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Holocene provenance shift of suspended particulate matter in the Amazon River basin

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ABSTRACT

The strontium (Sr), neodymium (Nd) and lead (Pb) isotope signatures of suspended particulate matter (SPM) in rivers reflect the radiogenic isotope signatures of the rivers' drainage basin. These signatures are not significantly affected by weathering, transport or depositional cycles, but document the sedimentary contributions of the respective sources. We report new Sr, Nd and Pb isotope ratios and element concentrations of modern SPM from the Brazilian Amazon River basin and document the past evolution of the basin by analyzing radiogenic isotopes of a marine sediment core from the slope off French Guiana archiving the last 40 kyr of Amazon River SPM, and the Holocene section of sediment cores raised between the Amazon River mouth and the slope off French Guiana. The composition of modern SPM confirms two main source areas, the Andes and the cratonic Shield. In the marine sediment core notable changes occurred during the second phase of Heinrich Stadial 1 (i.e. increased proportion of Shield rivers SPM) and during the last deglaciation (i.e. increased proportion of Madeira River SPM) together with elsewhere constant source contributions. Furthermore, we report a prominent offset in Sr and Nd isotopic composition between the average core value (ε_{Nd}: -11.7 ± 0.9 (2SD), $^{87}Sr/^{86}Sr$: 0.7229 ± 0.0016 (2SD)) and the average modern Amazon River SPM signal (ε_{Nd}: -10.5 ± 0.5 (2SD), $^{87}Sr/^{86}Sr$: 0.7213 ± 0.0036 (2SD)). We suggest that a permanent change in the Amazon River basin sediment supply during the late Holocene to a more Andean dominated SPM was responsible for the offset.

1. Introduction

The bulk of solid continental materials is transferred to the oceans as river suspended particulate matter (SPM) (Milliman and Meade, 1983). Other less significant transport mechanisms are aeolian and glacial input (Duce et al., 1991; Hallet et al., 1996). River SPM is deposited in river deltas or along continental margins and may provide valuable archives with high temporal resolution. These deposits record the isotope signatures of their continental sources as well as changes in provenance (Bentahila et al., 2008; Revel et al., 2010, 2014, 2015; Walter et al., 2000; Wei et al., 2013), provided the sediment sources of the individual drainage basins are sufficiently different in their radiogenic strontium (Sr), neodymium (Nd) and lead (Pb) isotope signatures.

The Amazon River drains an area of 6.3×10^6 km^2 with contrasting geology and radiogenic isotope composition including old Precambrian shields, Phanerozoic sedimentary deposits, and the Cenozoic Andean orogen with an active magmatic arc in the west (Fig. 1). The water discharge of the Amazon River accounts for roughly 20% of the world's river supply into the oceans making it the world's largest river not only in water discharge but also in drainage area (Gibbs, 1967). It supplies an average of $1.1–1.3 \times 10^9$ tons of sediments per year into the Atlantic Ocean (Meade, 1994), which are transported northwestwards and deposited from its mouth along hundreds of kilometers on the continental margin (Gibbs and Konwar, 1986). Two thirds of the drainage basin consists of a broad lowland plain and borders the Cenozoic Andes in the west and the Precambrian cratonic highlands in the north (Guiana Shield) and south (Brazilian Shield) (Gibbs, 1967) (Fig. 1). The five

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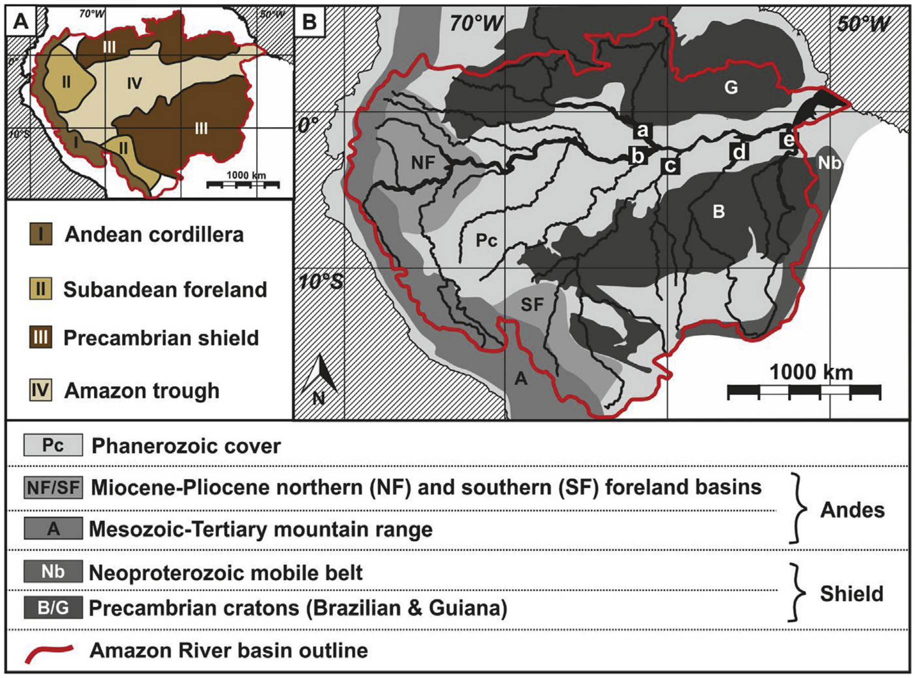

