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Research paper

Structural evolution of horst and half-graben structures proximal to a transtensional fault system determined using 3D seismic data from the Shipwreck Trough, offshore Otway Basin, Australia

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ABSTRACT

Using a three-dimensional (3D) seismic reflection dataset from the Shipwreck Trough, offshore Otway Basin, southern Australia, we aim to characterise and understand the structural evolution of the Shipwreck Fault Zone (SFZ) and associated extensional structures. The SFZ is a key structural element of the Otway Basin, which is a NW striking, Upper Jurassic-Cenozoic, rift-to-passive margin basin that formed due to the breakup of Australia and Antarctica. The SFZ marks the transition from the major southern margin rift system to the west and the oceanic-continental transform margin to the SE. The SFZ formed and bounds the Shipwreck Trough on the eastern side and is interpreted as a N–S striking transtensional fault zone, representing the northern *en echelon* extension of the transform margin to the south. The Shipwreck Trough is the downward thrown (western) side of the SFZ and is host to an array of horst and half-graben structures, two of which contain the producing Geographe and Thylacine gas fields. The Shipwreck Trough and SFZ are imaged by the Investigator 3D seismic dataset, which has previously been studied to conduct 2D restorations and interpret the timing, magnitude, orientation and nature of the structural events of the Shipwreck Trough. Our study adds to this previous research by using spectral decomposition and coherence volumes to further characterise the SFZ (and associated igneous features), basement structural elements and Late Cretaceous horst and half-graben structures. We have identified examples of releasing bend, releasing jog and restraining jog structures along the SFZ that are indicative of sinistral transtensional deformation and have highlighted areas of increased basement fault block relief, which have driven extensional faulting in the cover. We have also conducted throw-distance and throw-depth analysis on four horst and half-graben structures and shown that the associated normal faults have had continuous Late Cretaceous growth with the structures being formed through incidental linkage of normal fault segments. Finally, our two-way-time (TWT) and isochronal mapping of the entire 3D survey shows the development of the Late Cretaceous rifting event in the Shipwreck Trough and highlights numerous other structural closures similar to (and with close vicinity of) the Thylacine and Geographe gas fields, providing implications for prospectivity.

1. Introduction

The process of normal fault growth located near the furthest extent of a rift or rift compartment may increase in complexity due to the interaction with transfer zones, rift-oblique lineaments and continental transforms. The offshore eastern Otway Basin, Australia, is a relatively understudied petroleum province, with structural complexities due to the transition from an extensional setting to the west to a N–S oriented transform margin to the south (Fig. 1b; Stacey et al., 2013). The Shipwreck Trough (Fig. 1a) is located ~60 km offshore of Port Campbell, Victoria, and is a key geological feature of the offshore Otway Basin, marking abrupt change from the NW-SE striking southern rifted continental margin to the west (Fig. 1b) to a transitional zone, containing N–S striking transtensional fault systems. One of these fault systems is the Shipwreck Fault Zone (SFZ; Fig. 1a), which formed and bounds the Shipwreck Trough on the eastern side (Palmowski et al., 2004). The Shipwreck Trough and SFZ have previously been studied by Palmowski et al. (2004) and they interpreted the timing, magnitude, orientation and nature of the structural events of the Shipwreck Trough by conducting a 2D restoration of inlines and crosslines from the Investigator 3D seismic survey (Fig. 1a). Palmowski et al. (2004) showed that ~1.12 km of lateral offset occurred along the SFZ from the Coniacian to

