Tectonophysics 651–652 (2015) 1–18

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Evolution of faulting and plate boundary deformation in the Southern Taranaki Basin, New Zealand

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ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form 13 February 2015
Accepted 15 February 2015
Available online 22 February 2015

Keywords:
Tectonics
Plate boundary evolution
Crustal deformation
Fault inversion and reactivation
Fault reactivation

ABSTRACT

Faulting and folding in the Southern Taranaki Basin constrain the evolution of the New Zealand plate boundary since ~80 Ma. Sedimentary rocks up to 8 km thick record multiple phases of deformation which have been examined using 2D and 3D seismic reflection data, resulting in fault displacement–time curves and basin-wide isopach maps with temporal resolutions of 5–10 Myr and 1–4 Myr pre- and post-~23 Ma respectively. Three main phases of tectonic activity have been recognised; Late Cretaceous and Palaeocene extension (~80–55 Ma), mainly Oligocene and younger contraction and Plio-Pleistocene (~3.7–0 Ma) extension. Most of the largest faults (e.g., Cape Egmont Fault) accrued displacement during the Late Cretaceous and were reactivated one or more times during subsequent episodes of deformation. The oldest phase of extension occurred during Gondwana break-up and was ubiquitous throughout the basin. Contraction along the eastern boundary of the basin, associated with the onset of Hikurangi Margin subduction, commenced as early as Late Eocene. The zone of contraction widened and migrated westward during the Miocene with reverse faults and folds in westernmost parts of the basin formed in the Late Miocene (~7–5 Ma). Initiation and episodic widening of this zone of contraction may have been partly triggered by changes in the rate of plate convergence. Contraction is now mainly confined to the northern South Island and has been succeeded to the north by Plio-Pleistocene extension. The present day transition zone between extension in the north and contraction in the south is defined by a WNW-trending line across the basin. The extension–contraction transition migrated southward during the Late Miocene and Pliocene consistent with steepening of the subducting plate and associated southward movement of the southern termination of the Hikurangi subduction system.

1. Introduction

Active crustal deformation is generally concentrated within plate boundary zones. The style and magnitude of deformation in these zones can vary spatially and temporally, being dependent on many factors including, the relative plate motions and the type of plate boundary (e.g., subduction, seafloor spreading, transform and continental collision) (e.g., Bangs and Cande, 1997; Harding and Lowell, 1979; Molnar and Tapponier, 1975; Moore and Karig, 1980; Norris et al., 1990; Uyeda and Kanamori, 1979). Along convergent plate boundaries, like the Hikurangi subduction margin, New Zealand, uplift and erosion often results in partial or complete removal of the syn-deformational stratigraphic record. Preservation of these growth strata is most common in subsiding marine basins where sedimentation rates are higher than fault displacement rates and these strata provide important information about the regional tectonic evolution.

The mainly offshore Taranaki Basin contains up to 8 km of Late Cretaceous and younger strata which constrain the evolution of the New Zealand plate boundary during both Mesozoic break-up of Gondwana and Cenozoic subduction of the Pacific plate (Giba et al., 2010; King and Robinson, 1988; King and Thrasher, 1996; Nicol et al., 2005; Thrasher, 1990). The basin largely sits within the current New Zealand plate boundary zone and the observed deformation (i.e. faulting and folding) provides a distal record of plate boundary processes (Fig. 1). The Taranaki Basin is unusual in that its deformed sedimentary rocks are imaged by an extensive network of seismic reflection lines tied to many wells (~500 total with >150 offshore). We focus on the NE–SW trending southern Taranaki Basin (STB) which forms the westernmost 100 km of the current plate boundary zone, 300–450 km west of the Hikurangi subduction trough and 100–200 km north of the transpressive Alpine Fault (Fig. 1). While many deformation studies have been conducted on specific types of plate boundary (e.g., Bangs and Cande, 1997; Molnar and Tapponier, 1975; Moore and Karig, 1980), few have been completed in regions where the type of plate boundary changes along strike from subduction to continental collision

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http://dx.doi.org/10.1016/j.tecto.2015.02.009
0040-1951/

