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Earth-Science Reviews 76 (2006) 191–233
EARTH-SCIENCE REVIEWS
www.elsevier.com/locate/earscirev

A Late Cretaceous and Cenozoic reconstruction of the Southwest Pacific region: Tectonics controlled by subduction and slab rollback processes

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Received 21 July 2005; accepted 18 January 2006
Available online 3 May 2006

Abstract

A Cenozoic tectonic reconstruction is presented for the Southwest Pacific region located east of Australia. The reconstruction is constrained by large geological and geophysical datasets and recalculated rotation parameters for Pacific–Australia and Lord Howe Rise–Pacific relative plate motion. The reconstruction is based on a conceptual tectonic model in which the large-scale structures of the region are manifestations of slab rollback and backarc extension processes. The current paradigm proclaims that the southwestern Pacific plate boundary was a west-dipping subduction boundary only since the Middle Eocene. The new reconstruction provides kinematic evidence that this configuration was already established in the Late Cretaceous and Early Paleogene. From ~82 to ~52 Ma, subduction was primarily accomplished by east and northeast-directed rollback of the Pacific slab, accommodating opening of the New Caledonia, South Loyalty, Coral Sea and Pocklington backarc basins and partly accommodating spreading in the Tasman Sea. The total amount of east-directed rollback of the Pacific slab that took place from ~82 Ma to ~52 Ma is estimated to be at least 1200 km. A large percentage of this rollback accommodated opening of the South Loyalty Basin, a north–south trending backarc basin. It is estimated from kinematic and geological constraints that the east–west width of the basin was at least ~750 km. The South Loyalty and Pocklington backarc basins were subducted in the Eocene to earliest Miocene along the newly formed New Caledonia and Pocklington subduction zones. This culminated in southwestward and southward obduction of ophiolites in New Caledonia, Northland and New Guinea in the latest Eocene to earliest Miocene. It is suggested that the formation of these new subduction zones was triggered by a change in Pacific–Australia relative motion at ~50 Ma. Two additional phases of eastward rollback of the Pacific slab followed, one during opening of the South Fiji Basin and Norfolk Basin in the Oligocene to Early Miocene (up to ~650 km of rollback), and one during opening of the Lau Basin in the latest Miocene to Present (up to ~400 km of rollback). Two new subduction zones formed in the Miocene, the south-dipping Trobriand subduction zone along which the Solomon Sea backarc Basin subducted and the north-dipping New Britain–San Cristobal–New Hebrides subduction zone, along which the Solomon Sea backarc Basin subducted in the west and the North Loyalty–South Fiji backarc Basin and remnants of the South Loyalty–Santa Cruz backarc Basin subducted in the east. Clockwise rollback of the New Hebrides section resulted in formation of the North Fiji Basin. The reconstruction provides explanations for the

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0012-8252/$ - see front matter
doi:10.1016/j.earscirev.2006.01.002

formation of new subduction zones and for the initiation and termination of opening of the marginal basins by either initiation of subduction of buoyant lithosphere, a change in plate kinematics or slab–mantle interaction.

Keywords: subduction; slab; rollback; hinge-retreat; backarc; extension; spreading; Southwest Pacific; tectonics; geodynamics; reconstruction; Cretaceous; Cenozoic

1. Introduction

Most backarc basins have an extensional origin and are characterized by their relatively short time-span of backarc activity (10–30 Myr). Several backarc regions experienced sequential opening of individual backarc basins during distinct episodes. For example, in the Western Mediterranean region, two backarc basins can be identified, which developed during distinct episodes separated by a period of tectonic quiescence in the overriding plate (Séranne, 1999). Backarc extension started with opening of the Liguro–Provencal Basin from ~30 to ~16 Ma and resumed during opening of the Tyrrhenian Basin from ~10 Ma to Present. In the Western Pacific, two backarc basins can be identified which formed during two separate episodes. Opening of the Parece–Vela Basin from ~30 to ~15 Ma (Sdrolias et al., 2004a) was followed by a period of tectonic quiescence in the backarc region, while backarc basin formation resumed during opening of the Mariana Trough from ~10 Ma to Present (Fryer, 1996).

Probably the most striking example of episodic basin formation is located in the Southwest Pacific region east of Australia (Fig. 1). Here, a sequence of five basins can be recognized trending north–south to northwest–southeast. From west to east, these basins include the Tasman Sea Basin, the New Caledonia Basin, the Norfolk Basin, the South Fiji Basin and the Lau–Havre Basin. The easternmost basin is an active backarc basin and is bordered to the east by an active volcanic arc, the Tonga–Kermadec arc, underneath which the Pacific plate is subducting towards the west. The current rate of opening in the Lau–Havre Basin increases from only ~1.5–2.0 cm/yr in the south to ~15.9 cm/yr in the north (Wright, 1993; Bevis et al., 1995).

The opening of the previously mentioned five basins took place from the Late Cretaceous to Present, but the reason for opening of these basins, in particular the Late Cretaceous to Eocene ones, remains enigmatic. The absolute motion of the Australian plate was northward to eastward, subparallel to subperpendicular to its eastern and northern boundaries (Gordon and Jurdy, 1986; Yan and Kroenke, 1993; Müller et al., 2000). Thus, one can rule out that the absolute motion of the Australian plate away from the eastern and northern plate boundaries was the driving mechanism for extension and spreading in the basins. Potentially, the older basins formed as backarc basins, just as the Lau–Havre Basin, and would thus be genetically related to the Pacific subduction zone. This would imply eastward to northeastward rollback of the Pacific slab to accommodate the opening and extension of the basins along the eastern margin of the Australian plate. The process of slab rollback has been proposed previously for numerous backarc basins on Earth and is thought to be driven by the negative buoyancy of the slab with respect to the surrounding mantle (Elsasser, 1971; Molnar and Atwater, 1978; Garfunkel et al., 1986; Hamilton, 1988; Lonergan and White, 1997; Wortel and Spakman, 2000; Schellart et al., 2003; Funiciello et al., 2003; Schellart and Lister, 2004; Schellart, 2004a, 2005). The negative buoyancy force induces backward sinking of the slab at an angle oblique to the dip of the slab causing retreat of the hinge at the surface, which forces the overriding plate to extend as it collapses towards the retreating hinge (Elsasser, 1971; Schellart and Lister, 2004).

A problem with the rollback model for the Southwest Pacific marginal basins is that it requires west to southwestward subduction, but it is not clear how long the current Southwest Pacific subduction zone has been active. There is ample evidence for west to southwest-dipping Pacific subduction since ~45 Ma, based on arc volcanics from the Solomon Ridge, Fiji block and Tonga arc dating back to the Eocene (Hathway, 1993; Hawkins, 1995; Bloomer et al., 1995; Petterson et al., 1999; Crawford et al., 2003). Thus, rollback of the Pacific slab could potentially explain opening of the South Fiji and Norfolk basins in the Oligocene to Early Miocene, and opening of the Lau–Havre Basin from the latest Miocene to Present. However, the Tasman Sea Basin, Coral Sea Basin and New Caledonia Basin, as well as two former backarc basins (the South Loyalty Basin and the Pocklington Basin) formed well before 45 Ma.