Structure of the Inner Bristol Channel and Severn Estuary: regional mapping and seismic interpretation yield a refined model for mountain front deformation and inversion

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1. Introduction

Decades of work has been completed on the geology of the inner Bristol Channel and the Severn Estuary, yet there are few structural geological models that correctly portray their regional framework. Many charts in the published literature depict incorrectly the position, strike and structural effects of the Variscan deformation front and the type of mountain front geometry across South Wales. Thus, we attempt here to correlate legacy seismic data with detailed coastal outcrop at the appropriate scale and detail to present a refined model of the Variscan thrust fold belt. Geological mapping of coastal outcrops, in conjunction with the crustal scale seismic data of BIRPS, SWAT and LISPB, presents an opportunity to combine such well studied data sets with even more mature information on wide angle seismic reflection, seismic refraction and regional reflection records to justify the repositioning of the deformation front and to explain the geometry and history of its foreland.

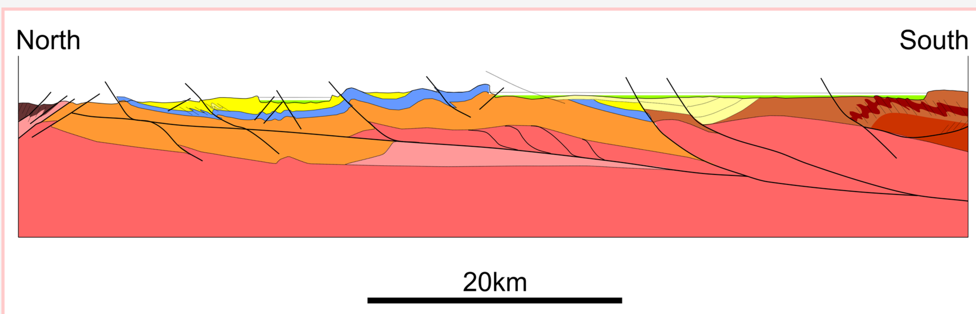
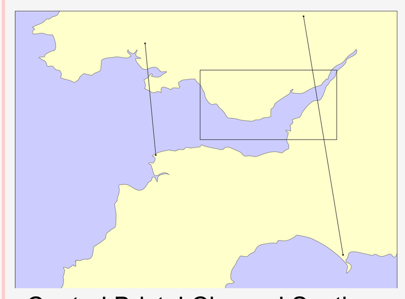
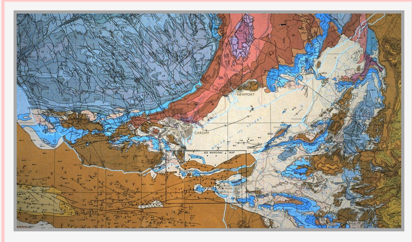


Figure 1: A geological section from north Devon to South Wales showing the position of the cleavage front, the Mesozoic Bristol Channel Basin, Gower and South Wales Coalfield affected by Variscan thrusts, folds and disturbances and the southern margin of the deformed Welsh Basin. Vertical scale = Horizontal scale. Pc Pink; Devonian Brown and Orange; Carboniferous Blue and Yellow; Mesozoic Cream; Recent Green; Welsh Basin Plzc Dark Brown. Thin black lines are major faults.

2. The Correlation of Structural and Geophysical Data



Central Bristol Channel Section (left) and LISPB Section (right).



Extract from the 1988 British Geological Survey map (original scale 1:250,000) of the inner Bristol Channel and Severn Estuary illustrating Silurian to Recent geological units.

