ISSN:1984-2295

Revista Brasileira de Geografia Física

Homepage: <https://periodicos.ufpe.br/revistas/rbgfe>

Early human-Earth interactions and the initial peopling of the lowlands of southeastern South America (São Paulo, Brazil)

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Artigo recebido em 05/07/2021 e aceito em 04/10/2021

ABSTRACT

Aiming to contribute to discussions of early (>8 thousand years ago) human-Earth interactions on South America, an integrated analysis was carried out between geological, geomorphological, paleoenvironmental and archaeological data in the Brazilian state of São Paulo. Despite the climatic fluctuations registered in São Paulo during Early Holocene (11.5-8.0 thousand years ago), human occupation (evidenced by flaked rock tools, anthropogenic sedimentary deposits and human skeletons linked to ¹⁴C and OSL ages prior to 8 thousand years ago) remained present there throughout the period and without major changes along time in the technological attributes of at least part of their lithic industries, suggesting resilience of such early humans groups in the face of these environmental changes. It was found that around 8,5 thousand years ago, human occupation was present in all the major geomorphological-geological domains of São Paulo State, considered representative of the physical landscape units of the southeastern South America, even though each of them had different availability of attributes valued by the hunter-gatherer ways of life, suggesting significant adaptive capacity to different contexts of the physical environment by these ancient human groups. Also, it was registered that early human settlements are more numerous and older (>10 thousand years ago) in one of the state relief domains: the Cuestas (a transition between two major geomorphological domains of southeastern South America), characterized by the high availability of rocky outcrops of geological units of good capability for manufacturing of stone tools macroscopically similar to the raw materials of many of the artifacts found on such early settlements, highlighting the importance that sources of lithic materials had in the way of life of these ancient populations. Regardless of the different landscape provinces in which they are inserted, most of these ancient human occupations are located in places of relative similar altitudes, inclinations, drainages and proximity (>16 km) of sources of lithic raw materials (e.g. flint, sandstones and quartz found at in situ rocky outcrops and/or gravels fluvial deposits) that strongly resembles those of the ancient artifacts, suggesting similar strategies to insert themselves in different geomorphological and geological contexts.

Keywords: Early Holocene; Human-Earth interactions; Human use of geological materials, Human-relief interactions; Geoarchaeology

Antigas interações entre humanos e o meio físico, e o povoamento inicial das terras baixas do sudeste da América do Sul (São Paulo, Brasil)

RESUMO

Com o objetivo de contribuir para as discussões sobre as interações iniciais (> 8 mil anos atrás) entre humanos e o meio físico, foi realizada uma análise integrada de dados geológicos, geomorfológicos, paleoambientais e arqueológicos do Estado de São Paulo. Apesar das flutuações climáticas registradas em São Paulo durante o Holoceno Inicial, a ocupação humana (evidenciada por artefatos de rocha lascada, depósitos sedimentares antropogênicos e esqueletos humanos ligados a idades ¹⁴C e LOE mais antigas do que 8 mil anos atrás) permaneceu presente ao longo deste período em diversos compartimentos geomorfológicos e sem grandes mudanças ao longo do tempo nos atributos tecnológicos de ao menos parte das indústrias líticas locais, sugerindo resiliência destes grupos humanos em face de tais mudanças ambientais. Verificou-se que por volta de 8,5 mil anos atrás, a ocupação humana já estava presente em todos os principais domínios geomorfológico-geológicos do Estado de São Paulo, representativos daqueles dominantes nas terras baixas do sudeste da América do Sul, embora cada um deles tivesse diferentes disponibilidades de atributos valorizados pelos modos de vida caçadores-coletores, sugerindo significativa capacidade adaptativa em diferentes contextos físico-

ambientais. Além disso, foi registrado que tais antigos assentamentos humanos são mais numerosos e por vezes mais antigos (> 10 mil anos) em uma das províncias geomorfológicas do estado: as *Cuestas* (uma transição entre dois grandes domínios de relevo do sudeste da América do Sul), caracterizada pela alta disponibilidade de fontes de unidades geológicas de boa aptidão para fazer instrumentos de pedra lascada, evidenciando a importância que fontes de matéria-prima rochosa tinham para tais antigos grupos humanos. Independentemente das diferentes províncias geomorfológicas em que estão inseridos, a maior parte desses antigos remanescentes humanos estão localizados em locais de relativamente semelhantes altitudes, inclinações, drenagens e proximidade (>16 km) de fontes de matéria-prima (ex: sílexitos, arenitos e quartzo encontrados em afloramentos rochosos *in situ* e/ou depósitos de cascalhos fluviais) similares as predominantemente usadas na confecção de antigos artefatos líticos por estas populações antigas, sugerindo estratégias semelhantes para se inserirem no contexto geomorfológico e geológico.

Palavras-chave: Holoceno Inicial, interações humanos-Terra, uso humano de materiais geológicos, interações humanos-relevo, geoarqueologia

Introduction

The studies about the interactions between geomorphology, geology, environmental changes and the initial anthropic settlement in the Late Quaternary show diversified patterns of relations between humans and the Earth. Some combinations of these distinct elements of nature may have contributed to intensify early human activities, while others have contributed to inhibit them (Haaland et al. 2020; Cascalheira et al., 2021). Such discussions, however, require merging studies from different areas of knowledge. Quaternary researchers dedicated to such questions usually focus their investigations either in the field of earth sciences, or in the field of human sciences. Research works that seek to superimpose data from these different knowledge fields are uncommon (Strauss and Araujo, 2012; Moreiras et al. 2013; Araujo, 2015; Xie et al., 2019; Cascalheira et al., 2021).

In the case of the lowlands of southeastern South America, many studies have been devoted to discussing the initial human occupation in the periods of Early Holocene and Late Pleistocene (Miller Jr; 1968; Neves and Hubbe, 2005; Buchanan et al. 2007; Araujo 2015; Okumura and Araujo, 2014 and 2016; Hadler et al. 2013; Moreno de Sousa, 2019) based on lithics human artifacts (Moreno de Sousa, 2019), bone artifacts (Mingatos and Okumura, 2020), and human skeletons (Hubbe et al. 2014), linked to 14C, OSL and TL ages prior to 8 ka. Such material remains have been interpreted as evidence of early hunter-gatherer, of a time prior to Tupi and Jê farmers and ceramists. Furthermore, less frequent is the research that characterizes these ancient South Americans human groups with a focus on their relationships with the physical-natural context: rocks, relief, soils, sediments, climate, rivers and other water sources (Morais, 1983; Ab'saber, 1998; Araujo, 2004, 2005 and 2015; Cheliz, 2011

and 2016; Suarez, 2018; Batalla et al., 2018; Nasato, 2019; Bertho, 2020; Cheliz et al., 2020).

As a contribution to the theme, we present a discussion on the role of the natural environment in initial human occupation from the characterization of early archaeological sites in the state of São Paulo, southeastern Brazil, considering their geomorphological, lithological, and paleoenvironmental context. This area was select for simultaneously present two of the most common geomorphological and geological patterns of the lowlands of southeastern South America: the landscapes of predominant gentle slopes linked to the phanerozoic Paraná Sedimentary Basin; and the rugged reliefs linked to the pre-Cambrian Mobile Belts (Ab'saber, 2003; Salgado et al. 2015). Thus, the search in this area for connections between the archaeological sites and their geological context may provide support for discussions on human-Earth and human-environment relations for wide extensions of southeastern South America.

To achieve the intended objective, the following activities were carried out: (1) a review of previous major studies on geomorphology, geological mapping and paleoenvironmental data; (2) a review of archaeological studies on sites with OSL, 14C and TL dates prior to 8 thousand years (kyr) ago; and (3) a study of the overlap in these different sets of previous information. We sought to mediate the distribution of the set of archaeological sites along the major geomorphological-geological compartments of the State of São Paulo and characterize their insertions in the features of morphological, lithological, drainage, and paleoenvironmental frameworks surrounding a portion of the individualized sites. We hypothesize that there would be patterns of similarities in the insertion of different sites in specific geological context of São Paulo state, which would contribute to

characterize strategies for landscape occupation of southeast South America.

