PS Controls of the Pre-Existing Structures on the Post-Jurassic Deformation of the Porcupine Basin, Offshore West Ireland*

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Abstract

Over the NW European continental shelf hydrocarbons have most often been encountered within Upper Jurassic traps, though increasing numbers of both structural and stratigraphic traps are hosted within younger Mesozoic and Cenozoic sequences. Many potential traps have been subjected to later deformation resulting in both localized compressional and extensional reactivation of Jurassic structures with both negative and positive implications for trap integrity and charge. This study focuses on the control of pre-existing Jurassic rift faults on the distribution and style of Cretaceous and Cenozoic normal faults within the Porcupine Basin as they could play an important role in hydrocarbon leakage from lower to higher structural levels and also in providing up-dip seal to post-rift stratigraphic plays. The location and geometry of post-Jurassic faulting is, to varying degrees, controlled by Jurassic structures. Here we classify the degree of this localisation into weak, moderate, and strong depending on the geometrical relationships between Jurassic and later structures. Where localisation is weak, the locations of overlying faults are clearly influenced by and soft-linked to underlying faults and/or structural ‘highs’, though their strike can be unrelated and they do not have a dominant dip direction. Moderate localisation is characterized by pronounced relationship in both strike and dip direction of faults, with displacements on overlying faults at a maximum within the Cretaceous or Cenozoic section to produce a predominantly soft-linked system, with only occasional hard-linkage into the Jurassic structures. By contrast, strong localisation is marked by hard-linked faults with displacements that are constant or decrease upwards through the post-Jurassic sequence, and with reactivation arising from upward propagation of Jurassic faults either as single fault surfaces or bifurcating array of oblique faults. Our analysis of faults across the Porcupine Basin indicates that the degree of localisation and linkage is controlled by three main factors: (a) relative orientation of later stretching and pre-existing Jurassic faults, (b) fault size (i.e. displacement), and (c) thickness and rheology of the intervening layer. Whatever the controlling factor, strong localisation during reactivation can provide up-fault pathways into post-rift strata, whilst weak localisation is unlikely to facilitate hydrocarbon leakage from lower to higher structural levels.

References Cited

Masson, D.G., and P.R. Miles, 1986, Structure and Development of Porcupine Seabight Sedimentary Basin, Offshore Southwest Ireland: American Association of Petroleum Geologists Bulletin, v. 70/5, p.536-548.

Petroleum Affairs Division, 2006, Petroleum System Analysis of the Rockall and Porcupine Basins Offshore Ireland, Digital Atlas: PAD Special Publication 3/06.

Saqab, M.M., C. Childs, J.J. Walsh, and E. Delogkos, 2016, Multiphase Deformation History of the Porcupine Basin, Offshore West Ireland: Abstracts Volume Atlantic Ireland 2016.

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Over the NW European continental shelf hydrocarbons have most often been encountered within Upper Jurassic traps, though increasing numbers of both structural and stratigraphic traps are hosted within younger Mesozoic and Cenozoic sequences. Many potential traps have been subjected to later deformation resulting in both localised compressional and extensional reactivation of Jurassic structures with both negative and positive implications for trap integrity and charge. This study focuses on the control of pre-existing Jurassic rift faults on the distribution and style of Cretaceous and Cenozoic normal faults within the Porcupine Basin as they could play an important role in hydrocarbon leakage from lower to higher structural levels and also in providing up-dip seal to post-rift stratigraphic plays. The location and geometry of post-Jurassic faulting is, to varying degrees, controlled by Jurassic structures. Here we classify the degree of this localisation into weak, moderate and strong depending on the geometrical relationships between Jurassic and later structures. Where localisation is weak, the locations of overlying faults are clearly influenced by and soft-linked to underlying faults and/or structural 'highs', though their strike can be unrelated and they do not have a dominant dip direction. Moderate localisation is characterized by pronounced relationship in both strike and dip direction of faults, with displacements on overlying faults at a maximum within the Cretaceous or Cenozoic section to produce a predominantly soft-linked system, with only occasional hard-linkage to the Jurassic structures. By contrast, strong localisation is marked by hard-linked faults with displacements that are constant or decreasing upwards through the post-Jurassic sequence, with reactivation arising from upward propagation of Jurassic faults either as single fault surfaces or bifurcating arrays of oblique faults. Our analysis of faults across the Porcupine Basin indicates that the degree of localisation and linkage is controlled by three main factors: (a) relative orientation of later stretching and pre-existing Jurassic faults, (b) fault size (i.e. displacement), and (c) thickness and rheology of the intervening sequence. Whatever the controlling factor, strong localisation during reactivation can provide up-fault pathways into post-rift strata, whilst weak localisation is unlikely to facilitate hydrocarbon leakage from lower to higher structural levels.

