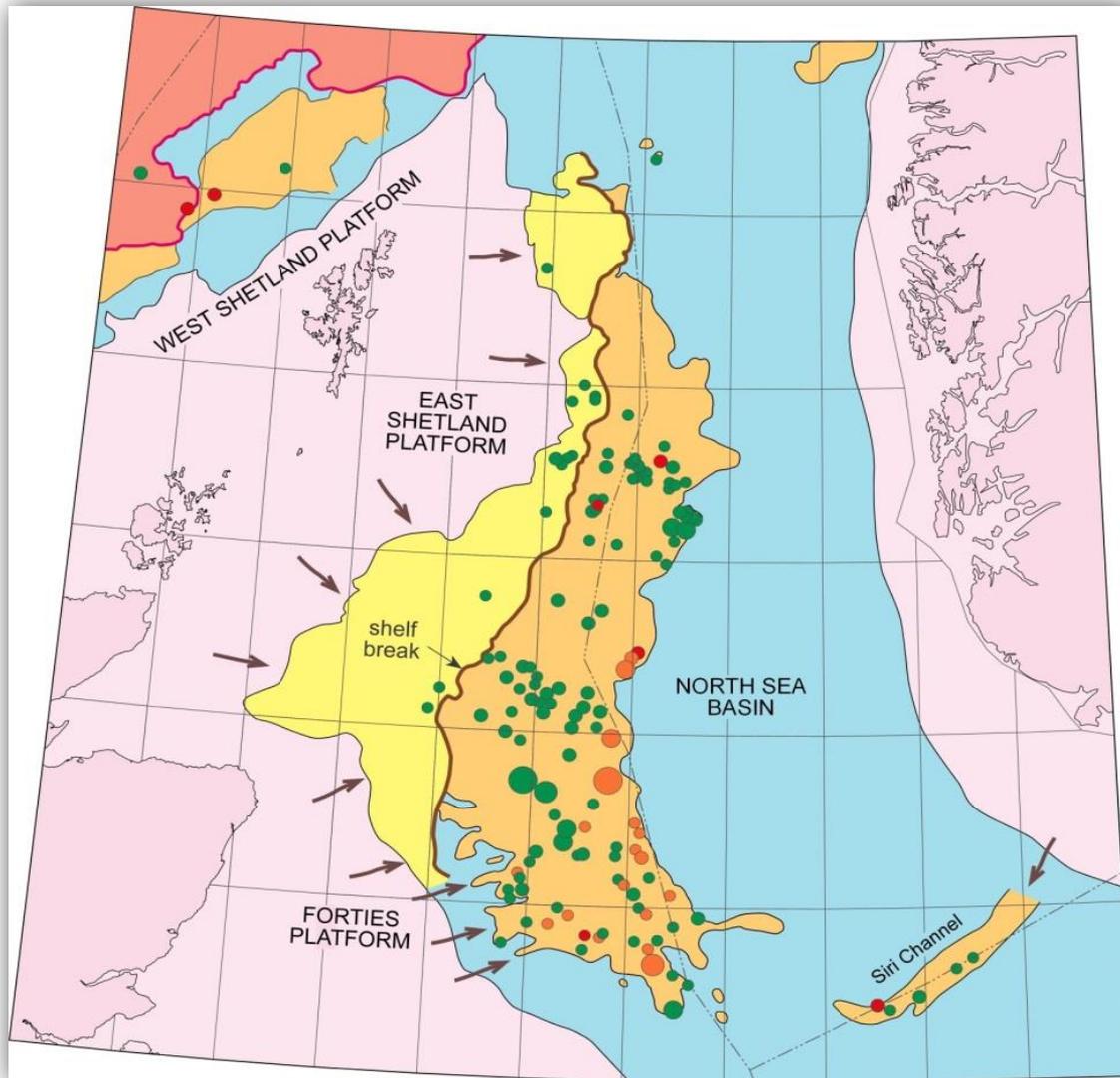
# Play Fairway Mapping

## Upper Jurassic Shelf



AGE		Play	Depositional Setting	Reservoir Units	
Tertiary	Eocene	U	Grid	Slope/Basin	Grid
		M	Alba	Slope/Basin	Alba, Caran, Upper Tay
		L	Frigg	Slope/Basin	Frigg, Skroo, Lower Tay
			Balder	Delta/Slope	Balder, Beauy, Odin
			Sele	Delta/Slope	Upper Dornoch, Cromarty, Flugga, Hermod
	Palaeocene	U	Forties	Slope/Basin	Forties, Skadan, Teal
		L	Balmoral	Slope/Basin	Balmoral, Heimdal
			Andrew	Slope/Basin	Andrew
			Maureen	Slope/Basin	Maureen, Ty
			Chalk	Marine	Top, Ekofisk, Kyrre
Mesozoic	Cretaceous	U	L Cretaceous	Slope/Basin	Scapa, Captain, Britainia, Skiff, Agat
		L	U Jurassic Basin	Basin	Ribble, Freshney, Eldfisk, Claymore, Burns, Brae, Magnus, Oxford-Kimm Ssts
	Jurassic	U	U Jurassic Shelf	Shelf	Fulmar, Ula, Piper, Ross, Sognefjord, Oxford-Kimm Ssts
		M	M Jurassic Shelf	Shelf	Emerald, Krossfjord, Fensfjord, Hugin, Beatrice, Sandnes
			M Jurassic Delta	Delta/Shelf	Brent, Sleipner, Brora Coal, Pentland, Bryne
		L	L Jurassic	Delta/Shelf	Nansen, Statfjord, Dunlin
	Triassic	Triassic	Fluvial	Skagerrak, Lunde, Cormorant	
Palaeozoic	Permian	Zechstein	Marine	Halibut Carbonate	
		Rotliegendes	Aeolian	Rotliegendes	
	Carboniferous	Carboniferous	Fluvial/Delta	Flora	
	Devonian	Devonian	Fluvial	Old Red Sandstone	
Basement	Basement		Basement		

# North Sea Tertiary Plays



## PALAEOCENE-EOCENE RESERVOIRS

- Deep-water sandstones
- Shelf sandstone overlying deep-water sandstones
- Mudstone
- Lavas
- Tertiary sediments absent
- Shelf break
- Sediment transport direction

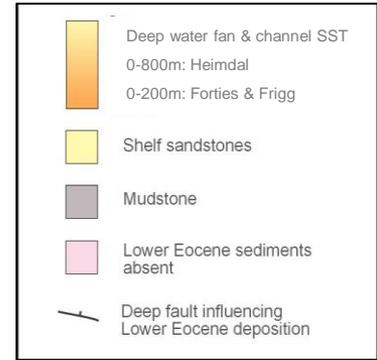
## PALAEOCENE-EOCENE FIELDS

- Oil
- Gas
- Gas-condensate

# Palaeocene-Eocene Reservoir Distribution

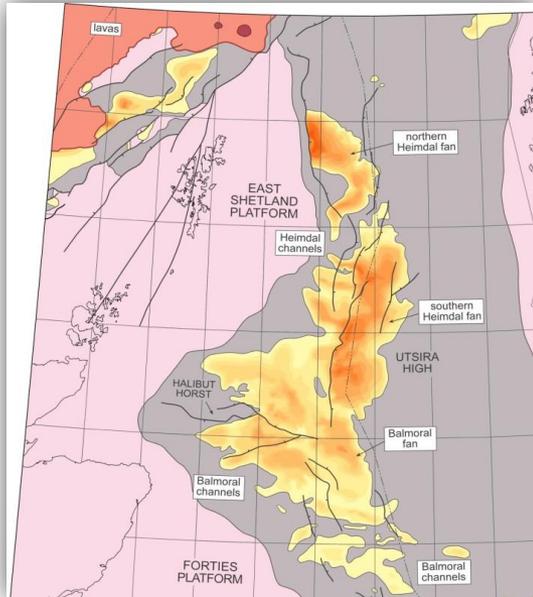
## Sandstone Thickness maps

- Complex patterns of sand facies in the North Sea basin
- Rapid changes in sand distribution as the basin evolved during the Palaeocene & Eocene.



