# A New Deformable Plate Reconstruction of the Irish – Newfoundland Conjugate Margin

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## Summary

The application of a new deformable plate reconstruction method gives us an enhanced understanding of the major controls and mechanisms for basin formation and evolution in offshore Atlantic Ireland and Eastern Canada, which has implications for petroleum exploration in those areas. The new method takes into account the wide range of geological processes responsible for basin development by incorporating seismic, magnetic and geological interpretation with analytical techniques that include 2D or 3D gravity inversion, flexural backstripping and forward modelling. The ability to apply the results of deformable plate modelling to restore pre-breakup geometry represents a major advance over the rigid plate models. The new deformable plate reconstruction method benefits from advances in the fields of kinematic and geodynamic modelling, while making use of all available onshore and offshore geological constraints. Restored structure maps, palaeogeography maps, sediment source area maps, source rock and reservoir facies maps may be reconstructed to their palaeo-position to be used to evaluate source rock and reservoir potential.

## Introduction

In comparison with other continental margins, the North Atlantic deep water basins of Ireland and Eastern Canada are very lightly explored with only a small number of wells drilled. Understanding the tectonic history of the conjugate margins of Newfoundland and Ireland is critical for evaluating their hydrocarbon potential, yet existing plate tectonic models for the North Atlantic are inadequate. In collaboration with a team of leading researchers from academia, government, and industry on both sides of the Atlantic, we are developing a *Kinematic Plate Reconstruction of the North Atlantic between Ireland and Canada* (Ady et al, 2010). The project team includes researchers from Memorial University of Newfoundland (MUN), University College Dublin (UCD), the Dublin Institute of Advanced Studies (DIAS), and the Geological Survey of Canada (GSC), and is due for completion in June 2012.

The project employs a new deformable plate reconstruction method that eliminates many of the inherent short-comings found in rigid plate reconstructions, particularly the problem of plate overlap. Plate overlap is a consequence of extension, yet it can obfuscate the geological relationships critical for basin analysis in deep-water basins (Figure 1). Our new method allows us to accurately remove the effects of pre-breakup extension across conjugate margins thereby providing a means to better evaluate basin formation and evolution. We also take into account the wide range of geological processes responsible for basin development by incorporating seismic, magnetic and geological interpretation with analytical techniques that include 2D or 3D gravity inversion, flexural backstripping, and forward modelling.

The rigid plate kinematics of the North Atlantic Ocean has been well documented and there is general agreement on the general timing of extension and break-up. Extensional deformation started in Triassic times and lasted until the Tertiary, with separation between the Flemish Cap and Galicia Bank occurring in the Early Cretaceous, the Irish – Newfoundland margin opening in the mid-Cretaceous, and Greenland and the Hatton Bank in the early Tertiary. However, there are also several key areas of uncertainty that can be better understood through the development of a deformable plate model, including the effects of large amounts of extension in the Orphan Basin, Rockall Trough and Porcupine Basins where extension factors of 6 or more have been interpreted. The relative movement of the Flemish Cap, Porcupine High and Rockall-Hatton High during the Cretaceous is an example of how geologically constrained deformable plate techniques that incorporate kinematic and dynamic modelling can provide insight that is not available through traditional rigid plate reconstruction methods.

