



Petroleum Systems Analysis of the Slyne, Erris and Donegal Basins Offshore Ireland

Digital Atlas

PAD Special Publication 1/05





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Introduction

This work was commissioned by the Petroleum Affairs Division (PAD) of the Irish Department of Communications, Marine and Natural Resources and supported by the Petroleum Infrastructure Programme (PIP).

The purpose of this document is to provide as objective a view as possible of the remaining potential of the Slyne-Erris-Donegal Basins through play fairway mapping, calibrated to well results, and analogue studies.

The work flow has comprised the following;

- An analysis of well failures and successes, with the reasons for failure to be used as a calibrant to play fairway maps
- A construction of regional cross-sections to define play types and simple back-stripping of these to define play history
- Basin modelling for each of the three basins and construction of petroleum system diagrams
- Construction of fairway maps for three critical parameters (reservoir, charge and seal preservation) and an overlay of these to construct integrated play fairway maps
- Areal fairway productivities defined from analogue basins, were integrated with the areas defined on the fairway maps to produce yet-to-find estimates.

The play fairway methodology used is that introduced by Hayward & Rattey for the North Sea. The structural nomenclature follows that of Naylor *et al.*, 1999 and 2001.

The study is based on all publicly released data (excludes two most recent wells and 3D seismic surveys).

The Study was conducted jointly by: **PGS Reservoir Ltd and Aceca Ltd.**



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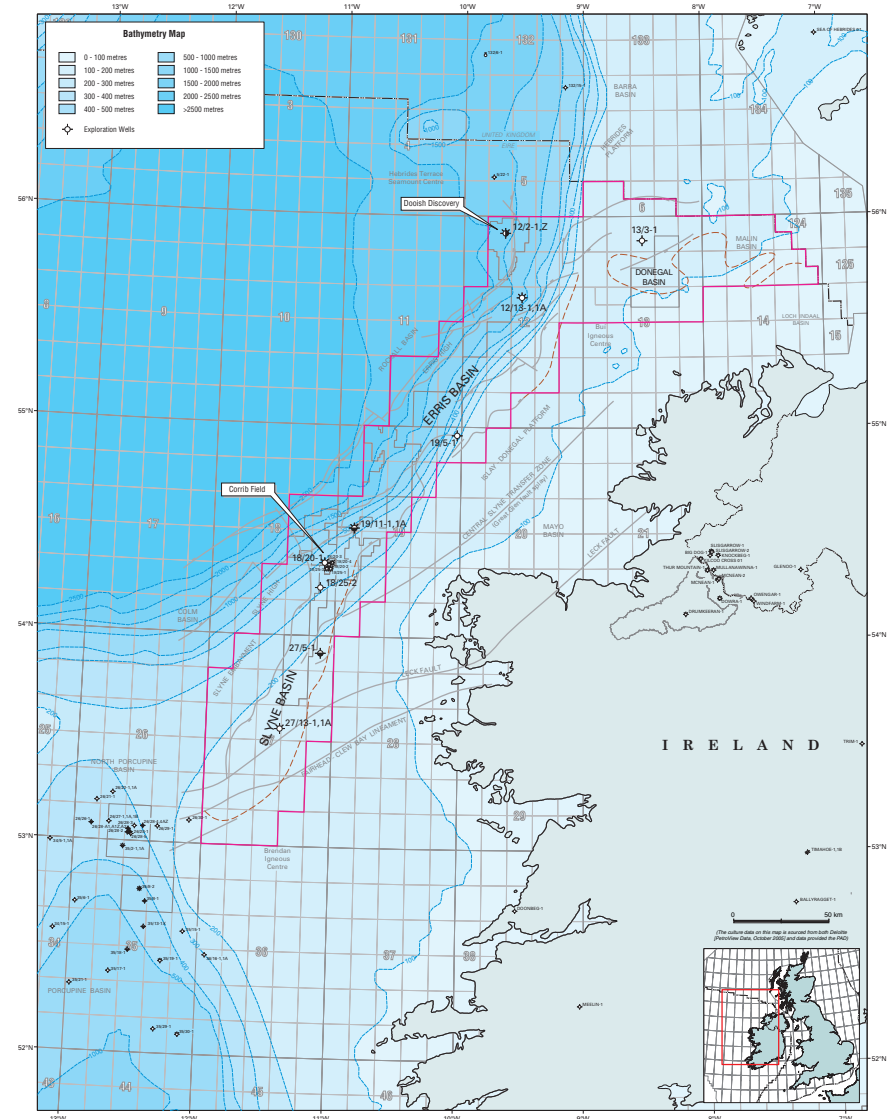
- 72 Appendix 1 - Well density methodology
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Location map and well database

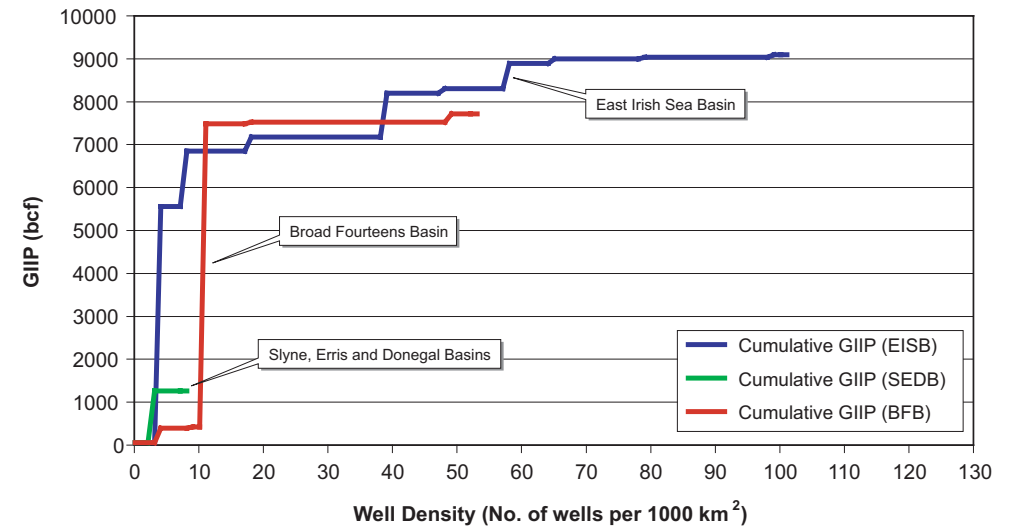
- The Slyne, Erris and Donegal Basins are located between 50 to 250 km off the West and North West coast of Ireland.
- The basins are located in a water depth of approximately 50 to 1000 m.
- The extreme western margins of the basins occur in water depths of 1000 to 2000 m.





Well density plotted with discovered GIIP

- By comparing the Slyne, Erris and Donegal basins with analogue basins in terms of exploration well density (per unit area of basin); the Broad Fourteens and East Irish Sea Basins, it is clear that the Irish Atlantic basins are grossly under-explored.
- By investing more time, money and resources, it is expected by comparison with the analogue basin histories that significant further discoveries will be made within the Slyne, Erris and Donegal Basins.
- The methodology for the well density calculations can be reviewed in Appendix 1.





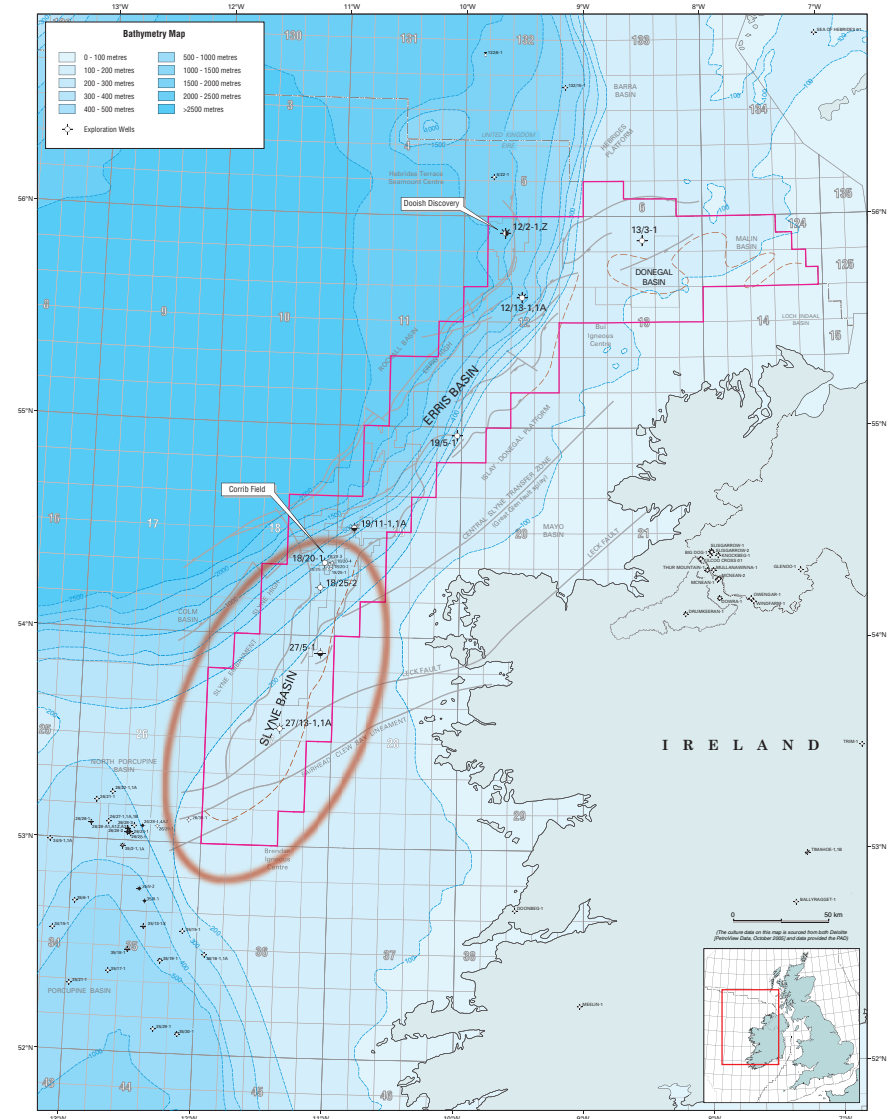
The Atlantic Ireland Basins





The Slyne Basin

- Located between 50 and 250 km offshore west Ireland.
- Occurs within 50 and 2000 m of water depth (90% under 100 m).
- An elongate (140 km x 25 km) NNE-SSW-trending half-graben system which changes polarity along strike.
- Three sub-basins defined separated by fracture zones.
- Lightly drilled, especially pre-Jurassic (1 success from 3 wells).

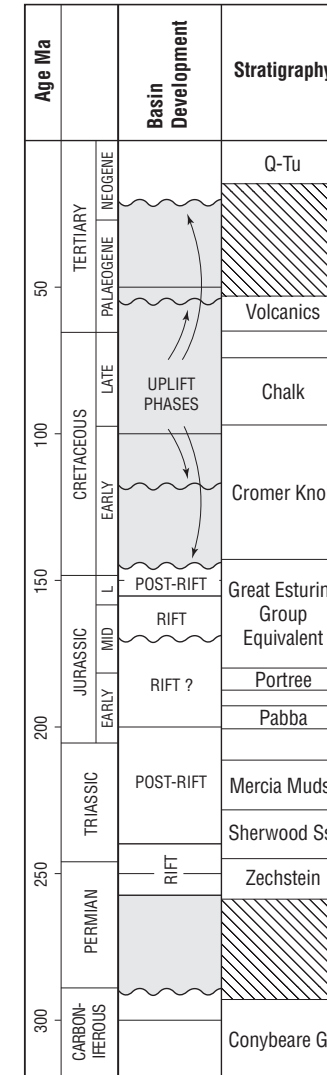




Slyne Basin chronostratigraphy

- Upper Palaeozoic strata are thought to underlie a substantial part of the basin.
- The underlying Permo-Triassic sequence includes a succession of Zechstein evaporites which have important implications in terms of Permian palaeogeography (Chapman *et al.*, 1999).
- Triassic sands are expected to occur across the basin, being overlain by Mercia anhydritic mudstones in the south and marginal parts of the basin, and by salt in the basin centre.
- The basin contains a thick development of Lower and Middle to Upper Jurassic strata, unconformably overlain by a relatively thin Tertiary section. Cretaceous present only in the extreme north.
- The Basin appears therefore to have been 'frozen' in the Late Jurassic and later uplifted by Oligo-Miocene compression.

Chronostratigraphy adapted from Dancer et al., 1999.

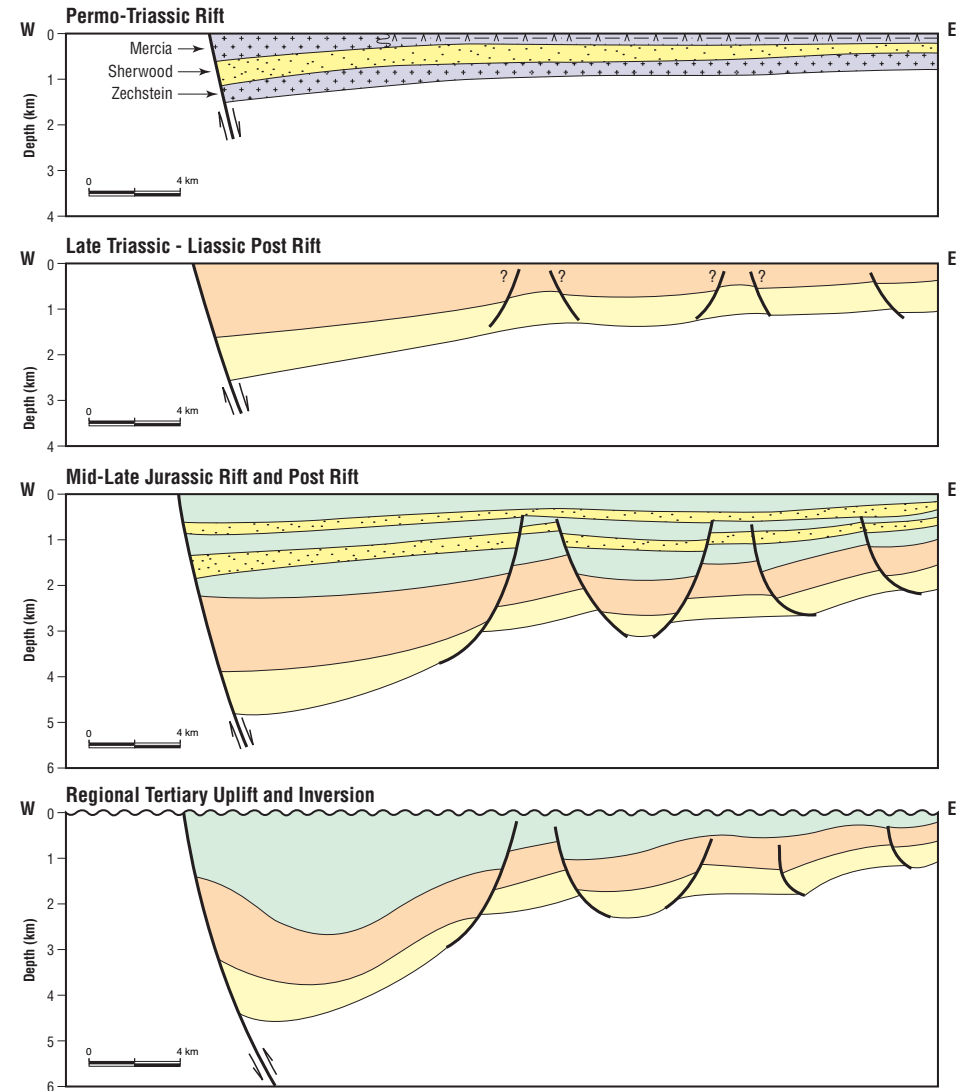


Chronostratigraphy, Slyne Basin



Slyne Basin structural history

- Mild rifting was initiated in the Permo-Triassic.
- Significant rifting/subsidence during the Mid Jurassic.
- Uplifted and deeply eroded as a result of end Jurassic and Tertiary inversion.
- During the Mid Eocene the Slyne Basin experienced igneous processes resulting in the deposition of intrusive and extrusive igneous rocks.
- Source and reservoir rocks generally at maximum burial in the Late Jurassic.



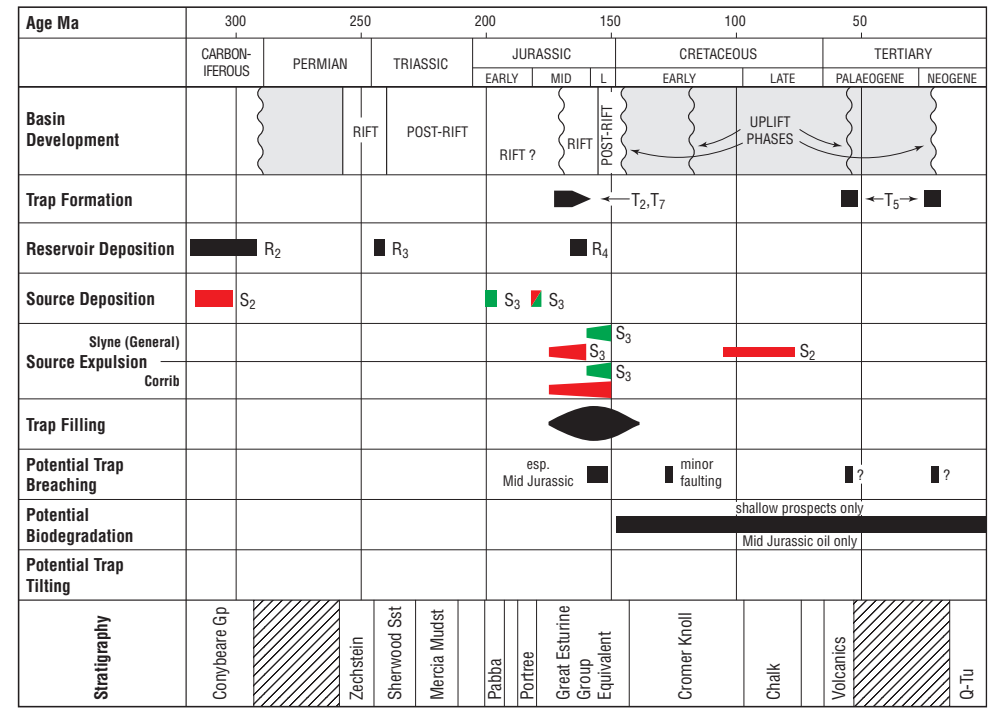
Structural History, Slyne Basin





Slyne Basin petroleum systems diagram

- Two potential source rocks are predicted; the Carboniferous coals (gas) and Early to Mid Jurassic anoxic shales (oil).
- Three potential reservoir rocks have been identified; sands deposited in the Carboniferous, the Triassic Sherwood Formation and Mid Jurassic Sands.
- Three general trap types are recognised; preserved normal faults, reservoir pinch-out formed by Zechstein rafting and inverted hanging wall closures.
- Oil expulsion from the Pabba and Portree Shales occurs at approximately 150 Ma.
- Gas expulsion from the Carboniferous Coals occurs at approximately 90 Ma.
- Due to the early generation, only older types of trap are likely to be charged. This focuses on palaeostructures and rafted pinch-outs.
- Leakage of traps during late stage fault reactivation and uplift may be a risk.



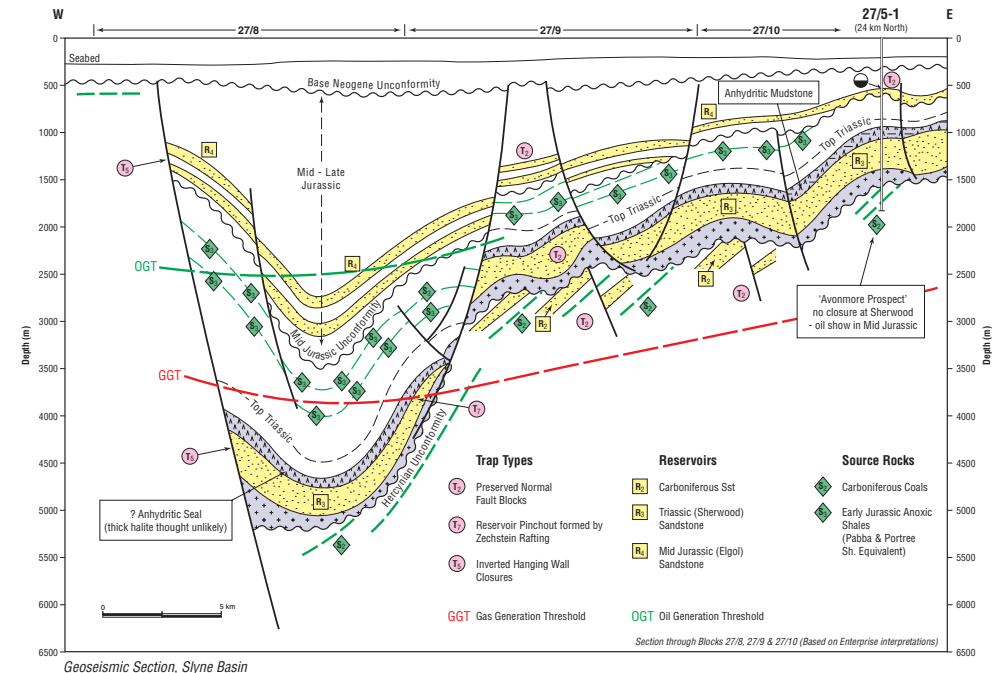
Petroleum Systems Diagram, Slyne Basin



Slyne Basin geoseismic section

- Following play types/petroleum systems are identified:
 - Carboniferous coals (gas) to Triassic sands (e.g. Corrib).
 - Reservoir continuous across area.
 - Seal largely anhydritic shale (salt in north of basin).
 - Due to early generation, identification of palaeostructures such as fault blocks shown is key.
 - Many large fault blocks remain un-drilled.
- Carboniferous coals (gas) to Carboniferous sands.
 - Not highly rated due to unfavourable subcrop and depth of reservoir.
- Early/Mid Jurassic shales (oil) to Mid Jurassic sands.
 - Petroleum system proven by oil shows in several wells.
 - Avonmore believed to be a breached trap.
 - Preservation is the critical issue.

The geoseismic section is based on a composite of three seismic lines: E94IE09, E96IE09 and E97IE20.

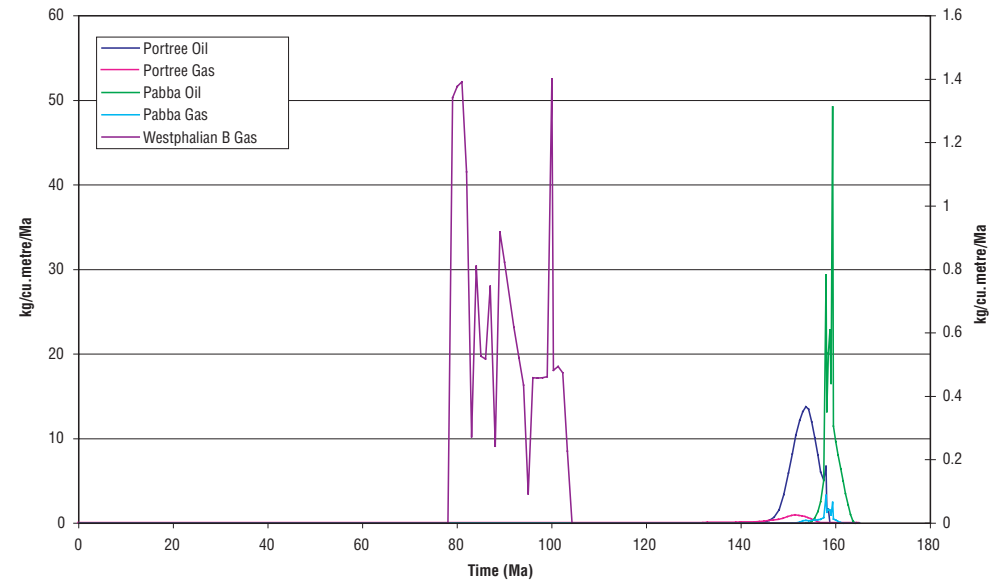




Slyne Basin expulsion plot

- Oil expulsion from the Pabba and Portree Shales occurs at approximately 150 Ma.
- Gas expulsion from the Carboniferous coals occurs between 80 and 111 Ma.
- The methodology for hydrocarbon expulsion can be found in Appendix 2.

