Paleoenvironment of southeastern São Paulo: contributions from the Itapeva Shelter to debates on anthropic and natural insertion

*Tatiane de Souza**
*Karina Chueng***
*Carlos Alberto Rizzi****

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Abstract: Paleoclimate reconstitution for the state of São Paulo results from past and ongoing research efforts in palynology, anthracology, and stable isotope studies. In cases such as southern São Paulo, however, researchers are required to extrapolate data from the states of Paraná, Santa Catarina, and Rio Grande do Sul for comparisons. Phytoliths and seeds were collected from sediments retrieved from excavation units D18 and G6 at the Abrigo de Itapeva [Itapeva Shelter] archeological site and analyzed. Seed results indicate that *Ocotea* (Lauraceae) is present in the initial levels, whereas *Syagrus romanzoffiana* predominates at all other stratigraphic levels. The former is a species of Atlantic Forest that occurs in Araucaria Forests; the latter is a palm species found in southeastern and southern Brazil. Phytoliths analysis reveals a change from a drier climate with grassland vegetation to a woody forest in the later periods of shelter occupation. As such, grassland and forest vegetation types occur from base stratigraphic levels up to level seven, dating from 5,510 cal BP to 730 cal BP. Conversely, from level seven up to the surface levels, dated from 730 cal BP to 560 cal BP, we see species linked to Araucaria Forest proliferation which may indicate the presence of Jê groups in the study area, thus corroborating studies on the possible anthropization of São Paulo forests from 1,000 BP.

Keywords: Phytolith; Environmental reconstitution; Anthropized environment; Archaeology.

Introduction

Locally, the biomes under study are forest savannah, known as Cerrado *stricto sensu*, characterized by a set of trees that serve as ecological support (Ab'Saber 2003: 36); Cerradão, also known as Xeromorphic highland forest (Ratter 1992: 172), defined by predominantly continuous canopy with 50% to 90% arboreal cover and average height of 8 to 15 m (Oliveira-Filho & Ratter 2002: 96); and mixed ombrophilous forest with secondary vegetation.

Due to these characteristics, the site can be considered an ecotone, for which

* Doutora em Arqueologia Brasileira. Pesquisadora Independente. <tatiane_sza@yahoo.com.br>

** Doutora em Dinâmica dos Oceanos e da Terra – DOT/UFF. <karinachueng@yahoo.com.br>

*** Doutor em Geografia. Instituto Federal Catarinense. <carizzi91@gmail.com>

definitions are varied and sometimes complementary. From Metzger (2001), whose definition points to different types of landscapes observed at different scales, to that of Veloso, Rangel Filho & Lima (1991)—a zone of tension characterized by floristic mixture between different types of vegetation—, the ecotone has always been attractive to human groups, whether due to recognizable landscape features, or due to plant use and management.

Despite its current exuberant vegetation, paleobotany data from non-archaeological contexts in São Paulo, mainly reconstituted through anthracology, palynology, and stable isotope analysis, are better studied (Behling 1997a, 1997b; Behling 2002; Garcia *et al.*, 2004; Silva *et al.*, 2015). Many works regarding paleobotanical analysis in archaeological contexts have been published (Hadler, Dias & Bauermann 2013; Scheel-Ybert *et al.*, 2003; Val Peon *et al.*, 2019), but there are practically no comparative studies on the southern plateau portion of São Paulo.

We therefore collected specific data from different paleoenvironmental natures at Morro de Itapeva, located in Campos do Jordão, 22°47'S, 45°32'W (Behling 1997a); Fazenda Boa Vista, located in Baixo Vale do Ribeira, 24°36'18"S, 47°38'33"W (Bissa *et al.*, 2000; Silva 2014); Núcleo Curucutu, Serra do Mar, 23°59'14.4"S, 46° 45'58" (Moffato 2005; Saia 2006); and Abrigo de Itapeva, Itapeva, 24°03'51"S, 48° 58' 26"W, for comparisons.

Serra da Mantiqueira [Mantiqueira Mountains] is a well-studied area in the state of São Paulo, which reconstituted paleoenvironmental data features on studies concerning ancient vegetation, climate history, and human populations.

Behling's study (1997a) on the period ranging from 9,900 to 2,610 years BP shows low grassland taxa (40-58%) due to a decrease in grasses (24-39%) and monocots (2-4%), andrecords increased Araucaria Forest taxa (4-8%) due to an increase in low crown trees (Behling 1997a).

Between 2,610 and 430 years BP, most grassland and forest taxa remain constant compared with the previous zone. Percentages of Araucaria (0.2-3.4%) and conifers (0.4-2.6%) slowly increase and low crown tree values decrease. Total rainforest taxa (4-12%) shows somewhat higher values, mainly due to increasing amounts of palm trees (Behling 1997a).

From 430 to 70 years BP, grassland taxa is well represented due to the increased presence of monocots (12%). We observe no significant change in the percentage of Araucaria and Atlantic Forest taxa. The shift to monocots could result from initial human management (Behling 1997a).

In São Paulo, the Atlantic Forest seems to be a constant starting on the Holocene (Saia 2006), perhaps resulting from the drier climate registered during the Pleistocene up to the Middle Holocene (Moffato 2005).

Based on isotopic data analysis, the soils of Parque Estadual Intervales [Intervales State Park] (PEI) indicate presence of arboreal vegetation from 14,000 years BP to the modern period (Saia 2006: 105), whereas analyses conducted at Parque Estadual da Serra do Mar – Núcleo Curucutu [Serra do Mar State Park – Curucutu Reserve] observed vegetative changes during the Upper Pleistocene up to the Middle Holocene, indicating a climate similar to today's (Moffato 2005).

Soil organic matter (SOM) values between 9,840 and 6,090 years BP point to a less dense vegetation, with probable mixture of C3 (trees) and C4 (grasses) plants. Around 1,000 years BP, data suggest anthropic action with remnants of a more open vegetation (Moffato 2005).

Palynological analyses conducted at Vale do Ribeira in the early 2000s showed significant changes in environmental conditions before 3,250 years BP, revealing a region covered by brackish waters in connection with the sea before being occupied by a swamp forest (Bissa *et al.*, 2000).

Recent studies conducted at Baixo Ribeira, region located between Vale do Ribeira and Cananéia, pointed to a predominance of marshy environments and or open fields colonized by herbaceous vegetation between 410 and 190 cm (Silva 2014). At 350 cm we find pollen elements from herbaceous plants; at 210 cm there is a significant increase in tree types; between 195 and 165 cm plant families indicate a flooded environment typical of swamp forests; and from 165 cm to the top layer, the increased tree pollen concentration suggests forest development and intense humidity (Silva, 2014: 71-73).

