BASEMENT CONSTRAINTS ON OFFSHORE BASIN ARCHITECTURE AS DETERMINED BY NEW AEROMAGNETIC DATA ACQUIRED OVER BASS STRAIT AND WESTERN MARGIN OF TASMANIA

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INTRODUCTION

The geology and petroleum potential of the western Tasmanian offshore basins is poorly understood. As part of a strategy to improve the understanding of these basins, aeromagnetic data was acquired by Geoscience Australia and Mineral Resources Tasmania under a National Geoscience Agreement and partly funded by the Commonwealth Government's Offshore Energy Security Program. The survey acquired 141,234 line km of high quality data with a line spacing of 800 m across the Bass, southern Otway and Sorell basins and Torquay Sub-basin (Figure 1). The aim of this survey was to acquire new aeromagnetic data to help delineate the structural architecture of the basins and underlying basement and the distribution of igneous rocks. The data fill a gap in the existing aeromagnetic coverage between Tasmania and mainland Australia and provide fresh insights into basement structure and its control on basin architecture and sedimentation patterns during the breakup of Gondwana and separation of Australia from Antarctica.

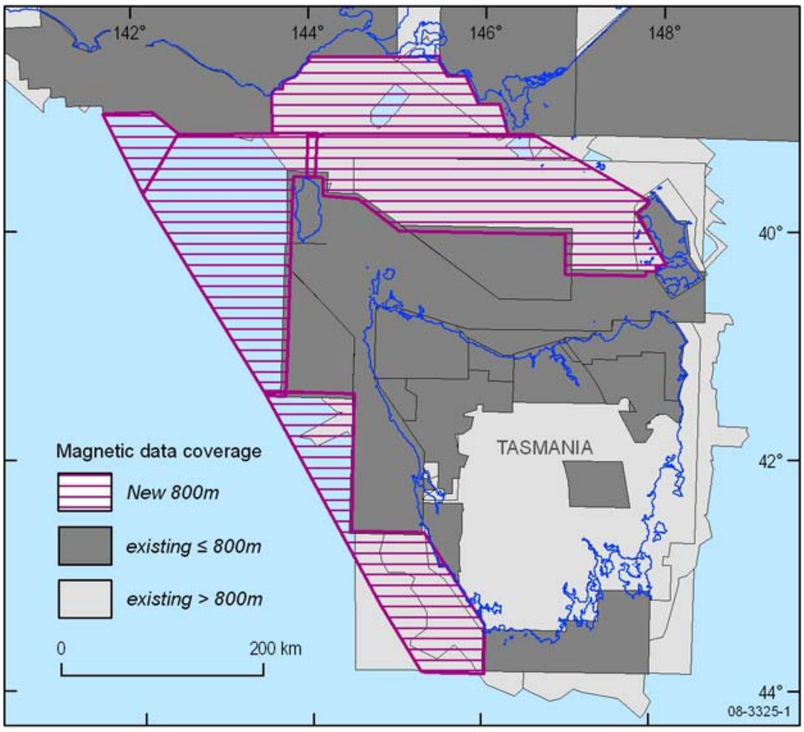


Figure 1: The extent of the new 2008 aeromagnetic coverage is shown in red.

AEROMAGNETIC DATA

Geophysical data provide both a framework and constraint for geological interpretation and structural models. Data coverage and quality have a direct relationship to constraining ability.

The magnetic data coverage in Bass Strait over the Bass, Otway and Sorell basins and Torquay Sub-basin is an excellent illustration of this concept. Until the acquisition of the new aeromagnetic dataset presented in this paper, the bulk of the area was covered by the 1961 Encounter Bay aeromagnetic survey (BMR, 1965). These data were flown at varying line directions and spacings (approximately 3 km) and digitised from the analogue recording charts by Geoscience Australia. This dataset is difficult to grid and integrate with higher resolution onshore aeromagnetic data. Geological interpretations in this area were consequently not as well constrained as they could be with a more complete and comprehensive aeromagnetic dataset. This has resulted in the development of a broad range of disparate geological models (e.g. Bernecker and Moore (2003), Teasdale et. al. (2003), and Miller et al. (2002)) for the region, all based on the same dataset. The new data provide an important new constraint that enables researchers to improve interpretation and modelling of the structural fabric and architecture of this region.