Central Slyne Basin Expulsion Rates





Critical issues

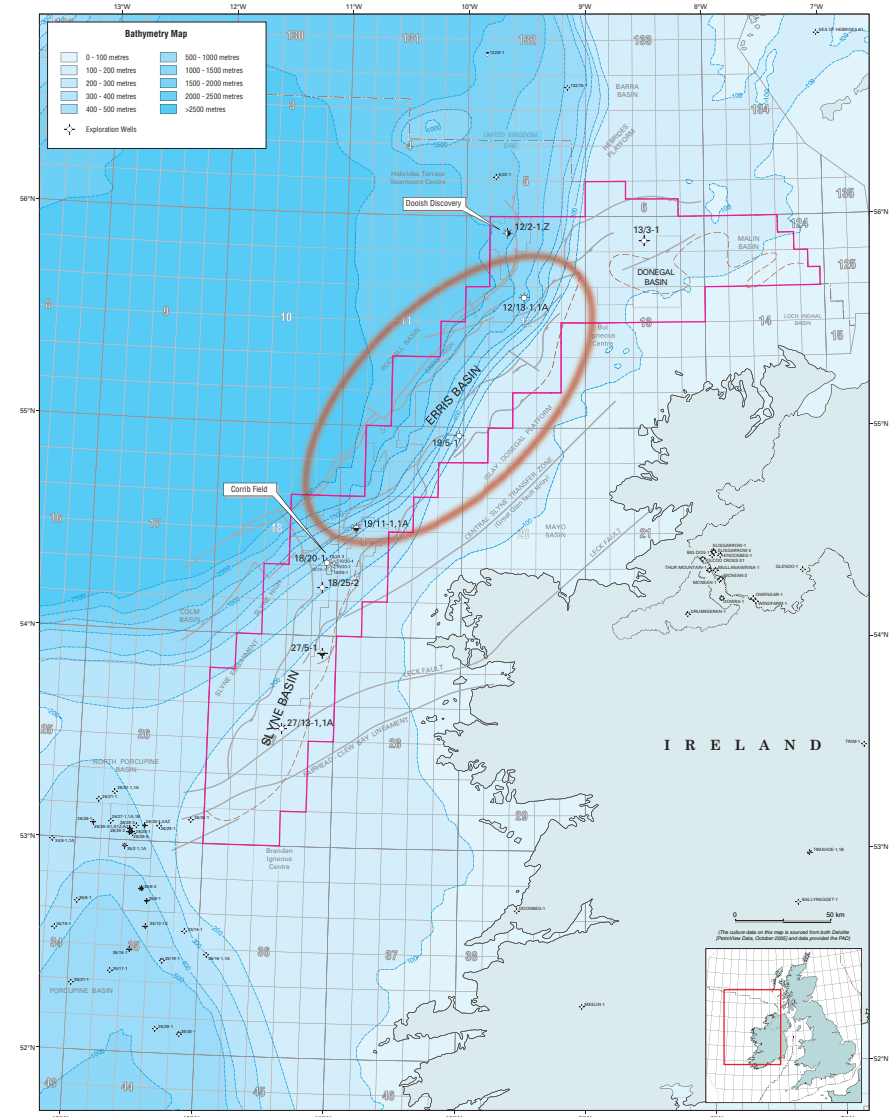
- Importance of seal facies
 - Corrib has both Zechstein (structure) and Mercia (seal) halites
 - Analogue field where Mercia is silty; Hewett Field, Southern North Sea.
 - Silty seal and ? breached accumulations in Mid Jurassic sands
- Timing critical
 - Emphasis on long lived (preserved) traps
 - Need to understand evolution of traps and relationship to generation phases
 - Trap breaching events
- Trap
 - Need to fully image
 - Fault style critical – often soles out in Mercia or Zechstein
 - Juxtaposition of lithologies on faults





The Erris Basin

- Located between 75 and 250 km offshore west Ireland.
- Occurs within 50 and 2000 m of water depth.
- It is a Mesozoic half-graben, probably underlain by Upper Palaeozoic strata.
- In the south there is considerable thickness variation in the Mesozoic units, particularly at Permo-Triassic level.
- A buried basement feature at the western boundary fault represents the Erris High, above which the Permo-Triassic abuts against Cretaceous strata within tilted fault blocks along the margin of the Rockall Basin.
- Thickness variation is less marked further north in the basin where there is little sign of growth or erosion at the western boundary against the Erris High.
- A diffuse faulted basement high at approximately 54° 30' N separates the Erris Basin from the northern Slyne Basin.
- Basin is under-explored. Two of three wells drilled were on basin margin well up-dip of kitchens and areas of seal development.

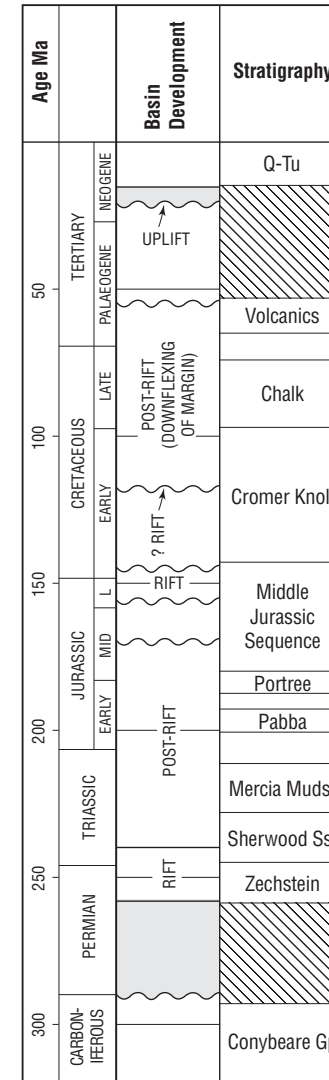




Erris Basin chronostratigraphy

- The basin contains a thick Permo-Triassic succession unconformably overlying Carboniferous strata. This is expected to include both Zechstein and Mercia salts in the basin deep.
- An early Jurassic unit is present that contains the Pabba and Portree Formations, the Upper Jurassic is missing.
- A Base Cretaceous unconformity is recognised throughout the basin, representing a major period of uplift and erosion (footwall uplift to Rockall Basin to west).
- Significant Early Cretaceous rifting occurred above this unconformity. Thick Cretaceous section deposited (major difference to Slyne Basin)
- A number of minor phases of uplift and erosion occurred throughout the Tertiary.

Chronostratigraphy adapted from Chapman et al., 1999.

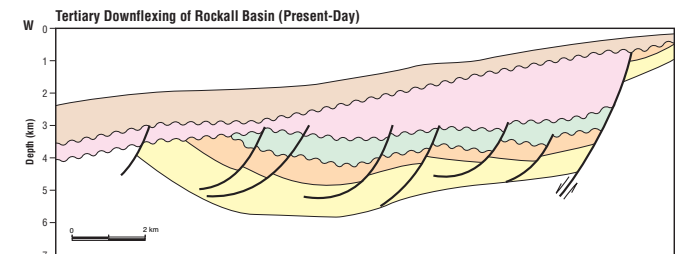
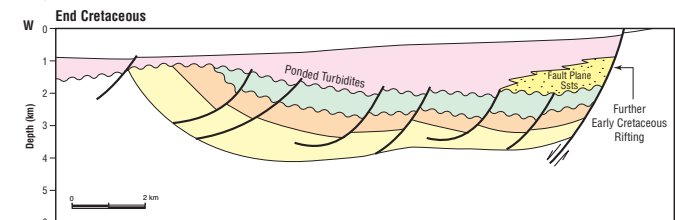
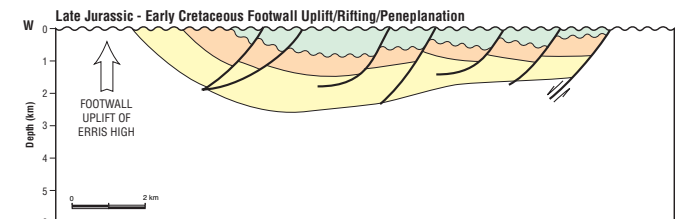
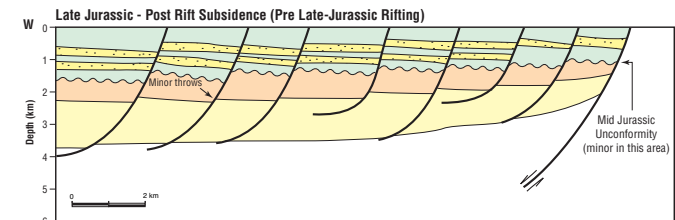
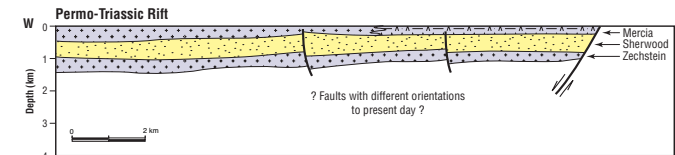


Chronostratigraphy, Southern Erris Basin



Erris Basin structural history

- Initial rifting occurs during the Late Permian. Basin centre seems to have lain in southwest of basin.
- During the Rhaetic, infilling of the Late Triassic rift topography occurs.
- This is followed by a second phase of rifting in the Late Bajocian.
- During the Early Cretaceous, rift shoulder uplift along western margins results in the uplift of the Erris Ridge. Subsidence occurs against a basin bounding fault to the east.
- By Late Cretaceous to Early Tertiary thermal subsidence in the Rockall Basin results in the current day western tilt of the basin.
- Source rocks and reservoirs reached their maximum burial during the Tertiary.



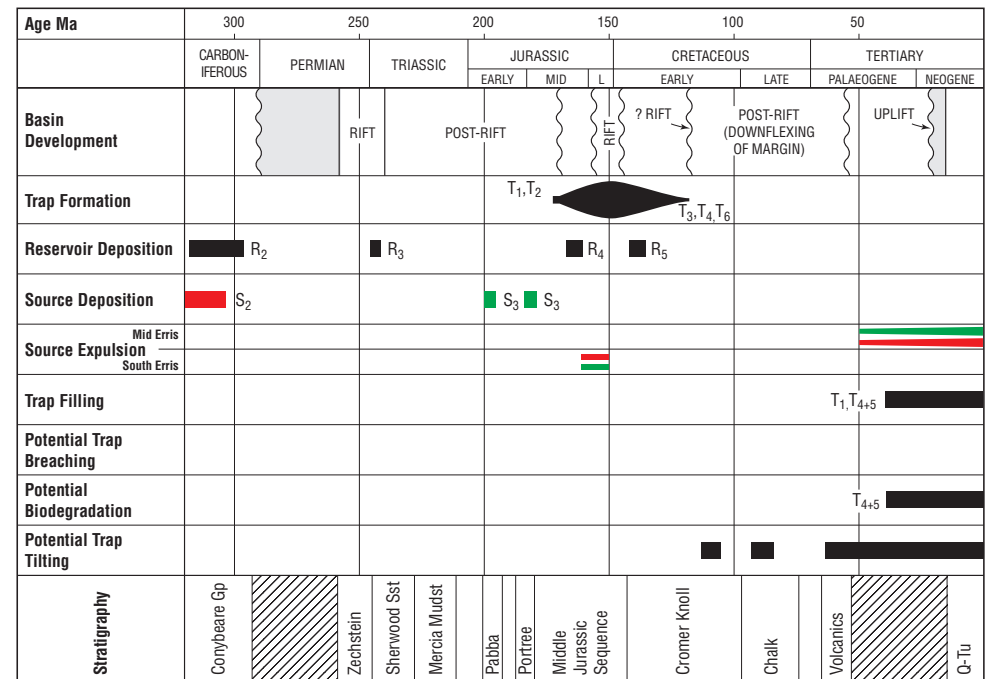
Structural History, Southern Erris Basin





Erris Basin petroleum systems diagram

- Two potential source rocks are predicted; the Carboniferous coals (gas) and Early to Mid Jurassic anoxic shales (oil).
- Four potential reservoir rocks have been identified; sands deposited in the Carboniferous, the Triassic, the Mid Jurassic and Cretaceous.
- Five general trap types are recognised; fault dip, preserved normal faults, sub-crop closure, fault abutment and stratigraphic pinch-out. All such traps were in existence at the time of maximum burial in the Tertiary.
- Late stage trap leakage is not expected to be a problem due to continued subsidence in the Tertiary.



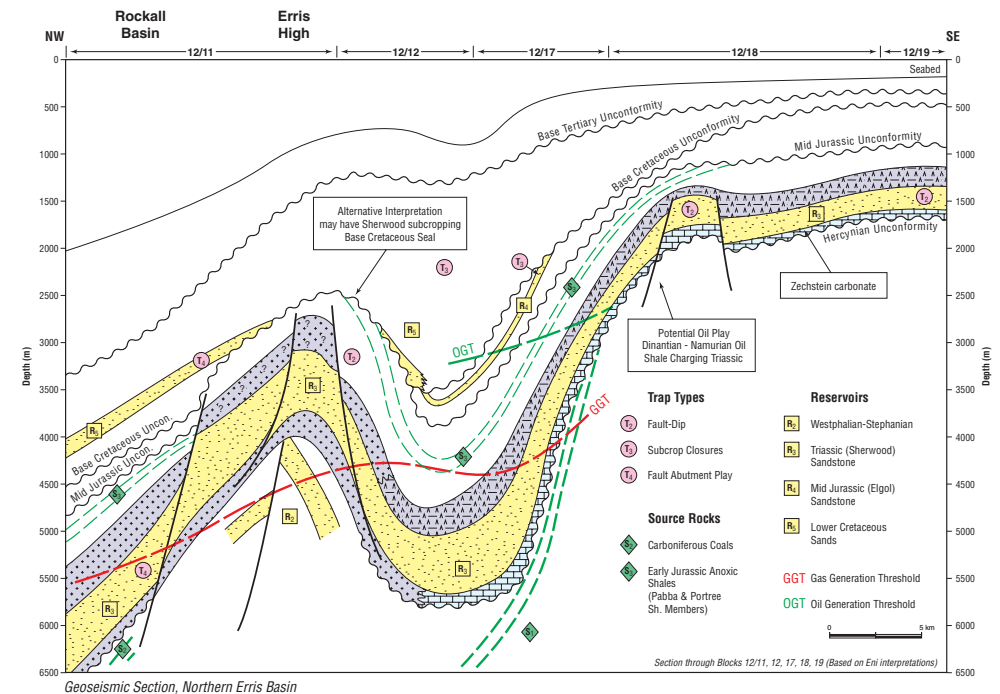
Petroleum Systems Diagram, Southern Erris Basin





North Erris geoseismic section

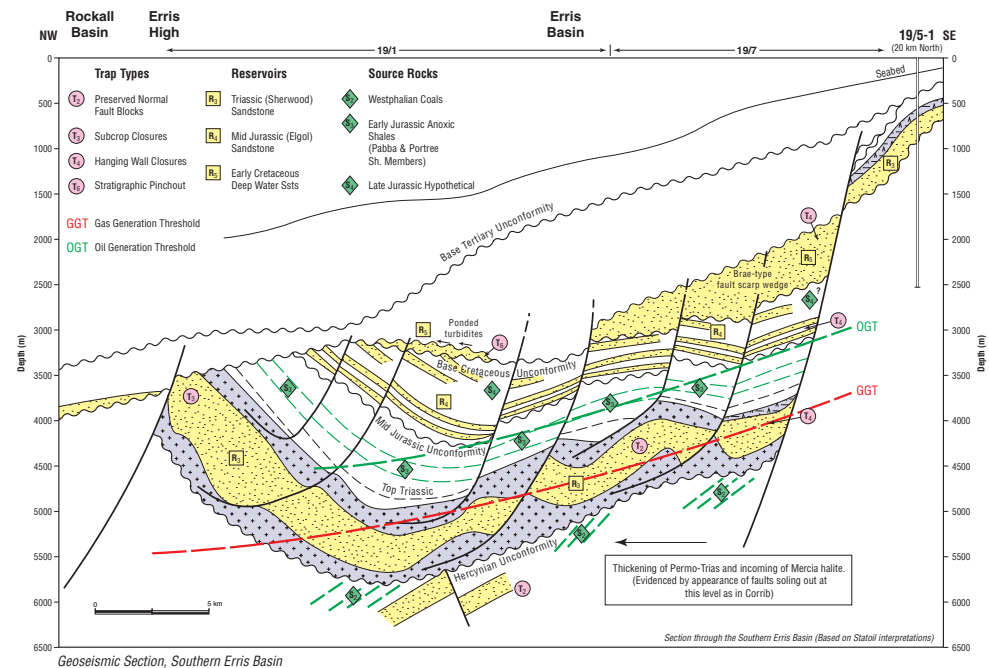
- Following play types/petroleum systems are identified:
- Dinantian-Namurian shales (oil) to Triassic sands.
 - New play type identified by analogy to the East Irish Sea Basin.
 - Holywell Shale (source to Douglas/Lennox) subcrops base Permian unconformity in area where Zechstein will be in carbonate facies, thus enabling migration to Triassic reservoir.
- Carboniferous coals (gas) to Triassic sands.
 - Reservoir continuous across area.
 - Seal largely anhydritic shale in north of basin.
 - Potential subcrop traps on Erris High with base Cretaceous seal.
- Carboniferous coals (gas) to Carboniferous sands.
 - Not highly rated due to unfavourable subcrop and depth of reservoir.





South Erris geoseismic section

- Following play types/petroleum systems are identified:
- Carboniferous coals (gas) to Triassic sands (e.g. Corrib).
 - Reservoir continuous across area.
 - Salt seal expected in deep areas.
 - Risk on reservoir quality in deepest parts of basin.
- Carboniferous coals (gas) to Carboniferous sands.
 - Not highly rated due to unfavourable subcrop and depth of reservoir.
- Early/Mid Jurassic shales (oil) to Mid Jurassic sands.
 - Untested play in Erris Basin.
 - Sands unproven though expected to occur (note NW provenance in Porcupine).
 - Risk of subcrop/erosion of reservoir and seal on base Cretaceous unconformity.
 - Fairway has failed in Slyne due to trap breach, this should not be an issue in;
- Early/Mid Jurassic shales (oil) to Early Cretaceous sands.
 - Brae-style hanging wall/fault scarp sands type trap.
 - In communication with source rock on base Cretaceous unconformity.
 - Critical factors are oil quality (shallow depth) and fault plane seal.



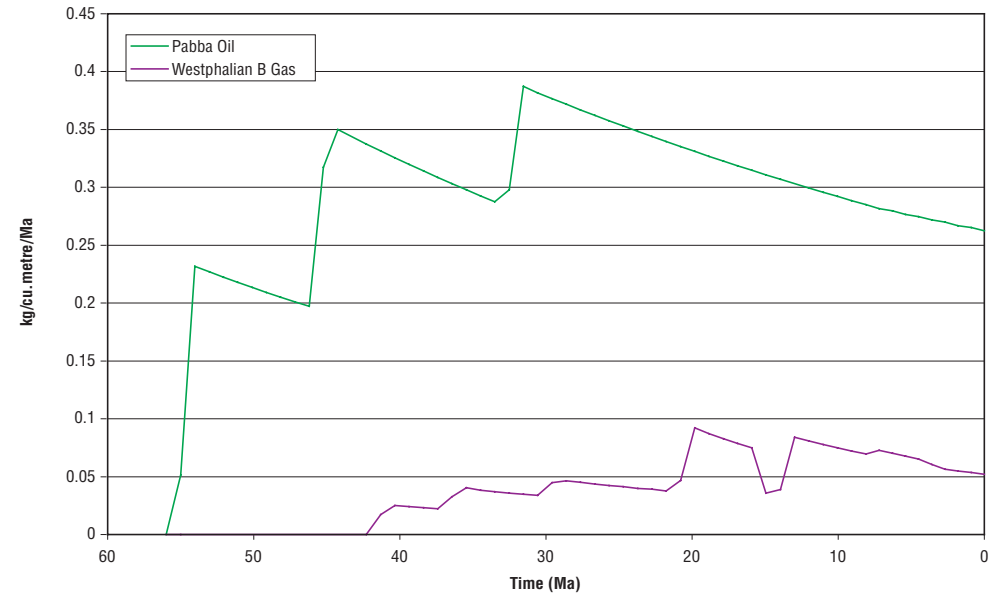
Geoseismic section adapted from seismic line NWI-93-109.



Mid Erris expulsion plot

- The Pabba Oil is expelled from 55 Ma to Present Day.
- The Westphalian B Gas is expelled from approximately 40 Ma to Present Day.
- The methodology for hydrocarbon expulsion can be found in Appendix 2.

Mid Erris Basin Expulsion Rates

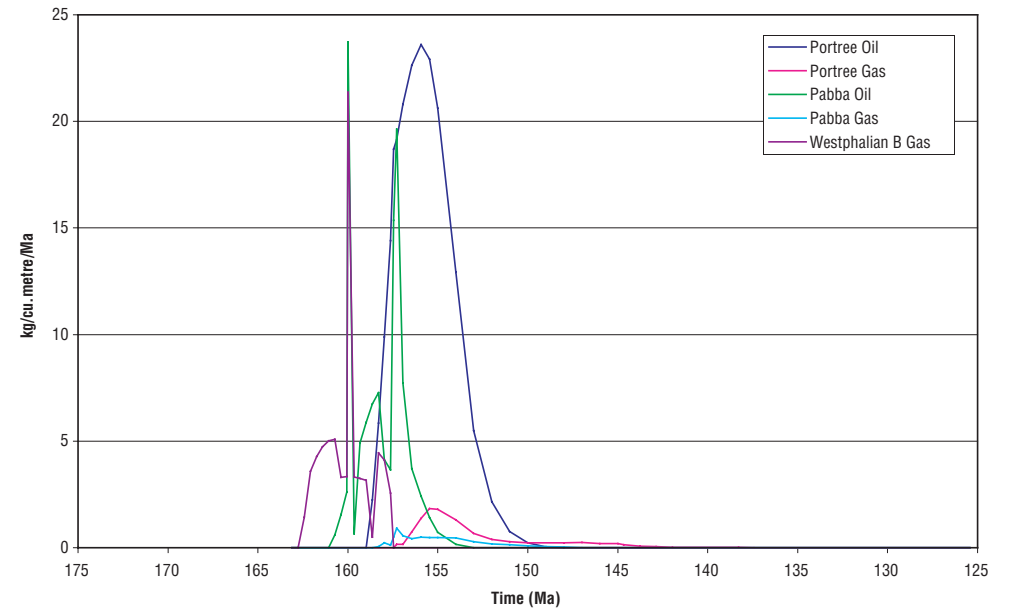




South Erris expulsion plot

- Corrib area expulsion plot
- The Westphalian B Gas is expelled between approximately 163 to 158 Ma.
- The Pabba Oil is expelled between 161 to 154 Ma.
- The Portree Oil is expelled between 158 to 149 Ma.
- The methodology for hydrocarbon expulsion can be found in Appendix 2.

