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Early anthropic occupation and geomorphological changes in South America: human–environment interactions and OSL data from the Rincão I site, southeastern Brazil

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ABSTRACT: This article aims to refine the description of the artefacts and the geomorphological, geological, pedological and chronological (optically stimulated luminescence (OSL) analyses of sedimentary deposits) characterisation of the Rincão I site (southeastern Brazil) to contribute to the understanding of early human–environment interactions. The archaeological site occupation took place on hillslopes truncated by the Mogi-Guaçu River's lateral (~1200 m) and vertical (~5 m) movements during the Late Quaternary, in an area where *in situ* bedrock outcrops are uncommon. This geological context favoured human groups simultaneously having access to the resources provided by the alluvial plain and hillslopes. Here we describe how about three hundred lithic artefacts are associated with soils that originated from sandy colluvium with OSL ages between 20.3 and 5.5 thousand years. These ages are consistent with the local palaeopedological and geomorphological contexts of landscape changes, and partly controversial from the perspective of models currently in vogue for the human occupation of southeastern Brazil. The vestiges of past human presence amid the hillslope sandy colluvium deposits include: 1) a set of flakes and formal artefacts (one stemmed point and three convex artefacts) made of sandstone obtained from hillslopes near (<10 km) the site; and 2) predominant detritus and flakes of quartz and flint obtained mostly from the adjacent (<1.5 km) alluvial plain, linked to flaking sequences other than those of the formal artefacts. Only quartz artefacts were found in the lower levels of the site stratigraphy, whereas in the intermediate and upper levels quartz, flint and sandstone artefacts were found, suggesting that there were changes in the raw materials used for flaking over time. The formal artefacts from the site have technological attributes like the ones observed in assemblages associated with a previously known lithic industry (Rioclarense), but a different pattern of choice of raw materials. This suggests that technical standards underwent a process of adaptation to the environmental particularities surrounding the Rincão I site. © 2023 John Wiley & Sons, Ltd.

KEYWORDS: alluvial plain occupation; geoarchaeology; hillslope occupation; Late Quaternary; palaeopedology

Introduction

The early human occupation of South America is a subject of continuous debate, including topics concerning how the early groups interacted with the natural landscape, the antiquity of the settlement in each segment of the continent, and the speed of human spread (Ab'Saber, 1994; Araujo, 2015; Bueno et al., 2013, 2021; Dillehay et al., 2015; Suárez, 2018; Batalla et al., 2019; Williams and Madsen, 2019; Cheliz et al., 2020; Prates et al., 2020; Gruhm, 2020). Bueno et al. (2013) note that in a wide area of eastern South America (e.g. Brazilian territory), vestiges of human presence dating to less than 10 000 years ago (10 ka) are more common and these dates are generally accepted in the literature as effective ages of human occupation. According to these authors, records of human occupation prior to 10 ka were sparse and with less consensus (especially those dated to the Late Pleistocene, or older than the Clovis Culture, in the US – Williams and Madsen, 2019; Politis and Prates, 2019), at least for some sectors of Brazilian territory. Indeed, Prates et al. (2020) point out that there are no archaeological sites older than 10 ka in the southern Brazilian Plateau area (which includes the states of Rio Grande do Sul, Santa Catarina, Paraná and São Paulo – Cheliz et al., 2020) that meet their criteria to suggest human presence during this time period. This would imply that this part of the continent was one of the most recent in the process of human occupation of South America. Other authors consider that archaeological data prior to 10 ka in this sector, although sparse and less common, are solid enough to be accepted as evidence of earlier human occupation over the time interval (e.g. Araujo and Correa, 2016; Troncoso et al., 2016; Moreno de Sousa, 2019; Bueno et al., 2021).