Materials and Methods

The Software Arcgis 10.0 was used to combine the horizontal distribution of the geomorphological-geological provinces of the state of São Paulo, as defined by Almeida (1964) and Carneiro (2018) with the location of all known archaeological sites of São Paulo dated by 14C, OSL or TL who had ages above 8 ka. These data were obtained by the review of environmental licensing activities (Documento Antropologia e Arqueologia, 2002; A Lasca Arqueologia, 2016 and 2017; Zanettini Arqueologia, 2003, 2016) and academic research (Beltrão, 1974; Plens et al. 2001; Calippo, 2004; Santos, 2011; Vialou, 1983; Araujo and Correa, 2016; Troncoso et al. 2016; Araujo et al. 2017; Batalla, 2018; Batalla et al. 2019; Moreno de Sousa, 2019). In a second moment, the spatial information mentioned above were superimposed, in order to verify the existence of geomorphological-geological provinces with greater or lesser concentrations of such archaeological sites. After, aiming to provide subsidies to discuss such distribution patterns of the sites along this landscape provinces of São Paulo, a review on previous earth sciences and archaeological research of São Paulo State was carried out.

Regarding the archaeological data, a descriptive summary of the major attributes of each archaeological site (main types of human remnants, major types of raw materials of artifacts, aspects of the horizontal and vertical distribution of the archaeological material, ages of OSL, TL and 14C obtained at the same depths in which artifacts and other remnants of human presence were recovered) were prepared, from a mix of bibliographic review and direct analysis of part of the artifact collections from such sites. In the cases of sites where the dates were not fully accepted by the academic community we presented the varying interpretations made by different researchers. With respect to the 14C dates, we considered those dates whose calibrated ages are older than 8 ka, even in situations where conventional ages do not exceed that age. The same was performed with OSL central ages, even if the margins of error eventually raised the possibility of ages below 8 ka.

The sites were divided into four groups, according to the geomorphological-geological provinces in which they are located, in order to verify the existence of similarities in some of the aforementioned attributes (types of raw materials for their artifacts and ages). in the archaeological areas belonging to a same geological-geomorphological province.

As for the physical landscape research review, the lithological, drainage and geomorphological data of each of Almeida (1964), IPT (1981) and Carneiro (2018) physiographical domains were reviewed and used to weighted the availability in each of this geological-geomorphological units of features which are usually more valued by populations linked to hunter-gatherer lifestyles: stable terrains for human settlement, sources of raw materials suitable for preparing lithic artifacts, and water sources (Binford, 1980). The availability of each of these three elements in each geological-geomorphic province was classified as high, medium or low. The criterion for such classification was related to their abundance in the State of São Paulo itself, as characterized by the bibliographic review: the provinces where such attributes are more abundant were linked to "high" availability, and those in which they are rarer to "low". The next step was to observe the availability of such features compared with the distribution of sites, aiming to discuss whether there was an association between a greater or lesser availability of those landscape elements valued by hunter-gatherers in some of the provinces and a greater or lesser number of archaeological sites in these same provinces. We also sought to compare these attributes with the knowledge of the literature on paleoenvironmental characterization of São Paulo State (e.g., - Ab`Saber, 1969 and 1998; Turcq et al. 1997; Cruz et al. 2005; Celarino, 2011; Souza et al. 2013; Aviles et al. 2019) to discuss the possibilities of at least some of the previously listed attributes being different from the current ones in the time interval potentially linked to the early human occupation in these archaeological sites.

In order to discuss whether the geomorphological and geological patterns of the areas surroundings the sites were similar to those described as predominant for each physiographical province delimited by Almeida (1964), or if they eventually presented exceptional characteristics, a survey for detail data were

carried out. Subsequently, lithological, altimetric, clinographic (terrain inclinations), and drainage details mapping of the surrounding areas (15 km radius) of part of the archaeological sites, according to data compilations from CPRM (2006), IBGE (1972), IGC (2020) and editions of orbital images from Aster satellites, were done, as suggested by Gigliotti (2010). Sites located nearby (within a radius of 30 km from each other) were included in the same detail plots. We also took some photographic register of the physical landscape near the archaeological sites that could be of interest to the objectives of the present work. Then, the results of the characterization of the stone artifacts were compared with the data compiled by the description of this detailed physical environment data, with a focus on mediating the availability of rocky outcrops and other sources of raw material in the surroundings of each site. For this purpose, a macroscopic comparison was made considering the similarities between the raw materials of the artifacts and the source of raw material closest to the site by: 1 – comparison between previous visual records of artifacts in archaeological literature and rock outcrops and sedimentary deposits in earth science literature, 2 – direct consultation of the collections of artifacts in the museums where the artifacts from the sites mentioned in the present work are kept, 3 - field works aiming at direct visualization and photographic register of the natural sources of raw materials at the surroundings of each site.

Results

The land of São Paulo: major geomorphological and geological domains, and their availability of natural recourses to early human groups

The landscape and relief of São Paulo where the early archaeological sites are located (figures 1 and 2) are usually considered a synthesis of the geomorphic features of tropical and subtropical southern Brazil and South America (Ab`Saber, 1956; Carneiro, 2018). In the characterization of Almeida (1964), IPT (1981) and Carneiro (2018), there are five major geomorphological domains in the state of São Paulo: The Coastal Province, the Western Plateau, the Peripheral Depression, Cuestas, and the Western Paulista Plateau (Figures 1 and 2).

The eastern relief compartments of São Paulo (Atlantic Plateau and Coastal Province) are associated with the geological units of the Mobile Belts (linked to igneous rocks, predominantly granites, and metamorphic rocks, predominantly schist and gneisses) and small (<900 km²) Cenozoic sedimentary basins. Most of the geomorphological patterns are more rugged and linked to greater local vertical inclinations and unevenness (figures 1 and 2B), such as the prevailing landscapes in the interior of the Brazilian southeast states of Minas Gerais, Rio de Janeiro, and Espírito Santo (Almeida, 1964; Salgado et al. 2015; Ross, 2016).

There is a predominance of concave slopes on multiple hills (figure 2B), described as a São Paulo State segment of the “Sea of Mounts”, a Brazilian landscape province thus named by Ab`Saber (2003) and linked to the major South America geomorphological unit of “Plateaus of Atlantic East-Southeast”, as described by Ross (2016). Rivers are perennial and abundant, running predominantly inland in the Atlantic Plateau, to the west, and to the Atlantic Ocean on the Coastal Province. Rocky outcrops are common, especially on the terrains with highest inclinations. However, semi-planed lands are rare. They are restricted to the tops of hills and narrow valley bottoms or small (<800 km) Cenozoic sedimentary basins located in the middle of the Atlantic Plateau. The Coastal Province (figures 1 and 2A) is also marked by the presence of coastal plains of low inclinations (<3°) and altitudes (<50 m), separated from the Atlantic Plateau by a set of high (> 800 m) escarpments - “*Serra do Mar*” (Almeida and Carneiro, 1998). In those plains, sandy-clay sedimentary deposits predominate on the south coast and rocky beaches on the north coast (Almeida, 1964; Carneiro, 2018).

In the western portion of the São Paulo state – inserted in the geological unit of the Paraná Sedimentary Basin - the relief compartments (Peripheral Depression, Cuestas, and Western Plateau) are associated with sedimentary rocks (predominantly sandstones) and intrusions of basic igneous rocks. There is a prevailing topography characterized by smooth slopes of the terrain and dominant minor inclinations and altimetry (figure 1 and 2E), like the majority landscapes in the interior of the Brazilian states of Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul, in Uruguay, and in center and south of Argentina (Ab`Saber, 1956; Almeida,

1964; IPT, 1981; Ross, 2016). These three relief compartments are, thus, São Paulo segments of two major geomorphological units of South America, as described by Ross (2016): the São Paulo Peripheral Depression is linked to the "Peripheral Depression of the Eastern Edge of the Paraná Basin"; and the Cuestas and Western Plateau are linked to the "Plateaus of the Paraná Basin".