South Erris Basin Expulsion Rate (near Corrib)





Critical issues

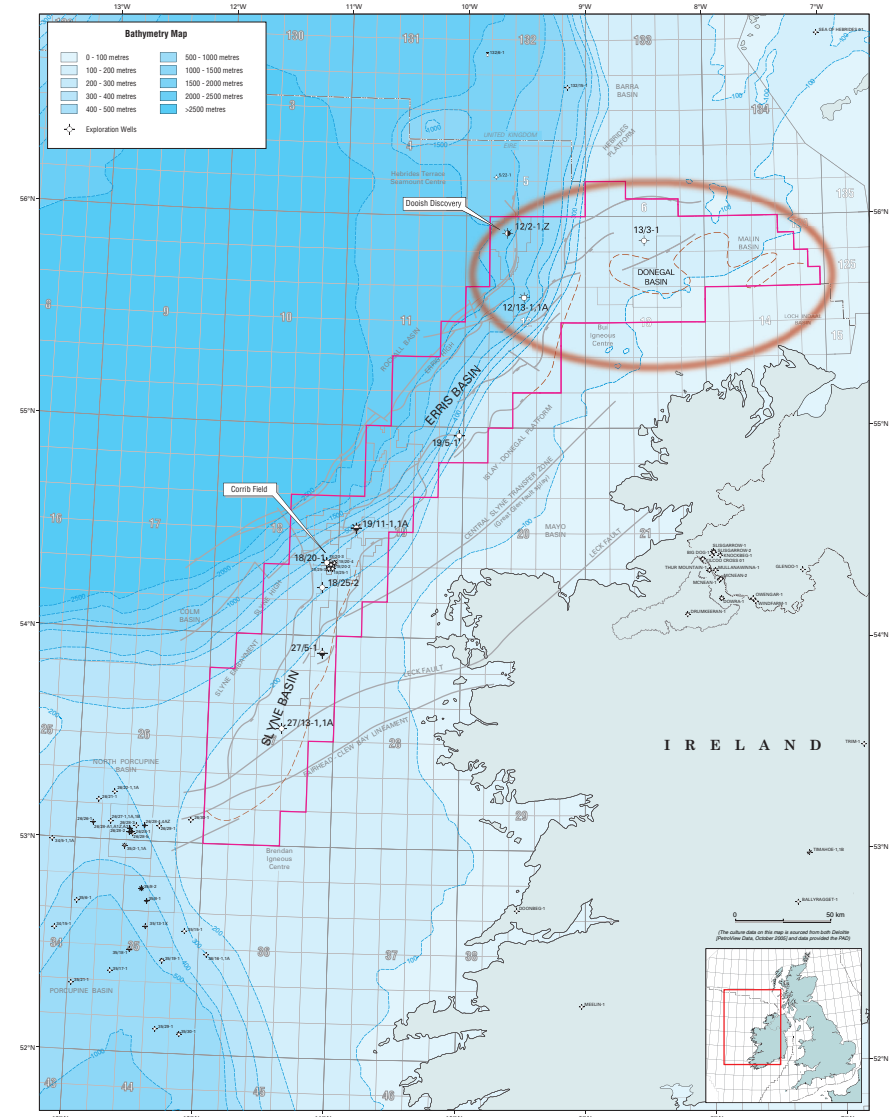
- Importance of seal facies.
 - Corrib has both Zechstein (structure) and Mercia (seal) halites.
 - No analogue field where Mercia is silty (cf. analogue study).
 - Silty seal and ? breached accumulations in Mid Jurassic sands.
- Timing critical.
 - Emphasis on long lived (preserved) traps.
 - Need to understand evolution of traps and relationship to generation phases.
 - Trap breaching events.
- Trap.
 - Need to fully image.
 - Fault style critical – often soles out in Mercia or Zechstein.
 - Juxtaposition of lithologies on faults.





The Donegal Basin

- Located between 50 and 100 km offshore North West Ireland.
- Occurs within 50 and 200 m of water depth.
- A basin (approximately 80 km x 60 km) with ENE trend, oblique to the NE-SW alignment of the Slyne-Erriis trend.
- Extending parallel to the north coast of Ireland into the area of the Malin Sea.
- Two sub-basins. The North Donegal Basin fill is assumed to be largely Upper Palaeozoic in age, as supported by the results of the Texaco 13/3-1 well. In the South Donegal Basin, Permo-Triassic to Jurassic strata may also be inferred from seismic character in structurally deeper parts of the basin, analogous to the proven Mesozoic occurrences in the adjacent Malin and Hebridean basins to the northeast.
- The South Donegal Mesozoic Basin is a completely untested basin.

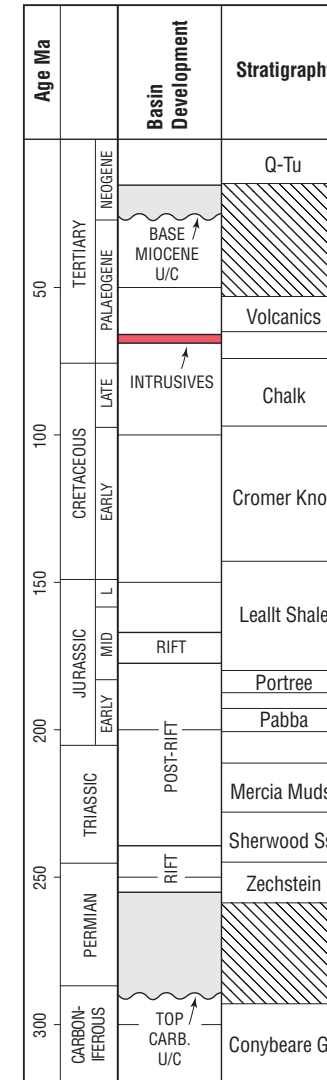




Donegal Basin chronostratigraphy

- The only well within the Donegal Basin is the 13/3-1 well, which drilled a thick and almost complete Carboniferous section
- The South Donegal Basin is interpreted to contain 3000 m of Mesozoic fill. This was not tested by the above well, which was drilled in the North Donegal Carboniferous basin.
- Carboniferous sediments are expected, unconformably overlain by deposits of the Zechstein, Sherwood and Mercia Mudstone Formations, by comparison to associated basins such as the Antrim Basin.
- In turn these should be overlain by Early to Mid Jurassic sediments including the Pabba and Portree Formations. The Late Jurassic is missing.
- Finally, the basin is filled with a Cretaceous and thin Tertiary cover.

Chronostratigraphy adapted from Shannon et al., 1991.



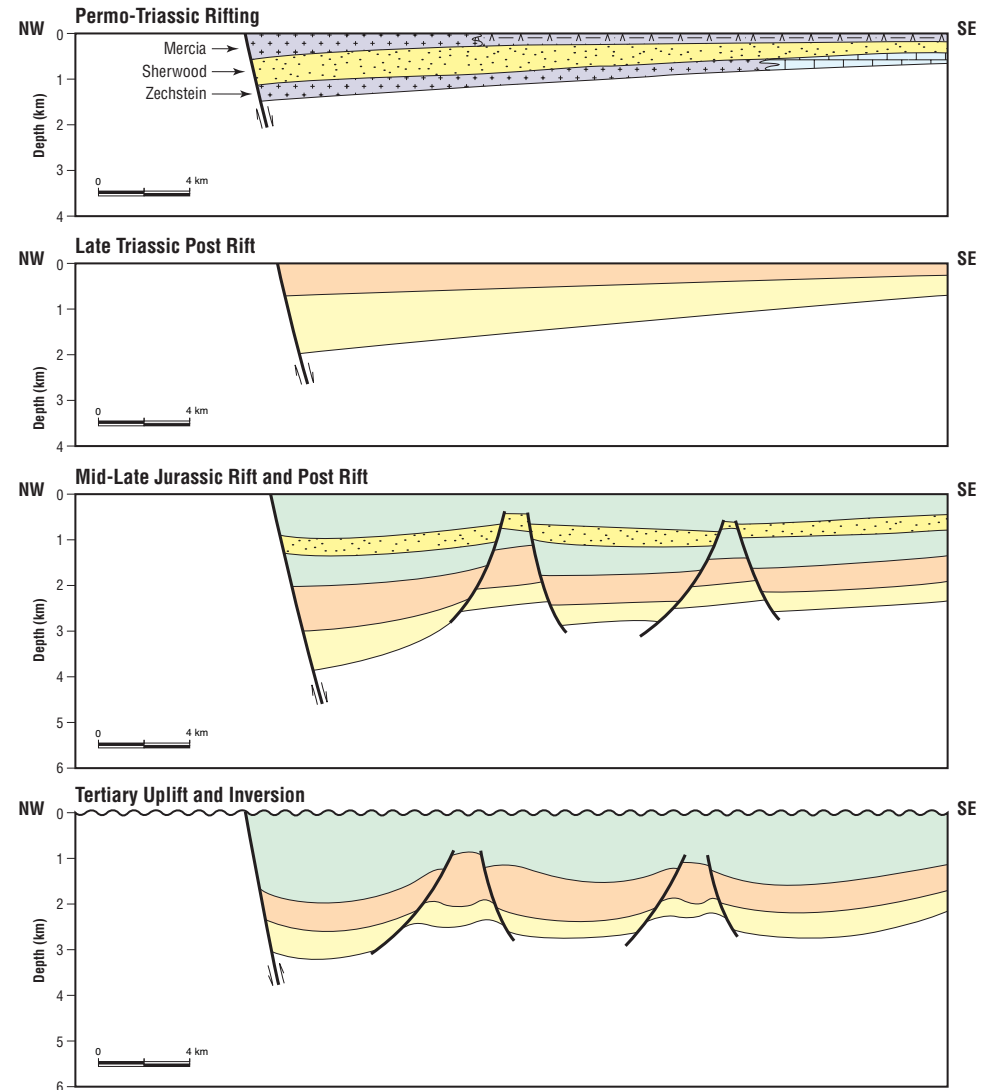
Chronostratigraphy, Donegal Basin





Donegal Basin structural history

- Expected to be similar to the Slyne and Antrim Basins.
- Initial Rifting occurs during the Late Permian.
- During the Rhaetic, infilling of the Late Triassic rift topography occurs.
- This is followed by a second phase of rifting in the Late Bajocian.
- Uplifted and eroded as a result of end Jurassic and Tertiary inversion.



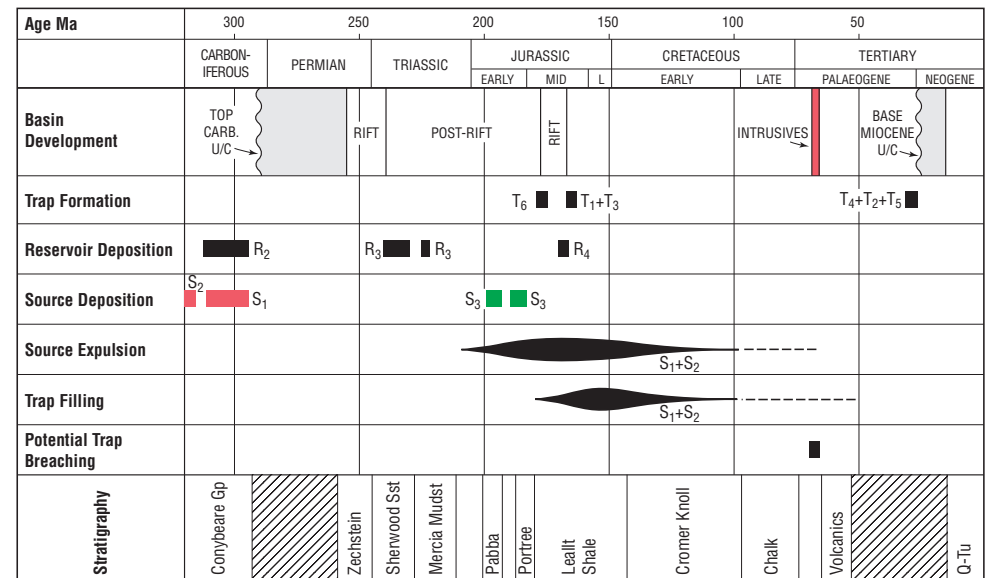
Structural History, Donegal Basin





Donegal Basin petroleum systems diagram

- Three potential source rocks are predicted; the Namurian shales, Westphalian coals and Early to Mid Jurassic anoxic shales.
- Three potential reservoir rocks have been identified; sands deposited in the Late Westphalian-Stephanian ('Barren Measures' equivalent), the Triassic Sherwood Formation and Mid Jurassic sands.
- Six potential trap types are recognised; salt cored anticlines, sub-crop closure, preserved normal faults, hanging wall closures, inverted anticlines, and stratigraphic traps. As in Slyne, the older generations of traps and those sealed by salts are believed to be lower risk.
- Although the top Carboniferous is not deep enough to be mature at Present Day, a full Carboniferous section is expected and the basal coals section should have been matured, particularly given deeper burial and heat flow in the Jurassic.
- Gas expulsion from the Carboniferous coals occurs between approximately 220 to 50 Ma, peaking at 150 Ma.
- The Jurassic shales are not expected to reach maturity.



Petroleum Systems Diagram, Donegal Basin

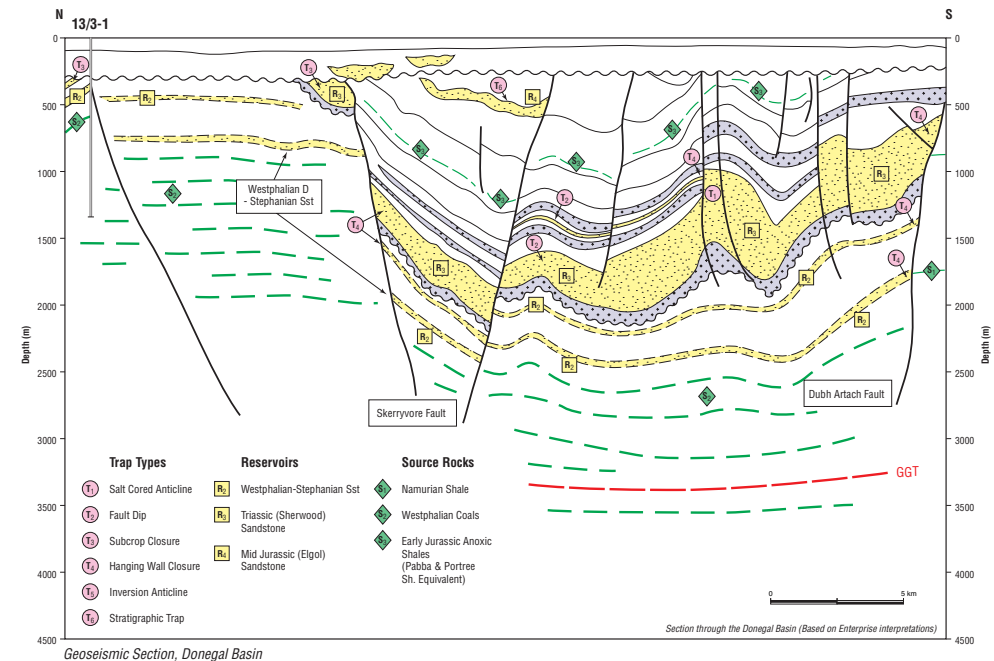




Donegal Basin geoseismic section

- Following play types/petroleum systems are identified:
- Carboniferous coals (gas) to Triassic sands.
 - Reservoir expected to be continuous across area.
 - Salt seal expected in deep areas (some seismic indications).
 - Reservoir quality not an issue.
 - Fault block or inversion traps – latter are higher risk on timing.
- Carboniferous coals (gas) to Carboniferous sands.
 - Southern North Sea 'Barren Measures' type play may be present in seismically transparent interval below Zechstein (note full Carboniferous section present in 13/3-1).

Geoseismic Section adapted from seismic line DBS99-207. Based on Enterprise interpretation.

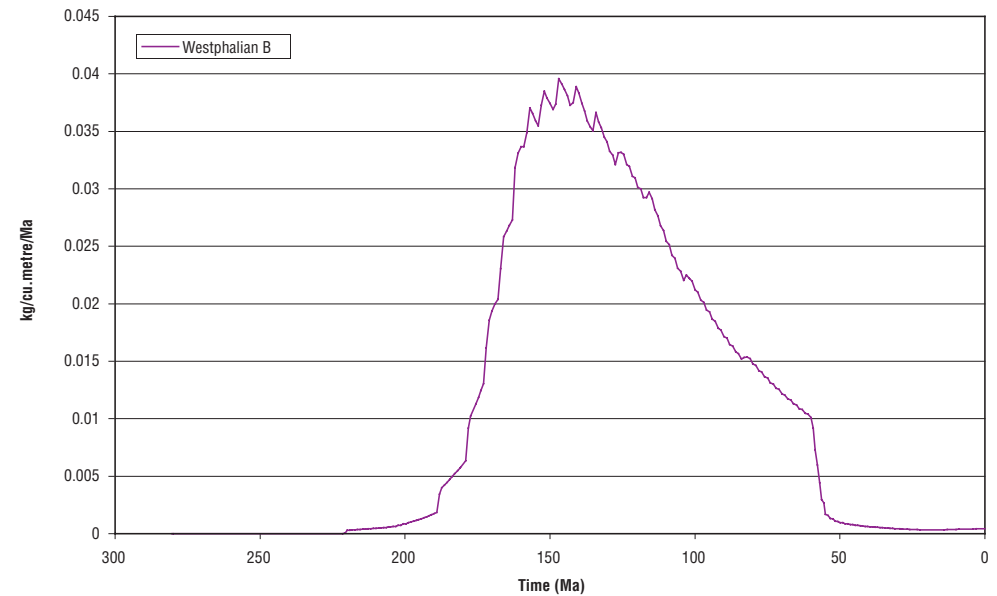




Donegal Basin expulsion plot

- Gas expulsion from the Westphalian B Formation occurs between approximately 220 to 50 Ma, peaking at 150 Ma.
- The methodology for hydrocarbon expulsion can be found in Appendix 2.

South Donegal Basin Gas Expulsion Rates





Critical issues

- Reservoir presence and quality uncertain.
- Timing critical.
 - Trap breaching events
 - Timing of generation is uncertain
- Seal facies
 - Risk on Zechstein lithology (halite, carbonate or sand).





The Play Fairways





Well success/failure analysis

- Key calibrant for play fairway maps: colours shown are transferred to maps at well location and apply to analogous locations.
- Only released wells shown here – 2 more recent wells have since been drilled.
- 1 success from 8 exploration wells, but;
 - Many wells too far up-dip to test viable play (e.g. Erris Basin wells) – poor seal and distance from kitchen.
 - Few wells in basin centres, where prospects lie close to kitchens and seal potential is maximised.
 - 13/3-1 did not test any viable play.
 - 19/5-1 and 27/5-1 probably not closed at Triassic level.
 - Only circa half the wells targeted at Triassic.
 - Many wells seem to have been chosen on acceptable water depths rather than regional geological analysis.
 - Common reason for failure of Jurassic target tests in Slyne – post-entrapment leakage through fault reactivation, should not apply in Erris.
 - In summary, only a handful of wells drilled in geologically favourable sites.

WELL	12/13-1 & 12/13-1A	13/3-1	18/20-1	18/25-2	19/5-1	27/5-1	27/13-1
LOCATION	Erris	Donegal		Slyne			Slyne
MAIN TARGET	Triassic	Triassic	Mid Jur	Triassic	Jur to Carb	Mid Jur	Mid Jur
SECONDARY TARGET	Jur	Jur & Carb	L. Triassic	Mid Jurassic	N/A	Triassic	
TD Formation	? Palaeozoic	Carb / ligneous	L. Triassic	Silurian	Carb	Carboniferous	Jur
1. CARBONIFEROUS							
Target Section Present?	not penetrated	yes	not penetrated	not penetrated	yes	Yes	not penetrated
Hydrocarbons?		some fluorescence			No	Gas shows	
Presence of Closure		not confirmed			??	??	
Topseal		Miocene			Zechstein carbonate	Yes (Halite)	
Possible Later Fault Breaching		likely			possible	possible	
Source Rock Presence		yes			Yes	Yes	
Source Rock Maturity		yes			immature at well	immature at well	
Migration Path		yes			long distance	long distance	
Charge Post-Trap Formation		unlikely			Yes	Yes	
Reservoir Presence		in youngest section			Yes	Thin sat	
Reservoir Quality		ok at top of section			No	Poor	
2. TRIASSIC							
Target Section Present?	yes	absent	yes	yes	yes	yes	not penetrated
Hydrocarbons?	Gas shows		Gas column	no	No	No	
Presence of Closure	could spill to west		yes	??	yes	poss open to east	
Topseal	silty	halite	halite	halite	silty	anhyd shale - sideseal (Lias) also in doubt	
Possible Later Fault Breaching	possible	no	no	no	no	possible	
Source Rock Presence	yes	yes	yes	absent at well	yes	yes	
Source Rock Maturity	immature at well		yes	yes	immature at well	immature at well	
Migration Path	long distance		yes	??	long distance	long distance	
Charge Post-Trap Formation	ok		yes	yes	yes	yes	
Reservoir Presence	yes		yes	largely removed on fault	yes	yes	
Reservoir Quality	yes		yes	yes	yes	yes	
3. MID-JURASSIC							
Target Section Present?	absent	absent	Yes	Yes	absent	Yes	Yes
Hydrocarbons?			Oil shows (biodegraded)	not known		palaeocolumn	shows
Presence of Closure			Yes (always by fault+1dip)	not known		yes	yes
Topseal			yes	not known		yes	yes
Possible Later Fault Breaching			possible	not known		probable leaked accumulation	likely
Source Rock Presence			yes	not known		yes	yes
Source Rock Maturity			yes	not known		yes	yes
Migration Path			yes	not known		yes	yes
Charge Post-Trap Formation			yes	not known		yes	yes
Reservoir Presence			yes	not known		yes	thin sands
Reservoir Quality			yes	not known		yes	yes



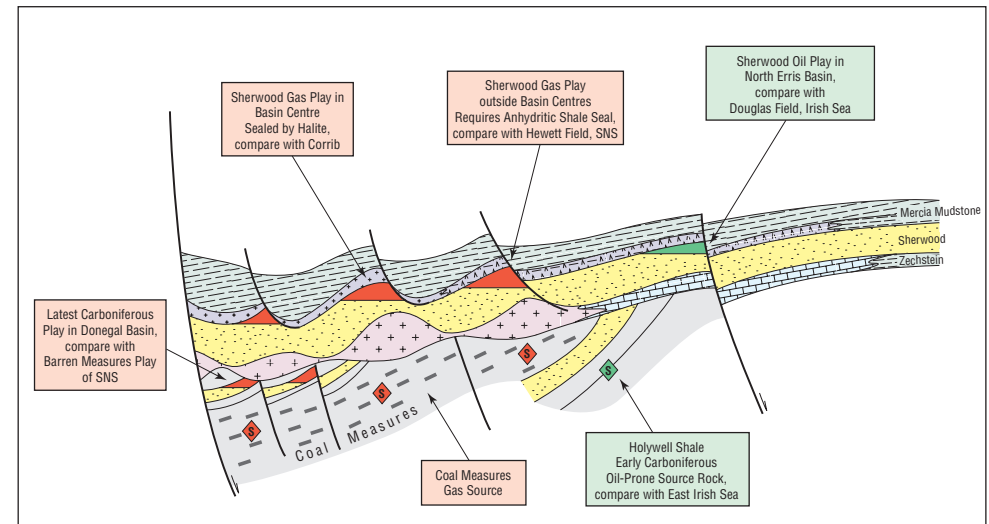


The Carboniferous and Triassic play cartoon

Summary of play dynamics for plays in Carboniferous and Triassic reservoirs.

