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# Rift initiation on Australia's southern margin: insights from the Bremer Sub-basin

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## SUMMARY

The Bremer Sub-basin occupies a unique position on Australia's south-west margin. It is influenced by two rift events associated with the breakup of Gondwana: rifting along Australia's western margin in the Early Cretaceous as well as the southern margin rifting in the Late Cretaceous. The basin is underlain by Proterozoic granites, gneisses and sedimentary rocks of the Albany-Fraser Orogen and the structural fabric of the basin is strongly influenced by the basement architecture. Weaknesses along shear zones localised deformation in the early rift phases, resulting in complex structures including ramp-flat faults and associated extensional folds.

The western part of the basin contains reactivated NW-trending shear zones in the basement, which are visible onshore in magnetic data and are shown to extend offshore using satellite gravity data. Strike-slip reactivation of these shear zones resulted in isolated deep depocentres and basement highs. In the central and eastern part of the basin, salt diapirs and associated salt withdrawal and expulsion structures were active during rifting and breakup. The salt is likely Proterozoic in age and is tentatively correlated with salt in the Polda Trough, 1500 km east of the Bremer Sub-basin, which has implications for our understanding of the pre-rift architecture of Australia's southern margin.

**Key words:** Bight Basin, Bremer Sub-basin, salt tectonics, structure, rifting, southern margin

## INTRODUCTION

The Bremer Sub-basin is a Middle Jurassic to Early Cretaceous rift basin on Australia's southern margin (Figure 1). Early extension was diachronous along the southern margin, occurring first in the west in the Callovian to Kimmeridgian; the Bremer Sub-basin therefore contains the earliest rift structures along the margin. The early extension was slow and the majority of extension occurred during the Berriasian to Aptian. The periods of extension were punctuated by several phases of thermal subsidence prior to breakup in the Santonian-Turonian (Bradshaw et al., 2005).

The basin is underlain by Proterozoic granites, gneisses and sedimentary rocks of the Albany-Fraser Orogen and the structural fabric of the basin is strongly influenced by this basement architecture (Nicholson and Ryan, 2005). The majority of the basin overlies the Nornalup zone of the Albany-Fraser Orogen and is transected by shear zones trending both NW-SE and NE-SW The Albany-Fraser Orogen preserves a long history of Proterozoic extensional basins and magmatism prior to continental collision in the Mesoproterozoic (Spaggiari et al., 2015). Refraction seismic studies of the basement to the Bremer Sub-basin suggest that it is mostly non-granitic in composition, with velocities closer to that expected of low-grade metasediments (Goncharov et al., 2006).

Here we present a new interpretation of the Bremer Sub-basin using infill 2D seismic acquired in 2009 by Arcadia Petroleum. In the western part of the basin we identify strike slip faults and deep depocentres associated with pull apart basin formation along Proterozoic shear zones of the Albany-Fraser Orogen. In the central and eastern parts of the basin we identify salt diapirs and associated salt withdrawal and expulsion structures forming during extension associated with rifting and breakup. Extrusive volcanics, likely aged 100-120 Ma, suggest an earlier date for breakup than previously assumed.

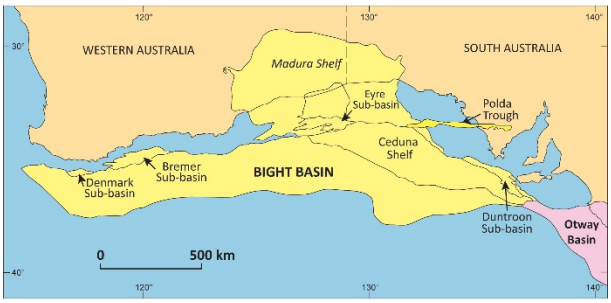


**Figure 1. Location of the Bremer Sub-basin in the western part of the Bight Basin. (Modified from Totterdell and Bradshaw, 2004)**

## DATA AND METHODOLOGY

No wells have been drilled in the basin and the stratigraphy is based on dredge samples and some shallow gravity cores (Blevin, 2005). Initial studies of the basin (Bradshaw, 2005) were based on widely-spaced regional seismic lines. In 2009, Arcadia Petroleum acquired a further 4,443 km of 2D seismic, infilling the existing surveys to provide a 5-10 km grid across the basin (Bradshaw et al., 2012). For this study, we have used all the available seismic surveys as well as satellite gravity and magnetic data (Sandwell et al., 2014; Meyer et al., 2017). A semi-automated structure detection routine was applied to an isostatic residual gravity grid by Fathom Geophysics. The results were used to highlight structures and deep discontinuities such as shear zones within the underlying Albany-Fraser Orogen.

## OBSERVATIONS

A pre-rift sedimentary sequence is visible as flat-lying sediment on top of rotated fault blocks. Early extension in the Jurassic formed E-W to ENE-WSW trending faults which were reactivated in the Cretaceous. In the western part of the basin, Cretaceous reactivation utilised NW-SE trending shear zones within the basement, visible in the magnetic data onshore and as offshore trends in gravity data (Figure 2). The shear zone reactivation and rotation of fault trends resulted in isolated basement highs adjacent to deep depocentres, ramp-flat faulting and associated extensional folds.