We found no comparative studies on the southern plateau portion of São Paulo or on the middle or upper Paranapanema. Hence, this study seeks to partially fill this gap. Our closest data on the Itapeva region are the paleoenvironmental reconstructions for northeast Paraná, specifically Campos Gerais, conducted by Behling (1997b) and, more recently, by Guerreiro (2011) and Calegari (2017).

According to Behling (1997a), during the glacial period, northeast Paraná's landscape was made up of steppes. The wetter and warmer trends introduced by post-glacial climate change led to the emergence of forests in the highlands, resulting in forest cover (Guerreiro 2011).

Campos Gerais also has a Pleistocene paleoclimatic enclave consisting of a phytogeographic mosaic of fields and forests (Guerreiro 2011). As for the Alto Tibagi plain, palynological data combined with isotopic analysis and radiocarbon dating point to tropical environments between 3,220 and 1,340 years BP. Records outline a region covered by natural grasslands and arboreal vegetation, with botanical affinities characteristic of tropical environments (Guerreiro 2011).

Macrobotany associated with material culture

In the Itapeva Shelter, at stratigraphic level 3 from excavation unit G6, we identified *Ocotea* (Lauraceae) with radiocarbon dates between 730 cal BP and 560 cal BP. For all other levels from excavation units D18 and G6, we found *Syagrus romanzoffiana* at levels ranging from 560 cal BP to 5,510 cal BP.

Both species can be found in southern and southeastern Brazil. *Ocotea* (Lauraceae) is a species of Atlantic Forest that occurs in Araucaria Forests and produces—like other trees in the family—hardwood, edible fruits, and aromatic species (Souza & Affonso 2017:111).

Of tropical distribution, the Lauraceae comprises 68 genera with 2,978 species (The Plant List 2013 *apud* Souza & Affonso 2017). Ecologically, it forms an important group in the Neotropical region and grows in most ecosystems, from sea level to high altitudes (Baitello 2016).

Brazil is home to 24 genera with 441 species (231 endemic), whereas the state of São Paulo accounts for 13 genera with 99 species (14 endemic). With 428 species, *Ocotea* is the largest genus of Lauraceae (The Plant List 2013 *apud* Souza & Affonso 2017).

Widely distributed throughout the Brazilian territory, but concentrated in the south and southeast, *Syagrus romanzoffiana* (cocos palm) is a species of palm (Silva *et al.*, 2011).

Although the species is not easily domesticated, research has tried to correlate its dispersion at different altitudes of Serra do Mar, finding positive correlation values with high-altitude forest (Oliveira *et al.*, 2015).

In the Abrigo de Itapeva [Itapeva Shelter], the presence of these seeds indicates a type of palm vegetation installed from the base, showing changes or introduction of woody trees of robust arboreal size at 730 cal BP, and probable correlation with Araucaria Forest.

Conversely, human groups may have transported these *Ocotea* seeds to the Itapeva Shelter, thus suggesting that the groups who frequented the shelter also circulated in the Araucaria Forest. According to archaeological studies, these are probably southern Jê groups who made extensive use of forest resources at that time (Iriarte & Behling 2007; Bitencourt & Krauspenhar 2006).

Jê groups are known for following the Araucaria Forest, manipulating its trunks and seeds and leaving distinct archaeological remains in the sites, such as fine well-burned and burnished ceramics, which belong to the Itararé-Taquara tradition.

Engravings and grooves carved into the shelter's rocky support also indicate the

presence of Jê groups at the site.
Aytai (1970), who documented this presence in depth, describes these archaeological records as follows:

- long furrows made by rounded objects, rubbed countless times along what would become the furrow (Aytai 1970: 32);
- short oval depressions which the artist inverts longitudinally before completing the movement (Aytai 1970: 32);
- round depressions (negative caps) made with a similar technique, but instead of rubbing the pebble in a straight or curved line, the artist would turn and half turn to each side until the desired depth was reached (Aytai 1970: 32-33).

Associations between the Itapeva Shelter and the Jê rocky records stem from observing rock engravings and traces of pigments left inside the heavily weathered domes by possible painted parts or paintings.

All 273 ceramic fragments recovered at the site, either in an excavation unit or sieve-collected, have a wall thickness between 3 to 4 mm and edges of 3 to 6 mm. In some cases, they are beveled extroverted and or reinforced extroverts. Firing is homogeneous and has a distinct level of porosity. Antiplastic (if added) appears unselected, varying in concentration, quantity, distribution, and size of quartz grain. At the macroscopic level, we identified no plant-based elements. Reconstituted shapes account for small, spherical, or hemispherical (conical) vases that hold no more than one liter, with no preference for the finishing techniques applied.

Associating macrobotanical records with rock and ceramic archaeological records affords us clues on the intense occupation of the shelter in the 1st millennium BC, including Jê groups, when circulation in the territory was related to paleoenvironmental changes following the woody arboreal contribution in Araucaria forests.

Paleoclimatic reconstructions linked to Jê groups in southern Brazil

Given the scarce studies on the paleoenvironment in southern São Paulo, researchers working in the area have to extrapolate data from the states of Paraná, Santa Catarina, and Rio Grande do Sul. Usually, five types of vegetation are mentioned: a) cerrado; b) mesophytic forest (bushes bordering one side of a watercourse); c) adjacent forest, whose roots are close to the saturation zone due to proximity to groundwater; d) forest with Araucaria; and e) fields (Ledru, Salgado-Labouriau & Lorscheitter 1998: 132).

In Brazil, phytolith research on sediments collected from archaeological sites is still scarce. Most studies based on phytolith analysis of archaeological sites have been conducted in southern and northern Brazil, with occasional studies in other regions (Bitencourt & Krauspenhar 2006; Chueng *et al.*, 2018; Chueng *et al.*, 2020; Iriarte & Behling 2007; Iriarte *et al.*, 2016; Macedo *et al.*, 2017; Pereira 2010; Ríos, Berna & Raz 2016; Watling *et al.*, 2018; Watling *et al.*, 2020).

Such studies clearly show the anthropic manifestation in the wake of the Araucaria Angustifolia forest expansion in the southern states starting from 1,500 years BP (Bitencourt & Krauspenhar 2006), which would have begun with the migration of riparian forests (between 4,000 and 3,000 years BP), indicating a more humid climate (Behling *et al.*, 2004).

In the case under study, research should focus on investigating Araucaria, since this good climate indicator allows for a detailed reconstruction of the climate history of plateaus in southern Brazil and indicates the history of human dispersion on said plateaus.

