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The role of Precambrian mylonitic belts and present-day stress field in the coseismic reactivation of the Pernambuco lineament, Brazil

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Abstract

The Pernambuco lineament is a steeply dipping continental-scale ductile shear zone rooted within the Precambrian lithosphere of intraplate northeastern Brazil. It was formed during the Brasiliano orogeny ~600 Ma and reactivated during the Pangea breakup in the Cretaceous, when it controlled fault propagation and sediment accumulation in several rift basins. The region is now under an ~E–W-trending horizontal compression and ~N–S-trending extension, and faulting occurs predominantly in a strike-slip regime. We investigated two aftershock sequences and the preexisting tectonic fabrics along the Pernambuco lineament in order to evaluate the role of these fabrics in the coseismic reactivation of continental-scale structures. The lineaments consist of a main ENE–WSW-trending mylonitic belt about 2–3 km wide, and two secondary NE-trending mylonitic belts about 100 m wide. They both present steeply dipping mylonitic foliations and shallowing plunging stretching lineations. The mylonites present granitoid protoliths and mineral parageneses that range from amphibolite to greenschist facies. Brittle deformation overprints the ductile fabric in all mylonitic belts. In 1991, coseismic reactivation nucleated along the ENE–WSW-striking, ~3.3-5.6 km deep, normal fault of less than 1 km in length in the main mylonitic belt. In 2002, seismicity migrated to a NE-trending secondary mylonitic branch and moved as a right-lateral strike-slip, ~1.2 km long, 3.8–4.9 km deep fault plane. Both fault segments reactivated the mylonitic foliation and form part of a major system. We conclude that the interplay between the present-day stress field and preexisting fabrics controls seismogenic fault location, attitude, and kinematics. The Pernambuco lineament is an example of a long-lived continental-scale structure, where selective reactivation has occurred. Other shear zones in the region also show a long history of brittle reactivation and present similar orientation in relation to the present-day stress axes. They might be dormant structures prone for reactivation under the present-day stress field.

Keywords: Shear zone; Mylonite; Reactivation; Intraplate seismicity; Stress

1. Introduction

Intraplate earthquakes are poorly understood. The current literature attributes the cause of intraplate seismicity to many features. Among the most common and best documented are faults associated with ancient rifted crust (e.g., Johnston, 1996; Rao et al., 2002), density contrasts and heat flow (Mazabraud et al., 2005), major terrane boundaries (e.g., Dentith and Featherstone, 2003), fault intersection (e.g., Talwani, 1999), mafic-intrusion boundaries (e.g., Campbell, 1978), and rigidity contrast (Stevenson et al., 2006).

Most of the features associated with intraplate seismicity described above fall in the category of zones of weakness, which consist of preexisting fabrics that could be reactivated. There is plenty of evidence for reactivation of these zones in the development of sedimentary basins, for example, where they have been recognized as an important control of fault propagation and

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sedimentation. To the contrary, despite numerous studies that indicate seismic reactivation of zones of weakness, their role in generating seismicity continues to be elusive in a significant part of the case studies. In common, these intraplate seismicity cases share only the acceptance that some type of geological feature is being reactivated by the present-day stress field (Denham, 1988). As a result, there has been a compelling need to improve knowledge of the linkage between zones of weakness and seismicity, which has led to an increased effort to investigate major structures in intraplate settings (e.g., Dawers and Seeber, 1991).

In intraplate regions, however, many potentially active seismogenic structures are covered by thick ice sheets or by sedimentary or volcanic deposits. Therefore, investigation of the link between preexisting structures and seismicity has been hindered or prevented. The most important limitations in intraplate areas are knowledge gaps in (1) the type of fabric (or weakness zone) being reactivated, (2) the attitude, geometry, and location of preexisting fabrics, (3) the reactivation history of faults, and (4) the variation in faulting regime expressed by a diversity of focal mechanisms. Well-investigated examples of intraplate seismicity, which present one or more of the above limitations, have been reported in the 1997 Jabalpur central India earthquake (5.8 Mw), which occurred in the ductile crust close to the Moho (Rajendran and Rajendran, 1999); the 1993 Latur southern India earthquake (6.2 Mw), which occurred in a ~450 m thick basalt-covered area (Ramakrishna Rao and Raju, 1996; Gupta et al., 1998); and the Lisbon area, Portugal, a site of historical and recent intraplate earthquakes capped by a sedimentary cover a few hundred meters to 2 km thick (Cabral et al., 2003).