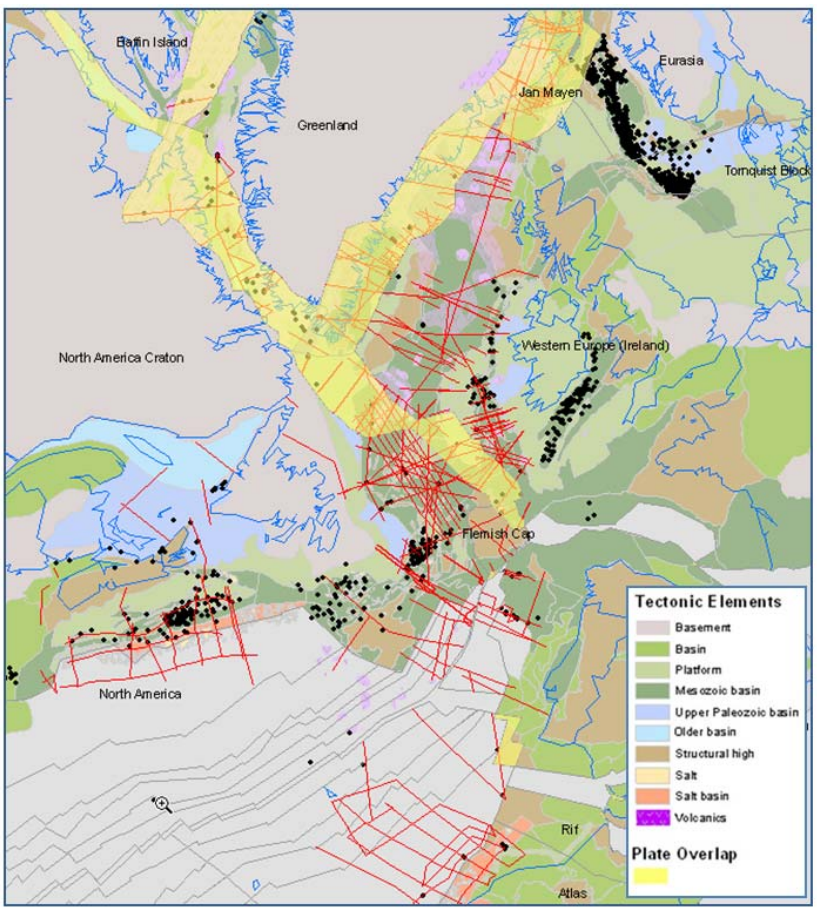


Figure 1: Rigid plate reconstruction of the study area at 120 Ma (Aptian) showing plate overlap, and major tectonic elements (Eurasia fixed plate).

## Methods

A regional seismic grid has been interpreted on each conjugate margin using a combination of high quality deep long-offset industry data, and reflection and refraction seismic profiles from government and academia. Key regional seismic profiles were selected on the conjugate margins for 2D flexural backstripping to establish the timing and amount of pre-breakup extension that has occurred. Selected seismic lines include deep long-offset seismic data on the Irish margin (courtesy of ION-GX Technology) and the Orphan Basin (courtesy of TGS-Nopec). Major tectonostratigraphic sequences defined from seismic interpretations around the margin are mapped to produce isopachs that are used to provide an estimate of the 3D tectonic subsidence for each time interval. The results of gravity inversion studies, flexural backstripping along selected regional profiles and tectonic subsidence calculations are used to determine crustal extension for each time interval for the deformable model.

## Interpretation

To date our seismic interpretation of the Newfoundland-Ireland conjugate margin illustrates that complex and multi-phase deformation related to large-scale plate movements has occurred. Seismic evidence for multiple stage break-up and rifting is seen together with periods of uplift and structural inversion. Gravity inversion results carried out as part of the study support the seismic interpretation indicating very high cumulative extension in basins on both sides of the margin. So far the application of deformable plate techniques using extension factors calculated from these new interpretations has helped to shed light on the apparent rotation of the Flemish Cap away from North America and the high relative movement between the Hatton-Rockall and Porcupine High blocks.

Early results from our study suggest that the relative movement between blocks on either side of the Newfoundland-Ireland conjugate margin can be quite simply explained by the differential extension in the surrounding basins during the Late Jurassic and Early Cretaceous. There is no evidence of significant extension of the Flemish Cap indicating that it is an intact block of continental lithosphere, which for the sake of simplicity has been previously described as acting as a microplate (Srivastava et al, 2000; Sibuet et al, 2007). In the past, similar microplate behaviour has also been proposed for the Hatton-Rockall and Porcupine blocks (Srivastava & Roest, 1989). However, there is no evidence for a plate boundary between the “microplates” on either margin, nor are they regarded as major strike slip boundaries. Our work shows that the removal of differential extension in the Orphan and Jeanne d’Arc basins results in the clockwise rotation of the intact continental lithosphere of the Flemish Cap relative to North America with a vector of movement corresponding to that described by Sibuet et al (2007) from their examination of the geological and geophysical constraints. Similarly, on the Irish margin most extension has occurred in the Porcupine, Rockall and Hatton Basins and inter-basinal highs are seen to be relatively undeformed. This results in large amounts of relative movement between the more rigid blocks that can also be explained by differential intra-plate extension.

## Conclusions

Examples taken from the preliminary work on the new deformable plate model for the North Atlantic demonstrate the advantages of the deformable plate method in basin analysis. The application of the new deformable plate reconstruction methods and integrated interpretations of good quality deep long-offset seismic data from the conjugate margins provides an insight into the development of the southern North Atlantic margin in the area of the Flemish Cap, Orphan Basin and Irish Margin.

The new deformable plate reconstruction method benefits from advances in the fields of kinematic and geodynamic modelling, while making use of all available onshore and offshore geological constraints. The ability to apply the results of deformable plate modelling to data that is vital for oil and gas exploration in order to restore their pre-breakup geometry represents a major advance over the rigid plate models. Restored structure maps, palaeogeography maps, sediment source area maps, source rock and reservoir facies maps may be reconstructed to their palaeo-position to be used to evaluate source rock and reservoir potential. Application of these methods will give us an enhanced understanding of the major controls and mechanisms for basin formation and evolution in offshore Atlantic Ireland and Eastern Canada, which has implications for basin analysis and petroleum exploration in those areas.


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