# Fault Geometry and Deformation History, Northern Carnarvon Basin

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## SUMMARY

The Carnarvon Basin has experienced three distinct phases of extension – in the Carboniferous-Permian, in the Upper Triassic to Middle Jurassic and in the Lower Cretaceous. Detailed mapping of fault patterns associated with each event is possible at a regional scale using widespread, publically available 3D seismic data sets.

The complex interaction between NNE and NE-SW oriented Carboniferous and Permian age faults provides the structural framework for subsequent rift events. Both sets of faults show evidence of oblique reactivation under a WNW oriented extensional regime in the Jurassic, somewhat at odds with the general perception of NW oriented extension associated with separation of Argoland from the NW shelf at this time.

Lower Cretaceous extension is much shorter lived, is primarily confined to the SW part of the Northern Carnarvon Basin and is associated with significant uplift and erosion. The relationship of this event to the separation of Greater India from Australia is less clear, but a proposed mantle plume goes some way to addressing some of the observed structural and stratigraphic relationships.

**Key words:** Northern Carnarvon Basin, extensional faulting, fault reactivation

## INTRODUCTION

The North West Shelf of Australia forms an unusual passive margin. Rather than being the result of a single, intra-continental rift event, it has always been located close to a continental margin and its tectonic evolution is characterised by the progressive rifting of continental ribbons from that margin. Although the timing, orientation and distribution of individual rift events is variable along the margin, in the Northern Carnarvon Basin at least it is possible to recognise three distinct episodes (Etheridge and O'Brien, 1994; Hill, 1994; Longley et al., 2002). A protracted period of rifting, which may have initiated in the Devonian, culminated in the Permian and resulted in extreme thinning of the crust, particularly in the region of the Exmouth Plateau. Most of the Triassic represents a post-rift sequence, but a second phase of extension was initiated in the uppermost Triassic and culminated in the early Oxfordian, broadly co-incident with the separation of Argoland, and the formation of oceanic crust in the Argo Abyssal Plain. Upper Jurassic and lowermost Cretaceous sediments again represent post-rift deposition, but a third phase of extension, essentially confined to the Exmouth sub-basin, occurred immediately prior to the formation of the Valanginian Unconformity, associated with the separation of Greater India from Australia.

In this paper was use detailed mapping of fault patterns from 2D and 3D seismic data sets covering large parts of the basin to establish the way in which the faults formed in the successive events interact with one another, the kinematics of fault propagation, the associated development of extensional fault propagation folds, the style of the individual extensional events and their relationship to the tectonic events described above.

## PALAEOZOIC EXTENSION

Initial Upper Palaeozoic extension is characterised by a series of N to NW trending basins best exposed onshore (the Merlinleigh Sub-Basin of the Southern Carnarvon Basin and the Fitzroy Trough in the Canning Basin) and on the southern flank of the Northern Carnarvon Basin (Scholl Island Fault; Figure, 1; Mory et al., 2003). Lower Palaeozoic sediments are preserved in some parts of these basins, but stratigraphic relationships suggest that fault activity had ceased by the Upper Permian (Figure 1; Lasky et al., 2002). A separate NE-SW trending basin bounding fault (the Mermaid Fault) appears to be younger, and has a distinct unconformity separating Permian and Triassic sequences, suggesting a change in stress orientation between Devonian-Carboniferous and Carboniferous-Permian phases of fault activity

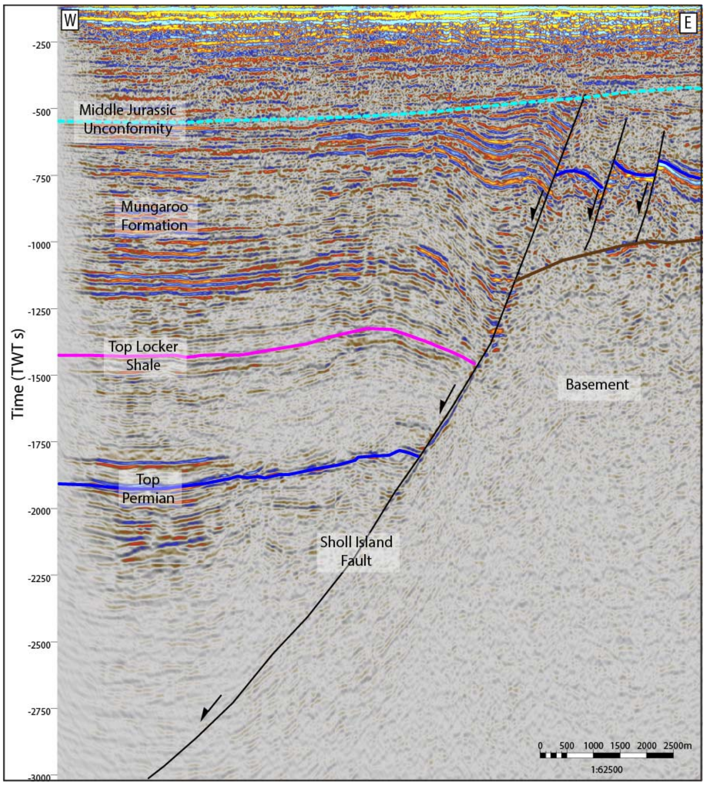


**Figure 1. 2D seismic line showing folding of Triassic and possibly Jurassic strata associated with the Sholl Island Fault**