The Cuestas compartment differs from these majoritarian patterns in the western São Paulo, as it is characterized by a set of escarpments with local vertical unevenness of up

to 400 m, which separates the Peripheral Depression from the Western Plateau (figure 1, and figure 2D). It is also noteworthy for the abundance of rocky outcrops, which shows preferentially in the steeper escarpments (Almeida, 1964; Carneiro, 2018; Ramos et al. 2019). In the other compartments connected to the Paraná Sedimentary Basin, rocky outcrops are rare, since they are deeply altered in soils that reach tens of meters in depth (EMBRAPA, 2020).

As for a comparative analysis of attributes of the physical environment valued by hunter-gatherer populations (Table 1), perennial

Figure 1. Composition containing: A - overlap between the map of the geomorphological compartments of the state of São Paulo and the location of areas with traces of hunter-gatherer groups, B - altimetric map of the state of São Paulo, C - topographic profile and geological cross-section of the main relief compartments of the state of São Paulo. Source:

Adapted from the overlay of Ab`Saber (1956), Almeida (1964), Assunção et al. (2011), IPT (1981), Libault (1971), Martinelli (2009), Documento Antropologia e Arqueologia (2002); A Lasca (2016 and 2017), Zanettini Arqueologia (2003 and 2016), Beltrão (1974); Beltrão et al. (1983); Plens et al. (2001); Calippo (2004); Santos (2011); Vilhena-Vialou (1983); Correa (2017), Araujo et al. (2017); Cheliz et al. (2018); Araujo and Correa (2016) and Troncoso et al. (2016).

Figure 2. Composition with photographs of the dominant landscapes of each major geomorphological-geological province of the State of São Paulo: A- Coastal Province, B - Atlantic Plateau, C - Transition between Peripheral Depression and Cuestas external front, D - Cuestas internal fronts, E- Western Plateau. Source: Photos by the first author.

Table 1 – Comparative analysis of the physical environment attributes valued by hunter-gatherer populations in São Paulo state.

Relief compartment	Availability of water sources	Availability of semi-planed terrains	Availability of rocky outcrops and other sources of lytic raw materials
Coastal Province	High	Average (Average-low at north coast, average at central coast, high at south coast)	Average. (High at north coast – as those near the local abundant rocky coastal cliffs, average at central coast, low at south coast; high at the inner scarps like Serra do Mar). Mostly granites, gneiss and schists, and includes restricted outcrops of quartzites and flint gravels dispersed among some metamorphic rocks
Atlantic Plateau	Average	Mostly low, but high in São Paulo and Paraíba valleys	Average. Mostly granites, gneiss and schist. Includes local quartzite outcrops (e.g – Serra do Japi) and silicified veins. São Paulo and Paraíba valleys have large deposits of quartz and flint gravels
Peripheral Depression	Average	High	Low. It includes the presence of flint and quartz amidst deposits of gravels, or as sparse blocks in middle of some paleozoic geological formations (e.g - Fm. Corumbatai)
Cuestas	Average	Low at the outer front , average at the inner Cuestas	High, emphasizing wide exposure of silicified quartz sandstones (Fm. Botucatu). Also include flint gravels dispersed in Fm. Itaqueri and sedimentary covers of the Cuestas reverses, and quartz, flint and sandstones in alluvial plains near the main rivers (e.g – Jacaré-Guaçu) also in the reverse of the Cuestas.
Western Plateau	Average	High	Low presence of in situ rocky outcrops, that include quartz sandstones, but average availability of secondary raw materials sources along the main rivers (as deposits of fluvial gravels, that include quartz and flint)

Source: adaptations from Almeida (1964), IPT (1981), Cheliz (2013) and Carneiro (2018).

fresh water sources are widely available in all five geological-geomorphological provinces. Semi-flattened terrains are more abundant in the Western Plateau, Peripheral Depression, with intermediate availability in the Cuestas, and low availability in the Atlantic Plateau. Regarding greater availability of rocky outcrops, the Atlantic Plateau, Coastal Province and, above all, the Cuestas stand out. The Cuestas have a special highlight regarding the availability of raw materials suitable for flaking, since in the local abundant silicified quartz rich sandstone outcrops (figure 4E) linked to the Botucatu Formation (Almeida, 1964; IPT, 1981; Gesicki, 2007) are known for their medium-high aptitude for preparing lithic artifacts (Araujo, 1992; Batalla et al. 2019; Cheliz et al. 2020). Although rocky outcrops are also common in the Atlantic Plateau and Coastal Province, their predominant rocks (e.g., – granites) do not show similar qualities for human flaking than those of the aforementioned sandstones. Similarly, quartz and flint veins associated with some fractures of the Atlantic Plateau are less frequent than the

silicified sandstone outcrops associated with the Cuestas of São Paulo (Almeida, 1964; IPT, 1981; Carneiro, 1984; Mantesso-Neto et al. 2004).

Ancient humans vestiges among the landscapes of São Paulo

Areas with early human settlements are present in all São Paulo geomorphological-geological major provinces (Figures 1, 2, and 3, Tables 2 and 3). The archaeological sites in question present several types of traces of past human presence (Table 2 and Figure 3). In some, the artificial character in which that the sediments are disposed — clearly incompatible with natural deposition processes, such as the clay pocket with shells where was found the skeleton with projectile point in their hand from the Capelinha site (Figure 3b and Table 2) — are indicators of human activities (Plens et al., 2001; Lima, 2005). These features are evident in sites of the Coastal Province (Capelinha, Batatal, and Cambriu Grande), characterized as mounds

Figure 3. Examples of vestiges of human presence associated with early human groups in São Paulo State, whose location are shown in figure 1: A - Lesma made on silicified sandstone, from the Caetetuba site, close to the limit between the Cuestas and Peripheral Depression, B – Human skeleton from the Capelinha site, in the scarps ranges of the Coastal Province, C - Silicified sandstone flakes from the Boa Esperança II site, in the province of Cuestas, D - Broken bifacial point in quartz, from the Foz do Moji-Guaçu site, close to the limit of the Western Plateau with the Cuestas, E – Flint point from the Carcará site, from the Atlantic Plateau, F- Silicified sandstone artifact from the Bastos site, in the province of Cuestas, G – Stemmed points from the Caetetuba site; H - Flint and quartzite artifacts from the Capelinha site, I – sandstone artifact from Estrela do Norte site. Source: Photos by the first, second and third author, and adaptation of images from Plens et al. (2001), Lima (2005) Documento (2002) and A Lasca (2016 and 2017),

Table 2. Early archaeological sites from São Paulo state, main types of human occupation evidence and chronological range.

