



The Hill of Six Lakes revisited: new data and re-evaluation of a key Pleistocene Amazon site



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ABSTRACT

The new analyses of a sedimentary record of Lake Pata in the Hill of Six Lakes, in NW Amazon and its correlation with other Quaternary proxy records in the region provide new insights regarding the vegetation and climate of the lowland forest during the Last Glacial. Despite what has been reported previously in the literature, the sedimentary and pollen records are not continuous. The hill remained forested; however, clear signals of structural change are seen in the record, which indicate that the area experienced a significantly drier climate during the Last Glacial Maximum (LGM). The herbs and taxa that are known to be more dominant in seasonally dry forests were all more abundant during the glacial part of the record, and the cool-adapted elements were mixed with warm lowland elements, which indicates a temperature depression. A comparison of the palaeoecological data with other regional geoenvironmental records of the Upper Negro River basin and other areas of the Amazon provides additional support for a cooler and more seasonal environment during the middle Pleniglacial, which then became drier during the LGM. A “wet” LGM is strongly refuted; therefore, the palaeoclimatic and ecological models that used the previous proxy data from Six Lakes to sustain “wet” conditions and a “continuous forest record” during the LGM to reconstruct the palaeoenvironmental conditions in the Amazon should be reviewed.

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1. Introduction

Over the past few decades, a large body of literature has focused on explaining the late Quaternary environments in the Amazon basin. Despite the fair contribution of palynology to palaeoecological reconstructions, the few scattered pollen sites in the vast continent-scale territory paint a speculative picture, rather than a conclusive one. The compilation and critical analysis of the lowland pollen sites have given rise to many ice age vegetation maps (Van der Hammen and Absy, 1994; Bush, 1994; Hooghiemstra and Van Der Hammen, 1998; Haberle and Maslin, 1999; Thomas, 2000; Cowling et al., 2001; Anhof et al., 2006) that in general show the same trend of forest retraction following a precipitation decrease as seen in present-day rainfall patterns.

In such reconstructions, the great majority of the pollen sites indicate dry periods, as indicated by both sedimentary records and pollen sequences that mostly show forest openings and the

expansion of savannah or other types of seasonally dry vegetation. The exception could be the Six Lakes Hill in the northwest corner of Brazil, for which an unbroken forest record during the past ~50 thousand years (ka) before present (BP) is indicated according to studies by Colinvaux et al. (1996) and Bush et al. (2002, 2004). They concluded that at this site, a) there was a continuous palynological record, b) the main forest change was triggered by a 4–5 °C regional cooling during the middle and upper Pleniglacial, c) the pattern of precipitation did not change significantly, and d) the Amazon persisted “wet” and without any kind of fragmentation or replacement by other types of vegetation communities (Colinvaux et al. 1996; Bush et al. 2004).

Despite the claim that the Six Lakes Hill was a stable forested area throughout the last glaciation (Colinvaux and Oliveira, 2000, 2001; Colinvaux et al., 2000, 2001; Bush et al., 2004), some authors have argued that the sedimentary record of Lake Pata (one of the lakes studied on the Hill) follows the same general pattern shown by Amazon lakes during the Lateglacial and early Holocene (Hooghiemstra and Van Der Hammen, 1998; Ledru et al., 1998; Van der Hammen and Hooghiemstra, 2000; Mayle and Power, 2008). However, little has been discussed and reported in the

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palynological literature on the characteristics of the sedimentary record of the lake, and some recent palaeoecological papers do not mention either the additional sedimentary records of Lake Pata that were studied by Santos et al. (2001), Barbosa et al. (2004) and Cordeiro et al. (2008, 2011) or a variety of geomorphologic and sedimentological information from the surrounding areas (Latrubesse and Franzinelli, 1998, 2005; Carneiro-Filho et al., 2002). As claimed by Latrubesse (2012), the “interpretations taking into account just a local record and one “proxy” indicator (pollen) have produced a significant drawback in the understanding of the Quaternary climatic changes of the South American tropics, in special in the Amazon basin”. In the face of this dilemma, we aim to produce data that are relevant to the understanding of the palaeoecological dynamics in the Six Lakes Hill region over the Last Glacial period by using the palynological and stratigraphic analyses of a parallel core from Lake Pata and by the critical analysis and correlation of Six Lakes with already published multi-proxy geo-scientific results related to other areas of the Amazon.

2. Setting

The hill, which is located at 0°16'N and 66°41'W (Fig. 1), is composed of Cretaceous intrusive carbonatites (Schobbenhaus, 1984). Six Lakes is classified as a type of lake that develops on older terrains without a direct relationship to the fluvial system (Latrubesse, 2012). This type of lake primarily develops on hills or tablelands of older Precambrian rocks that suffered intense chemical weathering over millions of years and that are now undergoing the dismantling of the laterite crust by pseudokarst processes. Six Lakes Hill is an erosional inverted relief produced by erosion of the older Brazilian shield rocks. The site is located ~300 m a.s.l. on a large planation surface, which is known in Brazil as the Rio Branco-Rio Negro Pediplain (Viegas-Filho and Bonow, 1976).