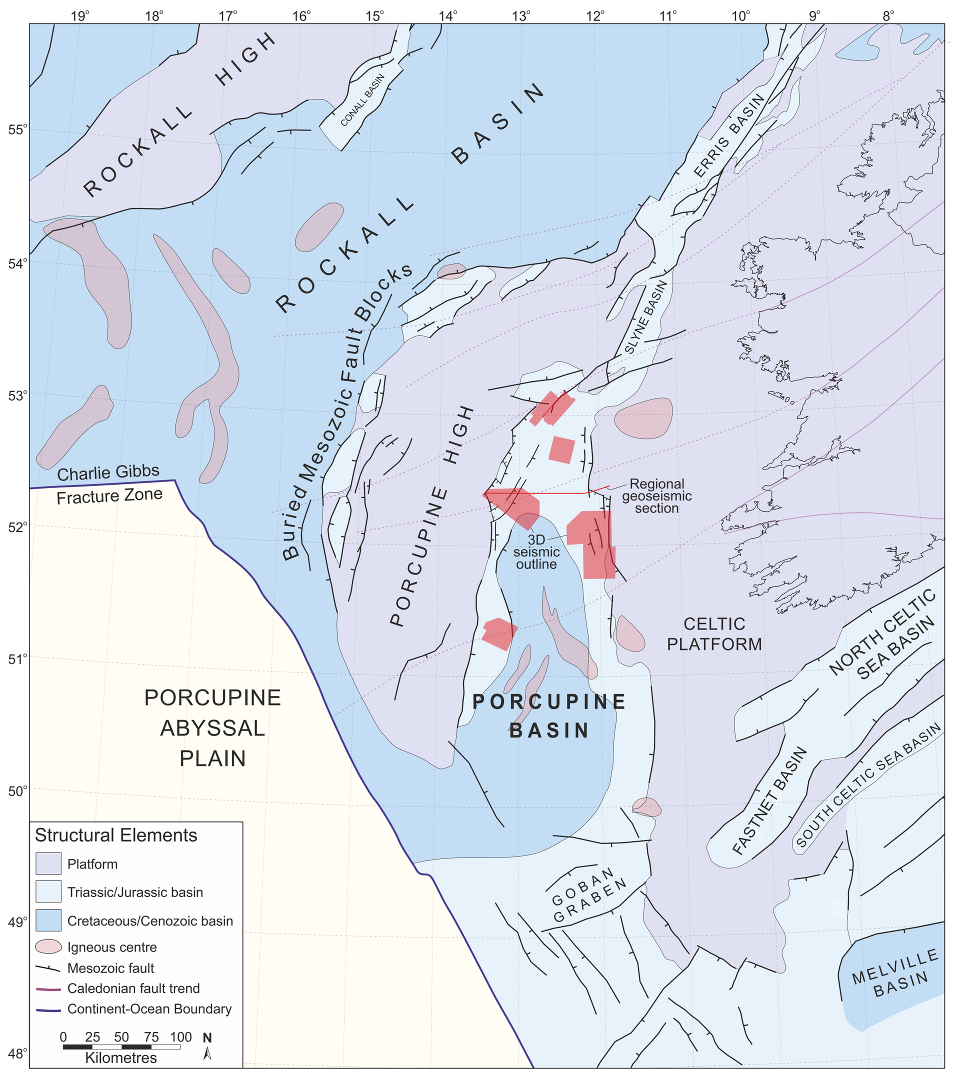
Geological framework

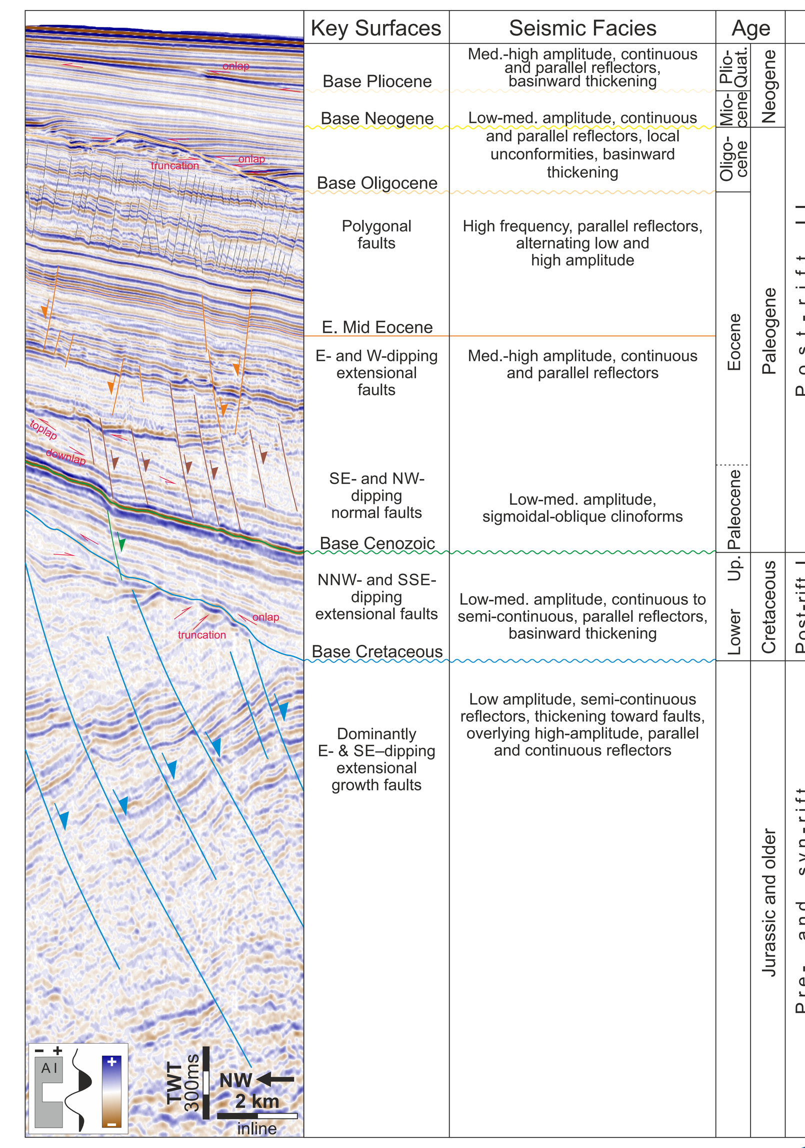
The Porcupine Basin is a large under-explored sedimentary basin located offshore west of Ireland. It is a part of the structurally complex European North Atlantic Margin.

The basin contains up to 10 km of Upper Paleozoic to Cenozoic sediments underlain by thinned conti-nental crust (rather than oceanic crust; Masson and Miles, 1986).

The north-south oriented basin appears to have developed mainly during Middle and Upper Jurassic times, broadly coincident with the main phase of syn-rift basin development.

A representative short seismic line highlights how the basin-fill is divided into four megasequences as pre-rift (PrR), syn-rift (SR), post-rift I (PRI) and post-rift II (PRII). In this case, key stratigraphic surfaces were identified based on reflection termination criteria and were mapped on the available 2D & 3D seismic dataset in the Porcupine Basin.