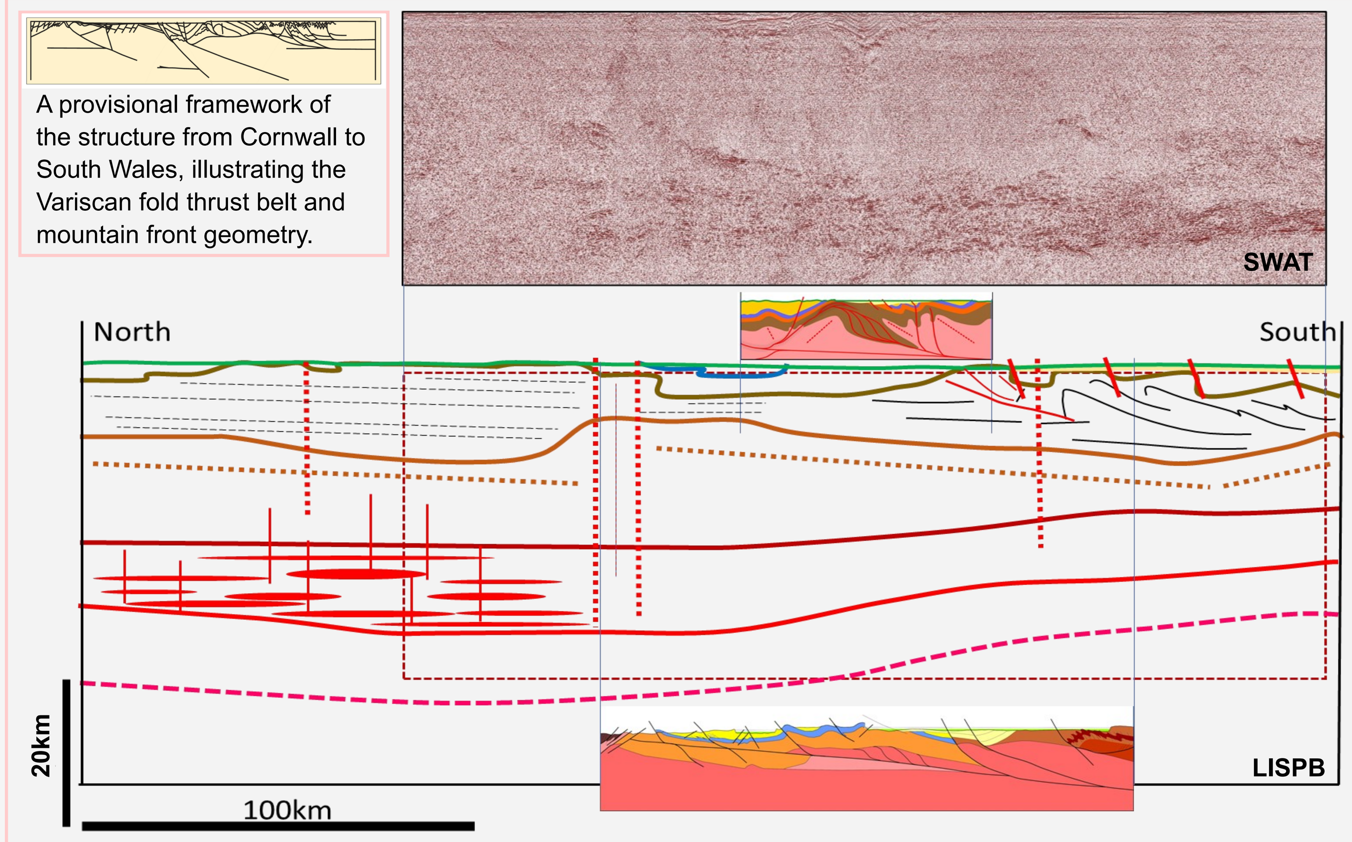
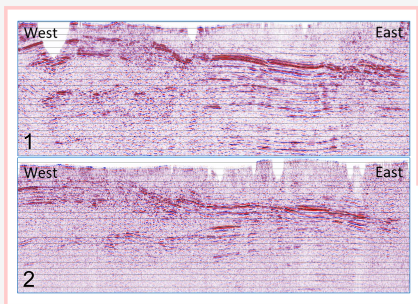


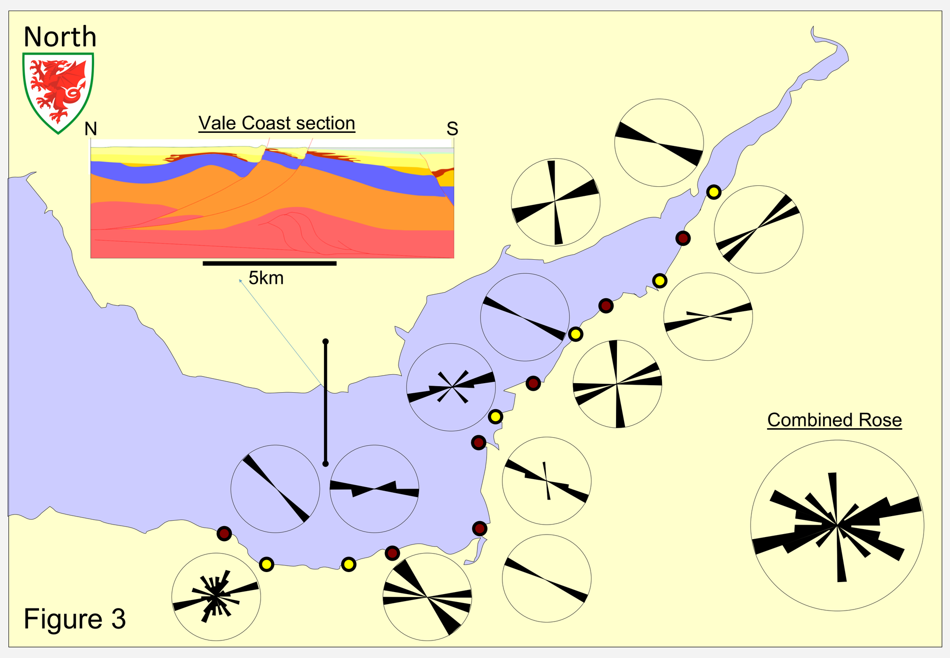
Figure 2: An extract from SWAT data lines 2 and 3 correlated directly to an interpretation of LISPB data and geological sections across the Bristol Channel (Figure 1) and the Severn Estuary from Newport West to the Bristol District East (Figure 5). It is a direct comparison of crustal scale seismic data with sections constructed from regional geological maps. Key reference: Maguire *et al*, 2011.

