A 2D and 3D seismic-based structural analysis of the Ashmore Platform in NW Australia is aiming to unravel the tectonophysical processes resulting from an early-stage foreland basin deformation in the Timor Sea region. A re-evaluation of lithospheric flexural models proposed for this region and a comparison against the observed fault pattern reveal various differences. The study area provides an exceptional opportunity to examine the early-stage development of the foreland basin between the colliding Australian continental margin and the Banda arc. The Timor region's abundant normal faulting within a remotely convergent plate-margin setting has been a debated subject with numerous studies devoted to explain this issue. 2D elastic half-beam models of and simple bending elastic beam models from evidence that bending of the Australian lithosphere is a key mechanism responsible for the current tectonic development of the Timor Sea. This seismic-based tectonic study constrains these numerical models inferring a combination of mechanisms to explain the modern extensional faulting of the study area. This study integrates interpretations from 2D and 3D seismic-reflection data with standard wireline logs of two wells to subdivide the subsurface of the study area into five seismic units, corresponding to a Paleozoic basement, thick Mesozoic clastic and carbonate sequences and a topmost Cenozoic succession of predominantly carbonate rocks. This sedimentary succession is deformed by numerous normal faults, of which 165 were mapped in 3D, particularly focusing on the displacement of the recent to sub-recent sedimentary cover. The modern structural styles encountered in the study area resulted in the differentiation of three normal-fault sets. This seismic-based tectonic analysis ultimately ground truths theoretical models of lithospheric flexure, highlighting the importance of combining modelling studies with observational field-based constraints.
1 INTRODUCTION

A 2D and 3D seismic-based structural analysis of the Ashmore Platform in NW Australia is aimed to unravel the tectonostratigraphic processes resulting from an early-stage foreland basin deformation in the Timor Sea region.

A re-evaluation of lithospheric flexural models proposed for this region (e.g., Llorens and Lorenzo 2004; Jangh et al. 2011) and a comparison against the observed fault pattern reveal various differences.

2 GEOLOGICAL SETTING

The study area is situated offshore on the Timor Sea region of the Australian North West Shelf. The Timor Sea region has a complex evolution history, involving the interaction of the Banda Arc, a volcanic and island arc belt (e.g., Flem and Wilson, 2000), a network of long-lived sedimentary basins, such as the Browse and Bonaparte Basin (Harmsworth and Keep, 2005), as well as highly structured blocks: Ashmore and Sahul Platforms (Geoscience Australia, 2011).

Key events in the evolution of North West Shelf Australia (NWS)

- Extension on NW Australia began in the Late Devonian in response to the break-up of Gondwana (Bailie et al., 1994). During the early Permian, extension led to the creation of a wide intracratonic rift. A Triassic-Jurassic sedimentary sequence was accommodated by this wide depocenter (Ethridge and O'Brien, 1994).
- During the Jurassic-Early Cretaceous, seaward spreading at the rift axis started and the present day passive margin of NW Australia developed (Bailie et al., 1994; Jangh et al., 2002). Tectonics ceased had the Aptian, after which time the NWS was blanketed by a thick passive margin succession comprising terrigenous and carbonate units (Harmsworth and Keep, 2005).
- During the Oligocene, the collision of the northern margin of Australia with the Banda Arc influenced the NWS (Bailie et al., 1994), collision reached the Timor region around 2.5 Ma (Keppie et al., 1998). Thrusted crust of the Australian continental margin was subducted beneath the Banda Arc, the attached oceanic crust was broken off during late Neogene (Hall and Wilson, 2000). Youngest Australian continental crust juvenile the subduction zone in the Timor region around 2 Ma (Keepie et al., 1998), causing a reversal of the subduction polarity (Christensen and Boethius, 1981; McCaffrey, 1986).
- At the present time, subduction in the Timor Basin has ceased (Hughes et al., 1996); the Timor Trough as well as the others troughs ranging the Banda Arc have evolved from subduction trenches to a distinct frontal (deepwater) foreland basin (Carter et al., 1976; Audley-Charles, 1986; Ziegler et al., 1998).

3 INPUT DATA

The tectonostratigraphic processes and their surface expression in the Ashmore Platform region were analyzed by integrating the following 2D seismic lines from the Browse-88 2D offshore seismic survey set (BMRX) and 9,467 km² from the North Browse TGS3D seismic survey. The wireline information of two wells: Ashmore Reef No. 1 (AR1) and Sahul Shelf No. 1 (SS1) was available for this study; the wells were drilled in 1969 and 1970, respectively. The well information was obtained from the ADMS database: which is provided by the Department of Mines and Petroleum from the Government of Western Australia.

