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Geologic and kinematic constraints on Late Cretaceous to mid Eocene plate boundaries in the southwest Pacific

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ABSTRACT

Starkly contrasting tectonic reconstructions have been proposed for the Late Cretaceous to mid Eocene (~85–45 Ma) evolution of the southwest Pacific, reflecting sparse and ambiguous data. Furthermore, uncertainty in the timing of and motion at plate boundaries in the region has led to controversy around how to implement a robust southwest Pacific plate circuit. It is agreed that the southwest Pacific comprised three spreading ridges during this time: in the Southeast Indian Ocean, Tasman Sea and Amundsen Sea. However, one and possibly two other plate boundaries also accommodated relative plate motions: in the West Antarctic Rift System (WARS) and between the Lord Howe Rise (LHR) and Pacific. Relevant geologic and kinematic data from the region are reviewed to better constrain its plate motion history during this period, and determine the time-dependent evolution of the southwest Pacific regional plate circuit. A model of (1) west-dipping subduction and basin opening to the east of the LHR from 85–55 Ma, and (2) initiation of northeast-dipping subduction and basin closure east of New Caledonia at ~55 Ma is supported. West-dipping subduction and basin opening were not driven by convergence, as has previously been proposed. Our plate circuit analysis suggests that between at least 74 Ma and subduction initiation at ~55 Ma there was little net relative motion between the Pacific plate and LHR, <20 km of convergence with a component of strike-slip motion. Subduction must therefore have been primarily driven by the negative buoyancy of the slab, or perhaps forced trench retreat due to orogenic collapse. We propose that at least two plate boundaries separated the Pacific plate from the LHR during this time, however, as there was little to no motion between these plates then a plate circuit which treats the Pacific plate and LHR as a single plate ("Australian" circuit) will produce similar kinematic results to a circuit which leaves their relative motion unconstrained and treats them as separate plates ("Antarctic" circuit). Prior to 74 Ma the reliability of magnetic anomalies from southwest Pacific spreading systems is questionable and it is difficult to properly test alternative plate circuits. After 55 Ma we advocate using an Antarctic plate circuit as the Australian plate circuit models that were tested predict significant net compression in the WARS, for which evidence is absent. Our preferred model makes testable predictions, such as burial of an arc beneath the Tonga and Vitiaz ridges, and Late Cretaceous to Eocene slabs in the mantle beneath the southwest Pacific, both of which can be investigated by future work. These predictions are particularly important for testing the earlier 85–55 Ma phase of the model, which is largely underpinned by ages and interpretations of South Loyalty Basin crust obducted onto New Caledonia, rather than an extinct arc or arc-related rocks.

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1. Introduction

The southwest Pacific (Fig. 1) has had a complex tectonic history since final Gondwanaland dispersal began, dominated by multiple episodes of marginal and back-arc basin formation, subduction and trench rollback (e.g. Crawford et al., 2003; Sdrolias et al., 2003; Schellart et al., 2006; Whattam et al., 2008; Cluzel et al., 2012a,b). Understanding the history of this complicated plate boundary activity in the southwest Pacific is of regional and global significance, including for understanding basin subsidence and hydrocarbon formation along the Lord Howe Rise (LHR) and around New Zealand, understanding the mechanisms accommodating Tasman Sea spreading (e.g. Schellart et al., 2006), and modeling mantle plumes within global plate kinematic models. However, less than 10% of the continental crust now in the South Pacific that rifted away from Australia and Antarctica is presently sub-aerially exposed and readily accessible for field exploration (Mortimer, 2008). Sub-aerial exposures are largely complicated by Cenozoic crustal thickening events in New Zealand and New Caledonia. Furthermore, data coverage in several offshore locations (e.g. Coral Sea) is sparse, and partial or complete basin subduction has destroyed large swaths of ocean crust. The magnetic isochrons created at the Tasman, Amundsen and Bellinghausen ridge systems provide the earliest robust constraints on the position of the Pacific plate relative to the rest of the global plate network — prior to this time the Pacific was completely surrounded by subduction zones (Seton et al., 2012). However, while spreading in the Tasman, Amundsen and Bellingshausen seas is reasonably well-constrained, alternative models exist for the early spreading history between Australia and Antarctica (Royer and Rollet, 1997; Tikku and Cande, 1999, 2000; Whittaker et al., 2007, 2013). Together, these data gaps have made it difficult to build well-constrained regional plate reconstruction models, and there remain many unresolved and hotly debated problems relating to southwest Pacific evolution. Questions remain concerning the timing, location and polarity of different subduction episodes, the driving mechanism for obduction events in New Caledonia and New Zealand, the mechanism for Tasman Sea opening and widespread rifting in Zealandia (Fig. 1), seafloor ages and the orientation of spreading in various basins (e.g. d'Entrecasteaux Basin), and the origin of several submerged tectonic features (e.g. South Rennell Trough). Conversely, the existence of Tonga–Kermadec subduction (Bloomer et al., 1995) and plate boundary activity within New Zealand (Sutherland, 1995) from at least 45 Ma is well established. Many of the unresolved issues related to southwest Pacific evolution are related to the poorly understood timing and type of plate boundary activity to the east of the LHR during the Late Cretaceous to mid Eocene. This problem will, therefore, be the focus of our study.

A robust reconstruction model for the southwest Pacific has wider implications for global geodynamic studies. Plates in the Pacific realm