Characterization of the seismogenic Samambaia Fault based on aeromagnetic data: preliminary results

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Abstract

This research integrates geophysical, geological and seismological data to characterize the Samambaia seismogenic fault and its host crystalline basement. New airborne aeromagnetic data were used to identify magnetic lineaments and their relationship with the crystalline basement fabric and the seismogenic fault. The main results indicate that the Samambaia fault presents a length greater than that illuminated by seismicity and that the seismicity reactivates the basement fabric.

Introduction

Northeastern Brazil stands out as one of the most seismically active areas of the country. Seismicity concentrates in places such as Caruaru (state of Pernambuco), Cascável and Palhano (state of Ceará), and Assu and João Câmara (state of Rio Grande do Norte) (Ferreira et al., 1998, 2008; Assumpção, 1992; Assumpção et al., 2015).

Previous studies have mapped structural features associated with seismogenic faults in this region (e.g., Bezerra et al., 2006; Bezerra et al.; 2007; Ferreira et al., 2008). The level of seismicity in northeastern Brazil is considered low, but a few events reached 5.0 m_b, indicating that the seismic risk should not be ignored (Ferreira et al., 1998 2008; Assumpção, 1992; Assumpção et al., 2015). A few studies investigated the Samambaia fault, the best characterized seismogenic fault in intraplate South America, describing its kinematics, geometry, and the relationship among seismicity, tectonic stresses, and geological setting (Bezerra et al., 2007; Ferreira et al., 1998, 2008). However, the assessment of fault geometry and size has relied mainly on seismological data, which could underestimate fault length and, consequently, seismic risk.

One way forward is the investigation of seismogenic faults using a variety of methods. Nowadays, geophysical methods are used to map faults both in crystalline and sedimentary terrains (e.g., Jacques et al., 2014; De Castro et al., 2014; Andrades Filho et al., 2014). One of these methods is based on magnetic data, which have been widely used to identify faults and establish the structural setting in complex regions, such as in Cameroon, Central Africa (Ndougsa-Mbarga, 2012*).*

The objective of the present study is the characterization of the seismogenic Samambaia fault and its relationship with basement fabric and seismological data using magnetic anomalies. This fault forms a NE-striking, strike-slip structure ~40 km long and 9 km deep. Its main period of seismic activity occurred from 1986 to 1994, causing a sequence of aftershocks that damaged buildings in João Câmara and nearby cities.

The epicentral area is located in the northern portion of the Borborema Province, comprising the eastern boundary of the Potiguar basin, which encompasses the Precambrian crystalline basement and Cretaceous to Quaternary sedimentary rocks (Figure 1). Three main units occur in the crystalline basement of the epicentral area (Figure 2): (1) Archean to Paleoproterozoic gneisses and migmatites of the Caicó Group (3.4 to 2.0 Ga); (2) supracrustal Neoproterozoic rocks (650–610 Ma) of the Seridó Group; and (3) Neoproterozoic granitic rocks (650–500 Ma) (Van Schmus et al., 1995; Brito Neves et al., 2000). The crystalline basement is overlain by late Cretaceous sandstones of the Açu Formation and limestones of the Jandaíra Formation, Miocene sandstones of the Barreiras Formation, and Quaternary alluvial sediments (Bezerra et al., 2007). The Precambrian units is deformed by ductile shear zones and is cut across by E-W-trending dikes.

Methods

We obtained epicenters earthquakes data that occurred in the region of João Câmara (RN) between 1987 and 1988 mainly from Takeya (1992), as well as some more recent data from 2013 to 2014 from Brazilian seismic catalog.

The aeromagnetic data were provided by the Brazilian Geological Survey – CPRM. The airborne surveys had N-S flight lines, spaced 500 m from each other, E-W perpendicular control lines spaced 10 km, and flying height of 100 m (LASA and Prospectors, 2008). This survey used magnetometers with cesium vapor sensor, mounted on the tail of the aircraft (stinger type), and measurements were performed every 0.1 second. The data we received were already micro-leveled and corrected by IGRF (International Geomagnetic Reference Field). However, a total of 20 random lines were selected and the quality of the regularity of the data acquisition spacing and the constancy of flight height in relation to the surface of the terrain were analyzed.

