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Provenance of Pliocene and recent sedimentary deposits in western Amazônia, Brazil: Consequences for the paleodrainage of the Solimões-Amazonas River

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ABSTRACT

Integrated data on paleocurrents, the morphology of detrital minerals and zircon grains, chemical compositions and U–Pb geochronology, reveal that the flow of the modern Solimões-Amazonas River has changed from west to east since the Plio–Pleistocene. This finding is supported by several lines of evidence, including paleocurrent directions and detrital mineral assemblages in the Içá Formation and in recent sediments. The Içá Formation, which was most likely deposited during the Pliocene, has NE and SE paleocurrents, a high proportion of stable detrital mineral assemblages and U–Pb zircon ages that we interpreted as being derived from the Amazonian craton (e.g., the Rondonian-San Ignácio and Sunsas-Grenvillian geochronologic provinces) and neighboring provinces, including the Neoproterozoic to Cambrian Brazilian Pampean mobile belts. A small proportion is derived from the Cambrian to Silurian Famatinian continental arch. Another source is the Precambrian and Paleozoic basement from the Andes cordillera, which includes several metamorphic inliers in Colombia, Peru and Bolivia. The overlying recent deposits have different provenances and are characterized by a more variable detrital assemblage with zircon grains that are enriched in trace elements and depleted in Si and have Mesoproterozoic ages. In our interpretation, the erosion of the Iquitos Arch after deposition of the Içá Formation allowed the westward expansion of the Solimões-Amazonas system in the Plio-Pleistocene.

1. Introduction

The uplift and subsequent orogenic deformation of the Andes has caused important paleogeographic changes in western Amazônia since the Miocene. The marine connection with the Caribbean sea closed, the courses of the Magdalena and Orinoco rivers changed, Andean foreland basins formed due to flexural subsidence and the Amazonas established a connection to the Atlantic, increasing the mass accumulation rates of terrigenous sediments in the Amazonas fan (e.g., Hoorn et al., 1995; Hooghiemstra and Van der Hammen, 1998; Dobson et al., 2001; Roddaz et al., 2005b; Wesselingh and Salo, 2006; Latrubesse et al., 2007; Figueiredo et al., 2009). Because the effects of these changes are not clear, different proxies for the geodynamics of the Solimões-Amazonas River must be considered. Hoorn et al. (1995); Dobson et al. (2001) and Wesselingh and Salo (2006) stated that the architecture of the modern Solimões-Amazonas River formed since the late Miocene. Campbell et al. (2001) interpreted that the Andean contribution to the Atlantic occurred in the end of the Pliocene (2.5 Ma), while Bezzerra (2003) and Rossetti et al. (2005) interpreted it as occurring in the late Pleistocene–Holocene.

The aim of this paper is to study detrital minerals from the Içá Formation and associated recent deposits along the Solimões River, both of which represent the youngest sedimentation event recognized in the Amazonia region, to establish their sediment sources (provenance) and to investigate the formation of the modern Solimões-Amazonas River and their connection to the Atlantic Ocean. These two units are part of the large sedimentary Solimões-Amazonas basin and therefore might clarify the geological evolution and timing of the development of the present course of the Solimões-Amazonas River systems. In addition, we will discuss the influence of the Iquitos Arch and Andes rocks in the sedimentation and landscape evolution of western Amazônia. To answer these questions, we selected the six most significant outcrops in the cliffs, islands and bars along the Solimões River between the cities of Tefé and Manaus (Fig. 1). According to Maia et al. (1977) and Melo and Villas Boas (1993), the cliffs along the river correspond to the Içá Formation, whereas the islands and bars are composed of recent riverbed sediments.