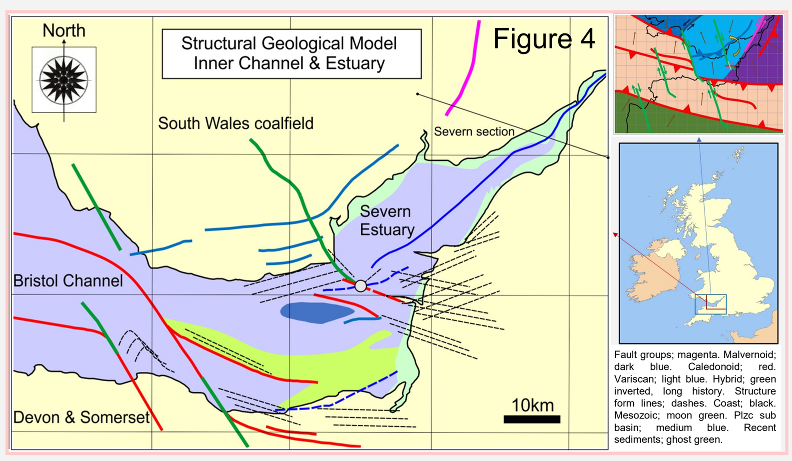


Online geophysical library sections (1) and (2) on-land across the Newport district, adjacent to the Severn Estuary. The reflection sections image the Silurian Wenlock series and a major sub-Silurian structure (thrust fault) that reaches the surface as a normal fault due to negative inversion, (accessed, November 2020). The sections also image a confrontation of geological structure from eastward verging thrusts and folds associated with the east crop of the South Wales coal basin and westward verging thrusts and folds linked to the Severn Estuary Fault Zone.

3. Methodology

Several hundred structural lineaments and planes were measured along the coastline of the English side of the Inner Bristol Channel and the Severn Estuary. The predominant orientation is ENE WSW, unlike the Central Bristol Channel which is WNW. ESE.





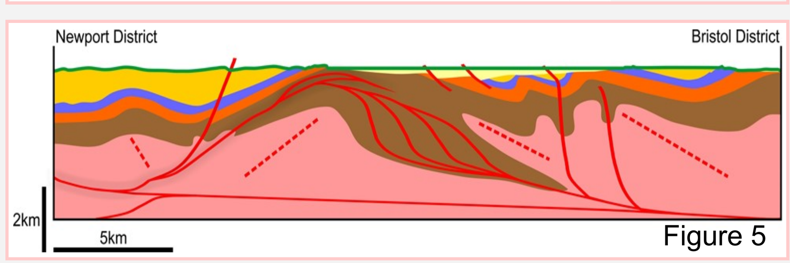


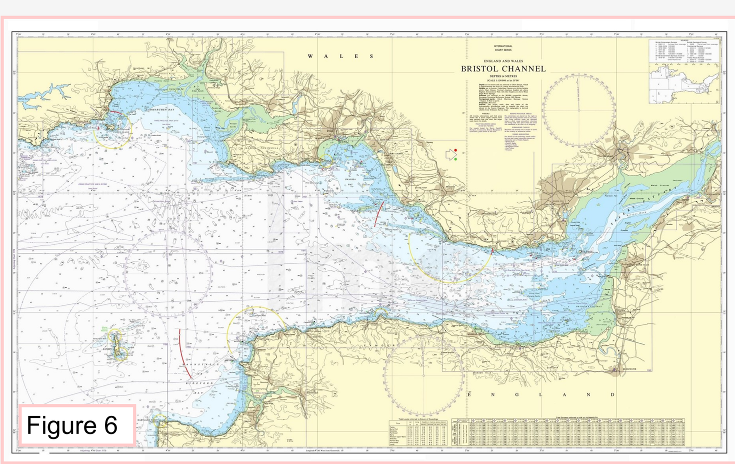
Figure 3: Rose diagrams give rise to:

