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ARTICLE

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Abstract

Numerous questions in Amazonian archaeology place great emphasis on the relationships between human groups and their environments, traditionally drawing inferences from ethnographic analogies. This analytical expedient is justified by the supposedly weak preservation potential of plant remains in the Amazonian environment; however, it is also rooted in a lack of collecting and systematic research of such botanical remains. This paper presents results of archaeobotanical studies undertaken at the Hatahara site, located in Central Amazonia. Analysis of macro and microbotanical remains produced direct evidence of relationships between humans and plants in pre-colonial Central Amazonia. Observation of microbotanical assemblages extracted from artifacts demonstrated a great diversity of dietary resources in the past, including the existence of cultivated and managed varieties of plants. These studies also pointed to a multifunctional use of certain artifacts, such as ceramic griddles. Anthracological analysis showed positive correlations between charcoal peaks and layers of anthropic soils (Amazonian Dark Earths), as well as a great floristic diversity in these charcoal assemblages, pointing to a complex scenario for the use of fire, as well as to the possibility of charcoal increases in the formation of these soils.

Keywords: Central Amazon, Archaeobotany, Charcoal, Phytoliths, Starch Grains

Introduction

The Amazonian region has been an important stage in the formation of Brazilian archaeological method and theory since the nineteenth century, being subject to intensive research and debate from the second half of the twentieth century onwards (Neves 1999/2000). One of the topics most present in the often heated discussions of Amazonian archaeology concerns the cultural processes that would have resulted in the formation of sites presenting extensive spatial distributions and high densities of archaeological materials.

In the historical debate of whether such sites are the result of a great number of small, short-term occupations or of much fewer but larger and longer-lasting occupations, fundamental importance is given to the surrounding environment. Amazonian archaeology has been strongly marked by discussions about the carrying capacity of the tropical forest environment, and this discussion has even been used to question the very possibility of the existence of large-scale and long-lasting occupations in the Amazonian past (Meggers 1971). In early interpretative models of these contexts, the surrounding environment was in several ways seen as an element external to culture, but that would have exerted great influence on the social and cultural development of these past human groups (Lathrap 1970; Meggers 1971; Roosevelt 1980). With the development of archaeological, anthropological, and historical theory, reciprocity in the relationships between human groups and the environment is now a recurrent theme in a great deal of research undertaken in the area, fundamental in current interpretations of how large human groups established themselves in the various Amazonian environments, and in the process reconfiguring the forest itself (Balée 1989; Heckenberger *et al.* 1999; Neves & Petersen 2006; Erickson & Balée 2008).

In the ongoing discussion on the nature of relationships between past Amazonian groups and their surrounding environment, it is imperative that more data be gathered using approaches aimed at the retrieval of archaeological material that might be directly attributed to such relationships. Archaeobotany (or palaeoethnobotany), the analysis and interpretation of botanical remains found in archaeological contexts, is one such approach. This paper presents the results of archaeobotanical studies undertaken at the Hatahara site, in Central Amazonia.

Hatahara: a case study in Central Amazonia

The Hatahara archaeological site, located on a high terrace adjacent to the Solimões River, in the municipality of Iranduba, State of Amazonas, Brazil (Figure 1), presents features common to other Late-Holocene sites of the Central Amazon region, such as a very large spatial distribution (16 hectares), very high densities of ceramic materials on the surface and in sub-surface layers, artificial mounds built out of soil and innumerous ceramic shards, and *Terra Preta de Índio* (TPI) or Amazonian Dark Earths (ADE), soils resulting from intense past human activity (Petersen *et al.* 2001).

Systematic and extensive ceramic analysis, with associated radiocarbon dates, has permitted the construction of a chronological framework for the precolonial occupation of the Hatahara site, beginning over two thousand years ago and lasting until the sixteenth century (Machado 2005). Evidence of Late Holocene occupations, beginning at roughly 300 B.C. and lasting to about 360 A.D, are scarce and characterized mainly by small concentrations of hearths with associated ceramic material of the local Açutuba archaeological Phase (Lima *et al.* 2006). From 600 A.D and up to the 1000 A.D, new evidence of occupation points to an expansion of the settlement pattern, reflected in a great increase in the density of archaeological material and features, associated with pottery of the Manacapuru ceramic phase (Lima *et al.* 2006).