The environmental context is also important in evaluating early human occupation of South America since the period

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before 10 ka most likely had palaeoenvironmental conditions different from today (Souza et al., 2013; Araujo, 2015). Thus, in this chronological range when hunter-gatherer lifestyles prevailed in South America (Moreno de Sousa, 2019), not only did the ways of life and culture of human groups change, but nature itself (e.g. relief, sedimentary deposits, soils and rivers) transformed over time (Ab'Saber, 1994; Araujo, 2015). Faced by this, and also the controversy over the reliability of the record of human presence before 10 ka in the Brazilian Southern Plateau area, the discussion of relationships between early human groups and the natural environment in this part of South America acquires singular importance and complexity (e.g. Renfrew, 1976; Davidson & Schaciley, 1976; Waters, 1992; Neves and Prous, 1998; Pollard, 1999; Araujo and Correa, 2016; Troncoso et al., 2016; Correa, 2017; Cheliz and Ladeira, 2017; Moreno de Sousa, 2020). Two aspects require special consideration: (1) natural landscape changes over time and their impact on resources essential to hunter-gatherers, including sources of drinking water and raw materials; (2) the need to assess whether dating results older than 10 ka for sedimentary deposits with artefacts can be reliably considered as effective ages of human occupation, which requires an analysis of their compatibility with the context of the physical environment where they were found (Bueno et al., 2013, 2021).

This work is a contribution to the aforementioned topic of discussion through an integrated analysis of the geomorphological, geological and pedological context and the artefacts from the open-air lithic archaeological site Rincão I, located northeast of São Paulo State, in the Southern Brazilian Plateau (Fig. 1). We seek to verify the hypothesis that attributes of the physical environment of the site may have favoured the development of the lithic industry and the choice of the settlement location, and that the human occupation at the archaeological site may have begun prior to 10 ka. We characterise the physical environment where the populations that produced the lithic artefacts lived, and its relationship with the characteristics of past human occupation. We also aim to assess whether the chronological data obtained for the site are consistent with the geomorphological and pedological changes observed in the geological record. Data from previous research on the site were reviewed (Zanettini Arqueologia, 2006 Galhardo, 2010, 2016; Cheliz, 2016) and integrated into new geomorphological, geological, pedological, chronological and archaeological data, which resulted from research carried out between 2018 and 2019, linked to the PhD work of Cheliz (2023).

Regional setting and history of research at the Rincão I site

Regional setting

The Rincão I site is in the geological domain of the cratonic Paraná Basin, in the western segment of the western sector of the Cuestas physiographic domain in São Paulo State (Almeida, 1964), and near (<100 m) the alluvial plain of one of the main rivers (Mogi-Guaçu) of this area. Gentle hillslopes (<7°), altitudes between 500 and 700 m, and smooth topographic variations prevail in this sector, with rare local relief ruptures higher than 30 m. The prevailing climate is subtropical, with an average annual temperature of 23°C and rainfall of 1300 mm. The rivers flow perennially and the most significant of them flow westward, inland. The original vegetation in the area is the *cerrado* (Souza, 2010), ranging from open fields to forests.

São Paulo State has hundreds of lithic archaeological sites considered to be pre-colonial (>0.5 ka). Among them, only the Rincão I site (Cheliz, 2023) and five other sites have archaeological artefacts in sediments dated older than 10 ka (Fig. 1).