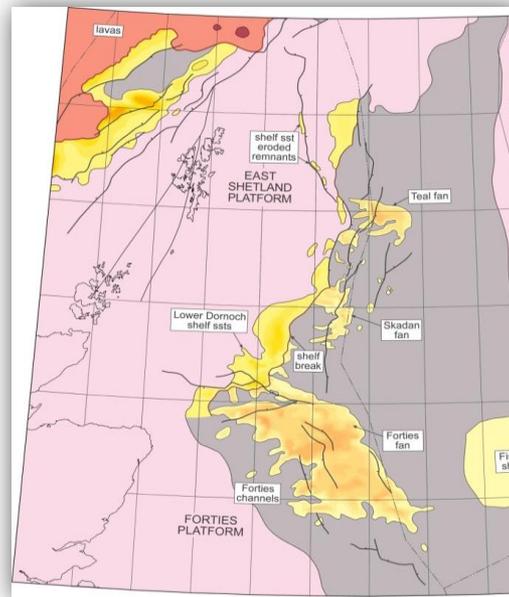
### Balmoral

Scale 0-800m sst thickness  
2 large deep water fans & feeder channels  
Regional fault control



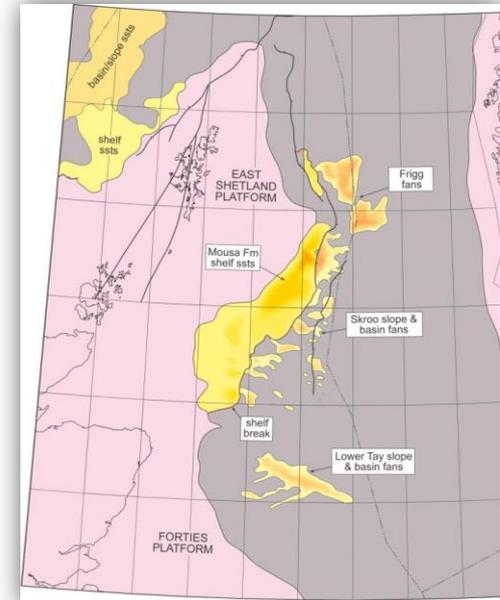
### Forties

200m max thickness  
1 major deep water fan with some shelf sst



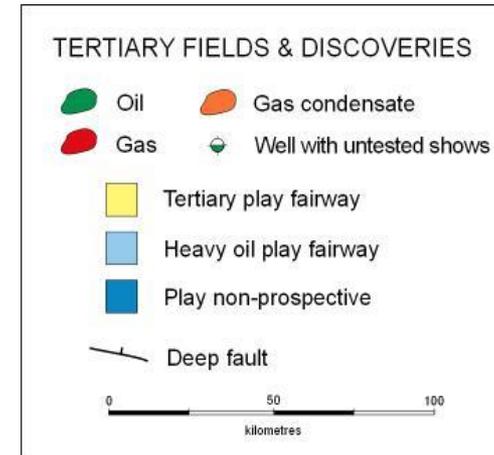
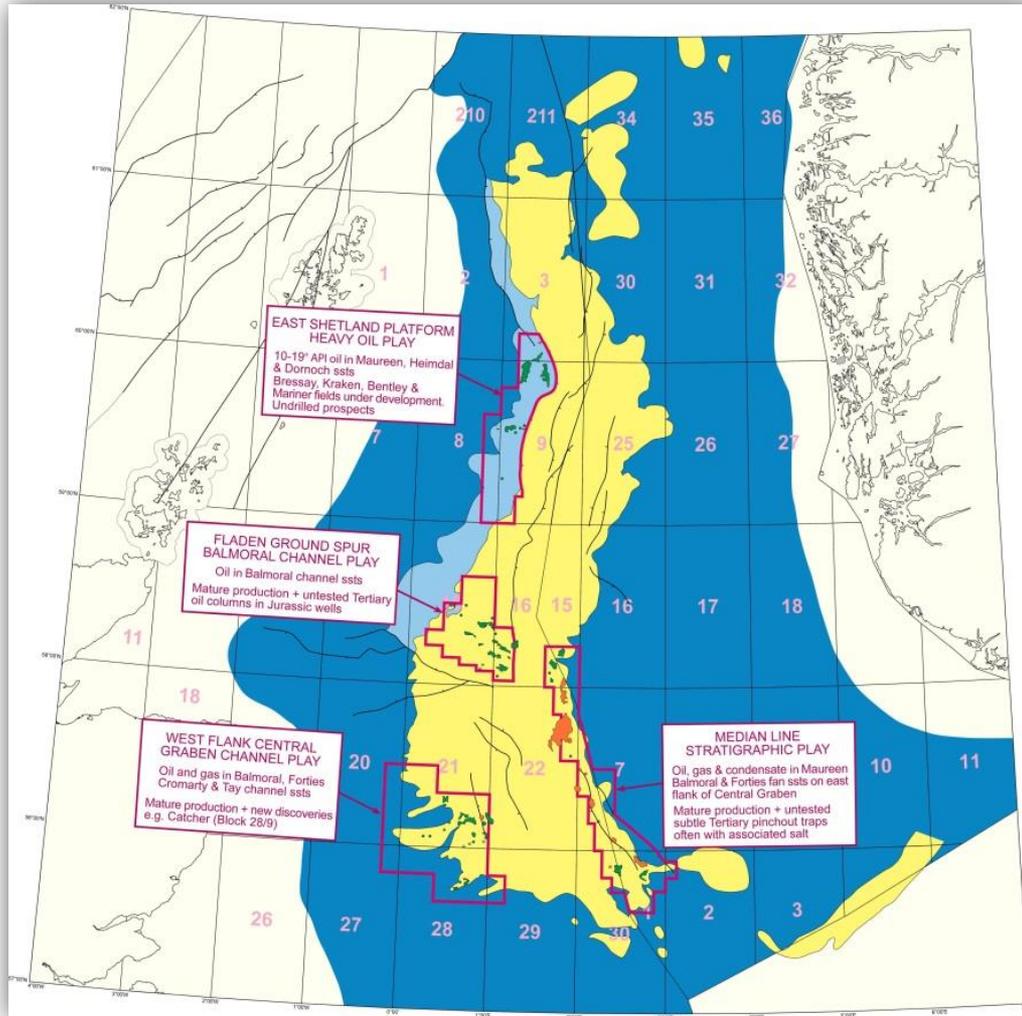
### Frigg