The area experiences the typical equatorial warm climate (Köppen Af). The northwestern region of the Amazon basin does not experience a true dry season: there is no month in which rainfall is less than 100 mm, and the mean annual rainfall is ~3000 mm (Sombroek, 2001). The main source of rain is the moisture brought from the tropical Atlantic by the intertropical convergence zone (ITCZ) and convective rain (RADAMBRASIL, 1976; Van Der Ent and Savenije, 2011). The limited information available regarding the vegetation of the Six Lakes Hill comes from

RADAMBRASIL (1976), from Projeto Seis Lagos held by CPRM (Viegas-Filho and Bonow, 1976), from colleagues who conducted botanical collections at the hill (M. T. Araújo, A. C. Webber and Bruce W. Nelson, personal communication), from herbarium sheets from Six Lakes collections (INPA Herbarium-Manaus) and from Bush et al. (2004), who commented briefly on their field observations of the composition and physiognomy of the vegetation. At the Six Lakes Hills area, the edaphically constrained vegetation is similar to heath forests of white sands (Whitmore, 1984; also known as Campinas and Campinaranas) not only structurally but also taxonomically. Nevertheless, given the presence of true dense-forest trees, bare rock/very thin soil areas and open areas with typical secondary forest elements, the overall vegetation present on the hill is better called a mixture rather than generalised as one single type. At several points on the hill, there are swamps where *Mauritia*, *Mauritiella*, *Euterpe* and *Ludwigia* are recorded. RADAMBRASIL (1976) includes the Six Lakes Carbonatite in the dense forest classification and points out the high abundance of the tree macucu-de-paca (*Aldinatifolia* Spruce ex Benth.). Furthermore, the following other taxa are reported to be abundant: *Alchornea*, *Ouratea*, Melastomataceae, Clusiaceae and Arcaceae.

The modern pollen spectra, which were obtained from moss polsters during one field session (Bush et al., 2004), show a high abundance of *Alchornea/Aparisthium*, in addition to other common forest elements, primarily trees and very few herbs.

3. Methods

Our study is based on a new analysis and interpretation of a core from Six Lakes and a comparison with previously published analyses.

The sediment samples analysed in this survey come from one of three parallel cores that were drilled in October of 1991 during a research project developed between American and Brazilian scientists in the early 1990s under the coordination of P. Colinvaux and E. Franzinelli. As mandated by Brazilian environmental laws, one of the parallel cores was stored as duplicate material at the local institution (the Federal University of Amazonas – UFAM, Manaus). The field procedures for coring are detailed in Colinvaux et al. (1999), and more information on the drilling methods can be found in Bush et al. (2004). The samples were taken to the National Institute for Amazon Research (INPA-Manaus-AM) for pollen analysis.

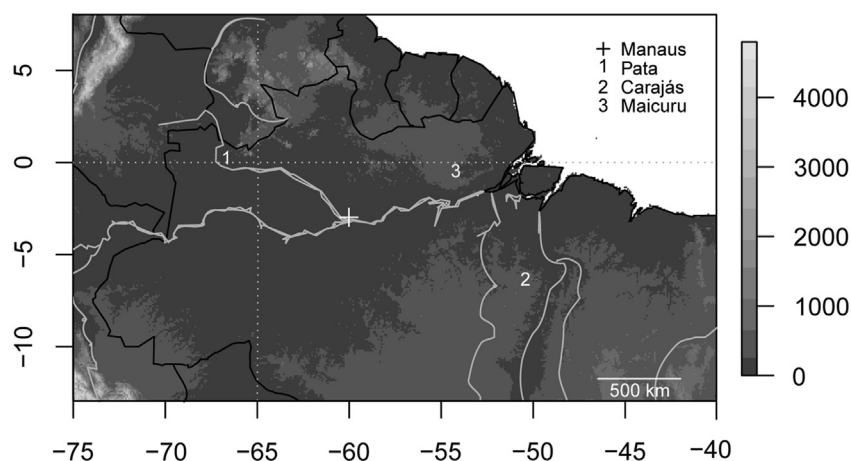


Fig. 1. Map showing the locations of the Six Lakes Hill, Brazil, and other sites discussed in the text: Carajás (Absy et al., 1991) and Maicuru (Colinvaux et al., 2001) (see the text for more details). Manaus is a capital city in the Northern Brazil state of Amazonas. Altitudinal scale is presented in metres; data derived from ETOPO1 (Amante and Eakins, 2009).

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