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Environmental and vegetation changes in southeastern Amazonia during the late Pleistocene and Holocene

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ABSTRACT

New insights about climate conditions and their effect on vegetation and lakes of southeastern Amazonia were achieved over the last 50 cal ka using recent data obtained from a filled lake located in the Serra Sul de Carajás. Our analysis was done in a sediment core (R2) comprising of faciological, palynological, isotopic and radio carbon measurement supported by Bayesian age-depth modeling, as well species distribution modeling. Wet and cool climate conditions are proposed for the mid-Pleniglacial, which is favorable to intense weathering of the lake's catchment area and the expansion of high altitude taxa (cool-adapted) into forest formations during this period. From the late Pleniglacial to the Last Glacial Maximum, a change from relatively wet to dry climate possibly converted the studied lake from oxidizing to reducing conditions, which leads to the formation of diagenetic siderites at the end of this time interval. Warming during the Pleistocene to Holocene transition caused the disappearance of cool-adapted taxa in the study site. Concomitantly, increasing precipitation allowed the expansion of forest and high lake levels. A drier early-mid Holocene produced extensive open vegetation and desiccated lakes. Current climate and environmental conditions were likely attained in the region from the mid to late Holocene.

1. Introduction

The Amazon rainforest presents an area of around 5.5 million km^2 that corresponds over half of the world's remaining rainforests (Gentry, 1988). This region comprises the richest assemblage of plant species, harbouring roughly 16,000 tree species (ter Steege et al., 2013), and playing a key role in regulating the global climate and sustaining the local water cycle. However, the spatial distribution of these species in this region varied significantly during the late Pleistocene to Holocene mainly due to geomorphologic and climate changes (e.g. Colinvaux et al., 1996; Van der Hammen and Hooghiemstra, 2000).

Considering climate and vegetation changes during this period, the effects of orbital-scale precipitation variability between western and eastern Amazonia were identified based on speleothem oxygen isotope records (Cheng et al., 2013). These data indicated the occurrence of dry climate conditions during the Last Glacial Maximum (LGM), while the western Amazon was relatively wet. The wetter condition is strongly supported by several previous studies from Morro dos Seis Lagos (western Amazon), which reported no forest fragmentation under wet and cool conditions based on pollen records (Colinvaux et al., 1996; Colinvaux and De Oliveira, 2000; Bush et al., 2004a), though D'Apolito et al. (2013) showed significantly different paleoenvironmental and paleoclimate scenario for this area. The cool climate was assumed based on the occurrence of *Podocarpus*, *Weinmannia*, *Alnus*, *Drimys* and *Hedyosmum* (Colinvaux et al., 1996), which are restricted nowadays to higher altitudes by temperature, thereby suggesting a cooling of around 5 to 6 °C during LGM. Indeed, increase of *Weinmannia* in Amazonian pollen records seems the best indicator of downward migration of montane vegetation belts (Van der Hammen and Hooghiemstra, 2000). In the eastern Amazonia, pollen records from east of Serra Sul de Carajás have indicated forest fragmentation under drier and cool condition during the LGM (Absy et al., 1991; Hermanowski et al., 2012, 2014), with the occurrence of the same taxa identified in the western Amazonia. However, according

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to these authors, the dry LGM in Serra Sul de Carajás was assumed by the presence of small forested areas (e.g. Melastomataceae/ Combretaceae) at the slopes of the plateau and expansion of montane savanna mainly represented by Poaceae, *Spermacoce* and Asteraceae co-occurring with semi-aquatic *Isoetes*. Nevertheless, the use of these taxa as an indicator of dry climate must be done with care. Because Amazon plant communities were not exclusively influenced by paleoclimate changes (Ayres and Clutton-Brock, 1992), and a broader range of environmental parameters must also be considered (Bush, 1994; Tuomisto et al., 1995; Bonaccorso et al., 2006). Morphological processes may control interrelated parameters such as soil type, topography and hydrology, which determined plant location (Rossetti et al., 2010). Moreover, the evolution of certain Amazon lakes such as in Coari and Acará, central Amazonia (Horbe et al., 2011), and Marabá, southeastern Amazonia (Guimarães et al., 2014), during the Holocene may reflect local processes and their geochemical and palynological histories, which are partly being the cause of morphological changes.

Recently, Guimarães et al. (2016) found incongruences mainly related to misinterpretation of the habitat of several taxa in some previous works from Serra Sul de Carajás (Absy et al., 1991; Hermanowski et al., 2012). Moreover, these works did not register the occurrence of several taxa exclusively related to forest formation/tropical forest or savanna as previously quoted. Guimarães et al. (2014) observed the occurrence of 34 species of Melastomataceae in this region, but around 50% of these species occurs nowadays in the montane savanna (650–800 m above mean sea level - amsl). Also, Combretaceae does not occur in this plateau and its surrounding. Other classical example is related to Poaceae and their specific occurrence in savannah and related to drier conditions, since these taxa can occur in a wide range of environments of Carajás from drier to wetter conditions (Golder, 2010a; Guimarães et al., 2014, 2016).