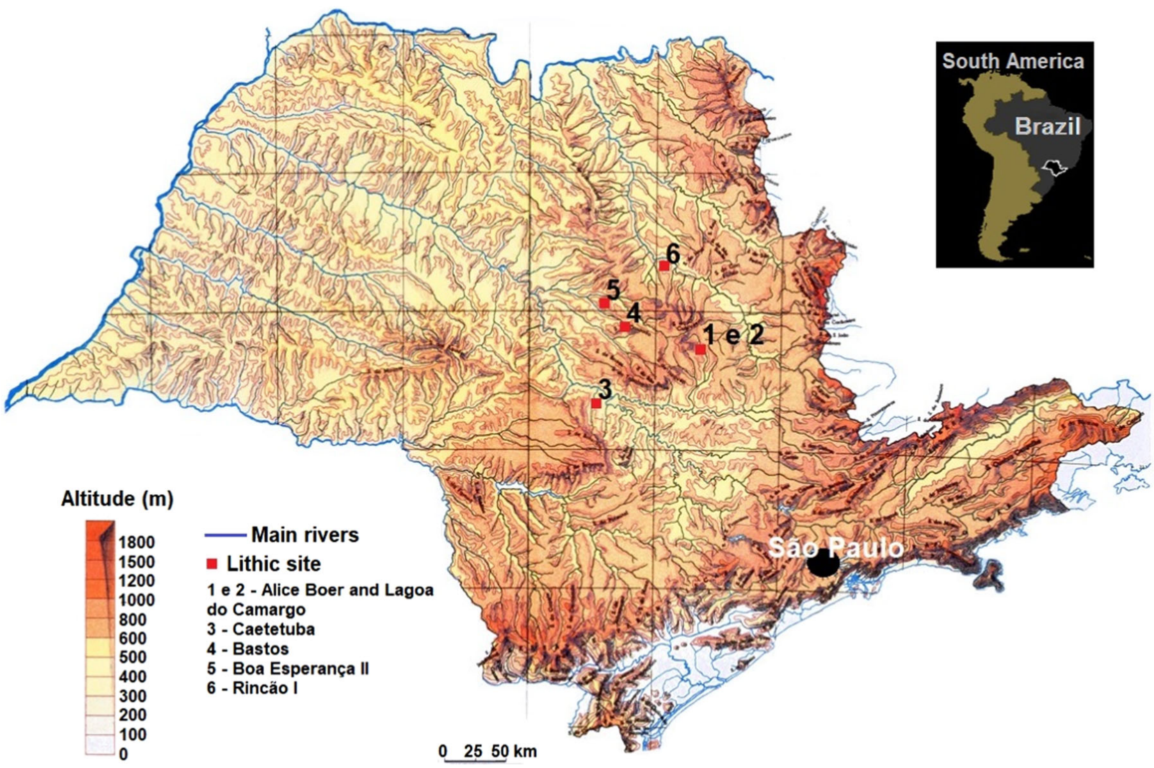

Figure 1. Archaeological sites associated with dates older than 10 ka in São Paulo State, Brazil. Source: Adapted from Libault (1971), Beltrão (1974), Martinelli (2009), Santos (2011), Cheliz (2011, 2016, 2021), Araujo and Correa (2016), Araujo et al. (2021), Correa (2017), Troncoso et al. (2016) and Santos and Cheliz (2019). [Color figure can be viewed at wileyonlinelibrary.com]

Of the dates older than 10 ka, the most accepted as being representative of human occupation are from the Early Holocene. Others have questioned whether these ages are really associated with human settlements due to doubts about the context of the archaeological findings, the dates themselves, or the lack of association between the dated samples and the artefacts (Cheliz, 2015; Cheliz & Oliveira, 2019; Santos and Cheliz, 2017, 2019; Araujo et al., 2017, 2021). These questions reinforce the need to better investigate the dates associated with the Rincão I site and their context within the local physical environment.

History of research at the Rincão I site

The first vestiges of the Rincão I site were originally found during the opening of artificial cuts on the terrain adjacent to the SP-255 paved road during the installation of a pipeline. The exposure of several lithic artefacts then led the people responsible for the road to contact authorities to carry out an archaeological investigation. The pipeline work was interrupted for 8 days and the Zanettini Arqueologia company team, coordinated by Dr Robson Rodrigues, carried out archaeological excavations at the site (Fig. 2A). Work included dozens of drillings and the opening of a 20 × 1 m trench (Fig. 2A), reaching a depth of 150 cm, where archaeological material was still found. A description of this material was presented in a report by Zanettini Arqueologia (2006). Later, Galhardo (2011, 2016) carried out a technological description of the artefact collection of the site, with an emphasis on three *lesmas* (a specific type of unifacial elongated and plano-convex tool) found on the surface. From 2014 to 2019, we carried out new investigations of the Rincão I site linked to the work of Cheliz (2016, 2023), aiming to carry out a geomorphological, geological and pedological characterisation, as well as the acquisition of dating samples and additional archaeological data (Fig. 2B, 2C and 2D).

Figure 2. Photographs of the 2006, 2018 and 2019 field investigations: (A) trench opened by Zanettini Arqueologia (2006), with 18 blocks of 1 × 1 × 1 m; (B) 2018 excavation unit (UE1R-2018) adjacent to the 2006 trench; (C) pedological drilling of 2019 (T3); (D) 2019 excavation unit (UE1R-2019). Source: adapted from Zanettini Arqueologia (2006) and P. Cheliz. [Color figure can be viewed at wileyonlinelibrary.com]

Materials and methods

Physiographic analyses

The altimetric, hydrographic and geological contextualisation of the site surroundings were initially carried out within a radius of 15 km. Hypsometric and hydrographic maps were made from the overlay of available topographic maps (IBGE, 1972; IGC, 2020) and by editing Aster images and the Worldview composition of the Arcgis 10.8 software, following the procedures recommended by Giglioti (2010). The map of geological units in the area was based on the review of previous maps (UNESP, 1982; Meaulo, 2007), combined with new field surveys. Within the aforementioned total area, a smaller portion was delimited in the vicinity of the site, where more intensive field surveys were conducted, and a map of landscape units with emphasis on relief attributes was created, according to the recommendations of geomorphological analysis by Ab'Saber (1969).