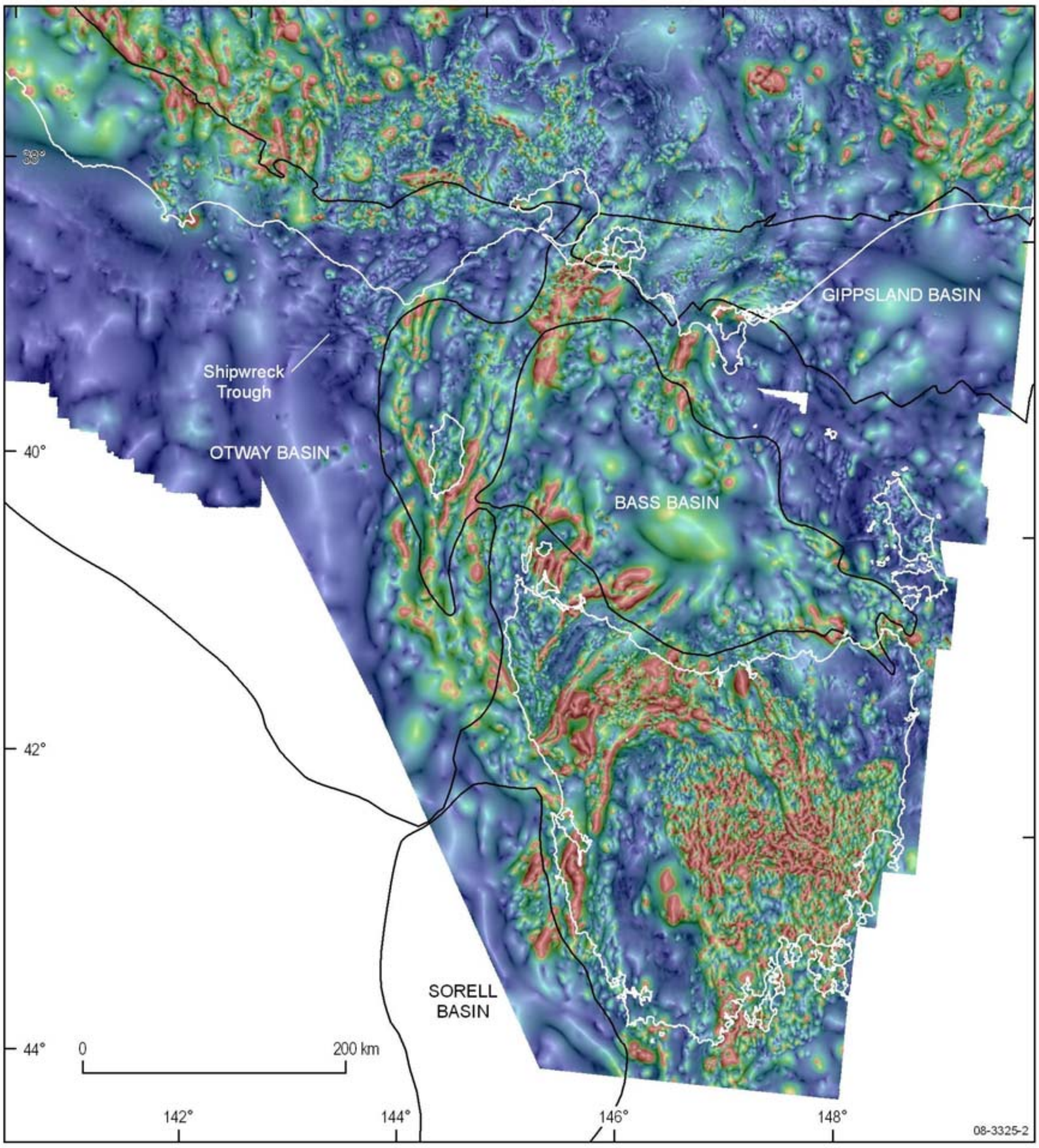


Figure 2: Analytic signal amplitude-phase image of 1 km upward continued total magnetic intensity (TMI) data. The TMI data are a merged grid of the existing and new aeromagnetic data.

