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Sediment provenances and drainage evolution of the Neogene Amazonian foreland basin

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INTRODUCTION

The Miocene to Pliocene paleoenvironments of western Amazonia are not well known. In particular, the Miocene paleoenvironment has long been a matter of debate. Recent studies however have demonstrated that during the Miocene, Western Amazonia was a tide-influenced sea (Gingras et al., 2002; Gingras et al., 2002; Hovikoski et al., 2005; Räsänen et al., 1995; Roddaz et al., in press). The transition from this tide-influenced sea to the modern fluvial basin drainage network has been poorly studied. Some authors (e.g., (Hoorn et al., 1995; Roddaz et al., in press)) suggest that Andean tectonics may have caused the closure of this Miocene sea and the subsequent individualization of the modern Amazon drainage network.

Based on extensive sampling and on the geochemistry of Amazonian foreland basin sediments that are likely to have preserved the erosonial unroofing history of the orogen, this study is aimed at i) establishing the provenance of Miocene tidal sediments and of Late Miocene-Pliocene fluvial sediments of the Western Amazonian foreland basin, deducing the kinematic unroofing of the potential source terranes and iii) assessing the potential control of Andean foreland basin tectonics in the paleo-Amazonian drainage network.

RESULTS

118 samples were collected from the Amazonian foreland basin (Fig. 1) and were analyzed by Quadrupole ICP-MS for trace elements at the LMTG (Toulouse, France) and 97 of these were selected for major elements, determined by ICP-AES at the CRPG (Nancy, France). 30 representative samples were selected for determination of Sc concentrations (Chemex Labs, Canada) and for Sr and Nd isotopic composition.

Details of the major and trace element (including rare earth elements) geochemistry of the Neogene Amazonian sediments were discussed in a companion paper (Roddaz et al., submitted). The main conclusion from this study is that weathering has increased from the Miocene to present in both the North Amazonian foreland basin (NAFB) and the South Amazonian foreland basin (SAFB) and that sedimentary sorting has not played a significant role in the chemical differentiation of the NAFB and SAFB sediments. Therefore, Trace elements such as Th, Sc, Zr, Hf and REEs as well as elemental ratios such as Th/Sc and Cr/Th are considered to be valid tools to determine the provenance of NAFB and SAFB sediments as it has been demonstrated in other studies (see (McLennan et al., 1993) for a review).

Nd and Sr-isotopic compositions of the NAFB and SAFB samples are plotted in a $^{87}Sr/^{86}Sr$ vs. $\gamma Nd(0)$ diagram (Figure 2a). Overall, Neogene Amazonian foreland basin sediments are the result of a mixing between Andean andesitic volcanic rocks and cratonic shield rocks.

The SAFB sediments are the result of long-term weathering, recycling, and erosion of the Brazilian shield and Andean Paleozoic/Mesozoic rocks also Brazilian shield in provenance. Compared with NAFB sediments, SAFB sediments are more felsic in provenance. The NAFB sediments have 3 distinct signatures: i) an upper crust signature with trace element characteristics similar to Post Archean Australian Shales (PAAS) and the Upper Continental Crust (UCC) (Taylor and McLennan, 1985) and with γNd(0) values between -8 and -11.9 that are present in the Huallaga basin (Peruvian Subandean Zone), in the Iquitos forebulge and in the Pevas backbulge; ii) an arc andesitic rock signature with high Cr/Th ratios, low Eu anomalies, low Th/Sc and with γNd(0) between -3 and -5 found in the Miocene syn-orogenic sediments of Ecuador (Curaray formation) and the Late Miocene-Pliocene sediments of the Amazon formation in the Iquitos forebulge depozone.; and iii) a cratonic signature with high Eu anomalies and Zr/Sc and with a very low γNd(0) value (-15.5) in the eastern (cratonic) part of the Iquitos forebulge. Our data indicate that most of the basic detritus came from the Ecuadorian Andes.