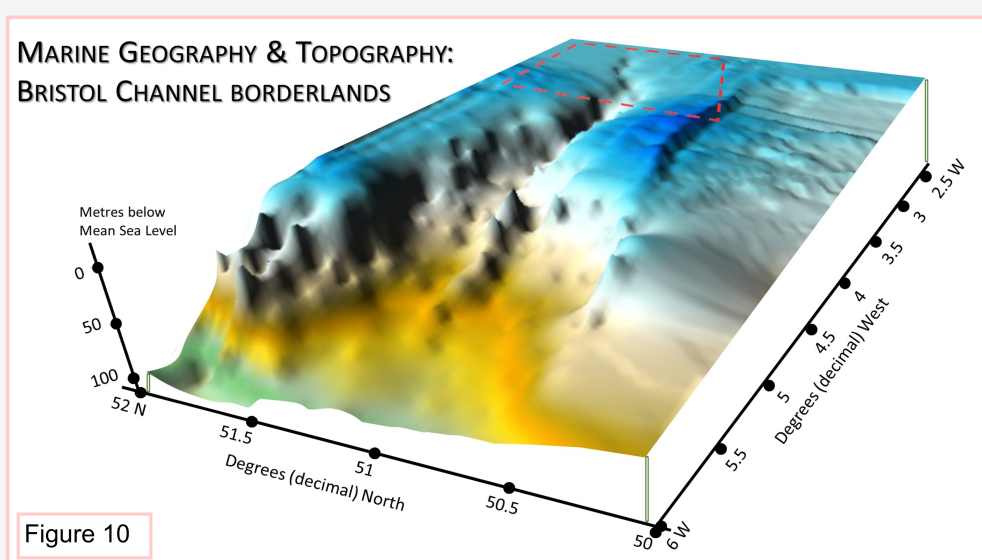
Figure 4: the structural geological model of the Inner Bristol Channel and Severn Estuary. The inset shows the tectonic partitions based on the orientations and geometry of structures as well as striation analysis of the orientation of palaeo-stresses from inverted faults outcropping along the coastlines of SE Wales and the west of England.

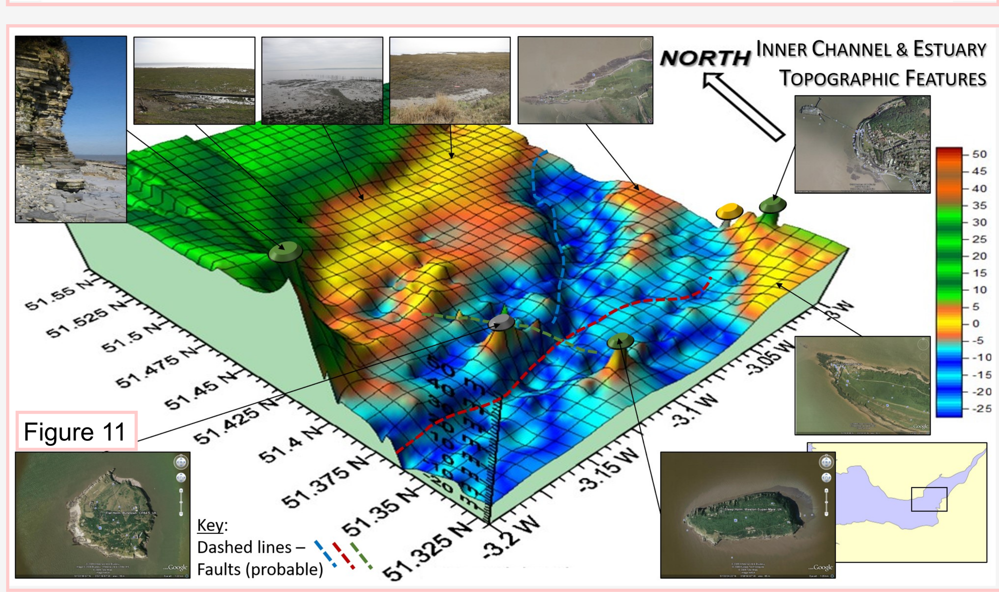
Figure 5: the structural section gives an interpretation of the mountain front geometry, beneath the Severn Estuary.