PROCESSING

The integration of the new data into the existing Geoscience Australia magnetic data grid provides a continuous coverage of magnetic data with only minor grid join edge effects. The complex join geometry makes it critical to know the location of these edges, which can be easily identified by applying a Laplacian transform to the grid. Two approaches were taken in the enhancement of the magnetic data grids; upward continuation and upward continuation residual grids and analytic signal methods. Upward continuation residual methods provide a robust method of frequency separation in potential field data (Jacobson, 1987). This method is locally adaptive and produces a visualization of the data that is more geologically interpretable than a fixed frequency or band-pass filtered image. The method also provides a more interpretable image than total horizontal derivative (gradient) presentations for interpreters.

A visualisation of the data utilising a combination of the analytic signal amplitude and phase (Figure 2) proved most useful in the mapping of the lineation fabric of the magnetic data (Nabighian, 1972, 1974). It accurately maps the location of the Shipwreck Trough (Figure 2) and displays the structural fabric of the western Tasmanian margin. To delineate magnetic features at depth, a 20 km upward continuation image of the data was produced (Figure 3) showing the large scale magnetic anomalies produced by deep (10 km and deeper) geological features.

INTERPRETATION

A preliminary interpretation of the processed aeromagnetic dataset is presented in Figure 4a. This interpretation is focused on southern Victoria and western Tasmania, and is mainly concerned with the identification of regional-scale basement fabrics and structural trends that influenced the architecture, distribution and propagation of petroleum-bearing sedimentary basins in both the onshore and offshore domain (e.g. Otway, Bass and Sorell). Previous studies concerned with the nature and structure of basement in this part of Australia (Miller et al., 2002; Cayley et al., 2002) identified many of the same structures and structural trends, and this study differs only in respect to the continuity and extent of some of the larger scale faults and discontinuities identified in the magnetic data (see below). The new data (Figure 4a) serve as a test of previously published basement structure maps (Figure 4b) as well as an opportunity to further refine the distribution and character of key structures within these maps based on a more complete and comprehensive dataset. Major structures and faults identified in this study are based on steep gradient changes or abrupt breaks and offsets in the upwardly continued magnetic anomalies and, where possible, have been checked against known geology and previously published geological and gravity anomaly maps.

Five major structural trends are recognised in the magnetic data:

1. NE- to NNE- trending structures best preserved in northwest Tasmania but also occurring farther north in southernmost central Victoria. These structures include the Arthur Lineament in Tasmania and appear to be developed in areas exclusively underlain by basement of known or inferred Proterozoic age (Tyennan Block in Tasmania and Selwyn Block in southern Victoria) (Black et al., 1997; Cayley et al., 2002). Normal faults in the Torquay and eastern Otway basins follow this trend and most likely originated in response to movement on reactivated late Proterozoic or early Cambrian basement structures.