From the end of seventh century onwards, Manacapuru ceramics are accompanied in the archaeological assemblage by pottery materials of the Paredão ceramic phase, the latter lasting until approximately 1100 A.D. The Paredão phase is characterized by circular settlements, an increase in population density, the construction of large earthworks, such as mounds, and the formation of TPI soils (Moraes & Neves 2012).

Lastly, at about 950 A.D. a clear change seems to have occurred in settlement pattern, with the appearance of a linear form of site occupation accompanying the river margin (Rebellato 2007), along with a distinctly new style of polychromic ceramic material. This period constitutes the Guarita phase of the Polychrome Tradition of Amazonia, which lasted up to European contact (Hilbert 1968; Heckenberger *et al.* 1998; Neves 2012; Tamanaha 2012).

Areas Chosen for Archaeobotanical Analyses

With the objective of attaining a better understanding of aspects of human influence on past vegetation of the Hatahara site, as well as the diet of its inhabitants, archaeobotanical studies at the site were done through the analysis of a variety of botanical remains, including both macroscopic and microscopic structures. The two areas studied were chosen due to their location at the site, which offered good chronological control (Figure 1). For macrobotanical analyses, a one-by-one excavation unit (N1345 W1260), referred to as unit 1, was selected in an area outside of the artificial mounds, in a peripheral sector of the site. For microbotanical analyses, a total of eight artifacts were selected from two different contexts; five from excavation unit 1, and three from another one-by-one excavation unit (N1309 W1298), referred to as unit 2.

