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Animated tectonic reconstruction of the Southern Pacific and alkaline volcanism at its convergent margins since Eocene times

Graeme Eagles [a,*], Karsten Gohl [b], Robert D. Larter [c]

[a] Geology Department, Royal Holloway University of London, Egham, TW20 0EX, UK
[b] Alfred Wegener Institute for Polar and Marine Research, Postfach 120161, Bremerhaven D-27515, Germany
[c] British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK

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Abstract

An animated reconstruction shows South Pacific plate kinematics, in the reference frame of West Antarctica, between 55 Ma and the present-day. The ocean floor in the region formed due to seafloor spreading between the Antarctic, Pacific, Phoenix and Nazca plates (a plate formed by fragmentation of the Farallon plate early in Oligocene times). The Pacific–Antarctic Ridge remained fairly stable throughout this time, migrating relatively northwestwards, by various mechanisms, behind the rapidly-moving Pacific plate. The Nazca and Phoenix plates also moved quickly, but relatively towards the east or southeast, and were subducted in these directions beneath the South American and Antarctic plates. Segments of spreading centres forming at the trailing edges of the Nazca and Phoenix plates periodically collided with these subduction zones, resulting in the total destruction of the Nazca–Phoenix spreading centre and the partial destruction of the Nazca–Antarctica spreading centre (the Chile Ridge) and Antarctic–Phoenix Ridge, which ceased to operate shortly before its northeasternmost three segments could collide with the Antarctic margin. Following collision of segments of the Chile Ridge, parts of the Antarctic plate underwent subduction at the Chile Trench. After these collisions, slab windows should have formed beneath both the South American and Antarctic convergent margins, and the animation shows occurrences of alkaline volcanism that have been, or can newly be, related to them. Further occurrences of alkali basalts, at the margins of the Powell Basin and, more speculatively, James Ross Island, can be related to the formation of a slab window beneath them following the collision of segments of the South America–Antarctica spreading centre in the northwest Weddell Sea.

Keywords: Plate kinematics; Subduction; Slab windows; Alkaline volcanism; Antarctica; South America

1. Introduction

The Late Cretaceous and early Tertiary plate kinematic history of the Southwest Pacific was complicated and involved independent movements of a small oceanic plate (Stock and Molnar, 1987; Stock et al., 1996; Eagles et al., 2004a), subduction and the consequences of its cessation (Larter et al., 2002), and a major plate-tectonic reorganization around chron C27 (~61 Ma) (Cande et al., 1995).

Further north and east (Fig. 1), and during later times, the situation was somewhat simpler. The Phoenix plate underwent subduction beneath the Antarctic Peninsula at its southeastern boundary, with which segments of the Antarctic–Phoenix ridge periodically collided leading to near-total destruction of the Phoenix plate (Larter and Barker, 1991). During much of Paleogene times, Antarctica underwent extension as the West Antarctic rift system slowly moved East Antarctica apart from West Antarctica, which we assume here included the Antarctic Peninsula (Behrendt et al., 1991; Cande et al., 2000). In addition to this, a complex of oceanic basins developed in the Scotia Sea at the region's eastern extremity, where west-directed subduction of the South American plate resulted in slow eastwards motion of an arc plate, as seen from Antarctica (Eagles et al., 2005). In the northeast of the study area, the Farallon plate moved rapidly eastwards towards a subduction zone at the western margin of South America (Cande and Leslie, 1986). At its southern and western edges, new seafloor material accreted

* Corresponding author. Tel.: +44 1784 443890; fax: +44 1784 471780.
E-mail address: g.eagles@gl.rhul.ac.uk (G. Eagles).