4 INTEGRATION OF SEISMIC AND WELL INTERPRETATIONS

Wireline-log interpretations were carried out to gain lithological information about the subsurface. From the seismic data interpretation the seafloor (1H), first few horizons (1H2, 1H4, 1H5 and 1H6) were mapped along the entire area. Based on the horizon interpretation the subsurface is subdivided into five seismic units: U2, U3, U4 and acoustic basement; which correspond to a Pechora, basement, thick Mezozoic clastics and carbonate sequences and a topmost Cretaceous succession of predominantly carbonate rocks.
Tectonophysical processes and their surface feedback in the Ashmore Platform region, Timor Sea: a combined 2D and 3D seismic-reflection analysis

Silvia B. Cardona & Stefan Back

4 INTEGRATION OF SEISMIC AND WELL INTERPRETATIONS

Seismic Unit U1

Seismic Unit U2

Seismic Unit U4

Acoustic Basement

Across the southern study area the acoustic basement is characterized by acoustically chaotic and discontinuous, low frequency reflectors.

The acoustic basement sub-units occur in the northern and central area, a sub-unit occurs above U4, which is characterized by high acoustic reflectivity with dipping dips.

<table>
<thead>
<tr>
<th>Seismic Unit</th>
<th>Boundaries</th>
<th>Seismic character</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>Low frequency, semi-continuous to discontinuous reflectors of low amplitude</td>
<td></td>
</tr>
<tr>
<td>U2</td>
<td>A set of reflections with low frequency, semi-continuous to discontinuous and low amplitude alternating with very high amplitude reflections</td>
<td></td>
</tr>
<tr>
<td>U4</td>
<td>High frequency, high amplitudes, discontinuous reflectors with increasing depth the reflections decrease in amplitude as well as in frequency</td>
<td></td>
</tr>
<tr>
<td>Sub-unit</td>
<td>Sub-unit reflections, strong amplitude in high frequency reflections are alternating with weak amplitude reflections</td>
<td></td>
</tr>
</tbody>
</table>

A set of variable reflectors with higher frequency, semi-continuous to discontinuous and low amplitude alternating with very high amplitude reflections.
5 LITHOSPHERIC FLEXURE MODELS

Different models have been proposed to justify the abnormal normal faulting within a remotely convergent plate-margin setting.

Loudot and Lorenz (2004) used simple bending elastic beam models and proposed that extensional stresses, created during the bending of the north-eastern edge of the Australian plate under the load of the Faroe-Synagregory accretionary prism, could have triggered the Neogene reactivation and/or the new growth of normal faulting in the Timor region.

By integrating the structural analysis with 2D elastic half-beam models and regional schematic plate reconstructions, Langh et al. (2011) argued that lithospheric flexure of the Australian plate margin, due to thrust loading around the Timor Island, could explain the Neogene structural style in the Timor region.

6 OBSERVED FAULT PATTERN

The topmost recent sedimentary cover is deformed by numerous normal faults, of which 16S were mapped in 3D. A detailed structural analysis of the recent to sub-recent fault development in the study area resulted in the differentiation of three normal fault sets:

- **FAULT SET 1** cut the seafloor, indicating that this fault population has been recently active and thus reflect the recent stress state. These sub-sets of currently active faults are identified:
  - Faults from sub-set 1a are NE striking and their location coincides with the Australian present-day shelf-slope break; this fault sub-set is interpreted to have developed due to the gravitational collapse of the present-day upper continental slope.
  - Faults of sub-set 1b are ESE striking; these faults are interpreted as flexure-induced normal faults that represent the structural response to bending at the current location of the modern foreland hinge.
  - According to the structural interpretations, this study evidences a different present-day foreland hinge location than Langh et al. (2011).

- **FAULT SET 2** trends NE-SW with shallower to moderate dips. These faults terminate with their upper tip between the seafloor (horizon 1H) and the underlying horizon 1G; they can be observed in the central part of the study area. This fault set is most likely associated to the flexure of the Australian Plate, and their sub-floor location at distance to fault set 1 evidences a landward migration of the flexural foreland hinge area.

- **FAULT SET 3** the oldest faults interpreted in this study are restricted to the northeastern area. These are extensional, NE striking faults that dip shallowly towards the NW and SE. These faults terminate downslope within the acoustic basement, and upward within horizon 1G. This fault set can be interpreted to have formed in response to the Australian lithospheric flexure. Their location, in the northern study area, confirms that the normal faulting front moved southwards across the Australian plate.

7 CONCLUSIONS

- This seismic-basins tectonic analysis constrains theoretical models of lithospheric flexure, highlighting the importance of combining modelling studies with field-based observations.
- 2D elastic half-beam models of Loudot and Lorenz (2004) and simple bending elastic beam models from Langh et al. (2011) evidence that bending of the Australian lithosphere is a key mechanism responsible for the current tectonic development of the Timor Sea.
- Based on structural interpretations, this study evidences that flexure-induced normal faulting began to affect the Australian plate in the northeast and propagated southwestward through time, contrasting with the eastward stress propagation proposed by Loudot and Lorenz (2004), as well as a different present-day foreland hinge location than Langh et al. (2011).

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