Structural and kinematic analysis of the Slyne Basin: exploring the links between structural evolution and traps

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Abstract:

Basin formation began in the Late Permian, with a first phase of rifting continuing until the end of the Early Jurassic, when the basin experienced a period of uplift and erosion. The most significant phase of rifting initiated in the Middle Jurassic and continued until the end of the Jurassic. Significant erosion of the Late Jurassic strata during the Early Cretaceous created a distinct regional angular unconformity before a thin Cretaceous cover was deposited. A second phase of uplift and erosion during the Paleocene resulted in a subtle angular unconformity between Cenozoic and Cretaceous sediments, and removed the Cretaceous section south of the Central Slyne Transfer Zone, juxtaposing Cenozoic and Jurassic sediments. Localised zones of strike-slip faults likely developed during this time. Eocene magmatism resulted in the emplacement of numerous sills within the Jurassic succession and extrusion of lava flows onto the Paleocene unconformity, followed by the deposition of Oligocene to Miocene sediments. Mild reactivation of a variety of structures occurred during the Miocene with evidence of both normal and reverse movements. A final minor period of erosion during the Miocene created a regional unconformity, upon which a thin cover of undeformed Miocene to Recent sediments was deposited.

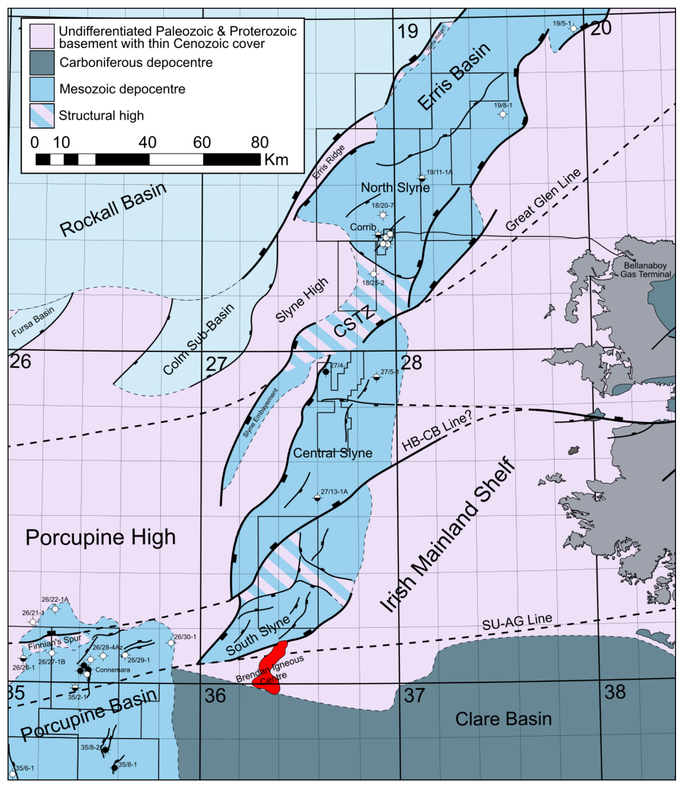
The structural architecture of the Slyne Basin is influenced by the presence of major structural lineaments which transect the basin, dividing it into three distinct sub-basins of opposed polarity and unique structural styles (figure 1). Extensional fault-related structures, typical of rift basins, are the main play types in this area. The geometry of these structures is strongly influenced by the presence of Permian and Triassic salt that mechanically detach the Mesozoic section from the underlying Palaeozoic basement, leading to rafting, salt withdrawal and forced folding above basement horsts. The Corrib gas field and the 18/20-7 (Corrib North) discovery are both salt-induced anticlines above basement horsts. Additionally, numerous culminations are observed in the hanging-walls of the basin-bounding faults, such as the structure containing the 27/4-1 (Bandon) oil discovery, which are likely to have formed by a combination of salt withdrawal and rapid subsidence during the Middle Jurassic. Post-rift evolution (exhumation and reactivation) possess a risk to the integrity of hydrocarbon traps, with the clearest example of this being the structure tested by the 27/5-1 (Avonmore) well, where a circa. 100m residual oil column was encountered in a horst block with distinct Oligocene to Miocene age reverse movement on the bounding faults.