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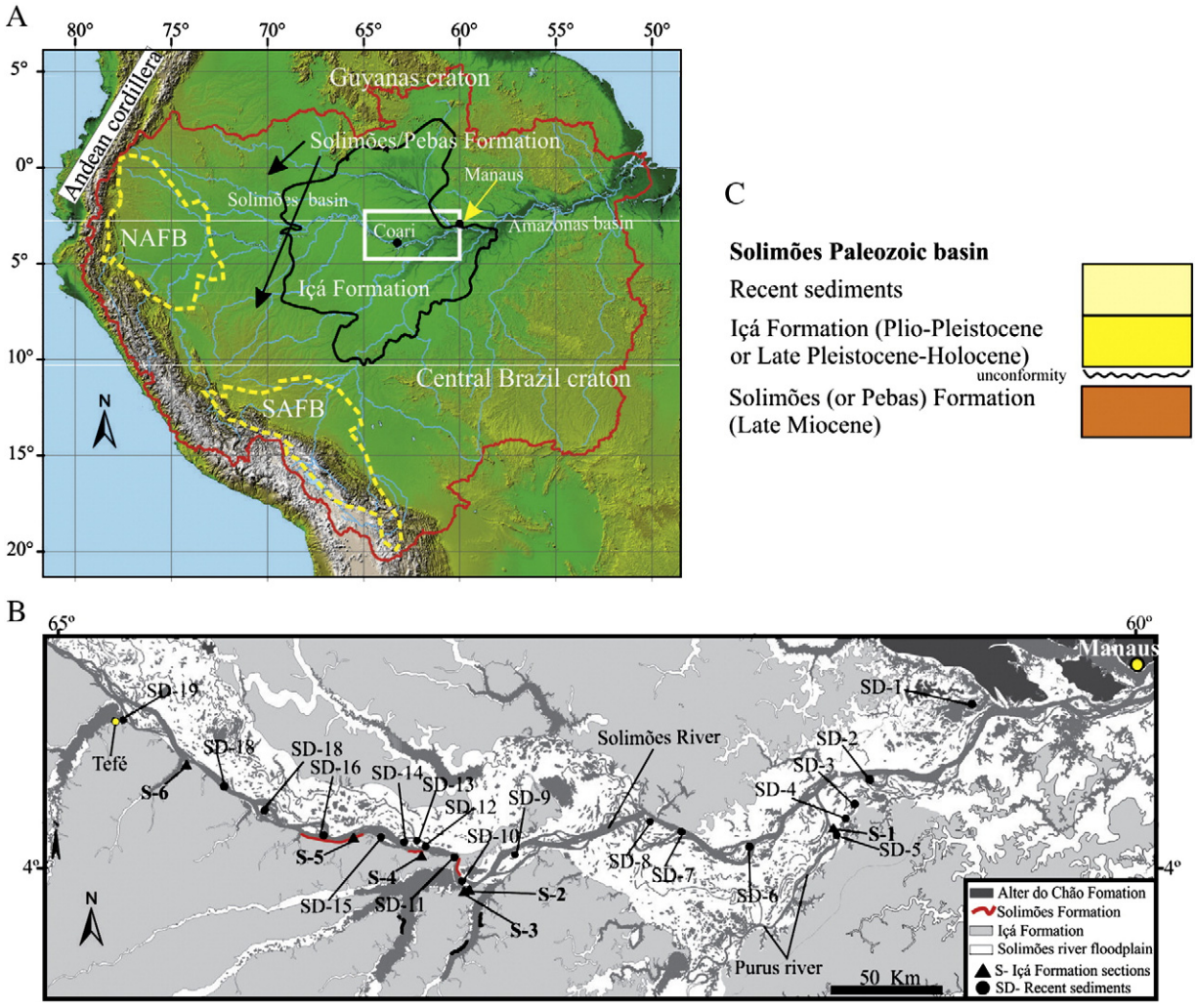

Fig. 1. (A) Location map showing the main Paleozoic sedimentary basins: Amazonas in the east side, Solimões in the center and the Peru and Bolivia foreland Amazon basin (NAFB and SAFB after Roddaz et al., 2005a, 2005b) in the west side in a SRTM image. The limits of the Içá Formation in black (CPRM, 2006) and the limit of the Solimões-Amazon hydrographic basin in red; (B) Geology and location of the samples in the study area, S stratigraphic section of the Içá Formation, SD samples from recent deposits. The Solimões Formation occurs in a large region in the west of the Içá Formation and in a few outcrops in the study area (1B); (C) Simplified chronostratigraphic diagram of the studied units in the Solimões Paleozoic basin.

2. Geological setting

The western portion of the Amazonas River in Brazil is called the Solimões River and drains the Andean cordillera, the sedimentary rocks of the Solimões Paleozoic basin, and the Central Brazil and Guyana shields (Amazonian craton) (Fig. 1A, B). The two youngest sedimentary units of the Solimões Paleozoic basin are the Solimões Formation (called the Pebas Formation in Peru and Colombia) and the Içá Formation (Fig. 1C).

Several studies have investigated the sedimentary environment and palynology of the Solimões Formation (e.g., Caputo and Silva, 1991; Hoorn, 1994; Hoorn et al., 1995; Leguizamón Vega, 2005; Wesselingh and Salo, 2006; Latrubesse et al., 2007). These studies indicate that the Solimões Formation occupied a large lowland area adjacent to the Andean foreland basins (Roddaz et al., 2005a) (Fig. 1A) and was deposited during the late Miocene (11–10 Ma; Cozzuol, 2006; Latrubesse et al., 2007) in a fluvio-lacustrine to transitional marine environment. Its upper part is composed of thin to thick sandstone layers interspersed with massive white-reddish clay layers that are centimeters to meters thick, and the lower part is composed of gray-greenish clay layers that contain plant fossil, fish teeth and scales, evidence of bioturbation and root marks. The Andes and the Amazonian craton are considered to be the source area for the rocks that make up this formation (Hoorn et al., 1995; Latrubesse et al., 2007).

In contrast, the Içá Formation, which overlies the eastern part of the Solimões Formation (Fig. 1) above an erosive unconformity (Maia et al., 1977; Leguizamón Vega, 2005), has not been well studied and cannot be dated by biostratigraphy because of the lack of fossils. It is characterized predominantly by whitish to reddish yellow sandstone that is intercalated with grayish-reddish silty-clay lenses and is thought to be Plio–Pleistocene (Maia et al., 1977; Melo and Villas Boas, 1993) or Late Pleistocene–Holocene (Rossetti et al., 2005) in age. The Içá Formation has been correlated to the Madre de Dios Formation in Peru (Campbell et al., 2006). However, the exact extents of the Içá and Solimões Formations are controversial because they are present in a large, fairly inaccessible region. Moreover, Leguizamón Vega (2005) described sedimentary rocks related to the Solimões Formation along the Solimões River (Fig. 1B). Quaternary deposits overlie both the Solimões and Içá Formations along the Solimões-Amazonas River. They formed by the erosion of the Andes and Amazon craton cover the lowland regions that formed an extensive Quaternary fluvial plain tens of kilometers in length during avulsion of the Solimões-Amazonas Rivers (Latrubesse and Franzinelli, 2002).