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Geomorphology and evolution of the late Pleistocene to Holocene fluvial system in the south-eastern Llanos de Moxos, Bolivian Amazon

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ABSTRACT

In the Bolivian Amazon several paleochannel generations are preserved. Their wide spectrum of morphologies clearly provides crucial information on the type and magnitude of geomorphic and hydrological changes within the drainage network of the Andean foreland. Therefore, in this study we mapped geomorphological characteristics of paleochannels, and applied radiocarbon and optically stimulated luminescence dating. Seven paleochannel generations are identified. Significant changes in sinuosity, channel widths and river pattern are observed for the successive paleochannel generations. Our results clearly reflect at least three different geomorphic and hydrological periods in the evolution of the fluvial system since the late Pleistocene. Changes in discharge and sediment load may be controlled by combinations of two interrelated mechanisms: (i) spatial changes and re-organizations of the drainage network in the upper catchment, and/or (ii) climate changes with their associated local to catchment-scale modifications in vegetation cover, and changes in discharge, inundation frequencies and magnitudes, which have likely affected the evolution of the fluvial system in the Llanos de Moxos. In summary, our study has revealed the enormous potential which geomorphic mapping and analysis combined with luminescence based chronologies hold for the reconstruction of the late Pleistocene to recent fluvial system in a large portion of Amazonia.

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1. Introduction

Paleohydrological studies are of major importance for understanding present day and future responses of rivers to environmental changes (Starkel, 1993). As the largest river system on Earth, the Amazon River with its tributaries should therefore contribute essential information to our understanding of global to regional-scale variability of fluvial systems over late Quaternary timescales. Little is known with regard to the longer-term evolution of rivers in the Amazon basin (Sinha et al., 2012), despite the extensive evidence for past geomorphological and hydrological variability documented in aerial photography and satellite imagery, such as underfit rivers, numerous paleorivers, meander scars and oxbow lakes. So far, most studies have focused on the Amazon River and its main tributaries in Brazil and Peru (summarized in Latrubesse, 2003). Even less information from marginal regions such as south-western Amazonia and the Llanos de Moxos (LM) lowlands of Bolivia is known, although several studies have reported large-scale river migrations of the Beni, Mamoré and Grande Rivers (Allenby, 1988; Dumont, 1996; Hanagarth, 1993; Hanagarth and Sarmiento, 1990; Lombardo et al., 2012; Plafker, 1964; Plotzki et al., 2011). Avulsive shifts along the Mamoré and Grande Rivers must have occurred in the mid to late Holocene (Lombardo et al., 2012; Plotzki et al., 2013), but no comprehensive geomorphological or chronological dataset is available for the older, Pleistocene fluvial system in the region. In the southern Llanos de Moxos, remnants of the fluvial lobe of the Grande River as well as other traces of former rivers were grouped in two generations of paleochannels (Lombardo et al., 2012). Partly, this may express a bias towards younger fluvial events, as older landforms and features have often been buried by younger ones, or appear less pronounced due to erosion and fragmentation (e.g. Hanagarth, 1993). In the Llanos de Moxos the abundance and diversity of former river traces, however, suggest that more channel generations are preserved than previously reported, likely covering longer timescales. Their wide spectrum of morphologies has not yet been documented but clearly provides crucial information on the type and magnitude of geomorphic and hydrological changes within the extensive drainage network of the Andean foreland in Bolivia. Therefore, in this study we (i) map geomorphological characteristics of paleochannels, (ii) apply radiocarbon and optically stimulated luminescence (OSL) dating to establish a first chronology for paleochannel activity, and (iii) analyze geochemical composition

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of fluvial sediments to assess a preliminary framework for changes in provenance of sediments in these paleorivers.

2. Regional setting

The study area is situated in the Llanos de Moxos in north-eastern Bolivia (Fig. 1). The region investigated comprises an area of around 130 km × 130 km. The Mamoré and the Grande River form the western and southern margins of the study area, respectively. The LM is a large, seasonal inundated savannah (150,000 km^2) within the Amazon Basin. To the east the plains are confined by the Brazilian Shield and in the south-west by the Andes Mountains. Whereas the Andes and Subandean ranges are primarily composed of Paleozoic sediments (shales and evaporitic sediments; Elbaz-Poulichet et al., 1999; Stallard and Edmond, 1983), the Brazilian Shield consists of crystalline rocks (granite and gneiss; e.g. Litherland et al., 1989). Elevation above sea level is around 150 m. The plains, which are drained by the Mamoré River flowing in a northerly direction, show a gradient of less than 10 cm km^{-1} (Dumont and Fournier, 1994). The Mamoré River originates in the Eastern Cordillera. As a white water river it carries a significant load of sediment (64 × 10^6 t y^{-1} at the confluence with the Beni River; Guyot et al., 1999). Mean annual discharge of the Mamoré River at Trinidad (Fig. 1) is 2850 m^3 s^{-1}, although interannual variability is high, with discharge ranging from <500 m^3 s^{-1} in the dry season to 7600 m^3 s^{-1} in the rainy season (data from the HYBAM-Observatory (1986–2008), IRD-SENAMHI joint research project in Bolivia, 1986–2008, gauging station Puerto Varador; Ronchail et al., 2005). The Grande River, which discharges into the Mamoré River around 100 km upstream of Trinidad, also originates in the Eastern Cordillera. It drains parts of the Subandean Ranges and the Chaco lowlands of eastern Bolivia, and carries a suspended sediment yield of approximately 136 × 10^6 t y^{-1} at Abapo (Guyot et al., 1994). More than 30% of transported sediments in rivers draining the Eastern Cordillera are deposited directly after emergence of the piedmont in megafans (Guyot et al., 1994; Horton and DeCelles, 2001). In the mid-Holocene the Grande River discharged in a northerly direction and formed a

