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Influence of subduction history on South American topography

Nicolas Flament[a,*], Michael Gurnis[b], R. Dietmar Müller[a], Dan J. Bower[b,1], Laurent Husson[c,d]

[a] EarthByte Group, School of Geosciences, University of Sydney, NSW 2006, Australia
[b] Seismological Laboratory, California Institute of Technology, Pasadena CA, USA
[c] Université de Grenoble Alpes, Institut des Sciences de la Terre (ISTerre), F-38041 Grenoble, France
[d] CNRS, Institut des Sciences de la Terre, F-38041 Grenoble, France

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ABSTRACT

The Cenozoic evolution of South American topography is marked by episodes of large-scale uplift and subsidence not readily explained by lithospheric deformation. The drying up of the inland Pebas system, the drainage reversal of the Amazon river, the uplift of the Sierras Pampeanas and the uplift of Patagonia have all been linked to the evolution of mantle flow since the Miocene in separate studies. Here we investigate the evolution of long-wavelength South American topography as a function of subduction history in a time-dependent global geodynamic model. This model is shown to be consistent with these inferred changes, as well as with the migration of the Chaco foreland basin depocentre, that we partly attribute to the inboard migration of subduction resulting from Andean mountain building. We suggest that the history of subduction along South America has had an important influence on the evolution of the topography of the continent because time-dependent mantle flow models are consistent with the history of vertical motions as constrained by the geological record at four distant areas over a whole continent. Testing alternative subduction scenarios reveals flat slab segments are necessary to reconcile inferred Miocene shorelines with a simple model paleogeography. As recently suggested, we find that the flattening of a subduction zone results in dynamic uplift between the leading edge of the flat slab segment and the trench, and in a wave of dynamic subsidence associated with the inboard migration of the leading edge of flat subduction. For example, the flattening of the Peruvian subduction contributed to the demise of Pebas shallow-water sedimentation, while continental-scale tilting also contributed to the drainage reversal of the Amazon River. The best correlation to P-wave tomography models for the Peruvian flat slab segment is obtained for a case when the asthenosphere, here considered to be 150 km thick and 10 times less viscous than the upper mantle, is restricted to the oceanic domain.

1. Introduction

Mantle flow influences the long-wavelength topography of continents (Gurnis, 1993), but progress has been relatively slow in quantifying the time-dependence of dynamic topography. South America is an ideal continent to investigate the evolution of subduction-driven long-wavelength dynamic topography (e.g. Lithgow-Bertelloni and Gurnis, 1997; Flament et al., 2013) because subduction has been continuous along its western margin at least since the Jurassic (Seton et al., 2012) and the last plume-related large igneous province to be emplaced regionally was the Parana-Etendeka at ∼132 Ma (Bryan and Ferrari, 2013). Several studies have investigated the influence of changes in subduction characteristic on the evolution of the topography of South America since the Miocene (Guillaume et al., 2009; Dávila et al., 2010; Shephard et al., 2010; Dávila and Lithgow-Bertelloni, 2013, 2015; Eakin et al., 2014). Changes in the geometry of subduction have been considered in series of instantaneous mantle flow models. The uplift of Patagonia (Guillaume et al., 2009; Pedoja et al., 2011; Fig. 1a) has been linked to the opening of a slab window under Patagonia, where an active spreading center has been intersecting the Chilean trench since ∼14 Ma (Fig. 1b). Changes in slab dip angle, particularly the flattening of the South American slab under Chile and Peru since the late Miocene (Fig. 1b; Kay and Mpodozis, 2001; Ramos and Folguera, 2009), are proposed to explain the uplift of the Sierras Pampeanas (Dávila et al., 2010; Dávila and Lithgow-Bertelloni, 2013, 2015; Fig. 1a), and the uplift

* Corresponding author. Tel.: +61 02 9351 7576; fax: +61 02 9351 2442.
E-mail address: nicolas.flament@sydney.edu.au (N. Flament).
[1] Now at: Institute of Geophysics, Department of Earth Sciences, ETH, Zürich, Switzerland.