Structural evolution

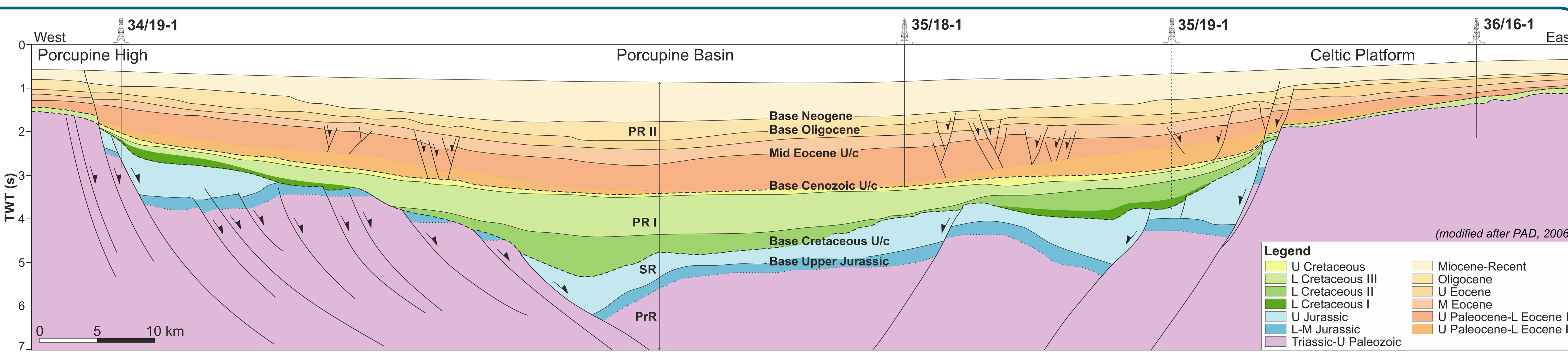
A regional geoseismic profile (on the right) highlights the principal structural styles and major sequences of the basin, which is typified by large-scale rotated fault blocks of Mid Jurassic strata, covered by a syn-rift Upper Jurassic sequence. Cretaceous and Cenozoic strata represent an associated post-rift 'thermal sag' phase of deposition.

The basin evolved through two episodes of Jurassic rifting, separated by the Base Upper Jurassic unconformity. A set of syn-rift faults truncate below this unconformity. Growth strata occur below (relatively thin) and above (relatively thick) the Base Upper Jurassic horizon.

A second phase of extension (mild) is represented by east-west trending Cretaceous normal faults. These faults are generally small (<50 ms TWT throw) and terminate below the Base Cenozoic unconformity. Along the margins of the basin, these faults displace the BCU and interact with the underlying Jurassic rift faults (Saqab et al., 2016). These faults add risk to syn-rift fault related entrapment, but may also provide migration paths to shallow reservoirs.

Most recent deformation in the Porcupine Basin is the Cenozoic phase of extensional faulting. These are north-south trending segmented normal faults, mainly contained within the Base Cenozoic and Base Miocene horizons. Faults dip to the east or west and form conjugate sets. Reactivation and upward propagation of the Jurassic rift faults also occurred during this phase.

Both Cretaceous and Cenozoic normal faults can be important in providing up-dip seal for the post-rift stratigraphic plays.