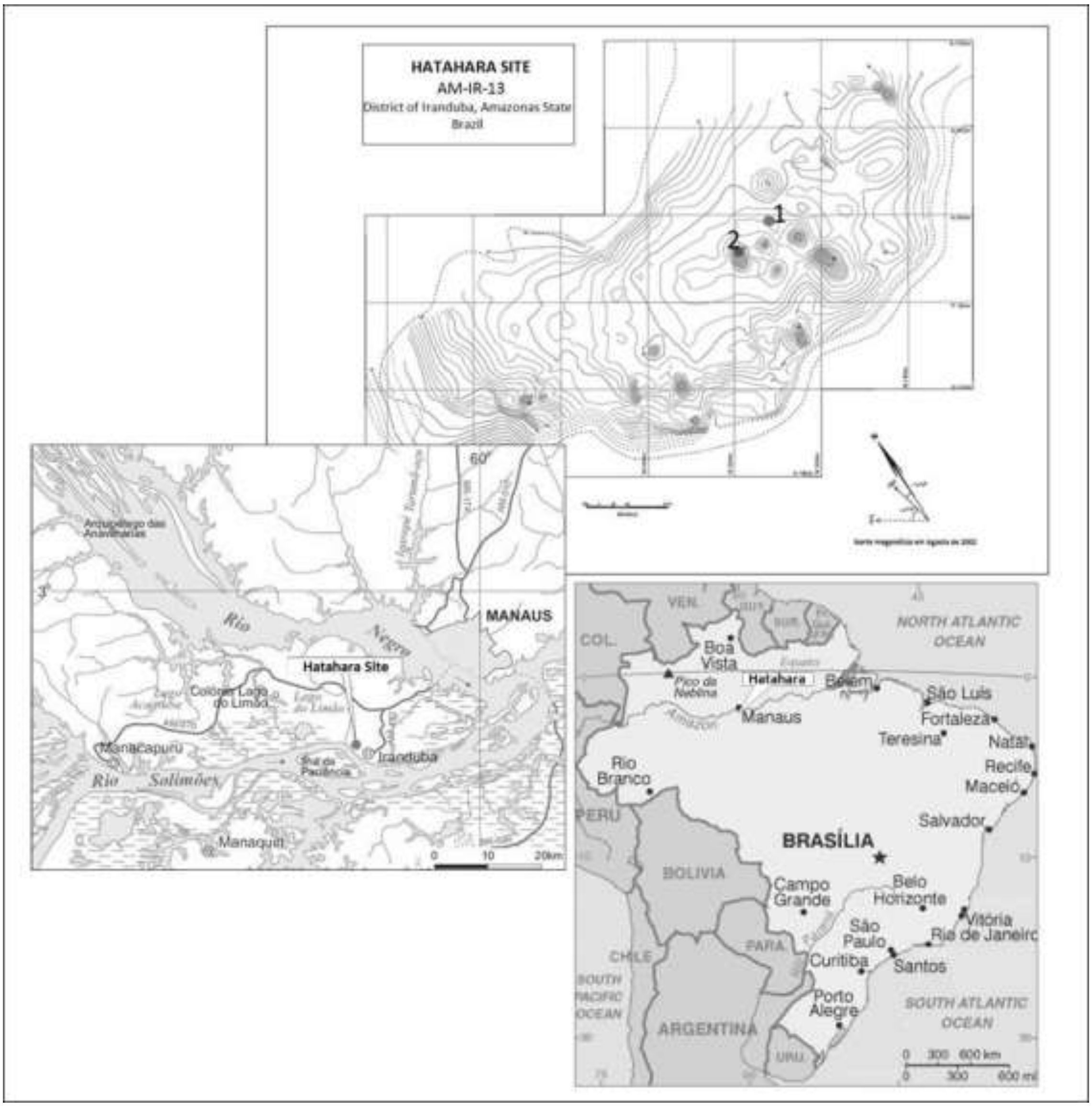

Figure 1. Location of Hatahara archaeological site, in the State of Amazonas, Brazil, and position of excavation units 1 and 2 within the site area. Regional and site maps by Marcos Brito, with modifications by Caroline F. Caromano.

Anthracological and other charcoal analyses

In the Central Amazonian archaeological context, anthropogenic fire, expressed through archaeological charcoal, is an important element in the search for in-

formation on patterns of intervention on the landscape. Anthracology (the anatomic identification of carbonized wood) can be a valuable analytical method in such contexts, allowing the simultaneous acquisition of paleoenvironmental information and of data on activities involved in the gathering and management of plant resources.

Carbonized macroremains were retrieved from an area with good chronostratigraphical control located outside of artificial mounds in a peripheral area of the site (Figure 1). This area presents a lower density of artifacts and a relatively thin layer of TPI, but with good potential for anthracological and other botanical analyses. A one-by-one meter unit was excavated in artificial 10 cm levels to a depth of 120 cm, respecting eventual layers and features identified during the excavations, such as archaeological structures or changes in soil composition.

Based on the ceramic assemblages observed in this unit, it is probable that the analyzed context corresponds to the Paredão ceramic phase, therefore belonging to a period between approximately 700 A.D. - 1100 A.D. Through the unit's profiles, four layers were identified: a first, deepest layer of native Oxisol; a second layer of light-colored TPI or *Terra Mulata*; a third layer of darker TPI; and a fourth superficial layer, which was not taken into account in the study (Figure 2).

Twelve liters of sediment were collected in every layer excavated, following the *blanket sampling* methodology (Pearsall 2000: 66). This sediment was wet-sieved using running water and sieves of 2.79 mm and 1 mm meshes, and later floated with the aid of laboratory detergent in order to disperse clay particles. Charcoal was also recovered through sieving during excavation, in which all the sediment from each layer (with the exception of the twelve-liter bucket set apart for wet-sieving and flotation) was dry-sieved in the field using a 5 mm mesh. This sieving was done with great care, so as to collect all visible charcoal fragments.

Analysis of this material consisted of charcoal study under a broad-spectrum perspective, with the simultaneous application of quantification methods as well as taxonomic determination through the anthracological method (Chabal 1997; Scheel-Ybert 2004).