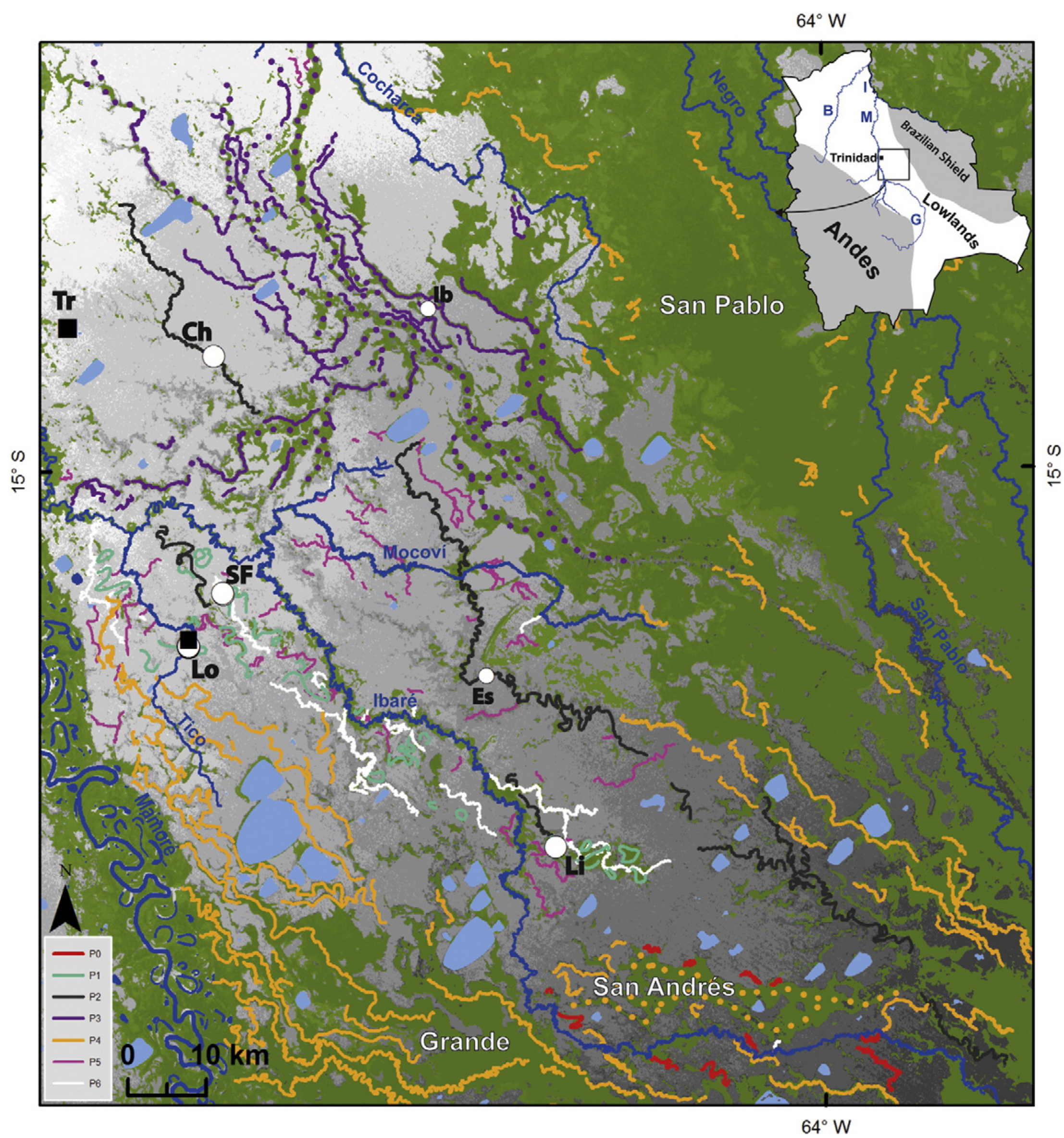

Fig. 1. Geographical setting. Study area within Bolivia (inset) and the north-eastern Bolivian lowlands, the Llanos de Moxos. B = Beni River, M = Mamoré River, G = Grande River, I = Iténez River (parallel to Brazilian border). Study sites are indicated with white circles. Ch = La Chacra, Ib = Ibiato, SF = Santa Fe, Lo = Loreto, Es = Estancia, Li = Limones. Tr = Trinidad. P0–P6 = paleoriver generations, dotted lines indicate paleochannels indicated by linear gallery forest, no channels could be detected there. Flow direction of rivers in north, north-western direction. Green = forests (San Pablo, San Andrés, Grande), gray colors = savannah. The sedimentary lobe of the former Grande River is represented by the P3 paleoriver generation.

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