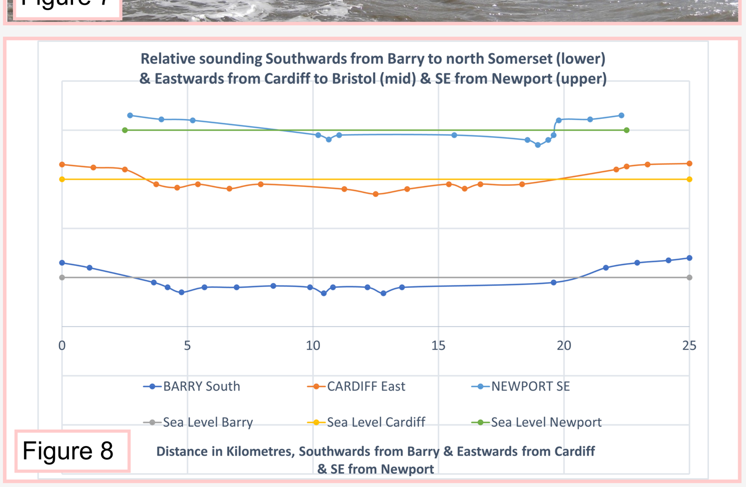
4. Marine Geogeographic Evidence for the Position of Major Lineaments

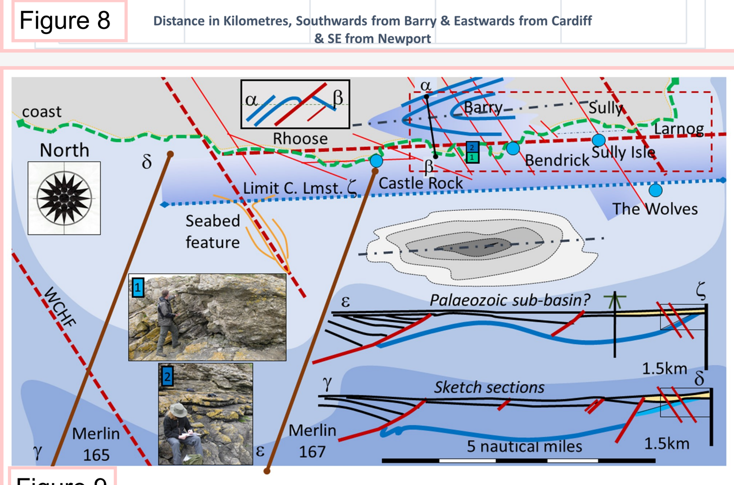
Much information can be gathered from the Marine Geography and Hydrography of the Severn Estuary. Special use of Admiralty charts 1152 and of the inner Channel Figure 6, yields chart soundings to the nearest 10cm in the immensely tidal waters of the Bristol Channel Figure 7. Profiles of seabed across the estuary Figure 8 illustrate the position of physical lineaments exploited by marine traffic as navigable routes to ports on the Welsh and English sides. Many seabed features align with geological structure Figure 9, both locally and on the grander scale Figure 10. The most striking result is illustrated by the 3D reconstruction in Figure 11, with photographs attached of land marks within and around the estuary. There is a crucial confluence of three discrete trends of lineament converging at Flat Holm and represent the pristine Variscan WNW, the Caledonoid NE and long-lived Cross Fault NNW trends. This isle's position is illustrated on the provisional tectonic sub-terrane model Figure 12, within the hybrid terrane (blue) that underlies the Vale of Glamorgan, Cardiff County and SE Wales.

