Cenozoic deformation in Ireland's offshore basins

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1. Introduction

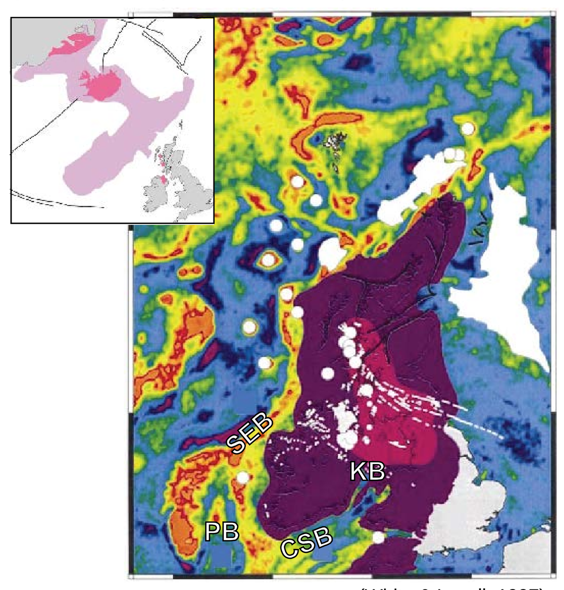
In much of the NW European continental shelf hydrocarbons are most often contained within Upper Jurassic traps, though increasing numbers of both structural and stratigraphic traps are hosted within younger Mesozoic and Cenozoic sequences. Previous work suggests that the 3 principal controls on Cenozoic deformation in offshore and onshore Ireland are: (i) the Icelandic plume, causing widespread uplift and denudation, (ii) Alpine compression and (iii) Atlantic spreading, generating both extensional and compressional structures (Box 2 & 3). The predominance of any one factor on the nature and spatial distribution of Cenozoic structures is uncertain and likely to vary both spatially and temporally.

Whether or not Cenozoic faults arise from later compression or extension they could play an important role in hydrocarbon leakage, either to higher structural levels or to the sea floor; as faults are widely recognised as fluid flow pathways, and seal breach by reactivation of trap-bounding faults is a major risk to hydrocarbon preservation. However, seal breach and trap integrity are dependent on the geometrical and kinematic attributes of trap-bounding faults. Thus, central to determining trap integrity is understanding the fault reactivation mechanisms and the factors controlling the geometry and growth of reactivated faults. Factors identified as strongly influencing fault reactivation and subsequent fault geometry include fault size, orientation, dip direction and displacement distribution (Box 4)

In this project, we aim to establish much improved constraints on the nature, evolution and spatial distribution of Cenozoic structures which have the potential not only to provide for up-fault leakage of pre-existing traps, potentially to traps at higher structural levels, but could also form anticlinal or fault-related traps. The Fault Analysis Group has developed structural models for Cenozoic deformation in the Irish Sea and Porcupine basin, elements of which are presented here. This structural analysis will be extended to include the other major Irish offshore basins.

2. Cenozoic deformation

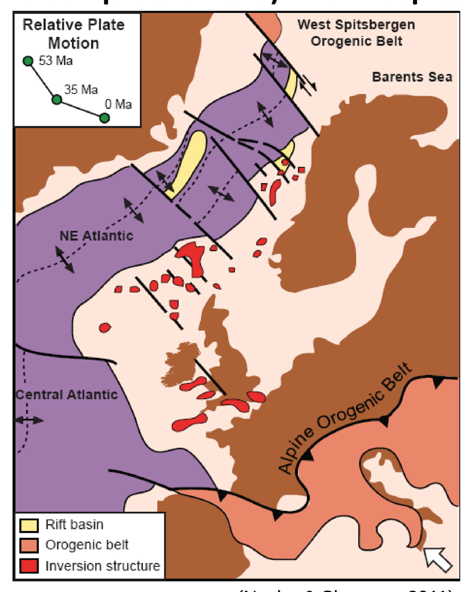
1) Icelandic plume activity



(White & Lovell, 1997)

A prolonged period of plume-related igneous activity during the Paleocene caused widespread uplift and denudation. Denudation of 0.5 -1km (purple) to 2-3km (pink) during the Palaeogene. Slyne-Erris Basin (SEB), Porcupine Basin (PB), Celtic Sea Basin (CSB) and Kish Bank Basin (KB). Inset: onshore (pink) and offshore (purple) basalts.