Archaeological sites of the Coastal Province		
Site	Traces of human presence	Estimated occupation times
Cambriu Grande	Artificial stratigraphy of the shellmound constituent materials	Calippo (2004), based on conventional C14 dating of organic material taken from the shellmound, interpreted that the interval of human occupation would include the age of 8 thousand years B.P.
Batatal 1	Artificial stratigraphy of the shellmound constituent materials, lithic artifacts	Figuti et al. (2004), based on calibrated dates of coal samples from the shellmound, interpreted an age of occupation that would include the time of 10,4 to 9,9 thousand years B.P.
Capelinha	Artificial stratigraphy of the shellmound constituent materials, skeletons, lithic artifacts (mostly flint), including flakes and pedunculated points	Plens et al. (2001), based on conventional C14 dating of a human skeleton, interpreted an age of occupation that would include the time of 9 thousand years B.P.
Archaeological sites of the Atlantic Plateau		
Site	Traces of human presence	Estimated occupation times
Carcará	Flaked rock artifacts (mostly quartz, flint, schist and amphibolite), including flakes and pedunculated points (flint, quartz and schists)	A Lasca Arqueologia (2016), based on the conventional C14 dating of a coal sample found adjacent to lithic artifacts, interpreted an interval of occupation that would include the time of 8.8 thousand years B.P.
Archaeological sites of Cuestas and transition Cuestas / Peripheral Depression		
Site	Traces of human presence	Estimated occupation times
Alice Boer	Flaked rock artifacts (mostly flint), including pedunculated points (flint)	Beltrão (1987) based on the association between C14 conventional dates of coals found adjacent to what she considered to be lithic artifacts, interpreted an occupation age that would include the ages of 14.2 and 3 thousand years B.P., and based on a TL dating of a lithic artifact that the occupation would also include the time of 10.9 thousand years B.P. Araujo et al. (2017 and 2021), based on the association of dating from 14C and lithic artifacts, proposed that the most remote age of occupation is around the limit between the Initial and Middle Holocene (~7,5 thousand years B.P)
Bastos	Lithic artifacts (mostly silicified sandstone), including retouched flakes	Araujo and Correa (2016), based on calibrated ages of 14C obtained from coals found adjacent to lithic artifacts, proposed that the local human occupation would include the interval between 12.6 and 7.5 thousand years B.P.
Boa Esperança II	Lithic artifacts (mostly flint, silicified sandstone and quartz), including flakes and cores	Santos (2011), based on the association of an OSL age obtained from sediment samples collected adjacent to rock artifacts, interpreted that human occupation would include the time of 14.5 +3 thousand years ago. Santos and Cheliz (2019) proposed, based on the association between a calibrated 14C age obtained from coal adjacent to a lithic artifact, that the occupation time would include the age of 8,8 thousand years B.P.
Caetetuba	Lithic artifacts (mostly flint and silicified sandstone), including flakes, flat-convex artifacts (lesmas), and pedunculated points	Troncoso et al. (2016), based on the association of calibrated 14C ages obtained from coals adjacent to lithic artifacts, interpreted that human occupation would include the time between 11 and 9 thousand years B.P. New dates were presented by Moreno de Sousa & Okumura (2020), but they reached the same conclusion.
Lagoa do Camargo	Lithic artifacts (mostly flint), including flakes	Araujo et al. (2017), based on OSL and 14C calibrated ages from sediment and coal samples obtained close to lithic artifacts,

		interpreted that human occupation would include the time between 10.3 and 8.8 thousand years B.P.
Archaeological sites of the Western Plateau and Western Plateau / Cuestas transition		
Site	Traces of human presence	Estimated occupation times
Água Vermelha	Lithic artifacts (mostly flint, quartz and silicified sandstone), including flat-convex artifacts and flakes	Documento Antropologia e Arqueologia (2003), based on calibrated 14C age obtained from a coal sample collected adjacent to lithic artifacts, interpreted that human occupation would include the time of 8.8 thousand years B.P.
Bríto	Lithic artifacts (mostly silicified sandstone and flint), including flakes and flat-convex artifacts	Vialou (1983), based on conventional age 14C obtained from a coal sample adjacent to lithic artifacts, interpreted that human occupation would include the interval of 8 thousand years B.P.
Estrela do Norte	Lithic artifacts (mostly flint and silicified sandstone), including retouched flakes	Documento Antropologia e Arqueologia (2002), based on calibrated 14C age obtained from a coal sample adjacent to lithic artifacts, interpreted that human occupation would include the interval of 8 thousand years B.P.
Foz do Mojiguaçu	Flaked rock artifacts (mostly quartz and silicified sandstone), including pedunculated point of quartz	A Lasca Arqueologia (2017c), based on calibrated 14C ages obtained from samples of coals adjacent to lithic artifacts, interpreted that human occupation would include the time between 11.6 and 11.2 thousand years before the present

Source: adapted from Documento Antropologia e Arqueologia (2002 and 2003); A Lasca (2016, 2017a, 2017b and 2017c); Beltrao (1974); Beltrão et al. (1983); Cheliz (2011 e 2015b); Figuti (2004); Plens et al. (2001); Calippo (2004); Lima (2005), Santos (2011); Santos e Cheliz (2017 and 2019); Vialou (1983); Correa (2017), Araujo et al. (2017); Cheliz et al. (2018); Araujo and Correa (2016); Troncoso et al. (2016); , Zanettini Archaeologia (2003 and 2016)

Table 3. Details of C14 dating from some of the early São Paulo state archeological sites.

Sites of the Coastal Province			
Archaeological site	Sample	C14 dates (years BP)	Calibration range (years BP)
Cambriu Grande	CENA 481	5390 ± 70	6290 – 5944
	CENA 480	7870 ± 80	8983 – 8427
Batatal 1	Beta 189329	9050 ± 100	10.487 – 9772
Capelinha 1	Beta 189339	6090 ± 40	7154 – 6748
	A 11236	8500 ± 70	9547 – 9295
	A 11239	8795 ± 105	10.154 – 9542
	Beta 153988	8860 ± 60	10.175 – 9610
	Beta 189331	9250 ± 50	10.550 – 10.243
Sites of Atlantic Plateau			
Archaeological site	Sample number	C14 dates (years BP)	Calibration range (years BP)
Carcará	Beta 303991	8870 ± 50	10.163 – 9690
Sites of Cuestas and transition Cuestas / Peripheral Depression			
Archaeological site	Sample	C14 dates (years BP)	Calibration range (years BP)
Alice Boer	SI - 1205	6050 ± 100	7160 – 6644
	SI - 1207	6085 ± 160	7274 – 6500
	SI - 1026	6135 ± 160	7416 – 6565
	Beta 320198	7200 ± 40	8160 - 7865
	Beta 320199	7680 ± 40	8540 – 8375
Bastos	Beta 442557	9650 ± 40	11.174 – 10.765
	Beta 442556	10.590 ± 40	12.691 – 12.481
Lagoa do Camargo	Beta 307833	7490 ± 40	8367 – 8183
	Beta 307837	7570 ± 40	8414 – 8200

	Beta 307835	7630 ± 30	8511 – 8341
	Beta 307834	7700 ± 30	8539 – 8389
	Beta 307836	8110 ± 40	9131 – 8771
	Beta 318511	9170 ± 40	10.485 – 10.208
	Beta 318510	9300 ± 40	10.573 – 10.278
Caetetuba	Beta 436336	8210 ± 30	9271 – 9012
	Beta 468374	9480 ± 30	11.056 – 10.570
	Beta 469373	9520 ± 30	11.068 – 10.582
	Beta 436337	9590 ± 30	11.087 – 10.710
Site of the Western Plateau			
Archaeological site	Sample	C14 dates (years BP)	Calibration range (years BP)
Água Vermelha 3	Beta 174976	7890 ± 70	8985 – 8459
Brito	GIF 6254	3930 ± 60	4517 – 4099
	GIF 6253	5080 ± 60	5917 – 5605
	GIF 7089	5140 ± 70	5998 – 5608
	GIF 6251	5920 ± 70	6886 – 6499
	GIF 8261	6450 ± 80	7480 – 7163
	GIF 7876	6550 ± 80	7570 – 7268
	GIF 6250	7020 ± 60	7935 – 7685
	GIF 7381	7090 ± 70	8012 – 7719
	GIF 7442	7230 ± 80	8182 – 7845
	GIF 7088	7950 ± 90	9012 – 8538

Source: adapted from Documento Antropologia e Arqueologia (2002 and 2003); A Lasca Arqueologia (2016 and 2017); Beltrao (1974); Beltrão et al. (1983); Figuti (2004); Figuti et al. (2013); Moreno de Sousa e Okumura (2020); Plens et al. (2001); Calippo (2004); Lima (2005); Vialou (1983); Correa (2017), Araujo et al. (2017); Araujo and Correa (2016); Teixeira (2014); Troncoso et al. (2016); Zanettini Archaeologia (2003 and 2016). Calibration was made using the SHCal 20 calibration curve.

composed by a mixture of artificial layers that include the accumulation of human and animals bones, rocks, and stone artifacts (Calippo, 2004; Plens et al. 2001).

In most of these sites, however, the evidence of human presence is marked by plenty of lithic artifacts dispersed among sedimentary layers (which include gravels, clays and sands of alluvial and/or colluvium deposition – Araujo et al. 2017; Cheliz et al. 2021) dated as formed between the Late Pleistocene and the Middle Holocene (Tables 2 and 3) located in all the relief compartments of the current São Paulo territory (Table 1 and Figures 1, 2, and 3). Such artifacts were collected in excavation units that reached depths of up to 2.5 meters, and include lithic flakes, cores, flat-convex artifacts (“lesmas”) and stemmed points. At least some of the lesmas and stemmed points as those represented in figures 3A, 3E and 3G are associated to the Rioclarense Lithic Industry (Moreno de Sousa, 2019; Moreno

de Sousa & Okumura 2020) which was noted to appear in sites located in three different relief compartments of São Paulo (Figure 1).