Scale 0-200m sst thickness  
Fragmented deep water sst,  
Significant shelf sst



# Palaeocene-Eocene Remaining Prospectivity

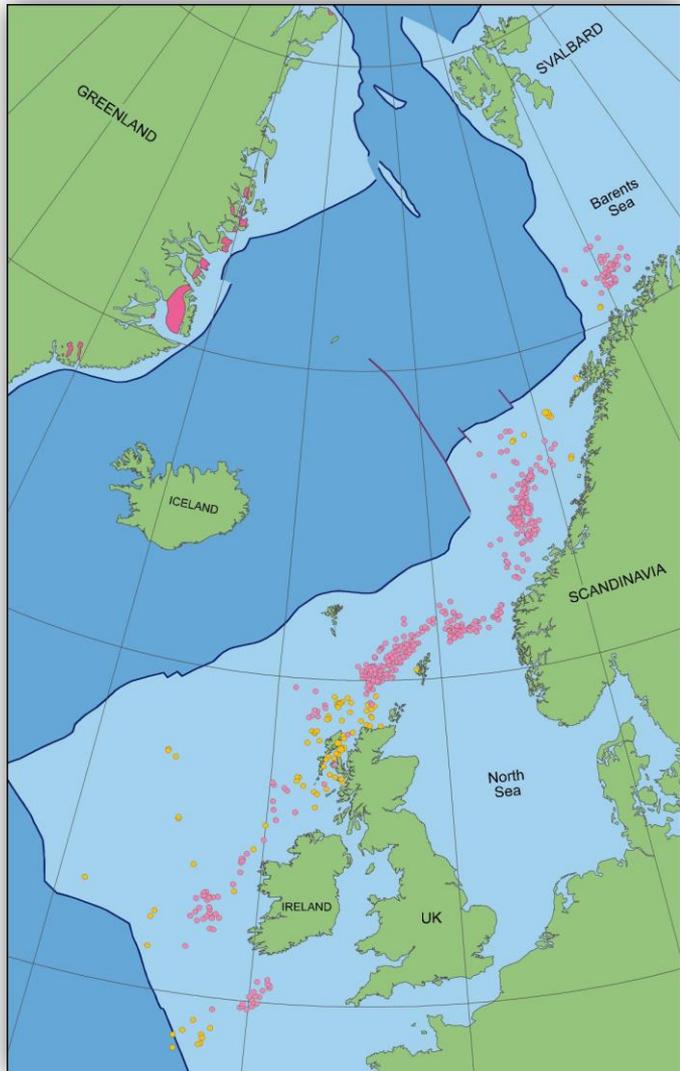
## Composite Play Fairway Map



Area with enhanced remaining hydrocarbon potential

# NE Atlantic Margin

## Stratigraphic Analysis



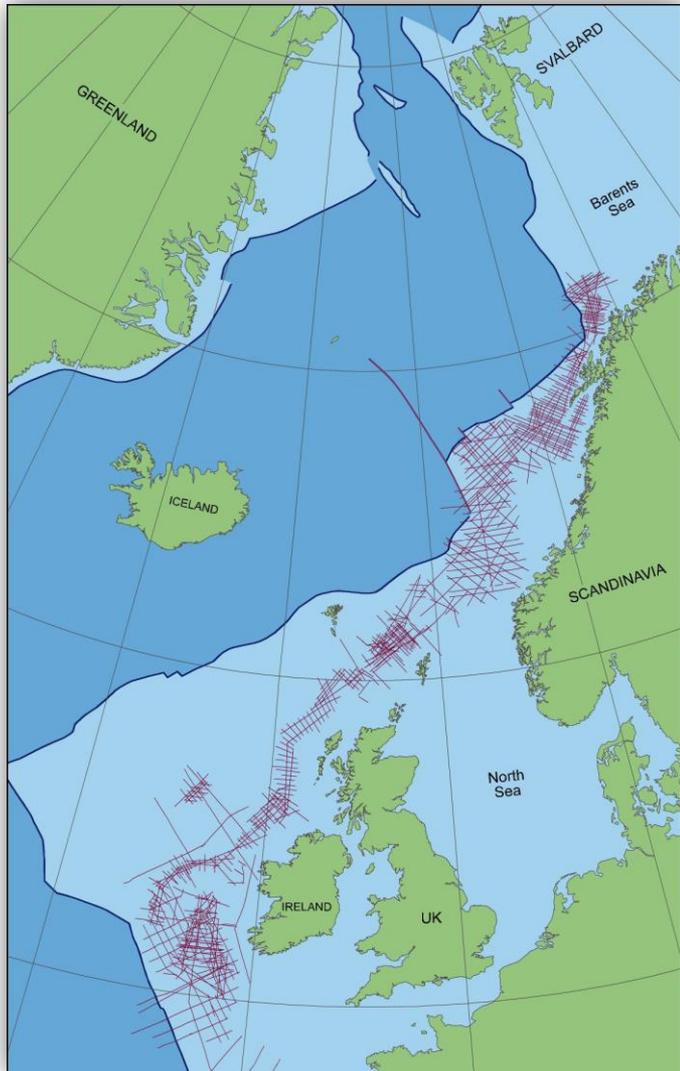
## Interpreted Database

- Well database: 500+
- BGS & NGU shallow boreholes for UK Atlantic Margin
- Onshore NE Greenland Tertiary & Mesozoic outcrops



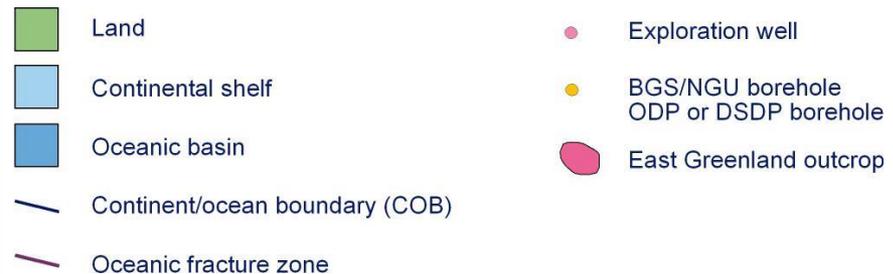
# NE Atlantic Margin

## Seismic Interpretation



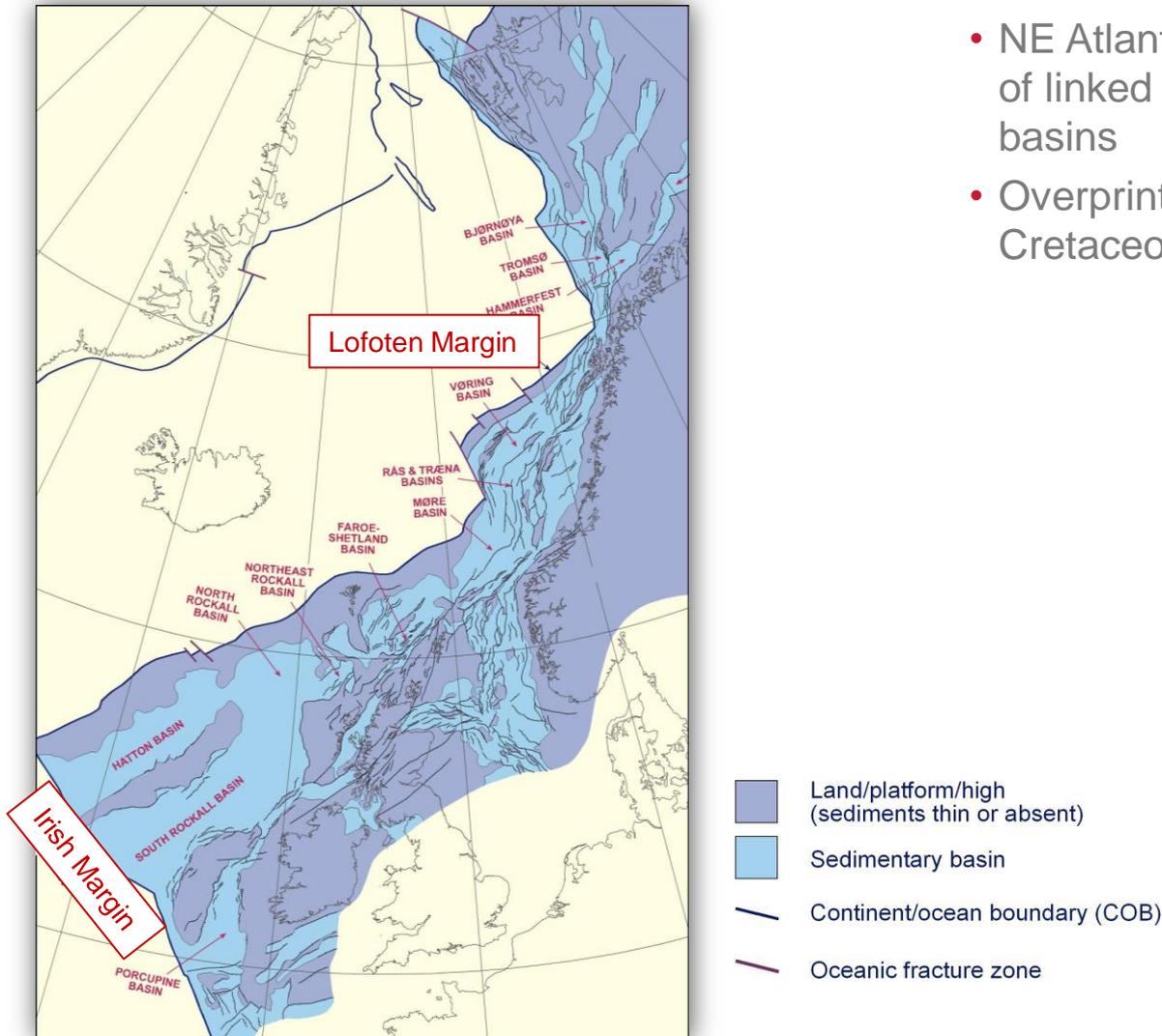
## Interpreted Database

- Well database: 500+
- BGS & NGU shallow boreholes for UK Atlantic Margin
- Onshore NE Greenland Tertiary & Mesozoic outcrops
- Extensive seismic database