The geophysical data were processed on the software Oasis Montaj 8.2 (Geosoft Inc.). They were interpolated using the bi-directional method, generating a Total Magnetic Intensity (TMI) grid with a 250 m cell size. Afterwards, a Reduced to the Pole map (RTP) was generated, with the inclination of -25.14º and declination of -22.24º. A Matched Filter was applied to separate spectral bands, which theoretically concentrate magnetic sources of four different depths (shallow, intermediate 2, intermediate 1 and deep sources). We observed that the map referring to shallower depths do not present a good resolution. Thus, this map was not interpreted. Analytical signal and tilt-derivative (TDR) of the intermediate 2 spectral band magnetic data were obtained for structural analysis of the fault. The magnetic lineaments were interpreted from the RTP and TDR maps.

Results

The investigations were focused on the interpretation of magnetic maps. The comparisons fault geometry and strike was based on earthquakes epicenters and various magnetic anomalies.

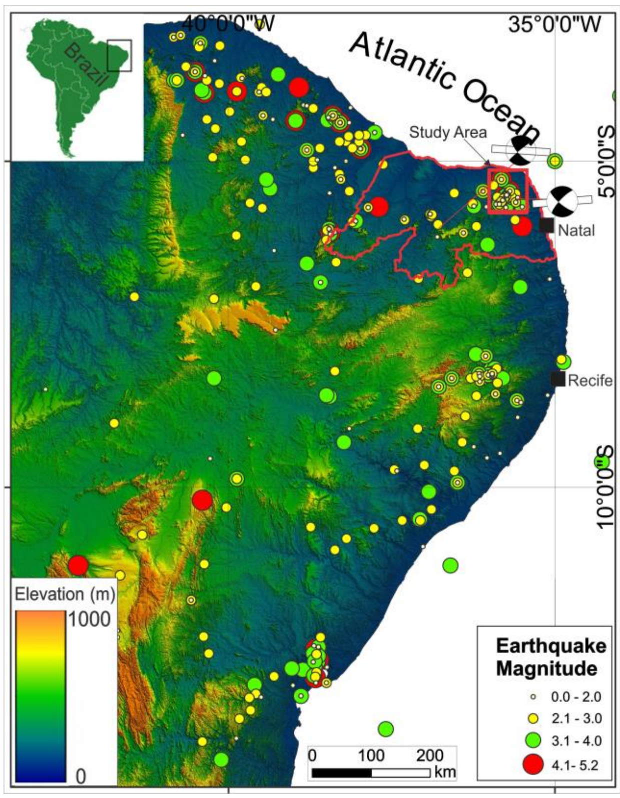

Figure 1: Map of seismicity in the eastern part of the Brazilian Atlantic margin (from Ferreira et al., 1998, 2008, and the seismic bulletin of the Brazilian Seismographic Network) superposed on the shuttle radar topography. Focal mechanisms in the study area are from Takeya (1992).