Regarding the major raw materials of the artifacts, sites linked to the relief compartments (Western Plateau and Coastal Province) associated with the geological domain of the Mobile Belts, show a relatively more expressive presence of materials of igneous and metamorphic rocks abundant in such areas in the composition of their artifacts (Table 2). The sites linked to the Paraná Sedimentary Basin relief units (Peripheral Depression, Cuestas, and Western Plateau) show a greater relative presence of artifacts made from sedimentary rocks (notably sandstones – Table 2). However, flint is present in the composition of artifacts from the sites of all the relief compartments of the state (Table 2).

The surrounding physical environment of the archaeological sites

The potentially early archaeological open-air sites of São Paulo State are also characterized by different contexts of altitudes, inclinations, geological units, and drainage in their

surroundings according to the different relief compartments in which they are inserted, as shown in the photos of Figures 4 and in the maps of figures 5, 6, 7, 8, 9, 10 and 11.

Figure 4. composition with photographs of features of the physical landscape in the vicinity of some of the archaeological sites in São Paulo: A - junction of rivers adjacent to the Alice Boer site, with deposits of gravels that include flint near the water level, in the transition between the Peripheral Depression and Cuestas; B - landscape of low inclinations around the BES II site, highlighting the low river terraces where the site is located, in the middle of the inner segment of the Cuestas; C - hillslopes that surround the Capelinha site, installed in the local bottom of the river valley; amidst the Coastal Province; D - gravel deposits amid the low terraces of the BES II site, in the bottom of a river valley in the inner part of the Cuestas; E - sandstone outcrops of the Fm. Botucatu of the Cuestas, whose usual occurrences are in the hillslopes with the highest inclinations of this geomorphological province; F - landscape of low inclinations in the vicinity of the Estrela do Norte site, in the middle of the Western Plateau; G - elongated valley and steep hillslopes that surround the Bastos site, in the middle of the Cuestas domain; H - narrow level of river terrace

where the Bastos site is located, surrounded by steep hillslopes, at the bottom of the valley depicted in 4G. Source: photos of first and third authors, and image of Lima (2005).

Figure 5. Composition on the surroundings of the Capelinha site, in the bottom valleys of the escarpments of the Coastal Province: A - altitude map; B - inclinations map; C- map of geological units. Location of the areas of those sites is show in figure 1A. Source: own made after Aster images and CPRM (2006), Plens et al. (2001), Lima (2005) and Karmann et al. (1999)

Figure 6. Composition with information about the surroundings of the Caracara site, inserted in a small sedimentary basin and bottom valley among the predominant escarpments of Atlantic Plateau: A- maps of altitudes; B - map of

inclinations; C - map of geological units. Location of the area of the site is show in figure 1A. Source: own made, after Aster images, Carneiro et al (1976), Mancini (1995), and CPRM (2006).

Figure 7. Composition on the characterization of the surroundings of the Cuesta and Peripheral Depression boundary sites (Alice Boer and Lagoa do Camargo): A - map of altitudes, B - map of inclinations, C- map of geological units. Location of the areas of the sites is show in figure 1A. Source: own elaboration, after Aster images, Petri and Pires (1992), Melo (1995) and CPRM (2006).

Figure 8. Composition on the characterization of the surroundings of Caetetuba Site (transition between Cuestas and Peripheral Depression): A - altitude map; B - inclination map; C- map of geological units. Location of the area of the site is show in figure 1A. Source: own elaboration, after Aster images, Ladeira (2001) and CPRM (2006).

Figure 9. Composition with characterization of the surroundings of two of the Cuestas sites (Bastos and BES II): A - altitude map, B - inclinations map, C- geological units map. Location of the areas of the sites is show in figure 1A. Source: own elaboration after Aster images, Meaulo (2005), Cheliz (2016), and CPRM (2006).

Figure 10. Composition with characterization of the surroundings of the Foz do MojiGuaçu site: A- maps of altitudes; B- map of inclinations; C- map of geological units. Location of the area of the site is show in figure 1A. Source: own elaboration after Aster images, Meaulo (2005) and CPRM (2006).

Figure 11. Composition with characterization of the surroundings of the Estrela do Norte site, in the Western Plateau: A - map of altitudes, B - map of inclinations, C- map of geological units. Location of the area of the site is show in figure 1A. Source: own elaboration after Aster images, Bartorelli (2004), and CPRM (2006).

The figure 5 shows that sites of Coastal Province are located on terrains of low altitudes and inclinations (bottom valleys) when compared to the dominant higher inclinations and altitudes of the surroundings escarpments and hills (figure 4C). The figure 6, for its turn, shows that the location of the Carcará site is on the bottom valley linked to one small sedimentary basin (*Paraíba do Sul*) marked by gentles inclines, a geomorphological pattern of exception among the dominant exposures of igneous and metamorphic rocks, escarpments and concave hills (figure 2B) of the Atlantic Plateau.

Figure 7 present the location of two sites (Alice Boer and Lagoa do Camargo) near the limit between the Cuestas and Peripheral Depression, with both near the foothills of the steep Cuestas

escarpments. Figure 8 show the insertion of the Caetetuba Site also near the limit of Cuestas and Peripheral Depression, but in the hillslopes near the Tiete River, whose surroundings (*Cuestas Percée* – Almeida, 1964) are characterized by inclinations more smoothed than those of the predominant outer escarpments of the Cuestas domain as those near Alice Boer and Lagoa do Camargo sites. Figure 9 present the surroundings of two more sites of the Cuestas – the Bastos site, insert in the bottom of a steep and long valley (figures 4G and 4H) among escarpments that surround a small local plateau (*Planalto de Dourado*), and the BES II site, located in a small alluvial plain (figure 4B) in the reverse segment of the Cuestas. The figure 10 characterize the surroundings from Foz do MojiGuaçu site, near the limit between the inner segment of Cuestas and the Western Plateau, marked by smoothed

inclinations than those near the outer limit of the Cuestas, but also with higher inclinations than that of the Western Plateau. Figure 11, for its turn, detail the surroundings of one of the sites (Estrela do Norte) of the Western Plateau (Figure 4F), where low inclinations are predominant.

All the sites discussed here are inserted on terrains characterized by low inclinations in relation to their surroundings (figures 5B, 6B, 7B, 8B, 9B, 10B and 11B). Such a pattern can be viewed not only in sites located on compartments where low inclinations is widespread in the areas near each settlement, as Foz do Mojiguaçu, Água Vermelha, and Estrela do Norte sites amid the wide expanses of gentle slopes of the Western Plateau, or at the limit of the internal Cuestas with the Western Plateau (Figures 1, 4F, 10B, 11B). Likewise, a similar pattern (archaeological sites placed on terrains of low inclinations) is noted in geomorphological provinces where terrains with small inclinations are exceptions within areas characterized by predominantly steeper terrains. Such a pattern is observed in Bastos and Capelinha sites, located in small areas of low inclinations surrounded by the dominant steeper and higher terrains of the Cuestas and of the Coastal Province (Figures 1, 4C, 4G, 4H, 5B, 9B, 12A and 12C), or the Carcará site, inserted in a bottom valley of low inclinations of terrains linked to the Paraíba Valley in the middle of the scarps and high hills of the Atlantic Plateau (Figure 6B). Also, despite the different altitudes that the sites are located (a few meters above sea level in the case of the Cambriu Grande - Figure 1 – and above 600 meters in Bastos site – Figures 1, 4H and 9), they are arranged predominantly in relatively low altimetric patterns when compared to their immediate surroundings (Figures 4H, 5A, 6A, 7A, 8A, 9A, 10A, 11A).