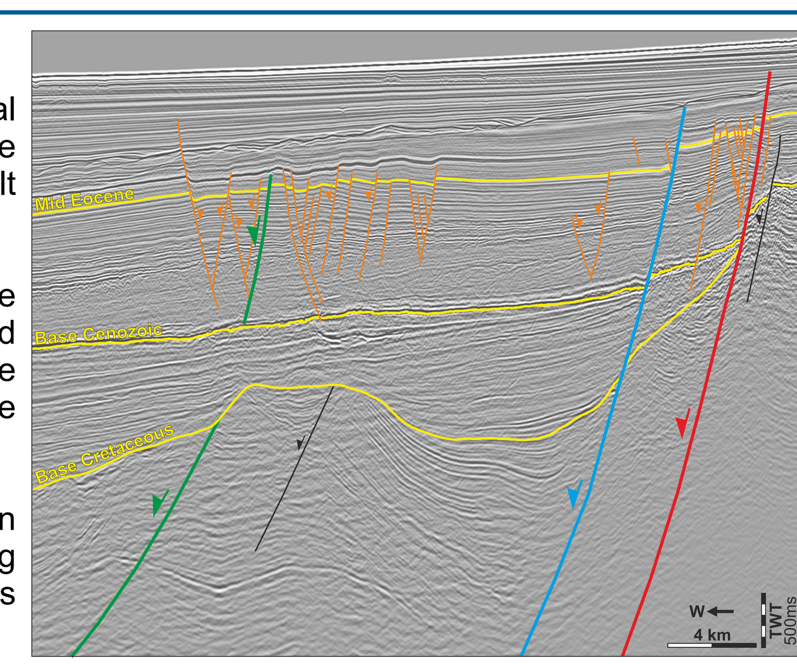


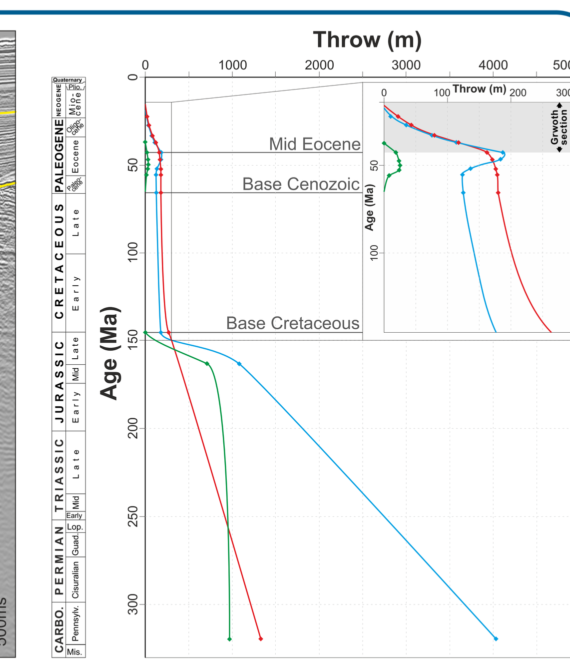
Throw profiles & strain localisation

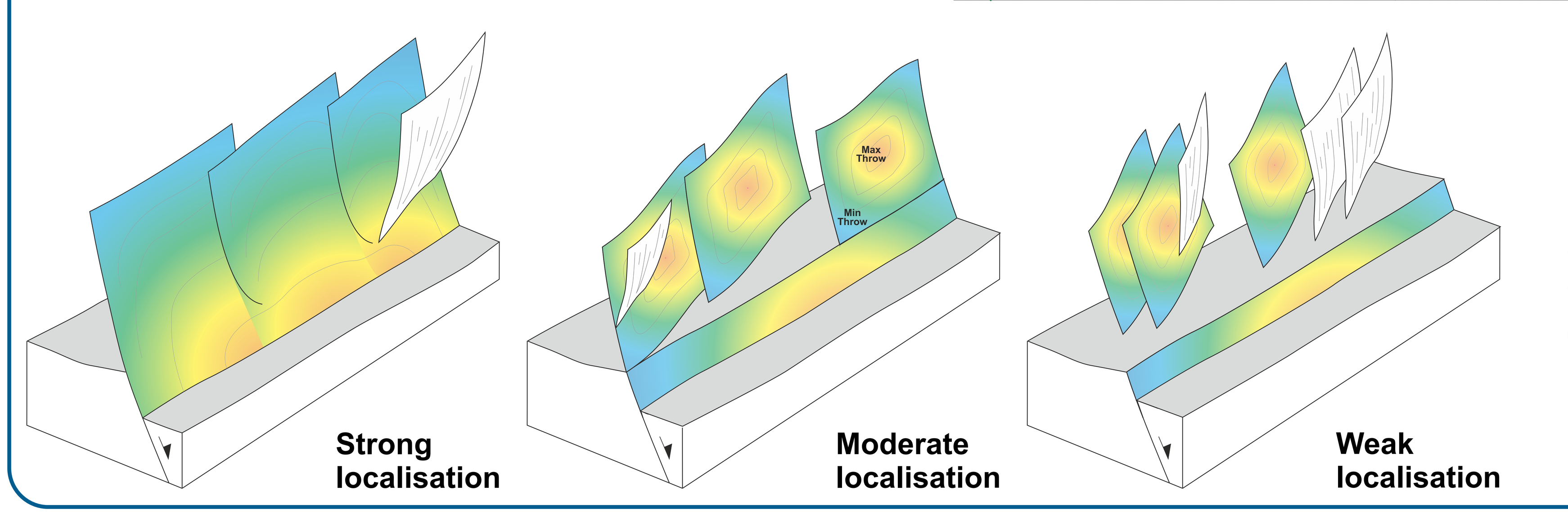
Analysis of the syn- & post-rift faults indicate three types of vertical throw distributions on the faults as shown in green, blue and red (on the right). This indicates different styles of vertical linkages and fault propagation history.