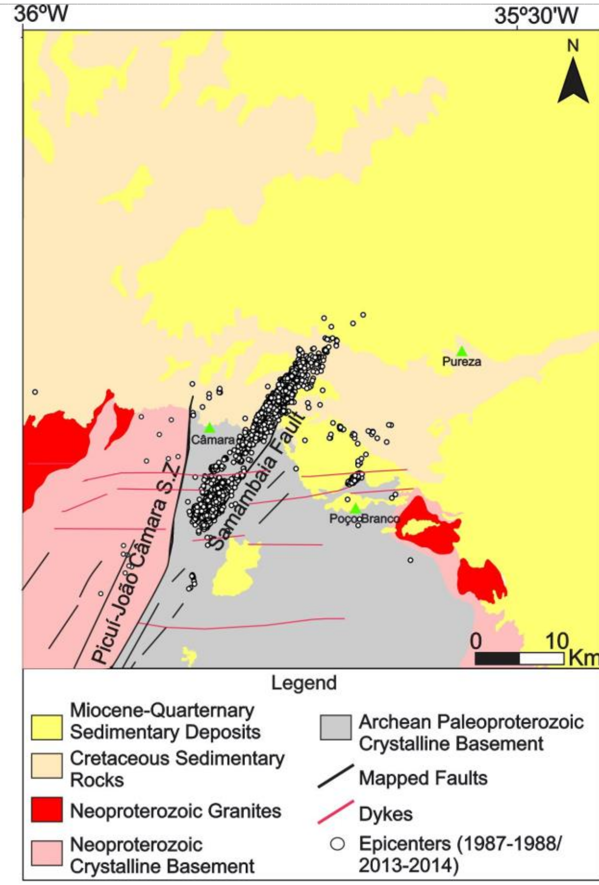

Figure 2: Geological map of the Samambaia fault in the eastern border of the Potiguar basin, NE Brazil (modified from Bezerra et al., 2014).

The Total Magnetic Intensity map (TMI) (Figure 3) shows a NE-SW-oriented negative anomaly (-160 to -40 nT), which is aligned with the epicenter cluster, the Samambaia fault. We observed that the Samambaia fault coincides with the magnetic lineaments, which corresponds to the crystalline basement fabric. We traced these lineaments below the basin. The location of the basement fabric underneath the sedimentary basin was unknown before the present study.

In the Reduced to the Pole (RTP) map (Figure 4), the Samambaia fault area is marked by a NE-SW-trending negative and positive anomalies, with amplitudes ranging from -3 nT to 114.9 nT. In addition, positive magnetic anomalies are associated with E-W-trending basic dikes.

After the application of the Matched-Filter, four different maps were obtained with anomalies related with magnetic sources at different depths. However, we interpreted only two of these maps: Intermediate 1, which corresponds to ~ 7.7 km depth and intermediate 2, which corresponds to ~1.6 km depth (Figure 5A e 5C, respectively). These maps indicate a correlation between basement structures and the Samambaia fault, which strikes between 31º and 35º Az. The parallel alignment between the epicenters and the Samambaia fault indicates that the Samambaia fault reactivates the Precambrian fabric. From the interpretation of the geophysical maps, it was possible to observe that the Samambaia fault also cuts across the E-W-trending basic dikes and offset them.