Starting from the late Holocene period, between 3,400 and 2,400 years BP, we observe an increase in the number of Araucaria angustifolia in several areas of the plateau (Behling *et al.*, 2004), but its greatest expansion towards the fields can be traced to 1,530 BP in Paraná, 1,000 BP in Santa Catarina, and 1,140 BP in Rio Grande do Sul (Bitencourt & Krauspenhar 2006).

Although this expansion is often attributed to better climate conditions, its peak coincides with the period of highland occupation, suggesting that human action may have played a complimentary role to climate in Araucaria angustifolia development (Bitencourt & Krauspenhar 2006).

In Santa Catarina, isotopic soil data point to intensive human occupation, mosaic-shaped forest patches limited to the south and the presence of fields. The northern and upper southern slopes show a history of stable vegetation, characterized by field and forest signatures (Robinson *et al.*, 2018).

The recovery of Butia (*Butia capitata*) and Pindo (*Syagrus romanzoffiana*) palm heart endocarps in this area reveal the exploitation of palm trees, as well as the presence of abundant palm phytoliths, which constituted an extremely rich seasonal resource for the prehistoric populations living in the area (Mazz *et al.*, 2014 *apud* Robinson *et al.*, 2018).

The study area

The city of Itapeva is located at latitude 23º 58' 56" S and longitude 48º 52' 32" W, at an altitude of 684 m, extending over an area of 1830.9 km^2. According to the last census by the Brazilian Institute of Geography and Statistics (IBGE) (2010), its population is estimated at 87,753 inhabitants. Since1997, the municipality comprises four districts: Itapeva, Alto do Brancal, Guarizinho, and Areia Branca.

According to information provided by its official website (SP 2015), Itapeva emerged in the early 18th century as a rural borough belonging to Sorocaba, used as a settlement for drovers. In a 1769 document, Dom Luiz de Souza determines the creation of a new Village, elevated to the name Itapeva da Faxina, which was then separated from the city of Sorocaba.

Its topography is dominated by the deep and sinuous Taquari-Guaçu River gorge, receiving water from several streams that flow into it from the highlands. In the past, the current Taquari-Guaçu River cut the deep furrow of the vertical walls, so that erosion continued to act in many places, excavating their depth and making their upper portions prominent (Aytai 1970: 30-31).

Traces of the Devonian period appear only 5 km SW of Itapeva, in the Taquari-Guaçu River canyon, precisely where the Abrigo de Itapeva [Itapeva Shelter] is located, occupying a large erosive channel covered by silty sediments of the Tubarão group (Petri & Fulfaro 1967: 56).

Cutting the landscape is the Itanguá canyon, whose escarpments and sinuous gorges associated with its dissolution area brings about debates regarding its formative processes and the ensuing consequences for the landscape characteristics.

According to Guerra (2005: 108), the name canyon refers to embedded steep-walled valleys that acquire typical characteristics when cutting through sedimentary structures, forming steps or a series of plateaus along the erosion-excavated corridor (Fig 1).

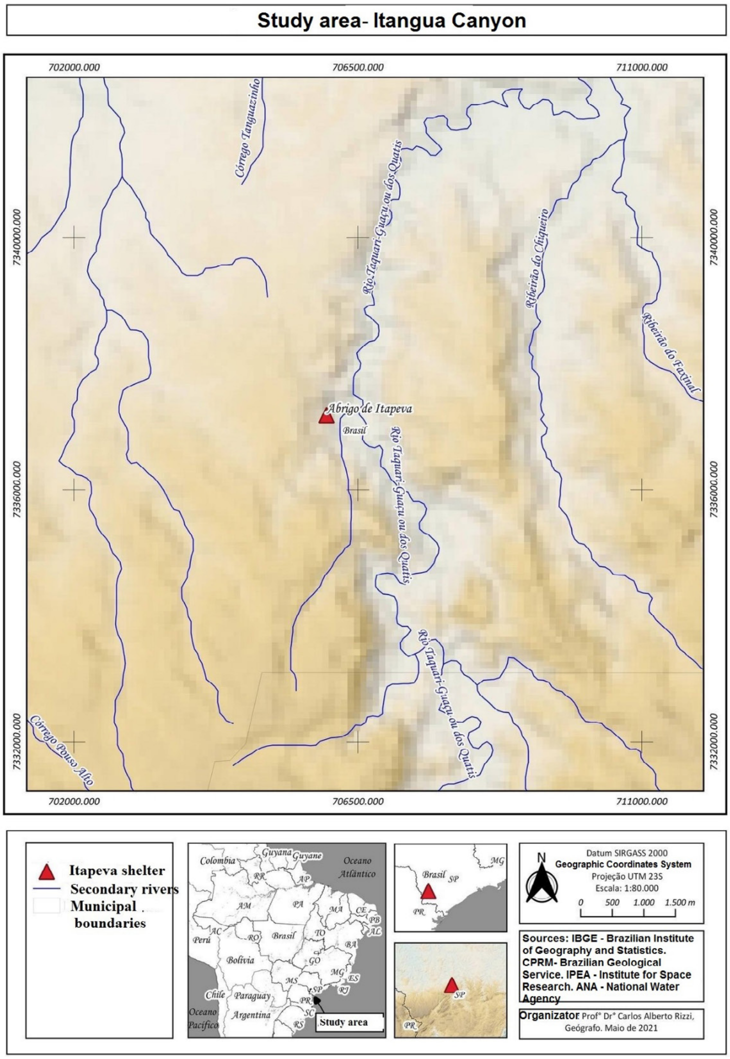

Fig. 1. Study Area – Itanguá Canyon
Source: Carlos Rizzi

The archaeological site

Araripe's report (1887) on the Itapeva Shelter archeological site, although not systematically organized, revealed excavations carried out at the site by individuals searching for precious metals, and that a human skull was collected and later returned to the archaeological site. The exhumation site is probably located near the rocky wall in the central sector, just below engravings overlaid by paintings.

Documentation on the excavation by Desiderio Aytai (1970) show that two blocks were opened near the site boulder, excavated to a depth of 40 cm to 50 cm. The objects found yielded a series of archaeological materials, mostly flakes and ceramics similar to those found in excavations carried out today. A supposed projectile tip and eleven smooth ceramic fragments were also collected, some of which were thin (3 mm to 4 mm) with a blackened surface on both sides.

In July 2015, a series of excavations began in consecutive stages to open 1 m^2 units aiming to reach maximum depth, collect the material culture there, and perform radiocarbon dating.