A characterisation of the soils was carried out at this detailed study area by opening two new excavation units of 1.25 × 1.25 m that reached depths of 0.9 m and 1.2 m, and three pedological drillings with a 7 m deep Dutch auger. The opening of the excavation units was made according to 10 cm thick artificial layers to control the stratigraphic position of the lithic artefacts found amid the excavations. All the excavated sediments were passed through sieves as soon as they were removed from their original position to identify and record the artificial layer with which materials greater than 2 mm were associated, and verify whether they were possible lithic artefacts. Pedological characterisation of the excavation units included macromorphological (Schoenerberger et al., 2012) and micromorphological (Castro and Cooper, 2019) analyses. Four soil samples were collected for chemical and granulometric analysis, performed according to Camargo et al. (2009). In the granulometric analysis, sediments with dimensions less than 2 mm were separated into coarse sand, medium sand, fine sand, silt and clay fractions, as defined by Camargo et al. (2016). The grain-size distribution was determined by the pipette method, with dispersion in 0.1 mol L^{-1} sodium hexametaphosphate (Teixeira et al., 2017), followed by the sieving of material coarser than 62 µm. Total organic carbon was quantified by the potassium dichromate (0.167 mol L^{-1}) method. Exchangeable P was extracted with Mehlich-1 solution. Subsequently, P levels were determined by photocolorimetry (Teixeira et al., 2017). Additionally, six soil samples were collected for micromorphological analysis, according to Castro and Cooper (2019). In this analysis, particles were subdivided into coarse (>0.062 mm) and fine (<0.062 mm) fractions, close to those defined by Castro and Cooper (2019).

After these above-mentioned procedures were completed, all physiographic data were integrated according to Ab'Saber's (1969) concepts of surface structure analysis of the landscape and the Ladeira (2010) concepts of palaeopedological analysis.

Optically stimulated luminescence (OSL) dating

In one of the excavation units with the presence of archaeological materials (U1-2018), three sediment samples were collected (OSL 1, 2 and 3, at depths of 25, 55 and 85 cm, respectively) for dating by the OSL method, carried out at the Laboratory of Gamma Spectrometry and Luminescence (Legal) of the Institute of Geosciences, University of São Paulo (IGc-USP, Brazil).

The sample analysis in Legal followed the single aliquot regenerative dose (SAR) protocol (Murray and Wintle, 2003), with the same procedures used by Oliveira et al. (2019).

Samples were wet-sieved to isolate the 180–250 μm grain-size fraction and treated to obtain quartz concentrates, following standard procedures (e.g. Aitken, 1998; Pupim et al., 2017). Aliquots of quartz (100–200 grains) were mounted on stainless steel discs for luminescence measurements on an automated Risø TL/OSL DA-20 reader system. The SAR protocol (Murray and Wintle, 2000, 2003) was applied to estimate the equivalent doses (Table 1), using only aliquots in agreement with rejection criteria (Murray and Wintle, 2006). The beta and gamma radiation dose rates were determined using the radionuclide concentrations (U, Th and K, determined by gamma-ray spectrometry) and conversion factors outlined by Guérin et al. (2011). Water content was determined by the ratio between water weight and dry sample weight. The cosmic dose rate contribution was calculated following the Prescott and Hutton (1994) model. Additionally, a dose recovery test was performed for the L1374 sample (OSL 3, 85 cm). In the test, the quartz grains had their luminescence signal reset (e.g. turned to 0 Gy) and given a known dose. The SAR procedure was then used, and it was verified if the given known dose was obtained. A more detailed description of the procedures used in the OSL analysis can be viewed in the supplementary material 1.

The distribution of the equivalent dose values from the single-aliquot procedure were analysed using the central age model (CAM) and the minimum age model (MAM) (Galbraith et al., 1999; Galbraith and Roberts, 2012). The CAM is appropriate for single-age distributions and the MAM is appropriate for partially bleached sediments.

