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Causes of intraplate seismicity in central Brazil from travel time seismic tomography

Marcelo Peres Rocha [a,*], Paulo Araújo de Azevedo [a], Giuliano Sant'Anna Marotta [a], Martin Schimmel [b], Reinhardt Fuck [a]

[a] Institute of Geosciences, University of Brasília, Brasília, DF, Brazil
[b] Institute of Earth Sciences "Jaume Almera", CSIC, Barcelona, Spain

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ABSTRACT

New results of travel time seismic tomography in central Brazil provide evidence that the relatively high seismicity in this region is related to the thinner lithosphere at the limit between the Amazonian and São Francisco paleocontinents. The transition between these paleocontinents is marked by low velocity anomalies, spatially well correlated with the high seismicity region, which are interpreted as related to the lithospheric thinning and consequent rise of the asthenosphere, which have increased the temperature in this region. The low-velocity anomalies suggest a weakness region, favorable to the build-up of stress. The effective elastic thickness and the strain/stress regime for the study area are in agreement with tomographic results. A high-velocity trend is observed beneath the Parnaíba Basin, where low seismicity is observed, indicating the presence of a cratonic core. Our results support the idea that the intraplate seismicity in central Brazil is related to the thin lithosphere underlying parts of the Tocantins Province between the neighboring large cratonic blocks.

1. Introduction

1.1. Motivation

Most of the seismically active regions on Earth, including where the largest earthquakes occur, coincide with the limits of tectonic plates. Over 90% of the world earthquakes occur at the edge of oceanic and continental plates. Unlike plate boundary regions, where the seismicity is relatively concentrated and the causes are well understood, intraplate seismicity represents diffuse deformation in relatively stable tectonic regions (Zoback, 1992), and their origins cannot be explained simply, given that they depend on the local tectonic context (Assumpção et al., 2014).

Most common models proposed to explain intraplate seismicity are related to pre-existing weakness zones, such as extended crust in aborted rifts or continental margins (e.g. Johnston, 1989; Schulte and Mooney, 2005), or stress concentration in the upper crust due to structural inhomogeneities (e.g. Sykes, 1978; Talwani, 1989; Talwani and Rajendran, 1991; Kenner and Segall, 2000). Liu and Zoback (1997) showed that stress concentration in the upper crust of the New Madrid seismic zone is the result of a weaker subcrustal lithosphere. Based on seismic tomography results, Assumpção et al. (2004) proposed that lithospheric thinning could provide favorable conditions for stress concentration in the brittle upper crust, which may explain the epicentral distribution within the South American Platform.

In the South American continent, the regional stress field is dominated by E–W compression (Zoback, 1992). The origin of this stress regime is mainly due to forces related with spreading in the Mid-Atlantic Ridge and the resistive forces exerted by the Caribbean plate to the north and the Nazca plate subduction to the west (Mendiguren and Richter, 1978; Coblentz and Richardson, 1996). Intraplate seismicity in Brazil is clearly not uniform and a few areas of higher activity have been identified (Assumpção et al., 2004, 2014). An example of the high seismic concentration can be observed in central Brazil. Significant seismicity, with preferential epicenter distribution in the SW–NE direction, is observed in the Tocantins Province. This is known as the Goiás-Tocantins Seismic Zone — GTSZ (Berrocal et al., 1984; Fernandes et al., 1991). The seismicity of central Brazil may be related to the limits between the São Francisco and Amazonian paleocontinents, which could represent a region of lithospheric thinning. According to Assumpção et al. (2004), in regions of tectonic lithospheric thinning, stress tends to focus on the crust, while in regions of thicker lithosphere the stress is more distributed within the upper mantle.

* Corresponding author at: University of Brasília, Institute of Geosciences — IG, CEP 70910-900 Brasília, DF, Brazil.
E-mail addresses: marcelorocha.unb@gmail.com, marcelorocha@unb.br (M.P. Rocha), paulopaico@hotmail.com (P.A. Azevedo), marotta@unb.br (G.S. Marotta), schimmel@ictja.csic.es (M. Schimmel), reinhardt@unb.br (R. Fuck).

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In seismic tomography results, regions with thinner lithosphere appear as low-velocity anomalies (Assumpção et al., 2004; Zhang et al., 2009; Rocha et al., 2011), which can be interpreted as regions of relatively higher temperature. Regions with thicker lithosphere, such as cratons, are characterized by stability and low temperatures, and normally appear as high-velocity anomalies in tomographic results. In this context, our objective is to relate new results of P-wave seismic tomography in central Brazil (Tocantins Province) with the seismicity distribution, in order to understand the causes of the high seismicity of the GTSZ.

1.2. Study area

The study area is located mostly in the Tocantins Province, in central Brazil, covering also the southeastern part of the Amazonian Craton, the western part of the São Francisco Craton, the southern part of the Parnaíba Basin and northeastern part of the Parana Basin. The area is crossed by the Transbrasiliano Lineament (TBL), a major lithospheric discontinuity in the region, which defines the boundary of different crustal domains (Cordani and Sato, 1999; Cordani et al., 2013; Brito Neves and Fuck, 2014). Here, we focus on the area marked by the dashed rectangle (Fig. 1). The black and white triangles are the seismic stations which have been added to the study carried by Rocha et al. (2011) for this purpose.