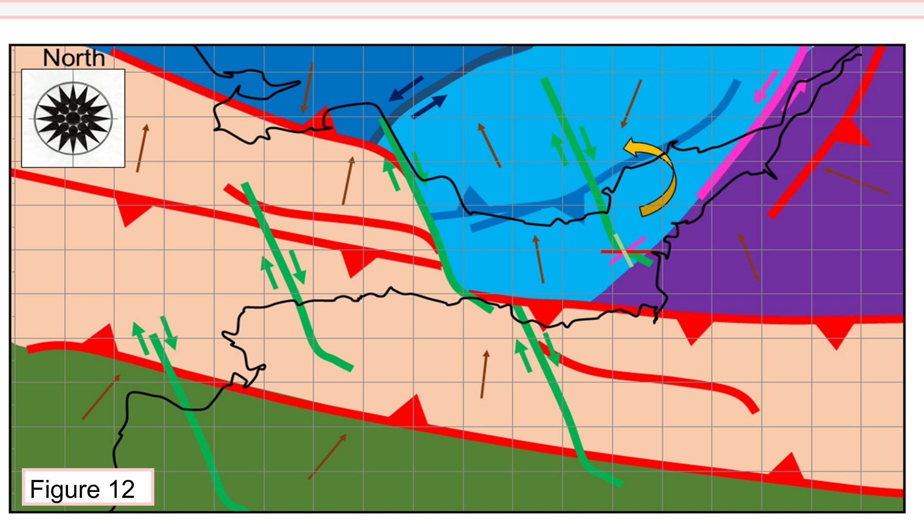












Refined Tectonic Model – Inner Bristol Channel & Severn Estuary

Figure 6: Admiralty Chart illustrating soundings, hydrography and obvious change of trend from ENE inner channel to NE estuary.

Figure 7: Flooding tide in the inner channel, along coastal outcrops.

Figure 8: Navigable channels to Barry, Newport and Bristol positioned above marine geographic lineaments.

Figure 9: Local correlation of seabed features with geological structures (schematic) with photographs of local outcrop.

Figure 10: Perspective 3D view of the Bristol Channel, Severn Estuary and the Borderlands illustrating the geological control on marine geography.

Figure 11: Perspective 3D view of the confluence of three structural trends at Flat Holm. Variscan, Caledonoid-Malvernoid and 'Cross Fault'.

Figure 12: Tectonic sub-terranes, Culmian Green, Pristine Variscan Pink, Caledonoid Blue, Hybrid rotation and decapitation Light Blue and Malvernoid Purple.

5. The Negative Inversion of the Foreland in South Wales UK

Veneers of Triassic and Jurassic strata unconformably above folded and faulted Variscan basement are preserved in part closest to negatively inverted faults. Ancient WNW frontal ramps, NNW and NW oblique & lateral ramps and NE disturbances with significant thrust displacements have decametre scale normal displacements due to at least two late phases of normal faulting. In order to reconstruct the orientation of lineaments within the basement, the effects of the inversion must be restored. The Figures 13-16 below illustrate the type of sequences and the style of faulting evident along the coastline of the inner channel & estuary. Additional to late extension are evidences for growth and rapid facies transitions from marginal to distal.