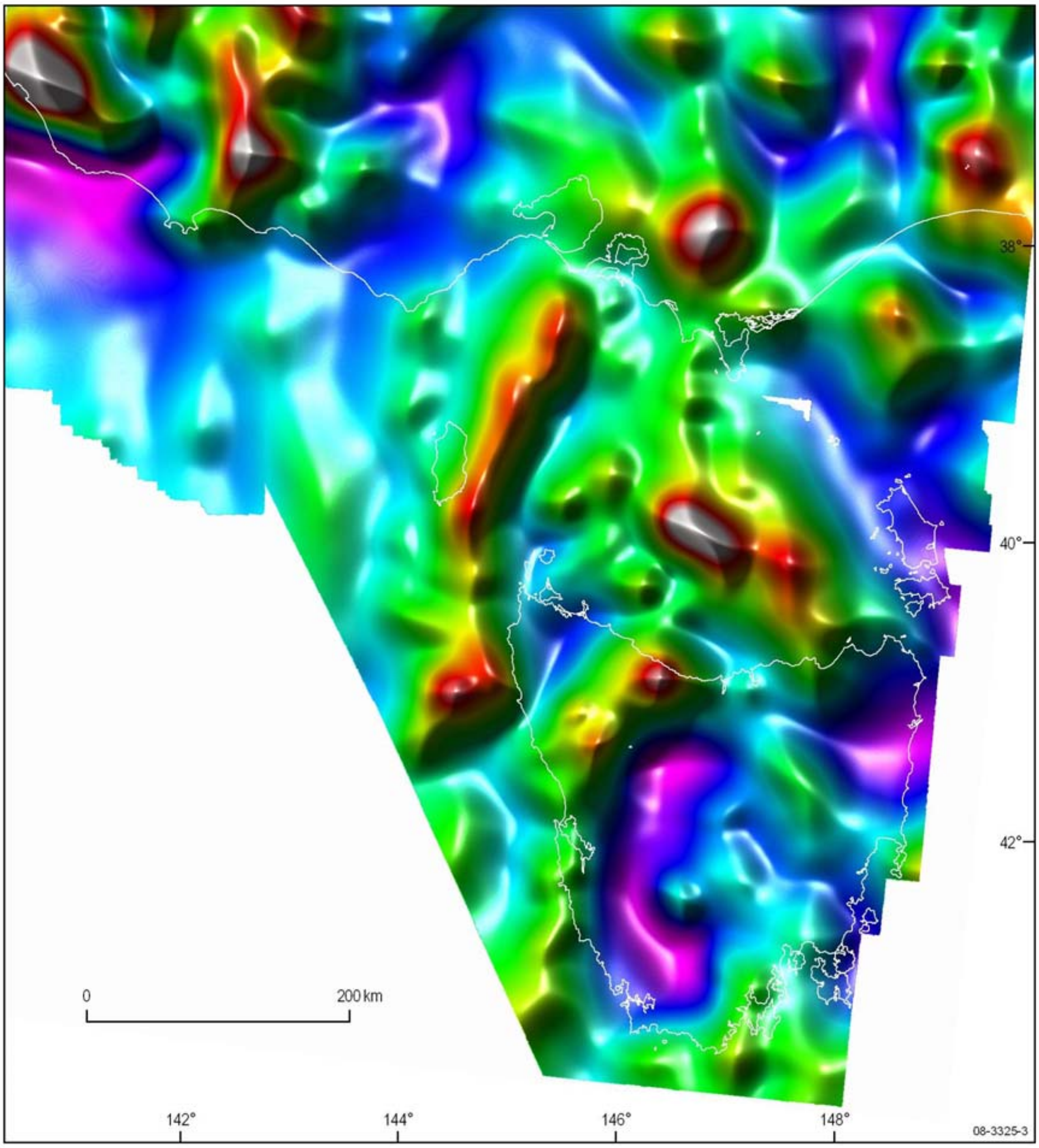


Figure 3: 20 km upward continued total magnetic intensity (TMI) data image with a NE hill shade and NW illumination applied.

2. NW-trending structures best observed in basement rocks of western Victoria (Glenelg River Complex) but extending farther south into the Bass and western Otway basins. They share the same trend as the late Neoproterozoic or early Palaeozoic Hummocks Fault (Turner et al., 1993) in western Victoria (Figure 4a) and include basement structures that were optimally oriented for reactivation during Mesozoic NE-SW-directed continental extension and rifting. NW-trending faults in the Bass basin truncate and locally displace the older NE-trending basement structures referred to above.

   This same structural trend is also evident in faults, shear zones and mafic dyke swarms of much older age identified farther afield in the Gawler and Curnamona cratons of southern Australia. These structures are widely interpreted to reflect an earlier episode of contintinental extension and rifting related to the initial NE-SW oriented breakup of Rodinia (Direen and Crawford, 2003)

3. North- or NNW-trending structures and fabrics that extend southward from mainland Victoria through the Shipwreck Trough into the Sorell Basin (Figure 2) and which appear to represent an offshore continuation of basement fabrics previously mapped within the Palaeozoic turbidite sequences of the Glenelg, Stavely and Bendigo zones in western Victoria (e.g. Cayley & Taylor, 1998; Morand et al., 2003). They include major faults and structural discontinuities such as the Moyston Fault (Figure 4a), which separates the Delamerian and Lachlan fold belts (Cayley and Taylor, 1998). Also included are two terrane-bounding structures - the Avoca and Yarramyljup faults (Figure 4a) representing the eastern margins of the Glenelg River Complex and Bendigo zone respectively (Gibson and Nihill, 1992; Moore et al., 1998; Birch & Vandenberg, 2003)