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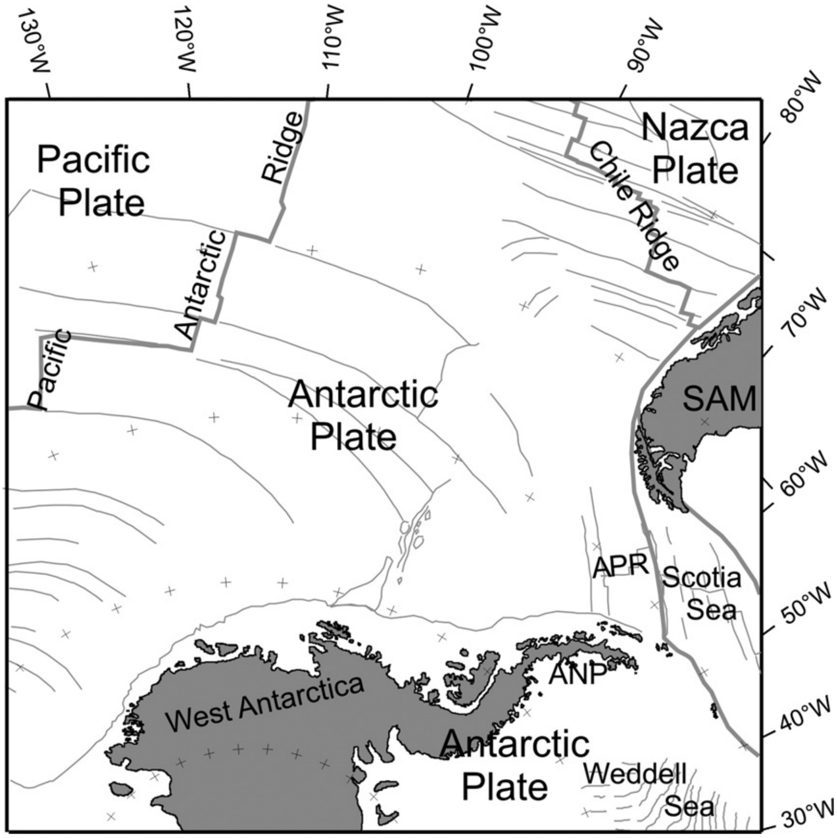

Fig. 1. Prominent lineaments interpreted from gravity anomalies of the southern Pacific, illustrating places referred to in the introduction. ANP: Antarctic Peninsula, APR: Antarctic–Phoenix Ridge, SAM: South America. Present-day plate boundaries are shown as bold grey lines.

to the Farallon plate at its margins with the Pacific, Antarctic and Phoenix plates (Cande et al., 1982). At about 23 Ma, the Farallon plate broke up into two smaller plates (Meschede and Barckhausen, 2000) the southern of which, Nazca, continued to subduct at the southern Chile Trench.

From time to time, ridge crests and/or transform faults collided with the subduction zones at the east of the region, changing the identity of the overriding plate and, with it, the rate and azimuth of relative plate motion. As a result, subduction either ceased, or changed in such a way that the subducted slabs momentarily or permanently disappeared from the depths they had previously occupied below the overriding plates, forming so-called slab windows. Worldwide, the formation of slab windows has been related to the presence of alkaline volcanism on the overriding plates in those locations lacking features that are usually taken as independent evidence for extension or mantle plumes, to which such volcanism is otherwise usually attributed (Thorkelson and Taylor, 1989). Because these rocks contain little or no trace of contamination by subduction-related processes, it is thought that they originate when mantle material that had previously been trapped beneath the slab rapidly ascends into the volume vacated by the slab, and undergoes decompression melting.

Here we review together the plate tectonic history of the southern Pacific Ocean and the alkaline volcanism at its convergent margins, using a high resolution animation of plate kinematics illustrated by its oceanic free-air gravity anomalies (McAdoo and Laxon, 1997; Sandwell and Smith, 1997).

2. Method

Eagles et al (2004b) describe the creation of a set of grid files showing reconstructed gravity anomalies and the BEDMAP sub-ice topography data set (Lythe et al., 2000) that are used as the bases of colour frames for an animation concentrating on the period 90–45 Ma. In addition to these, for this new animation we have included gridded data showing the onshore topography of South America (Smith and Sandwell, 1996), and gravity data showing the formation of the Powell Basin and motion of the Nazca plate east of the Chile Ridge. To do this we used rotation parameters for Antarctica–Nazca and Powell Basin relative motions taken from Tebbens and Cande (1997) and Eagles and Livermore (2002). Small motions of the Hudson microplate (Eakins, 2002), and the Selkirk, Friday, and other microplates at the margins of the Nazca plate (Tebbens and Cande, 1997; Tebbens et al., 1997) are not depicted as there are no rotations published to describe them, although the incorporated microplates are shown after their extinctions.

As in the earlier study, we show reconstructed plate boundaries and isochron data from Cande et al. (1989) as vector data overlaid on the individual frames. All magnetic anomalies are dated based on the magnetic reversal timescale of