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Late Quaternary fluvial terrace evolution in the main southern Amazonian tributary

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ABSTRACT

Late Quaternary sedimentary deposits from Amazonian lowlands are important geological archives for understanding the origin, evolution and controls of the largest fluvial drainage basin on Earth. Climate has been most often claimed as the main factor affecting river evolution in this region. An increasing volume of publications have also highlighted tectonics as a relevant control. This work investigates the late Quaternary evolution of the Madeira River, the biggest southern tributary of the Amazonas Basin and a major waterway in South America, with the goal of discussing the factor with highest potential of influence on its development in space and time. The approach consisted of carrying out a detailed morphological, sedimentological and chronological characterization of terrace deposits. Three terraces were recognized, which record sandy/pebbly channel, muddy channel/oxbow lake, point bar, floodplain, as well as crevasse channel, crevasse splay and levee deposits. The topographically highest terrace T1 formed in the time interval before 43,500 and 31,696–32,913 cal yrs BP, the intermediate terrace T2 between 25,338–26,056 and 14,129–14,967 cal yrs BP, and the lowest terrace T3 between 12,881–13,245 and 3158–3367 cal yrs BP. These terraces are the testimony of successive downcutting and sediment aggradation. Episodes of terrace erosion and deposition cannot be fully accommodated within the framework of fluctuating river base level tied to Late Pleistocene–Holocene global or regional climate fluctuations. Changes in tectonic subsidence rates might have played an important role in the equilibrium state of this particular fluvial system.

1. Introduction

Neogene and Quaternary deposits of Western Amazonia have been of scientific interest because they are the most relevant archive for understanding the geological history of the largest fluvial drainage basin on Earth. An increasing number of publications have demonstrated that the area drained by the Amazonas River and its tributaries was a dynamic depositional paleoenvironment in the late Quaternary (e.g., Hayakawa et al., 2010; Latrubesse, 2002; Rossetti and Valeriano, 2007; Rossetti et al., 2005). However, the factors that have led to frequent paleoenvironmental fluctuations in this area during this time interval remain controversial. Several authors have highlighted the role of climate on the evolution of this landscape, particularly during alternating dry and wet periods of the Last Glacial (e.g., Freitas et al., 2001; Latrubesse, 2002; Pessenda et al., 2001; Rigsby et al., 2009; Van der Hammen et al., 1992). However, interpretations are still controversial. While a dominantly dry Amazonia has been claimed until the mid-Holocene (Mayle and Beerling, 2004; Mayle and Power, 2008), many records of continuous rainforest have led several authors to propose a mostly uniform wet climate in this region for the last 40 ka years (e.g., Bush et al., 2004; Irion et al., 2006; Mayle and Power, 2008). In addition, changes in the Amazonian landscape in the late Quaternary have been related to sea-level fluctuations (Irion et al., 1995). There is also a long list of literature addressing the importance of tectonics in the development of many Amazonian drainage basins (Almeida-Filho and Miranda, 2007; Bezerra, 2003; Franzinelli and Igreja, 2002; Souza-Filho et al., 1999; Sternberg, 1950). Determining the factor(s) with the highest impact on the evolution of this large tropical river system is an issue still open for debate. A larger body of information focusing on paleoenvironmental reconstruction and stratigraphic relationships considering many different Amazonian areas remains to be achieved to advance this discussion.

Large areas of Western Amazonia are covered by Late Pleistocene–Holocene deposits that occur mostly in fluvial terraces of great interest for reconstructing river paleodynamics (e.g., Rossetti et al., 2005). Fluvial

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terraces of this age are particularly well recorded in the middle course of the Madeira River. This is the longest southern tributary of the Amazonas River and a major waterway in South America (Latrubesse, 2008). A striking characteristic of this river is its straight to slightly sinuous channel pattern that contrasts with other southern meandering tributaries of the Amazonas River, such as the Purus and Juruá Rivers. Answering why the Madeira River has such a distinguished pattern and what were its late Quaternary dynamics might contribute to understand the factors controlling the evolution of other large tropical river systems.

In this work, we present a detailed morphological, sedimentological and chronological characterization of fluvial deposits along an extensive (i.e., up to 400 km long) segment of the middle Madeira River. These data provided elements for investigating the history of a large Amazonian River during the late Quaternary and discussing the factor with the highest potential of influencing its evolution through time.