2) Alpine compression & 3) Atlantic spreading



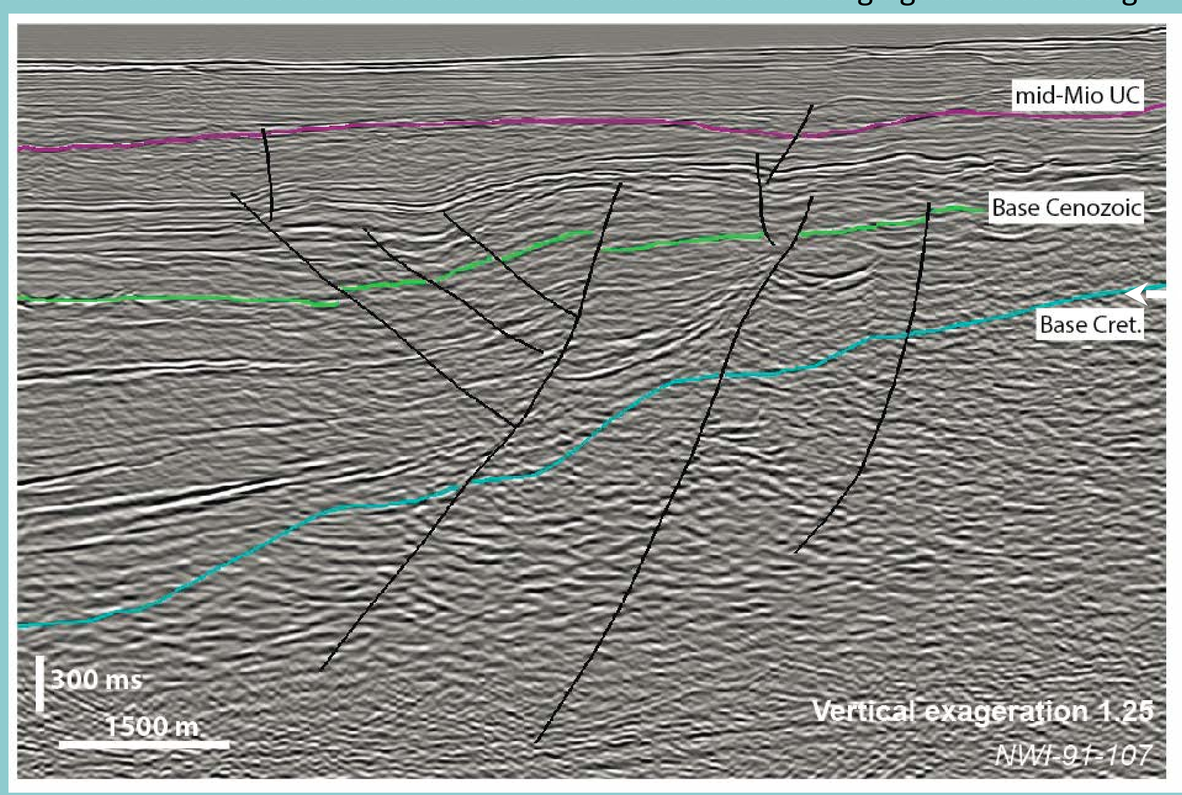
(Naylor & Shannon, 2011)