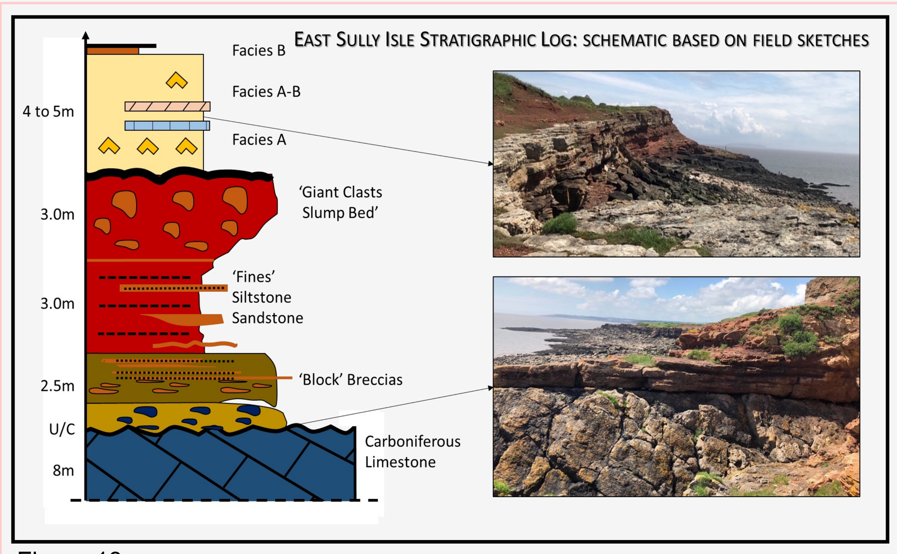


Figure 13

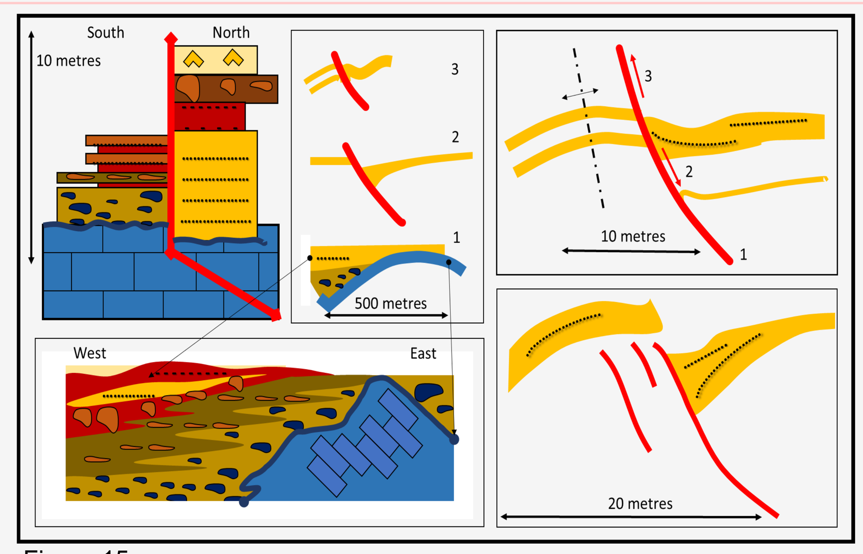
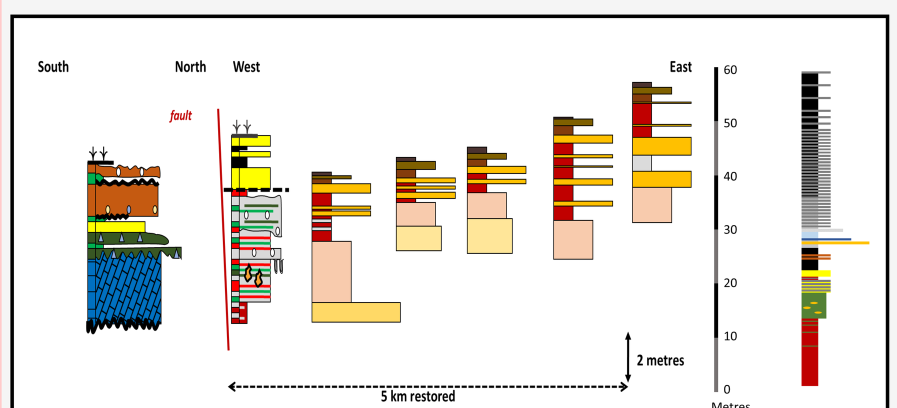


Figure 15



Column far left Carboniferous Limestone overlain unconformably by Triassic Whitmore Breccias. Column second to left Red Marls and Blue Anchor Formation. Five columns to the east over a distance of 5km consist of facies A-D of the beds of Sully Bay. Column far right complete sequence from Triassic red marls to the Blue Lias of Lavernock Bay. Left to right is marginal to distal facies.

Figure 14

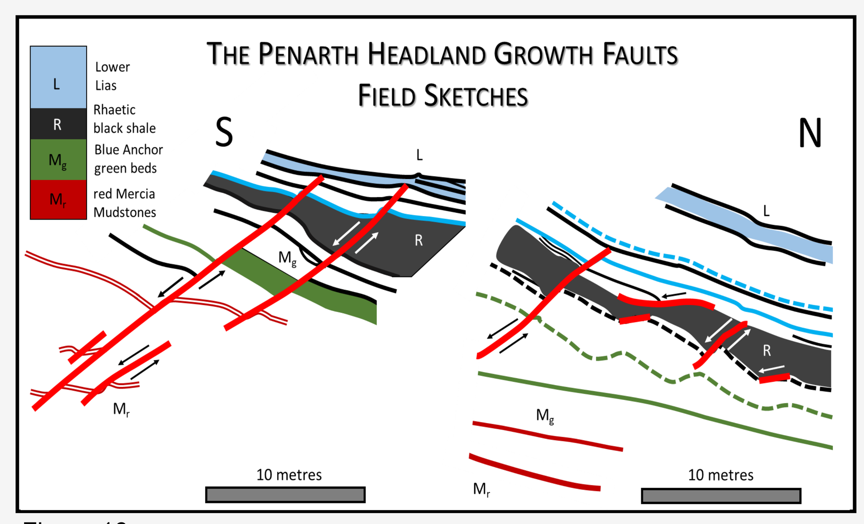


Figure 16

6. Discussion & Development

An overview of data combined from various maps and charts, outcrop and generations of geophysical exploration permits a different interpretation of the geological structure through construction of new and useful geological sections from the local scale to regional and crustal scales. The refined sections and tectonic subdivision of the South Wales foreland has illuminated the geometry evident from the crustal scale geophysics as well as the evolution of faults and basins contained therein.