Characterisation of lithic artefacts

A revision of data from previous analyses of the artefacts of the Rincão I site (Zanettini Arqueologia, 2006; Galhardo, 2010, 2016) was made, with an emphasis on the quantity of artefacts, horizontal and vertical distribution, raw material and their main morphological types and the characteristics of flaking sequences. Similarly, the artefacts recovered in the 2018 investigation were described, adopting the same artefact classification system used by Galhardo (2010) to standardise the information. There was a direct consultation of the artefact collection available at the Araraquara Museum of Archaeology and Paleontology, aiming to revise previous analyses, and then minor changes of the morphological classification of part of the artefacts were made. Through direct consultation of the collection and an analysis of the individual descriptions database for each piece of the site according to the protocol of Galhardo (2010), we sought to present a detail of the variation of the flake attributes to verify differences and similarities between those made of quartz and those made of sandstone or flint. Moreover, additional descriptions of the stemmed point and *lesmas* of the site were made, according to the standard technological analysis protocols proposed by Moreno de Sousa (2019) and Moreno de Sousa and Okumura (2020).

Results

Characterisation of the physical environment

The geology and geomorphology of the Rincão I site's surroundings are show in Figs. 3, 4, 5, 6 and 7. The Mogi-Guaçu River has a meandering pattern in this area, and its course is predominantly aligned east–west. A wide alluvial plain (relief unit I, Figs. 3 and 4) with unconsolidated sediments, low inclination (less than 2°), and altitudes between 500 and 510 m occur along the river banks. The hillslopes that border it (relief unit II) have dominant inclinations between 3 and 8° and altitudes from 510 to 580 m, and are constituted by sandstones (Piramboia and/or Botucatu formations) and igneous rocks (lava flows of Serra Geral Formation and associated intrusions) of the Paraná Basin (São Bento Group), as well as colluvium and alteration products of these lithologies.

Abrupt slope breaks, associated with 20–50 m high scarps, mark part of the boundary between the alluvial plains and the hillslopes on the study area's southern margin (Figs. 3, 4 and 5). The Rincão I site is located in an artificial cut made for the opening of the road and pipeline in the hillslope close to one of these abrupt breaks (Fig. 4, profile B).

The deposits of the alluvial plain show a predominance of sand and clay, with the presence of scattered pebbles (Fig. 8B). In a sample of 100 of these pebbles, the presence of quartz, flint and sandstone was recorded, 74 of them were smaller than 3 cm, and the other 26 were between 3 and 10 cm. There were abundant fragments of sandstone dispersed on the surface, most of which were larger than 30 cm (Fig. 8A) in scarps of a greater inclination, especially at the Santa Lúcia escarpments, located 7 km south of the Rincão I site (Figs. 3 and 8A). Likewise, part of the current bed of the Mogi-Guaçu River is rocky. These are also some of the few places in the area where *in situ* rocky outcrops were found.

The characterisation of the soils (Cheliz, 2023) of the hillslope on which the Rincão I site is located allowed the delimitation of three distinct pedological horizons (Figs. 2 and 7) in excavation unit UE1R-2018 carried out adjacent to the 20 × 1 m archaeological trench previously made by Zanettini Arqueologia (2006). The 1C2 soil horizon, in which the archaeological artefacts of the excavation unit are concentrated, presents different characteristics from the others, highlighting the higher compaction (supplementary material 2). Horizon 2C1 stands out, with a high phosphorus concentration (6 mg dm^{-3}), greater than twice the overlying horizon 1C2 (supplementary material 3). The granulometric distribution is similar in all horizons, with a predominance of coarse sand and fine sand fractions (supplementary material 4). The soil horizons found in the excavation units of the Rincão I site are similar to Arenosols in the FAO classification (FAO, 2006).

The pedological drilling carried out close to UE1R-2018 (Figs. 2C, 6 and 7) showed a soil horizon similar to horizon

Table 1. OSL dating results

			Central age model data						Minimum age model data			
Sample	Laboratory number	Dose rate (Gy/1000 years)	Equivalent dose (Gy)	Error (Gy)	Central age (years)	Error (years)	Dispersal (%)	Equivalent dose (Gy)	Error (Gy)	Minimum age (years)	Error (years)
OSL1	L1412	0.696	8.0	0.8	11491	1416	49.0	3.862	0.13	5548	435
OSL2	L1375	0.704	12.1	0,6	17200	1600	23.5	9.383	0.2	13296	1027
OSL3	L1374	0.693	14.1	1.0	20300	2100	33.9	10.7	0.4	15543	1298