# NE Atlantic Margin

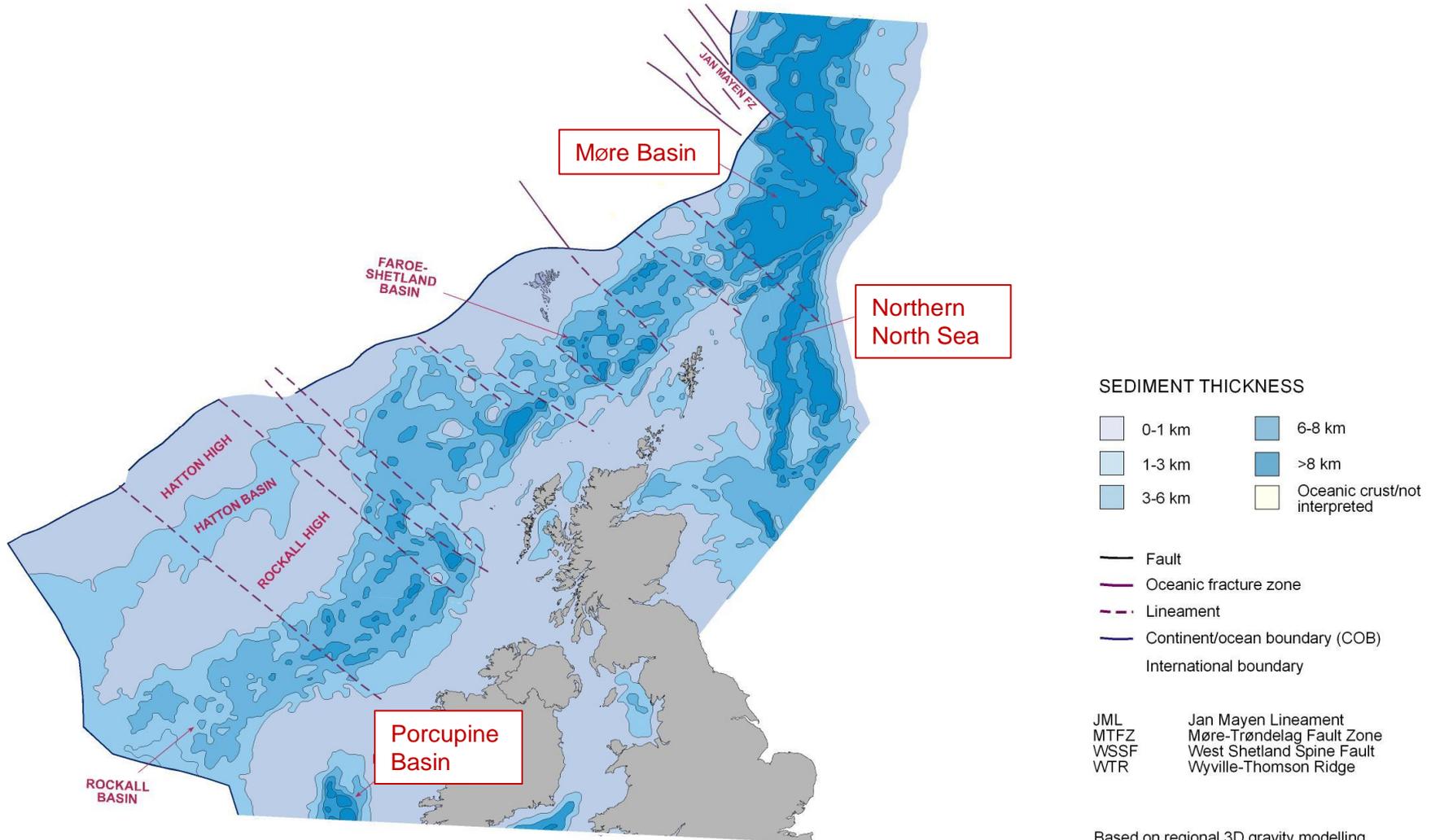
## Tectonic Elements



- NE Atlantic province contains a series of linked Triassic – Lower Cretaceous basins
- Overprinted by deep Upper Cretaceous – Tertiary basin system

