

# The impact of Cenozoic deformation on potential hydrocarbon traps in Irish offshore basins

Delogkos E.<sup>a</sup>, Walsh J.J.<sup>a, b</sup>, Childs C.<sup>a, b</sup>, Manzocchi T.<sup>a, b</sup> and Saqab M.M.<sup>b</sup>

<sup>a</sup> Fault Analysis Group, School of Earth Sciences, University College Dublin

<sup>b</sup> ICIRAG (Irish Centre for Research in Applied Geosciences), School of Earth Sciences, University College Dublin

## 1. Project Summary - Aim

Hydrocarbons on the NW European continental shelf are often contained within Upper Jurassic traps, though increasingly both structural and stratigraphic traps are being recognised within younger Mesozoic and Cenozoic sequences. Cenozoic deformation may be important in controlling both the geometry and charging of these traps and also in determining the integrity of Jurassic traps. Cenozoic structures formed by reactivation of earlier faults can, therefore, represent either a major risk to hydrocarbon preservation of Jurassic traps or can provide for upward leakage into associated inversion-related closures or overlying stratigraphic traps. However, not all Jurassic faults are reactivated and not all reactivated faults leak. This work aims to provide a better understanding of the mechanisms of fault reactivation and inversion, and an improved basis for the prediction of trap integrity and hydrocarbon preservation potential, on the one hand, and trap formation, on the other.

## 2. Origins of Cenozoic deformation

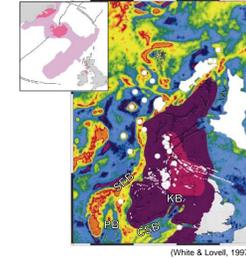
Three deformation events are thought to have controlled Cenozoic deformation in offshore and onshore Ireland.

Widespread igneous activity, manifest as regional dyke swarms, igneous intrusive centres and locally thick sequences of basalt flows, attests to a prolonged period of Icelandic plume-related deformation, and associated uplift, mainly during the Paleocene.

Alpine-related deformation is apparent as regional scale basin inversion, compressional deformation against earlier normal faults, either involving fault reactivation or hanging wall buttressing, and strike-slip faulting.

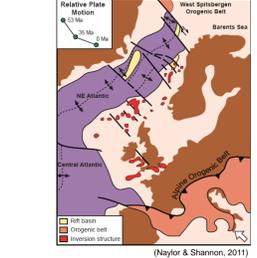
Finally, Atlantic spreading related deformation can be both extensional and linked to Atlantic rifting, or compressional arising from ridge-push related stresses or local plate reorganisation.

1) Icelandic plume activity



(White & Lovell, 1997)

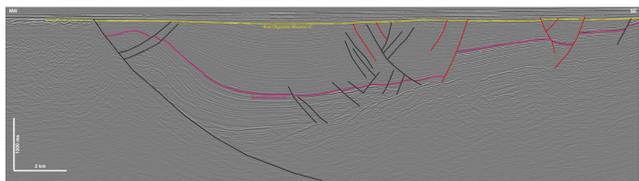
2) Alpine compression & 3) Atlantic spreading



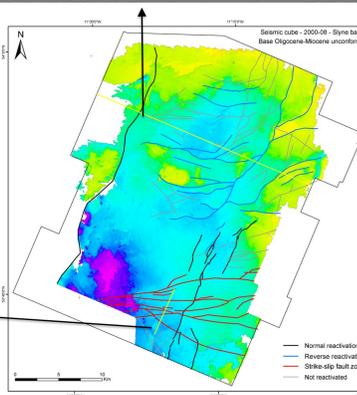
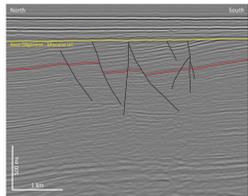
(Naylor & Shannon, 2011)

## 3. Cenozoic deformation offshore Ireland

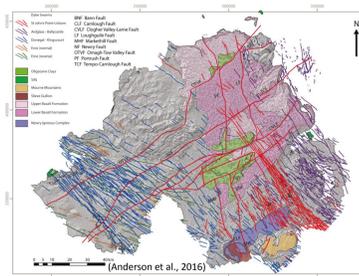
### Slyne Basin



Extensional reactivation of the basin bounding normal fault, reverse reactivation of the intra-basin normal faults (possibly due to the halokinesis), and strong evidence for strike-slip faulting.