Fig. 1. Panel A: Main morphostructural zones of the Amazon River basin adapted from Stallard and Edmond (1983). Panel B: Major geological units of the Amazon River basin. The outline of the Amazon River basin is shown in red and the main tributaries of the Amazon River are marked with white lowercase letters as follows a: Negro River, b: Solimões River, c: Madeira River, d: Tapajós River and e: Xingu River. Geological units are simplified after Roddaz et al. (2005) and Tassinari and Macambira (1999). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

largest tributaries of the Amazon River are (in descending order of drainage area) the Solimões and Madeira (draining the Andes), the Negro, Xingu and Tapajós Rivers (draining the Shield areas) (Gibbs, 1967).

Numerous studies have investigated the chemical and mineralogical composition of the Amazon River and its tributaries' water and sediment load in order to characterize the different source areas and to understand the influence of distinct processes as e.g. sedimentation, transport and weathering on these signatures (e.g. Medeiros Filho et al., 2016; Guyot et al., 2007; Santos et al., 2015; Vital and Stattegger, 2000). In contrast to the elemental composition, the radiogenic isotopes are not influenced by these processes making them particularly suited for provenance studies. The Sr, Nd and Pb isotope composition of SPM from the Amazon River and its tributaries is poorly known and most of the existing data are from the Solimões and Madeira Rivers, both draining the Andes (Allègre et al., 1996; Bouchez et al., 2011; Viers et al., 2008). Only limited values are available for the main channel of the Amazon River and the Shield draining Negro, Tapajós and Xingu Rivers (Allègre et al., 1996; Bouchez et al., 2011). Several studies have shown that the main sediment supplier to the modern Amazon River (Filizola and Guyot, 2004; Meade et al., 1985) during the late Quaternary (Govin et al., 2014; Milliman et al., 1975) are the Andes. There is, however, evidence for small variations in the proportions of Andean and cratonic Shield material within the Amazon River SPM. Given the continental extension of the Amazon River basin, even small variations may have large paleoenvironmental implications. Horbe et al. (2014) report a shift in Sr and Nd signatures from a more cratonic Shield component in Quaternary floodplain sediments of the Solimões River to more Andean material in modern Solimões River SPM. McDaniel et al. (1997) studied Nd and Pb isotopes on glacial stage sediments from the Amazon fan and suggested that Pleistocene muds have a more cratonic composition. The identification and interpretation of changing source contributions in the past relies on an accurate knowledge of the modern Sr, Nd and Pb isotopic composition of the Amazon River and its tributaries.

Here we present the Sr, Nd and Pb isotopic and elemental composition of SPM from the five main Amazon River tributaries (Solimões, Madeira, Negro, Tapajós and Xingu Rivers), as well as from the Amazon River main channel and mouth. We applied our isotopic source characterization to a marine sediment core representing the integrated Amazon River basin discharge for the last 40 kyr and a range of marine core top samples representing the late Holocene deposits of the Amazon River. The new data accurately constrain the modern contributions of the Andean highland and cratonic lowland source areas, while the marine deposits indicate a shift toward a more Andean signature during the late Holocene as a response to a change in climate.

2. Regional setting

2.1. Geological setting

Stallard and Edmond (1983) divided the Amazon River basin into four morphostructural zones (Fig. 1A): The Andean Cordillera, the Subandean foreland, the Precambrian Shield and the Amazon trough. Subzones of the Andean Cordillera include the Eastern Cordillera, the Altiplano and the Western Cordillera. The Amazon trough is mainly filled by Phanerozoic sedimentary rocks (Pc). Its uppermost Neogene and Quaternary sedimentary units (Dino et al., 2012; Rossetti et al., 2005) are a mixture of the material weathered upstream from the principal source areas in the Andes, and Brazilian and Guiana Shields. Similarly, the Subandean foreland with the northern (NF) and southern (SF) Amazon foreland basins is mainly composed of Miocene to Pliocene sediments from the same sources (Roddaz et al., 2005). The Precambrian Amazon Craton is subdivided into the Guiana Shield to the north and the Brazilian Shield to the south. The volcano-plutonic and the metamorphic units have ages between 3.7 and 1.0 Ga (da Rosa-Costa et al., 2006; Tassinari and Macambira, 1999; Tassinari et al., 2000). The region of