Salt diapirs are observed in the central and eastern part of the basin (Figure 3). The diapirs and associated minibasins trend E-W and initiated in the Callovian, with later growth during the Valanginian to Aptian. Other salt-related structures in the eastern part of the basin include expulsion rollovers, salt-cored anticlines and turtle structures.

Isolated volcanic intrusions are identified in the seismic data, and one sample of porphyritic basalt was produced from dredging of the canyons (Blevin, 2005). Lava flows and extrusive igneous rocks occur between the Aptian and Santonian horizons along the southern margin of the basin, suggesting earlier volcanic activity than previously interpreted.

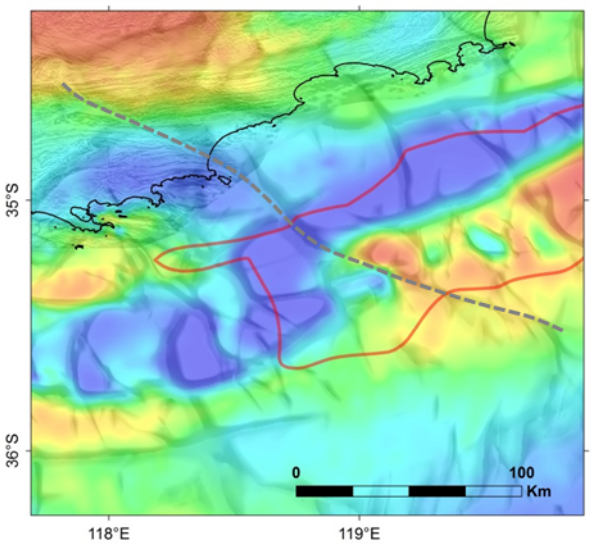


**Figure 2. Image showing the first vertical derivative of onshore magnetic data in greyscale overlain by an isostatic residual gravity image with enhanced edge detection (Buckingham, 2016), showing continuation of onshore shear zones (grey) into the offshore Bremer Sub-basin (red outline).**

## DISCUSSION

The extent and age of the salt is uncertain as no samples have been recovered, so its existence is only hypothesised from seismic data. It is unlikely that there were suitable conditions for evaporite deposition during the early stages of rifting in the Middle Jurassic, given the proximity of Australia's southern margin to the South Pole. Bradshaw et al. (2012) suggested the salt may be similar to Proterozoic-Early Cambrian sequences in the Polda Trough or alternatively the Neoproterozoic salt in the Officer Basin.

Both of those occurrences are some distance from the Bremer Sub-basin, leading to the interesting possibility that salt sequences may extend further along the southern margin to the east of the Bremer Sub-basin. The E-W trending Polda Trough may represent the eastern end of a continent-scale narrow basin extending west to the Bremer-Sub-basin, offset along several continent-scale shear zones (Figure 4).

The presence of this narrow basin supports the concept that rifting was controlled by pre-existing, long-lived E-W zones of weakness along Australia's southern margin, offset by major shear zones. The presence of a pre-rift sedimentary sequence suggests that extension may have initiated prior to the mid-Jurassic. The architecture of the rift may also influence the location of oceanic fracture zones which occur along-strike from continental basement shear zones (e.g. Gibson et al., 2013).

## CONCLUSIONS

Infill seismic data combined with reprocessed gravity data enables a new interpretation of the structural evolution of the Bremer-Sub-basin. A pre-rift sequence, possibly containing salt, influences the later rift structures. Salt mobilisation was concurrent with extension due to rifting. Reactivation of NW trending basement shear zones associated with Australia's breakup from Greater India produced deep, isolated depocentres bound by strike-slip and transfer faults. Extrusive igneous rocks occurring between 120-100 Ma suggest that breakup may have occurred earlier than previously interpreted.