### Onshore Ireland

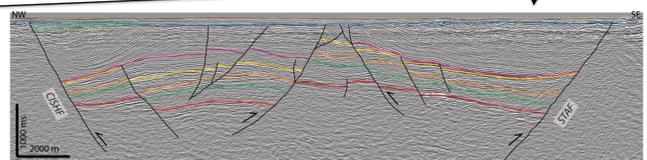
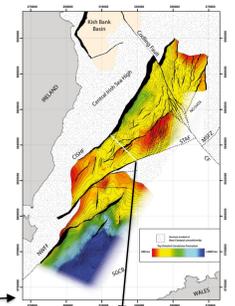


(Anderson et al., 2016)

The Tellus aeromagnetic dataset shows that Tertiary dykes are offset by sinistral strike-slip displacements of up to 2.5km on pre-existing NE-striking Carboniferous normal faults. Together with NNW-striking dextral strike-slip faults (such as the Irish Sea Codling Fault which has ca 7km displacement and leaks hydrocarbon), they form a conjugate fault system arising from N-S Alpine-related compression during the Palaeocene and Neogene. This faulting can be followed laterally through the west of Ireland and into the Slyne Basin.

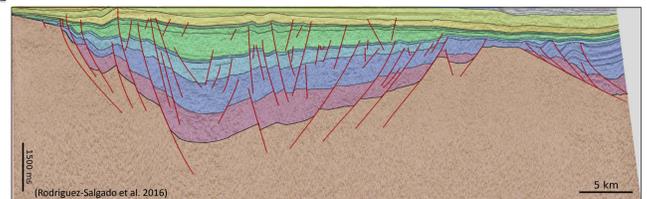
### Central Irish Sea Basin

The Central Irish Sea Basin has a large wavelength inversion-related anticlinal fold, ca 13km wide and up to 2km in amplitude. The anticline is flanked by 2-3km wide hangingwall synclines and anticlines on the Central Irish Sea High (CISHF) and Tudwal's Arch Faults (STAF) (Anderson, 2013).



### Celtic Sea Basin

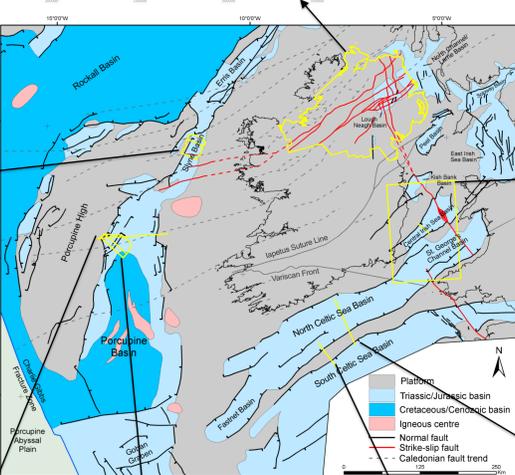
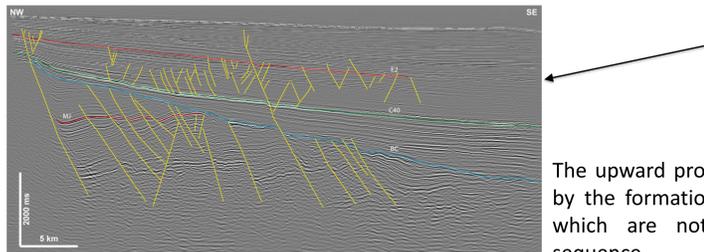
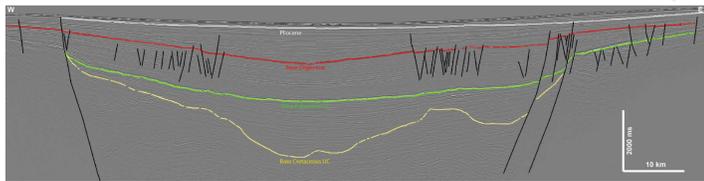
Alpine-related uplift and inversion is widespread in the Celtic Sea. Characterised by basin doming and reverse faulting, which has formed km-scale compressive anticlines.