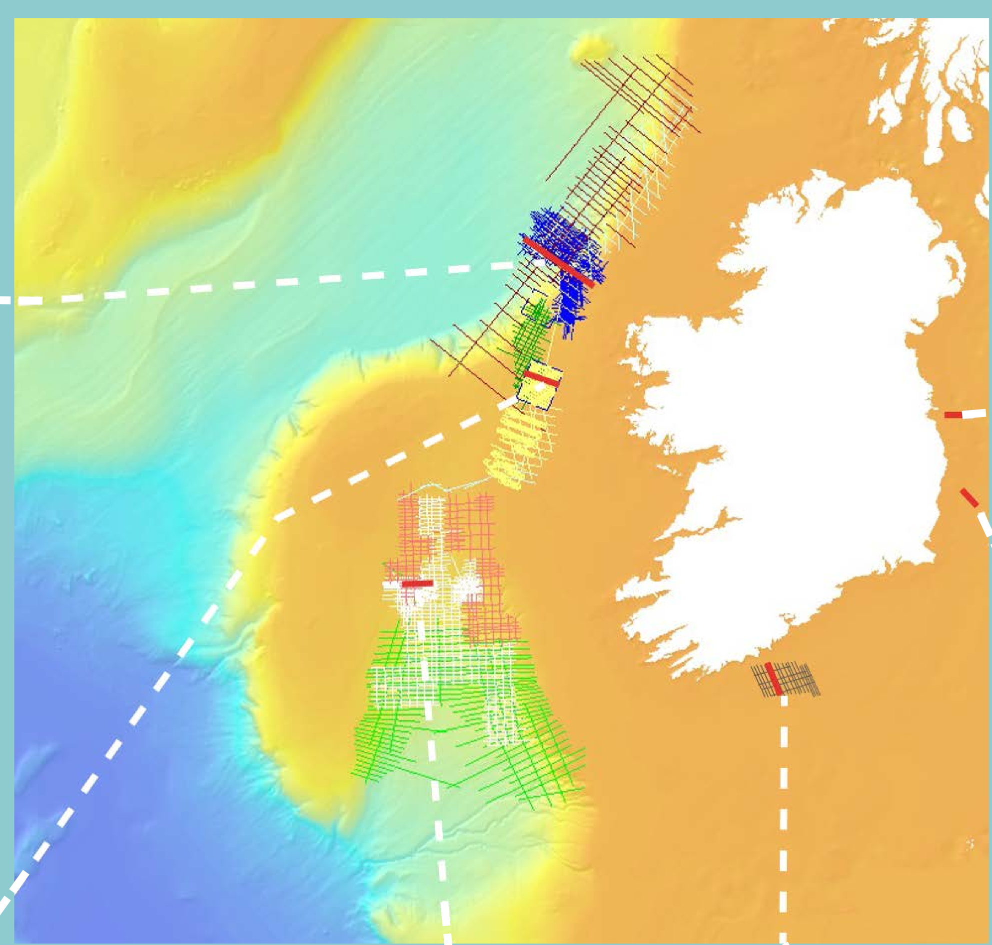
Alpine deformation is manifest as regional scale basin inversion and compressional deformation as either fault reactivation, hangingwall buttressing or strike-slip faulting. Deformation linked to Atlantic spreading can be either extensional, caused by rifting, or compressional arising from ridge-push related stresses or local plate reorganisation.