Three contiguous quadrants were opened in unit C18, line 18y, forming a small trench; in the southern sector, below a sandstone level characterized by paintings applied directly on the rocky support, another unit was opened in line 6y (Fig. 2).

In total, the site's central sector comprises four units (Fig. 2). Excavation unit D18, adjacent to C18, consists of 13 artificial stratigraphic levels measuring 10 cm and forms a thick stratigraphic package, funneled by sandstone blocks in the NE/SE quadrant. The latter comprises 6 archaeological facies, which were described according to texture, granulation, and color. Excavation in the G6 unit accounted for 12 artificial excavation levels.

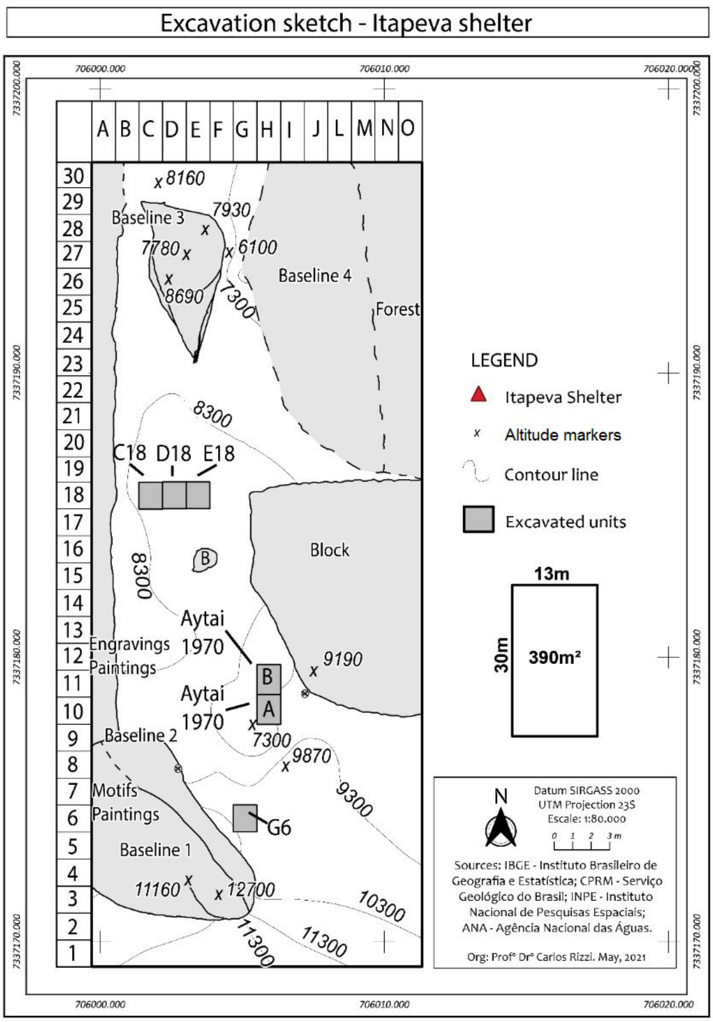

Fig. 2. Excavation sketch of the Itapeva Shelter.
Source: Tatiane de Souza

In 2016, five coal samples collected from the artificial levels 2, 4, 6/7, and 13/14 at D18 unit were sent to Beta Analytic Inc. to be dated by Accelerator Mass Spectrometry (AMS). Importantly, although level 13/14 shows a distance of 5 cm between one sample and the other, they are housed in different archaeological facies (facies 2 and 6).

Description of the archaeological facies, the structures involved, and the set of evaluated radiocarbon dates characterize the stratigraphic modification over time. The identified characteristics describe three moments of occupation.

In unit D18, from level 1 to level 4 we find patches of coal in the block center, configuring a more recent occupation. Considered a transition section, levels 5 and 6 are characterized by burnt sandstone blocks. Levels 7 through 9 show sandstone blocks that advance along the excavation unit, configuring a second moment of occupation. A second transition moment is observed between levels 10 and 11, where sandstone blocks continue to advance towards the center. Finally, levels 12 through 14 point out a first moment of occupation.

In unit G6, a first moment of occupation extends from level 1 to level 6, showing only sedimentary archaeological facies. We observe a second moment of occupation between levels 7 and 10, with sandstone blocks advancing along the excavation unit and transition moments configured by different archaeological facies. Finally, a third moment of occupation emerges between levels 11 and 12, in which sandstone blocks obstruct the excavation.

Studies concur that the site has three periods of occupation: a briefer phase at the base; an intermediate period gathering a series of cultural features represented by bonfires, lithic and ceramic material, entwined with sedimentary archaeological facies from which we extracted phytoliths; and a third moment from level seven onwards, where the pattern of human deposition behavior in unit D18 changes, going from explored blocks to a cavity excavated inside the unit. In unit G6, in turn, the deposition pattern presents overlapping archaeological layers.

Sample	CRA	Date cal BP	Date cal AD	CI 95% SE BP	CI 95% SE AD
Beta 432530	640 +- 30	560	1.390	575; 540	1.375; 1.410
Beta 432531	860 +- 30	730	1.220	770; 675	1.180; 1.775
Beta 432532	860 +- 30	730	1.220	770; 675	1.280; 1.775
Beta 432533	1,470 +- 30	1.310	640	1.365; 1.295	585; 655
Beta 432534	4.770 +- 30	5.510	3.620	5.585; 5.505	3.635; 3.555

Table 1. Radiocarbon data from the Itapeva Shelter. Araujo, 2016
Source. Beta analytic

CRA = Conventional Radiocarbon Age; BP = Before Present (Before 1950); AD = Anno Domini; CI = Confidence Interval; SE = Standard Error

Theoretical reference

Phytoliths are microscopic (<60-100µm) opal (SiO_2nH_2O) particles formed as plant roots take up silicic acid [$Si(OH_4)$] from the soil, whereupon, through plant transpiration, it is polymerized and solidified within the epidermal and vascular tissues of plants (Piperno 1988). These plant solids end up being incorporated into the soil by senescence, fall and the addition of plant remains, where they remain for a long time in the form of silt-sized small particles. Phytoliths are well preserved in soils and paleosols, as they are quite stable and resistant to chemical and biological attacks in environments where organic material is poorly preserved. Because they present typical configurations of the original vegetation, phytoliths can become important microfossils, whereby their shape essentially function as a "mold" of the original plant cell structure (Coe & Osterrieth 2014).