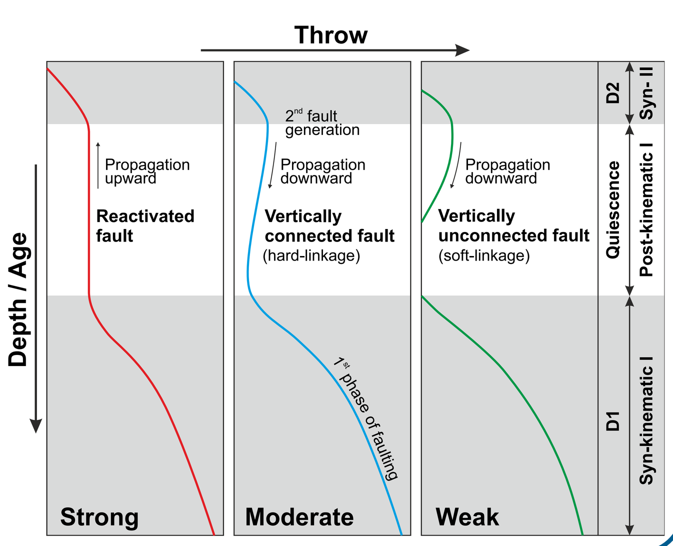
The basin-bounding fault (red) shows a constant throw through the Cretaceous up to Mid Eocene, from where is suddenly drops upward within the growth section. Blue fault has a maximum throw around the Mid Eocene that decreases downward up to the BCU. Throw on the green fault is relatively small and it dies-out at the Base Cenozoic.

Based on the distribution, vertical linkage and throw profiles, the strain localisation (during younger deformation) above pre-existing structures is classified into strong, moderate and weak categories (simplified block diagrams and idealized throw profiles shown below).







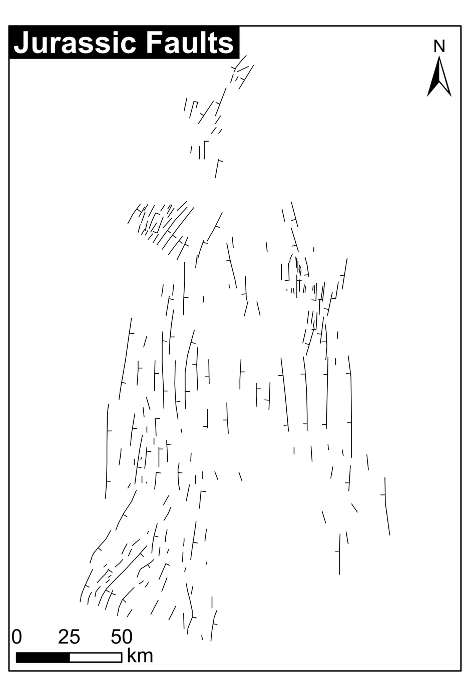


Jurassic & Cenozoic fault traces

Jurassic and Cenozoic faults are mapped on the available 2D and 3D seismic data.

Cenozoic faults density is higher in the northern part as compared to the south.

Cenozoic faults are either focussed along the basin margins or above the underlying 'highs', suggesting strong control of pre-existing structures on their distribution.