3. Cenozoic deformation structures offshore Ireland

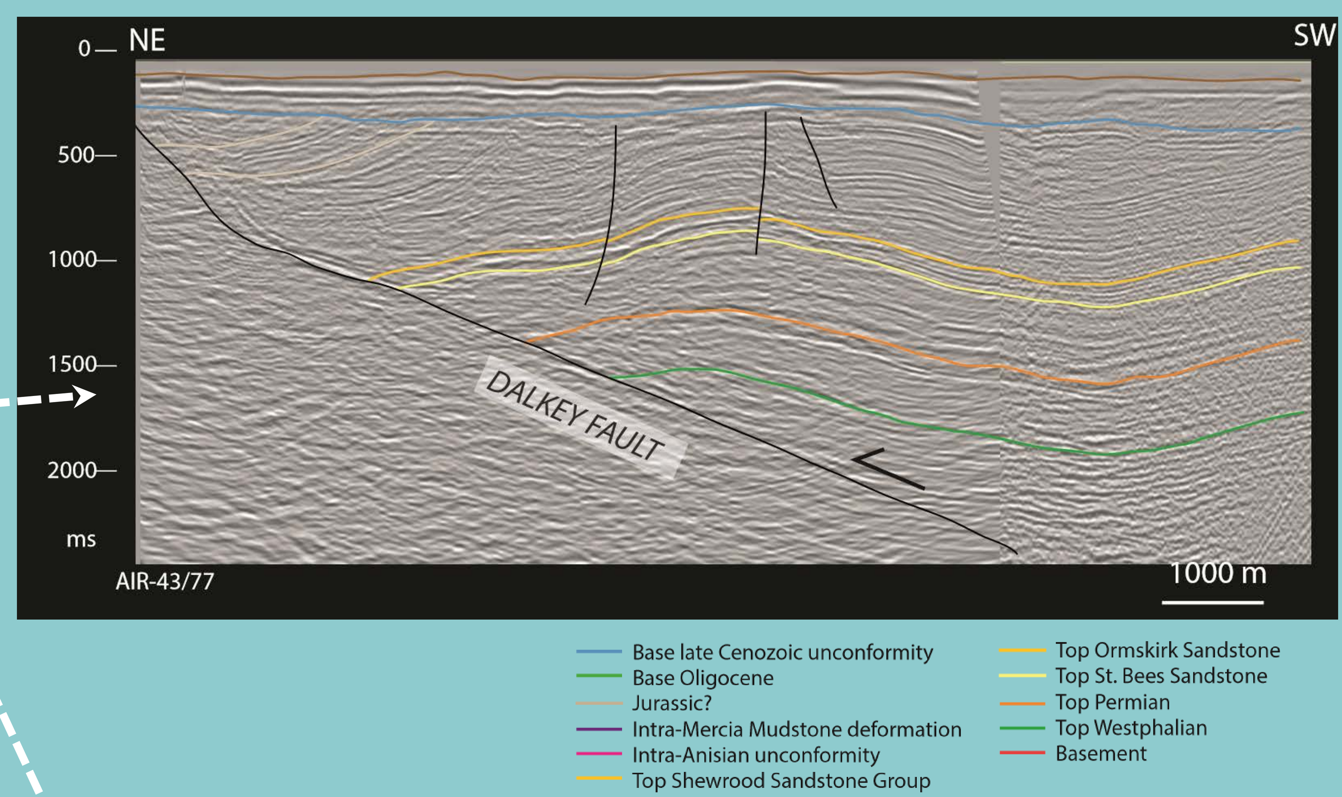
We have examined Cenozoic structures from multiple 2D seismic datasets covering the Irish offshore basins. The seismic sections below illustrate the various forms of Cenozoic reactivation structures observed within each basin.

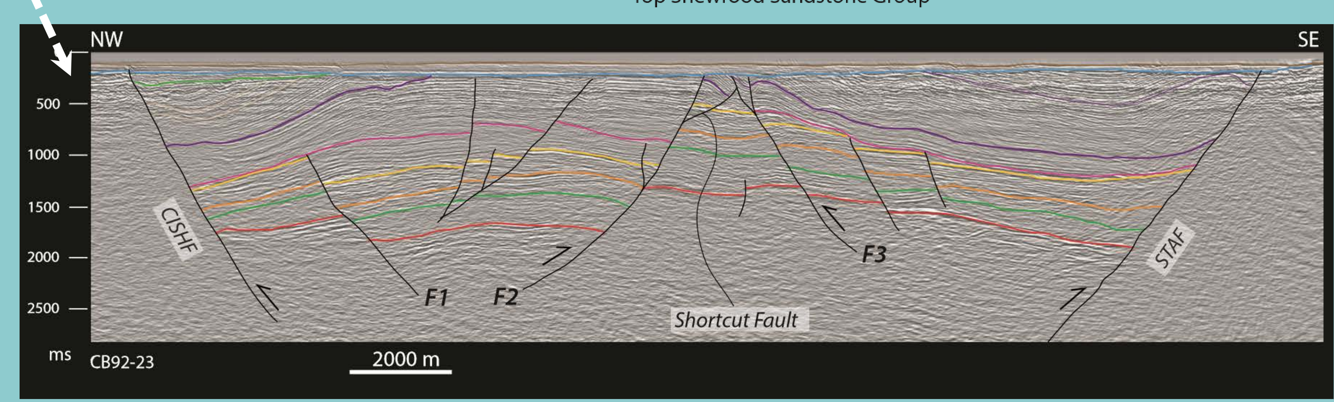
Erris Basin: Reverse reactivation of normal faults and hangingwall buttressing