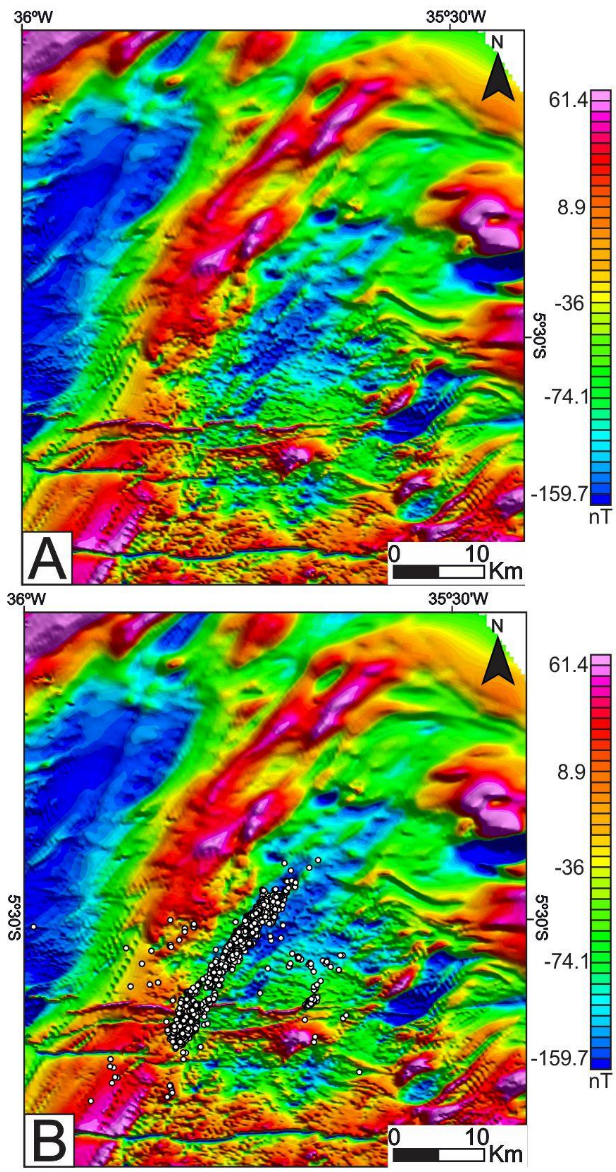

Figure 3: (A) Total Magnetic Intensity Map. (B) Total Magnetic Intensity Map with epicenters.

Conclusions

The interpretation of the aeromagnetic data enabled us to investigate the geometry and length of the Samambaia fault and its correlation with magnetic lineaments and the basement fabric. The magnetic maps contributed to a better characterization of the crystalline basement fabric, which is mainly composed of metamorphic foliations. This fabric coincides with epicenter alignment, which corresponds to the Samambaia fault. We conclude that this fault reactivates the Precambrian metamorphic foliation.

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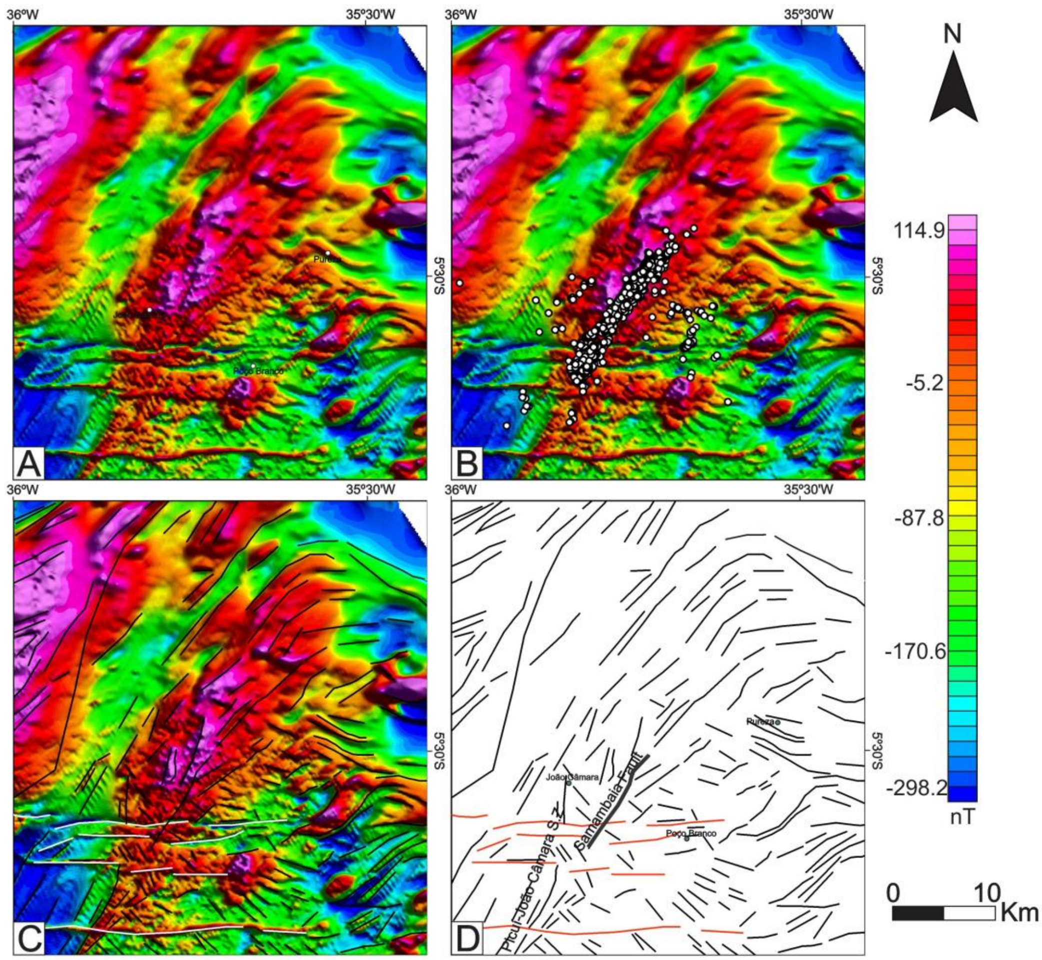