The most striking discovery of this present work is the new hybrid sub terrane that has characteristics of Variscan and Caledonoid trending faults. The conclusion is one of clockwise rotation of a major thrust trajectory and the reactivation of deeper lineaments. This is followed by structural decapitation once the main thrust faulting event had encroached South Wales, during the late stages of the Variscan Orogeny. This change in trend is not only present in time structures of basement faults, but also inherited by the Mesozoic veneer Figure 17, that records the negative inversion of the Variscan thrust faults.

Further, close examination of the late fault history is now required to restore Palaeozoic trends without Mesozoic displacement. This facilitates a better understanding of the nature and magnitude of the rotation within the foreland. Figure 18 shows an example of a post-Palaeozoic fault at Lavernock Bay with a long history, which would have caused such rotation.

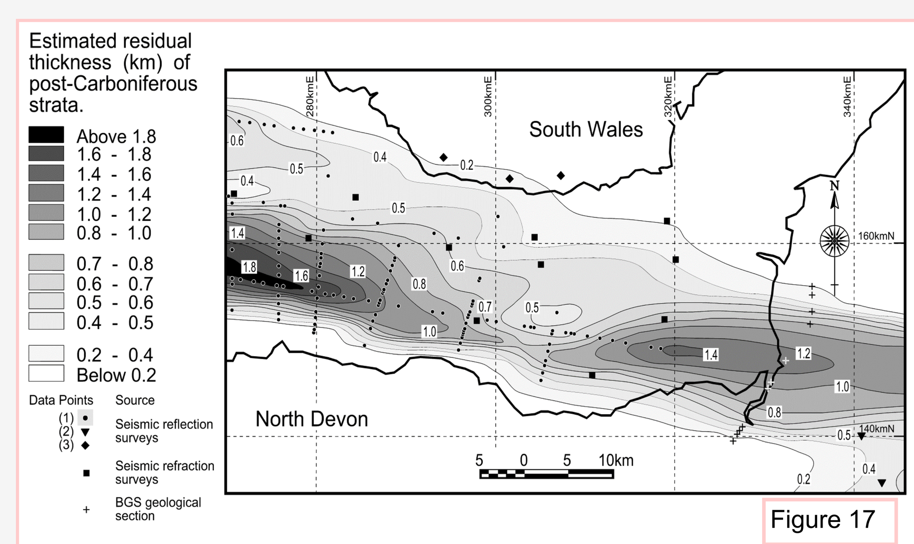


Figure 17

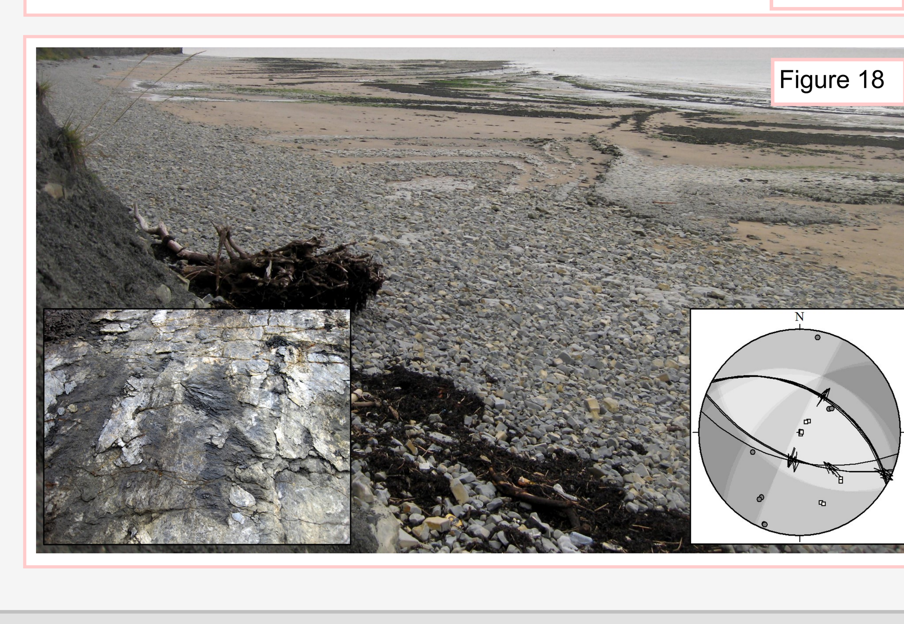


Figure 18

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