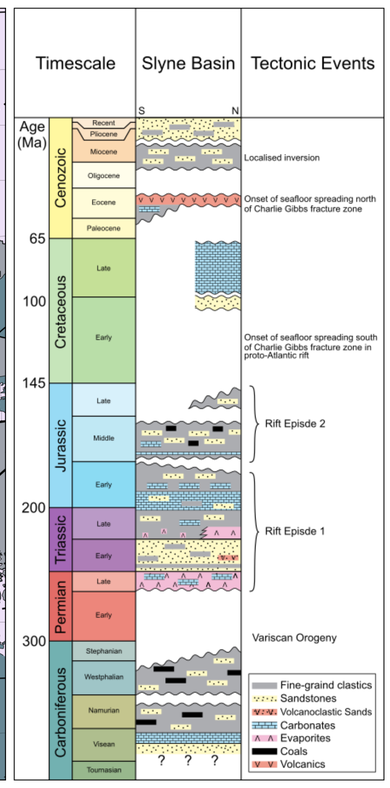
Geological Framework:

The Slyne Basin is a narrow, elongate rift basin off the west coast of Ireland. The basin is subdivided into three sub-basins by transfer zones, with different structural styles and basin polarity changing across these zones.

Transfer zones occur where major crustal lineaments transect the basin, with the line of the Great Glen fault coinciding with the Central Slyne Transfer Zone (CSTZ), and the Highland Boundary-Clew Bay-Fairhead line forming the boundary between the Central and Southern sub-basins. These lineaments stretch across the Porcupine High and influence the Porcupine Basin in a similar manner.

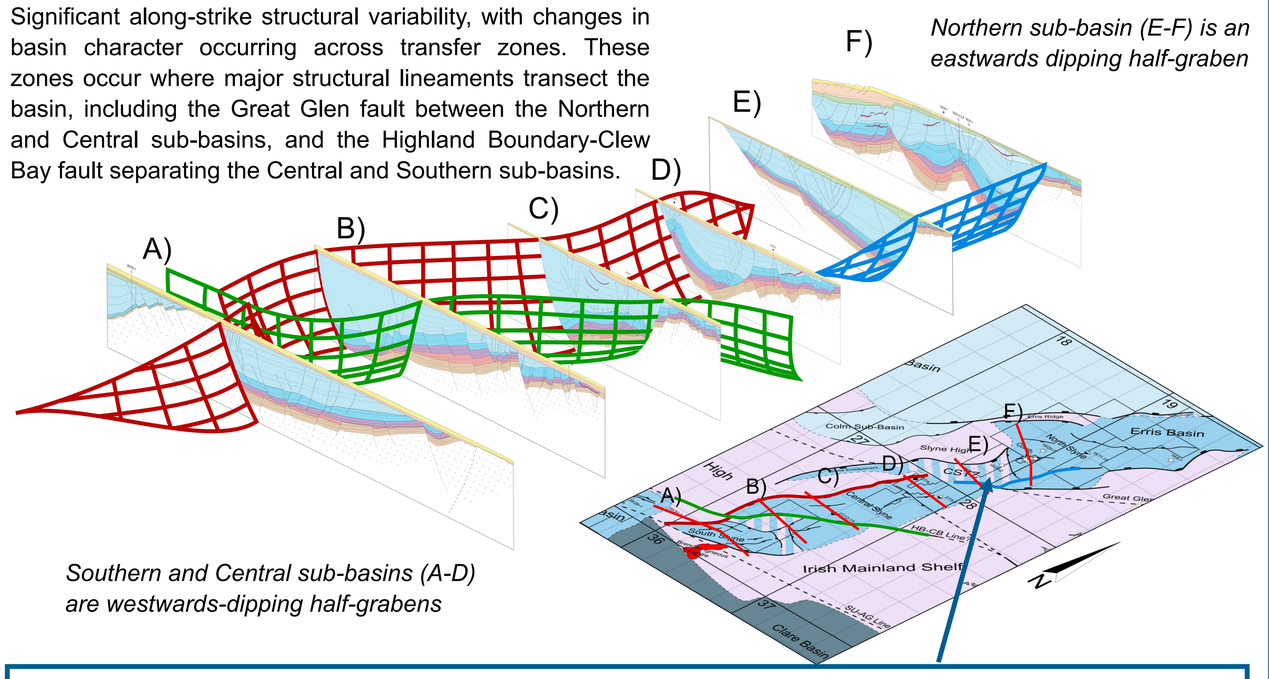
The Slyne Basin is part of a chain of basins extending along the NW European Atlantic margin, including the Porcupine Basin to the south and the Erris Basin to the north, with similarities in their structural development.