Key issues are;

- Carboniferous
 - Thick reservoirs likely only at subcrop of Namurian-Westphalian A and Westphalian C-Stephanian intervals (as in Southern North Sea).
 - Only base Permian sealed play considered : presence of Zechstein salt critical.
- Triassic
 - Oil play in Northern Erris only where Carboniferous subcrop enables communication with 'Holywell Shale' equivalent.
 - Gas play deeper in basin. Seal is critical issue.



Carboniferous and Triassic Plays





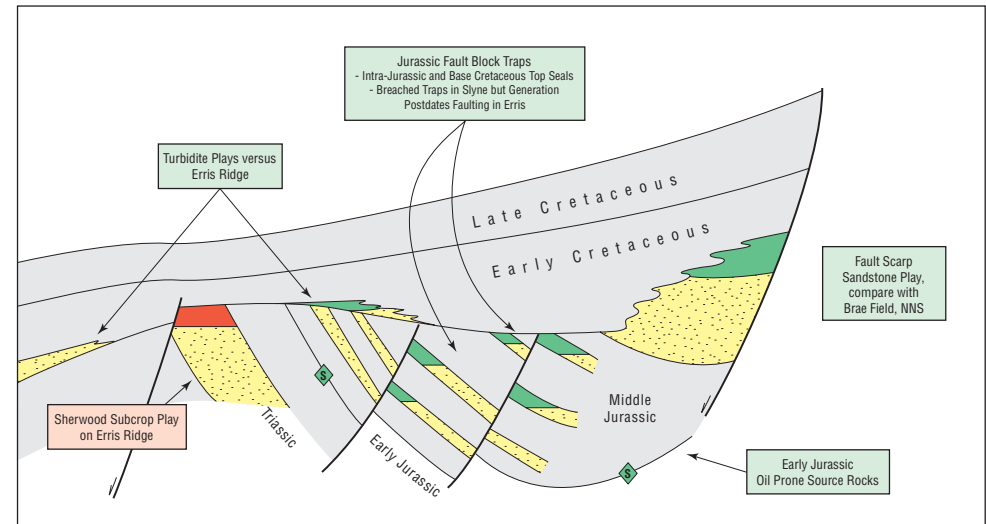
The Jurassic and Cretaceous play cartoon

A summary of the play dynamics for plays in the Jurassic and Cretaceous reservoirs, typified by Erris Basin.

The Triassic subcrop play on the Erris High is also shown.

Key issues are;

- Jurassic
 - Preservation of reservoir and seal on base Cretaceous unconformity.
 - Only base Permian sealed play considered : presence of Zechstein salt critical.
- Triassic
 - Oil play in Northern Erris only where Carboniferous subcrop enables communication with 'Holywell Shale' equivalent.
 - Gas play deeper in basin. Seal type is critical issue, particularly in basins where generation occurred as early as the Jurassic and long term preservation is required.



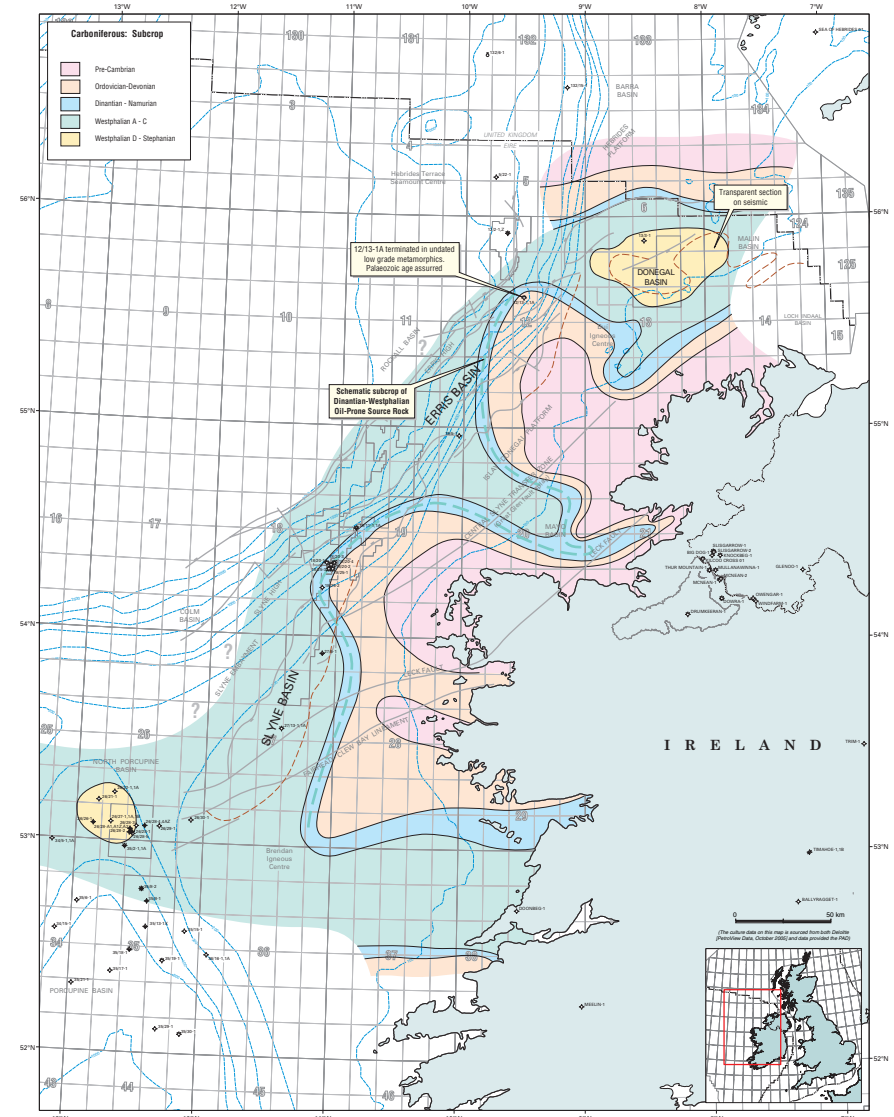
Jurassic and Cretaceous Plays





Late Carboniferous subcrop map

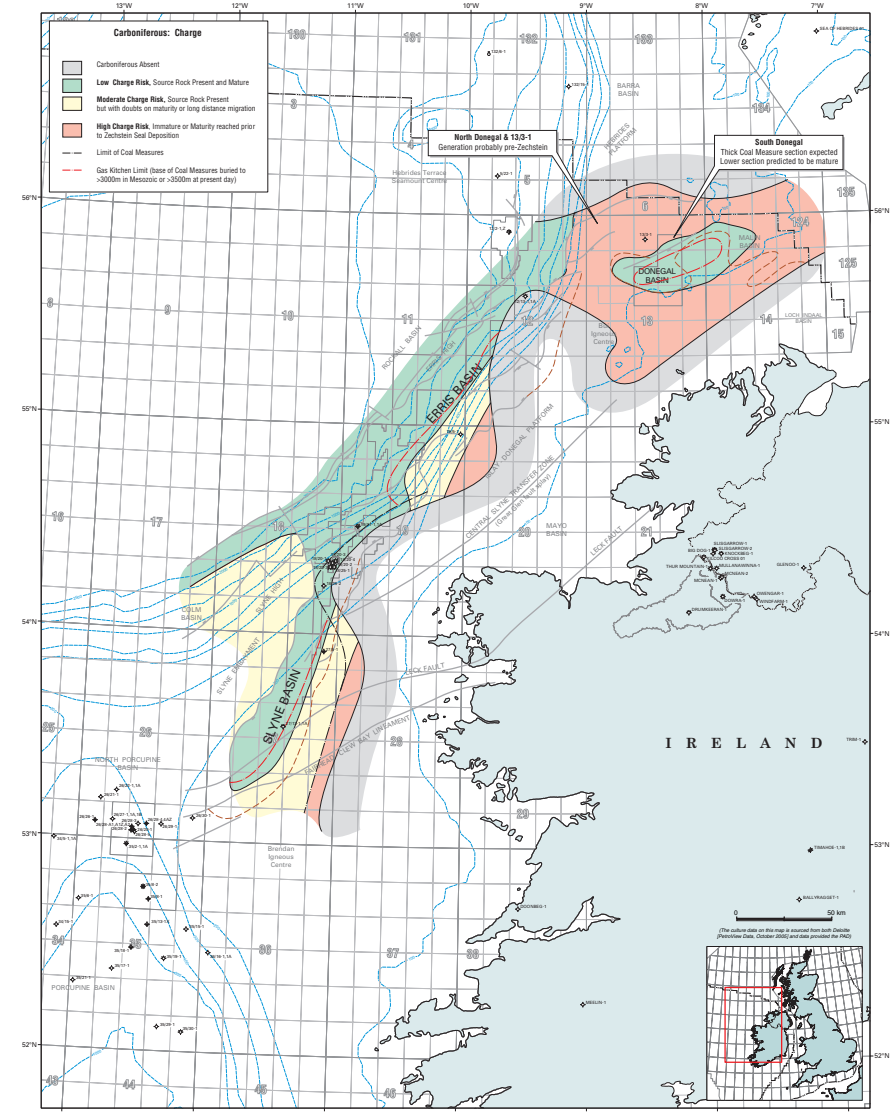
- Map was prepared as an aid to drawing the Carboniferous/Triassic charge maps and the Carboniferous reservoir map.
- It honours the subcrop at the well points, including that at 12/13-1 which is thought to have terminated in low grade Early Palaeozoic metamorphics. Some interpretations show this as Westphalian D, although this is inconsistent with a metamorphic grade.
- This is significant as it means that the Dinantian-Namurian oil prone source rock must subcrop the unconformity in this area, supporting the invoked Triassic oil play.
- These well subcrops are tied to the mapped outcrop geology of Ireland in the most reasonable pattern possible.
- Links to the Carboniferous basins offshore Mayo and onshore Clare are proposed.
- True subcrop pattern may be more complex than this.





Carboniferous charge map

- Green area based on kitchens where Present Day burial exceeds 3.5 km or palaeoburial 3 km (cf. modelling results).
- Also restricted to the area of expected Coal Measures subcrop (source rock).
- Maturity is worked on the expected base of Coal Measures (Late Namurian?). In some cases, the top coal measures may be immature (e.g. Donegal Basin).
- Yellow requires long distance migration (Slyne/Erris).
- Red areas are immature or generation is possibly too early (pre-Permian).





Well section through Carboniferous reservoir sands

Well section for 13/3-1 (fullest Carboniferous section seen). Based on Enterprise interpretation (depths in metres).

Reservoirs

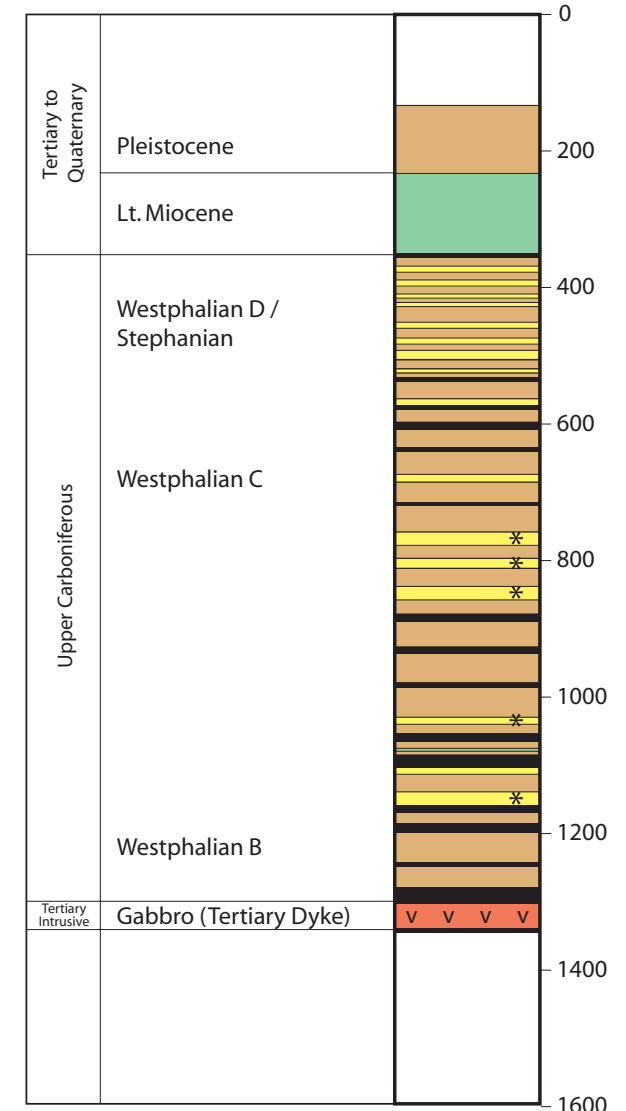
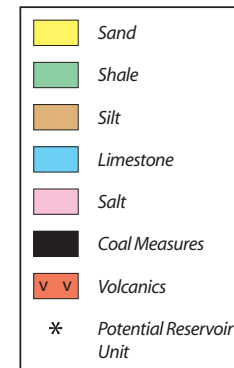
- Carboniferous sandstones.
- 248 m in Westphalian B-C.
- 36 m in Westphalian D with beds up to 7.5 m.

Source rocks and maturity

- Coal measures: 80 m of coal in Westphalian B-C.
- Gas maturity below fault contact at 505 m.

Shows

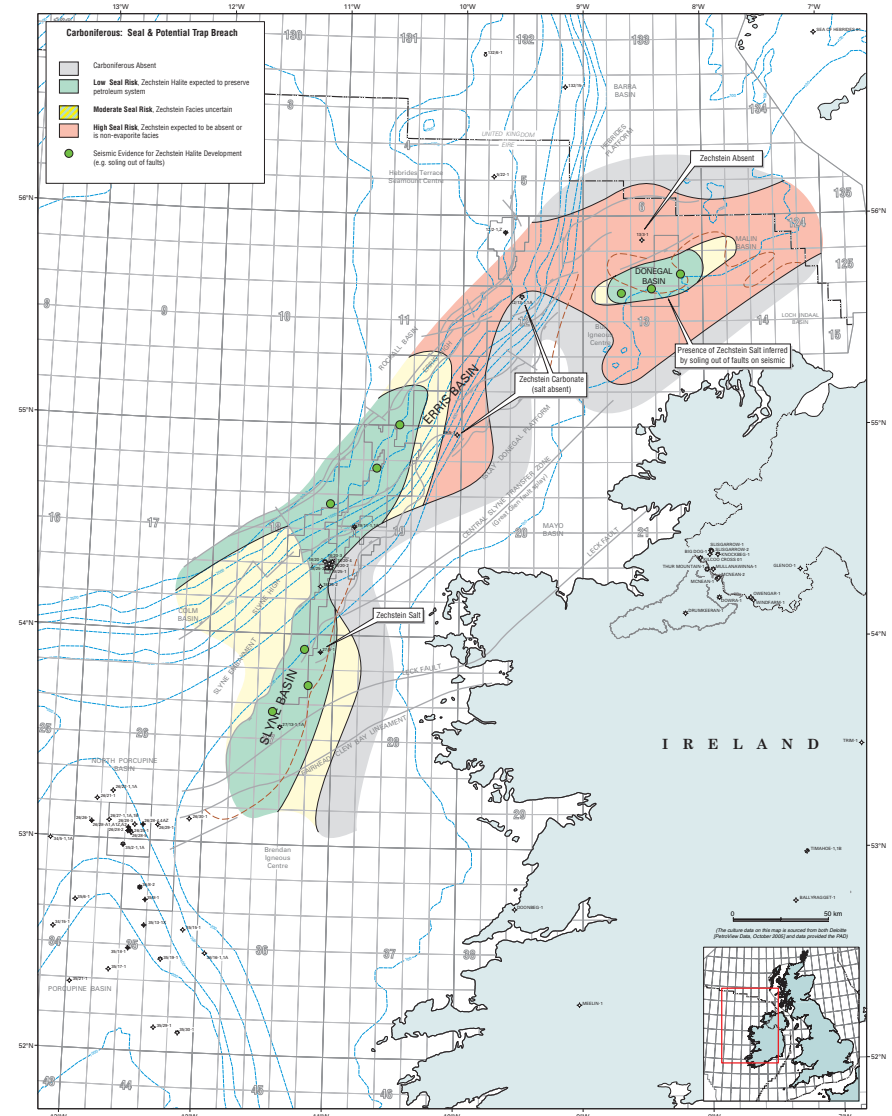
- Oil shows in Westphalian D.
- Gas shows through rest of section to 1117 m.





Carboniferous seal map

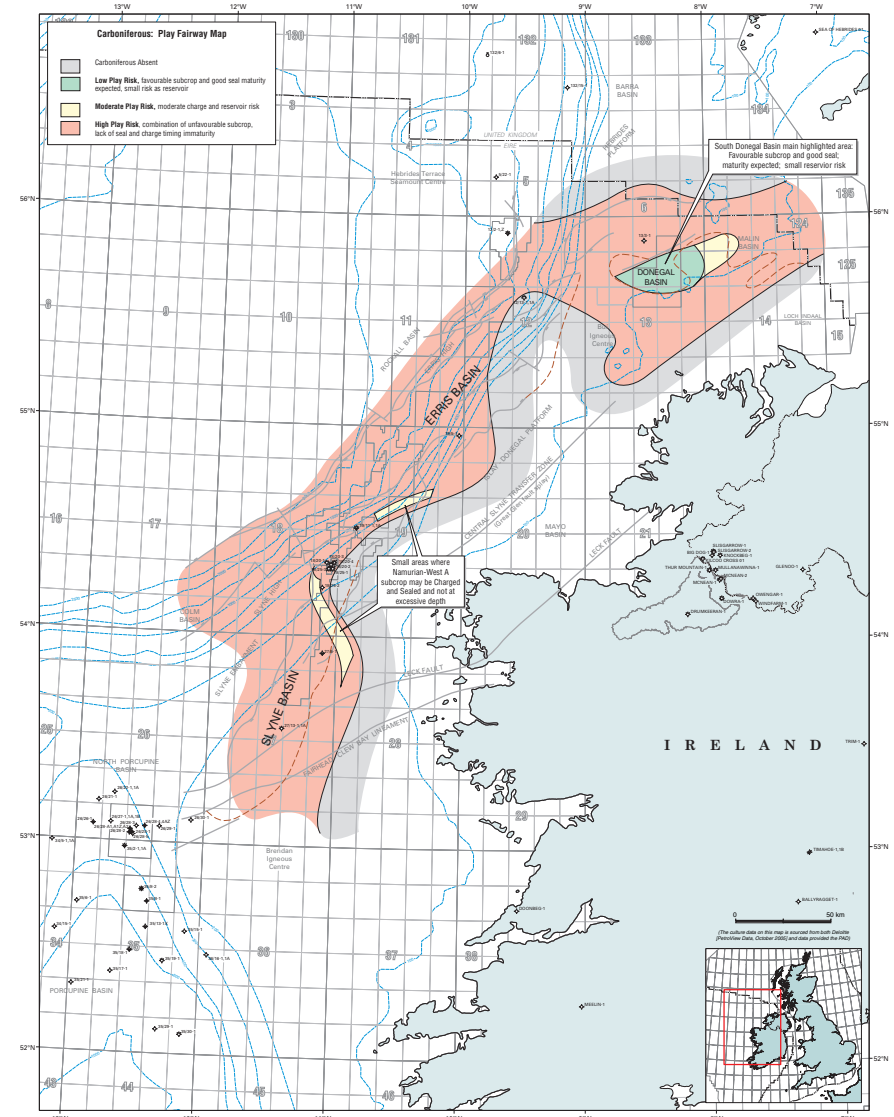
- Green area indicates areas where the Zechstein halite is expected to be present, based on facies mapping, seismic indications of swells or on faults soling out at a certain level.
- Yellow indicates that the Zechstein facies is speculative.
- Red indicates that the Zechstein is represented by non-sealing carbonates or sandstones.
- Intra-Carboniferous seals are not considered here.





Carboniferous play fairway map

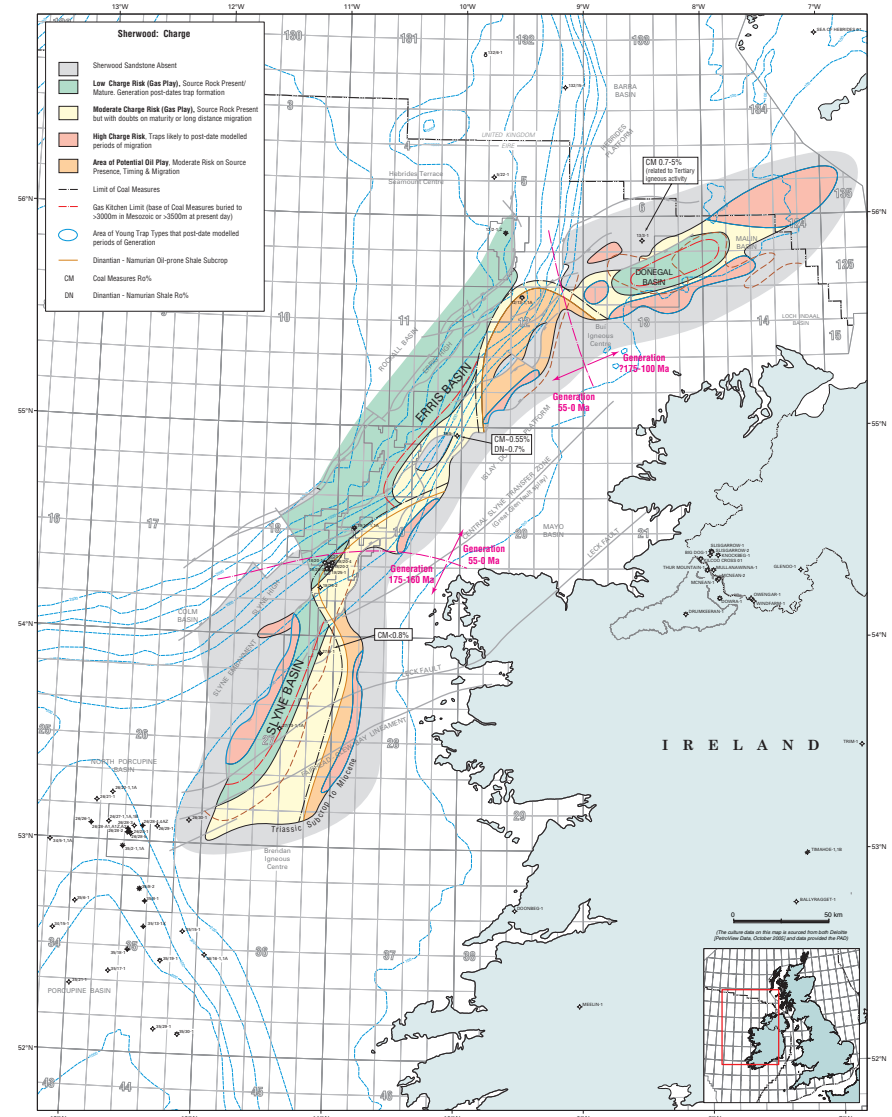
- The southern region of the Donegal Basin represents the most prospective area. Key Features include;
 - the presence of the Zechstein Salt (seal) is inferred by the soling out of faults on seismic,
 - there is a thick Coal Measures unit predicted to be mature, including the equivalent of the SNS 'Barren Measures',
 - good quality Carboniferous sandstones are present (in well 13/3-1),
 - the Basal Coal Measures are expected to be mature.
- There are small areas in the Slyne and Erris Basins that display moderate play risk. In these areas the Namurian to Westphalian A subcrop may be charged and sealed and not at excessive depth. However, the location of these subcrops cannot be accurately predicted with current information.