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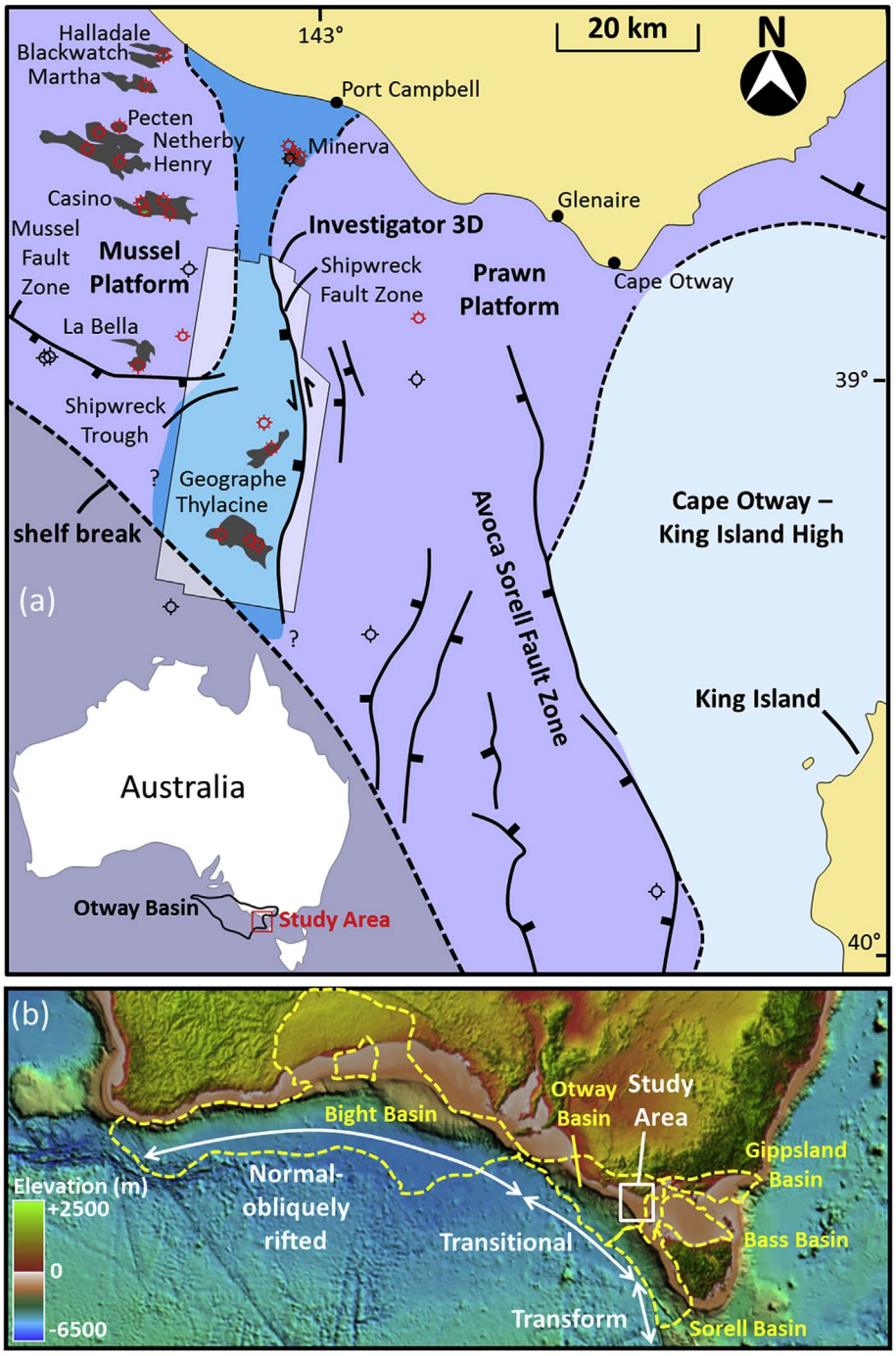

Fig. 1. (a). Location map of the 3D seismic reflection survey (Investigator 3D) relative to coastal Victorian towns Port Campbell, Glenaire and Cape Otway. Surrounding offshore gas fields are labelled and shown in grey, with associated well locations also displayed. Broad scale structural features are shown on the map, including the location of the transtensional Shipwreck Fault Zone, which borders the eastern side of the Shipwreck Trough. (b) Digital elevation map showing the location of the Bight, Otway, Gippsland, Bass and Sorell basins in relation to the study area and the broader southern margin tectonic elements (modified from Totterdell et al., 2012; Stacey et al., 2013).

the Early Eocene and proposed that the SFZ is the northern en echelon extension of the transform margin to the south (Fig. 1b). The SFZ (Fig. 1a) is characterised by a negative flower structure, which formed during Late Cretaceous rifting in the Otway Basin and accommodated greater south-southwest directed extension on the western side (~1.91 km) compared to the east (~0.79 km) from the Coniacian-Early Eocene (Palmowski et al., 2004).

The Shipwreck Trough contains several horst and half-graben structures imaged by the Investigator 3D seismic survey, two of which are host to the Thylacine and Geographe gas fields (Fig. 1a). Furthermore, the Investigator 3D seismic survey provides a wealth of information on the development of extensional structures proximal to a transtensional fault system. This, in addition to the proven gas discoveries in the Shipwreck Trough, is the reason we are aiming to further the understanding of the structural evolution of the Shipwreck Trough (Fig. 1a). Our study adds to previous research on the Shipwreck Trough (Palmowski et al., 2004) by using spectral decomposition and coherence volumes to characterise the SFZ (and associated volcanics), basement structural elements and Late Cretaceous horst and half-graben structures. We also conduct throw-distance and throw-depth analysis of the four major horst and half-graben structures and two-way-time (TWT) and isochronal mapping of the entire 3D survey to constrain the structural evolution of the Shipwreck Trough and SFZ (Fig. 1a).

Our interpretation of the 3D seismic survey documents a basement plateau, or high, in the north of the survey, with at least three kilometer-scale basement horsts in the central region and an isolated basement high in the southern portion of the survey. We observe