In recent decades, phytolith analysis has become an increasingly popular archaeobotanical tool used to corroborate fundamental hypotheses on food crop domestication and on the study of ancient diets, assuming particular importance in contexts where other plant remains are poorly preserved (Shillito 2013).

Its main advantage over other botanical remains is that phytoliths do not require charring or water saturation to be preserved. Archeological studies founded on plant resource have traditionally used charred remains that are preserved in temperatures up to 500 °C, while lighter plant components, such as straw, are readily lost when burned. Carbonized macrobotanical records result from plants being as fuel or food (Hillman 1981), whereas phytoliths can provide evidence for a more diverse range of activities. Phytoliths can enter the archaeological record by remaining after plants are burned as fuel, or during the decomposition of organic remains (Shillito 2013).

In summary, since they allow to incorporate information on archaeobotanical records, phytoliths present three advantageous characteristics for archaeological studies: durability, immutability, and the capacity to provide general anatomical representation and a broader taxonomic coverage.

Durability

Due to their physicochemical characteristics, phytoliths are the only botanical remnant preserved in non-exceptional conservation conditions, that is, sedimentary environments with pH ranging from 2 to 9. Other factors such as the presence of organic matter or coal occlusions also prevent dissolution. Extensive research in sciences with a much greater temporal depth than Archeology (Paleontology, Geology) confirms this durability (Fredlund & Tieszen 1997; Stromberg 2002). Archeology has applied this technique to hunter-gatherer societies, but only secondarily, preferring to analyze materials from more recent chronologies, for which one finds other archaeobotanical remains under good conservation. Thus, studies on agriculture or on contexts related to its origins have flourished (Miller-Rosen & Weiner 1994; Mindzie *et al.*, 2001; Pearsall & Trimble 1984; Trombold & Israde-Alcántara 2005; Zhao & Piperno 2000). Silica durability can bridge the lack of references to analyze vegetable consumption in cases of strong degradation of archaeobotanical and carpological remains.

Immutability

Phytolith analysis identifies plant materials other than those that have been processed, intentionally or accidentally, by fire. This is probably the major difference between Anthracology, in which particle conservation generally results from roasting or carbonization, intentional or otherwise, and Paleocarpology. Hence, phytolith analysis enables an overview of vegetable consumption regardless of the processes to which they were subjected (cut, ground, cooked, grilled, etc.), seeing as the protocols to be followed or technique results do not change, and phytoliths are not modified when plants undergo these transformations. Phytoliths from materials that underwent heat treatment also usually yield a faithful representation, since the silica melting temperature is extremely high (500°C for silica melting and 1,150°C for it to undergo changes and crystallization).

General anatomical representation

Anthracology and Paleocarpology, the most common archaeobotanical techniques, have limited objects of analysis if the research objective is to outline general vegetable consumption. Both analyze particular materials related to taxa that are defined according to the anatomical part of the plant being studied. In both cases, they refer to specific resources that are usually, albeit not in all cases, associated with their role as fuel (Anthracology) or as food (Paleocarpology). Phytolith analysis encompasses virtually any type of plant tissue and plant, thus covering a broader spectrum of tissues and plant groups.

In Archeology, phytolith studies can be divided into two broad categories: samples of specific archaeological features and artifacts, such as "food crusts," adhered to pottery, dental calculus, coprolites, and ash deposits, and those extracted from sediments and soil samples. With specific characteristics, the sample set can be more securely linked to a specific activity due to the associated contextual information. When numbers are small, the whole set is recorded as morphological types or divided into categories of different plant parts (stems, leaves, bark, etc.). A more general picture of plant use can be obtained from sediment samples, given their possible various origins (Matthews 2010; Shillito 2011), and counts are made on a "representative" proportion of the whole.

Geographically, archaeological phytolith research can be divided by continent. In the Americas, studies focus on the origins of domesticated maize and other food crops (Piperno *et al.*, 2009; Piperno 1990, 1998, 2009); East Asia shows a similar focus on rice agriculture (Pearsall *et al.*, 1995; Zhao *et al.*, 1998); whereas studies in West Asia have focused on major cereals, such as wheat and barley (Rosen 1992; Tsartsidou *et al.*, 2007), and on non-food plants like those used for fuel, bedding, and basketry (Albert *et al.*, 2000; Albert *et al.*, 2008; Albert & Goldberg 2010; Gé *et al.*, 1993; Madella, Alexandre & Ball 2005; Madella *et al.*, 2002; Rosen 2005;).

In the 1990s, Piperno (1990) considers phytolith analysis as sufficiently mature to provide source of data in tropical paleoethnobotany and paleoecology independent from archaeology. A review of recent studies (Bertoldo, Paisani & Oliveira 2014; Bremond *et al.*, 2005; Calegari 2017; Calegari, Raitz & Paisani 2011; Luz *et al.*, 2015; Piperno 1990, 2006; Ramirez *et al.*, 2019) shows that phytolith analysis brings major contributions to research on the distribution and composition of past plant communities in contact with humans.

Phytolith studies are a joint effort to outline adequate contexts for overall phytolith production, taxa, and location of silica deposition within species, which are important for establishing the analysis of genera and species sampled from different taxa in the Itapeva region, configuring a gap between Campos Gerais, Paraná, São Paulo Atlantic Forest, as well as Vale do Ribeira.

Materials and Methods

The analyses carried out on the sediments collected from the stratigraphic levels at the D18 and G6 units in the Itapeva Shelter were decisive for establishing knowledge of the local past vegetation. General observations on the analysis method are described below.

We followed the protocol proposed by Chueng *et al.* (2018) for the archaeological area of Serra Negra, Espinhaço Meridional, Minas Gerais. Initial preparation consisted of drying 10g of sample and sieving it at 2mm, before removing carbonates (with HCl), iron oxides (with sodium citrate and dithionite), organic matter (with nitric acid, sulfuric acid and H_2O_2), and the clay fraction (by decantation with EDTA and Sodium Hexametaphosphate solution).

An 25 µl aliquot of material (precipitate) was removed and mounted on microscope slides using immersion oil (temporary) and Entellan® (permanent) to determine particle content and describe the main phytolith morphotypes and the altered state of the particles. At least 200 classifiable phytoliths were identified and counted under an optical microscope at 500x to 630x magnification to: a) estimate the relative frequency of the different morphotypes according to the International Phytolith Nomenclature Code 1.0. (2005); b) analyze the degree of phytolith alteration (classifiable/non-classifiable); and c) calculate the total phytolith stock in each sample. Based on this count, phytolith indices (abundance rates of certain phytolith morphotypes) are calculated, which allow inference of vegetation parameters, such as: (1) tree cover density (D/P); (2) palm density (Pa/P); (3) aridity index (Iph); (4) climate index (Ic); and (5) water stress index (Bi) (Coe *et al.*, 2021).

