Style, geometry and characteristics of Cenozoic inversion structures in the central part of the North Celtic Sea basin, offshore Ireland

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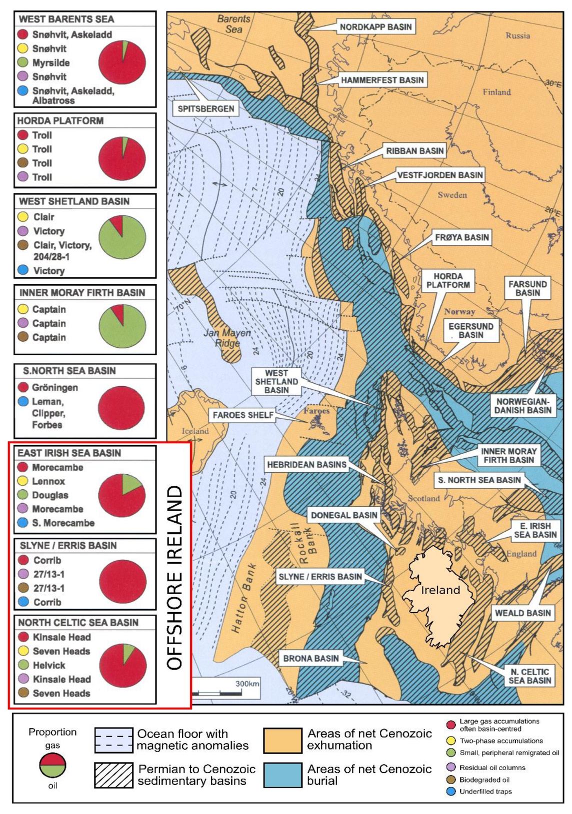


Figure 1. The NW European basins affected by Cenozoic inversion and its effect on the gas/oil ratios of the existing hydrocarbon fields and discoveries. (modified from Doré et al., 2002).

Introduction

Compressional structures developed as a result of Cenozoic inversion are well known along the north-western Atlantic passive margin, (Fig. 1). Despite their significance in the North Atlantic petroleum systems, many details of their mechanisms of formation remain unclear.

In the Celtic Sea, compressional domal structures are widely distributed and provide the structural closure for the main gas fields in the area, Kinsale, Seven Heads and Ballycotton, also including several undeveloped oil accumulations.

The primary aim of this work is to study Cenozoic inversion structures in the central part of North Celtic Sea basin in order to understand the main mechanisms and elements controlling the style of inversion within the study area. This is achieved through seismic interpretation of 2D and 3D seismic surveys provided by the Petroleum Affairs Division (PAD) and 2D palinspatic restoration of several interpreted profiles.