# NE Atlantic

## Sediment Thickness

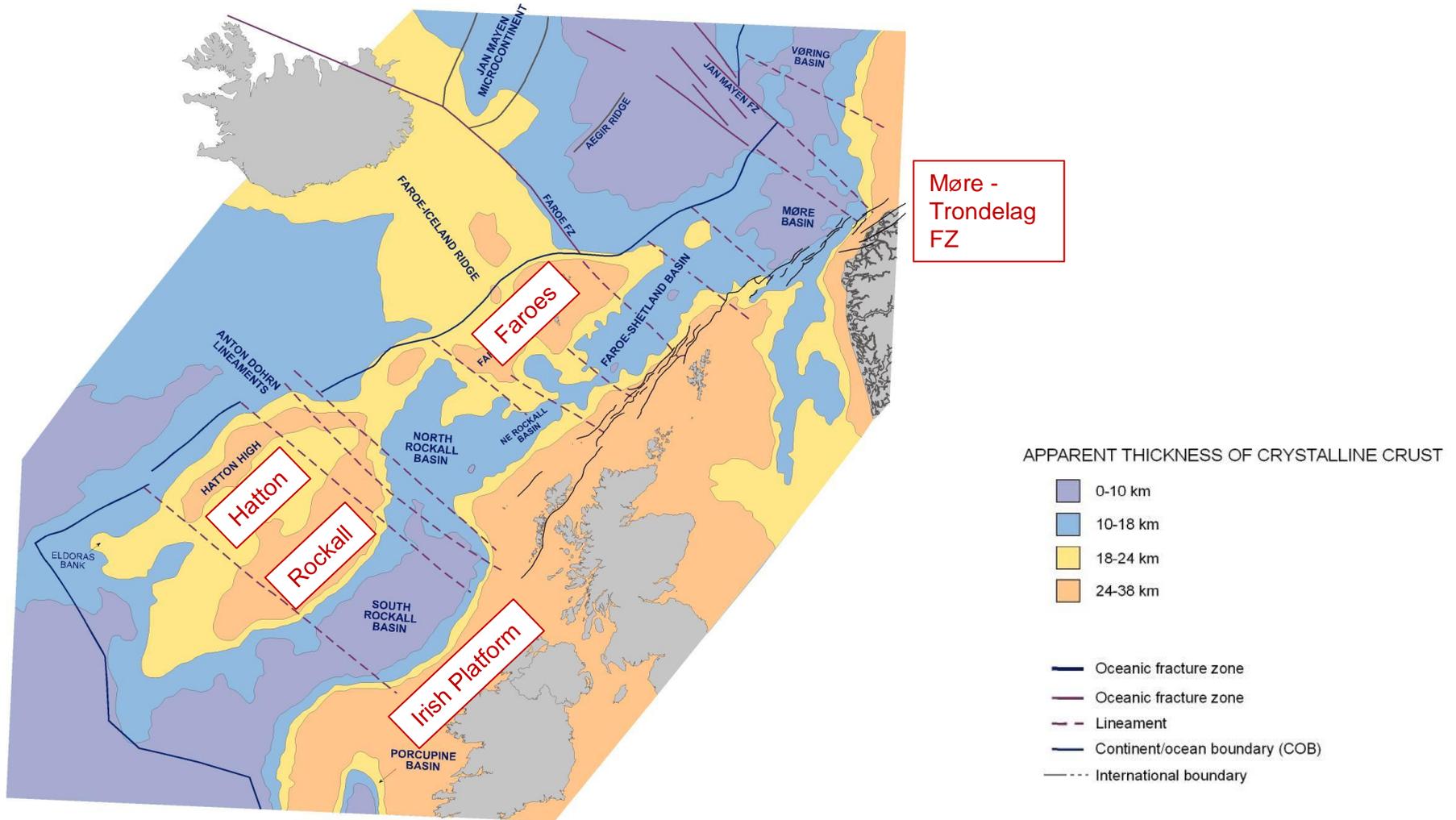


Based on BGS regional 3D gravity modelling

Based on regional 3D gravity modelling

Published sources: Kimbell *et al.* (2004)  
Kimbell *et al.* (2005)

# NE Atlantic Deep Structure



Møre -  
Trondelag  
FZ

Hatton

Rockall

Irish Platform

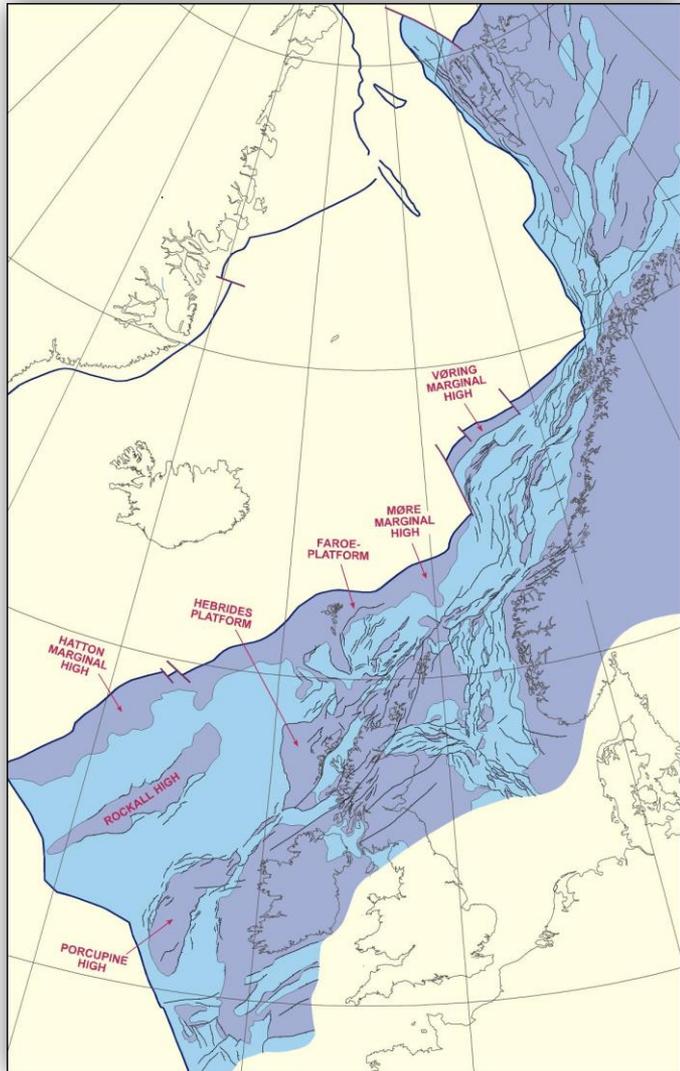
Faroes

Mapping based on regional 3D gravity modelling  
(Kimbell *et al.* 2004, 2005)

Based on BGS regional 3D gravity modelling

# NE Atlantic Margin

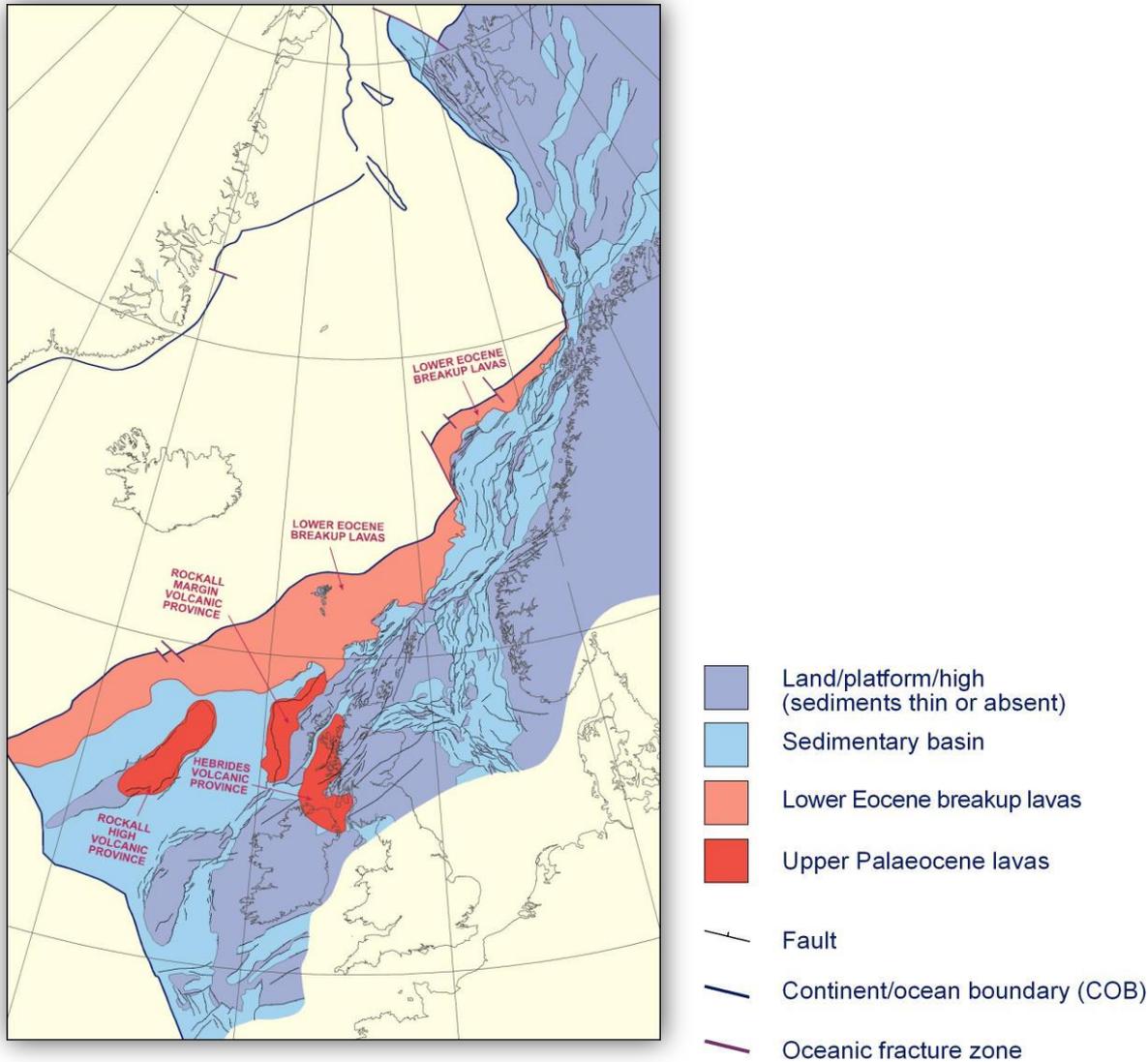
## Tectonic Elements



- Land/platform/high (sediments thin or absent)
- Sedimentary basin
- Continent/ocean boundary (COB)
- Oceanic fracture zone