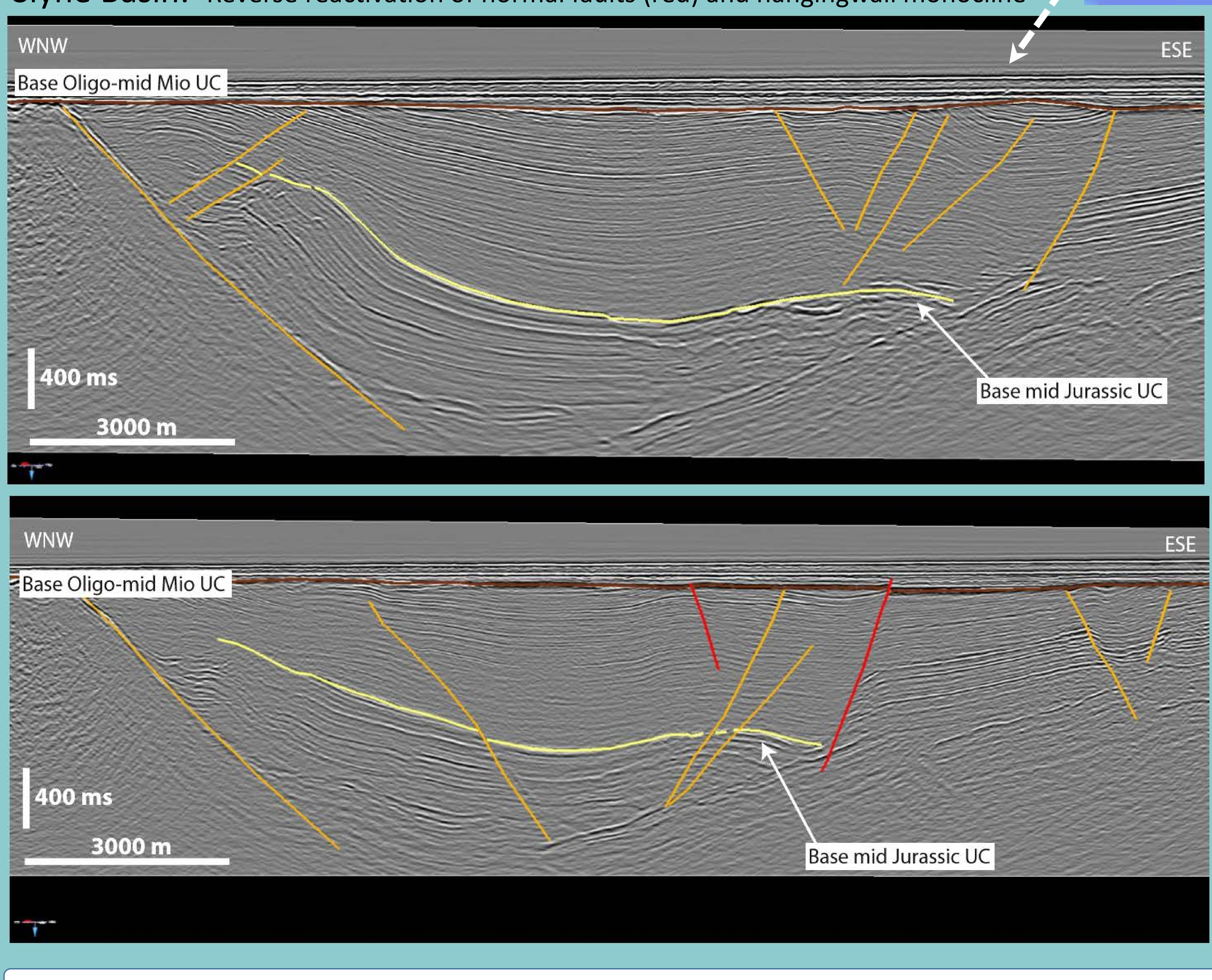


Kish Bank & Central Irish Sea Basins

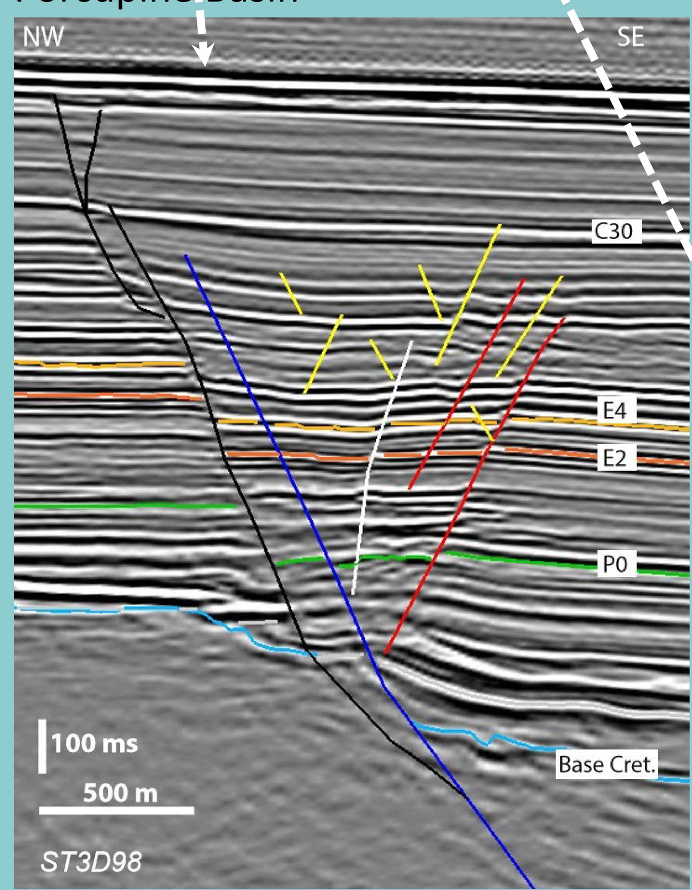




Slyne Basin: Reverse reactivation of normal faults (red) and hangingwall monocline