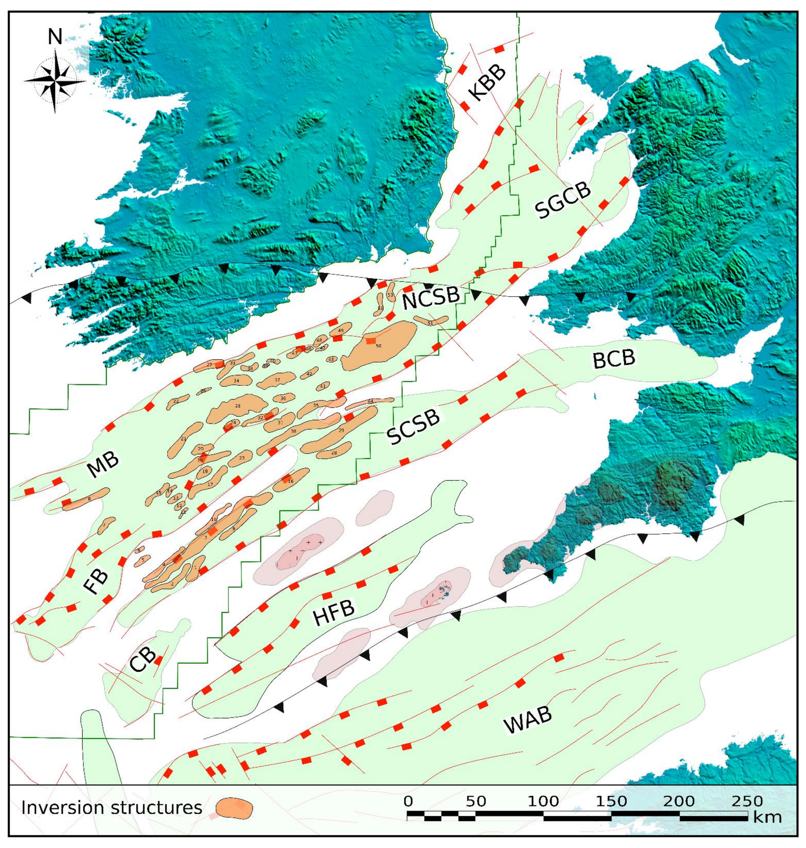


Figure 2. Generalized map of the Celtic Sea basins area highlighting the inversion structures on the study area.

NCSB: North Celtic Sea Basin, SCSB: South Celtic Sea Basin, MB: Mizen Basin, FB: Fastnet Basin, SGCB: Saint George's Channel Basin, BCB: Bristol Channel Basin, CB: Cockburn Basin.

Geological setting

The Celtic Sea basins lie on the continental shelf south of Ireland. They consist of a paired set of ENE-WSW trending elongate basins that extend from St George's Channel Basin to the east to the Fastnet Basin in the west, Naylor and Shannon, 2011, (fig.2).

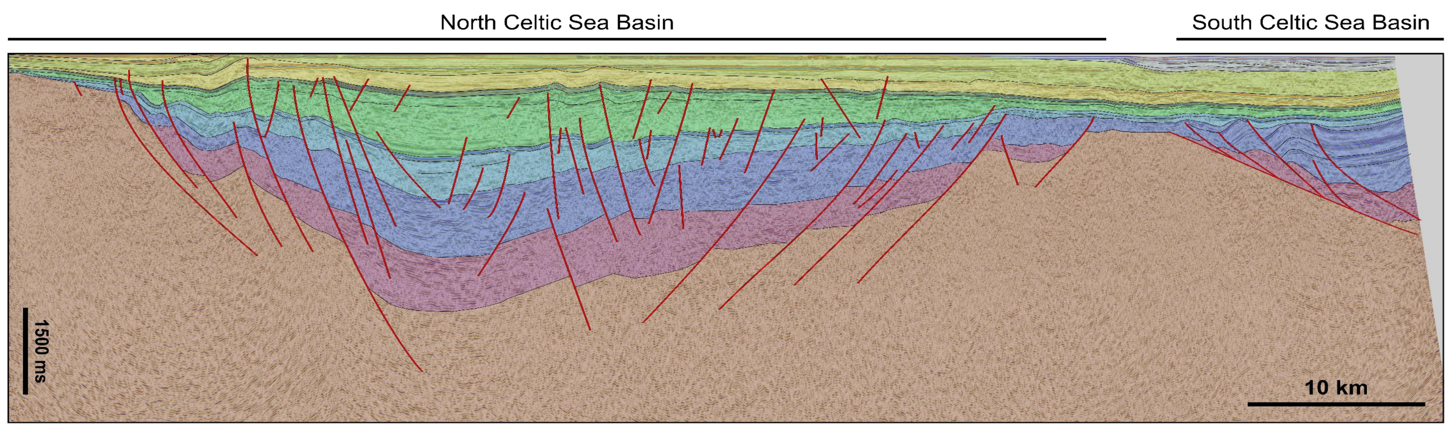


Figure 3. Regional scale seismic section illustrating the contrast in structural styles between the NCSB and SCSB that are separated by a basement high (Pembrokeshire ridge).