2. Physiography and geological framework

The study area, located southwest of the city of Manaus in the State of Amazonas (Fig. 1A–C), is characterized by tropical climate (Am in Köppen's classification), mean annual temperature of 28 °C, and precipitation averaging 2500 to 3000 mm/year (Radambrasil, 1978). The Madeira River has its headwaters near Cochabamba, Bolivia, extending from this locality to the Atlantic Ocean over a distance of up to 3352 km, being the second longest Amazonas tributary. This river has a mean discharge along the Brazilian lowlands of up to 31,200 m^3/s (Molinier et al., 1997). The total suspended sediment flux exported from the present orogenic wedge of northern Bolivia is 667.4 million t $year^{-1}$, around 50% of which is retained upstream in the foreland basin. Downstream, 82% of the total sediment load is between 7 μm and 13 μm in diameter (Guyot et al., 1999).

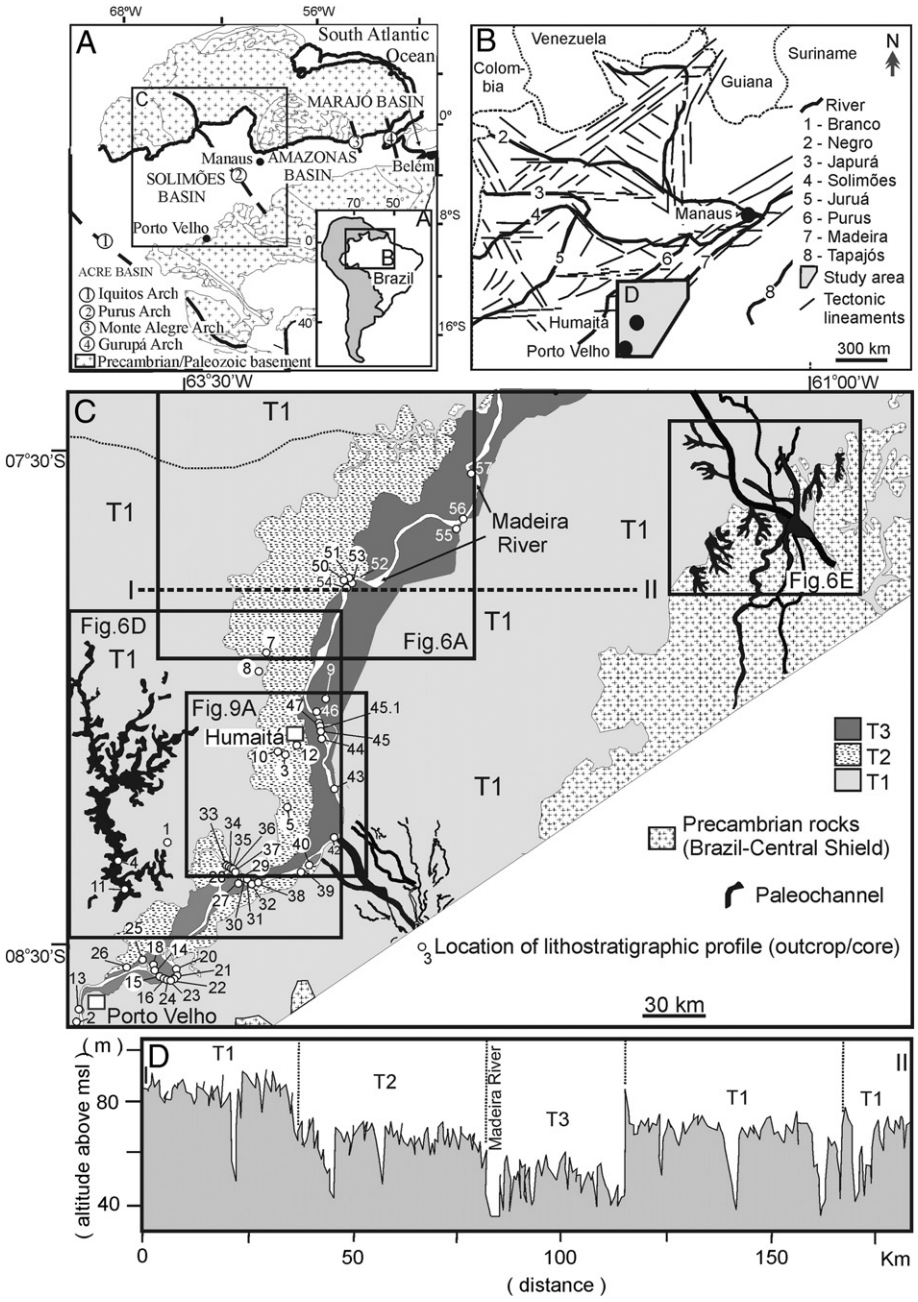

Fig. 1. A,B) Location of the study area to the southwest of the city of Manaus, Western Amazonia, and its geological context. C) Spatial distribution of the three terraces mapped along a segment of the Madeira River and location of the studied lithostratigraphic profiles. D) SRTM–DEM topographic profiles along transects I–II located in C.