Tectonophysics 633 (2014) 211–220

Contents lists available at ScienceDirect

Tectonophysics

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

Earthquake sequences in the southern block of the Pernambuco Lineament, NE Brazil: Stress field and seismotectonic implications

Heleno C. Lima Neto [a], Joaquim M. Ferreira [a,b,*], Francisco H.R. Bezerra [a,c], Marcelo Assumpção [d], Aderson F. do Nascimento [a,b], Maria O.L. Sousa [c], Eduardo A.S. Menezes [b]

[a] Programa de Pós-Graduação em Geodinâmica e Geofísica, Universidade Federal do Rio G. do Norte, Campus Universitário, Natal, RN 59078-970, Brazil
[b] Departamento de Geofísica, Universidade Federal do Rio Grande do Norte, Campus Universitário, Natal, RN 59078-970, Brazil
[c] Departamento de Geologia, Universidade Federal do Rio Grande do Norte, Campus Universitário, Natal, RN 59078-970, Brazil
[d] Instituto de Astronomia, Geofísica e ciências climáticas, Universidade de São Paulo, Cidade Universitária, São Paulo, SP 05508-900, Brazil

ARTICLE INFO

Article history:
Received 17 July 2013
Received in revised form 9 July 2014
Accepted 12 July 2014
Available online 22 July 2014

Keywords:
Earthquake series
Intraplate South America
Focal mechanism
Stress field
Fault reactivation

ABSTRACT

The Pernambuco Lineament (PeL) is an E–W-striking, 700 km long shear belt located in the central part of the Borborema Province, Brazil. Seismic sequences have been monitored in the region since 1991, and they are clearly correlated with the main shear belt and its NE-trending branches. A new sequence of small earthquakes occurred in April 2010 away from the main belt in the southern block of the lineament. We monitored this seismicity using a ten station network for 154 days and used the observations to determine the nature of the seismicity and the stress patterns. In addition, we used data from five previous local seismograph networks to determine the stress tensor. The results indicate that the seismicity is concentrated in three clusters, two of which are associated with normal faults: the first strikes 96°, dips 51°, and has a rake of −65°, and the second strikes 253°, dips 64°, and has a rake of −120°. These faults are 2.2 km and 1.5 km long and 2.0–3.0 km and 3.0–3.5 km deep, respectively, and are not correlated with the Pernambuco Lineament or its NE-trending branches. The inversion of focal mechanisms from our investigation and previous studies indicates E–W-trending compression and N–S-trending extension that affects both the northern and southern blocks of the PeL. The new data indicate that the fault behavior in the shear zone area is more complex than has previously been observed along reactivated mylonitic belts.

1. Introduction

Brazil is located in the eastern part of the South American plate and it has experienced earthquakes up to magnitude 6.2 and a maximum intensity of VII MM (Barros et al., 2009; Berrocal et al., 1984; Ferreira et al., 1998). Among the main seismic areas of the country is Borborema Province, in northeastern Brazil. Over the past forty years the seismic activity in this region has been characterized by events with magnitudes of up to 5.2 m_b and intensities up to VII MMI (Assumpção, 1983, 1992; Berrocal et al., 1984; Ferreira et al., 1998), which generally occur as swarms of earthquakes that can last more than 10 years, and sometimes include more than 1000 events per day (Ferreira et al., 1998).

One of the most active areas in the Borborema Province is the Pernambuco Lineament (PeL). The PeL is a ductile Brasiliano (PeL) (740–540 Ma) shear zone more than 700 km long (Fig. 1a) (Davison et al., 1995). This shear zone and many others in the region were reactivated in a brittle mode in the Cretaceous during the breakup of South America and Africa (de Castro et al., 2008, 2012; Matos, 1992). Several earthquake series have been reported along this shear zone and its NE-striking branches since the nineteenth century. In recent years, seismic sequences have occurred in Caruaru (Ferreira et al., 1998, 2008), Belo Jardim (Lopes et al., 2010) and São Caetano counties (Lima Neto et al., 2013).