Controls on fault reactivation & vertical linkages

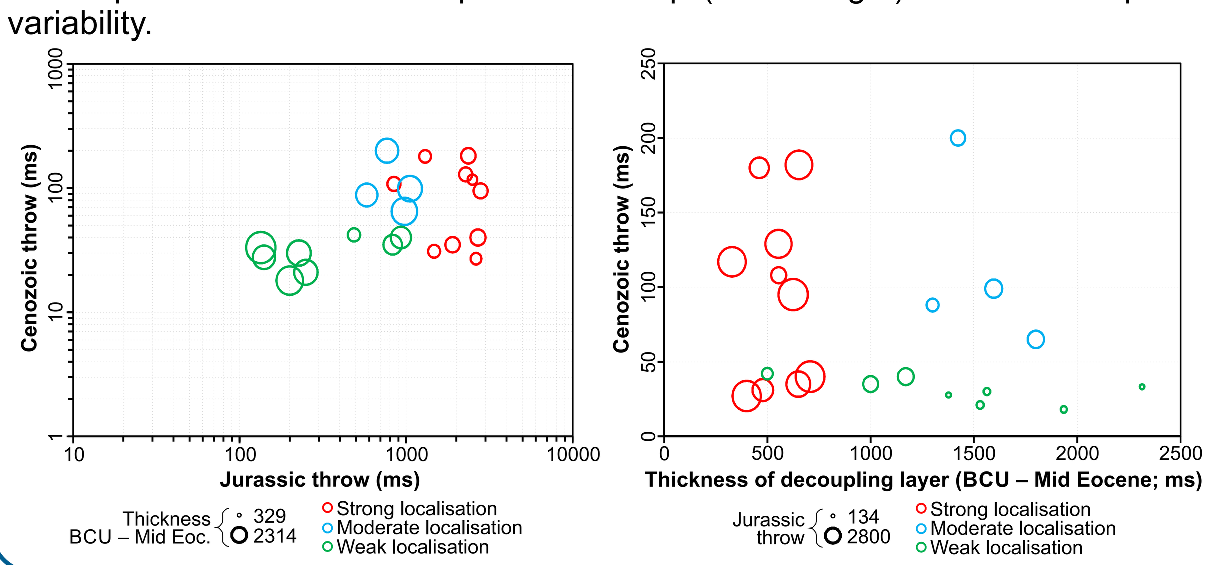
The degree of strain localisation, that relates to fault reactivation and vertical linkages between different generations of faults, is controlled by three main factors:

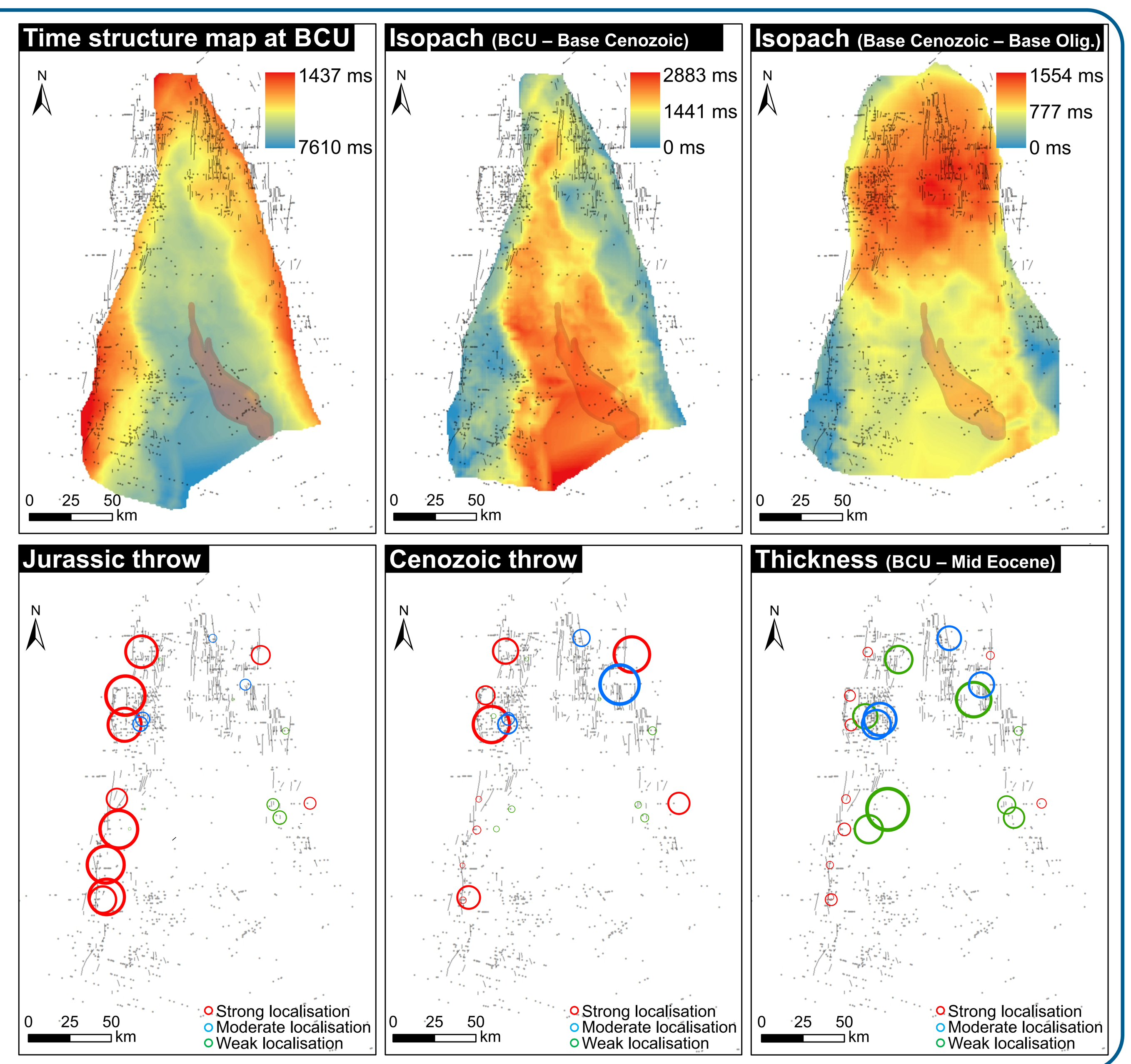
- Fault size (i.e. displacement)
- Thickness and rheology of the intervening layer
- Relative orientation of pre-existing faults and later stretching

