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Timing and mechanisms for the generation and modification of the anomalous topography of the Borborema Province, northeastern Brazil

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ABSTRACT

The results of apatite fission-track analysis in 14 granitic-gneissic samples from two regional transects across the Borborema Plateau, northeastern Brazil, show evidence for two dominant paleothermal events: a Late Cretaceous cooling event beginning sometime between 100 and 90 Ma, and a second cooling event in the Neogene. The distribution of the fission-track results suggests that the cooling events have a broad regional expression and are consistent with the geologic record in the Araripe Basin, western Borborema Province, which attests to a post-Albian uplift of the whole region. We hypothesize that the first event is due to the uplift and denudation of regional, permanent topography generated after the breakup of Brazil and Africa. Such topography is predicted by models of continental margin extension in which continental lithosphere thinning is followed by thickening of the adjacent hinterland lithosphere and crust (Kusznir, N.J., Karner, G.D., 2007. Continental lithospheric thinning and breakup in response to upwelling divergent mantle flow: application to the Woodlark, Newfoundland and Iberia margins. In: Karner, G.D., Manatschal, G., Pinheiro, L. (Eds), Imaging, mapping and modeling continental lithosphere extension and breakup. Special Publication 282, Geological Society, London, pp. 389–419.). In northeastern Brazil, this extension-engendered topography may have been amplified by magmatic underplating related to the Saint Helena and Ascension plumes. The Miocene cooling event (20–0 Ma) occurred at a time characterized by the transition from carbonate ramp to progradational clastic systems on the Pernambuco–Paraíba margin and the offshore Potiguar Basin. This same stratigraphic response characterizes the Neogene stratigraphy of many passive margins and attests to a global increase in the delivery of clastics to margins, the simplest explanation of which is a climate change that accentuated erosion of pre-existing topography. Thus, the present rugged landscape of northeastern Brazil is interpreted to be a product of this younger denudation event. A corollary of this study is that the history, distribution and delivery of clastics to the northern and northeastern margins of Brazil are a function of the regional development of the continental landscape during the Late Cenozoic.

1. Introduction

The Borborema Province, a large cratonic shield area in northeastern Brazil (Fig. 1), underwent significant uplift during and after Cretaceous times, as indicated by many lines of evidence, most notably the shallow-water Albian limestones in the Araripe Basin (western Borborema Province) at present elevations of 700–800 m above sea level.

The main topographic expression of this uplift is the Borborema Plateau, which shows maximum elevations on the order of 1200 m above sea level and encompasses almost the whole northeastern shield of Brazil. The Borborema Plateau shows a regional axis oriented in the NE–SW direction. It is surrounded by marginal lowlands (the "Sertaneja Depression" and the coastal cuestas) (Fig. 2). Within the Borborema Plateau area, there are several mesas partially covered by the sediments of the Serra do Martins Formation, a sequence of continental sandstones and conglomerates of presumed Paleogene age. The occurrence of these sediments at high elevations also has been viewed as evidence for Cenozoic uplift affecting at least the eastern Borborema Province and possibly beyond. However, the sediments of the Serra dos Martins Formation are non-fossiliferous and the stratigraphic age has been inferred from fission-track analysis (Morais Neto et al., in press) and

