New Insights into a major Early-Middle Triassic Rift Episode in the NW Shelf of Australia

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SUMMARY

The offshore Roebuck Basin is an amazingly complex and unexpected piece of North West Shelf geology. Large scale seismic geometries within the Triassic section is interpreted to define a complex of lava deltas associated within even a bigger scale rift complex. The location of the magmatic outpouring can be associated with a failed triple junction. Gravity and magnetic modelling supports this model and the apparent thickness of the volcanic complex is up to 10km.

The impact of this rifting is felt regionally along the three arms of the proposed triple junction. The northern arm is easily identified and extends up to the proto-Barcoo and proto-Caswell sub-Basins. The eastern arm propagates with strike-slip motion through the Fitzroy Trough creating numerous transpressional and transextensional features in the Palaeozoic and Early Triassic stratigraphy - previously known as the Fitzroy Movement. The western arm is only recognised to the north of Wombat Plateau. In this area, the Early Triassic thins dramatically and sets up the uplifted outboard edge of a broad epicentre extending across the present-day Northern Carnarvon Basin. The sequences described above across all three arms are overlain by a major unconformity that is interpreted to be a product of these rifting/uplift events.

This paper highlights that a regional approach, incorporating data from multiple sources, geographical areas and formations, assists with the broader understanding of tectonic history of the North West Shelf during the Early Triassic to Middle Triassic.

INTRODUCTION

There is abundant seismic evidence for Triassic faulting across the Northwest of Australia. It has commonly been associated with an ambiguous tectonic event called Fitzroy transpression, inversion or movement depending on its local expression. Some authors have attempted to explain it with multiple tectonic pulses (e.g. I, II and III) whilst others have reported its age from Middle to Late Triassic. A unified model is proposed that can potentially explain all these features on a regional scale.

The study area for this study is initially centred in the offshore Roebuck Basin (Figure1). In 2013 this was largely an unexplored area with only 2 wells (Huntsman-1 and East Mermaid-1). Supporting information will be gleaned across the region from the ODP-760B well on the Wombat Plateau, through the Barcoo and Caswell sub-Basins to the northeast and into the Canning Basin to the east to construct a model for the proposed major rifting event.

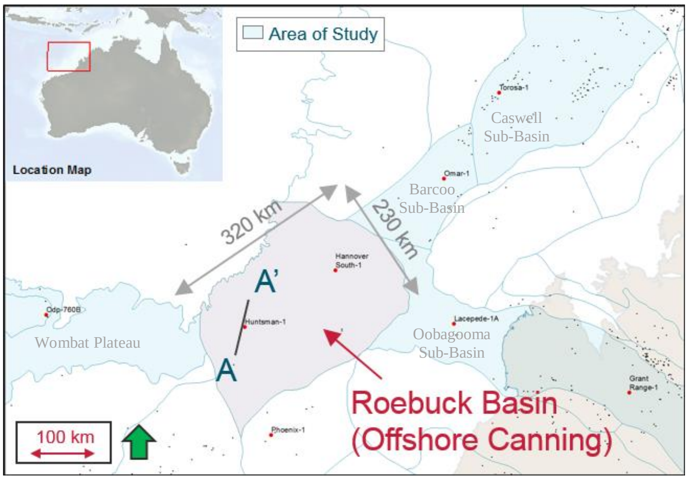


Figure 1: Study Area

METHOD AND RESULTS

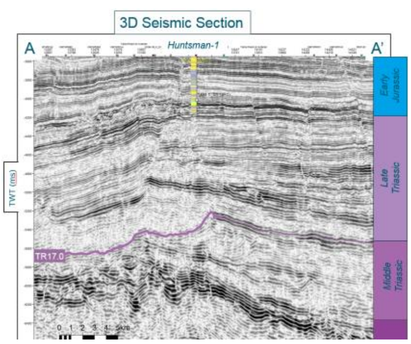


Figure 2: Triassic Clinoforms

In 2014, Woodside and Shell acquired the Curt 3D seismic survey. This covered 11,000 km^2 and provided new insights into the subsurface within a region that had previously only been covered by sparse 2D seismic data.

One feature that was particularly intriguing was visible beneath the Huntsman-1 well (Figure 2). This has the seismic appearance of steeply dipping clinoforms that in the past have been interpreted to be associated with deltaic progradation e.g. paleo-shelf edge. This event was tied to the Phoenix-1 well in the Bedout Basin and correlated with the top of the *S. quadrificus* spore/pollen zone which places it near the top of the Middle Triassic.

