Tectonophysics 644–645 (2015) 81–91

Contents lists available at ScienceDirect

Tectonophysics

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

Bulk crustal properties of the Borborema Province, NE Brazil, from P-wave receiver functions: Implications for models of intraplate Cenozoic uplift

R.M.N. Luz [a], J. Julià [a,b,*], A.F. do Nascimento [a,b]

[a] Programa de Pós-Graduação em Geodinâmica e Geofísica, Universidade Federal do Rio Grande do Norte, Natal, Brazil
[b] Departamento de Geofísica, Universidade Federal do Rio Grande do Norte, Natal, Brazil

ARTICLE INFO

Article history:
Received 29 August 2014
Received in revised form 9 December 2014
Accepted 28 December 2014
Available online 9 January 2015

Keywords:
Borborema Province
Cenozoic uplift
Mafic underplate
Receiver functions

ABSTRACT

We investigate variations in crustal thickness and bulk V_P/V_S ratio across the Borborema Province of NE Brazil by analyzing teleseismic P-to-S conversions recorded at 52 seismic stations in the Province. The Borborema Province represents the western portion of a larger Neoproterozoic mobile belt that resulted from the assembly of Gondwanaland, and that split from the African continent during Mesozoic times. The evolution of the Province after continental breakup was marked by episodes of diffuse intraplate magmatism, perhaps leading to uplift of the Borborema Plateau in the Cenozoic. A number of geodynamic models have been proposed to explain coeval Cenozoic magmatism and uplift in the Province, which invoke either thermal anomalies under the Plateau and related mantle upwellings, channeling along lithospheric thin spots from a distant mantle plume, and small-scale convection at the continental edge. Alternatively, plateau uplift might have resulted from thickening of the crust after depth-dependent stretching of the continental lithosphere in the Mesozoic. Most of the models imply mafic underplating of the Plateau's crust in order to fully explain its elevated topography, but the volume of such mafic underplate varies among them. Our results show that: (i) the crust is 32–40 km thick under the Borborema Plateau, (ii) the crust is generally thinner – about 30–33 km – under the lower topographies surrounding the Plateau, and (iii) V_P/V_S ratios are in the 1.68–1.80 range for both regions of higher and lower topography. No apparent correlation is observed between V_P/V_S ratio and crustal thickness. Our results suggest that compositional differences between thick and thin crust across the Borborema Province are minimal, and that models of plateau uplift involving a small volume of mafic underplate provide a more plausible explanation for the observed topography of the Borborema Plateau.

1. Introduction

Magmatism and uplift in continental interiors are important tectonic processes that are not easily contextualized within the framework of plate tectonics. Contrary to the relatively well-understood process of rift-flank uplift, in which undercompensated topography is basically supported by the flexural strength of the lithospheric plate (e.g., Kearey and Vine, 1999), the mechanisms that could explain the interpreted Cenozoic uplift of intraplate continental regions are more varied and controversial. An excellent example is the Colorado Plateau of the southwestern United States, for which van Wijk et al. (2010) invoked a small-scale convection cell on the edge of the Plateau driving a lithospheric drip as responsible for both magmatism and uplift, while Bailey et al. (2012) gave a secondary role to edge-driven convection and proposed that it is the lithospheric root that plays a key role in the long term stability of the Plateau. Another good example is the Mongolian Plateau of central Asia, for which Cenozoic magmatism and uplift have been explained invoking either the presence of an isolated mantle plume (Windley and Allen, 1993) — perhaps two (Tiberi et al., 2010), scattered asthenospheric diapirs (Cunningham, 1998), and/or as being externally driven by the collision between Asia and the Indian subcontinent (Calais et al., 2003, 2006).

In northeast Brazil, the Precambrian Borborema Province may be contributing another interesting case study of Cenozoic magmatism and uplift of the continental lithosphere. Cenozoic magmatism in NE Brazil consists mostly of small-volume, alkaline magmatism with Ar–Ar dates that range between 57 and 2 Ma (Knesel et al., 2011; Mizusaki et al., 2002; and references therein), and overlaps in time with episodes of inferred coeval uplift in the Borborema Plateau (Jardim de Sá et al., 1999; Morais Neto et al., 2009; Oliveira and Medeiros, 2012). Several competing models have been proposed to explain this overlapping Cenozoic activity, including the existence of deep-seated mantle plumes (e.g., Jardim de Sá et al., 1999; Mizusaki et al., 2002) or shallower bodies under the Plateau (Pinheiro and Julià,

* Corresponding author at: Campus Universitário - Lagoa Nova, CEP 59072-970, Natal, RN, Brazil. Tel.: +55 84 3342 2502x209.
E-mail address: jordi@geofisica.ufrn.br (J. Julià).

http://dx.doi.org/10.1016/j.tecto.2014.12.017
0040-1951/

2014; Ussami et al., 1999), lateral flow from a distant mantle plume under the Paraná Basin (Sleep, 2003), and a small-scale convection cell at the edge of the continent (Knesel et al., 2011; Oliveira and Medeiros, 2012). Alternatively, thermal re-equilibration of laterally thickened crust induced by depth-dependent stretching during Mesozoic rifting, has also been proposed as a viable mechanism for plateau uplift (Kusznir and Karner, 2007; Morais Neto et al., 2009). Interestingly, most of the models require the presence of a layer of mafic material under the Plateau to fully explain its elevated topography. The volume of such mafic underplate, however, may vary substantially among the models.