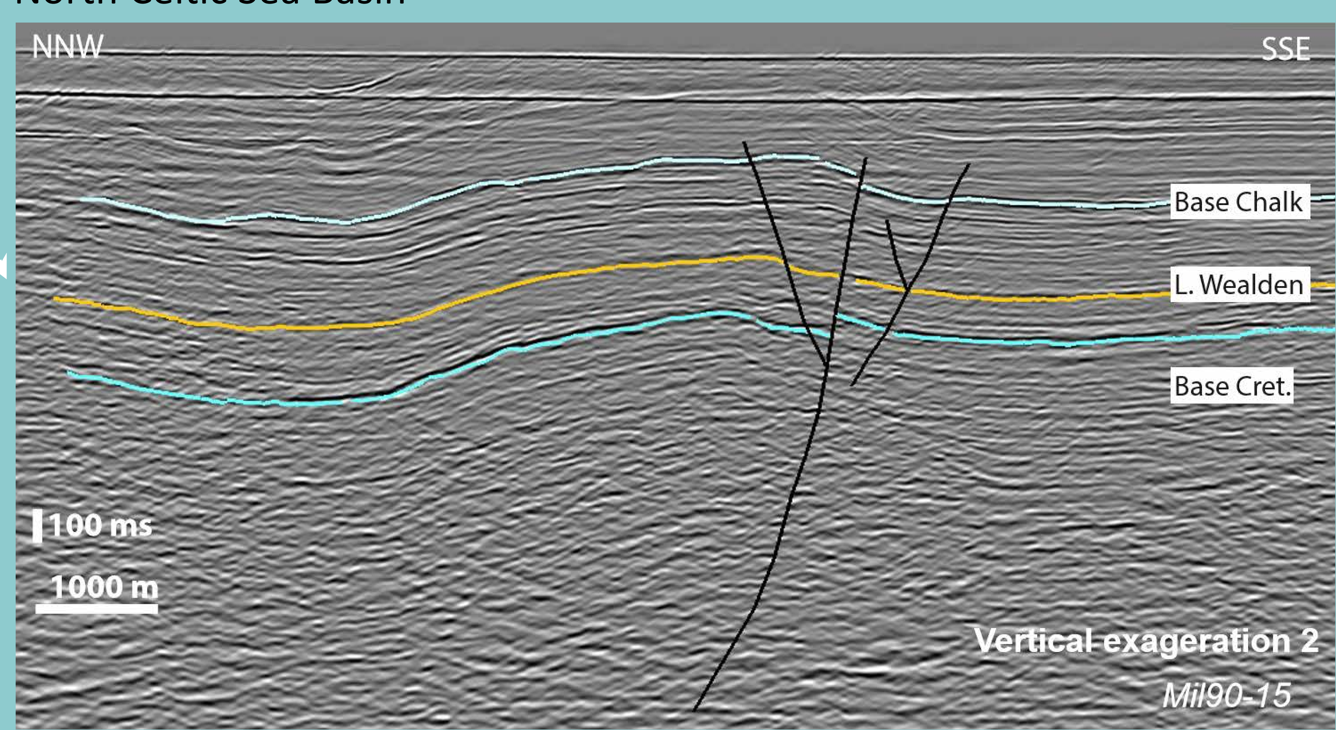


Porcupine Basin



Extensional reactivation of a Jurassic basin bounding normal fault. Upward propagation into overlying cover sequence results in fault segmentation.