These steeply dipping clinoforms can be mapped using 3D seismic. The resulting TWT surface is shown in Figure 3 and highlight some important characteristics:-

- The reconstructed Palaeo-bathymetry implies water depth of 400-500m
- The steepness of the clinoforms is between 20-30 degrees
- There is a northwest to southeast direction of progradation

The steepness of the slope immediately implies a non-clastic origin for the creation of these clinoforms. The obvious interpretation of a carbonate bank or carbonate capped deltaic system is supported by the thick Cossigny limestone package at Phoenix-1. However magnetic and gravity modelling, 2 well penetrations at the base of Anhalt-1 and Hannover South-1 and comparison to depositional analogues have been used to propose an alternative geological model for this system, which is a volcanic lava delta complex.

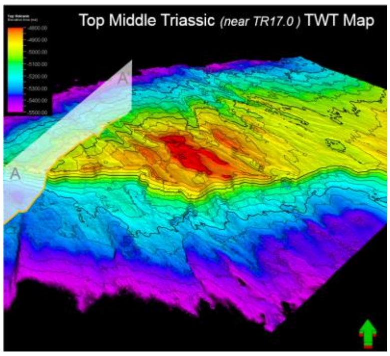
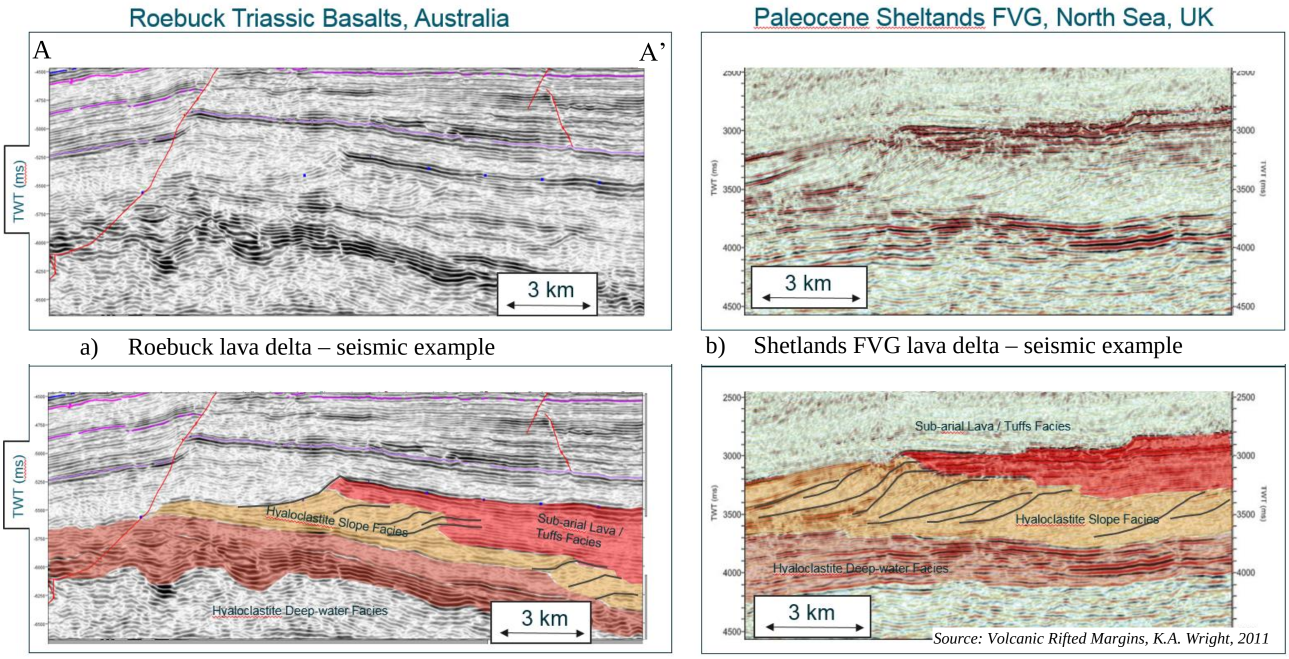


