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Implications of drainage rearrangement for passive margin escarpment evolution in southern Brazil

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ABSTRACT

Although several authors have pointed out the importance of earth surface process to passive margin escarpments relief evolution and even drainage rearrangements, the dynamics of a consolidated capture area (after a drainage network erodes the escarpment, as the one from the Itajaí-Açu River) remain poorly understood. Here, results are presented from radar elevation and aerial imagery data coupled with in-situ-produced ^{10}Be concentrations measured in sand-sized river-born sediments from the Serra Geral escarpment, southern Brazil. The Studied area's relief evolution is captained by the drainage network: while the Itajaí-Açu watershed relief is the most dissected and lowest in elevation, it is significantly less dissected in the intermediate elevation Iguaçu catchment, an important Paraná River tributary. These less dissected and topographically higher areas belong to the Uruguai River catchment. These differences are conditioned by (i) different lithology compositions, structures and genesis; (ii) different morphological configurations, notably slope, range, relief; and (iii) different regional base levels. Along the Serra Geral escarpment, drainage features such as elbows, underfitted valleys, river profile anomalies, and contrasts in mapped χ-values are evidence of the rearrangement process, mainly beheading, where ocean-facing tributaries of the Itajaí-Açu River capture the inland catchments (Iguaçu and Uruguai). The ^{10}Be derived denudation rates reinforced such processes: while samples from the Caçador and Araucárias Plateaus yield weighted means of 3.1 ± 0.2 and 6.5 ± 0.4 m/Ma respectively, samples from along the escarpment yield a weighted mean of 46.8 ± 3.6 m/Ma, almost 8 times higher. Such significant denudation rate differences are explained by base-level control, relief characteristics, and the geology framework. The main regional morphological evolutionary mechanism is headward denudation and piracy by the Itajaí-Açu River tributaries. As the escarpment moves from east to west, Itajaí-Açu River tributaries develop, leading to regional relief lowering and area losses within the Iguaçu and Uruguai catchments. Such processes were accelerated since Itajaí-Açu tributaries reached into sedimentary and volcanic rocks. From this moment on, Serra Geral became the main hydrographic divide between the ocean- and inland facing-catchments in the area.

1. Introduction

Passive margin escarpments are among the most notable landforms worldwide and their origin is associated to extensional tectonics, which results from continental plate breakup, rift opening and oceanic expansion (Summerfield, 1991; Gilchrist and Summerfield, 1994; Matmon et al., 2002). Escarpments are typical features of passive margins, separating inland plateaus from coastal plains (Seidl et al., 1996). Over the last decades, significant advances in low-temperature thermochronological (zircon and apatite fission track) and in-situ-produced cosmogenic nuclide techniques have reactivated discussions about the long-term evolution of passive margin escarpments (Seidl et al., 1996; Cockburn et al., 2000; Brown et al., 2002; Matmon et al., 2002; Persano et al., 2002; Braun and van der Beek, 2004; Vanacker et al., 2007; Roller et al., 2012; Salgado et al., 2014, 2016; Braun, 2018). Such studies have shown that after an initial phase of accelerated retreat, during the early stages of seafloor spreading, escarpments remain almost stationary, with their location being a function of the crustal structure and the distribution of the normal faults related to rifting and expansion. After stabilization, escarpments are then eroded mainly by surface processes, namely hydrographic and mass-wasting processes, in close relation to headward erosion and migration of knickpoints along river profiles.

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Along passive margin escarpments, the ocean-facing catchments are steeper and generally exhibit higher denudation rates than their continental counterparts (Summerfield, 1991; Gilchrist and Summerfield, 1994). Such is the case for the eastward South American passive margin, where high levels of precipitation are concomitant to increased denudation rates (Salgado et al., 2014, 2016; Gonzalez et al., 2016). But what exactly happens once the ocean-facing catchment finally crosses the escarpment and start to drain the highland plateaus? Along the South American margin of southern Brazil, it has already been documented that ocean-facing catchments can capture small channels from the continental highlands (Oliveira and Queiroz Neto, 2007; Cherem et al., 2012; Salgado et al., 2014, 2016). However, no studies have attempted to understand the relief evolution in a consolidated captured area; in other words, how relief evolves when the coastal rivers have established their headwaters within the highland plateaus. Our study thus focuses on the most consolidated capture of this type along the South American passive margin, where the Itajaí-Açu River, which broke through the Serra do Mar Range and set its headwaters at Serra Geral escarpment, located roughly 200 km westward of the Atlantic coast (Fig. 1), is draining considerable areas in the Brazilian highlands.