4. Late north- and NNW-trending faults with conspicuous sinistral strike-slip offsets in magnetic markers (including probable serpentinised ultramafic rocks in western Tasmania) that truncate, post-date and displace all previously formed structures and fabrics included in categories 1-3. Structures of this age and character are particularly common along the west coast of Tasmania and together constitute a crustal-scale Riedel shear zone related to strike-slip faulting accompanying the final stages of continental breakup. This shear zone is here named the West Tasmanian Shear Zone. Transform faults in oceanic crust adjacent to extended continental crust off western Tasmania exhibit the same north-south trend and sinistral shear sense as this shear zone, consistent with the proposition that strike-slip faulting was not only intimately related to continental breakup but took place in a north-south-directed transtensional tectonic regime. This regime superseded earlier NE-SW directed extension in the Otway and Bass basins and may have been associated with further reactivation of basement structures and earlier-formed normal faults.

5. A subsidiary set of ENE structures that truncate the Riedel shear zone and appear to be of even younger age. They are best developed in southern Victoria and may locally serve as a southern limit to the “Newer Volcanics”

Normal faults bounding onshore and offshore Mesozoic and Tertiary sedimentary basins trend NW (Bass and western Otway basins), NE (eastern Otway Basin) or north-south (Shipwreck Trough), parallel or sub-parallel to major basement structures identified in this study (Figure 4a), indicating that structural inheritance and pre-existing basement fabrics exercised an important control on the distribution, orientation and geometry of these sedimentary basins. Similar suggestions have been made before, with the three basinal trends interpreted as a response to rifting along separate arms of a former triple junction (Norvick & Smith, 2001; Miller et al., 2002). Miller et al (2002) were of the view that one arm of this triple junction extended southward from the Moyston Fault (Figure 4a) although in the analysis presented here, the Moyston Fault lies too far east and therefore was not the locus for initial rifting. Rather, the critical structure is the Yarramyljup Fault some distance to the west (Figure 4a); it truncates the Moyston Fault and unlike the latter is readily traced south of the Otway Basin in the magnetic data.

In this analysis the distribution and extent of Proterozoic basement at depth, particularly beneath central Victoria (Selwyn Block) and western Tasmania (Tyennan Block) is important in the interpretation, because basement structures identified in these blocks match one or more of the normal fault trends in the overlying sedimentary basins. Mapped faults along the inferred western margin of the Selwyn Block (Heathcote and Mt Williams faults) can also be followed in the magnetic data as far south as the eastern Otway Basin (Figure 4a) where they merge into the West Tasmanian Shear Zone. Shearing and strike-slip faulting may in part have been localised along the western margin of the Selwyn Block. Similarly, the southern continuation of this shear zone along the west coast of Tasmania may coincide with the western margin of the Tyennan

Block. The triple junction may therefore have failed to propagate along the northeast arm because it encountered strong basement rocks of the Selwyn Block.