Figure 3: TR17.0 TWT Map

One of the best studied lava deltas globally is the Faroes volcanic group (FVG) located in the northern Atlantic Ocean. This has a robust geological volcanic model supported by numerous well penetrations and regional 3D seismic coverage. Lava deltas are effectively a result of extrusive continental flood basalts (lavas and tuffs) that meet the ocean. Rapid cooling upon contact with the water initiates a change of petrological state as they enter the sub-aqueous environment and they subsequently form hyaloclastite slope and deep-water facies. Figure 4a and 4b shows the amazing similarity of the Triassic Roebuck lava delta to the Paleocene FVG lava deltas in size, scale and geometry. This makes it fairly easy to transpose the geological model (Figure 4d) onto the Roebuck Triassic basalts (Figure 4c).



a) Roebuck lava delta – seismic example

b) Shetlands FVG lava delta – seismic example

c) Roebuck lava delta with geological interpretation

d) Shetlands FVG lava delta with geological interpretation

Figure 4: Comparison with known lava delta

The Roebuck lava delta complex can be seen to be part of a much larger volcanic province on the semi-regional transect through the Curt 3D (Figure 5). The majority of the volcanogenic sediments appear to be the extrusive lava/tuff 'top-sets' with potentially some clastic sediments interleaved or embedded. This section is penetrated at the base of the Anhalt-1 and Hannover South-1 wells and consists mainly altered basalts and altered products of subaerial extruded basaltic lava flows.

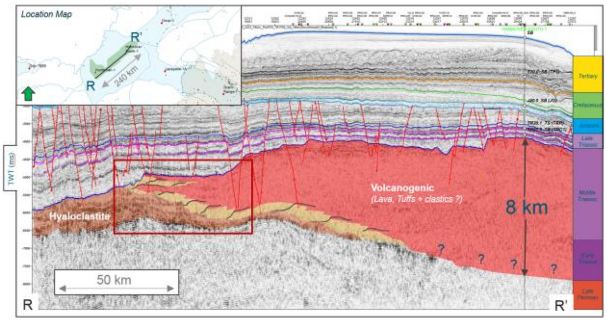
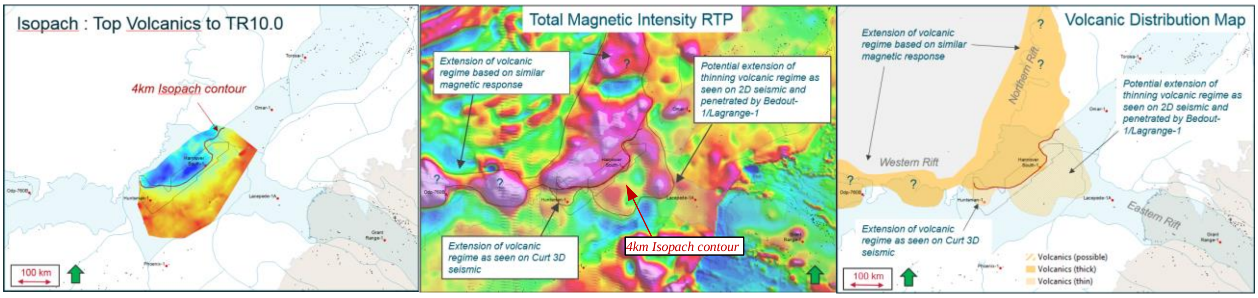


Figure 5: Semi-Regional 3D seismic line

Angular fore-sets, indicative of a prograding lava delta system, are also visible at the base of this package. These give some hints to the early development of the volcanic system.

The volcanic package has a thickness up to 10km (Figure 6a) and this has excellent correlation with regional magnetics anomalies (Figure 6b). Utilising the combination of the magnetic data and seismic interpretation a regional distribution of the Triassic volcanic complex can be interpreted (Figure 6c).



a) Isopach of Volcanics b) Total Magnetic Intensity c) Volcanic distribution Map

Figure 6: Derivation of the Volcanic Distribution

The origin of large-scale continental flood basalts fall into 2 main categories:

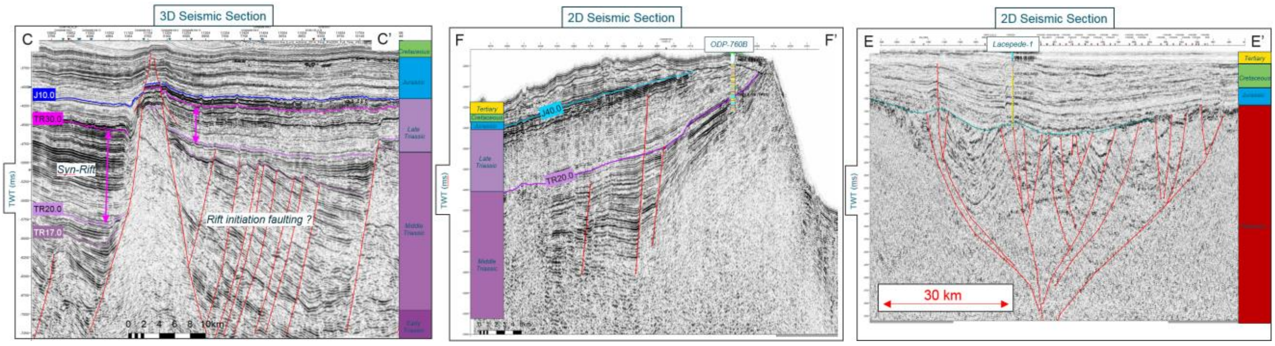
- Mantle plumes (NAIP, Deccan Traps)
- Rift provinces including triple junctions (Siberian Traps, Panjal traps)

Debate exists whether triple junctions occur due to mantle plumes or alternatively invoke magmatic activity. The volcanic distribution map (Figure 6c) lends itself to a triple junction geometry with an obvious major northern, western and eastern arms. Faulting related to this major tectonic event has different expressions along each arm:

1. The northern rift arm throughout the Barcoo sub-Basin extending up to at least the Caswell sub-Basin. An indispensable seismic example of this faulting is shown in Figure 7a. This highlights the following key features
   - Intense faulting at depth which terminates at the Top middle Triassic (e.g. end of volcanism)
   - Large syn-rift growth packages within the Late Triassic. It appears that preferential earlier faults are utilised to accommodate this later extension.

2. The western rift arm interpretation is dominated by the magnetic response described earlier however the 2D seismic data again highlights early to middle Triassic faulting (Figure 7b).

3. The eastern rift arm is the most structurally complex. Strike-slip structures caused by a Triassic tectonic event have been commonly referenced in literature in the onshore Canning Basin [Zhan & Mory, 2013]. This is believed to extend into the offshore Oobagooma Sub-basin where strike-slip movement appear to be present (Figure 7c).



a) Lord/Admiral 3D seismic b) AGSO 56-013P2 2D seismic line c) JN88-24A 2D seismic line

Figure 7: Triassic faulting examples

CONCLUSIONS

In conclusion the Roebuck triple junction helps explain the enigmatic Fitzroy event(s) tying in varying local expressions within a regional context.

Data is presented to support the development of a triple junction during the Early to Middle Triassic on the NW Shelf of Australia (Figure 8). This is believed to have started with a magma plume that provided the source for the massive outpouring of continental flood basalts. Large scale uplift would have occurred regionally with intensive faulting located proximal to the plume centre.
The magma plume eventually initiates a triple junction. This early period of the rift is considered the main candidate for propagating compressional strike-slip motion along the eastern arm resulting in large scale uplift within the Oobagooma Basin and localised uplift associated with transpressional highs through the Fitzroy Trough. This uplifted region has previously been referenced as a major source of sediment for the Triassic Mungaroo Formation within the Northern Carnarvon Basin whilst eroded basaltic material could help explain the presence of Triassic zircons recorded within the Mungaroo Formation [Lewis 2013].
Extensive extensional faulting along the northern arm during the Late Triassic is visible throughout the Browse Basin and is believed to have occurred post rift initiation uplift.
The Western arm is thought to have resulted in the large scale uplift of the Wombat Plateau in the Early to Middle Triassic. This uplifted flank fringes the Northern Carnarvon Basin, and potentially set-up the bowl-like geometry for the Triassic Mungaroo deposition.

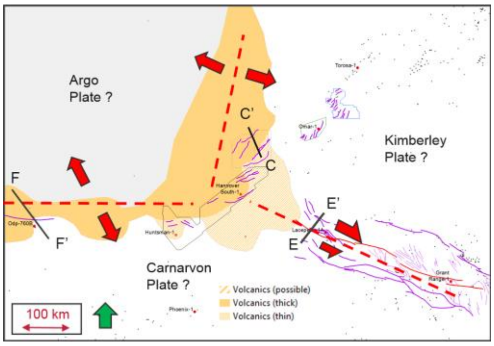


Figure 8: Roebuck triple junction

ACKNOWLEDGMENTS

I would like to thank Woodside for permission to present this material as well as Shell and BP for their guidance and input on volcanic regimes and lava deltas.

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