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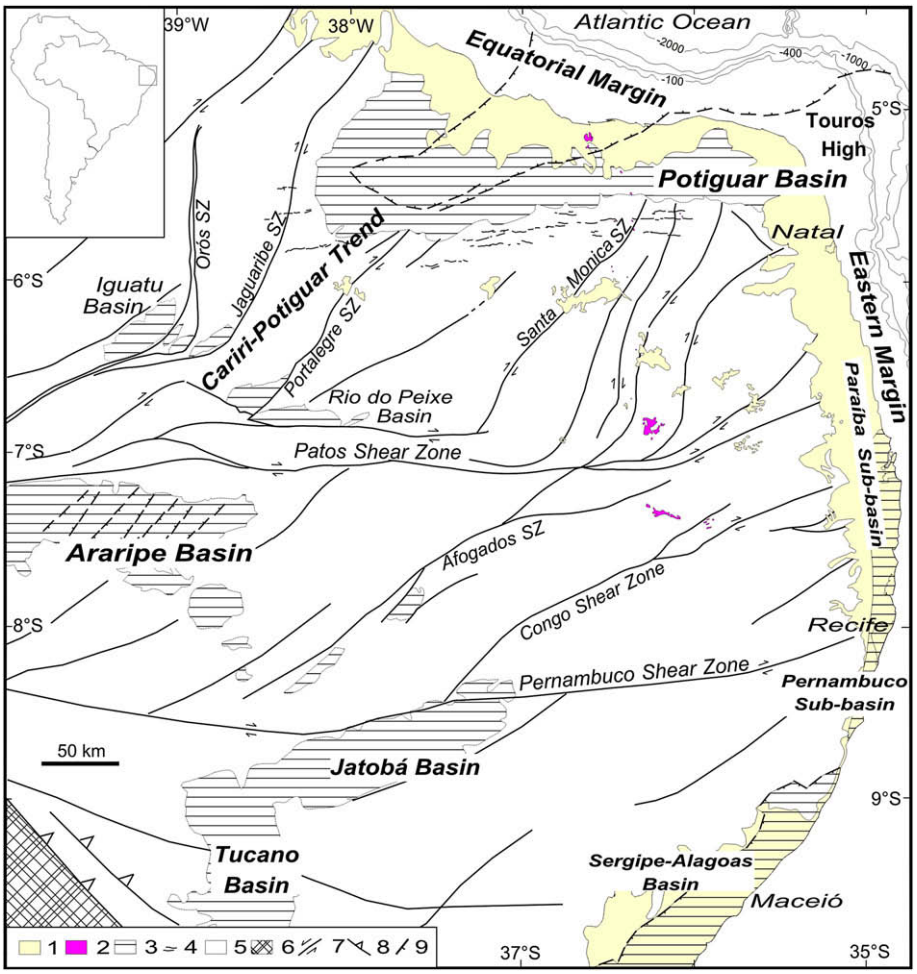

Fig. 1. Simplified geological framework of the Borborema Province, northeastern Brazil: (1) Cenozoic covers; (2) Cenozoic volcanics (3) Phanerozoic basins; (4) Early Cretaceous Tholeiitic Dike Swarm (5) Precambrian crystalline rocks; (6) São Francisco craton; (7) Precambrian shear zones; (8); Thrusts; (9) Early Cretaceous rifts.

indirect relationships with Cenozoic volcanics (Menezes et al., 2003; Jardim de Sá et al., 2005).

During the last three decades, many hypotheses have been formulated to explain the morphological evolution of the Borborema Province, in particular, and the timing and causative mechanisms for the regional topography of northeastern Brazil, in general. These studies, mostly based on morphoclimatic arguments, interpreted the development of the Borborema Province using regional correlations of distinct (and undated) peneplained surfaces. Using these correlations, many authors assigned a range of ages for the planation surfaces and their "correlative" sediments, leading to many redundant, controversial, and sometimes inconclusive correlations. Rather than to rely on non-fossiliferous, continental deposits to constrain the timing of uplift, we used apatite fission-track analysis (AFTA) on samples from the Borborema Plateau region and surrounding areas to provide a quantitative constraint on the timing of various cooling (or paleothermal) events and thus insights into the timing of formation and denudation of the topography of northeastern Brazil.

In regions such as the Borborema Plateau, where large periods of geological time are not represented in the geological record, thermal history tools are unusually powerful in studying the nature of events during time intervals unrepresented in the preserved rock record. Constraints from thermal histories provide a unique opportunity to better understand important aspects of the Phanerozoic tectonic evolution of a region that is presently dominated by only Precambrian terrain. In this paper, we present the results from 14 apatite fission-track analysis, which provide new quantitative constraints on the thermal history of this region by constraining the timing of cooling, such as caused by uplift and/or topographic denudation, from the thermal history of individual samples. In addition, we evaluate models for the generation of regional, permanent continental topography, and discuss possible mechanisms responsible for the development of the present-day topography of the Borborema Province in terms of post-rift thermal events related to the breakup of Gondwana, tectonics and climate changes.

The origin of the positive long wavelength topography of northeastern Brazil remains enigmatic, both in terms of its timing and causative mechanism (Hegarty et al., 2004). Topographic relief distributed over many 100s of kilometers can be generated via a number of first-order processes, such as thin- and thick-skinned folding and thrusting of the crust, mantle plume activity, lithosphere delamination, and magmatic underplating of the crust. While extension can generate flanking flexural topography, the distribution tends to be spatially limited, with asymmetric flank width generally being between 100 and 200 km. These mechanisms generate permanent topography, which is in contrast to the transient topography engendered by solely thermal processes. Magmatic underplating, by effectively thickening the crust, leads to permanent topography coeval with the underplating (Brodie and White, 1995).