# NE Atlantic Margin

## Lavas



# NE Atlantic Margin

## Plate Reconstruction at 54 Ma



- Land/platform/high (sediments thin or absent)
- Sedimentary basin
- Continent/ocean boundary (COB)
- Oceanic fracture zone

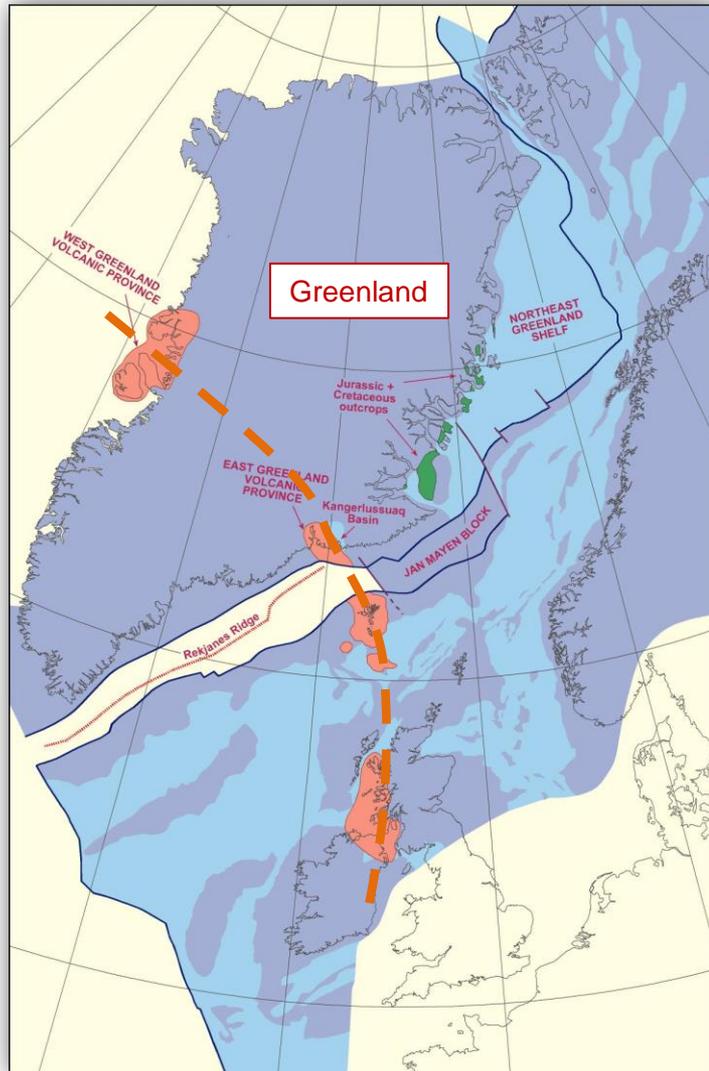
### Early Ypresian (54 Ma)

- Mesozoic + Tertiary plate reconstructions by the NGU in Trondheim
- NW Europe plate fixed; movement of Greenland plate determines overall width and morphology of NE Atlantic seaway
- Interpretation uses Ternan mapping in Atlantic Ireland, UK Atlantic margin, Norwegian Sea and North Sea

Includes data from  
Norwegian Geological Survey  
[www.lr-senergy.com](http://www.lr-senergy.com)

# NE Atlantic Margin

## Plate Reconstruction at 54 Ma



- Conjugate NE Greenland & Norwegian margins but line of breakup follows SW-NE Caledonian trend cutting across the basin system
- Jan Mayen restored to Eocene position.
- Gap between SE Greenland and Faroe-Hatton margins: may be due to earlier Palaeocene start of sea-floor spreading along Rekjanes Ridge
- Line of pre-breakup Palaeocene volcanic centres from W Greenland to Hebrides

Includes data from  
Norwegian Geological Survey  
[www.lr-senergy.com](http://www.lr-senergy.com)

# NE Atlantic Margin

## Plate Reconstruction at 85 Ma

Santonian (85 Ma)



- Land/platform/high (sediments thin or absent)
- Sedimentary basin
- Continent/ocean boundary (COB)
- Oceanic fracture zone

Includes data from  
Norwegian Geological Survey  
[www.lr-senergy.com](http://www.lr-senergy.com)

# NE Atlantic Margin

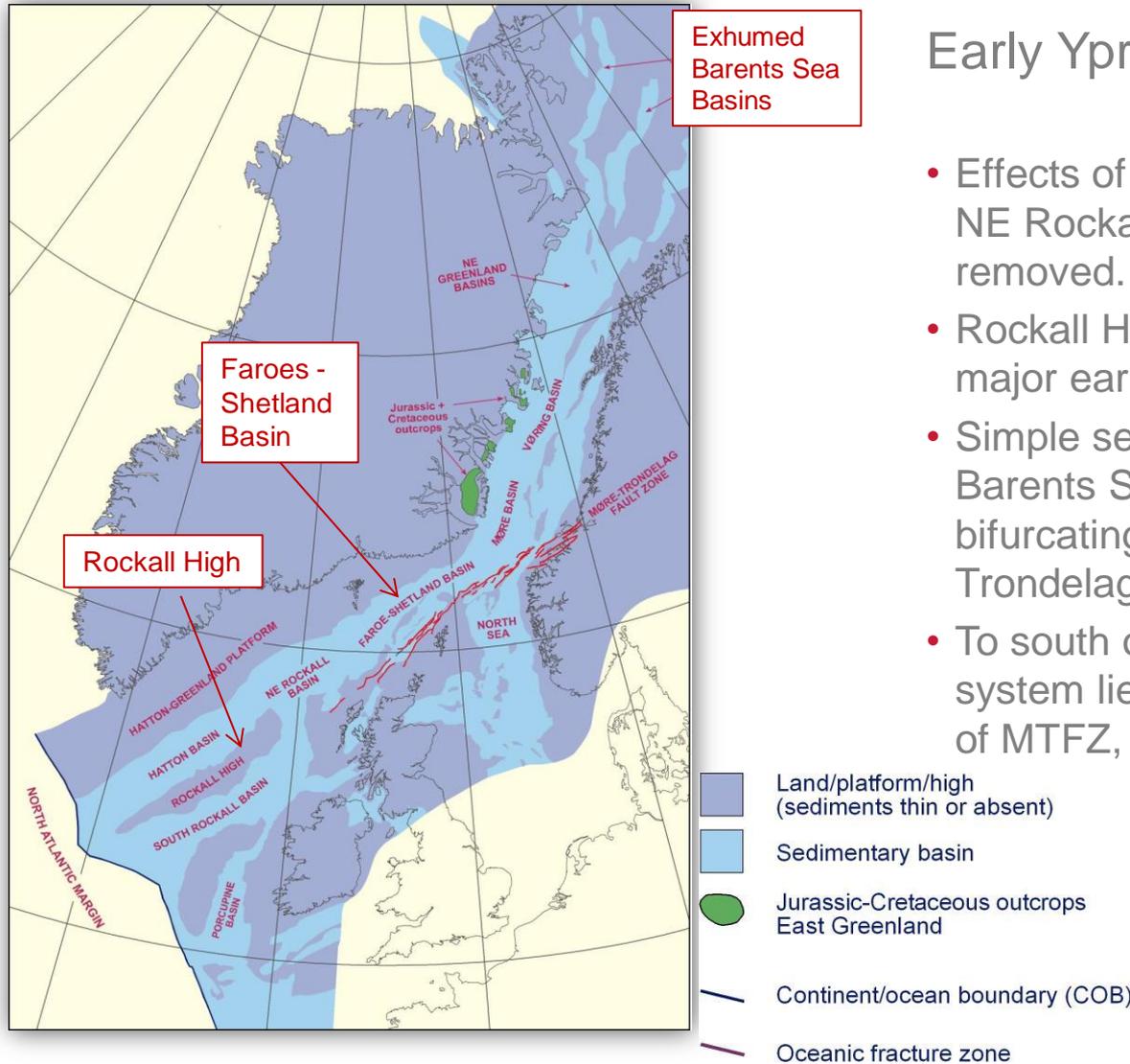
## Plate Reconstruction at 140 Ma

Berriasian (140 Ma)