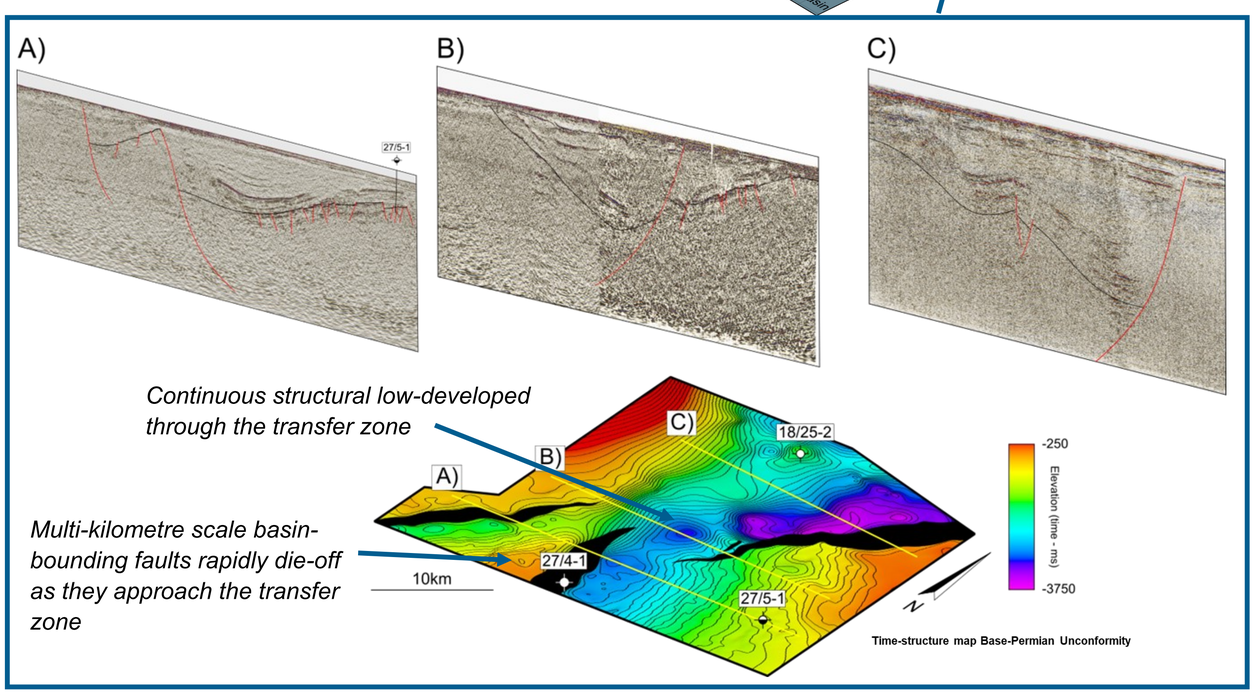
Transfer Zones:

Significant along-strike structural variability, with changes in basin character occurring across transfer zones. These zones occur where major structural lineaments transect the basin, including the Great Glen fault between the Northern and Central sub-basins, and the Highland Boundary-Clew Bay fault separating the Central and Southern sub-basins.