These sites are at most 16 km from sources of geological materials that could be used to knapping activities. Some of the sites' surroundings, like those of the outer segment of Cuestas province, those potential sources of raw materials include terrains with slopes above 20° (figures 7C, 8C and 9C), more likely to have thinner soils (EMBRAPA, 2020), and more common rock outcrops of the geological units of the surroundings of each site (e.g. – potential primary sources of raw materials - figures 5, 6, 7, 8 and 9) along the time. It should also be noted that the Estrela do Norte site is located at an

intermediate distance (~40 km) from Morro do Diabo (Ab'Saber, 1956), which is an exception in the gently sloping terrains of the Western Plateau (Figure 1), being characterized by local vertical breaks of more than 200 meters and terrain with high slopes associated with frequent quartz sandstone outcrops. Others sites surroundings, including those of the Western Plateau – Figures 1, 10 and 11, or near the limits of Cuestas and Western Plateau, are characterized by the rarity of rock outcrops, since the gentle slopes in the surroundings favor the alteration of rocks in deep soils. Sites like Estrela do Norte (figure 11C), Carcará (Figura 6C), Foz do Mojiguaçu (Figure 10C), BES II (Figure 9C) are, however, close to sedimentary deposits near rivers where the literature (Carneiro et al. 1976; Mancini, 1995; Bartorelli, 2004, Zanettini Arqueologia, 2003; Cheliz et al. W / D) relates abundant rock fragments (quartz, flint, and/or sandstones) similar to those associated with the artifacts of the aforementioned sites in Table 2 and Figure 3D e 3E. Thus, such deposits (Valley Bottom sediments - Figures 4D, 5C, 9C, 10C, 11C) are potential secondary sources of raw materials for people whose lived in those surroundings. In addition, it should be noted that the sites listed in this work are arranged close to river channels (Figures 4A, 4E, 4H, 5, 6, 7, 8, 9, 10 and 11), which currently constitute perennial sources of water.

Discussions

Integration between the major geomorphological-geological provinces and the archaeological data

Based on a conservative approach - considering only the distribution of sites that have conventional 14C ages associated with human remains and lithic artifacts - it can be suggested that by at least 8,5 ka prior to the present, humans already occupied and were able to live in all major geomorphological-geological provinces of São Paulo State (figure 13). Thus, they manifested an ability of adapting to significantly different physical-environmental conditions connected to each of the relief compartments. This is a different pattern from that documented in areas as the Beijing Plain (Xie et al. 2019), in which the Early Holocene occupation was restricted to the more elevated relief compartments, with lower areas being occupied only during Middle Holocene.

Figure 12. 14C and OSL dates from Early Holocene archeological sites in São Paulo State versus their distribution over the geomorphological-geological provinces. Archaeological site numbers are like those in figure 1. Geomorphological-geological provinces: A – Coastal Province; B - Atlantic Plateau; C – Peripheral Depression, near to the limit with Cuestas; D – Cuestas; E – Western Plateau.

Simultaneously, the distribution of the archaeological sites over the major geomorphological-geological compartments of the of São Paulo State is heterogeneous. There is a greater number of sites associated with one of the relief compartments (Cuestas) or in the boundary segments between the Cuestas and the Peripheral Depression (Figure 1, and Tables 2 and 3). Furthermore, the sites linked to older ages (>10 kyr) are concentrated in this area (Figure 12, and Tables 2 and 3). This spatial pattern could have a contribution of more intense archaeological research in specifics areas in São Paulo State over the years and with the investment in dating in other sites the results could be expanded. Also, this greater association between ancient sites and one of the geomorphological domains could have also a contribution of the different availabilities presented by each landscape compartment of the attributes considered to be valued by hunter-gatherers (Table 1).

Therefore, the high availability of rocky outcrops considered of good quality for artifact flaking - primary sources (Luedtke, 1979; Batalla, 2018) of raw materials - from the Cuestas (Table 1) may contribute to this distribution pattern, since the abundance of one of the other attributes of the physical environment highlighted here (water sources) is not exclusive to any of the compartments, and even though the Cuestas do not present as much semi-planed land as some other near state geomorphological provinces (Peripheral Depression and Western Plateau – Figures 1 and 2). Sandstones visually similar like that of the aforementioned geological unit are abundant amidst the raw materials of artifacts (Table 1, and Figures 3A, 3C and 3F) of the sites installed in the Cuestas (Table 1), especially those far from the larger rivers (Santos, 2011; Cheliz, 2016; Batalla, 2018). In this sense, it should be emphasized that also the Peripheral Depression has two of three archaeological sites analyzed in

this article installed close to the limits with the Cuestas (Figure 1). Therefore, ancient human groups could take advantage of both installation in the wide lands of gentle inclinations of the Peripheral Depression itself and access to the abundant raw materials of the adjacent escarpments of the Cuestas.

Such high presence of early sites in places with greater availability of rocky outcrops differs from the patterns seen in several places linked to landscapes of lower latitudes, such as those in the lowlands of Europe (Duke and Steele, 2010), or higher altitude in South American mountain areas, as in the Andes (Capriles et al., 2018). This distinction may have a contribution from the alteration of the rocks into deep soils to be favored in tropical and subtropical lowlands areas, where soils commonly have tens of meters of thickness (EMBRAPA, 2020), as opposed to the usually less expressive thickness of soils (<4m) of European or Andean landscapes. Thus, in tropical and subtropical areas linked to predominantly mild inclinations, rocky outcrops tend to be rare, and so the areas where they are less unusual would tend to be more valued and targeted by old populations of hunters and gatherers. In landscapes of lower latitudes or high altitudes, in turn, rocky outcrops *in situ* tend to be more common and widespread, so that their occurrences would not be such a significant factor to explain the location of lithic archaeological sites in a given place to the detriment of another.

Sites located in compartments with less availability of rock outcrops *in situ* (Western Plateau), or whose dominant lithologies are considered less apt for flaking (Atlantic Plateau and Coastal Province), show a greater use of raw materials (quartz and flint – table 2) considered common (Bartorelli, 2004) in gravel deposits associated with each of these relief provinces and available in the vicinity of the sites (Figures 4D, 5, 6, 10 and 11) near rivers. Therefore, it is suggested that the lower availability of outcrops *in situ* of raw materials suitable for flaking in these locations would have contributed to a more intense human use of secondary sources of supply, that is, sources that did not include the removal of rocks from the rocky outcrops *in situ* themselves (Luedtke, 1979; Batalla, 2018).

The raw material patterns of the artifacts from the sites considered in this study are, thus, predominantly consistent with the availability of

raw material of their respective geomorphological-geological provinces. Araujo (2015) points out - based on the composition of raw materials from lithic industries of early (>10 kyr) eastern South American archaeological sites - that at least some of the ancient human populations devoted little energy to the search and selection of raw materials, using mostly what was closest – even using large quantities of materials considered to be of poor quality for flaking artifacts. In the case of early sites in São Paulo State, we noticed a similar apparent trend of using nearby materials. Simultaneously, there seems to have been an effort to select, among the materials available in the vicinity, those that looked better for lithic artifact manufacture, as seen by the abundance of flint or silicified sandstones use in several sites located in São Paulo relief compartments, even when the other options of types of raw materials are also present (Figures 5C, 6C, 7c, 8C, 9C, 10C and 11C).

Interactions between the early human occupation and the surroundings physical environments

The association of most of the archaeological sites with terrains of low slopes and altitudes (Figures 5, 6, 7, 8, 9, 10 and 11) suggests that the need for semi-planed and stable land appears to assume some type of relevance for these potentially early human groups of the state of São Paulo. Even when installed in relief provinces characterized predominantly by high inclinations of the terrain, they would have directed efforts to locate exceptional segments characterized by occasionally reduced inclinations (Figures 4H, 5B and 9B). Thus, they appear like the installation patterns documented in archaeological sites with occupational ages older than 8 thousand years (Early Holocene) in southern Brazil (Cheliz et al., 2020).