Triassic charge map

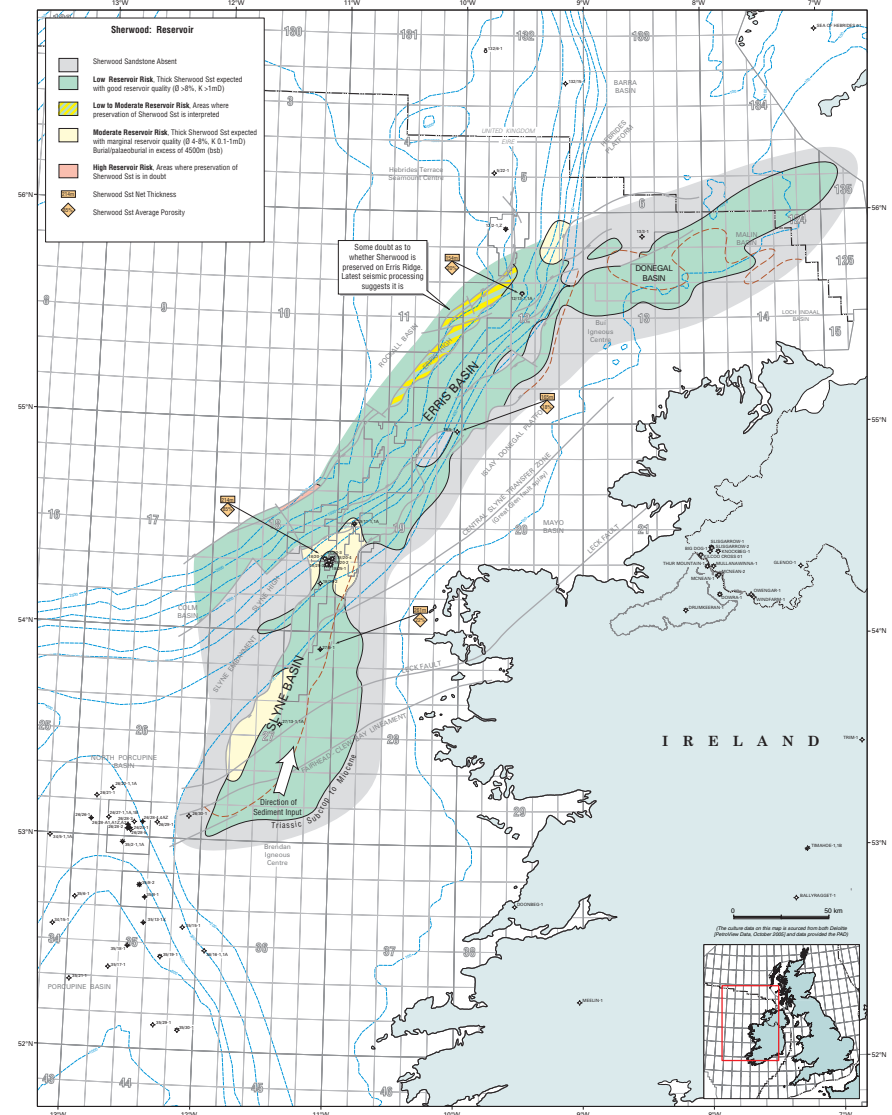
- Very similar to the Carboniferous charge map; Green and yellow areas defined on similar criteria.
- Red indicates areas of young traps that postdate generation and areas where long distance migration must be invoked.
- The Orange segment represent the North Erris oil play, located up-dip of mapped subcrop of Dinantian to Namurian oil shale (expected to be in oil window in Erris, as indicated by maturity data from 19/5-1).
- Note Zechstein salt, where unbroken, may locally block migration (taken to be a prospect specific factor and not shown on maps).





Triassic reservoir map

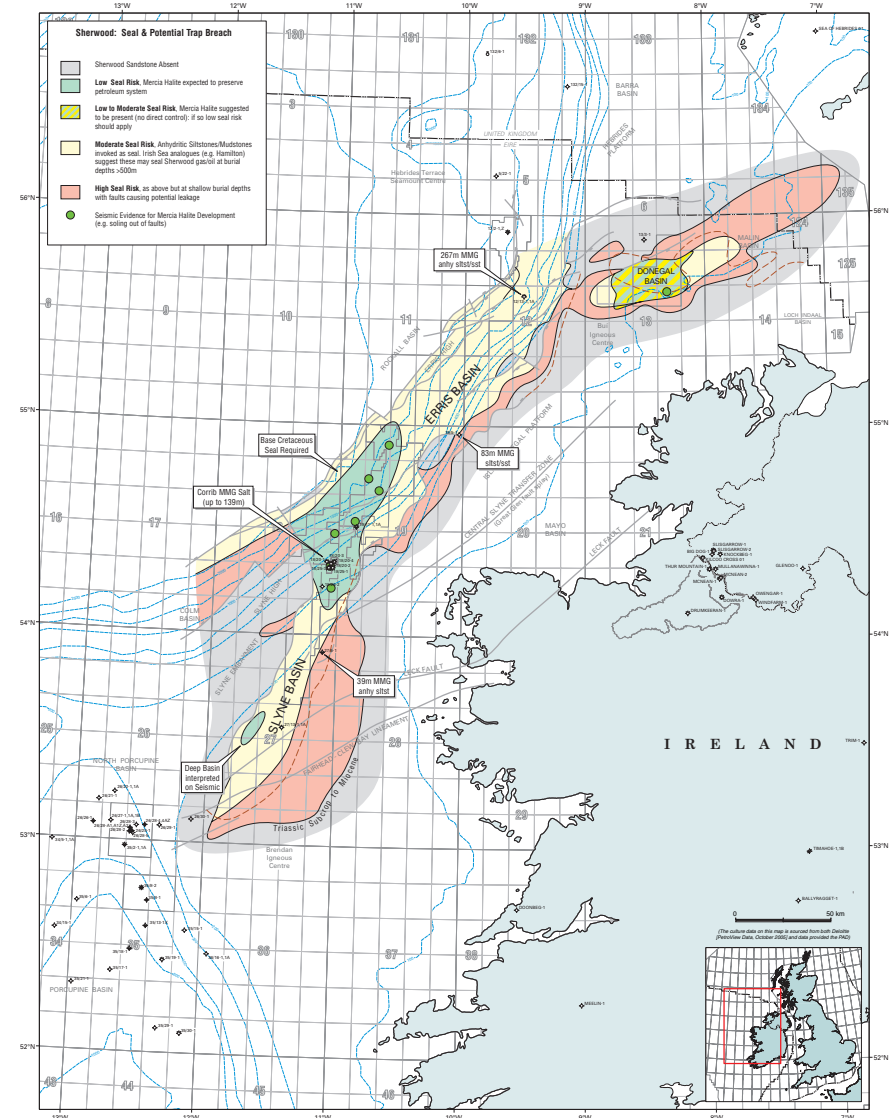
- The Triassic Sherwood Formation should be regionally continuous.
- The Yellow segments are restricted to areas where;
 - there are doubts on the preservation of the Sherwood below unconformities, such as the north Erris High (where differing seismic interpretations have applied: the most recent data favours the reservoir being present) and
- Areas of reservoir quality risk in the deepest parts of basins (<8% porosity expected at 4500m burial or palaeoburial, circa 1mD permeability).





Triassic seal map

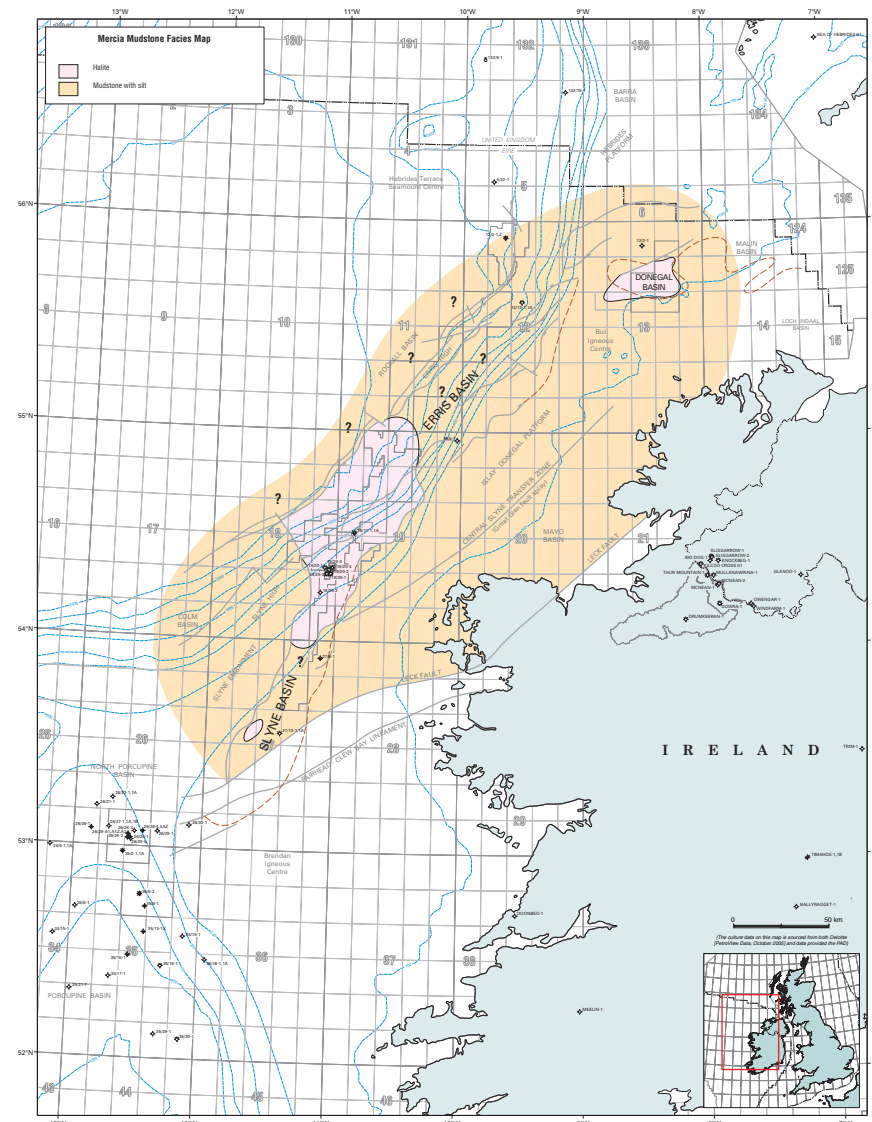
- The seal represents the most critical factor in the Triassic play fairway.
- The Green segment represents the areas where the Mercia Halite is expected (see map) to have been deposited. This corresponds to the proven seal at Corrib and to the sealing mechanism in the majority of NW Europe Triassic gas accumulations.
- Faulting out of the halite is taken to be a prospect specific factor and cannot be predicted by a study at this scale.
- In the Donegal Basin the uncertainty on halite presence is primarily due to a lack of data.
- Yellow indicates areas where the Mercia Mudstone is represented by anhydritic mudstones, (these act as a seal in some small fields in the analogous East Irish Sea Basin at burial depths > 500 m, and more significantly in the 3 Tcf Hewett field of the Southern North Sea).
- Erris has a rather lower risk due to later generation. It is considered more likely that an anhydritic shale will be effective over a short preservation time (i.e. Erris) rather than the long preservation times required in the Slyne Basin.
- Red segments are representative of areas where the Triassic seal is thin and lies less than 500m below a major unconformity.





Mercia Mudstone facies map

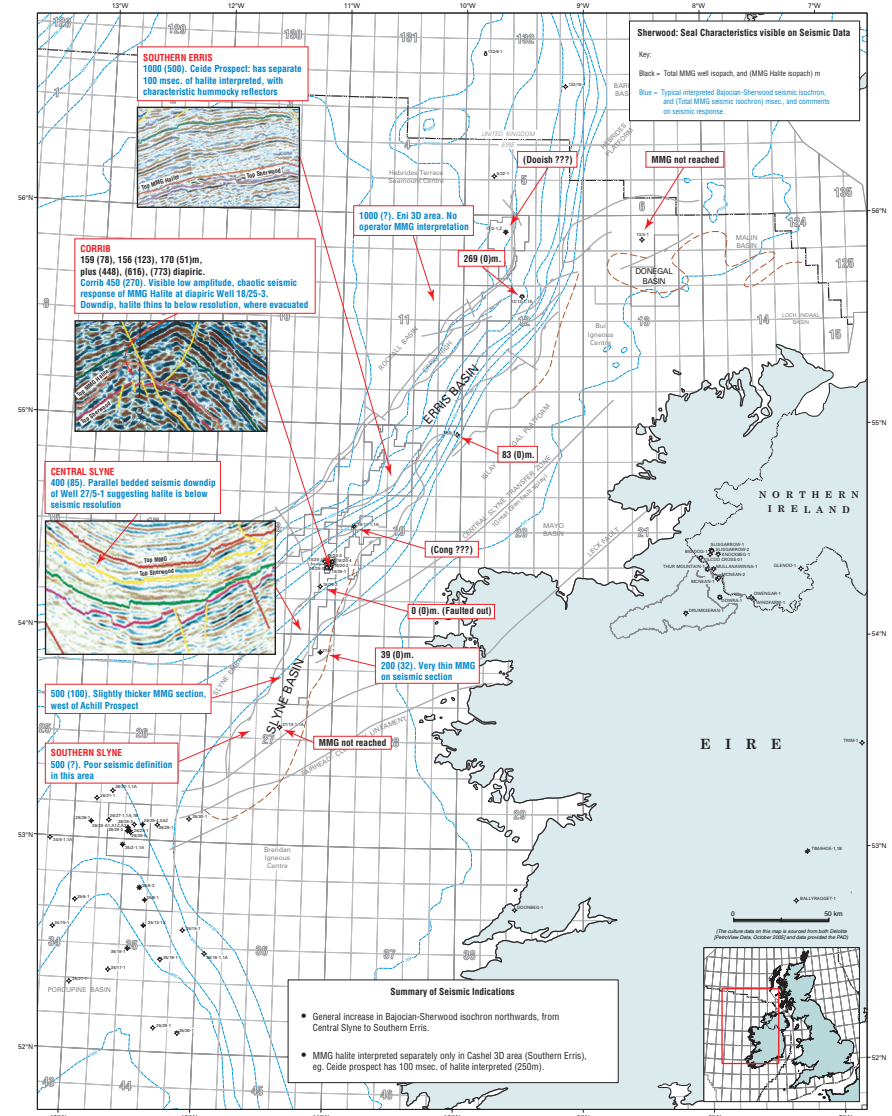
- The areal distribution of halite is interpreted from the following criteria:
 - Indications for faults soling out in the Mercia on seismic.
 - Isopach and isochron thicks mapped over the Erris and Donegal Basins, indicating active Triassic basins in these areas (see map).
 - A lack of thickening into the Slyne basin at this level shown on seismic sections in the vicinity of 27/5-1 (suggesting no active Triassic basin).
 - A deep trough suggested on poor quality seismic lines around 27/13-1.
 - Well data.
 - Analogue to the Antrim Basin where halite is present only in the basin deep.
- Halite is predicted to be restricted to two discrete areas; the Donegal Basin and the Northern Slyne/Southern Erris Basins.





Mercia Halite seismic distribution map

- General increase in Bajocian-Sherwood thickness northwards, from central Slyne to Southern Erris.
- MMG halite interpreted separately in previous interpretations only in South Erris area (up to 250 m).
- Distinct seismic horizon and character seen in South Erris/Corrib area only.
- Halite not resolvable below circa 28 m and only seen as a discrete event in South Erris, hummocky seismic facies often seen.
- Soling out of faults in Mercia may be the most reliable indicator, as utilised on play fairway maps.

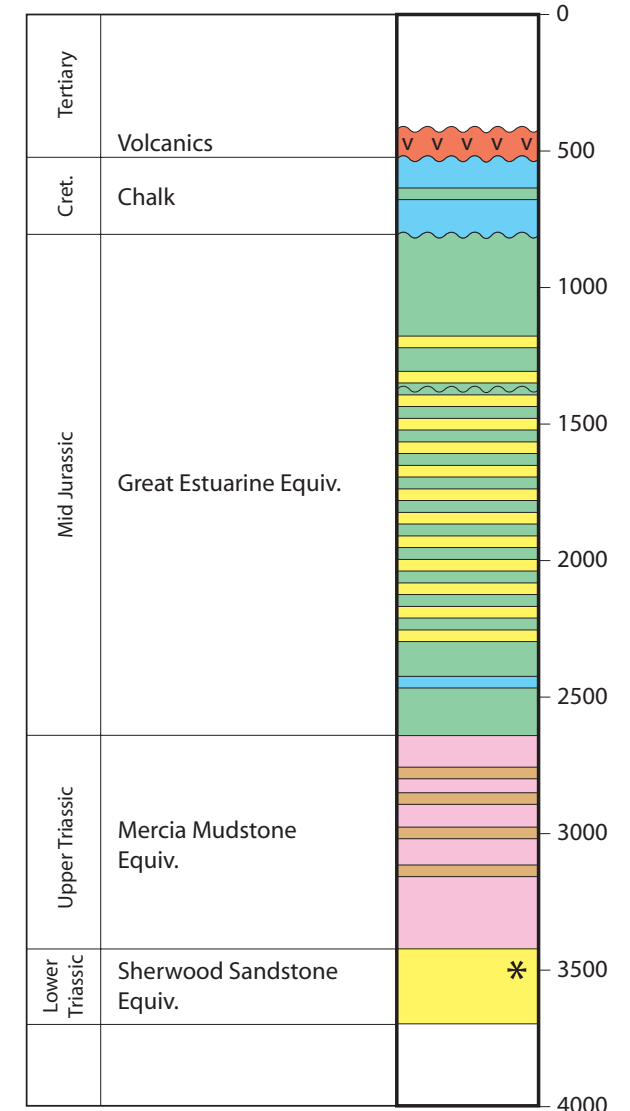
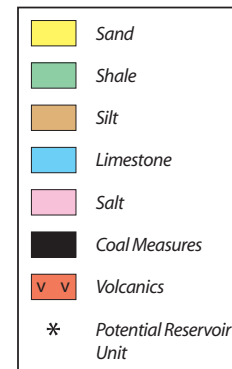




Well section through Triassic reservoir and seal section

Well section for 18/20-2Z (depths in metres).

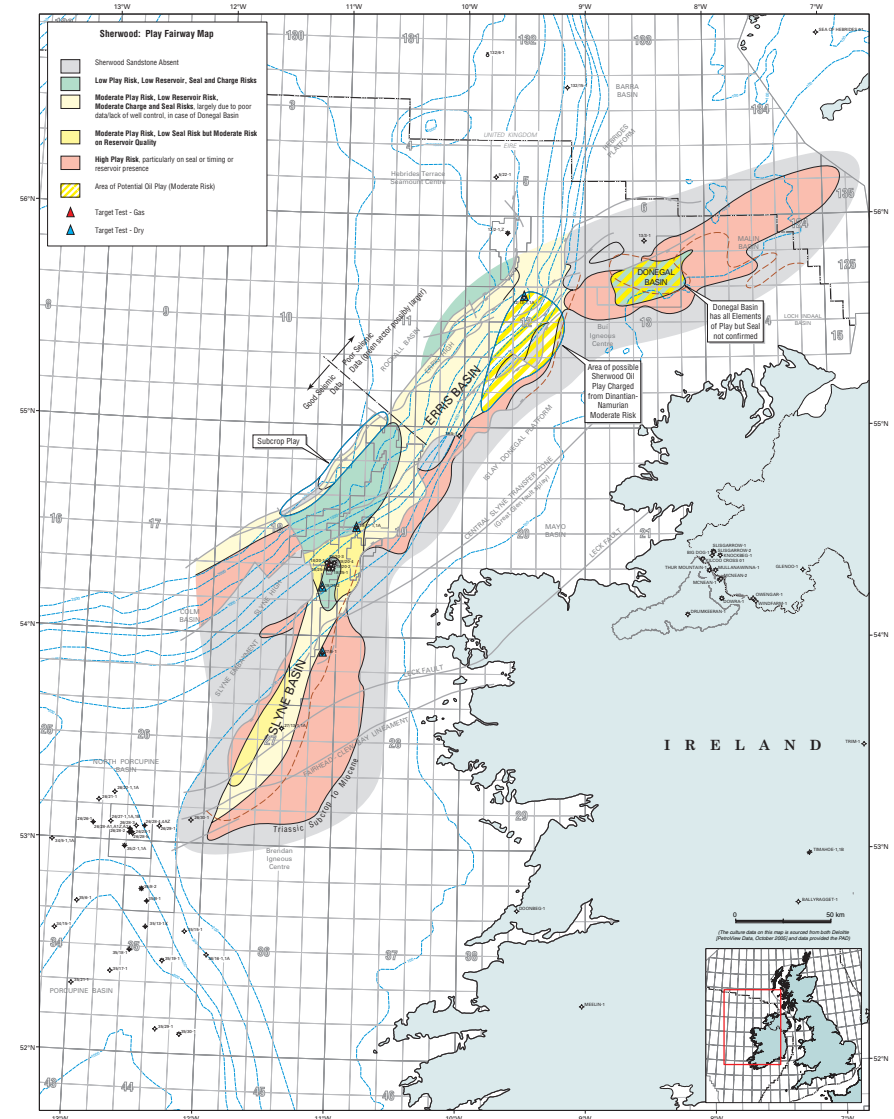
- Corrib well.
- Triassic Sherwood Sandstone reservoir. Primary objective in Corrib.
- Mercia halite acts as seal.





Triassic play fairway map

- The Green Segment is taken from the seal and reservoir quality overlays, this represents an area of approximately 1820 sq km.
- This area is analogous to the most productive, halite-sealed, area of the East Irish Sea Basin.
- The yellow areas mainly reflect seal, except in deeper areas of the Slyne Basin, where this is due to reservoir quality. In Donegal, the yellow reflects the lack of stratigraphic control rather than risk.
- The yellow area in Erris is suggested not to be so much a high risk area as one of likely localised and lower hydrocarbon productivity, limited non-spillful gas columns etc. Analogy to the low productivity southern part of the Irish Sea can be invoked, where mudstone seals are effective. However, it should also be noted that the seal here is analogous to that of the Hewett field, which is the largest Triassic gas field of the Southern North Sea.
- The presence of seal (halite) is the main limiting factor on fairway.
- Hatched area shows area of North Erris oil play, up-dip of Dinantian-Namurian shale subcrop. Seal facies is thought to be less of a risk for an oil play, particularly given relatively recent generation in this area. The main risk on this oil play is the accuracy of the subcrop model and the quality of the source rock.