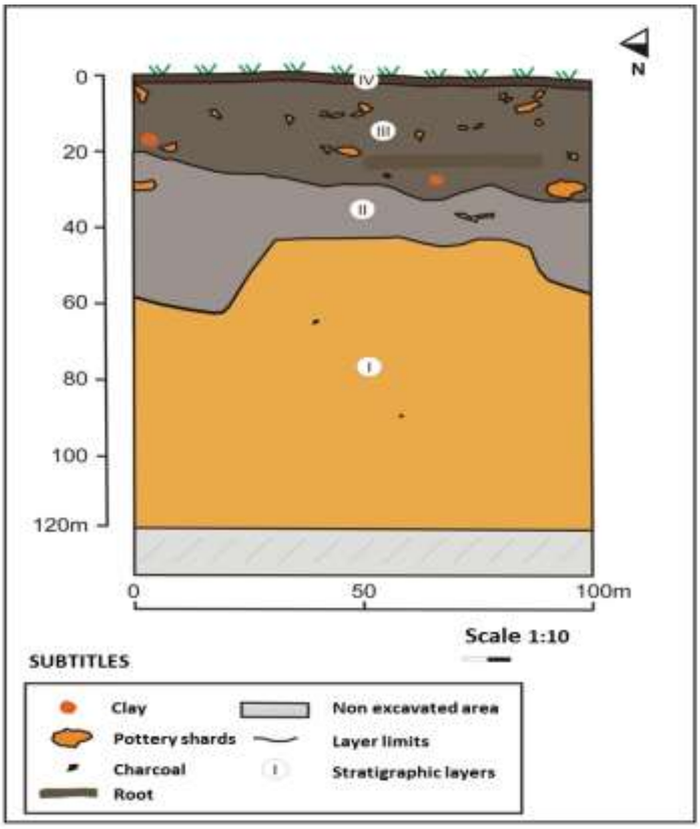

Figure 2. East profile of Unit 1 (N1345 W1260) at the Hatahara site, Iranduba, Amazonas, Brazil. Illustration by Gina F. Bianchini.

Quantification (charcoal weights and counts)

Previous research in the Colombian Amazon has demonstrated the importance of charcoal weighing and counting as indicators "of human activity intensity through time" (Mora 2003:113). With this potential in mind, all charcoal from the excavation unit was weighed and counted, respecting the divisions of each layer excavated and method of charcoal recovery used. Over 13,000 charcoal fragments were documented for the unit studied, with the great majority of these presenting dimensions of under 1 mm in length. Quantification therefore demonstrated that, although very present in soil of the area studied, this charcoal is extremely fragmented.

Weight quantification of charcoal fragments by archaeological layers presented an interesting set of data. With total charcoal weight by flotation, it was possible to identify increases in samples throughout each layer's formation. A sharp peak in charcoal amount was noted for the first soil transition in the profile, from the yellow Oxisol to the first layer of anthropogenic soil, at 50-60 cm of depth. A second, smaller peak occurs at the second soil transition in the profile, from the earliest layer of anthropogenic soil to the second layer of anthropogenic soil, at 30-40 cm of depth (Figure 3).