One factor that may have contributed to such pattern is that these areas of reduced inclinations and relatively low altimetric positions in relation to their surroundings tend to be receptors for different natural transport flows, including eventual rock clasts, that are potential sources for knapping activities. In fact, the interfluvies near Caetetuba and Alice Boer sites are characterized by diversified sedimentary coverings (e.g., - Vale do Rio do Peixe and Itaqueri Formations - Figures 7C and 8C), with part of them Ladeira (2002) correlates to the presence of sandstone fragments like those

documented by Moreno and Sousa (2019) near those sites. In the case of the Capelinha and Alice Boer sites, the gravels of flint dispersed in the middle of the river channel (Figure 4) adjacent to the sites may have been remobilized from adjacent slopes. In fact, dispersed fragments of flint along rocky outcrops – of metacalcareous rocks in the case of Capelinha, and in the Corumbatai Formation in the case of Alice Boer – near those sites were characterized by Lima (2005) and by Moreno de Sousa (2019). The sandstones fragments described by Batalla (2018) near the Bastos site, in turn, also could be remobilized from the sedimentary covers of the top of the near interfluvies of Dourado Plateau (figure 8), as also suggested by Araujo and Correa (2016). Part of the rock artifacts (table 2, and figure 3A, and 3H) from these sites have macroscopic similarities with such rock fragments, suggesting that they were used as raw materials for the aforementioned lithic archaeological records (Lima, 2005; Batalla, 2018; Cheliz et al. 2020; Araujo et al. 2021).

The potential sources of raw material around the sites (figures 5C, 6C, 7C, 8C, 9C, 10C and 11C) – both primary and secondary - are placed within distances (<16 km) from them that authors, such as Higgs and Vita-Finzi (1972), list as characteristic of the daily displacements undertaken by populations of hunter-gatherers to search the resources necessary for their survival. This close spatial relationship of the early archaeological sites with potential sources of raw materials is similar to the one documented by Cunha (2017), in the north of the Brazilian Minas Gerais state. In another way, it diverges from the pattern identified by Morrow (2014) on some of the Clovis sites from North America that are described as being linked to the use of exotic stones obtained from distant sources. Further research for each of the individualized sites, which consider not only the macroscopic visual similarities recorded in the present work between artifacts and rock outcrops and sedimentary deposits close to the sites, but also use techniques of geochemical or microscopic characterization of those materials may contribute to refine discussions of the supply of raw materials used by those ancient human groups. Similar approaches to those mentioned were previously made by Batalla (2018) at the Bastos site and by Cheliz et al. (2020) at the Alice Boer and Caetetuba sites, but remain pending to be made at most of those early lithic archaeological sites of São Paulo.

Also, the close relationship between the location of the sites with rivers (Figures 1, 5, 6, 7, 8, 9, 10 and 11) are consistent with Binford (1980), that point that the proximity to water courses as one of the major features of the physical landscape valued by populations of human groups of hunter-gatherers. The sites show, thus, a diverse pattern than that documented by Cunha (2017) in the north of Minas Gerais Brazilian State, where water sources are not linked to be adjacent to most of the local Paleoamerican sites. Also, the presence of lithic fragments (e.g – flint and quartz) suitable for flaking of stone tools in the bottom valley sedimentary deposits near many of the major rivers of São Paulo (e.g - Bartorelli, 2004; Cheliz et al, w/d) may also contributed to the association of those early sites with those water channels.

However, the positioning of the sites in relation to the current drainage network must be viewed with care and reservations, as paleoenvironmental studies on oxygen isotopes (Cruz et al., 2005); pedology (Celarino, 2011), palynology (Souza, 2010; Aviles et al., 2019); paleohydrology (Turcq et al., 1998) geomorphology and sedimentology (Cheliz and Giannini, 2020) characterize at least part of the Early Holocene linked to alternations between drier conditions than those of today, for others characterized by increments of humidity in at least a portion of the current continental area of the state of São Paulo. Therefore, many of the river channels in question, especially the smaller ones, far from the main rivers, could be shown with less flow of water or even absent or situated in vertical or horizontal positions different from the current ones (Celarino, 2011; Celarino et al. 2013; Oliveira et al., 2019; Cheliz and Oliveira, 2019).

In the specific case of the Coastal Province sites, it is also worth considering the record of Late Pleistocene and Holocene sea level changes near those site areas (Callipo, 2004; Angulo et al., 2006; Giannini et al., 2007; Cheliz, 2015a). Thus, the estuary of many of the local rivers, including those that are currently close to hunter-gatherer sites, such as Cambriu Grande, could be in different positions than the current ones. In fact, even some coastal continental islands from São Paulo, separated today from the mainland by shallow waters - as is the case of Ilha do Cardoso (figure 2A), where the aforementioned Cambriu Grande site is located - along the Pleistocene-Holocene transition and at

least part of the Early Holocene possibly do not show themselves then as islands and were part of the continuum of emerged lands of the Coastal Province (Cheliz, 2015a). Also, the rise of the sea along the Late Pleistocene and Early Holocene (Angulo et al. 2006) in the Coastal Province may have contributed to an increase in population in the other geomorphological provinces of the state, as previous pointed by Araujo (2004). Such variation may have occurred because this climate induced elevation in sea level reduced the areas of available plains, and the scarps ranges of the Coastal Province have rare extensions of wide extensions of semi-flat terrains, so that this local decrease in land more suitable for human settlement may have been a pressure factor for the displacement of part of these populations to the interior (Araujo, 2004).

Such environmental and climate alterations are also linked to significant changes in the patterns of dominant vegetal associations in each relief province along the Early Holocene. These changes include the passage, in several areas in the Western Plateau, Cuestas and Peripheral Depression from patterns of predominantly open field vegetation before 10 ka to others linked to the growing presence of forests, as pointed out by the palynological studies by Souza (2010) and Aviles et al. (2019). Such oscillations may have contributed to changes in the abundance and types of flora and fauna available in each geomorphologic compartment. The set of 14C and LOE ages from samples near to lithic artifacts (tables 2 and 3, and figure 11) show that despite these environmental changes, the human occupation has been present in São Paulo throughout the entire Early Holocene (tables 2 and 3), allowing us to infer that the ways of life of these human groups showed significant resistance in the face of such climate transformations. Additionally, the presence of archaeological records throughout the Early Holocene set suggests that the climate changes that took place in this period were less intense or abrupt than those associated with the Middle Holocene in Central Brazil, which were associated by Araujo (2005) as having a contribution for a regional hiatus of records of human occupation during such period of time, in a similar way than previous suggested by Bissa and Toledo (2016).

Furthermore, the absence record of modifications in the technological characterization of at least part of the local lithic industries – as

characterized by stemmed points linked to the Rioclarense industry (figure 3E and 3G) being found either in deposits of the Pleistocene-Holocene boundary, and in deposits linked to 14C ages near the end of the Early Holocene (Moreno de Sousa, 2020; Moreno de Sousa and Okumura, 2020; Cheliz et al., 2020), suggests that pre-established lithic industries were resilient to such environmental changes. Constituting, thus, a different pattern from those identified by Haaland et al. (2020) and Cascalheira et al. (2021), which associates climate and environmental changes with larger shifts in technology of early human groups along Late Pleistocene in South Africa (Haaland et al. 2020) and Iberian Peninsula (Cascalheira et al. 2021).

However, in some sites placed near to each other (<30 km), such as the BES II and Bastos (figures 4B, 4D, 4G, 4H and figure 9) there are differences in the quantity of artifacts associated with deposits and soils linked to each of these phases of transformation of the environment (Santos, 2011; Correa, 2017; Cheliz and Oliveira, 2019; Cheliz et al., 2019). Near the Pleistocene-Holocene transition, the BES II site (located on an alluvial plain, figures 4B and 9) presents its archaeological levels with greater amounts of artifacts, while the Bastos site (located amid hillslopes, figures 4H, 4G and 9) presents fewer artifacts during the same period. At the Early to Mid-Holocene Transition, in turn, the BES II site has a decrease in the number of artifacts, meanwhile Bastos site presents an increase in lithic artifacts (Araujo and Correa, 2016; Correa, 2017; Santos and Cheliz, 2019; Cheliz and Oliveira, 2019). Such alternation of denser levels of human traces along fluvial plains and slope scarps landscape units throughout the Holocene on the Cuestas geomorphological domain are opposite to those documented in the same time interval at Beijing Plain by Xie et al. (2019), but may also have had a contribution of environmental and climatic changes. The drier climate associated with the Pleistocene-Holocene limit favored the formation of deposits of ephemeral torrential channels rich in flint and silicified sandstones in some fluvial valley bottoms of the Cuestas, as recorded in the vicinity of the BES II site (Cheliz et al. 2021). Such gravels (figure 4D), when exposed, would be a source of raw material for artifact making, and a strong attraction factor for human occupation, combining to the very abundance of water and semi-planed terrain of the alluvial plains.