(Rodríguez-Salgado et al. 2016)

### Porcupine Basin

Kinematic analysis of faults within the Porcupine Basin reveals a period of fault reactivation during the Eocene, in which earlier Jurassic normal faults were subjected to later extension (Worthington and Walsh 2016). Reactivation of faults is accompanied by upward propagation into overlying cover sequences characterised by cross-fault sequence growth during the mid-upper Eocene.

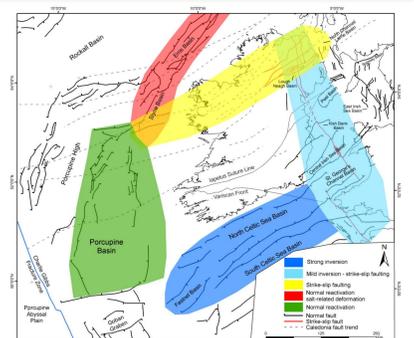


The upward propagation of faults is often characterised by the formation of arrays of fault segments, some of which are not linked through the Tertiary cover sequence.

## 4. Conclusions and future work

In this study, we establish constraints on the geometry, kinematics and spatial distribution of Cenozoic structures in the major basins offshore Ireland. We show how the nature of Cenozoic Alpine-related deformation changes around offshore and onshore Ireland, with strong inversion in the Celtic Sea Basins, milder inversion, strike-slip faulting and plume-related uplift in the Irish Sea and Northern Ireland, which is directly linked to strike-slip faulting extending into the Slyne Basin. Cenozoic sinistral strike-slip movement on pre-existing Carboniferous normal faults, is strongly localised and appears to be related to major Caledonian Terrane Boundaries. In the western offshore basins, no indicators of Alpine deformation are observed, other than very rare strike-slip faults, particularly in the Slyne Basin. Instead, Cenozoic deformation is represented by a Mid Eocene phase of N-S normal faulting, together with broad-scale plume related uplift and localised halokinesis in the Slyne Basin. The boundary between the southern part of the Porcupine Basin and the Cenozoic inversion seen in the Celtic Sea Basins is very sharp and is believed to be defined by pre-existing Variscan structures.

Future work will concentrate on providing quantitative constraints on the nature of Cenozoic deformation, including the potential for hydrocarbon leakage along reactivated faults and the generation of associated anticlinal closures adjacent to inverted faults.



### References

- Anderson, H., Walsh, J.J. and Cooper, M.R., 2016 'Faults, intrusions and flood basalts: the Cenozoic structure of the north of Ireland' in M.E. Young (ed.), *Unearthed: impacts of the Tellus surveys of the north of Ireland*. Dublin. Royal Irish Academy.
- Anderson, H. (2013) The origin and nature of Cenozoic faulting in North-East Ireland and the Irish Sea. Unpublished PhD, University College Dublin
- Naylor, D. & Shannon, P.M. (2011) *Petroleum Geology of Ireland*. Dunedin Academic Press.
- Rodríguez-Salgado, P., Childs, C., Shannon, P., Walsh, J. (2016). Structural analysis of Cenozoic inversion structures in the central part of the North Celtic Sea Basin, offshore Ireland, in: 59th Irish Geological Research meeting.
- White, N. & Lovell, B. (1997) Measuring the pulse of a plume with the sedimentary record. *Nature*, V. 387; p888-890.
- Worthington, R.P. & Walsh, J.J. 2016. Timing, growth and structure of a reactivated basin-bounding fault. In: *The Geometry and Growth of Normal Faults*. (Edited by Childs, C., Holdsworth, R. E., Jackson, C. A.-L., Manzocchi, T., Walsh, J. J. & Yielding, G.). Geological Society of London, Special Publication 439