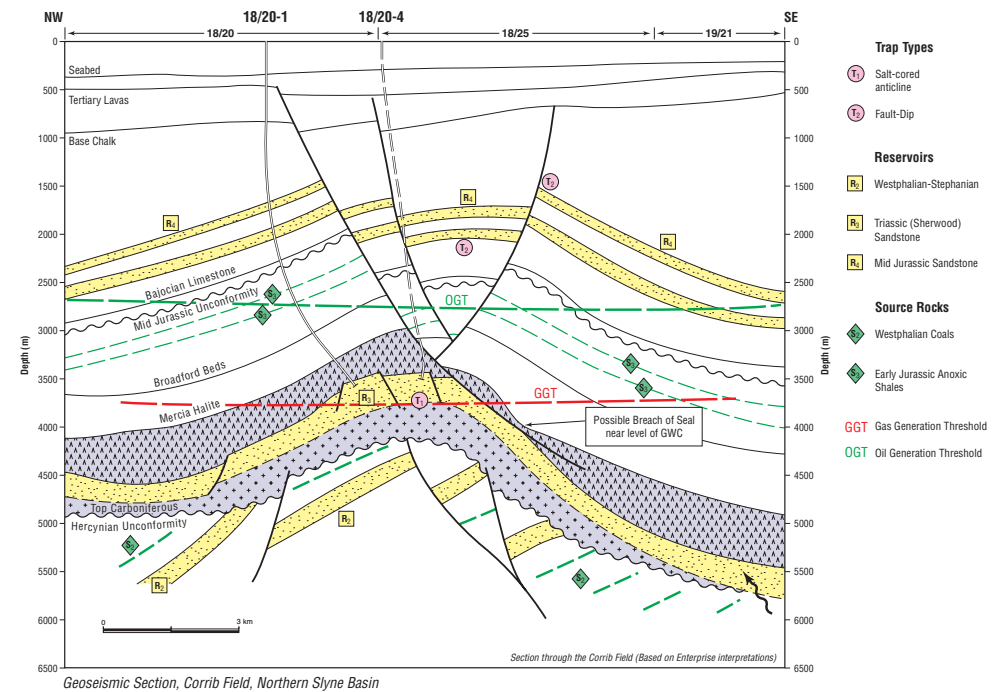




Geoseismic section: The Corrib Field

- The Corrib Field was discovered in 1996 by well 18/20-1.
- It proved the Triassic Play Fairway.
- It contains 1.2 Tcf GIIP, with a gas column of approximately 220 m.

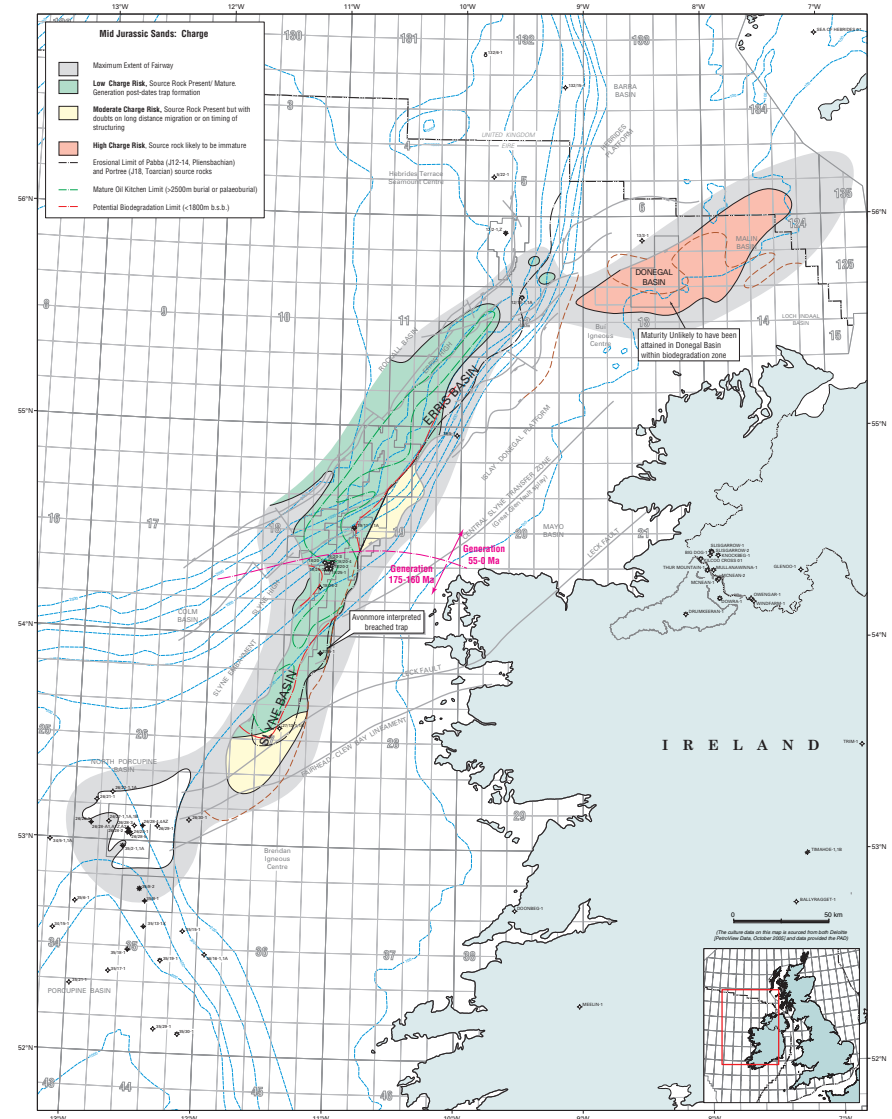
Geoseismic section adapted from 3D seismic survey E97IE, inline 3265. Based on Enterprise interpretation.





Jurassic charge map

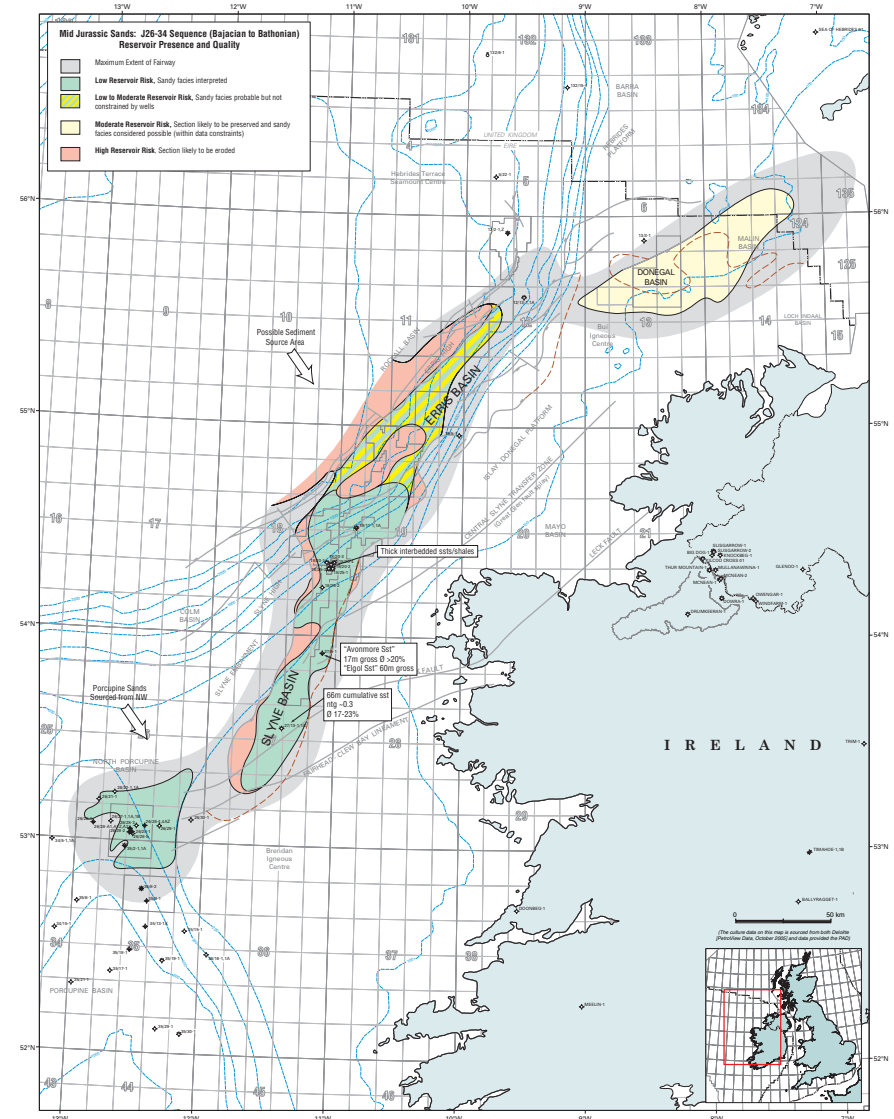
- The Green Segment is based on the oil kitchen defined by the erosional limit of the Pabba Shale and a burial/palaeoburial depth in excess of 2500 m (cf modelling results).
- Areas coloured Yellow require long distance migration.
- The Donegal Basin is immature.
- Biodegradation is an issue in the southern and eastern areas, where the reservoir is at overburdens less than 1800 m. Slightly degraded oil was seen at this depth in 27/13-1.





Jurassic reservoir map

- Reservoir well established in Slyne wells (Corrib, 27/5-1, 27/13-1)
- Thick sandy sequence with several sands in Corrib.
- Stratigraphy uncontrolled in Erris Basin, variety of regional models have been suggested; some suggest reservoir will thin northwards, others that the sediment provenance (as in Porcupine) lies to NW, so it could thicken, 'Yellow' therefore applied in Erris on reservoir presence.
- Erosion risk also applies over portions of Erris Basin on base Cretaceous unconformity, increasing to north. This risk is judged on an examination of the mid Jurassic to Cretaceous isopach across the area, tied to lithologies and thicknesses as seen in the nearest available well at Corrib.

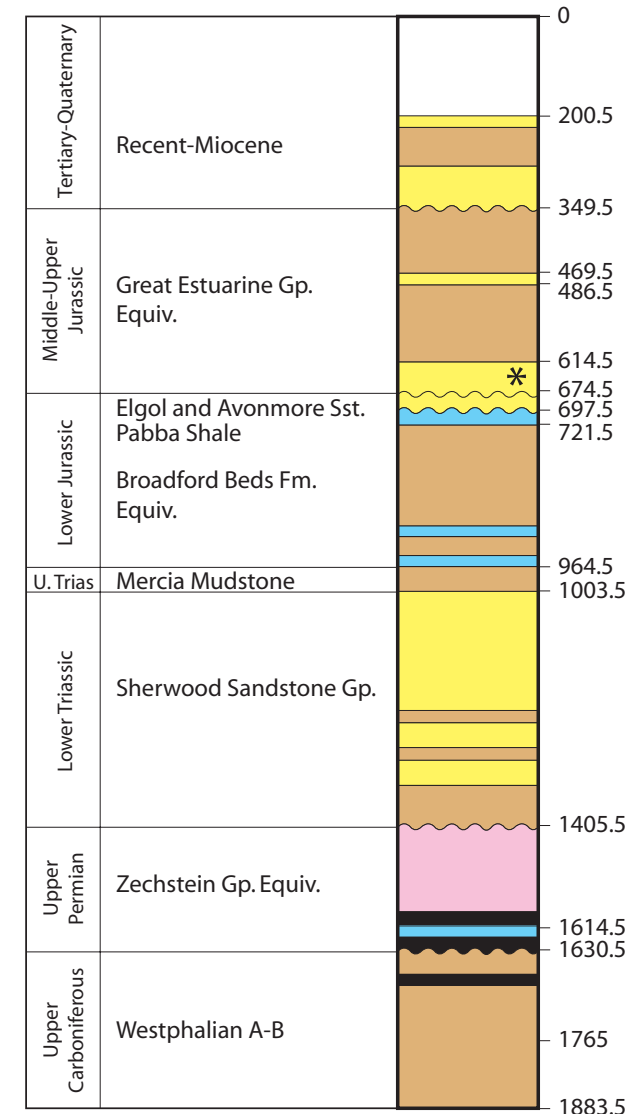
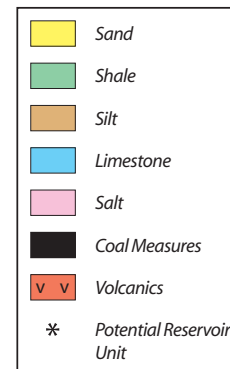




Well section through Jurassic reservoir sands

Well section for 27/5-1 (depth in metres).

- Two distinct high quality sandstones in 27/5-1, termed 'Elgol' and 'Avonmore' Sandstones of Bajocian-Bathonian age.
- Good seal observed above these sandstones.



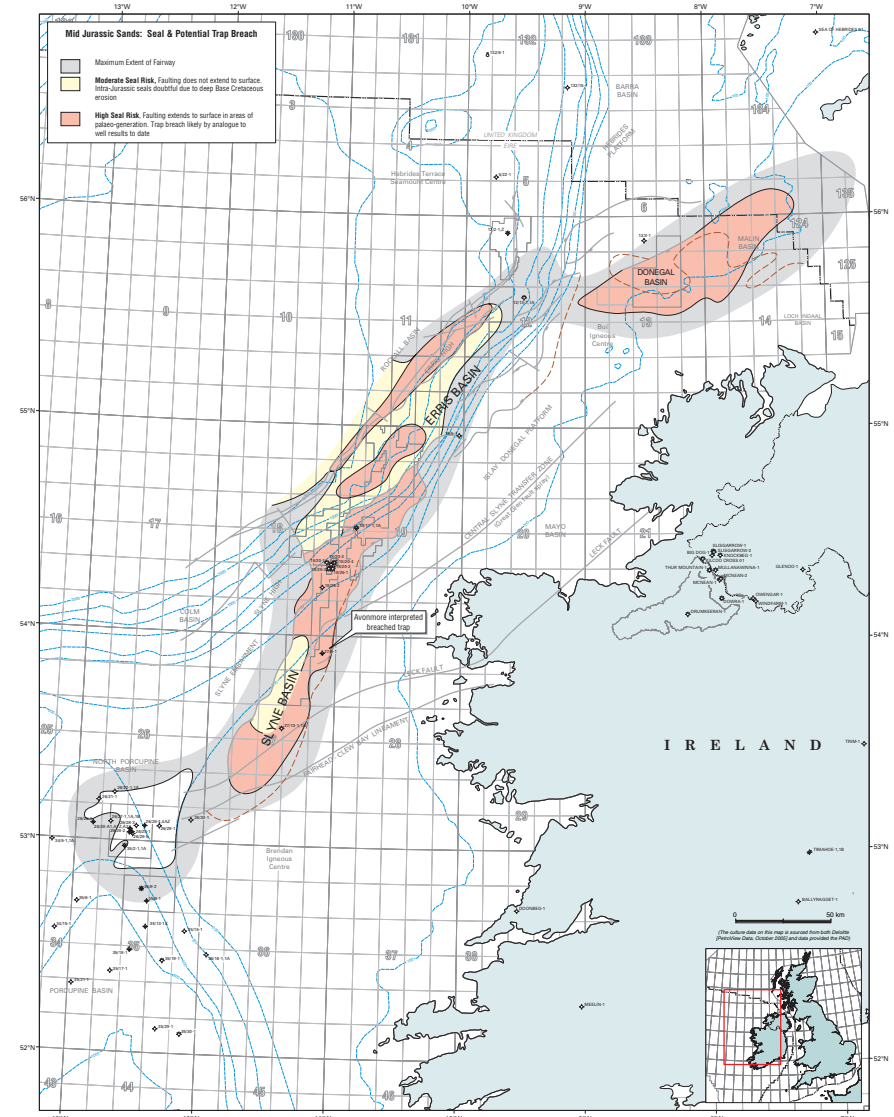


Jurassic seal map

- The Green Segments indicate areas where the Jurassic shale seals are probably preserved within areas of recent generation that postdate faulting (Erris). This is based on an examination of the mid Jurassic to Cretaceous isopach across the area, tied to lithologies and thicknesses as seen in the nearest available well at Corrib.
- Yellow is applied where the Jurassic section is thinned by Base Cretaceous erosion and there is a risk of removal of the thickest shale sections. Thinner shales must then be appealed to for the preserved section (Erris).
- The Red segment reflects a history of palaeogeneration followed by faulting that is likely to have caused trap leakage (analogous areas to those drilled at 27/5-1 and 27/13-1).

Subsequently two critical issues arise:

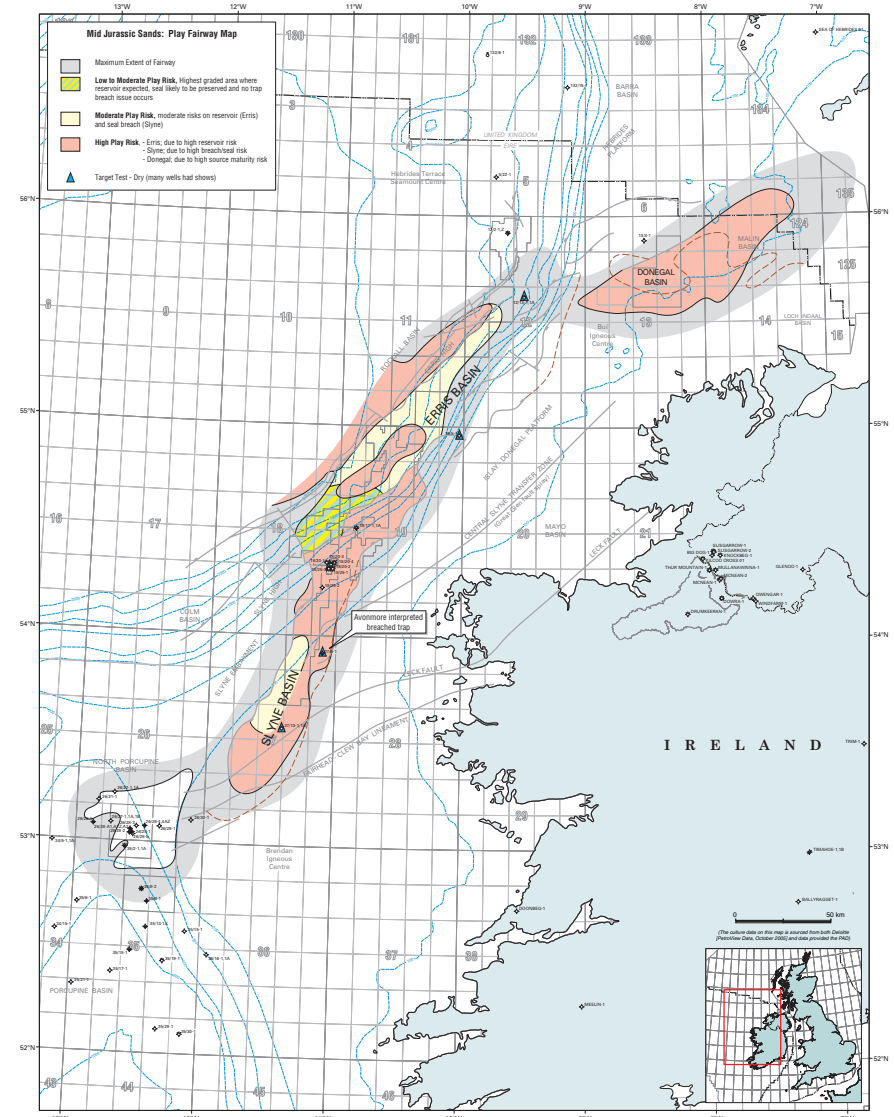
- **Slyne Basin** - Trap breach is taken as the likely reasons for failure of 3 target tests on the fairway (27/13-1, 27/5-1, 18/20-1), therefore, a red area is drawn around these wells and analogous areas where faulting extends from the reservoir to the base Tertiary unconformity.
- **Erris Basin** – Reservoir section may subcrop the base Cretaceous unconformity in some areas (which is never closed itself) and a trapping configuration involving both intra-Jurassic and Cretaceous seals may then have to be invoked.





Jurassic play fairway map

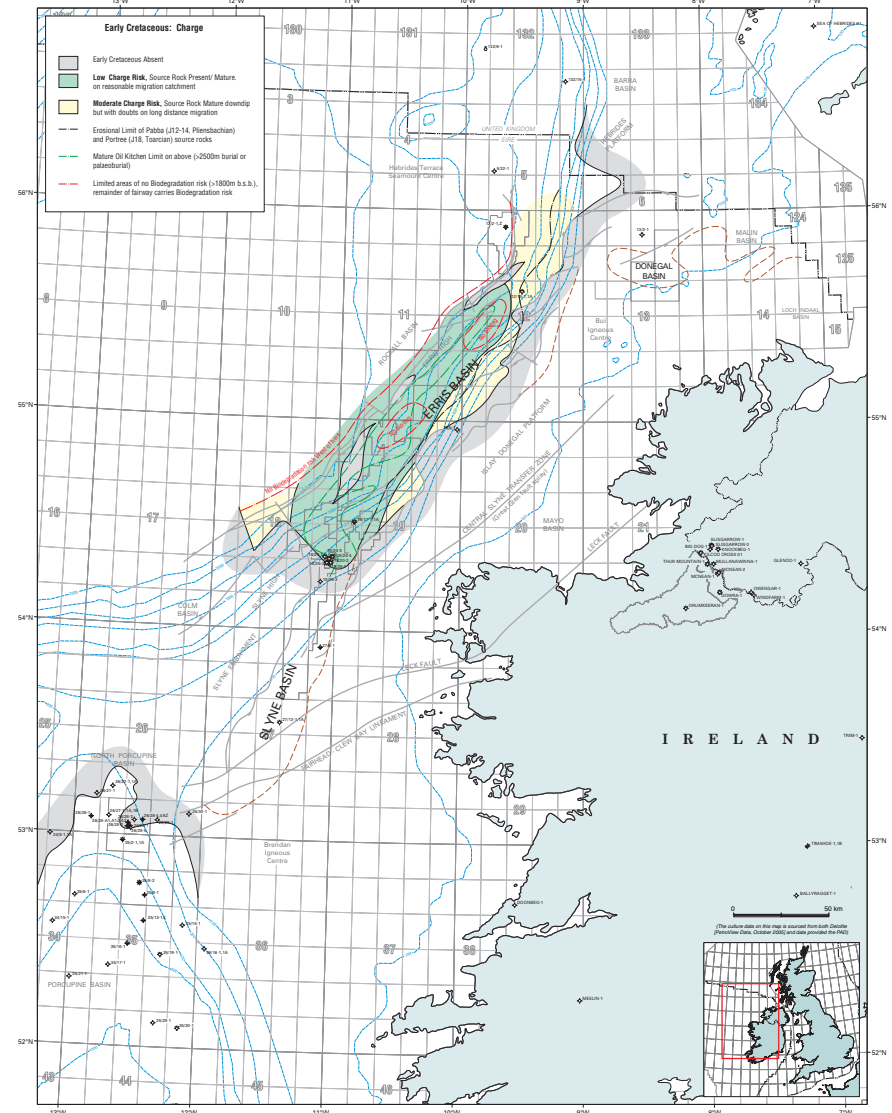
- Only the erosional outliers are prospective in Erris, (recent generation but reservoir risk).
- There is a small Yellow Segment in Slyne, however, no traps are expected in this deep.
- The Red Segments are a consequence of a variety of features. High risk is associated with reservoir presence and quality in thinned Jurassic sections of the Erris Basin, trap breaching in the Slyne Basin and source immaturity in the Donegal Basin.
- Proven petroleum system- 27/5-1 is a breached oilfield.
- Well failures to date largely tied to leakage.
- Failures concentrated in areas of Jurassic generation.
- Thus, most promising (and un-tested) portion of the fairway lies in Erris Basin, where generation is more recent and there has been no active faulting since the Aptian.