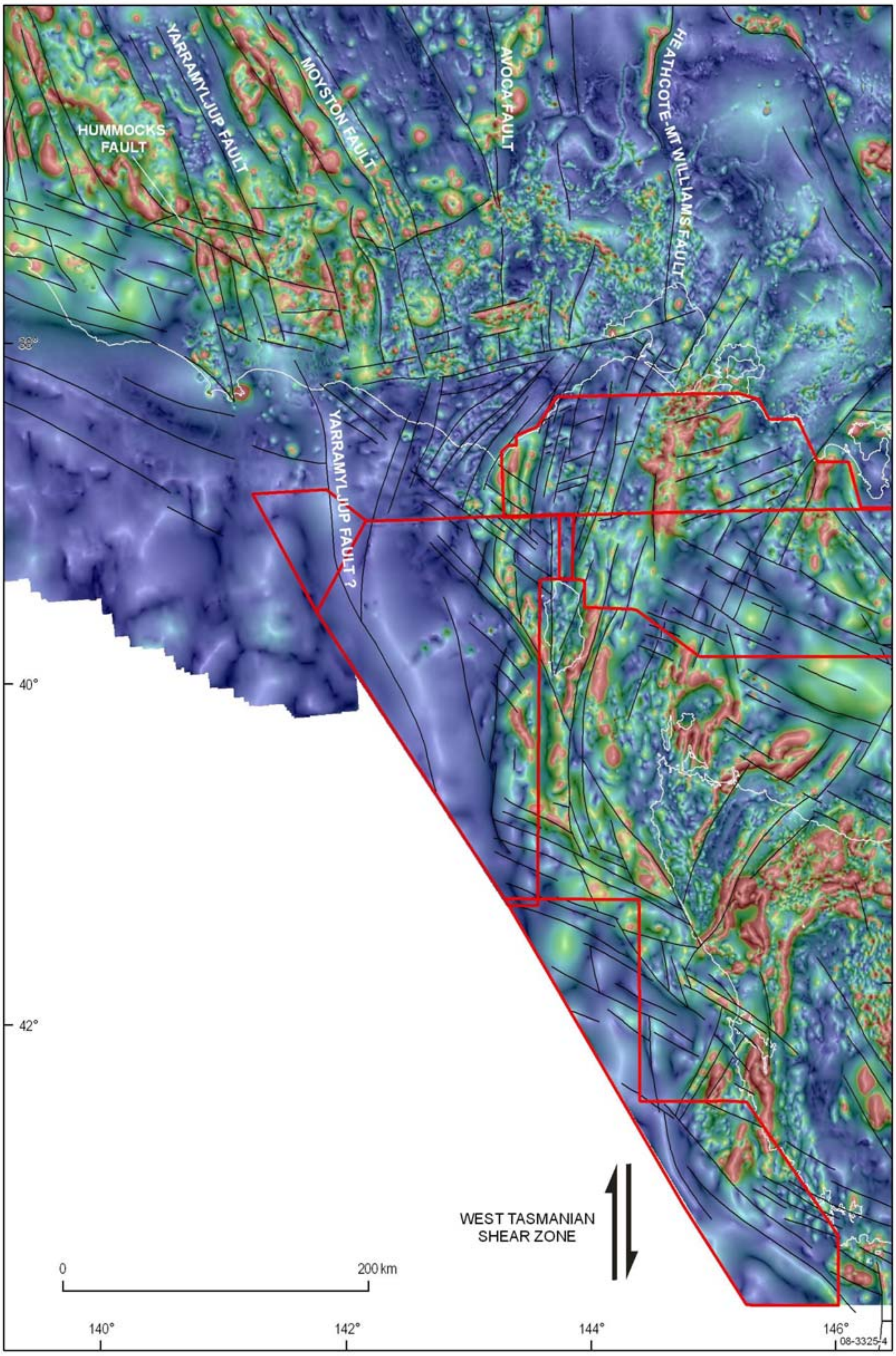
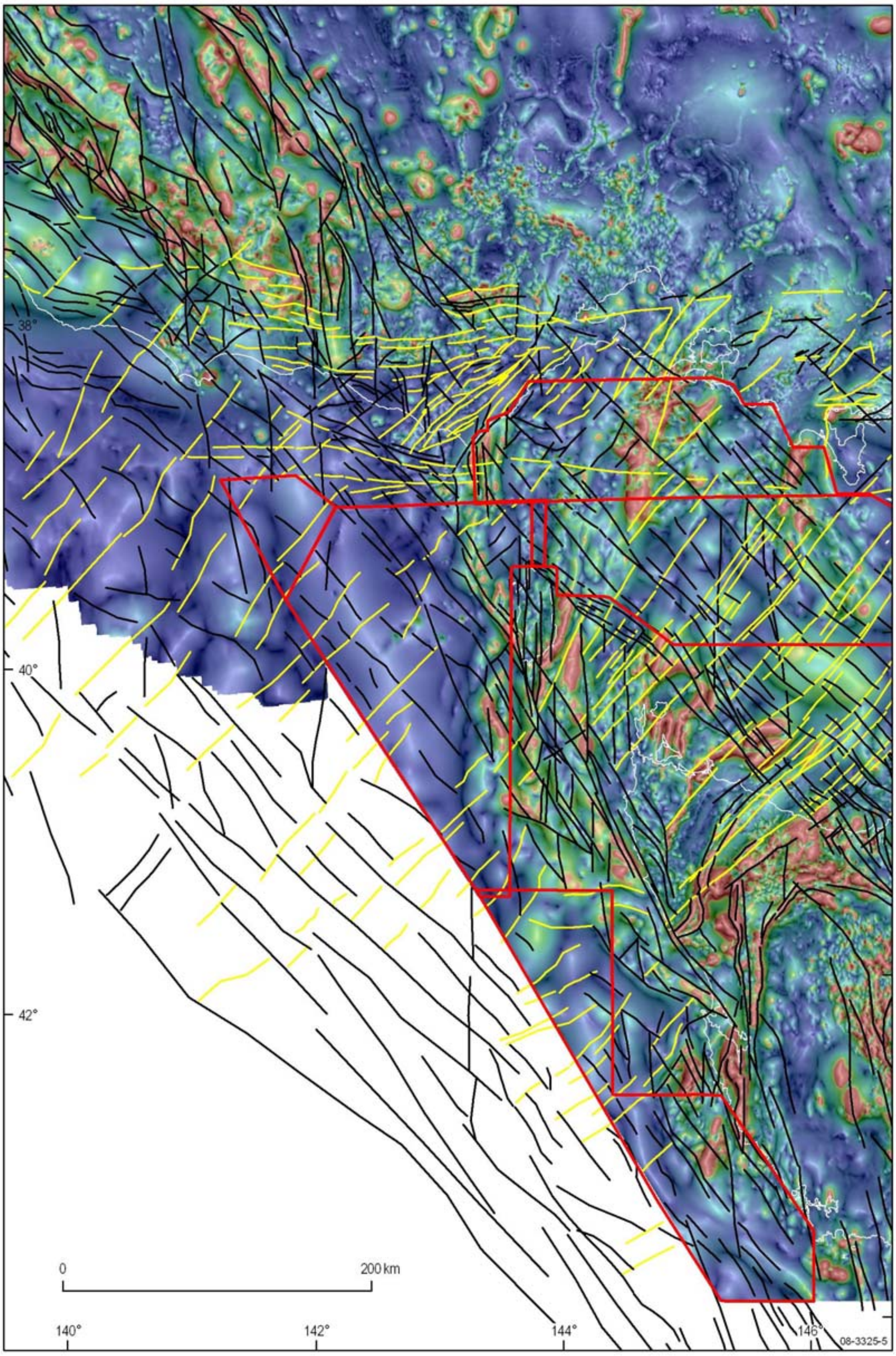