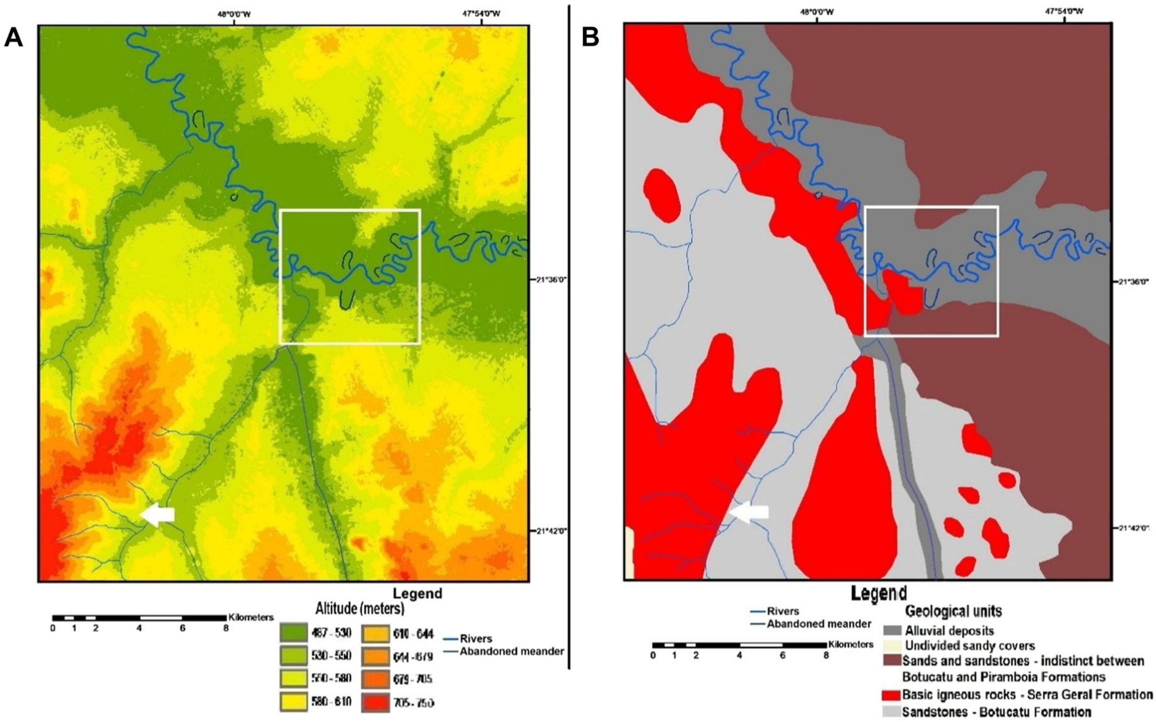

Figure 3. Image composition with hypsometric map (A) and geological units (B) around the area delimited for detailed geomorphological mapping (white rectangle) near the Rincão I site. In the southwestern corner of the maps, the Santa Lúcia escarpments stand out (white arrow), with a higher concentration of sandstone outcrops. [Color figure can be viewed at wileyonlinelibrary.com]

1C2, at a depth of up to 1.3 m, and another, similar to 2C1, at a depth between 1.3 and 6.5 m. In a second excavation unit (UE1R-2020) with a depth of 1.5 m, carried out 22 m southwest of UE1R-2018 (Figs. 6 and 7), no soil horizon with characteristics similar to 1C2 or with archaeological artefacts was identified, but only horizons similar to UE1R-2018's 2C1. Moreover, no natural rock fragments (>2 mm) were found scattered among the sandy sediments of the UE1R-2019, nor in the pedological drilling (Figs. 2C, 6 and 7) carried out on those hillslopes, even with all the material removed from the excavation having been sieved. In the micromorphological characterisation of the coarse fraction of soil horizons (Fig. 9), the almost exclusive presence of well-sorted quartz grains, sub-rounded to well-rounded, predominantly as sandy coarse fraction, was registered; there are also a few dispersed feldspar grains (up to 2% of the coarse fraction), already in an advanced state of weathering. The fine fraction is reddish and corresponds to proportions between 25% and 35% of the thin sections, appearing either in the form of coatings involving the coarse fraction grains or as menisci connecting them.