In practice, the technique is performed as follows: put 50 ml of nitric acid (HCN) into a 100 ml beaker, and then handle it with a Pasteur pipette. Add a maximum of 0.5 g of sample to a test tube—work with the same samples inside the same beaker, as to avoid possible contamination in case of leaks. After adding a few drops of acidic solution to the samples, heat the test tube on a lamp while adding the acidic solution as it evaporates. Burn the samples until they become clearer and the smoke released by the reaction turns white. Let it sit for a few minutes and add a little more acid solution to ensure effective burning. Once the samples are cooled, add a few drops of hydrogen peroxide (H_2O_2) and then transfer them back to the falcon tube. Complete the falcon tubes with distilled water. Rinse and centrifuge for 5 minutes at 2,000 rpm, at least, extracting the supernatant until the samples reach a pH between 5 and 7. Agitate the samples plus distilled water many times until a pH between 8 and 10 is obtained. Oven-dry the samples at 50°C. Start the whitening stage by placing the samples in a 500 ml beaker and using a glass rod to macerate lightly. Add 6% sodium hypochlorite (NaClO), enough to cover the sample and mix, and cover with a watch glass. Let it react for up to 72 hours. On the first day, observe how the reaction occurs—if violent, neutralize with distilled water and repeat the process with less reagent. Rinse the samples with very hot (or boiling) distilled water every 2 hours (settling time). When the samples no longer smell of chlorine, released by 6% sodium hypochlorite (NaClO), they are ready. It is not necessary to transfer the samples to the falcon tubes, as the next step is done in a 500 ml beaker, respecting the minimum settling time.

According to morphotype presence and the low amount of short cell phytoliths, we calculated the following indices:

D/P = Spheroid Ornate / (Bilobate + Cross + Saddle + Acute bulbosus + Bulliform Flabellate + Blocky);

Bi% = Bulliform Flabellate + Blocky/(Bilobate + Polylobate + Rondel + Trapezoid + Acute bulbosus + Blocky + Bulliform Flabellate)*100;

IC% = (Rondel + Polylobate + Trapezoid) / (Rondel + Polylobate + Trapezoid + Saddle + Cross + Bilobate).

Results

Units D18 (facie 1) and G6 (no facies) (10 cm to 20 cm), dated to 560 cal BP, show a predominance of Poaceae phytoliths. Moreover, we observed a dry-to-humid environment transition with great tree support, as Bilobate (Panicoideae subfamily) and some Panicoideae C3 Bambusoideae provide records of a warm environment under a tropical forest canopy (Barboni *et al.*, 1999). We also found Rondel and Trapezoid (Poaceae, Pooidae subfamily – grasses from highland areas or more humid environments). High altitude forest accounted for the most positive correlation (Oliveira *et al.*, 2015: 1051).

Units D18 (facies) and G6 (facie 3) between 30 cm and 40 cm, dated to 730 cal BP, presented well-preserved phytoliths, predominantly bulliform, cuneiform, bilobed, acicular, and elongated bulliform parallelepipeds (Poaceae). We also observed Rondel and Trapezoid (Poaceae, Pooidae subfamily – grass from highland areas or more humid environments). Echinated Spheroid Echinate type (characteristic of Arecaceae – palm trees), some Spheroid Ornate morphotype (woody dicots), and Collapsed Saddle morphotype (Bambusoidae) were also found. These findings point to a transition between a dry and humid environment since 730 cal BP with significant increase in tree size, while the presence of grasses or low Chloridoideae C4, which belong to dry regions of low latitude and altitude, decreases (Barboni *et al.*, 1999).

In units D18 (60 cm to 70 cm) and G6 (facie 6), dated to 730 cal BP, Blocky, Bulliform Flabellate, and Elongate Entire (Poaceae) are the predominant phytoliths. We also observed large numbers of Spheroid Echinate (characteristic of Arecaceae – palm trees), Spheroid Ornate (woody dicots), and Spheroid Psilate morphotypes.

Units D18 (facie 2) (120 cm to 130 cm) and G6 (facie 13), dated between 5,510 cal BP and 730 cal BP, had Blocky, Bulliform Flabellate, Bilobate, Cross, and Elongate Entire (Poaceae) as the predominant phytoliths. We also found Rondel and Trapezoid morphotypes (Poaceae, Pooidae subfamily – grass from highland areas or more humid environments), Spheroid Echinate morphotype (characteristic of Arecaceae – palm trees), and Collapsed Saddle morphotype (Bambusoidae).

The predominance of Poaceae phytoliths, and the presence woody dicots phytoliths and Arecaceae and Bambusoidae, in both units indicate a grassland vegetation that progressively increased its tree stratum over time, thus becoming a suitable site for human settlement.

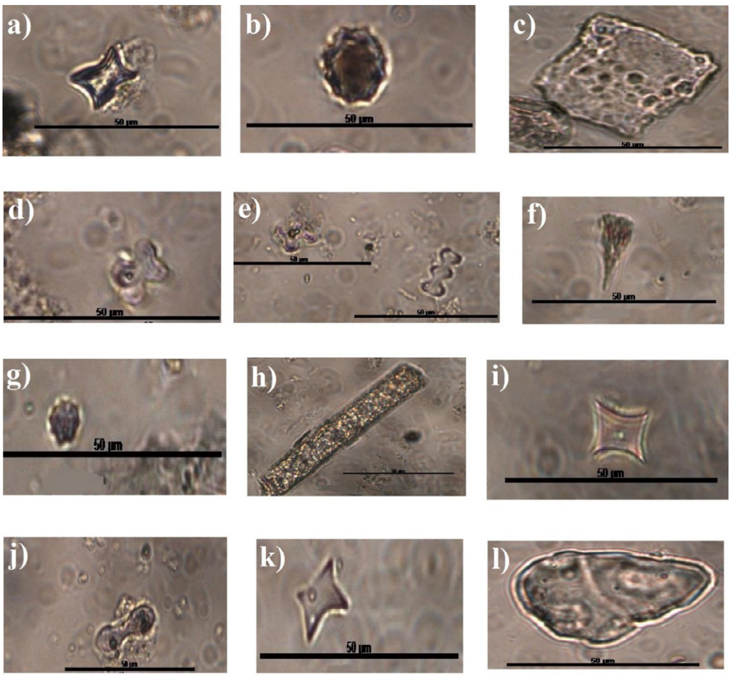

Fig. 3. following ICPN 2.0 – a) RONDEL morphotype (D18 10-20 cm); b) SPHEROID ECHINATE morphotype (D18 30-40 cm); c) BLOCKY morphotype (D18 60-70 cm); d) CROSS morphotype (D18 120-130 cm); e) CROSS and POLYLOBATE morphotypes (G6 10-20 cm); f) ACUTE BULBOSUS morphotype (G6 30-40 cm); g) SPHEROID ECHINATE morphotype (G6 60-70 cm); h) ELONGATE ENTIRE morphotype (G6 110-120 cm); i) D18 and G6 RONDEL morphotype (all levels); j) D18 and G6 BILOBATE morphotypes (all levels); k) D18 and G6 TRAPEZOID morphotype (all levels), l) D18 and G6 BULLIFORM FLABELLATE morphotype (all levels).
Source: Karina Chueng