These studies showed that the seismic activity in each of the epicentral areas was related to the Pernambuco Lineament or its NE-trending branches. These seismic sequences have been reported as classic cases of the brittle reactivation of preexisting fabrics that behaved as zones of weakness (Bezerra et al., 2011). However, in 2010, new sequences of events occurred in the southern block of the PeL away from the main E–W-striking mylonitic belt and its NE-striking branches. These earthquake sequences cut across the preexisting ductile shear zones and did not conform to the strict definition of swarms (Vidale and Shearer, 2006) because local networks were not deployed when the main event occurred.

This study is the first to be performed with a local network of seismographic stations south of the Pernambuco Lineament. The first felt earthquake of the new sequences of events occurred on April, 18,

* Corresponding author at: Departamento de Geofísica, Universidade Federal do Rio Grande do Norte, Campus Universitário, Natal, RN 59078-970, Brazil.

http://dx.doi.org/10.1016/j.tecto.2014.07.010
0040-1951/

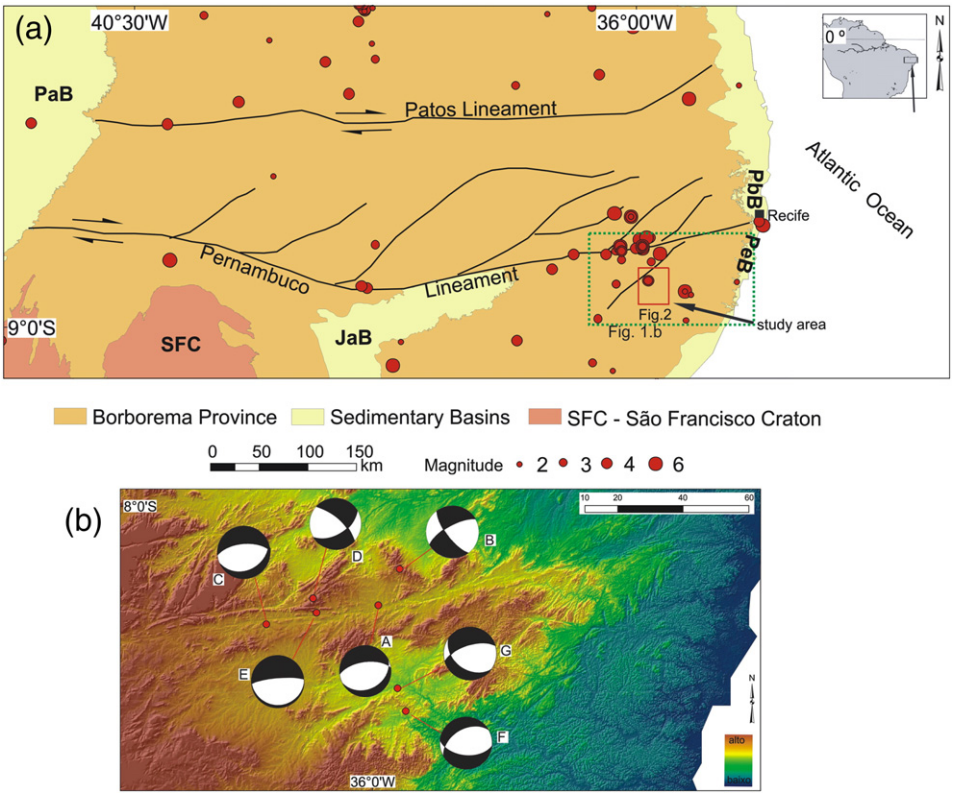

Fig. 1. (a) Location of the study area (red rectangle) and major geological features of the Borborema Province. The sedimentary basins in the figure: PaB — Parnaíba, PbB — Paraíba, PeB — Pernambuco, and JaB — Jatobá (Almeida et al., 2000; Brito Neves et al., 2000). The red circles are the epicenters of earthquakes from Brazilian Seismic Bulletin catalog from 1720 to 2010; (b) distribution of focal mechanisms: A (Caruaru1991: Ferreira et al., 1998), B (Caruaru 2002: Ferreira et al., 2008), C (Belo Jardim 2004: Lopes et al., 2010), D (Santa Luzia 2007: Lima Neto et al., 2013), E (São Caetano 2010: Lima Neto et al., 2013), F (this study), and G (this study).