Cretaceous charge map

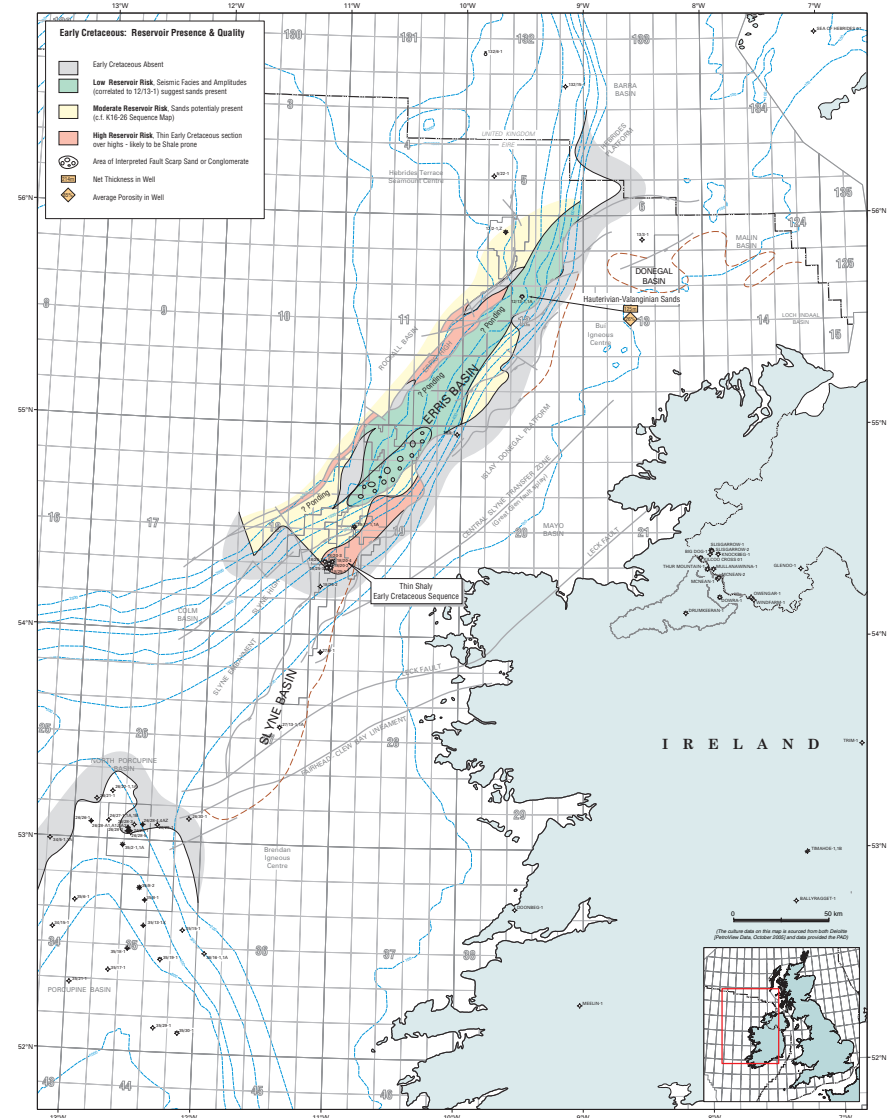
- The source kitchen shares the similar limitations as the Jurassic.
- Most of fairway is at a depth of <1800m, and there is a risk therefore of biodegradation. This is not taken account of in the colour coding applied.
- The Green Segments are located close to the source kitchen. This area generally covers most of the fairway.





Cretaceous reservoir map

- A good reservoir unit is observed in 12/13-1 in a down-lapping sequence; analogous seismic facies are therefore ascribed a green colour. Fault plane conglomerates and sandstones are also considered low risk.
- High amplitudes are seen onlapping against the Erris High: these are also thought likely to indicate presence of reservoir.
- Areas of duller seismic facies are ascribed a yellow or red colour.
- The section is shaly at Corrib and a 'red' colour is applied to this area.





Well section through Cretaceous reservoir sands

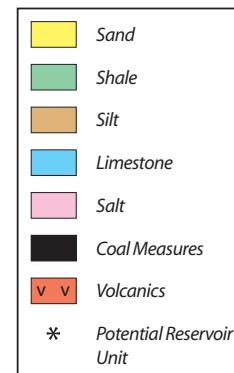
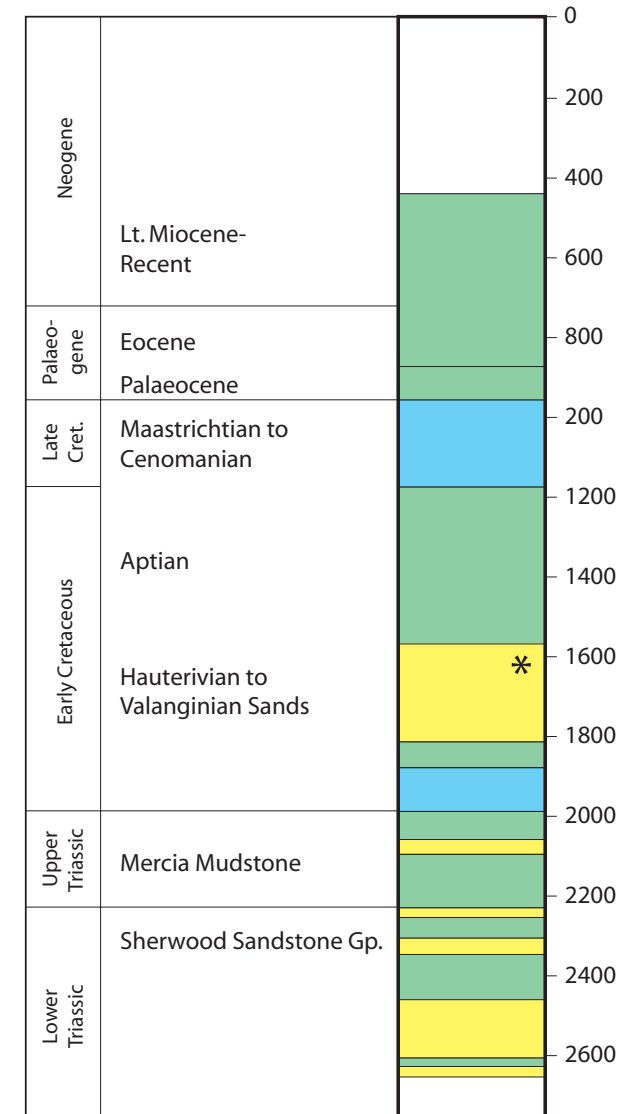
Well section for 12/13-1. Based on Enterprise interpretation (depth in metres).

Reservoirs

- Hauterivian - Valanginian sands: Porosity = 26%, n/g = 40%, Gross = 308m.
- Ryazanian sands: Porosity = 20%, n/g = 50%, Gross = 7m Reservoirs.
- Hauterivian - Valanginian sands: Porosity = 26%, n/g = 40%, Gross = 308m.
- Ryazanian sands: Porosity = 20%, n/g = 50%, Gross = 7m.

Shows

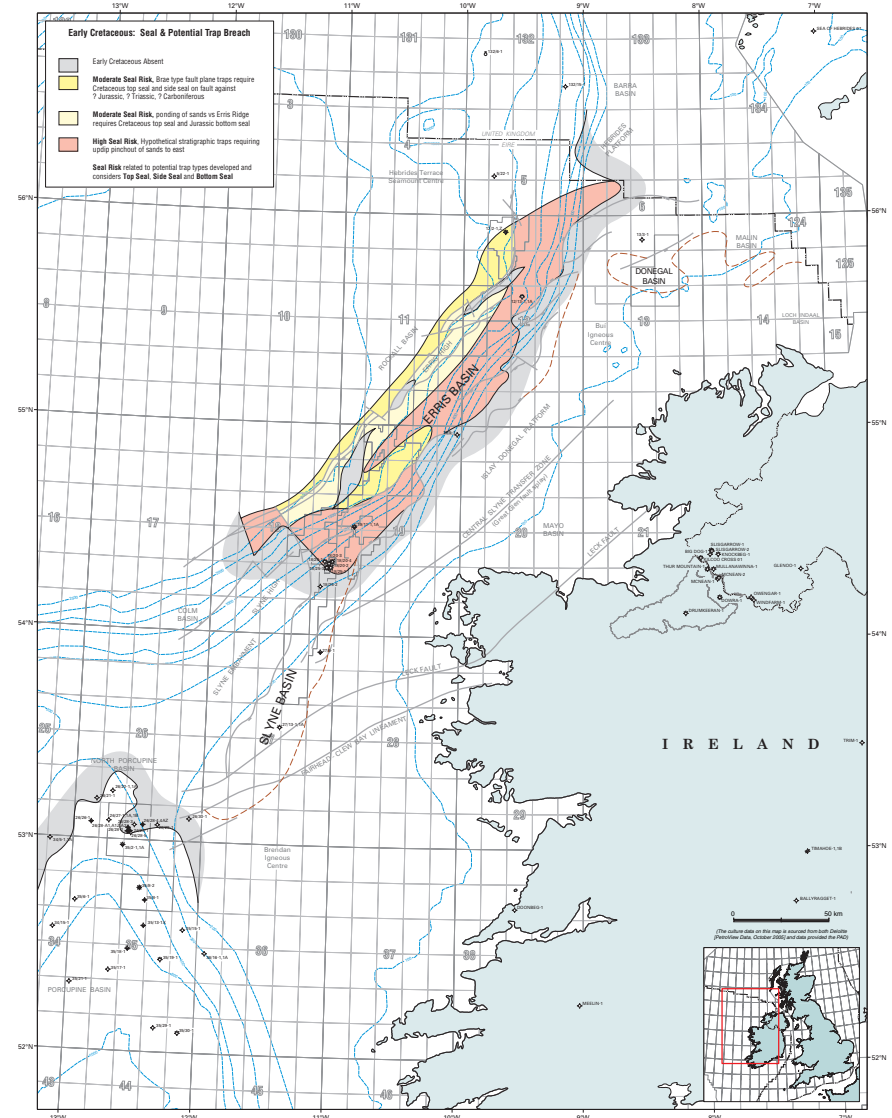
- Traces of gas Hauterivian-Eocene.





Cretaceous seal map

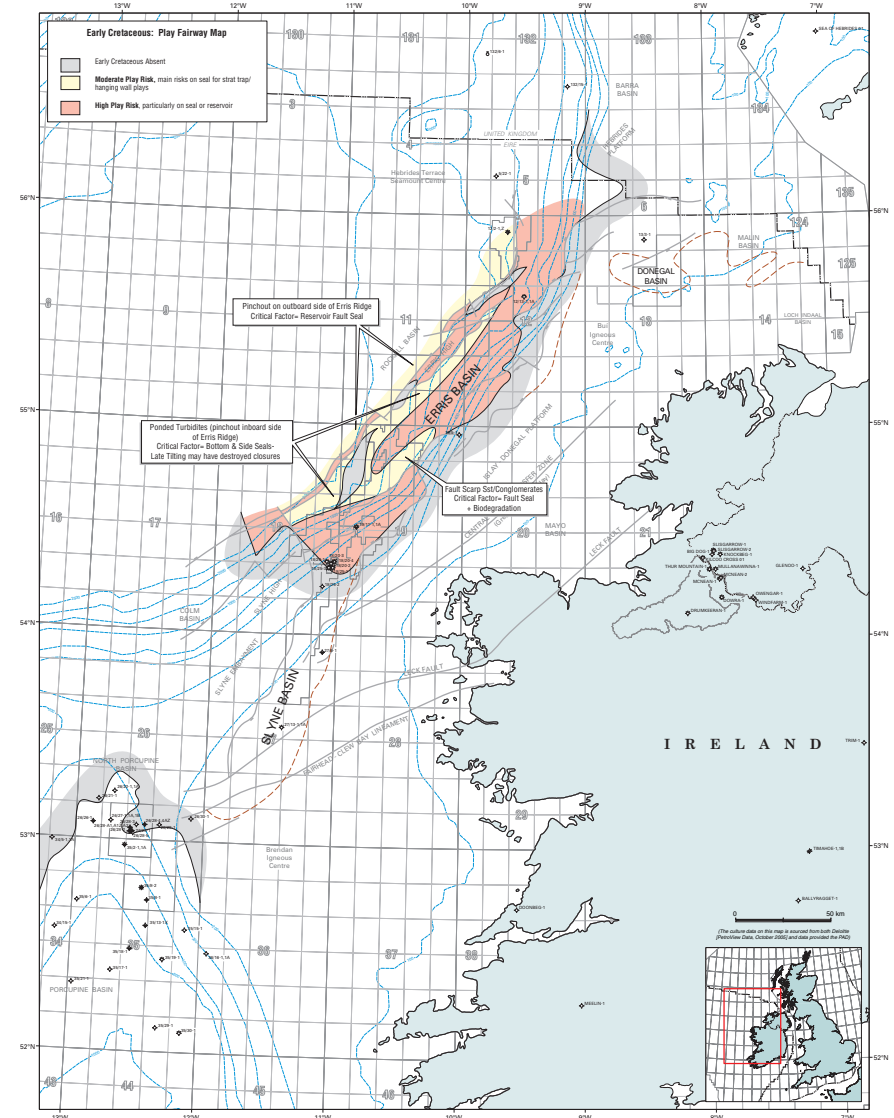
- The dark Yellow Segment - Brae style traps require hanging wall/side seal.
- The light Yellow Segment - Ponding against the Erris High, requires Jurassic bottom seal.
- Elsewhere hypothetical stratigraphic traps only (Red).





Cretaceous play fairway map

- Largely controlled by seal analysis.
- Two sub-plays are identified: Brae-style fault plane conglomerates/sandstones charged by Liassic source rocks and West Africa style ponded turbidites against the Erris High.
- Key risks for the two sub-plays are : Brae-style sands: fault plane seal; Ponding versus Erris:late stage tilting destroying closures.
- Note excellent reservoir quality in Cretaceous sands penetrated by 12/13-1A. Porosity circa 27%, from sonic log.
- Oil quality also critical factor across fairway, which lies entirely above the level of 1800m bsb (biodegradation risk).





The Yet-To-Find Potential





Yet-To-Find (YTF) analysis

Introduction

The analogous area productivities are assessed from play fairway analysis of the East Irish Sea Basin, Broad Fourteens Basin and the Barren Measures province of the Southern North Sea.

These analogues are basins with similar tectonic, sedimentary and thermal histories but are up to 10x more densely drilled than the Slyne, Erris and Donegal Basins. This allows a 'look-ahead' to what might be expected to be found in the Irish basins if they were as drilled to the density of the analogue basins.

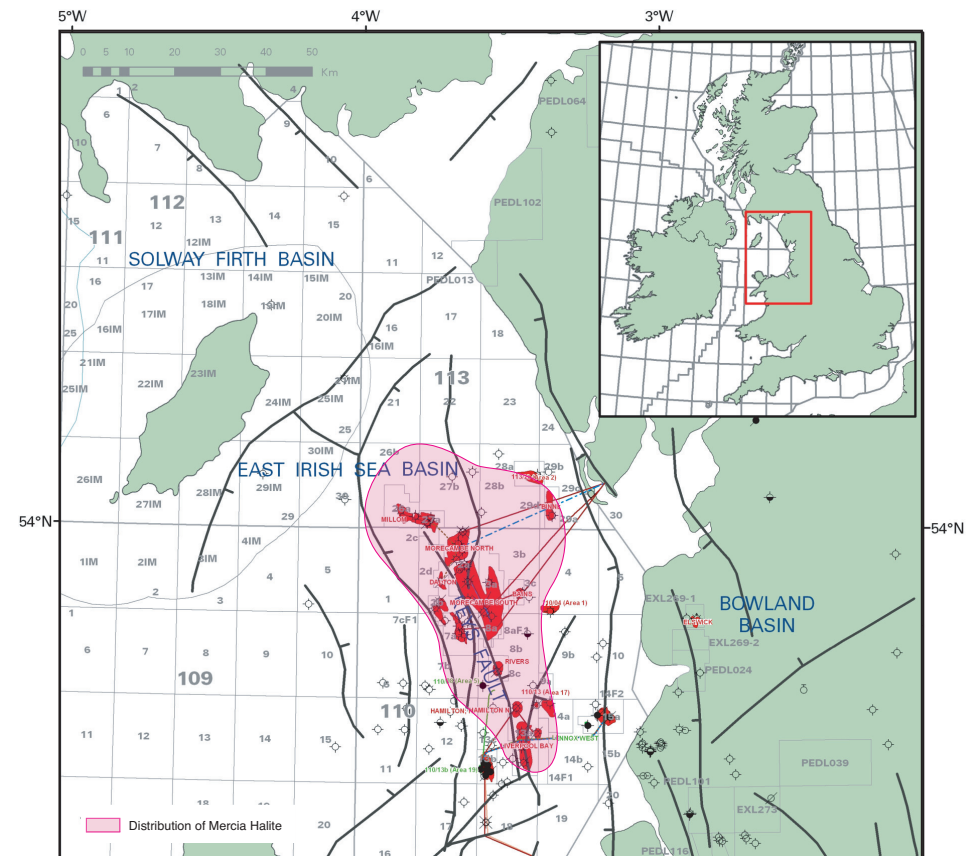




The East Irish Sea Basin

The application of the East Irish Sea Basin Analogue.

- The East Irish Sea is divided into two distinct segments; an area covered by a halite seal and an area that is not covered by a halite seal. Both these areas can provide an insight into calculating an areal productivity in the Slyne, Erris and Donegal Basins.
- An areal productivity is calculated for the area within the East Irish Sea Basin that is covered by a salt seal and is utilised in calculating the yet-to-find potential for the green segments identified on the Triassic play fairway map for the Erris and Donegal Basins.
- An areal productivity is then calculated for the area within the East Irish Sea Basin that is covered by a mudstone seal and is utilised in calculating the YTF potential for; the yellow segments identified on the Triassic play fairway map for the Erris and Slyne Basins.
- These areal productivities are then adapted downwards to reflect differing reservoir parameters between Slyne/Erris and the Irish Sea to obtain the areal productivities applied in YTF estimation. No such adjustment is made for the Donegal Basin, where Sherwood porosity is expected to be higher than in Slyne/Erris.

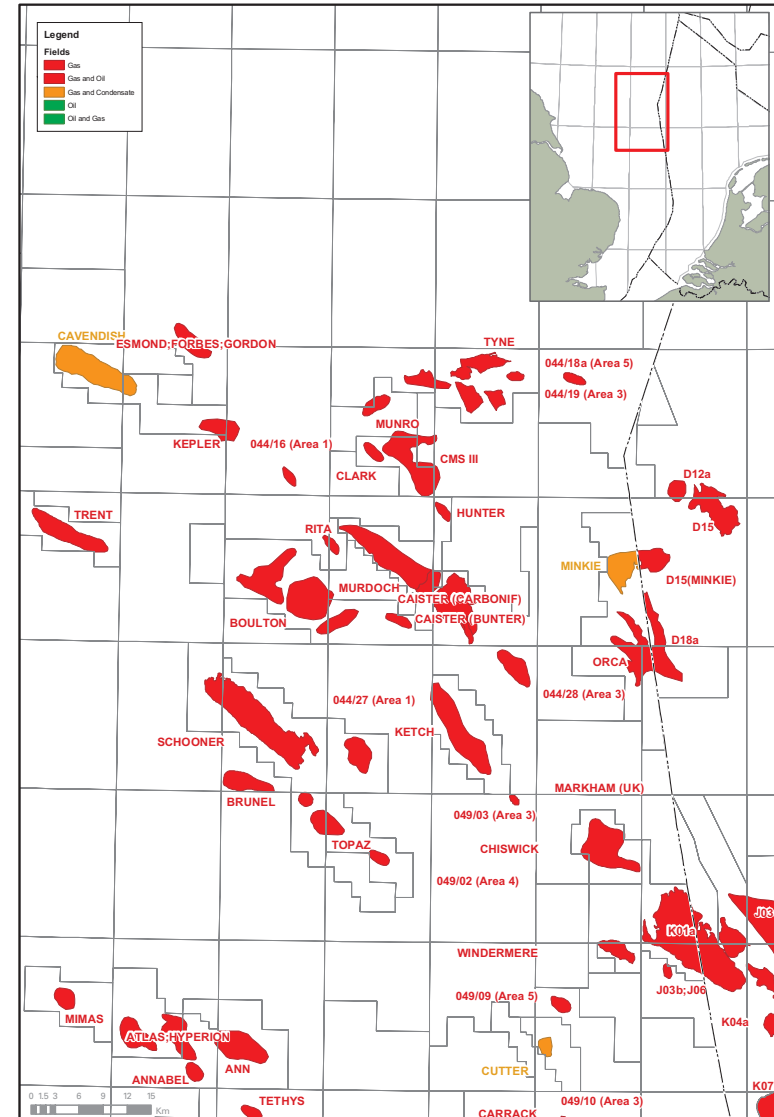




The Barren Measures (SNS)

The application of the SNS Barren Measures analogue.

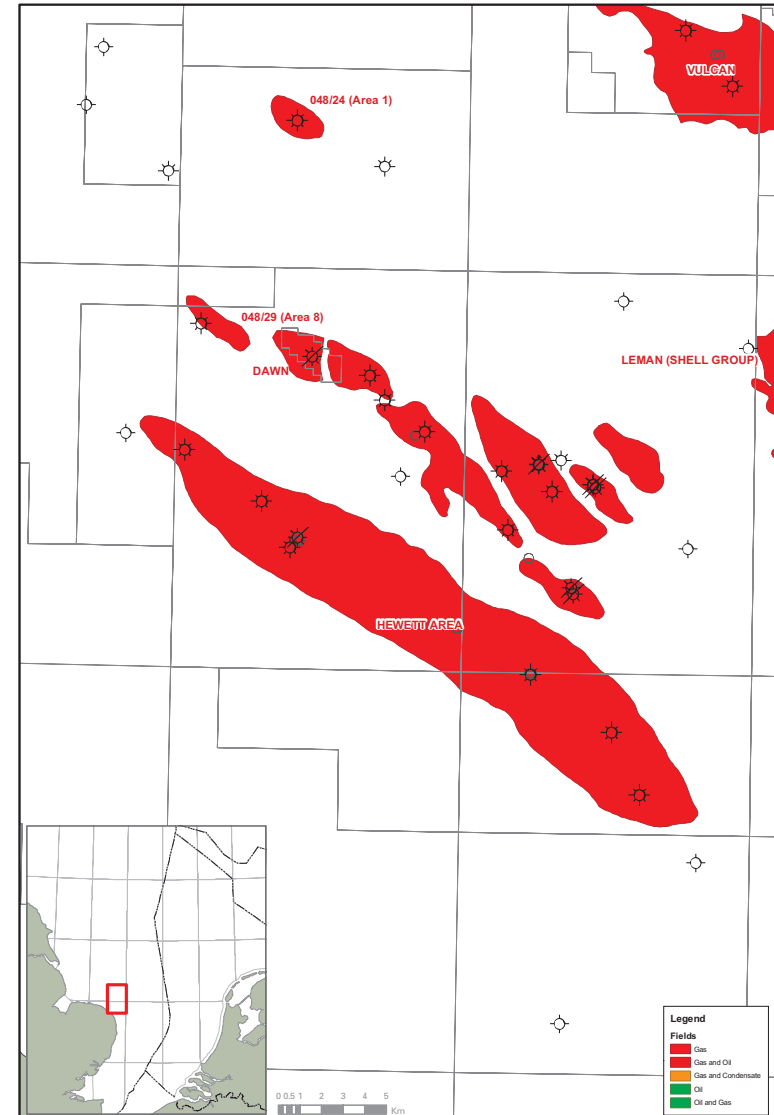
- An areal productivity is calculated for the SNS Barren Measures area is utilised in calculating the yet-to-find potential for the yellow segments identified on the Carboniferous play fairway map for the Slyne, Erris and Donegal Basins (mainly Donegal Basin).
- These areal productivities are then adapted to reflect reservoir parameters.