Figure 4: (a) TMI analytic signal amplitude-phase image overlain by the interpreted basement structural fabric.



(b) TMI analytic signal amplitude-phase image overlain by faults from Teasdale et.al.(2003). Note the similarities and differences between the two interpretations. In areas where good quality aeromagnetic data was previously available the two interpretations show similar trends in the mapped structural features. However, in the areas covered by the new data, within the red polygons, there is a marked difference between the interpretations. The West Tasmanian Shear Zone lies inboard of the Tasman Fracture Zone (transform fault).

Younger magmatic rocks that have intruded into the Bass, Otway and Sorell basins and Torquay Sub-basin are clearly delineated in the new aeromagnetic data. The large broad anomaly in the central Bass Basin (146.5° E, 40° S) is interpreted to represent shallow sills. Isolated, possibly remnantly magnetised, anomalies in the Sorell Basin and shallow complex anomalies in the Otway Basin are interpreted to be magmatic rocks at (shallow) depth.

CONCLUSION

This paper illustrates and validates the benefit of acquiring high resolution aeromagnetic data offshore over the Australian Continental margin and slopes. Even over water depths of 1000 to 2000 m, magnetic structure is resolved, leading to the delineation and mapping of basement structure in frontier basins with limited seismic data. These data provide an important constraint on the geological interpretation and models of the structural fabric and architecture of this region. These new data allow the basement structures to be more clearly identified and mapped, providing additional information about the controls on basin architecture along the Mesozoic-Cainozoic rifted margin.

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