Figure 4: (A) Reduced to Pole Map – RTP. (B) RTP with epicenters. (C) RTP interpreted. (D) Interpretation of the RTP map.

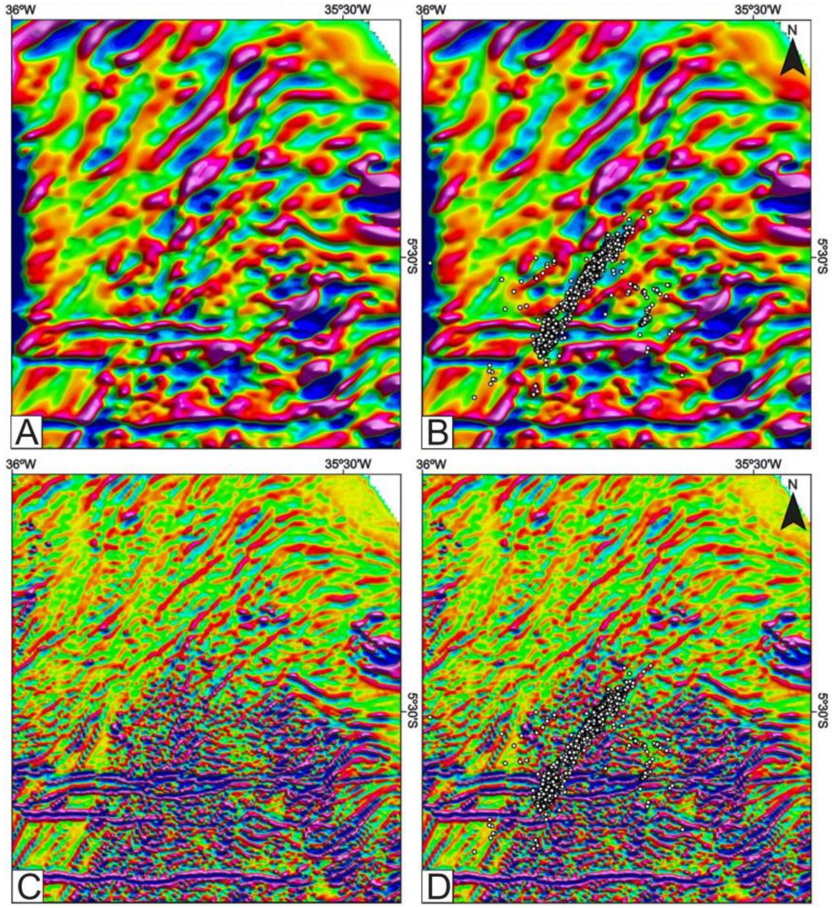

Figure 5: Matched-Filter maps. (A) Intermediate 1 (Source depth: 7.7 km) and (B) map with the Samambaia fault epicentral data; (C) Intermediate 2 (Source depth: 1.6 km) and (D) map with the Samambaia fault epicentral data.

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