Discussion

Our phytolith stock analysis (total observed phytoliths) showed well-preserved phytoliths in both units D18 and G6, with minor variations in layer depth. In unit G6, stocks ranged from 296 to 253 (unit values); in unit D18, stocks ranged from 344 to 268. Unit D18 showed higher amounts of phytoliths at levels (59 cm-69 cm) and (60 cm-70 cm).

Phytoliths were mostly classifiable (74% to 86%) and non-classifiable (14% and 26%). Poaceae (grasses) and Poaceae from the Pooidae subfamily (adapted to lower temperatures or altitudes) were the predominant morphotypes. Most Pooideae grasses are found in temperate, cold, and high intertropical elevations (Barboni *et al.*, 1999). We also observed relevant quantities of echinate globular phytoliths, characteristic of the Aracaceae (palm trees). D/P (tree density) index was low, ranging from 0.07 to 0.13%; the Bi (water stress) index was low to moderate, with values ranging from 32.7% to 72.9%; and the Ic (climate) index was moderate to high, ranging from 50.7% to 89.5%.

The D/P, Bi, and Ic indices showed small variations, indicating open vegetation during the studied period, with a predominance of grasses (Poaceae) and palms (Areaceae). Water stress (Bi) was mild to moderate, indicating a slightly drier environment, whereas the Ic suggests good adaptation of the vegetation to lower than current temperatures.

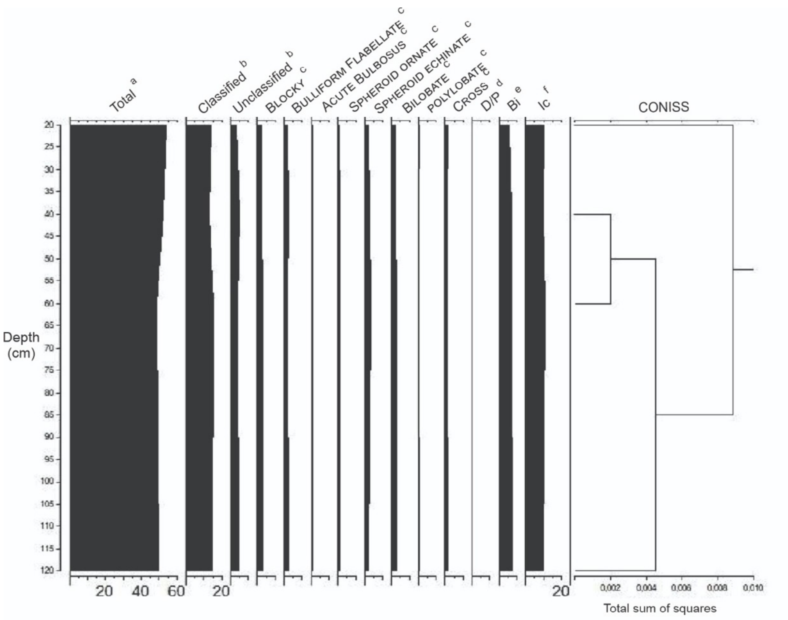

Fig. 4. Results of phytolith analysis for unit D18: a – units; b – % of total; c – % of classified phytoliths; d – D/P=Spheroid ornate/ (Bilobate + Cross + saddle + Acute bulbosus + Bulliform flabellate + Blocky); e – Bi% = bulliform flabellate + blocky/(bilobate + polylobate + rondel + trapezoid + acute bulbosus + blocky + bulliform flabellate)*100; f – CI%= (rondel + polylobate + trapezoid)/(rondel + polylobate + trapezoid + saddle + cross + bilobate).
Source: Karina Chueng

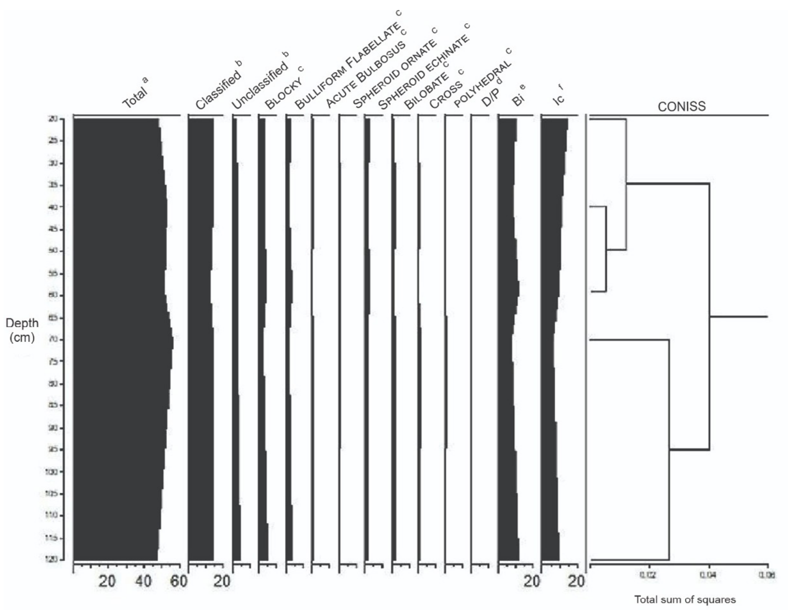

Fig. 5. Results of phytolith analysis for unit G6: a – units; b – % of total; c – % of classified phytoliths; d – D/P=Spheroid ornate/ (Bilobate + Cross + saddle + Acute bulbosus + Bulliform flabellate + Blocky); e – Bi% = bulliform flabellate + blocky/(bilobate + polylobate + rondel + trapezoid + acute bulbosus + blocky + bulliform flabellate)*100; f – CI%= (rondel + polylobate + trapezoid)/(rondel + polylobate + trapezoid + saddle + cross + bilobate).
Source: Karina Chueng

Some hypotheses posit that the climate became drier during the Holocene due to paleofires and human activities, which also altered vegetation patterns. According to Pessenda *et al.* (2001), variations in charcoal concentration may refer to changes from forest vegetation (C3 plants, associated with trees) to cerrado and grasslands (C4 plants, associated with grasses) during the lower and middle Holocene, from approximately 10,000 to 4,000 cal years BP.