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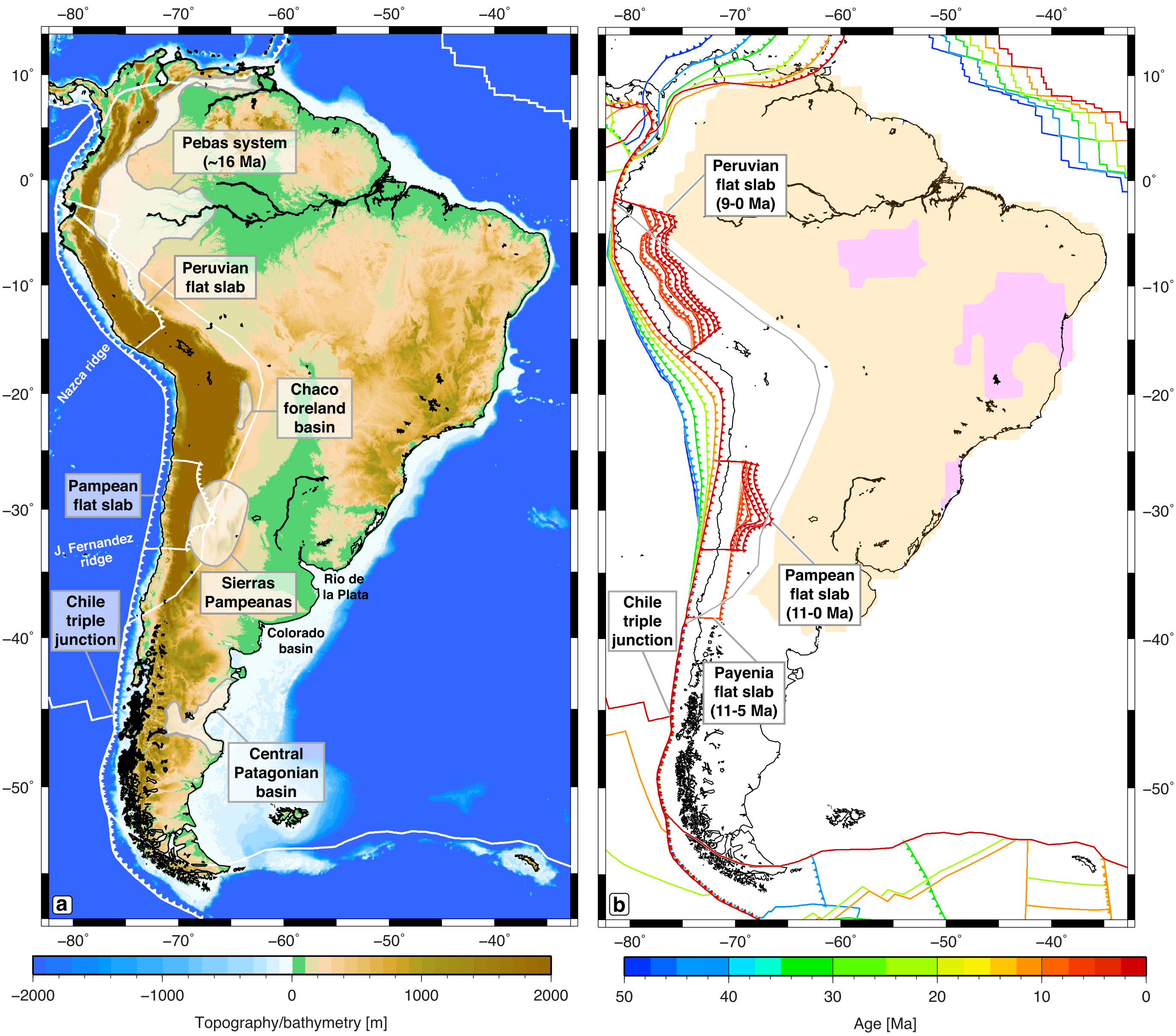

Fig. 1. a/ Topography of South America, geological and geographical features referred to in this study, plate boundaries (white lines) and flat slab segments (triangles indicate the overriding plate for subduction zones). The extent of the Pebas system is shown at 16 Ma for the paleogeography of Wesselingh et al. (2010), the extent of Neogene strata in the Chaco foreland basin is taken from Uba et al. (2006), that of the Sierras Pampeanas from topography and Dávila and Lithgow-Bertelloni (2013), and that of the Central Patagonian basin from Guillaume et al. (2009). b/ Scenario of flat slab subduction along South America. Subduction zones and mid-oceanic ridges in the reference frame of South America, colour-coded by age, and with triangles on the overriding plate. Flat slab segments from Ramos and Folguera (2009) are plotted in 1 Myr increment, and other subduction zones and mid-oceanic ridges are plotted in 10 Myr increment. Present-day coastlines are shown in black, and the outline of Andean deformation (Arriagada et al., 2008) is shown in grey. The extent of Proterozoic (Archean) continental lithosphere is represented as a light orange (light magenta) shading. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of northwestern South America that ended Pebas shallow-water sedimentation (Wesselingh et al., 2010; Eakin et al., 2014; Fig. 1a). In addition, a time-dependent inverse model of mantle flow predicted a dynamic tilting to the east of northern South America during the Miocene, which is proposed to have resulted in the drainage reversal of the Amazon River (Shephard et al., 2010). Other features of South American paleogeography may be associated with mantle flow. For instance, the eastward migration of the depocentre of the Chaco foreland basin (Fig. 1a) and associated change in drainage direction (Uba et al., 2006) is reminiscent on a smaller scale of the migration of the depocentre of the Western Interior Basin of the United States, attributed to subduction-driven dynamic subsidence (Liu et al., 2011). Here we investigate the influence of subduction on the evolution of the large-scale topography of the South American continent in a series of time-dependent global forward mantle flow models that progressively assimilate tectonic reconstructions. We investigate the influence of flat slab subduction (Fig. 1b) and of the asthenosphere across four model cases.

2. Modelling the evolution of South American dynamic topography in global time-dependent mantle flow models

2.1. Mantle flow models assimilating tectonic reconstructions with flat slab subduction

We solve the convection equations with the finite-element method in a spherical domain using *CitcomS* (Zhong et al., 2008),