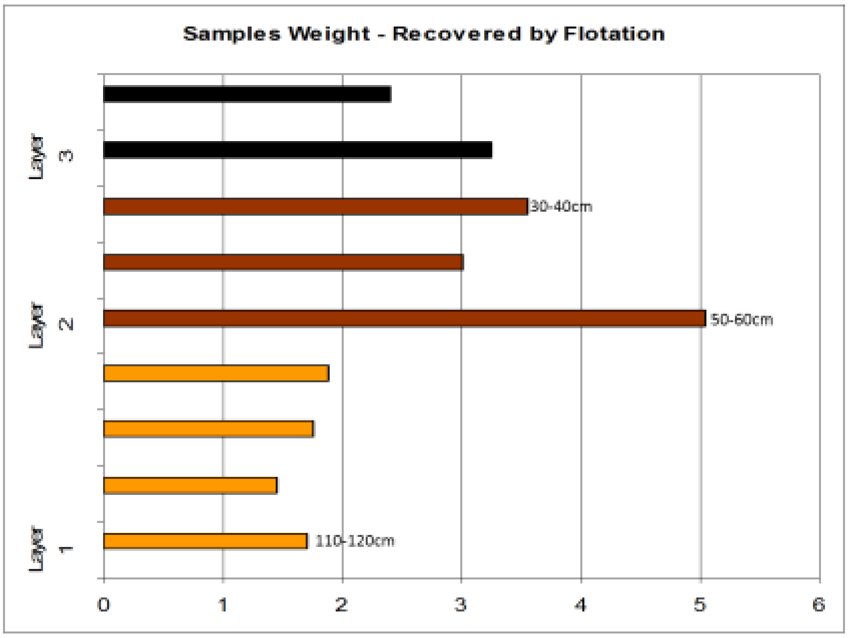

Figure 3. Total charcoal weight (in grams) recovered by flotation from excavation unit 1 at the Hatahara site, Iranduba, Amazonas, Brazil. Each bar represents an artificial 10 cm layer; colors represent the three archaeological layers observed.

Anthracological analysis

Besides quantification, charcoal fragments were taxonomically identified through observation of anatomical structures. Determination was based on the analysis and systematic description of the main characters of wood anatomy (IAWA Committee 1989), and observed characteristics were inserted into the "Atlas Brasil" database program for charcoal identification (Scheel-Ybert *et al.* 2006). A comparison was then done of anatomical features observed in archaeological fragments with the carbonized wood reference collection of the *Laboratório de Arqueobotânica e Paisagem* of the *Museu Nacional*, Rio de Janeiro, as well as with wood anatomy descriptions present in specialized literature (e.g., Détienne & Jacquet 1983; Metcalfe & Chalke 1950) and in a wood anatomy database (Insidewood 2004). The association of these data provided the basis for the taxo-

nomic identification of the archaeological charcoal fragments. Taxonomic identification is presented according to the APG III system (Tropicos.org 2010).

For the anthracological analysis, a total of 708 charcoal fragments from all layers excavated were observed, with 486 of these being taxonomically identified to 147 different *taxa*, including 43 families and 63 genera. In seven families (Arecaceae, Fabaceae, Lauraceae, Linaceae, Lythraceae, Myrtaceae, and Rubiaceae) identification to genus level was not possible, and in these cases fragments identified to family level were further gathered into types, according to similar anatomical characteristics.

Anthracological analysis revealed a great diversity of angiosperm families and genera, all observed in modern vegetation types in the region. Amongst these, most correspond to taxa present in forest formations, such as *Várzea* (riverine flood areas) and *Terra Firme* (non-flooded highland areas), formations that, due to the site location, were amongst those most likely to have been used to obtain resources (Figure 4).

In general, there was not significant variation in vegetational composition among the local formation, nor in the dominant botanical families through time in the Hatahara area. The five families with the largest percentages in layer I, the oldest and composed of Oxisol, were Melastomataceae (20%), Fabaceae (10%), Rubiaceae (9%), Euphorbiaceae (7%), and Myrtaceae (5%). In layer II, composed of light-colored TPI or *Terra Mulata*, the families with the highest numbers of individuals were Fabaceae (14%), Myrtaceae (12%), Melastomataceae (10%), Sapindaceae (7%), and Euphorbiaceae (6%). The most abundant families in layer III, corresponding to the *Terra Preta* soil, were Fabaceae (16%), Melastomataceae(15%), Rubiaceae (14%), Myrtaceae (10%), and Euphorbiaceae (9%). To summarize, the family with the highest number of charcoal fragments was Melastomataceae (15%), followed by Fabaceae (12%), Myrtaceae (9%), Rubiaceae (8%), Euphorbiaceae (7%) and Sapotaceae (5%). Furthermore, the presence of *taxa* representative of secondary vegetation in all excavated layers, such as several Melastomataceae and Rubiaceae genera, and also of genera from other families, such as *Tapirira*, *Himathantus*, *Rauwolfia*, *Vernonia*, *Vismia*, *Casearia*, *Byrsonima*, and *Cupania*, points to constant human influence in the surrounding vegetation.