Baker and Fritz (2015) re-evaluated the speleothem records from eastern Amazonia and indicated that the LGM $\delta^{18}O$ presented similar precipitation amounts as present-day rather than severely dry as previously reported by Cheng et al. (2013). This new evidence may weaken the interpretation of glacial aridity for the eastern Amazonia if supported by other palaeoclimate proxies and new studies are necessary to test such hypothesis.

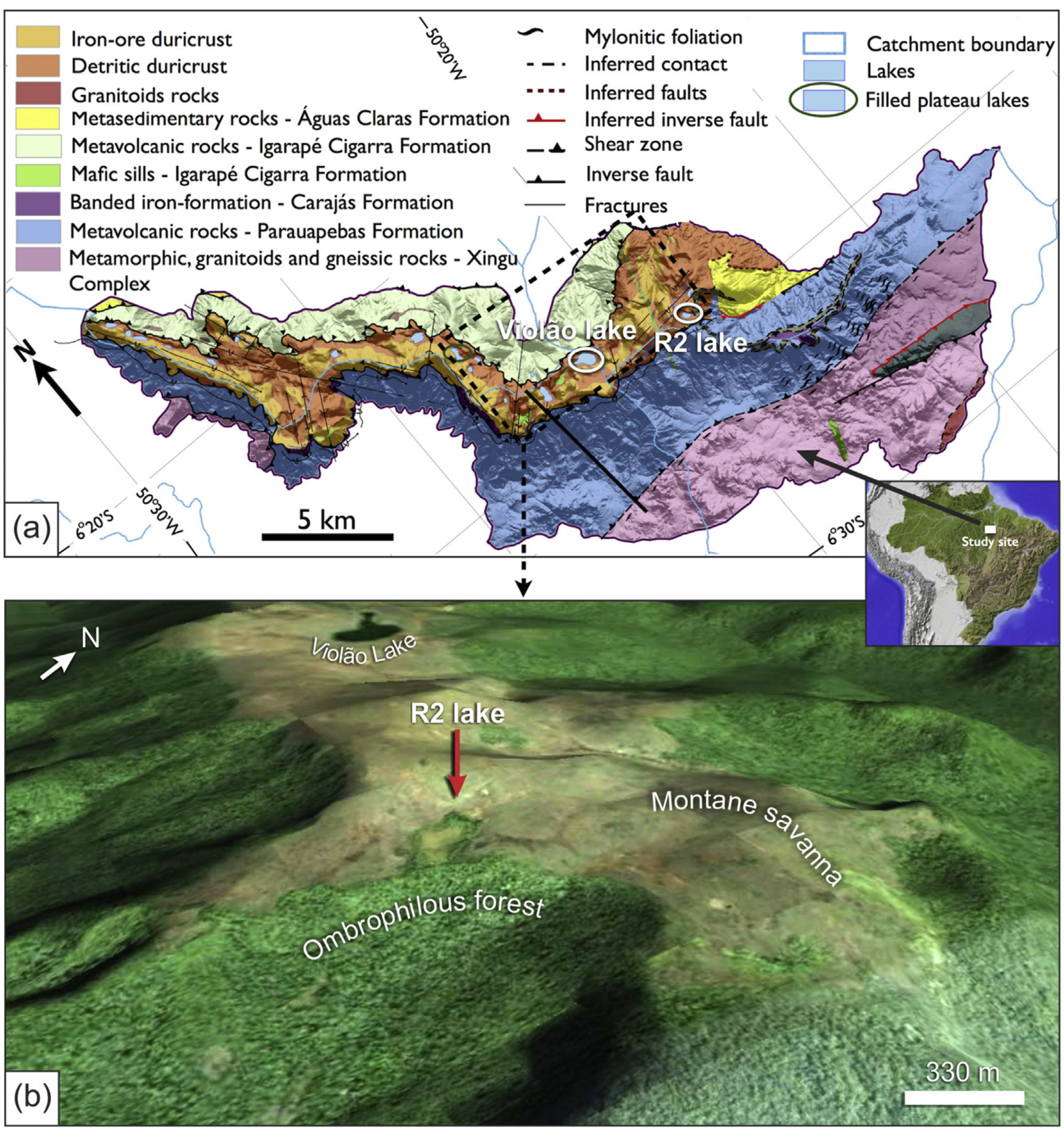

Fig. 1. A) Location map of the R2 core (06°24′35,39837″S 50°19′05,76399″W) in the Serra Sul de Carajás (adapted from Guimarães et al., 2016). B) Satellite image, oblique view, of the lateritic plateau of the Serra Sul de Carajás with the contact between ombrophilous forest and montane savanna, as well as the studied lake (from Google Earth).