INSIGHTS INTO THE DRAINAGE AND TECTONIC HISTORY OF WESTERN AMAZONIA

The Iquitos forebulge is a key area as it is the place where the Marañón River joins the Ucayali River to form the Amazon River. Sixty-five kilometers eastwards, the Rio Napo (the largest river draining the Ecuadorian Andes) joins the Amazon River. The development of several Neogene formations that outcrop in the Iquitos forebulge was controlled by the forebulge uplift (Roddaz et al., in press). Based on our geochemical results and on our field studies (Roddaz et al., in press), we propose a schematic evolution of the Neogene Amazon drainage basin (Fig. 2b).

During the Middle-Late Miocene (Fig. 2b), the NAFB was covered by the Pebas tide-influenced sea (Gingras et al., 2002; Hermoza et al., in press; Hovikoski et al., 2005; Räsänen et al., 1998; Roddaz et al., in press). At that time, the Ecuadorian Oriente basin and the Peruvian Huallaga basin formed the foredeep depozone (i.e., the most subsiding depozone; (DeCelles and Giles, 1996)) of the NAFB (Christophoul et al., 2002; Hermoza et al., in press). Sediments from these basins have a distinct provenance: the sediment of the Oriente basin has a strong basic/andesitic signature not shown by the sediments of the Huallaga basin and did not arrive to the Iquitos forebulge depozone. At approximately the same time, however, the sediments from the Pebas formation were Andean in origin both in the Iquitos forebulge and in the Pevas backbulge.

Since the Late Miocene, Andean uplift proceeded in phases culminating in a period of most rapid uplift in the Plio-Pleistocene. In the Amazonian foreland basin, sedimentation became continental. The geochemical signatures of Late Miocene-Pliocene continental sediments indicate that the Iquitos high acted as a drainage divide between transverse rives issued from the Andes (Nauta2 Mb) and rivers issued from the eastern craton (White Sand Fm; Fig. 2b). This pattern is interpreted as the result of the flexural uplift of the Iquitos forebulge in response to thrust-induced tectonic loading of the Eastern Cordillera and Subandean Zone (Roddaz et al., in press). The amount of sediment derived from basic/andesitic rocks in the Paleo-Amazon River near the Iquitos forebulge also supports this interpretation. It is suggested that overfilling of the foreland basin associated with regional increase in slope and a stage of relative tectonic quiescence was responsible for overcoming of the Iquitos forebulge by the transverse major rivers issued from the Andes (Marañon, Napo, Ucayali; Fig. 2b) thus creating the present-day drainage network (Fig. 2b). The Amazonian drainage network is no younger than the Pliocene.

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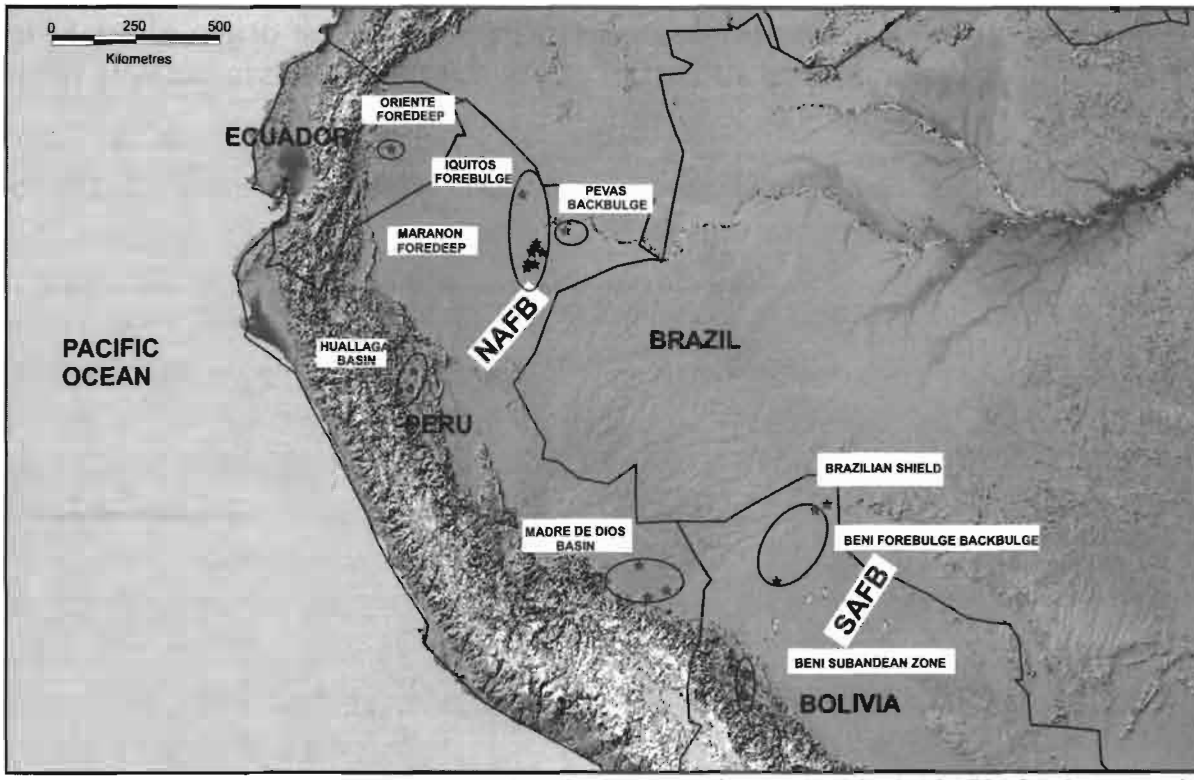