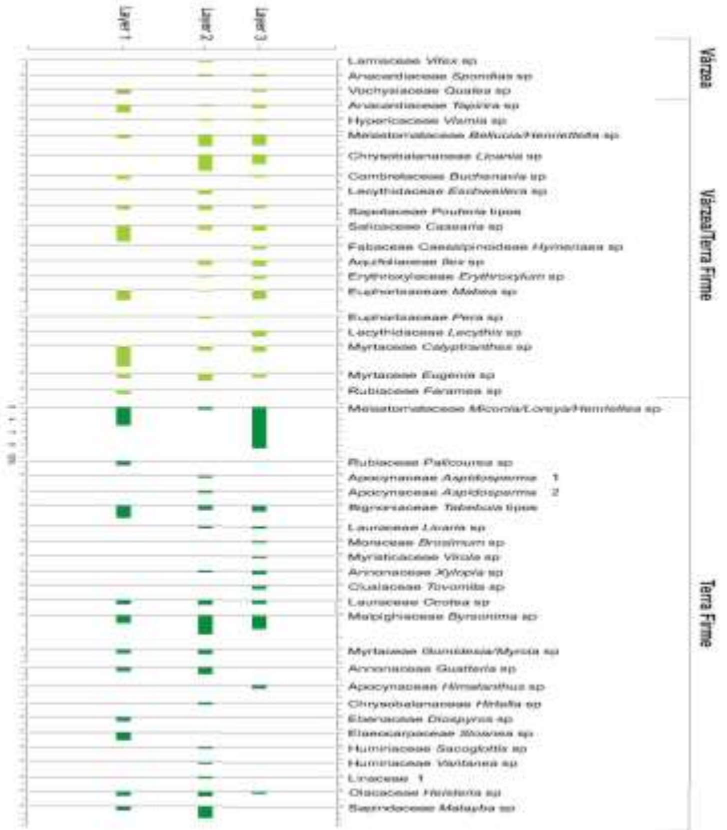

Figure 4. Synthetic anthracological diagram of taxa identified and associated with vegetation adjacent to the Hatahara site, Iranduba, Amazonas, Brazil.

Microbotanical analysis

Along with macrobotanical analysis, microbotanical analysis was conducted in order to better understand how dietary practices developed throughout the period of the Hatahara site occupation. Archaeological material chosen was composed mainly of ceramic shards from recipients traditionally correlated with food processing and consumption, or which presented signs of heating, therefore possibly pointing to a similar use. The collecting of this material was done in areas with good chronostratigraphical control.

Five ceramic artifacts were collected from unit 1, associated with the Paredão ceramic phase, from the artificial levels 10-20 cm, 20-25 cm, 30-40 cm and 50-60 cm. Another three ceramic shards were collected in unit 2, from the previous Manacapuru ceramic phase. The latter context was located underneath an artificial mound constructed during the Paredão period, in a depth corresponding to a time previous to its construction (Figure 5).

Figure 5. Clockwise from top left: excavation unit 1; ceramic griddle shard analyzed for microbotanical remains; excavation unit 2; profile of unit 2 with mound layers on top and sampled area, underneath mound construction, circled in red at the bottom. Profile of unit 1, showing artificial layers chosen for microbotanical analysis circled in red. Photos by Val Moraes and Leandro M. Cascon.

Analysis was done within a multiple-microbotanical remains approach (Coil *et al.* 2003), with the simultaneous retrieval and analysis of botanical microstructures, such as phytoliths, starch grains, calcium oxalates, and diatoms. This methodology was designed to gather the maximum amount of information possible on plants used as food-sources throughout the time of site occupation. For extraction of samples from the artifacts, a 'step-wise' methodology was implemented. Sediment adhered to the artifact shards was removed in sequential and separate steps, taking into consideration the characteristics of each artifact studied, such as its context *in situ*, probable surfaces used, and microremains expected to be retrieved. Step-wise methodology has been previously used in the analysis of artifacts related to plant processing (Piperno & Holst 1998; Babot 2009).