- Land/platform/high (sediments thin or absent)
- Sedimentary basin
- Continent/ocean boundary (COB)
- Oceanic fracture zone

Includes data from  
Norwegian Geological Survey  
[www.lr-senergy.com](http://www.lr-senergy.com)



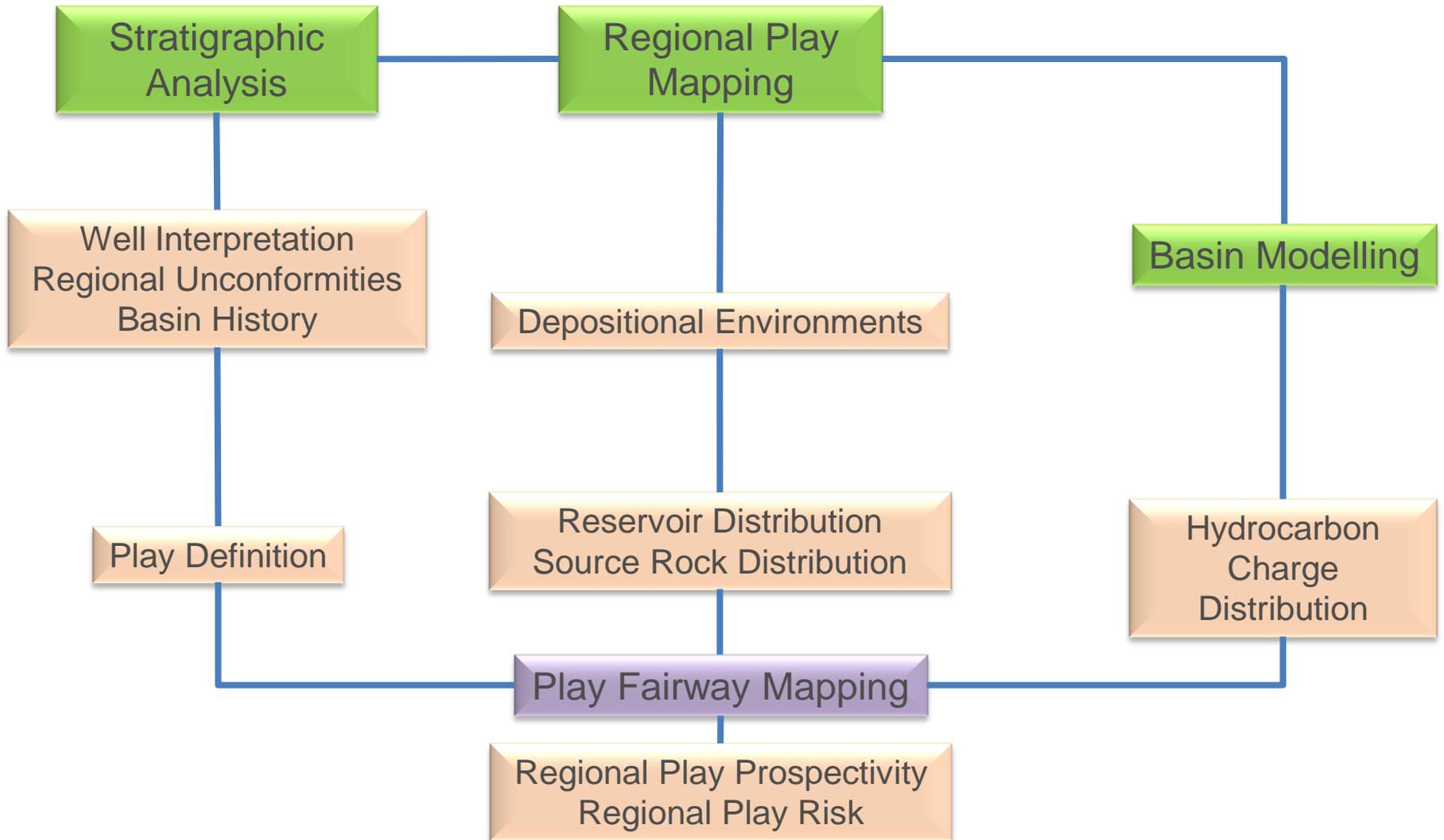
### Early Ypresian (54 Ma)

- Effects of Palaeocene thermal uplift in NE Rockall-Feroes Shetland areas removed.
- Rockall High moved SE to allow for major early Cretaceous extension.
- Simple seaway/basin system from Barents Sea to N Atlantic margin bifurcating into North Sea along Møre-Trondelag FZ
- To south of MTFZ, W margin of basin system lies on NW Europe plate; to north of MTFZ, it lies on Greenland plate.

Includes data from  
 Norwegian Geological Survey  
[www.lr-senergy.com](http://www.lr-senergy.com)