Chronology and OSL data

The dose recovery test featured almost full agreement between the values of the given dose and the measured dose (Supplementary Material 5 – Tables 5SC and 5SD). For quartz grains to which a dose of 5 Gy was given, the ratio between measured dose and given dose was 1.03, with dispersion close to zero. For quartz grains submitted to a dose of 25 Gy, the proportion between measured dose and given dose was 0.99, and the dispersion only 7.1%. Such data demonstrate that the quartz grains have high luminescence sensitivity and are suitable for dating by the SAR protocol.

The equivalent doses obtained from the studied sediment samples (Fig. 7) range from 8.0 ± 0.8 to 14.1 ± 1.0 Gy (Table 1), and decrease with bottom-up stratigraphy. The dose rate values (Table 1 and Supplementary Material 5 – Tables 5SA and 5SB) range from 0.693 to 0.704 Gy/ka, and are similar to those previously obtained by Feathers (2017) in deposits of two other lithic archaeological sites, also located in the Cuestas geomorphological domain of São Paulo State, and with geological sedimentary sources analogous to the Rincão I ones (basic igneous rocks and sandstones of the São Bento Group).

In colluvium deposits, which are admitted to be the case for the sediments dated here, OSL ages obtained by the CAM (Table 1) occasionally diverge from the true ages of deposition (Yu et al., 2016) due to the sometimes incomplete optical bleaching of quartz grains in such deposits (Fuchs and Lang, 2009). The typical pattern of samples with incomplete optical bleaching is characterised by high dispersion and a multi-peak dose-distribution histogram. However, this same pattern, especially in sediment samples taken just below current surfaces or palaeosurfaces (where the biological action many times is or was more intense), may be due to intense mixing of vertically remobilised grains (Arnold and Roberts, 2009), including from distinct depositional events. In these cases, there is an intense mixture of quartz grains with different ages.

The histogram of the distribution of dose values for the aliquots of the OSL 1 sample has characteristics similar to those of mixed ages, while those of the OSL 2 and 3 samples are similar to the ones described by Arnold and Roberts (2009) as typical of single-aged sediments (Supplementary Material 6). The over-dispersion values of the equivalent dose distributions from the samples, for its turn, range from 25% to 49%; this is higher than that obtained from the dose recovery test, which is single-aged by design. This raises the possibility of mixed aged samples, more likely for the sample (OSL 1) with the highest over-dispersion and multi-peak dose distribution histogram. If the possibility of mixed age sediments is admitted, the application of the most conservative approach of MAM (supplementary material 7) to the OSL data provides ages of 5.2 ka, 13.3 ka and 15.5 ka, whereas CAM provides ages of 11.4 ka, 17.2 ka and 20.3 ka (Table 1, Fig. 7). In both