2010 and had a magnitude 2.8 m_R (Brazilian regional scale — equivalent to mb scale, Assumpção, 1983) and an intensity of VI MMI. This event caused panic in the town of Belém de Maria and in the village of Lajes de São José (Cupira County, Fig. 2). The 2.8$m_R$magnitude event that motivated this study occurred along the Serra Verde seismogenic fault (Serra Verde cluster) and was the first event recorded in this area. The epicentral determination of this event was done through analysis of the record of a regional station that operated 40 km away from this epicentral area. During the period of operation of a local network, other events were recorded in the Serra Verde cluster and in two other separate clusters — Barra do Chata and Lagoa dos Gatos, with microtremors ≤ 1.5 m_R (Fig. 2).

This study presents the results of the campaign carried out from April, 21, 2010 to August, 10, 2010. The study confirmed the existence of three seismic areas; the main area was located in Cupira County, and the two smaller seismic areas were located in the Agrestina and Lagoa dos Gatos counties.

The objective of this study is to investigate the new seismic areas to the south of the PeL, the stress patterns, and the causes of the seismicity. We show detailed hypocentral locations, focal mechanisms, and the regional stress pattern. The results indicate that the new seismic sequence cut across a preexisting ductile fabric, whereas the seismogenic faults identified in previous studies reactivated these preexisting structures. We also show the complexity associated with intraplate seismicity and the importance of the stress field determination.

2. Seismo-tectonic setting

The Borborema Province, which is located in the northeastern part of the South American continent, is an intraplate area 900 km long and 600 km wide. The province is limited to the west by the Parnaíba Basin, to the east by coastal basins, and to the south by the São Francisco Craton (Fig. 1a). The BP encompasses Archean, Paleoproterozoic, and Neoproterozoic terranes that were formed or reworked during the Brasiliano orogenic cycle at 750–540 Ma (Almeida et al., 2000; Brito Neves et al., 2000). The Borborema Province was deformed by a system of ductile shear zones that form the boundaries between most of these terranes. The main structural features of the Borborema Province in the south are the Patos and Pernambuco (PeL) lineaments (Fig. 1a), which strike approximate EW.

The Cretaceous sedimentary basins along the continental margin and within the Borborema Province were formed by the brittle reactivation of the major ductile lineaments during the breakup of Pangea into South America and Africa (de Castro et al., 2008, 2012; Matos, 1992). The PeL forms the northern boundary of the Jatobá Basin and the boundary between the Paraíba and Pernambuco basins (Fig. 1a) (Lima Filho et al., 2006; Matos, 1992).

The PeL and its branches are among the most seismic areas of the Borborema Province (Bezerra et al., 2011; Ferreira et al., 1998, 2008; Lima Neto et al., 2013; Lopes et al., 2010), whereas the Patos Lineament is nearly aseismic. The seismicity associated with the PeL and its vicinity has been recognized since the early nineteenth century (Ferreira and Assumpção, 1983), and the most active area is located between 100 and 180 km west of Recife (Fig. 1). In 1967,a sequence of earthquakes, including a main event of magnitude 3.8 m_R and intensity V MM, caused panic in the city Caruaru (Ferreira and Assumpção, 1983). A magnitude 4.0 m_R event occurred in São Caetano in 2006 (Lima Neto et al., 2013) and reached an intensity of VI MM.