Overlay of the Cenozoic faults above the BCU time structure map, and isopachs (BCU – Base Cenozoic; Base Cenozoic – Base Oligocene; on the right) show that the rift topography have strong control on the distribution of younger faults.

Cenozoic throw is plotted against the Jurassic throw and thickness of the decoupling layer (BCU – Mid Eocene; below) showing that strong localisation occur where decoupling layer is <700 ms TWT thick.

These parameters were also plotted on map (bottom right) to see their spatial variability.





Conclusions & future work

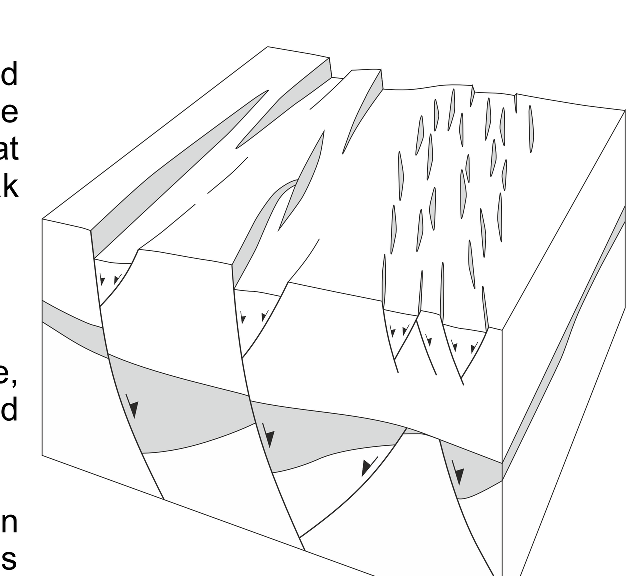
Distribution of the Cenozoic faults is controlled by the pre-existing Jurassic rift structures.

Larger faults (i.e. with higher throw values) are more prone to reactivation. In addition, greater thickness of the decoupling layer lowers the chance of vertical linkage.

Throw profiles indicate reactivated faults, propagation direction and type of vertical linkage (hard vs soft) that define the strong, moderate & weak localisation categories.

Future work includes:

- Relate fault geometry (i.e. fault size, stepping & segmentation) and kinematics to strain localisation
- Improved definition of controls on fault reactivation and linkage modes



References

Petroleum Affairs Division, 2006. Petroleum System Analysis of the Rockall and Porcupine Basins offshore Ireland, Digital Atlas. PAD Special Publication 3/06.
Saqab, M.M., Childs, C., Walsh, J.J., Delogkos, E., 2016. Multiphase deformation history of the Porcupine Basin, offshore west Ireland. Abstracts Volume Atlantic Ireland 2016.
Masson, D.G., Miles, P.R., 1986. Structure and development of Porcupine Seabight sedimentary basin, offshore southwest Ireland. AAPG Bulletin, 70(5), pp.536-548.

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