Northern sub-basin (E-F) is an eastwards dipping half-graben

Southern and Central sub-basins (A-D) are westwards-dipping half-grabens

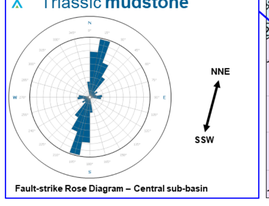


Continuous structural low-developed through the transfer zone

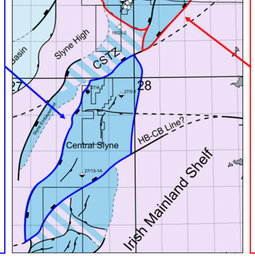
Multi-kilometre scale basin-bounding faults rapidly die-off as they approach the transfer zone

Time-structure map Base-Permian Unconformity

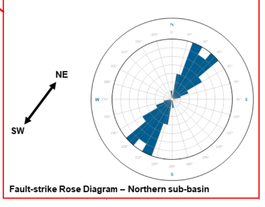
Central Slyne:
- **Westward** dipping
- **NNE-SSW** structural orientation
- **Oil**-prone
- Cretaceous **absent**
- Triassic **mudstone**



Fault-strike Rose Diagram – Central sub-basin



Northern Slyne:
- **Eastwards** dipping
- **NE-SW** structural orientation
- **Gas**- and **oil**-prone
- Cretaceous **preserved**
- Triassic **halite**



Fault-strike Rose Diagram – Northern sub-basin

Central Slyne Transfer Zone (CSTZ):

A number of differences are apparent in the sub-basins north and south of the CSTZ, including structural strike, fluid phase and the presence of Triassic salt. This highlights the long-lived impact these Caledonian lineaments exert on the development of Mesozoic sedimentary basins offshore Ireland.

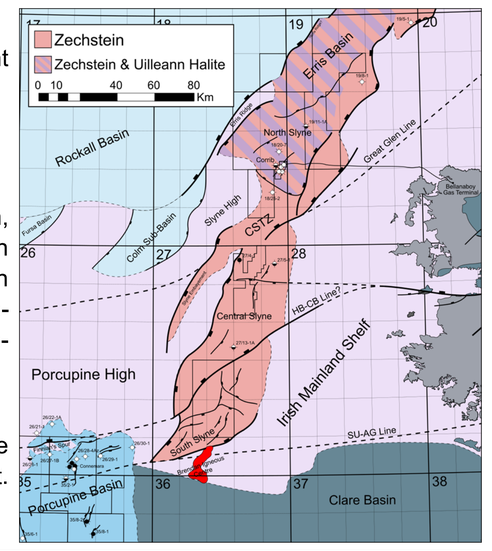
Salt Tectonics:

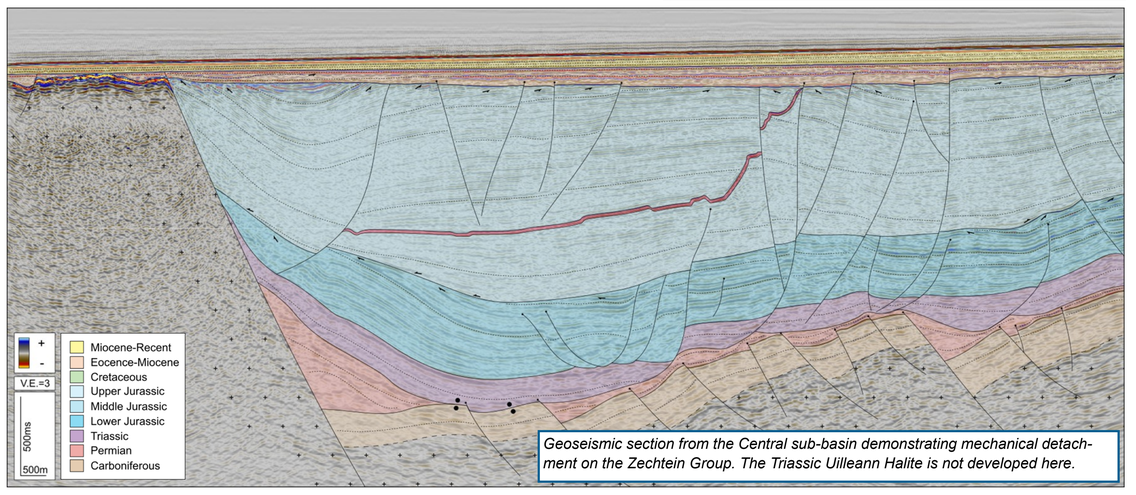
Salt plays a very important role in the structural development of the Slyne Basin. There are two salt-prone intervals:

- Zechstein Group (Permian)
- Uilleann Halite (Upper Triassic)

The Zechstein group is present throughout the Slyne Basin, while the Uilleann Halite is only developed in the Northern sub-basin. The presence of two layers of salt in the Northern sub-basin and only one in the Central and Southern sub-basins influences the structural style and trap types that develop in both areas.

Salt acts as a décollement, which mechanically detaches the Mesozoic section from the underlying Palaeozoic basement. Most faults in the Mesozoic section are therefore listric.

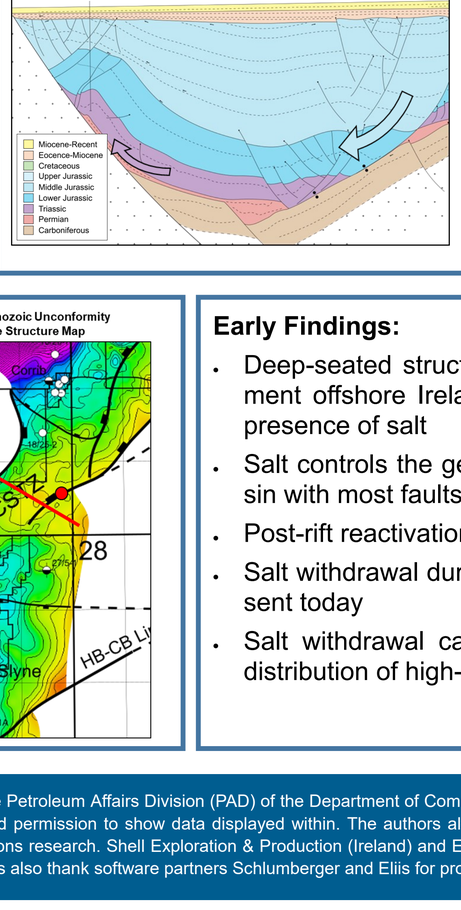


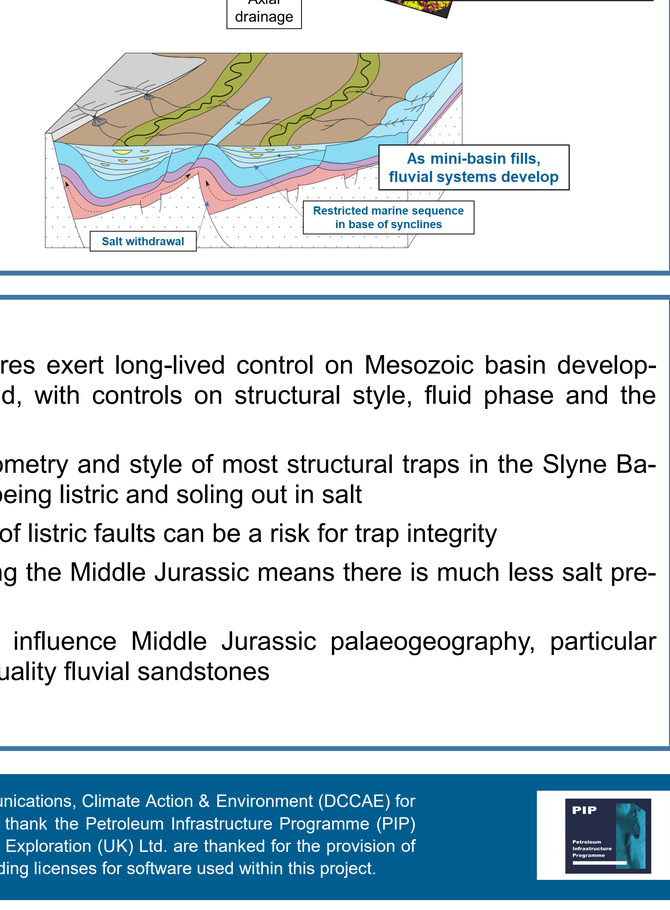


Geoseismic section from the Central sub-basin demonstrating mechanical detachment on the Zechtein Group. The Triassic Uilleann Halite is not developed here.

27/4-1 (Bandon) Oil Discovery

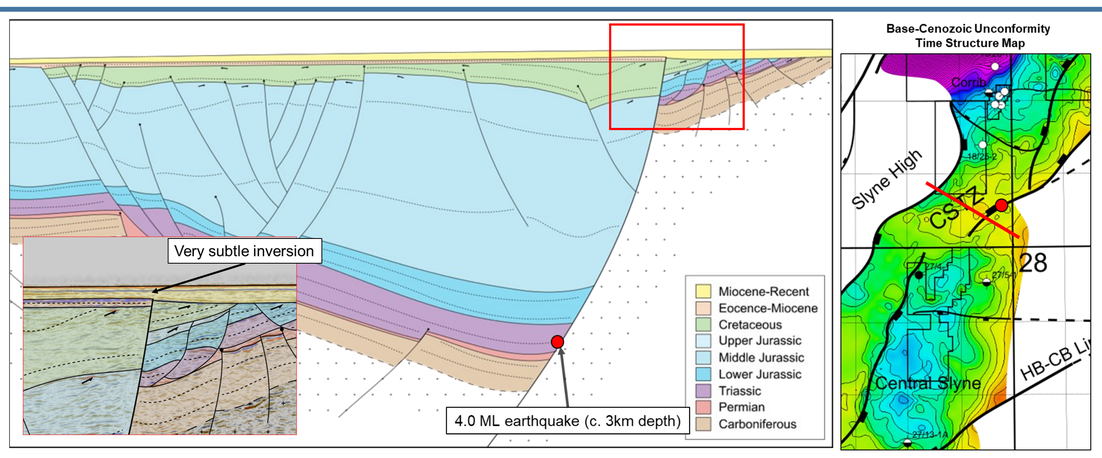
The 27/4-1 structure is a structurally complex hanging-wall culmination, characterised by high relief at Jurassic and Triassic level, bedding parallel the bounding fault, and the involvement of salt. Salt withdrawal during the Middle Jurassic may have created this structure and influenced palaeogeography at the time.





Post-Rift Activity:

Post-rift activity is subtle but pervasive throughout the Slyne Basin. This includes inversion of the CSTZ, in addition to present day seismicity, with a magnitude 4.0 earthquake occurring on the bounding fault in 2012, one of the largest ever recorded in Ireland.



Base-Cenozoic Unconformity
Time Structure Map

Early Findings:

- Deep-seated structures exert long-lived control on Mesozoic basin development offshore Ireland, with controls on structural style, fluid phase and the presence of salt
- Salt controls the geometry and style of most structural traps in the Slyne Basin with most faults being listric and soling out in salt
- Post-rift reactivation of listric faults can be a risk for trap integrity
- Salt withdrawal during the Middle Jurassic means there is much less salt present today
- Salt withdrawal can influence Middle Jurassic palaeogeography, particular distribution of high-quality fluvial sandstones

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