Figure 1: Locations of sampled outcrops. NAFB: North Amazonian foreland basin; SAFB: South Amazonian foreland basin Depozone is labeled dz. SAZ: Subandean Zone.

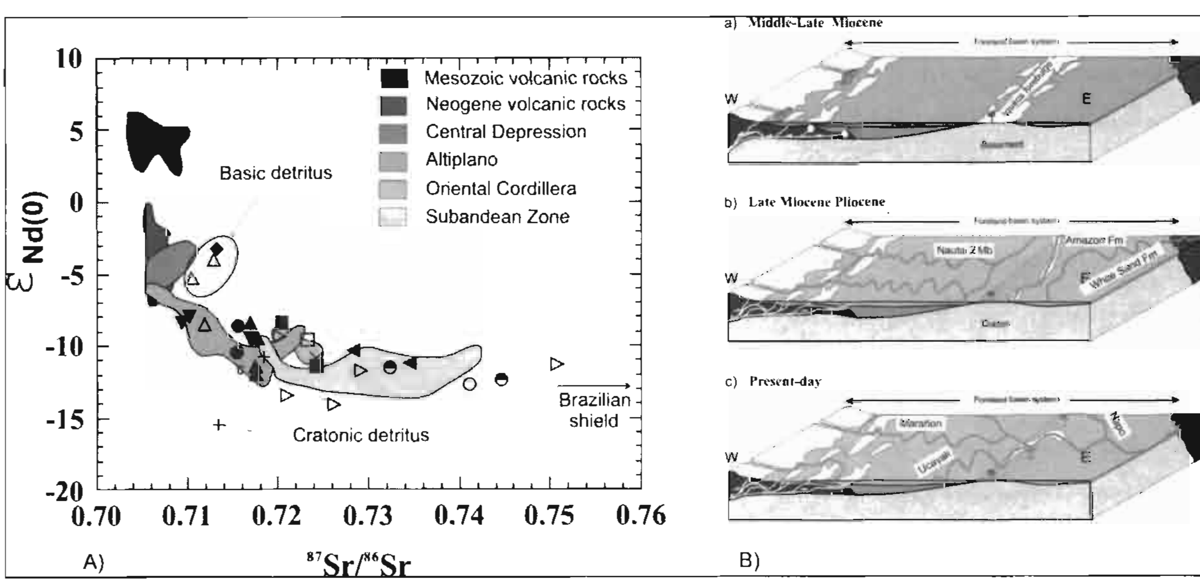

Figure 2: A)$^{87}Sr/^{86}Sr$-$\gamma Nd(0)$ diagram for Western Amazonian sediments. Data sources: Mesozoic and Neogene volcanic rocks from Rogers and Hawkesworth (Rogers and Hawkesworth, 1989)) and from Kay et al., (Kay et al., 1994). Data for Central Depression, Altiplano, Oriental Cordillera, Subandean Zone fields are available in Pinto (Pinto, 2003). ◀, ○, ◓, ▷ : SAFB sediments. Other symbols represent NAFB sediments. B) Schematic Neogene evolution of the NAFB. See text for explanations.