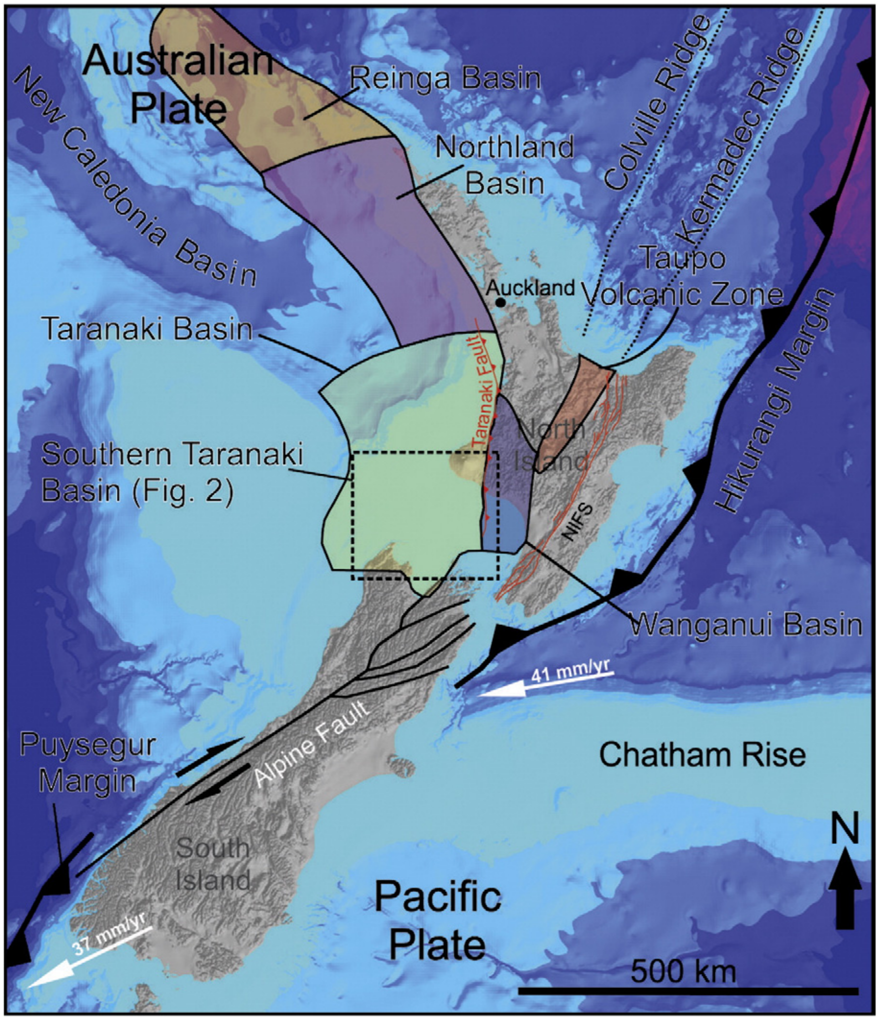

Fig. 1. New Zealand's plate tectonic setting astride the Pacific–Australian plate boundary showing the study area (Fig. 2) and main tectonic elements of the plate boundary zone. Grey shading indicates onshore topography and blue colours offshore bathymetry in 1000 m contours. Relative plate motion vectors are denoted by white arrows and numbers.
From Beavan and Haines (2001).

and the deformation record is near complete. This paper offers insights into plate boundary evolution along the margin of a region where plate convergence transitions southwards from subduction to continental collision and oblique strike-slip faulting.

This paper outlines the tectonic history of faults in the STB since ~80 Ma. Displacement histories for 21 of the largest faults have been analysed using displacement backstripping and the influence of faulting on sedimentation examined with regional isopach maps. These data and analysis provide improved resolution of the kinematics of faulting and the timing of deformation during Gondwana break-up and subsequent Cenozoic plate convergence. Many of the faults have been reactivated multiple times with faulting migrating along and across the basin at different times. Changes in the styles, spatial distribution and magnitudes of faulting suggest changes in the geometries and relative motion of the Pacific and Australian plates during the Cenozoic. The results of this study have implications for the evolution of the New Zealand plate boundary, for other plate boundaries where spatio-temporal changes in deformation are not well resolved by growth strata, and for the formation of petroleum structural traps.

2. Tectonic setting and history

The Southern Taranaki Basin (STB) is mainly offshore west of New Zealand's North Island and north of the South Island (Figs. 1 & 2). The basin developed on the Australian plate and much of it constitutes part of the deformation zone associated with the present Australian–Pacific plate boundary. The STB has accumulated up to 8 km of mainly Late Cretaceous (~80 Ma) and younger sedimentary strata (Fig. 3). The basin is asymmetric and thickens towards its eastern boundary which is formed by the contractional Taranaki Fault System (Fig. 2) (Holt and Stern, 1994; King and Thrasher, 1996; Stagpoole and Nicol, 2008).

The STB is located towards the southern end of the Kermadec–Hikurangi subduction system and records deformation associated with the transition from subduction to transpression along the Alpine Fault (Fig. 1). The New Zealand land mass primarily exists due to uplift associated with Cenozoic plate convergence across the Australian–Pacific plate boundary (Kamp, 1986; Nicol et al., 2007; Tippett and Kamp, 1993; Walcott, 1978, 1998; Wallace et al., 2007). East of the North Island, the Pacific Plate is subducting westward beneath the Australian plate along the Hikurangi Trough at rates of 41–48 mm/yr (e.g., Barnes and de Lepinay, 1997; Davey et al., 1986; Lewis, 1980; Wallace et al., 2004). In the northern South Island, subduction transitions to transpression and continental collision along the Alpine Fault. Southwest of the South Island, the Alpine Fault gives way to the Puysegur subduction system where the Australian plate subducts eastward beneath the Pacific Plate at rates of 30–35 mm/yr (Fig. 1) (Lamarche and Lebrun, 2000; Walcott, 1978, 1998).