North Celtic Sea Basin

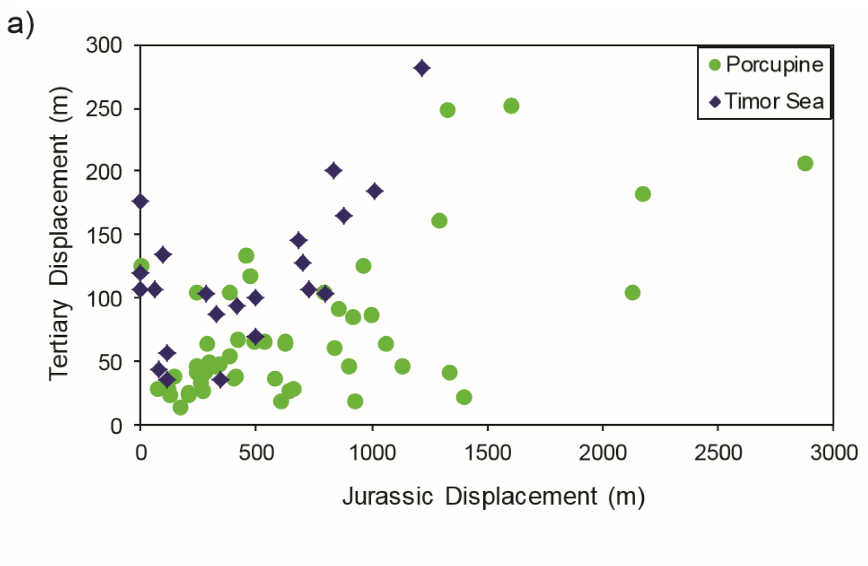


Alpine-related uplift and inversion is widespread in the North Celtic Sea. Characterised by basin doming and reverse faulting, which has formed km-scale compressive anticlines.

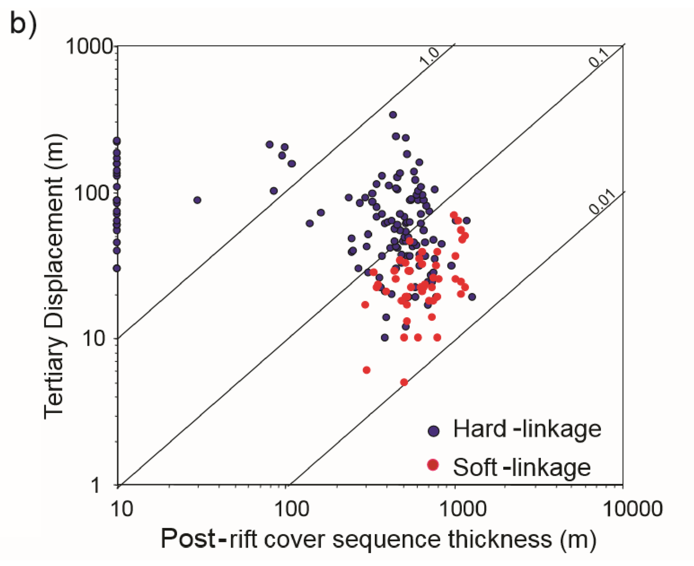
4. Cenozoic deformation structures offshore Ireland

Previous work by the Fault Analysis Group (Walsh et al., 2002) suggested that fault reactivation is controlled by certain geometrical parameters (fault size, orientation, dip direction). This hypothesis is supported by data from the Porcupine Basin indicating that: a) Large faults are more likely to reactivate than smaller faults and b) the linkage of reactivated fault segments through a cover sequence depends on sequence thickness. Hence quantitative analysis of faults may provide a basis for predicting the upward continuity of reactivating faults.