Central Brazil, and especially the Tocantins Province, is one of the most complex tectonic regions in South America. The most important event related to the formation of the Tocantins Province is the collision between the Amazonian and the São Francisco cratons and a third stable area, the Paranapanema block hidden beneath the Paraná Basin (Pimentel et al., 2000, 2004), giving rise to the Neoproterozoic Araguaia, Paraguay and Brasília fold belts (01, 02 and 03 in Fig. 1). To the north of Tocantins Province lies the Parnaíba Basin. This is one of the largest cratonic basins of South America (like the Paraná, Solimões and Amazonic basins). This basin occupies an area of more than 600,000 km^2 (Brito Neves, 1998), and covers a rigid lithosphere block, which probably represents its cratonic core (Brito Neves et al., 1984; Góes et al., 1993; Nunes, 1993; Castro et al., 2014; Daly et al., 2014).

2. Data and method

For this study, new data were acquired through a permanent network recently installed in Brazil – Brazilian Seismographic Network (BSN) – with more than 80 stations distributed throughout the country (black triangles in Fig. 1) and providing, for this study, data between 2011 and 2015. We used also data from a temporary network with 15 stations (white triangles in Fig. 1), with events recorded between 2007 and 2013 (Azevedo et al., 2015). These new data were included in a database previously assembled by prior works (VanDecar et al., 1995; Schimmel et al., 2003; Rocha et al., 2011). We used records of P and PKIKP phases for events with minimum magnitudes larger than 4.6 and 5.4 (mb), respectively. Events were chosen in the epicentral distance range of 30° to 95° for P-waves and 150° to 180° for PKIKP

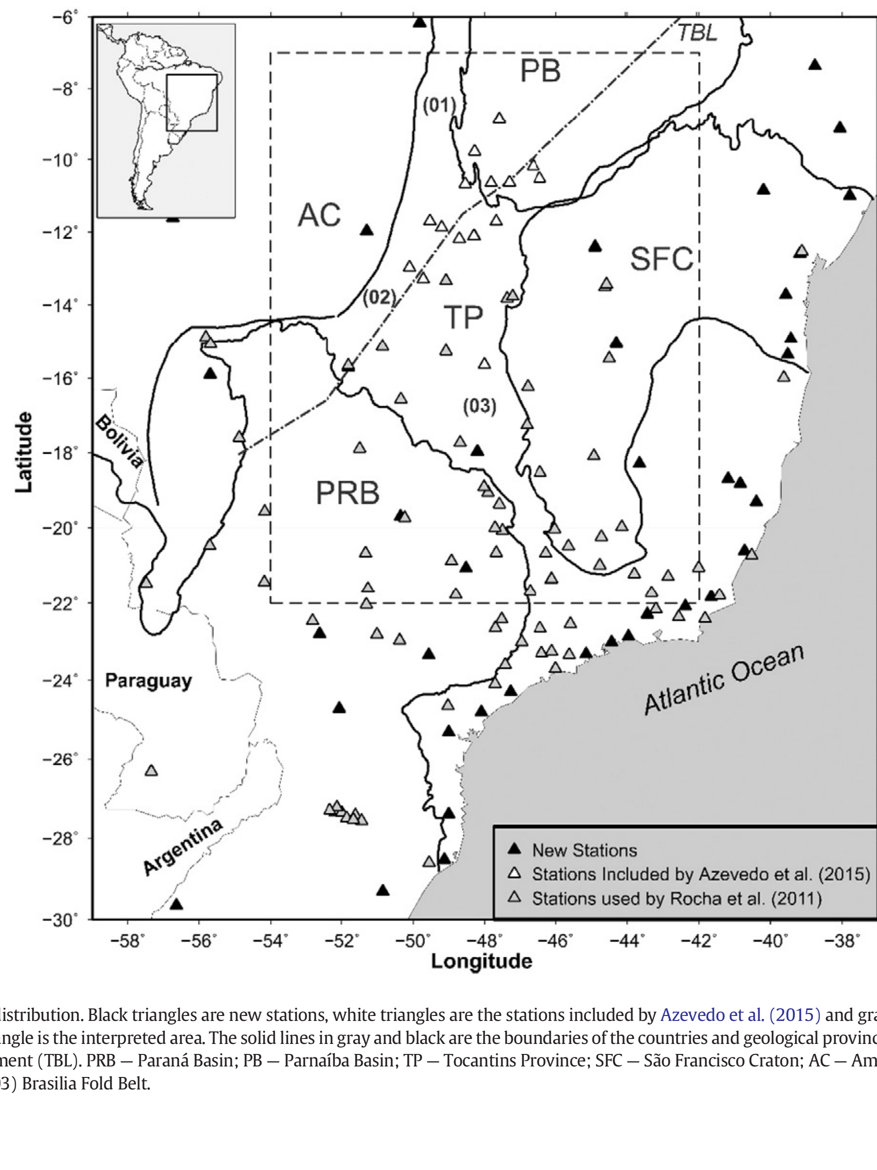

Fig. 1. Study area with stations distribution. Black triangles are new stations, white triangles are the stations included by Azevedo et al. (2015) and gray triangles are old stations used by Rocha et al. (2011). Dashed rectangle is the interpreted area. The solid lines in gray and black are the boundaries of the countries and geological provinces, respectively. Dashed and dotted line is the Transbrasiliano Lineament (TBL). PRB — Paraná Basin; PB — Parnaíba Basin; TP — Tocantins Province; SFC — São Francisco Craton; AC — Amazonian Craton; (01) Araguaia Fold Belt; (02) Paraguay Fold Belt; (03) Brasilia Fold Belt.