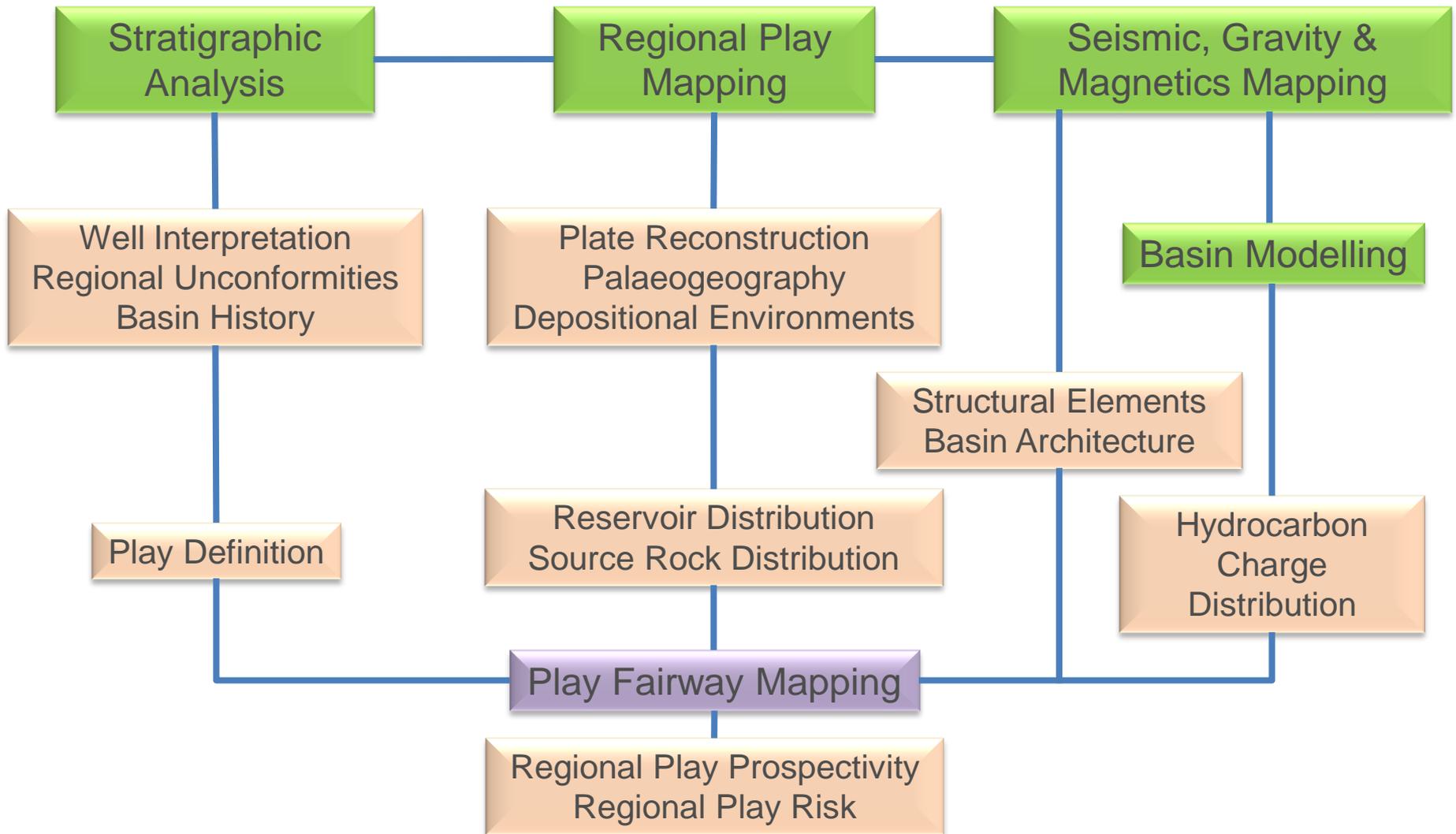
# Play Fairway Work Programme

North Sea



# Play Fairway Work Programme

## Northeast Atlantic Margin



# NE Atlantic Margin

## Source Rocks

STRATIGRAPHIC COLUMN	ATLANTIC IRELAND	UK ATLANTIC MARGIN	NORWEGIAN SEA	LOFOTEN W BARENTS SEA
EOCENE				
PALAEOCENE				
UPPER CRETACEOUS				
LOWER CRETACEOUS				
UPPER JURASSIC	Kimmeridge Clay Fm U Kimmeridgian-Tithonian	Kimmeridge Clay Fm U Kimmeridgian-Tithonian	Spekk Fm U Oxfordian-Kimmeridgian	Hekkingen Fm U Oxfordian-Kimmeridgian
MIDDLE JURASSIC				
LOWER JURASSIC	Toarcian Shale Unit	Stack Skerry Fm Sinemurian + Toarcian	Åre + Ror Fms Sinemurian + Toarcian	
TRIASSIC				
PERMIAN				
DEVONO-CARBONIFEROUS				
PRECAMBRIAN				

**INNER HEBRIDES**  
Skye/The Minches/Sea of the Hebrides

Lower Toarcian		Portree Shale Fm
L Pliensbachian U Sinemurian		Pabba Shale Fm

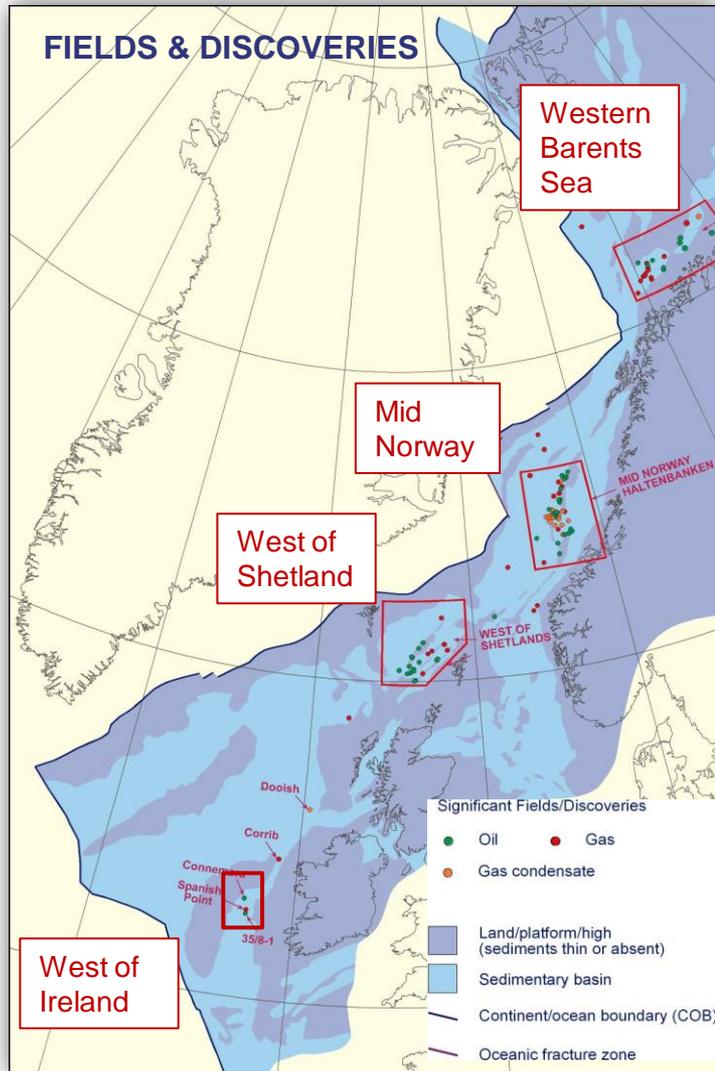
# NE Atlantic Margin

## Reservoirs

STRATIGRAPHIC COLUMN	ATLANTIC IRELAND	UK ATLANTIC MARGIN	NORWEGIAN SEA	LOFOTEN W BARENTS SEA
EOCENE	Ypresian-Lutetian shelf plays	♦ Ypresian-Lutetian shelf/slope plays		
PALAEOCENE	Selandian basin fan play	♦ Selandian-Thanelian basin/slope plays		
		♦ Danian basinal play	♦ Danian slope channel play	
UPPER CRETACEOUS		Cenom-Turon slope play	♦ Maastr-Campanian fault scarp/slope play	Maastr-Campanian fault scarp/slope play
LOWER CRETACEOUS	Aptian-Albian shelf play	♦ Valanginian-Albian shelf/slope plays	♦ Valang-Cenomanian shelf/slope plays	♦ Valang-Cenomanian basin/slope plays
	♦ Berrias-Aptian basin play			
UPPER JURASSIC	♦ Kimm-Tithonian slope play	♦ Kimm basinal play		
	♦ Oxfordian shelf play	♦ Oxford-Kimm shelf play	♦ Bathon-Oxfordian shelf/slope plays	Bathon-Oxfordian shelf/slope play
MIDDLE JURASSIC	♦ Bajocian-Callovian deltaic play	Bajocian-Bathonian deltaic play	♦ Pliensbachian-Bajocian shelf plays	♦ Aalenian-Bathonian shelf play
LOWER JURASSIC			♦ Rhaetian-Sinemurian fluvio-deltaic plays	♦ Triassic-Lower Jurassic shelf plays
TRIASSIC	Triassic play	♦ Strathmore fluvial play		
PERMIAN	♦ Dooish play			
DEVONO-CARBONIFEROUS		♦ Clair fluvial play		
PRECAMBRIAN		♦ Clair fractured basement play		

Fields & Significant Discoveries

- ♦ Oil
- ♦ Gas
- ♦ Gas Condensate



- NE Atlantic margin basins contain major hydrocarbon resources.
- Large areas of the NE Atlantic margin remain undrilled. Compared to the North Sea, individual basins have far fewer wells.
- Understanding the complex tectonic history is required before mapping the depositional history and correctly mapping the hydrocarbon plays.
- Ternan has successfully applied North Sea play fairway mapping techniques to basins on the NE Atlantic margin.
- A new Integrated North Sea Ternan report is being finalised, with updated databases and interpretation

# David Mudge

Ternan  
LR Senergy

Data:

British Geological Survey  
Norwegian Geological Survey  
Fugro, PGS, Spectrum, TGSNopec,  
Veritas, Western Geco, NPD