Microbotanical identification was done through comparison with reference collections and specialized literature (Pearsall 2000; Perry 2004, 2005; Ba-

bot 2004, 2007, 2009; Morcote-Rios 2006, 2008; Piperno 2006). Aside from individual diagnostic phytoliths and starch grain morphotypes, assemblages of these microstructures and others, such as calcium oxalates, were taken into account during identification. The combined use of diverse microremains permits that the diagnostic 'weaknesses' of one structure be complemented by the 'strengths' of another, thereby allowing the construction of identifications of a relational nature, similar to other deductive methods in archaeological practice.

Analysis of eight ceramic artifact shards resulted in the observation of a total of 2776 phytoliths and 21 starch grains, of which 638 phytoliths and 13 starch grains were identified as being from plants with possible nutritional value for past populations. The combined observation of multiple microremains pointed to a wide spectrum of dietary plant resources. Palm phytoliths were identified on all artifacts studied, frequently in large quantities. The palm phytolith assemblage was composed of six probable genera (*Astrocaryum*, *Attalea*, *Bactris*, *Euterpe*, *Mauritia*, *and Oenocarpus*) and an assortment of non-identified taxa.

Maize (*Zea mays*) was also observed on the artifacts. Maize identification was done through starch grain analysis. Maize starch grains were identified in four out of the eight artifacts, two from Manacapuru and two from Paredão periods. Many of these starch grains presented damages characteristic of cooking and roasting, reinforcing the correlation of such microremains to the artifacts studied.

Besides starch grain analysis, an attempt was made to identify maize use through phytolith analysis. The identification of maize phytoliths in archaeological contexts is generally achieved through multivariate analysis of *bilobate* and *cross-shaped* phytolith forms produced in leaves of Poaceae, including maize (Piperno 2006). Individual samples of the study at hand did not present the minimum amount of phytoliths necessary for such an analysis, and therefore an alternative method of identification was used, based on the observation of starch grains, as well as available phytoliths of *bilobate*, *cross-shaped* and *rondel* form, the latter being produced in kernels as well as cobs of maize.

A total of six artifacts (three from Manacapuru and three from Paredão periods) had phytoliths that presented great resemblance to those characteristic of maize, such as *cross-shaped* and *wavy-top rondel* forms. Two of the Manacapuru artifacts had maize starch grains along with these phytoliths. Due to the fact that these phytoliths were extracted from artifacts with probable use for food-processing and consumption, and the aforementioned presence of maize starch grains in the context studied, these phytoliths were considered probable further indicators of maize.

Other possible food sources identified through artifact analysis were yam (*Dioscorea* sp.) and *Cyperus* sp. Starch analysis resulted in the identification of one grain of *Dioscorea* on an artifact belonging to the Paredão period; other lines of analysis outside of archaeology indicate that two species of this root-crop were likely cultivated in pre-colonial Amazon (Clement 1999). *Cyperus sp.*, which was possibly used as a condiment in pre-colonial Amazonia (Clement 1999), was identified on four artifacts, including all three of the Manacapuru artifacts, in the form of *hat-shaped* as well as *achene* phytoliths characteristic of this Cyperaceae genus (Piperno 2006).

Macrobotanical analysis

Analyses at the Hatahara site provided an interesting case-study on the use of the archaeobotanical approaches to the discussions of large sites in the Central Amazon region. Macrobotanical studies showed that the association of charcoal quantitative data and anthracological taxonomic determination are important markers of human activity in the context studied; demonstrating that, in this world of waters, fire also played an important part.

Charcoal quantification at Hatahara allowed the gathering of information on past human activities, similar to what was achieved in the Colombian Amazonian context (Mora 2003). In the studied area, charcoal peaks showed a positive correlation between charcoal amount and the formation and transitions of anthropic soil layers observed in the profile, demonstrating that the manage-

ment of fire may have been an important factor in the formation of these anthropic soils.