Previous paleoenvironmental reconstitution studies based on phytolith indicators (Chueng *et al.*, 2018; Chueng *et al.*, 2020; Coe *et al.*, 2020; Coe *et al.*, 2021) have noted the development, during the Holocene, of a favorable climate for ancient human occupations of hunter-gatherer and horticultural groups in southeastern and southern Brazil. Our phytolith results proved promising for archaeobotanical understanding and paleoenvironmental reconstruction to infer the climatic, vegetational, and regional context, thus elucidating the natural and cultural repertoire of the Itapeva Shelter.

By combining the radiocarbon dating and the characteristics of the morphotypes found in excavation units D18 and G6, we observed a transition from a dry to humid environment in the final periods of occupation, dated to 560 cal BP, as well as a definitively warm environment under a tropical forest canopy. In 730 cal BP, grasses from high altitude areas or more humid environments predominate, suggesting that in the transition phase to a humid environment the tree size increased significantly, while the presence of grasses decreased. At the final excavation levels (120 cm to 130 cm), dated to 5,510 cal BP, we observed high-altitude grasses or humid environments and palm tree morphotypes.

We can thus argue that the forest was only established during the final levels of human occupation, in which one sees a series of transitions—starting from a more humid level, with no dicotyledons at the basal level, up until level seven, around 730 cal BP, where a series of vegetative transformations start taking place, where morphotypes of field vegetation are mixed, but tree support increases significantly.

However, some phytolith indicators point to a cold, dry climate in which fields predominates over woody forest. What we observe is a possible transition period to a large forest, with vegetation similar to that of northeastern Paraná: a colder climate with a tendency for little tree cover, consisting of mixed ombrophilous forest.

During the final periods of human occupation in the Itapeva Shelter, the vegetation transforms into a woody forest and, given the macrobotanical presence of *Ocotea*, we can infer that species accompanying the Araucaria Forest are present on the landscape, which may be evidence of environmental management as a result of Jê groups circulating in the area.

Conclusions

Our findings indicate predominant grassy vegetation and a humid climate until level 7 (730 cal BP), where landscape transformations begin to occur with the establishment of woody trees.

Considering the correlation with other remains from the archaeological site, such as ceramics and rock art, we can suggest that this transformation may result from landscape management by Jê groups who frequented the shelter, finally establishing themselves at the final levels of occupation.

Level 7 seems to be a milestone between this transition from dry climates and open fields to a humid climate characterized by dense forest vegetation. From deeper levels to level 7, the data agrees with what other researchers in the São Paulo area have already indicated (Moffato 2005; Saia 2006), that is, some types of vegetation continue to exist while others undergo a series of major changes.

In the plateau region, phytolith indicators suggest that drier phases can be observed mainly due to the existence of specific high savanna morphotypes, albeit with low grasses adapted to drought conditions, such as C4 grasses adapted to warm climatic conditions, subjected to periods of water stress. In turn, from level 7 to surface levels dating back to 730 cal BP, species linked to Araucaria Forest proliferation are present at 560 cal BP.

This suggest an environmental memory, seeing as certain types of plant species culminate, through a creative process, in the reinvention process of human groups with the environment, becoming a place that overlaps with time and shapes a new way of life.

As for recovering societies in archeology, the question is: what elements displaced them? How did their botanical preferences serve over time to represent a transformation? One important finding is the presence of palm trees at all levels examined, indicating a different management of the past persistent vegetation, which could be both a source of food and fuel due to the oiliness of its fruits.

Such a suggestion stems from the fact that the seeds found in the bonfire structures are burned, and their palms can be used as palisade.

Vegetative transformation can also mean a reoccupation of the site by groups other than those who manipulated the palm trees. These groups could be the southern Jê. According to correlations between the dating and vegetation distribution in southern Brazil, these areas underwent vegetation transformation at the same time that the Jê groups began to occupy archaeological sites more emphatically.

Importantly, pottery is present up to deep excavation levels, but the fragment sizes are quite small, suggesting displacement in the stratigraphy. However, we cannot rule out that these groups may have sporadically frequented the site since its inception; thus, the archaeological site may have been gradually occupied by Jê groups until they became its absolute inhabitants in the final period of human occupation.

SOUZA, T. de; CHUENG, K.; RIZZI, C. A. O paleoambiente do sudeste paulista: contribuições do abrigo Itapeva para uma discussão sobre inserção antrópica e natural. *R. Museu Arq. Etn.* 39: 260-279, 2022.

Resumo: A reconstituição do paleoclima do estado de São Paulo é resultado de esforços de pesquisa ao longo dos anos em estudos de palinologia, antracologia e isótopos estáveis. No entanto, em alguns casos, como no sul de São Paulo, os pesquisadores ainda são obrigados a extrapolar dados dos estados do Paraná, Santa Catarina e Rio Grande do Sul para fins de comparação. Fitólitos e sementes do sítio arqueológico Abrigo de Itapeva foram coletados de sedimentos das unidades de escavação D18 e G6 e analisados. Os resultados das sementes indicam que *Ocotea* (*Lauraceae*) está presente nos níveis iniciais, enquanto *Syagrus romanzoffiana* predomina em todos os outros níveis estratigráficos. A primeira é uma espécie da Mata Atlântica e acompanha a Floresta com Araucárias, enquanto a segunda é uma espécie de palmeira encontrada nas regiões sudeste e sul do Brasil. Os fitólitos apontam para uma mudança do clima mais seco com vegetação campestre para a contribuição de floresta lenhosa nos períodos finais de ocupação do abrigo. A conclusão é que nos níveis estratigráficos de base até o nível sete, datando de 5.510 cal BP a 730 cal BP, ocorrem tipos de vegetação campestre e florestal. Em contrapartida, do nível sete até os níveis superficiais, datados de 730 cal BP a 560 cal BP, proliferam espécies ligadas à Floresta com Araucária e podem indicar a presença de grupos Jê na área de estudo, corroborando estudos que promulgam uma possível antropização das florestas de São Paulo a partir de 1.000 BP.

Palavras-chave: Fitólito; Reconstituição ambiental; Ambiente antropizado; Arqueologia.

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