The Celtic Sea basins evolved in three phases of Mesozoic rifting (two major extensional phases during the Triassic and Jurassic and one minor phase during the earliest Cretaceous) that ended with an episode of widespread thermal subsidence during the Late Cretaceous. During the Cenozoic several episodes of basin inversion occurred. Inversion-related structures were strongly influenced by Caledonian and Variscan basement structures (Croker and Shannon, 1995), oriented NW – SE and E – W respectively (Figs. 2 and 3)

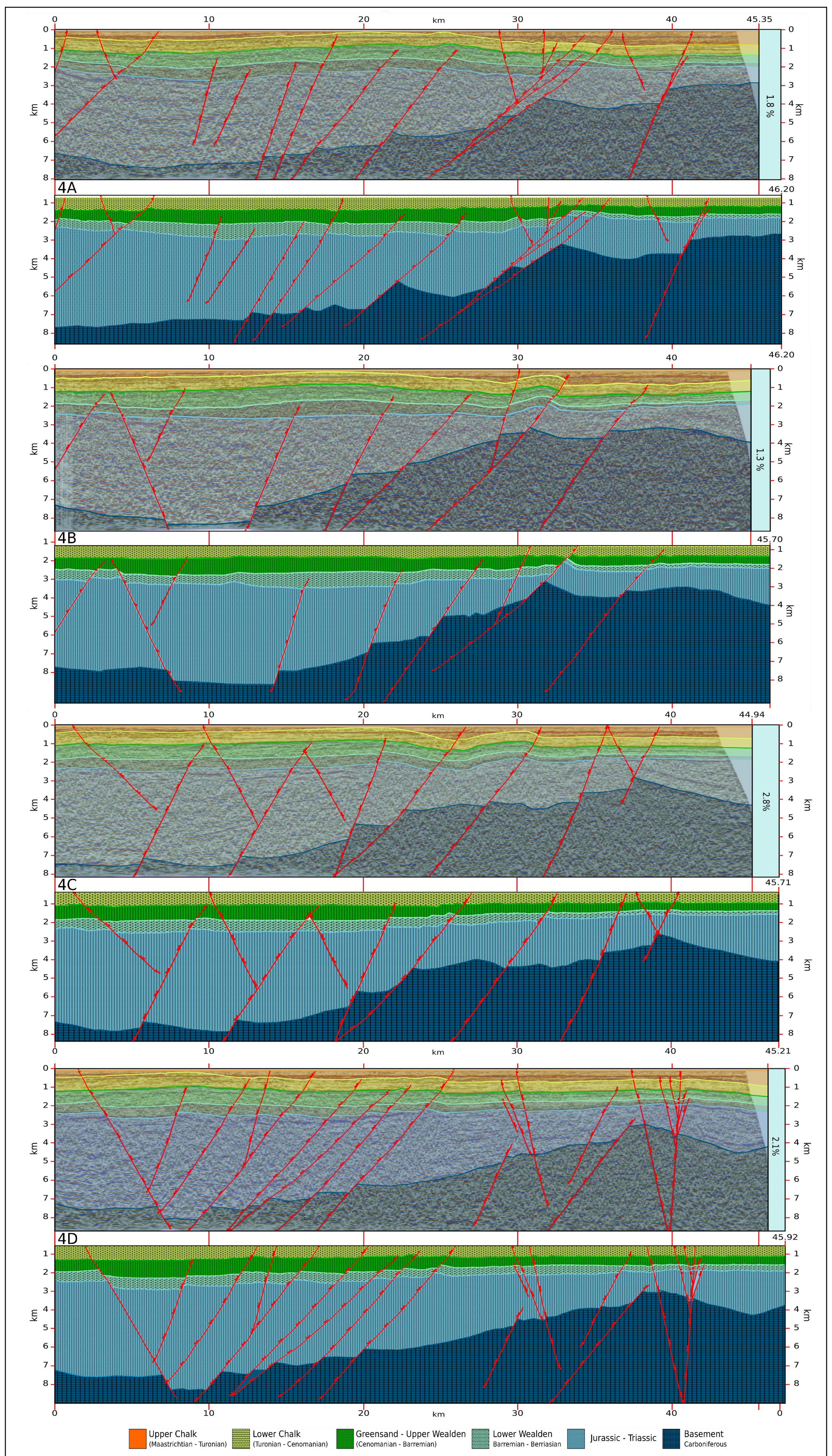
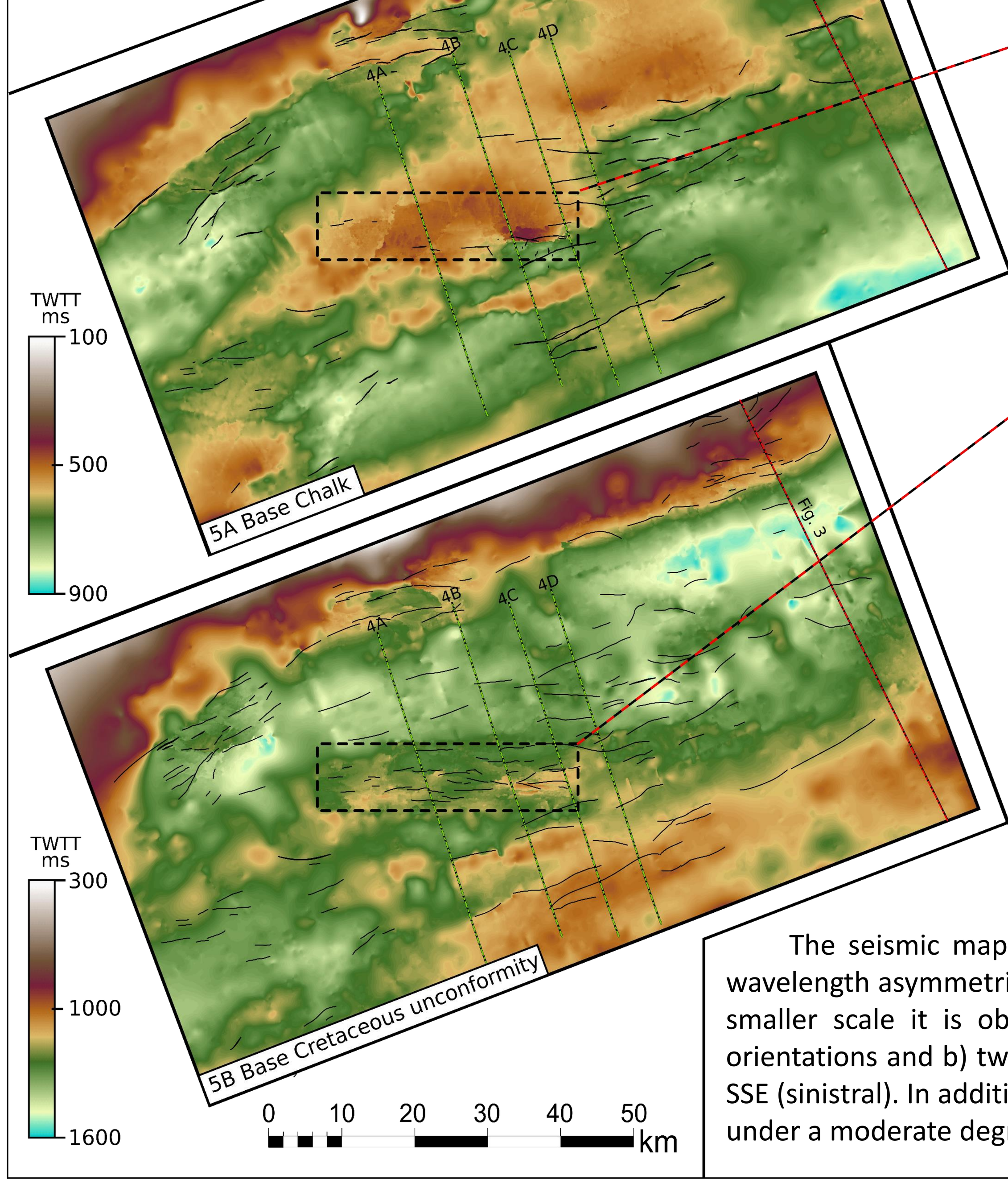
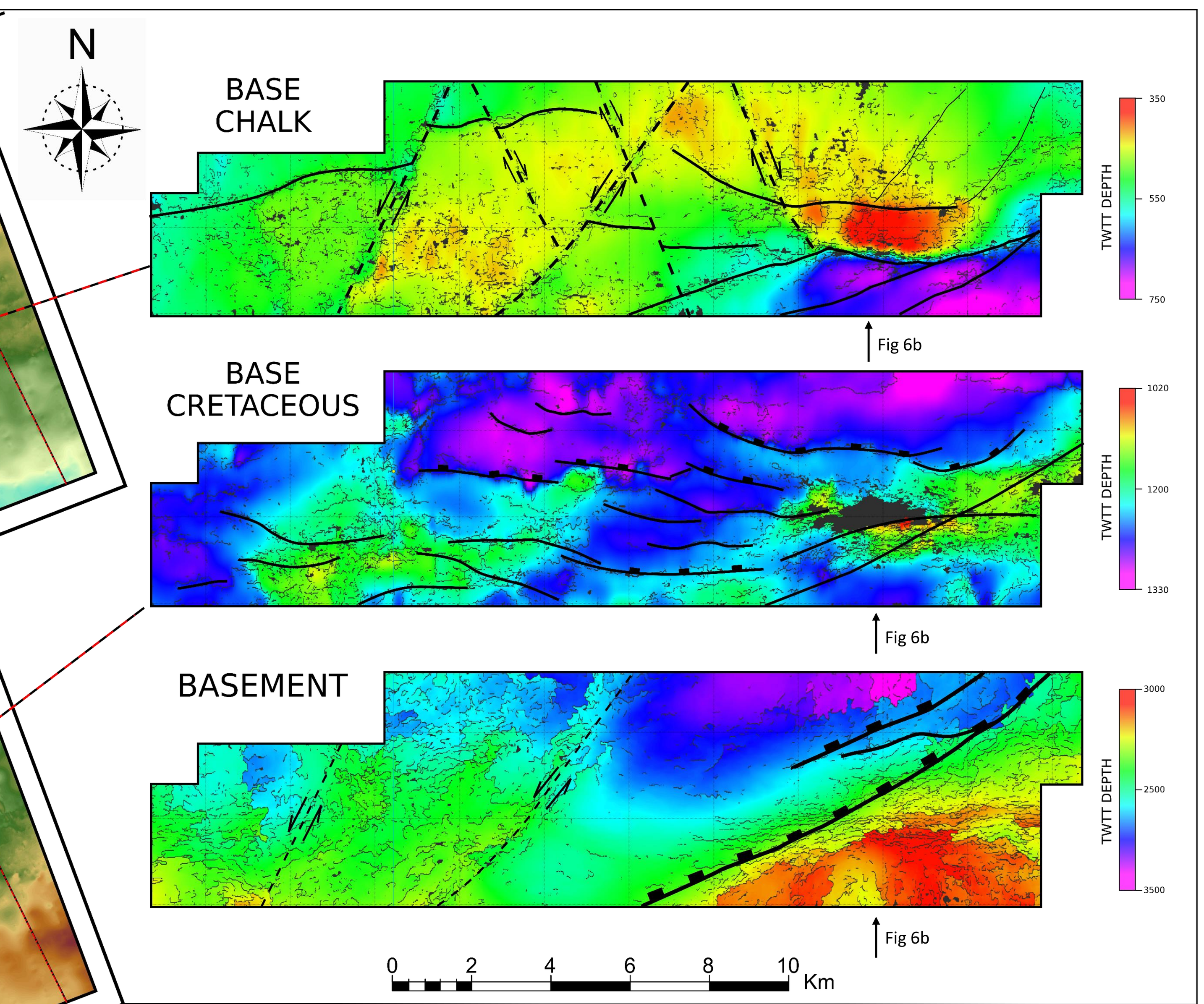