Through anthracological analysis, it was shown that all layers in the profile presented high taxonomic diversity, especially considering the size of the area studied. The elevated diversity found in a one-by-one-meter area does not corroborate the hypothesis that the charcoal recovered could be the result of *in situ* burning. The data obtained allows the suggestion that there would have been a combination of burnings for the cleaning of the land or fallowing of specific trees, accompanied by the addition of charcoal from other areas (such as wastes from domestic fires, or wood added to the area and later burned).

Anthracological analyses also indicated human presence in the first and oldest layer present in the profile studied. This layer lacked archaeological material, such as ceramic or lithic artifacts and anthropogenic soils, and was therefore considered 'archaeologically sterile' during field excavation. However, the high taxonomic diversity observed in this layer is incompatible with the expected diversity for natural fires in the tropics (Scheel-Ybert 2004), considering the small size of the sampled area. Consequently, charcoal present in this layer cannot be the sole result of natural fires, suggesting that this layer corresponds to a previous period of human occupation in the area. The analysis at Hatahara also demonstrated, therefore, that charcoal can be an important marker of human activities for sites of the region in contexts where anthropogenic soils and other indicators are not visible in the field.

Microbotanical analysis

Analysis of the artifacts resulted in the identification of a large dietary spectrum used by the inhabitants of Hatahara. Microremains from maize, various palms, and *Cyperus* sp. were identified on artifacts correlated to early ADE formation, demonstrating that at the beginning of the formation of anthropogenic soils, the inhabitants of the area were manipulating a wide range of collected and cultivated resources.

The analysis of the artifacts correlated to a later period, when anthropogenic soils had further expanded in the area, pointed to the possibility of some changes in diet constitution. Phytoliths from *Cyperus* sp. were rarely found. Microremains of maize and various palms continued to be present, along with evidence of root crops, such as yam (*Dioscorea* sp.).

By allowing the observation of a large amount of microbotanical remains, multiple microremains analysis provided valuable information on the diet of the past inhabitants of Hatahara, pointing to the existence of subsistence systems based not only on cultivated resources, such as maize and yam, but also on managed resources, such as palms. The data points to the great importance of palms in the diet, inferred by a high percentage of palm phytoliths, especially of probable *Bactris* sp. phytoliths, in the microbotanical assemblage.

The multiple microremains approach also provided interesting new data on artifact functionality. Three artifacts presented a combination of maize starch grains and palm phytoliths, and one artifact contained a yam starch grain together with palm phytoliths. Multiple microremains analysis therefore helped point to the multi-functional use of these artifacts. This discovery is of special importance, for at least one of these artifacts, a ceramic griddle shard, is typically attributed to manioc (*Manihot esculenta*) consumption. The use of a methodology that allows the simultaneous observation of phytoliths and starch grains in the sample maximized the possibility of documenting eventual manioc consumption (which was not the case for the artifact), at the same time that presented evidence on the processing of other food sources on the same artifact, thereby providing new information to be used with ethnographic analogy. Multiple microremains analysis was shown to be an interesting path for studying the precolonial Amazonian diet, providing information not only on plant food sources utilized by the past inhabitants of the site, but also on the functionality of the artifacts studied.

Conclusion

The combined use of macrobotanical and microbotanical analysis was shown to be an interesting approach for studying people-plant relationships in pre-Columbian Central Amazonia. Open-area sites of the region are highly susceptible to weathering, resulting in the destruction of a large amount of plant remains, therefore contributing to the formation of archaeological contexts that are biased in their representation of these past relationships. Such biasing is further enhanced by other factors, such as differentiated potential of archaeobotanical remains in representing specific plant groups.

Combining macrobotanical and microbotanical analysis allows a larger amount of information to be retrieved in the studied contexts, in which weaknesses inherent in each approach individually are partially compensated with strengths of the other. This was the case for the archaeobotanical study of the Hatahara site, where data on past diet attained through microbotanical analysis was interpreted in view of data on cultural landscape formation attained through charcoal analysis. Through such complementary approaches, archaeobotanists have more information to work with, permitting that more light may be shed on past events that only a few decades ago seemed impossible to observe.

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