In this work, we have utilized seismic stations from a newly deployed seismic monitoring network in NE Brazil and from a number of temporary deployments in the region to develop 52 point estimates of crustal thickness and bulk V_P/V_S ratio throughout the Province. V_P/V_S ratios are mostly sensitive to silica content in rocks (e.g., Christensen, 1996) and, together with crustal thicknesses, are routinely utilized to determine the presence or absence of mafic underplate in continental regions (e.g., Chevrot and van der Hilst, 2000; Julià and Mejía, 2004). Our results show that the crust is 32–40 km thick under the Plateau and 30–33 km thick under the areas of lower topography around it. V_P/V_S ratios, on the other hand, are in the 1.68–1.80 range throughout the entire Province and, most importantly, do not correlate with crustal thicknesses. We argue that a layer of mafic material under the Borborema Plateau – if present – must be thin (<5–6 km), and that models of magmatism and uplift involving minimal mafic underplating of the crust are favored by our observations.

2. Tectonic setting and post-breakup evolution

2.1. Geology and tectonic setting

The Borborema Province of NE Brazil comprises the northeasternmost corner of the Brazilian shield (Fig. 1). Covering an area of

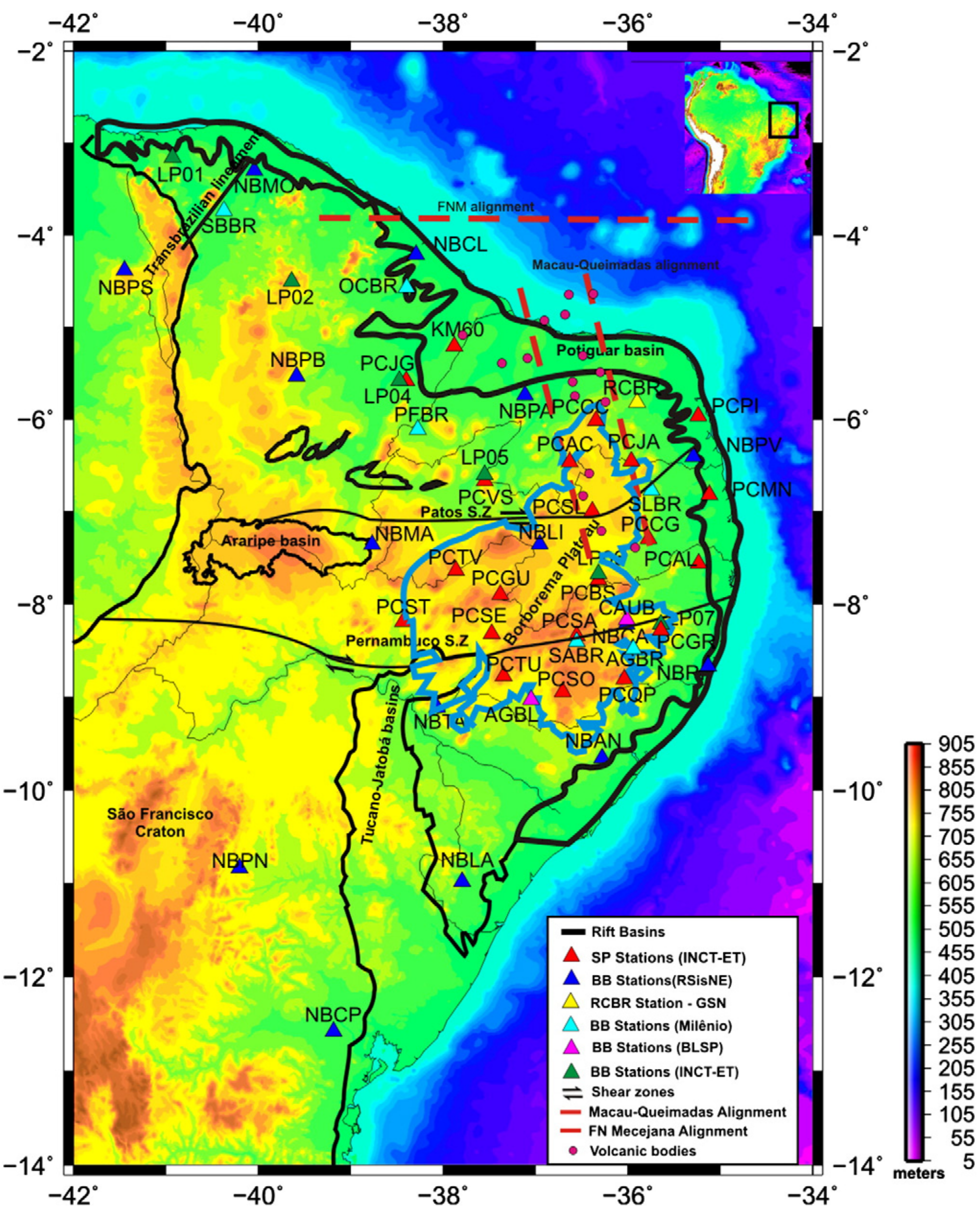

Fig. 1. Topographic map of NE Brazil with locations of broadband and short-period stations considered in this study superimposed (see legend). The borders of the main physiographic provinces (Parnaíba basin, Borborema Province, São Francisco craton) are indicated through thin, black, solid lines, while the borders of the Mesozoic basins are indicated through thick, black, solid lines. The small red circles mark the location of diffuse, Cenozoic volcanic bodies in the Borborema Province that define the NNW–SSE trending Macau–Queimadas alignment (dashed blue lines).