In intraplate South America, the seminal study by Sykes (1978) was the first to propose reactivation of major faults in the continent and transform faults in the ocean, in areas of Neogene volcanism. More recently, two studies presented a correlation between preexisting tectonic fabric and seismicity in northeastern Brazil. Ferreira et al. (1995) presented evidence that the induced seismicity of the Açu dam area occurred along ductile shear zones. Bezerra et al. (2007) pointed out that the

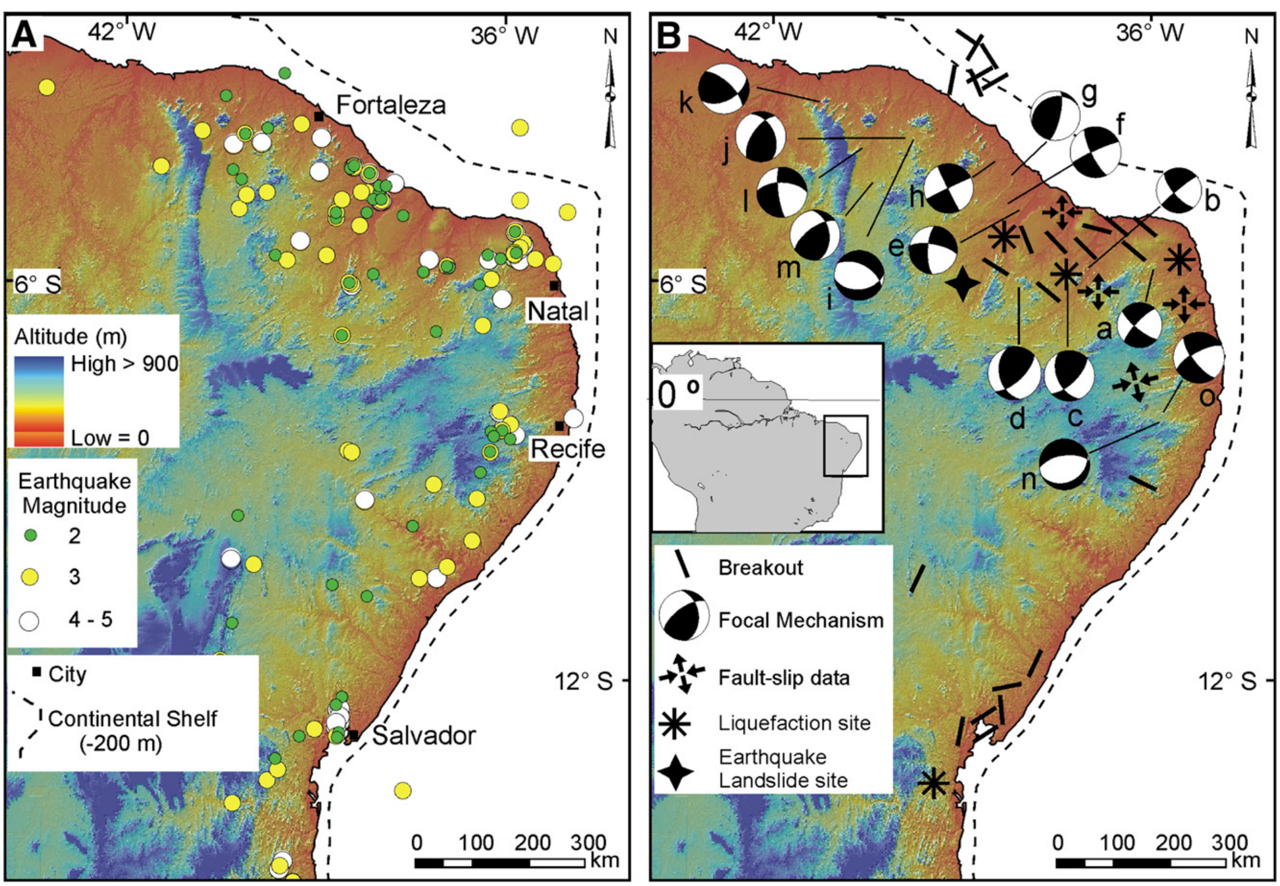

Fig. 1. Seismicity, stress, and secondary effects of earthquakes plotted on a digital elevation model of the Shuttle Radar Topographic Mission (SRTM): (A) Map showing distribution of instrumental and historical seismicity in northeastern Brazil. Seismological data have come from Ferreira and Assumpção (1983), Berrocal et al. (1984), and the Seismological Bulletin of the Brazilian Geophysical Journal. (B) Stress indicators and secondary effect of seismicity. Focal mechanism location and date of seismicity: (a) João Câmara 1986–1987, (b) Açu reservoir 1989, (c) Augusto Severo 1991, (d) Tabuleiro Grande 1993, (e) Palhano 1989, (f, g) Cascavel 1993, 1989, (h) Pacajus-Cascavel 1980, (i, j) Irauçuba 1991, (k) Senador Sá 1997, (l) Groaíras 1988, (m) Hidrolândia 1991, (n, o) Caruaru 1991, 2002. Source of focal-mechanism data are the following: (a) Ferreira et al. (1987); (b) Ferreira et al. (1995); (c, d, f, g, I, j, l, m, and n) Ferreira et al. (1998); (h) Assumpção et al. (1985); (k) França et al. (2004); (o) this study. Breakout data simplified from Lima et al. (1997); black bars indicate direction of maximum horizontal compression (S_{Hmax}). Fault-slip data are from faults that affect Neogene sedimentary deposits. Paleoseismological data (liquefaction and paleostress) were simplified from Sousa and Bezerra (2005), and Bezerra et al. (2008).