a)

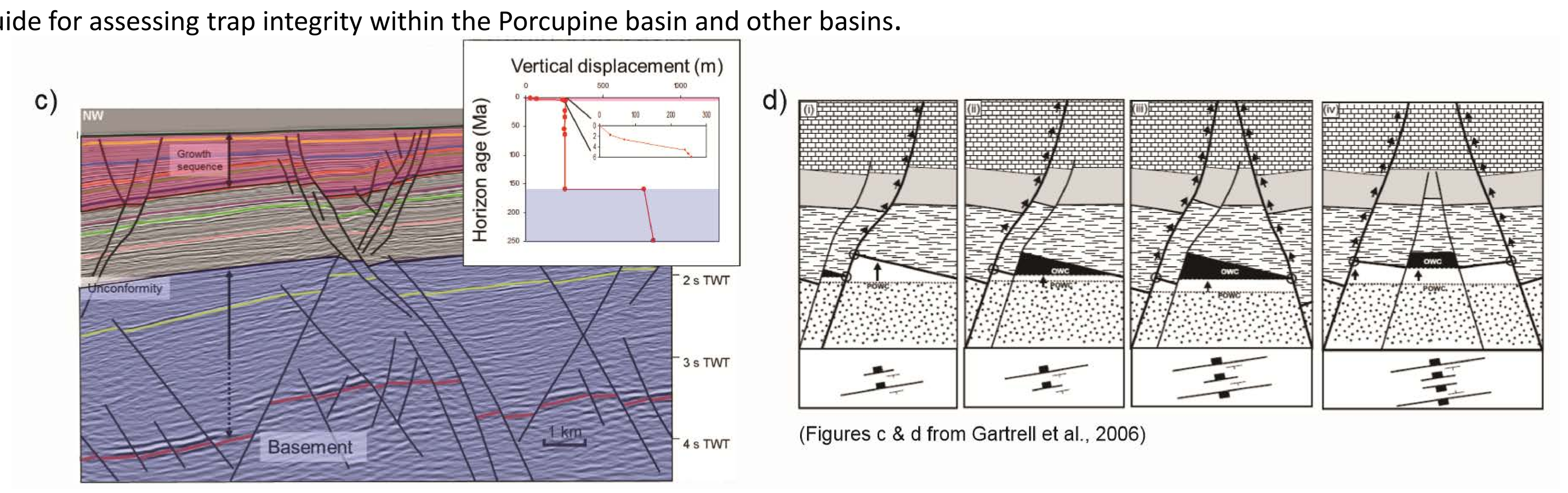


b)



Assessing the integrity of reactivated fault-bound traps and hydrocarbon preservation in the Timor Sea (c) Gartrell et al., (2006) demonstrated the importance of the relationship between trap geometry and post-rift displacement distribution on bounding faults. Interactions between overlapping faults resulted in heterogeneous displacement distributions associated with low-risk trap geometries and greater likelihood of hydrocarbon preservation. Simple models were developed with which to risk trap integrity and hydrocarbon preservation (d). Reactivated faults within the Porcupine basin have features similar to those in the Timor Sea (see our quantitative data in (a)) and it appears that similar factors control fault reactivation. Hence, trap integrity models developed for the Timor Sea may serve as a guide for assessing trap integrity within the Porcupine basin and other basins.

c) d)



(Figures c & d from Gartrell et al., 2006)

4. Conclusions

Geometric analysis of reactivated faults offshore Ireland suggests that there are spatial and temporal changes in the nature of Cenozoic deformation. Alpine compression is the predominant influence on deformation in the Irish Sea and Celtic Sea Basins. The origin of Cenozoic deformation in the Porcupine and Slyne-Erris basin is unclear, and may be linked to Atlantic spreading or plume activity or both; both extensional and compressional structures are observed.

Determining the factors controlling fault reactivation and the geometry of the structures resulting from these driving forces is central to assessing the potential for reactivation of trap-bounding faults and thus trap integrity, as well as identifying possible anticlinal or fault-related traps.

Using a combined approach of structural analysis and hydrocarbon migration modelling this project will identify the factors controlling Cenozoic deformation and fault reactivation, the link between Cenozoic structures and underlying structures or potential traps and the impact of later deformation on trap formation and integrity

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