During the last decades, long-term relief evolution investigations benefited from development of morphometric analyses and dating methods. For example, geomorphic indices and tools (Chi, Ksn index, surface index, Swath profiles) have been developed to assist geomorphologists in understanding tectonics and erosion dynamics over long-term landscape evolution in active mountain belts (Perron and Royden, 2013; Andreani et al., 2014; Willett et al., 2014; Chen et al., 2015; Giletycz et al., 2015). Though meaningful, such parameters are not commonly applied to the study of passive margins and intraplate tectonic contexts marked by the subtle influence of tectonics (Jelinek et al., 2003; Tello Saenz et al., 2003; Hackspacher et al., 2004; Franco-Magalhães et al., 2010; Karl et al., 2013). These are powerful tools when coupled with denudation rates derived from in-situ-produced cosmogenic nuclide or low-temperature chronological data. The strength of this methodology is because of a process-dating duality. While geomorphic indices and remote sensing tools allow an analysis

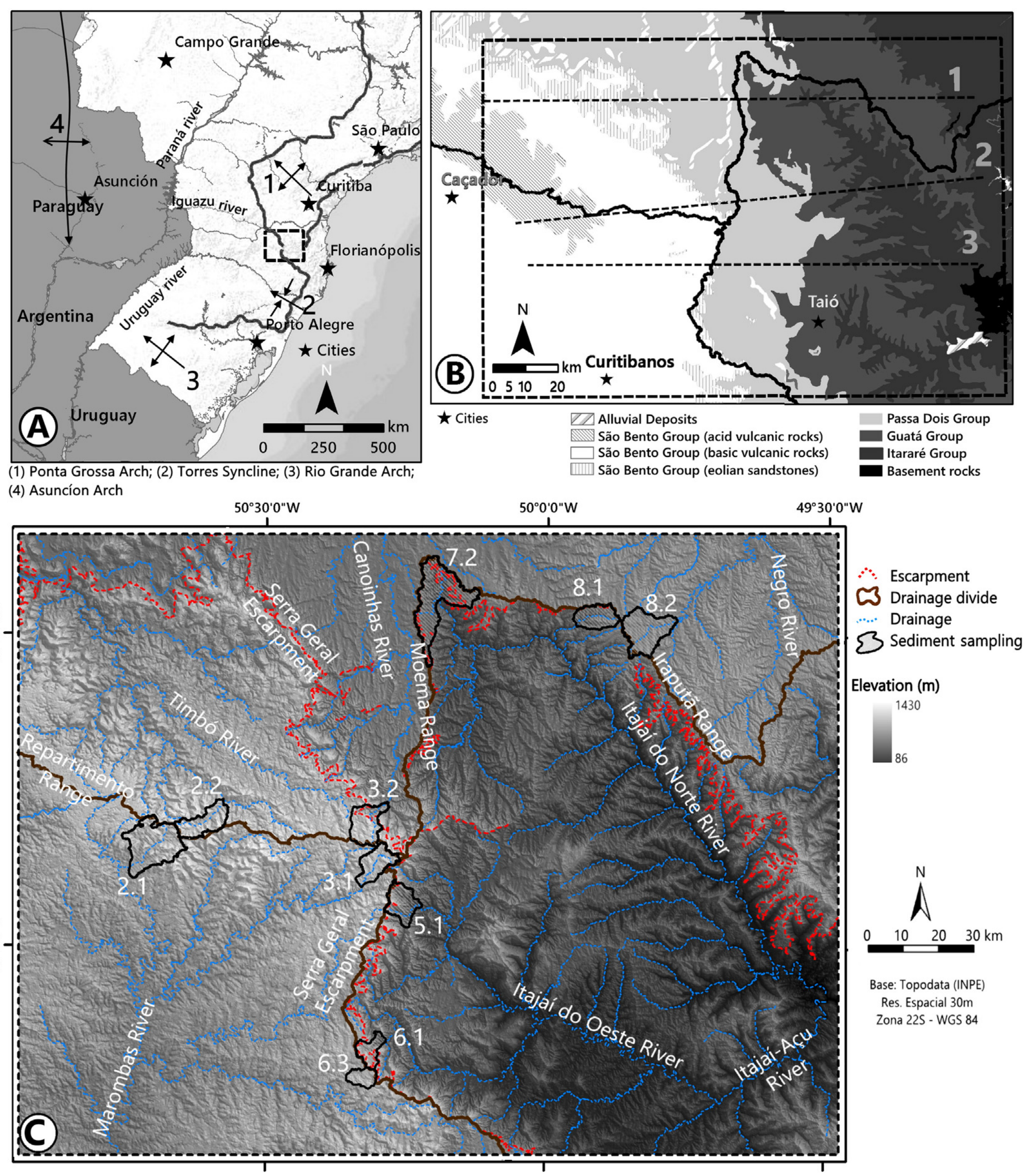

Fig. 1. (A) Localization of the study area in central Santa Catarina State, at the triple divide between Itajaí-Açu, Iguaçu (Paraná), and Uruguai watersheds. (B) Geological map of the studied area. Black dashed lines identified by numbers (1, 2, and 3) localize swath profiles shown in Fig. 7. (C) Digital elevation model of the studied area, indicating catchments sampled for measuring in-situ-produced cosmogenic ^{10}Be concentrations in river-borne sediments. White numbers refer to the ^{10}Be samples list detailed in Tables 1 and 2.