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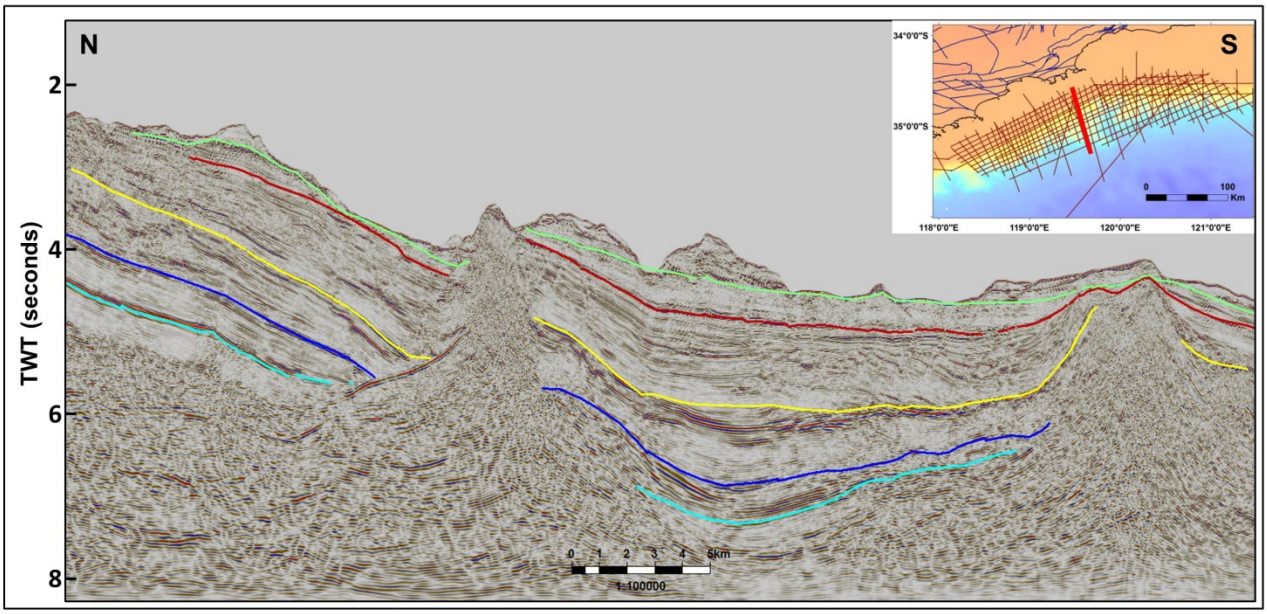


**Figure 3. Seismic section across the Bremer Sub-basin showing possible salt structures. Turquoise horizon is Callovian, dark blue is Berriasian, yellow is Valanginian, red is Aptian and green is the Santonian unconformity.**

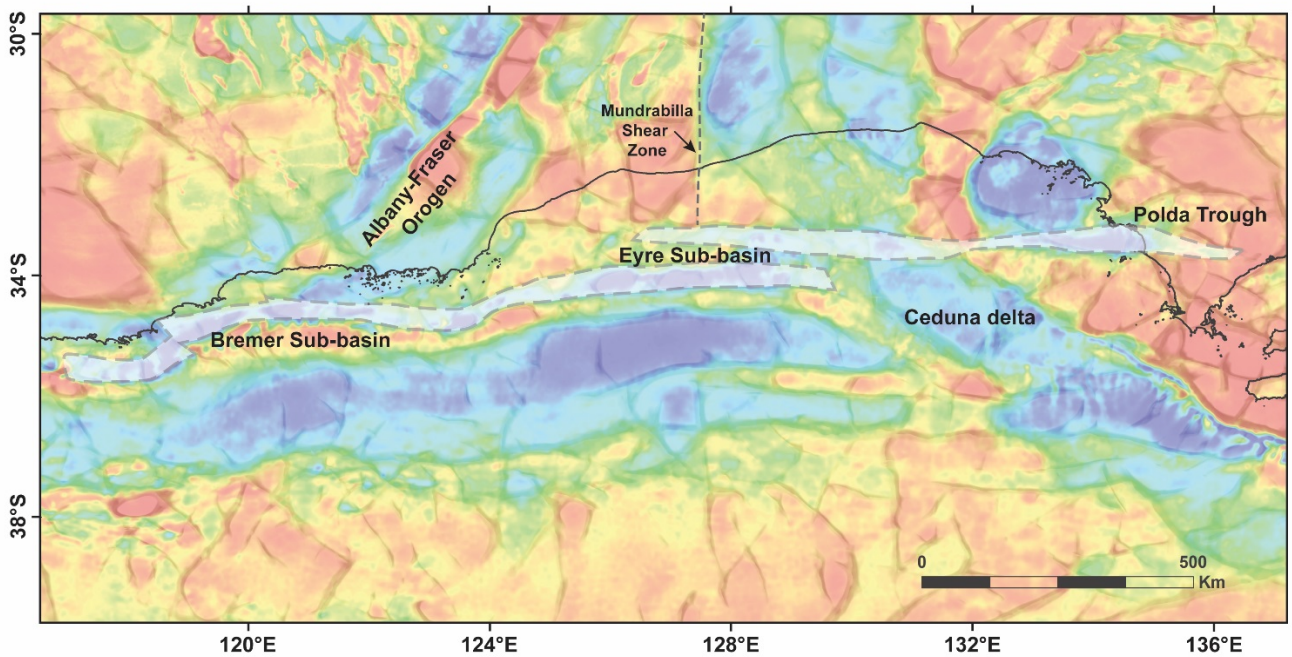


**Figure 4. Isostatic residual gravity image (Buckingham, 2016) across Australia's southern margin, with enhanced edge detection to highlight major structural trends. A series of E-W trending depocentres from the Bremer Sub-basin in the west to the Polda Trough in the east is highlighted.**