## JURASSIC EXTENSION

Jurassic extensional fault patterns are exceptionally well imaged over large parts of the Exmouth Plateau. Faults are generally N to NNE oriented and in places show well developed NNE-trending en-ecehlon patterns, indicative of oblique reactivation of a NNE-trending fabric under an E to ENE oriented extensional regime. The bimodal pattern of NE and NNE trending faults on the northern margin of the Dampier Basin is also indicative of ENE oriented extension, but here obliquely reactivating a NE trending fabric. Thus, the two differently oriented fabrics developed during Palaeozoic extension can be seen to influence the Mesozoic fault patterns. However this phase of deformation is often linked to the separation of Argoland, which should result in NW oriented extension (Etheridge and O'Brien, 1994; Hall, 2012). E to ENE oriented extension is evident across large parts of the Northern Carnarvon Basin and may instead reflect early development of the N-S trending segment of the rift system that ultimately resulted in the separation of Greater India from Australia, and the formation of the western margin of the Exmouth Plateau.

Upward propagation of faults from Triassic into Jurassic sediments is often associated with offsetting of fault segments. Anticlines develop above the tips of the lower offset fault segments to accommodate the differences in displacement. Such anticlines are relatively common and are indicative of extensional fault propagation rather than a phase of compression.

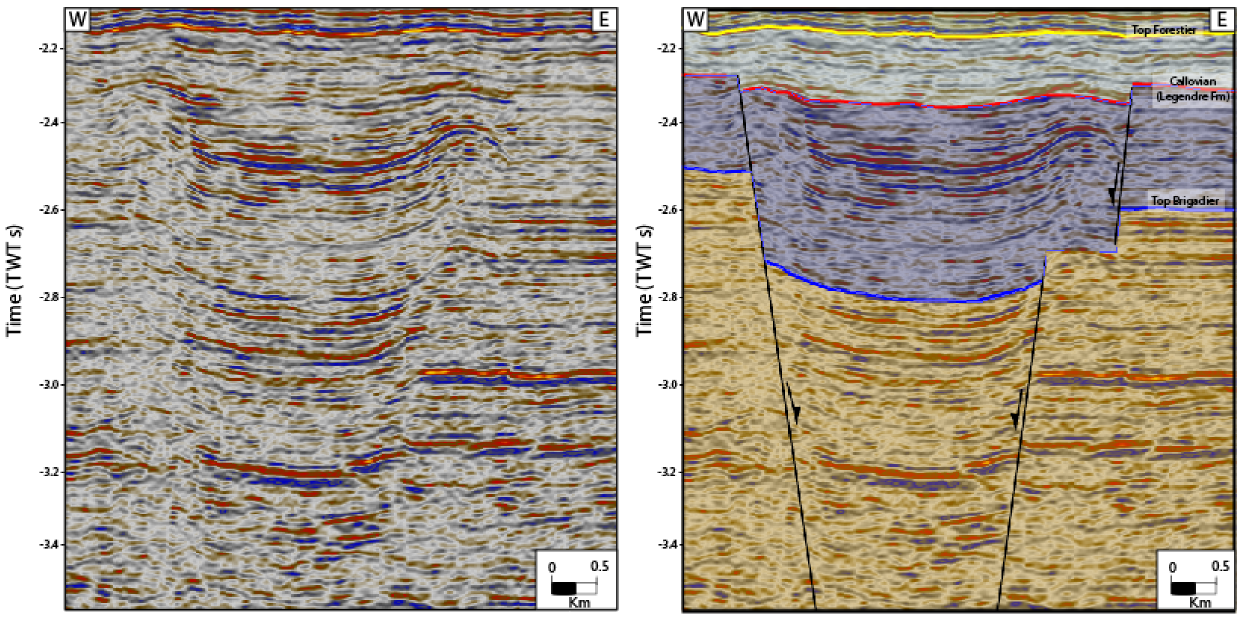


**Figure 2 - Uninterpreted and interpreted composite line of Rosie 3D seismic survey showing folding of Jurassic strata above the tip line of a fault terminating at the top Triassic Brigadier Formation.**

## LOWER CRETACEOUS EXTENSION

Lower Cretaceous extensional faults are spectacularly developed in the Exmouth sub-basin. However, they demonstrate a number of intriguing features. They cut sediments of Berriasian age, which appear to be pre-extensional, but are truncated by the Valanginian unconformity. Hence they represent a very short lived period of deformation. Furthermore, there is significant uplift and erosion which appears offset from the main depocentre in the Exmouth sub-basin, but which may increase in intensity to the SW, towards the Perth Basin. Outside of the Exmouth sub-basin both Lower Cetaceous faulting and Valanginian uplift are minimal. A recently proposed Exmouth mantle plume may account for the uplift (Rohrman, 2015), but the faulting, and its relationship to the southward propagating rift that culminated in the India-Australia break up remains enigmatic.

Folding of the Valanaginian unconformity surface demonstrates some of the deformation that has affected the margin in the post break-up phase, and which continues to expressed in present day topographic features such as the Cape Range Peninsula. Reverse reactivation of extensional faults is not documented, but is widespread in the Pliocene in adjacent parts of the Perth Basin.

## CONCLUSIONS

Readily available extensive 3D seismic data sets provide the opportunity to study the evolution of the Northern Carnarvon Basin in considerable detail. Spatial and temporal relationships between faults developed during different phases of the evolution of the margin demonstrate the importance of structural inheritance in influencing fault patterns and growth, and also reveal stress patterns that can be integrated with tectonic reconstructions. Although this part of the Australian margin has been extensively studied, integration of observations at different scales helps to further refine our understanding of its evolution.

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