The climatic changes to patterns characterized by less rainy seasonality, and the transition of open vegetation to forest vegetation (Souza, 2010) contributed to the local stabilization of river systems and the development of perennial channels, which occurred simultaneously with deposition of sandy deposits over the previously exposed gravels (Cheliz and Oliveira, 2011 and 2019; Cheliz 2015b; Cheliz and Giannini, 2020). Then, human groups would not have the same access to the gravel fluvial deposits and could eventually turn to other sources of raw materials, such as those linked to the most abundant rocky outcrops (figure 4C) and rocky fragments on the escarpments as those near the Bastos site (Almeida, 1964; Sá and Ladeira, 2017; Batalla, 2018; Cheliz et al. 2019). The higher areas with dominant greater inclinations would thus be possibly preferred for human occupation at this time due to their then greater availability of raw materials, even when having less semi-planed land and water sources than the lower areas of alluvial plains inside the Cuestas geomorphological domain. Further research that may refine such discussions about potential associations between climate changes and oscillations in the reliefs units used for more intense early human settlement inside the same geomorphological province include making detailed comparisons between the lithic industries of the sites linked to such different relief units. Likewise, the discovery of new archaeological sites and their detailed excavation in these two relief contexts (those in wider alluvial plains and those in small terraces with low inclinations amid steeper hillslopes), in order to verify the occurrence of similar asymmetries in the distribution of artifacts could also help to better discuss if such patterns of Bastos and BES II sites correspond to a regional trend of Cuestas Domain.

The potential symbolic role of relief and archaeological records in the early human peopling

It can be considered that such early populations could be also motivated to settle in certain areas due to aspects that not necessarily always having some practical attribute capable of assisting in their livelihood (Zedeño, 2008). In fact, there are previous records of South America early populations settled even in environments clearly more challenging to their survival than other nearby places, such as the Puchuncho site, which records a human occupation between 12.8

and 11.5 thousand years ago in the ridges of the Andes Mountains at altitudes above four thousand meters (Rademaker et al. 2014). Symbolic aspects associated with certain features of the landscape considered unusual in their context may have thus contributed to the choice of settlement places. Therefore, it should be noted that several of the sites analyzed here are close to the intersection of different rivers, such as Foz do Mojiguaçu, Estrela do Norte, Capelinha, Alice Boer, Carcará, and Boa Esperança II sites (figures 4A, 5, 6, 7, 9, 10 and 11), or with topographic features diverse from those landscapes that predominate in the surroundings, such as the deep, steep and long valley (figure 4G) of the Bastos site (Correa, 2017; Cheliz et al., 2019), which may have contributed in this direction.

The rarity of landscape features characterized by more expressive topographical breaks in the western portion of the São Paulo state may, in this context, have contributed to a greater potential symbolic fascination that such features, when present, would have on past human groups. Thus, this relief pattern shows itself as a possible additional factor to discuss the greater presence of potentially ancient archaeological sites in the Cuestas compartment, linked to abrupt topographical features that stand out amidst the predominant landscapes of gentle slopes of the adjacent Peripheral Depression and Western Plateau. Mano (2006) recorded that the abrupt relief features of the landscape linked to the Cuestas compartment played a prominent role in the symbolic imagery of the native populations living during the arrival of the Portuguese colonizers; therefore, it does not seem senseless to suggest that something similar has also occurred among older Amerindians.

This possible symbolic fascination linked to certain unusual features of the landscape may also be an element that could contribute to discussing the reason for these human groups that once lived in the actual area of São Paulo state, although usually associated with a nomadic life style (Santos, 2011; Correa, 2017), to apparently return from time to time to certain specific and well-defined locations, in addition to the memory that such human groups have of the natural resources from those places. This contributes to justify the presence of human records associated with dates significantly spaced from each other in the same location, such as in the Caetetuba and Bastos linked to the Cuestas, which record human

occupation over a period of at least 3 ka (Troncoso et al., 2016; Araujo and Correa, 2016) – figure 12.

Conclusions

Some predominant trends in interactions between the settlements of human groups potentially older than 8 ka and the geology, geomorphological and paleoenvironmental patterns of the state of São Paulo were characterized. At least by 8,5 ka, the regional early hunter-gatherer groups used ways of life capable of adapting to physical-environmental contexts that were significantly different from each other, being inserted in all the main geomorphological-geological provinces of São Paulo, from the steep coastal scarps of the east, to the wide fields of gentle slopes of the western portion of the state of São Paulo. It was noted that one of these provinces, the Cuestas (the escarpment transition between the Plateaus and Peripheral Depressions of the Paraná Sedimentary Basin), had a greater number of such early settlements. It was argued that this may have a contribution from the high abundance of geological materials of good quality for flaking lithic artifacts that such landscape province makes available, since other major attributes of the physical environment valued for the subsistence of hunter-gatherer groups (sources of drinking water and stable land for human installation) are not exclusive to any of São Paulo major geomorphological-geological units. The rarity of abrupt topographical breaks in the western territory of the state of São Paulo may have caused the Cuestas compartment, characterized by prominent rocky escarpments, to draw the attention of these ancient populations also in the field of their symbolic constructions and not only in the sense of providing them with favorable elements to guarantee their subsistence, which may also have contributed to the greater number of early hunter-gatherer settlements present there.

Despite paleoenvironmental and paleoclimatic changes that characterize expressive portions of São Paulo area during the Early Holocene, human occupation was present throughout the aforementioned time interval. Likewise, it was noted that at least part of the local lithic industries (e.g., Rioclarense lithic industry) did not show significant changes throughout Early Holocene, suggesting resistance of these technological patterns even in the face of

those environmental changes. However, there were differences in human activities linked to time intervals associated with different climatic conditions in different relief units inside the same geomorphological major province, suggesting a possible contribution of such environmental changes to oscillations in the relief detail contexts taken for preferential occupation. Further research may contribute to refining the discussion on the hypothesis of simultaneous occurrence of regional technological stability and oscillations in preferred relief units for occupation in parallel to climate change along Early Holocene.

Also, it was noted that, despite the different geomorphological-geological provinces in which they were located, most of the human settlements were located in places where these three elements of the physical environment were present close together: (1) low-lying and flatten terrain in relation to those predominant in the surroundings, (2) proximity (<600m) to fluvial channels, and (3) proximity (<16 km) to hillslopes with high inclinations (> 20°) likely to present rocky outcrops suitable for lithic artifact making, or to unconsolidated deposits (e.g. – alluvial plains deposits) associated with the presence of quartz and flint. It was argued that such patterns suggest similar installation strategies in the landscape among the human groups linked to those early settlements, and that such strategies were used in the different geomorphological provinces of São Paulo landscape. To the extent that the relief provinces of the state of São Paulo are representative of those predominant in vast expanses of southern, southeastern and midwestern Brazil and of adjacent countries, the patterns of human-Earth interfaces described here may support studies in broader areas. Providing subsidies both to assist in mediation between early human occupation and the geomorphological and geological environment, as well as to delimit preferential areas to search for new archaeological sites in the lowlands of southeastern South America.

Acknowledgments

We dedicate this work to the loving memory of archaeologist Sara Herter, whose dedication to preserving the historical heritage of São Paulo included helping to organize the collections of some of the archaeological sites covered in this article. PMC is grateful to CNPQ for granting a PHD research grant (n° 308772/2018–0). LTC is

grateful to FAPESP for granting a PHD research grant (2017/20340-1) JCMS holds a FAPESP research grant (nº 2019/08870-0). We are grateful to the suggestions and/or indications of information sources to the article made by Claudia Plens, Celso dal Ré Carneiro, Fabio Parenti and Francisco Ladeira.

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