Figure 4. Restored and unrestored seismic interpretations. For location see figure 5.

Figure 5. (Left): regional scale seismic mapping of the Base Chalk and Base Cretaceous horizons showing the main structural trends and inversion structures and **(Right)**: Detailed seismic and structural interpretation of the Base Chalk, Base Cretaceous and top basement horizons





Results

The seismic mapping of three key horizons reveals several inversion structures characterized by long-wavelength asymmetrical anticlines with associated smaller structures of short wavelength (Figs 3, 4 and 5). At smaller scale it is observed a) reversely reactivated normal faults with E – W and NE – SW dominant orientations and b) two sets of strike slip faults with showing orientations of NNE – SSW (dextral) and NNW – SSE (sinistral). In addition, the 2D restoration of four seismic profiles shows that these structures are developed under a moderate degree of shortening (values between 1.3 and 2.8%).

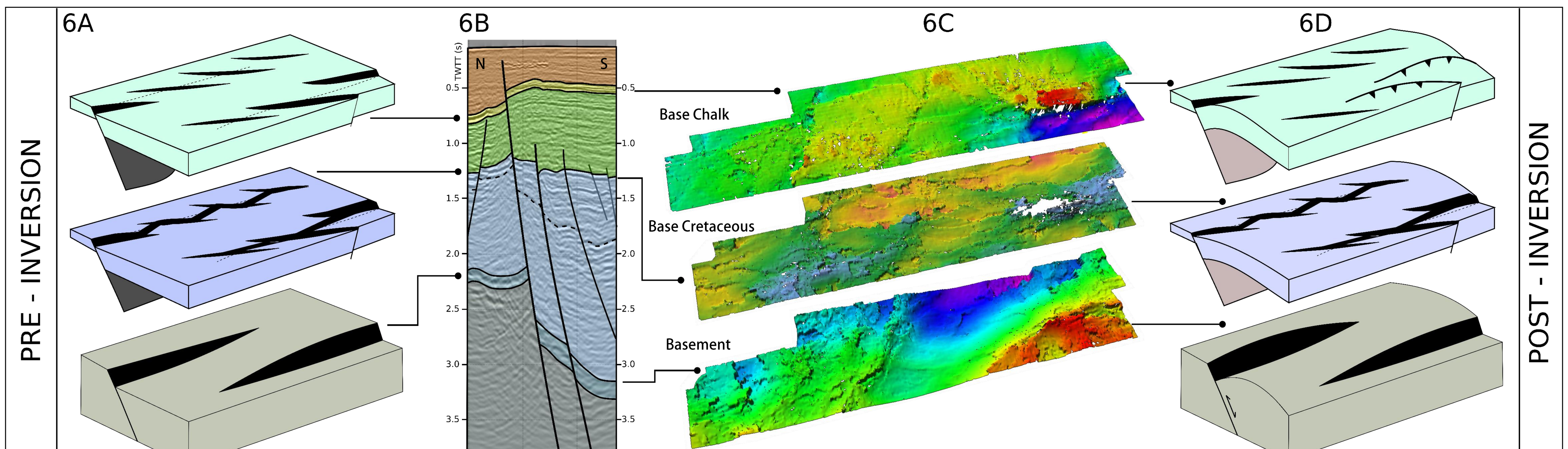


Figure 6. Sketch showing the influence of the pre-existing normal fault orientation on the local styles of inversion

Conclusions

- The inversion structures mapped in the Celtic Sea typically consist of 4-way dipping anticlines of variable size. They are dominantly aligned along two orientations, NNE-SSW and NE-SW following Mesozoic extensional faults that in turn follow Caledonian and Variscan structural trends (Fig. 2).
- The inversion structures located in the Central part of North Celtic Sea Basin are characterised by:
  - ❖ Low relief and long-wavelength asymmetrical anticlines.
  - ❖ Located in areas containing thick Mesozoic cover, preferentially aligned with North Celtic Sea Basin depocentre (Fig. 2).
  - ❖ Their location coincides with pre-existing grabens and local structural highs (Figs. 3 and 4).
  - ❖ Typically bounded by Cretaceous and Jurassic normal faults.
- The main mechanism of inversion is long wave-length folding whereas reverse reactivation of normal faults and strike slip faulting controls locally the style of inversion and increases the asymmetry of the observed structures (Fig. 5).
- The structural framework previous to the Cenozoic tectonic inversion plays a key role at the time of defining the size, geometry and orientation of the inversion structures. Whereas Triassic to Jurassic normal faults are dominantly NE – SW oriented, during the Cretaceous, these faults are reactivated with a dominant E – W orientation (Fig. 5 and 6).
- The oblique reactivation of the Cretaceous normal faults increases the degree of segmentation. This favours that the E – W oriented faults are locally inverted generating pop-up structures. In contrast, NE – SW oriented faults tend to act as rigid buttresses. In other cases, the inversion of the normal faults is not enough to achieve a net reverse offset.