The Hewett Field (SNS)

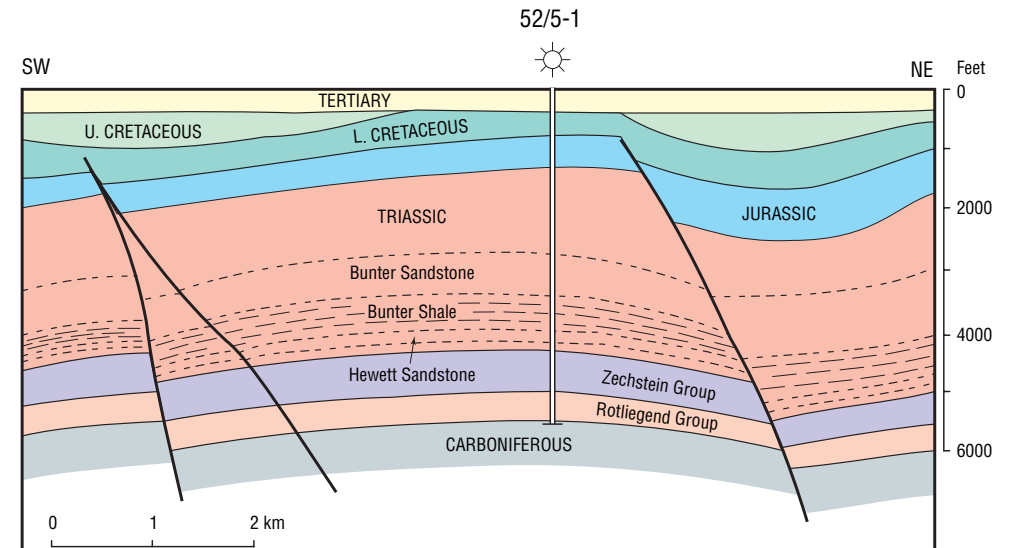
- The Hewett Field is located within the Southern North Sea.
- It provides an example of Triassic reservoir sandstones (The Hewett Sandstone) that have been sealed by Triassic mudstone (The Bunter Shale Formation), without the occurrence of an evaporitic facies. In addition, sideseal is developed on the bounding fault plane.
- Published burial plots for the Hewett area show close similarities to that constructed for the Erris Basin.
- This lack of halite and anhydrite within the sealing facies of an analogue basin provides a positive example for the Slyne Basin, where a significant evaporite succession is absent across much of the southern margins of the basin.





The Hewett Field cross section

- The Hewett Field is located within the Southern North Sea.
- It provides an example of Triassic reservoir sandstones (The Hewett Sandstone) that have been sealed by Triassic mudstone (The Bunter Shale Formation), without the occurrence of an evaporitic facies. In addition a side seal is developed on the bounding fault plane.
- Published burial plots for the Hewett area show close similarities to that constructed for the Erris Basin.
- This lack of halite and anhydrite within the sealing facies of an analogue basin provides a positive example for the Slyne Basin, where a significant evaporite succession is absent across much of the southern margins of the basin.





Yet-To-Find calculations

Methodology

- Subdivide the Slyne, Erris and Donegal Basins into fairway segments based upon regional geology and resulting play risk.
- Calculate the area of each segment in the Slyne, Erris and Donegal Basins.
- Identify a suitable analogue segment from an analogue basin (see previous section concerning analogues).
- Calculate the areal productivity of the analogue segment (Reserves/Area).
- Apply areal productivity to the relevant segment within the Slyne, Erris and Donegal Basins.
- Apply a recovery factor and then risk the play.





Slyne Basin YTF table

By utilising areal richness calculations from a variety of analogous basins we can reasonably demonstrate that the undiscovered risked potential of the Slyne Basin is in the order of ~300 bcf recoverable gas with an oil upside.

GAS											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (GIIP bcf/sq km) (corrected for reservoir parameters)	Ultimate GIIP Indicated (bcf)	GIIP found to Date (bcf)	YTF GIIP (bcf)	assumed recovery factor	Unrisked YTF recoverable (bcf)	Play Risk Assumed	Risked YTF recoverable (bcf)
Sherwood	Yellow (Slyne)	2200.0	E Irish Sea - segment below MMG mdst	0.5	990.0	0.0	990.0	0.8	742.5	0.40	297.0
Sherwood Total							990.0	0.8	742.5		297.0

OIL											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (mmbo STOIP/sq km)	Ultimate STOIP Indicated (mmbo)	STOIP found to Date (mmbo)	YTF (STOIP : mmbo)	assumed recovery factor	Unrisked YTF recoverable (mmbo)	Play Risk Assumed	Risked YTF recoverable (mmbo)
Mid Jurassic	Yellow (Slyne & Erris)	1609.0	Broad Fourteens Mesozoic oil play	0.4	643.6	0.0	643.6	0.4	225.3	0.3	67.6
TOTAL OIL							643.6		225.3		67.6





Erris Basin YTF table

By utilising areal richness calculations from a variety of analogous basins we can reasonably demonstrate that the undiscovered risked potential of the Erris basin is in the order of ~ 2.9 tcf recoverable 'yet-to-find' with an oil up-side in Cretaceous, Jurassic and Triassic fairways.

GAS											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (GIIP bcf/sq km) (corrected for reservoir parameters)	Ultimate GIIP Indicated (bcf)	GIIP found to Date (bcf)	YTF GIIP (bcf)	assumed recovery factor	Unrisked YTF recoverable (bcf)	Play Risk Assumed	Risked YTF recoverable (bcf)
Sherwood	Green (mainly Erris)	1820.0	E Irish Sea - segment below MMG salt	1.7	3094.0	1200.0	1894.0	0.8	1420.5	1.00	1420.5
Sherwood	Yellow (Erris)	3207.0	E Irish Sea - segment below MMG mdst	1.0	3207.0	0.0	3207.0	0.8	2405.3	0.63	1515.3
Sherwood Total							5101.0	0.8	3825.8		2935.8
TOTAL GAS							10202.0	0.8	7651.5		2935.8

OIL											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (mmbo STOIP/sq km)	Ultimate STOIP Indicated (mmbo)	STOIP found to Date (mmbo)	YTF (STOIP : mmbo)	assumed recovery factor	Unrisked YTF recoverable (mmbo)	Play Risk Assumed	Risked YTF recoverable (mmbo)
Sherwood	Yellow (N Erris Oil Play)	1150.0	E Irish Sea oil play	0.3	356.5	0.0	356.5	0.4	124.8	0.3	37.4
Early Cretaceous	Yellow (Erris)	1332.0	Broad Fourteens Mesozoic oil play	0.4	532.8	0.0	532.8	0.4	186.5	0.3	55.9
TOTAL OIL							889.3		311.3		93.4





Donegal Basin YTF table

By utilising areal richness calculations from a variety of analogous basins we can reasonably demonstrate that the undiscovered risked potential of the Donegal Basin is in the order of ~900 bcf recoverable gas. Risks are higher in this basin, so the un-risked figure is considerably higher.

GAS											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (GIIP bcf/sq km) (corrected for reservoir parameters)	Ultimate GIIP Indicated (bcf)	GIIP found to Date (bcf)	YTF GIIP (bcf)	assumed recovery factor	Unrisked YTF recoverable (bcf)	Play Risk Assumed	Risked YTF recoverable (bcf)
Carboniferous	Yellow (Donegal)	1021.0	SNS Barren Measures	1.1	1123.1	0.0	1123.1	0.6	673.9	0.4	269.5
Carboniferous Total							1123.1	0.6	673.9		269.5
Sherwood	Yellow (Donegal)	630.0	E Irish Sea - segment below MMG salt	3.3	2053.8	0.0	2053.8	0.8	1540.4	0.40	616.1
Sherwood Total							2053.8	0.8	1540.4		616.1
TOTAL GAS							3176.9	0.8	2382.7		885.7





Carboniferous play YTF table

By utilising areal richness calculations adapted from the 'Barren Measures' fairway, we can reasonably demonstrate that the undiscovered risked potential of the Carboniferous play fairway is in the order of ~ 350 bcf recoverable gas with an oil up-side.

GAS											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (GIIP bcf/sq km) (corrected for reservoir parameters)	Ultimate GIIP Indicated (bcf)	GIIP found to Date (bcf)	YTF GIIP (bcf)	assumed recovery factor	Unrisked YTF recoverable (bcf)	Play Risk Assumed	Risked YTF recoverable (bcf)
Carboniferous	Yellow (Donegal)	1021.0	SNS Barren Measures	1.1	1123.1	0.0	1123.1	0.6	673.9	0.4	269.5
Carboniferous	Yellow (Slyne/Erris)	450.0	SNS Barren Measures	1.1	495.0	0.0	495.0	0.6	297.0	0.3	74.3
Carboniferous Total							1618.1	0.6	970.9		343.8





Triassic play YTF table

By utilising adapted areal richness calculations from the Irish Sea and Broad Fourteen Basins, we can reasonably demonstrate that the undiscovered risked potential of the Triassic play fairway is in the order of ~ 3.8 tcf recoverable gas with an oil up-side. This is based on the area of the green and yellow segments, with a lower productivity applied for the latter, based on the productivity of the East Irish Sea outside the area of evaporite seal development.

GAS											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (GIIP bcf/sq km) (corrected for reservoir parameters)	Ultimate GIIP Indicated (bcf)	GIIP found to Date (bcf)	YTF GIIP (bcf)	assumed recovery factor	Unrisked YTF recoverable (bcf)	Play Risk Assumed	Risked YTF recoverable (bcf)
Sherwood	Green (mainly Erris)	1820.0	E Irish Sea - segment below MMG salt	1.7	3094.0	1200.0	1894.0	0.8	1420.5	1.00	1420.5
Sherwood	Yellow (Erris)	3207.0	E Irish Sea - segment below MMG mdst	1.0	3207.0	0.0	3207.0	0.8	2405.3	0.63	1515.3
Sherwood	Yellow (Slyne)	2200.0	E Irish Sea - segment below MMG mdst	0.5	990.0	0.0	990.0	0.8	742.5	0.40	297.0
Sherwood	Yellow (Donegal)	630.0	E Irish Sea - segment below MMG salt	3.3	2053.8	0.0	2053.8	0.8	1540.4	0.40	616.1
Sherwood Total							8144.8	0.8	6108.6		3848.9
TOTAL GAS								0.8			3848.9

OIL											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (mmbo STOIP/sq km)	Ultimate STOIP Indicated (mmbo)	STOIP found to Date (mmbo)	YTF (STOIP : mmbo)	assumed recovery factor	Unrisked YTF recoverable (mmbo)	Play Risk Assumed	Risked YTF recoverable (mmbo)
Sherwood	Yellow (N Erris Oil Play)	1150.0	E Irish Sea oil play	0.3	356.5	0.0	356.5	0.4	124.8	0.3	37.4
TOTAL OIL							356.5		124.8		37.4





Mid Jurassic play YTF table

By utilising areal richness calculations from the Broad Fourteens Basin, we can reasonably demonstrate that the undiscovered risked potential of the Mid Jurassic Play in the Slyne, Erris and Donegal Basins is in the order of ~ 70 mmb of recoverable oil.

Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (mmb/o STOIIP/sq km)	Ultimate STOIIP Indicated (mmb/o)	STOIIP found to Date (mmb/o)	YTF (STOIIP : mmb/o)	assumed recovery factor	Unrisked YTF recoverable (mmb/o)	Play Risk Assumed	Risked YTF recoverable (mmb/o)
Mid Jurassic	Yellow (Slyne & Erris)	1609.0	Broad Fourteens Mesozoic oil play	0.4	643.6	0.0	643.6	0.4	225.3	0.3	67.6
TOTAL OIL							643.6		225.3		67.6





Cretaceous play YTF table

By utilising areal richness calculations from the Broad Fourteens Basin, we can reasonably demonstrate that the undiscovered risked potential of the Cretaceous Play in the Slyne, Erris and Donegal Basins is in the order of ~ 60 mmb of recoverable oil.

Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (mmb/stoip/sq km)	Ultimate STOIP Indicated (mmb)	STOIP found to Date (mmb)	YTF (STOIP : mmb)	assumed recovery factor	Unrisked YTF recoverable (mmb)	Play Risk Assumed	Risked YTF recoverable (mmb)
Early Cretaceous	Yellow (Erris)	1332.0	Broad Fourteens Mesozoic oil play	0.4	532.8	0.0	532.8	0.4	186.5	0.3	55.9
TOTAL OIL							532.8		186.5		55.9





Slyne, Erris and Donegal Basin YTF table (Total)

By utilising areal richness calculations from a variety of analogous basins we can reasonably demonstrate that the undiscovered risked potential of the Slyne, Erris and Donegal Basins is in the order of ~ 4.2 tcf recoverable gas with an oil up-side.

GAS											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (GIIP bcf/sq km) (corrected for reservoir parameters)	Ultimate GIIP Indicated (bcf)	GIIP found to Date (bcf)	YTF GIIP (bcf)	assumed recovery factor	Unrisked YTF recoverable (bcf)	Play Risk Assumed	Risked YTF recoverable (bcf)
Carboniferous	Yellow (Donegal)	1021.0	SNS Barren Measures	1.1	1123.1	0.0	1123.1	0.6	673.9	0.4	269.5
Carboniferous	Yellow (Slyne/Erris)	450.0	SNS Barren Measures	1.1	495.0	0.0	495.0	0.6	297.0	0.3	74.3
Carboniferous Total							1618.1	0.6	970.9		343.8
Sherwood	Green (mainly Erris)	1820.0	E Irish Sea - segment below MMG salt	1.7	3094.0	1200.0	1894.0	0.8	1420.5	1.00	1420.5
Sherwood	Yellow (Erris)	3207.0	E Irish Sea - segment below MMG mdst	1.0	3207.0	0.0	3207.0	0.8	2405.3	0.63	1515.3
Sherwood	Yellow (Slyne)	2200.0	E Irish Sea - segment below MMG mdst	0.5	990.0	0.0	990.0	0.8	742.5	0.40	297.0
Sherwood	Yellow (Donegal)	630.0	E Irish Sea - segment below MMG salt	3.3	2053.8	0.0	2053.8	0.8	1540.4	0.40	616.1
Sherwood Total							8144.8	0.8	6108.6		3848.9
TOTAL GAS							9762.9	0.8	7322.2		4192.7

OIL											
Fairway	Segment	Area (sq km)	Analogue Used	Analogue Areal Productivity (mmbo STOIP/sq km)	Ultimate STOIP Indicated (mmbo)	STOIP found to Date (mmbo)	YTF (STOIP : mmbo)	assumed recovery factor	Unrisked YTF recoverable (mmbo)	Play Risk Assumed	Risked YTF recoverable (mmbo)
Sherwood	Yellow (N Erris Oil Play)	1150.0	E Irish Sea oil play	0.3	356.5	0.0	356.5	0.4	124.8	0.3	37.4
Mid Jurassic	Yellow (Slyne & Erris)	1609.0	Broad Fourteens Mesozoic oil play	0.4	643.6	0.0	643.6	0.4	225.3	0.3	67.6
Early Cretaceous	Yellow (Erris)	1332.0	Broad Fourteens Mesozoic oil play	0.4	532.8	0.0	532.8	0.4	186.5	0.3	55.9
TOTAL OIL							1532.9		536.5		161.0





Conclusions





Conclusions

- The most promising fairway in the area is the Triassic.
- This has not been adequately tested, particularly by the older wells on the basin margins, and much potential remains.
- The critical factor for the fairway is seal, particularly in areas of Mesozoic gas generation. Analogues suggest the most productive area of the fairway will be below the area of expected Mercia salt, but there are notable analogues, particularly the Hewett Field, that suggest discoveries can also be expected outside this area, particularly in areas of more recent generation. (Top seal equates fairway risk, Side seal equates prospect specific risk).
- From this point of view, the most prospective area would seem to be the southern part of the Erris Basin – Mercia Mudstone Group salt present and recent generation. The Central and North Erris and Slyne Basins can still be considered prospective , given the Hewett and Southern Irish Sea analogues.
- Attractive untested frontier potential exists in other fairways and in other areas. This includes:
 - A Brae-style Cretaceous fault plane play in the Erris Basin,
 - An Early Carboniferous sourced Triassic oil play in the northern part of the Erris Basin,
 - Late Carboniferous and Triassic Donegal potential in an undrilled and ill-understood frontier play, in the South Donegal Basin.
- A Yet-To-Find of the order of 4 tcf and 160 mmbbls risked reserves is estimated in all these plays, based on analogue area productivities.





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References





References

ANSORGE, J., BLUNDELL, D. AND MUELLER S. 1992. Europe's Lithosphere – seismic structure, in A continent revealed, The European Geotraverse, Blundell, D, Freeman, R and Mueller, S, eds. Cambridge University press, pp 33-69

BEHAR, F., VANDENBROUCKE, M., TANG, Y., MARQUIS, F. and ESPITALIE, J. 1997. Thermal cracking of kerogen in open and closed systems: determination of kinetic parameters and stoichiometric coefficients for oil and gas generation. *Organic Geochemistry*, 26, 312–339.

CHAPMAN, T.J., BROKS, T.M., CORCORAN, D.V., DUNCAN, L.A. and DANCER, P.N. 1999. The structural evolution of the Erris Trough, offshore northwest Ireland, and implications for hydrocarbon generation. In: FLEET, A.J. & BOLDY, S.A.R.(eds) *Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference*. Geological Society, London, 455-453.

DANCER, P.N., ALGAR, S.T. and WILSON, I.R. 1999. Structural evolution of the Slyne Trough. In: FLEET, A.J. and BOLDY, S.A.R. (eds) *Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference*. Geological Society, London, 445-469.

RATTEY, R.P. and HAYWARD, A.B. 1993. Sequence stratigraphy of a failed rift system: the Middle Jurassic to Early Cretaceous basin evolution of the Central and Northern North Sea. In: PARKER, J.R. (ed.) *Petroleum Geology of Northwest Europe, Proceedings of the 4th Conference*. The Geological Society, London, 215–249.

NAYLOR, D., SHANNON, P., and MURPHY, N. 1999. Irish Rockall Basin – a standard structural nomenclature system. *Petroleum Affairs Directorate Special Publication 1/99*.#

NAYLOR, D., SHANNON, P., and MURPHY, N. 2002. Porcupine to Goban Region – a standard structural nomenclature system. *Petroleum Affairs Directorate Special Publication 1/02*.

ROBERTS, D.G., THOMPSON, M., MITCHENER, B., HOSSACK, J., CARMICHAEL, S.M.M. and BJORNSETH, H.M. 1999. Palaeozoic to Tertiary rift and basin dynamics; mid-Norway to the Bay of Biscay; a new context for hydrocarbon prospectivity in the deep water frontier. In: Fleet, A.J. & Boldy, S.A.R. (eds) *Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference*. Geological Society, London, pp7–40.

SHANNON, P.M. 1991. The development of the Irish offshore sedimentary basins. *Journal of the Geological Society, London*, V.148, 1991



Petroleum Systems of Slyne, Erris & Donegal Basins



Appendices





Appendix 1 - Well density methodology

- Identify all HC fields within the area of interest.
- Search for HC reserve data (predominantly HIIIP quoted).
- Calculate a cumulative reserve total through time.
- Breakdown into discrete play fairways where applicable.
- Calculate number of wells drilled within the area of interest.
- Identify primary and if relevant secondary objectives and spud date of each well.
- Calculate area of each basin.
- Calculate well density for each basin.
- Calculate areal richness for each basin.
- Apply areal richness to play fairway maps.





Appendix 2 - Basin modelling

2.1 Software

Burial, thermal and expulsion modelling was carried out using Fobos Pro, a 1-D basin modelling package. This software uses lithospheric parameters (initial thickness and heat productivity) and changes to the lithosphere (stretching and underplating) to predict paleotemperatures through time. These paleotemperatures are used in the prediction of expulsion of hydrocarbons from source rocks in the wells and depocentres sites.

2.2 Input Parameters

Lithosphere Composition, Thickness & Regional Stretching

As a result of the Caledonian Orogeny the crust and lithosphere are expected to be thickened over the whole area prior to Carboniferous sedimentation. According to Roberts et al (1999) crust in the Slyne-Erris-Donegal area will be mostly composed of Proterozoic sediments and Archean crust of the Moine Terrane, and Vendian –Ordovician sediments of the Dalradian terrane, with a strongly SW-NE grain.

Initial thickness (32-50 km crust, 90-120 km mantle lithosphere, partly based on Ansorge et al, 1992, Figures 3-17 and 3-21) and stretching parameters (total $\epsilon=1.2-2$) have been applied in the basin modelling and provide satisfactory explanations for present day bathymetry and downhole thermal measurements, when sediment

radioactivity is taken into account. Curiously an exception is 18/20-1, where the simplest solution is thinner initial crust (30 km) and lithosphere (100km). This may be a result of anomalous salt thickening affecting the thermal gradient via thermal refraction. Paleoheatflow

Stretching parameters are adjusted to provide best fits with observed subsidence through time. Stretching times are constrained to only occur when extensional faulting is observed on seismic; during the Carboniferous, Late Permian-Triassic, Jurassic and, in the central and northern Erris Basin, in the Early Cretaceous. Compressional events were modelled in the early Permian, earliest Cretaceous and early Tertiary.

Calibration

Calculated paleotemperatures were used to predict downhole maturity. These were checked against measured vitrinite reflectances. Additionally, the paleotemperature models were checked against cooling paths from fission track analyses.

Stratigraphy.

Fobos Pro includes a large dataset of sediment compaction, thermal conductivity, density and radioactivity parameters, which are based on samples largely taken from offshore Norway wells. These are considered suitable for the Irish Atlantic margin. For well section down to TD, sediment ages,

paleobathymetry and lithologic composition were based on the AcecaGeologica FMB database. Section below TD and above first returns was interpreted on regional considerations and seismic interpretations.

Source rocks were characterised from available TOC, HI data and assigned to standard kerogen Types. Compositional kinetics for Types II and III (Behar et al, 1997) were used for this study. It is recognised that these models are an empirical average of these types, and that specific compositional kinetic analysis may give slightly different (or briefer duration) expulsion timings.

2.3 Modelled Well Locations

In order to assess local expulsion and possible expulsion and longer distance migration from west of the study area, all available wells were modelled in the Slyne-Erris-Donegal area. Pseudowell models were created for basin depocentres based on crude geoseismic interpretation discussed elsewhere. These latter were designed to assess the timing of oil and gas expulsion from the deeper parts of the basin.





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