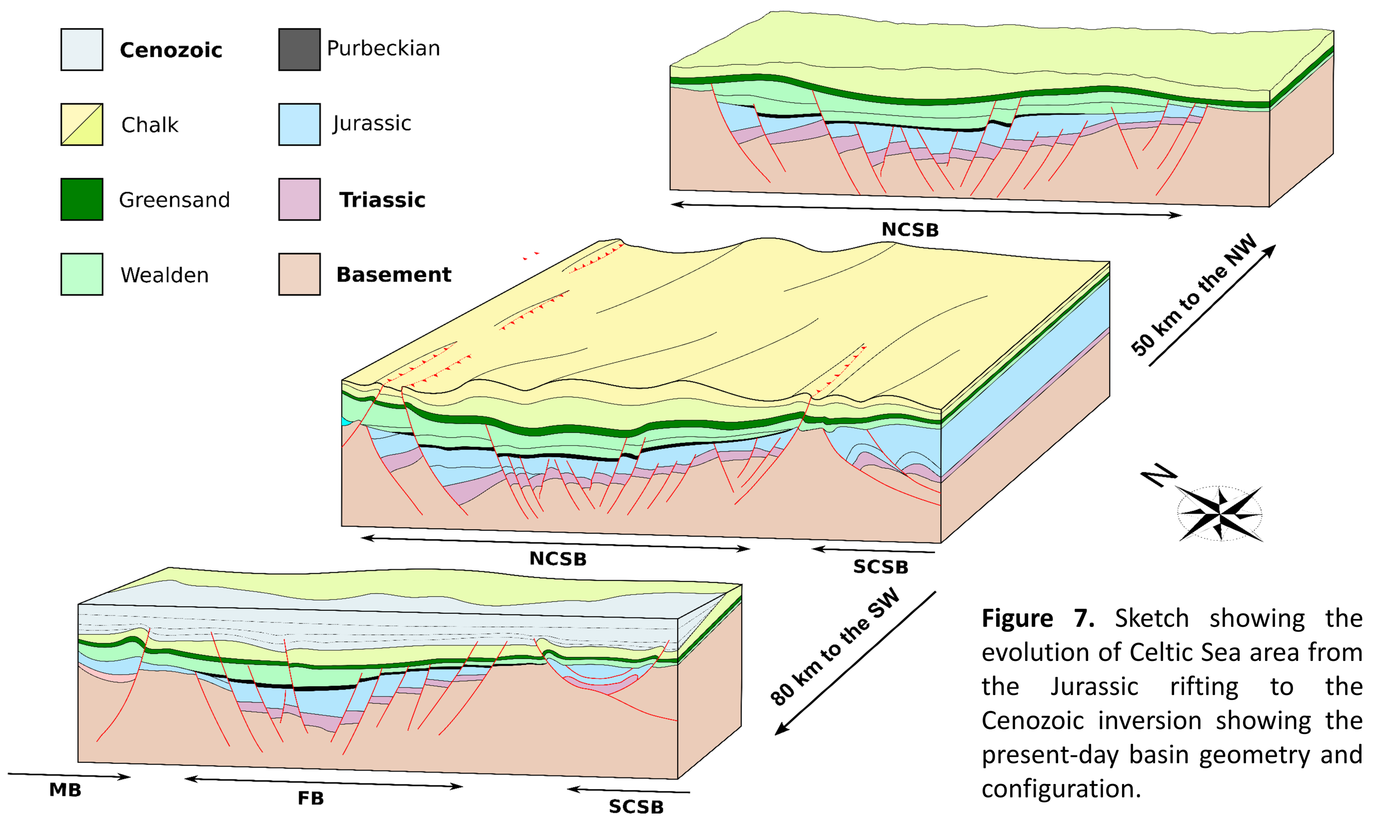


Figure 7. Sketch showing the evolution of Celtic Sea area from the Jurassic rifting to the Cenozoic inversion showing the present-day basin geometry and configuration.

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This publication has emanated from research supported in part by a research grant from Science Foundation Ireland (SFI) under Grant Number 13/RC/2092 and co-funded under the European Regional Development Fund and by PIPCO RSG and its member companies.

We gratefully acknowledge the Petroleum Affairs Division (PAD) of the Department of Communications, Climate Action and Environment (DCCAE) for providing the data used in this project and the permission to show the seismic profiles. We also thank the Petroleum Infrastructure Programme (PIP) for co-funding this research.