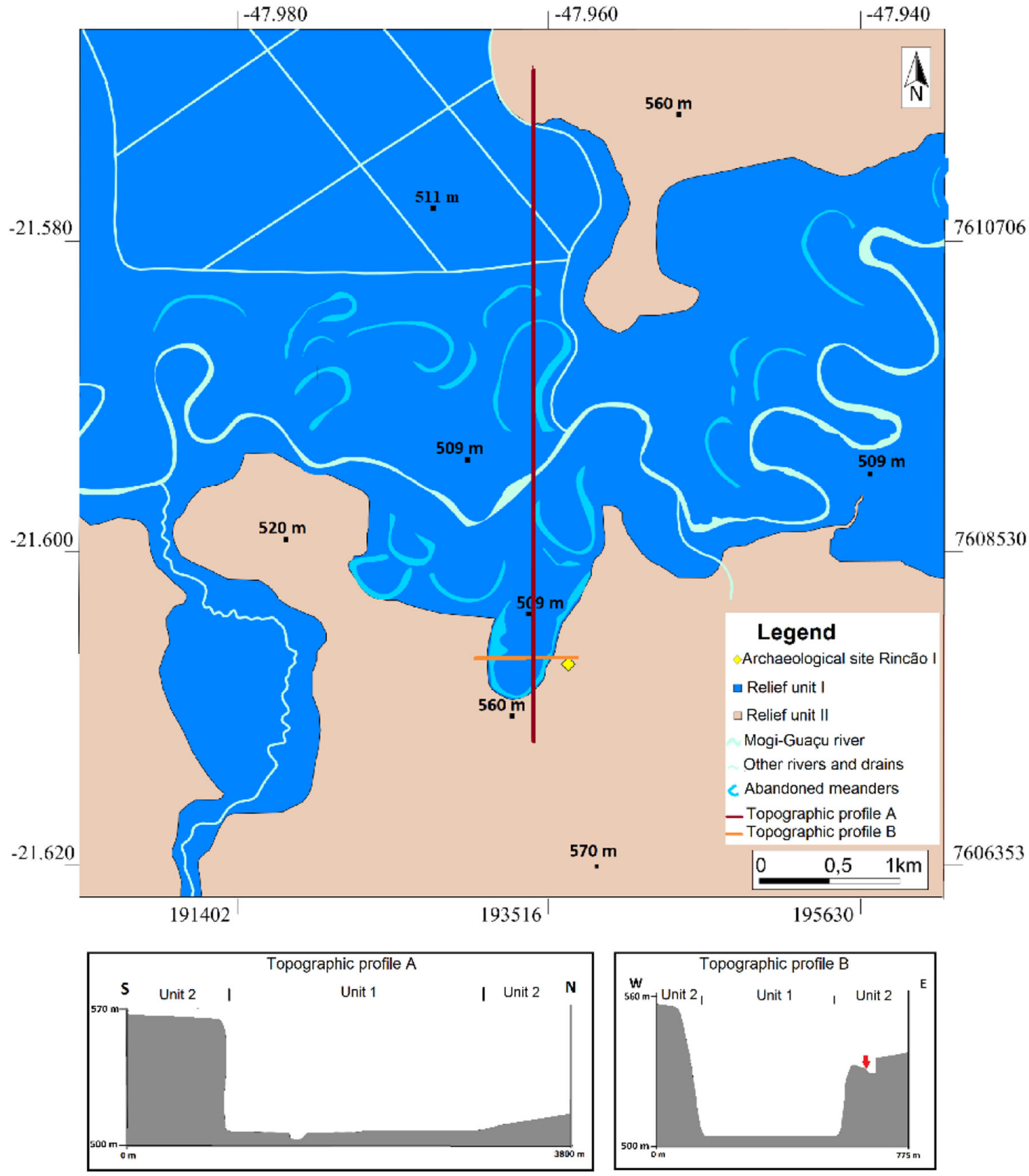

Figure 4. Geomorphic units and topographic profiles surrounding the Rincão I site, in the area highlighted in Fig. 2 by the white rectangle. In topographic profile B, the Rincão I site location is indicated by a red arrow. [Color figure can be viewed at wileyonlinelibrary.com]

models, the ages respect the stratigraphic order and are contained partially in the Late Pleistocene.

Characterisation of lithic artefacts

In total, at least 595 artefacts (Figs. 10, 11, 12 and 13, and Tables 2, 3 and 4) were registered at the Rincão I site, including 98 unipolar flakes, seven unipolar cores and 20 bipolar flakes. The artefacts are characterised by the predominance of quartz, flint and sandstone as raw materials (Fig. 10). Most of them have small dimensions, not exceeding 3 cm on their principal axis (Fig. 11). There were also three *lesmas* and one stemmed point (Fig. 13) found on the surface after the artificial cuts of the pipeline installation were done.

The eight drilling surveys (Fig. 6) presented archaeological materials at depths of up to 120 cm. In the 2006 trench (Zanettini Arqueologia, 2006), 325 lithics were found at depths of up to 150 cm, with most of them concentrated above 60 cm (Figs. 11 and 12). In the blocks of this trench and the two immediately adjacent drillings (S7 and S4, Fig. 6), the artefacts (Figs. 11E, 11F) found between depths of 150 and 80 cm are made of quartz. The first flint or sandstone artefacts only begin to appear between 80 and 60 cm, with peak concentration between 60 and 30 cm (Figs. 11A, 11B, 11C, 11D and 12). In the adjacent 2018 excavation unit (EU1-2018), in turn, 35 artefacts (Figs. 11C, 11D and 12; Table 2) between the depths of 30 and 60 cm have been reported. Although the UE1-2018 pieces are not finished artefacts like the ones depicted in Fig. 13, they have technical features that clarify their connection with flaking human activities (Supplementary Material 8, and Figs. 11C and 11D).

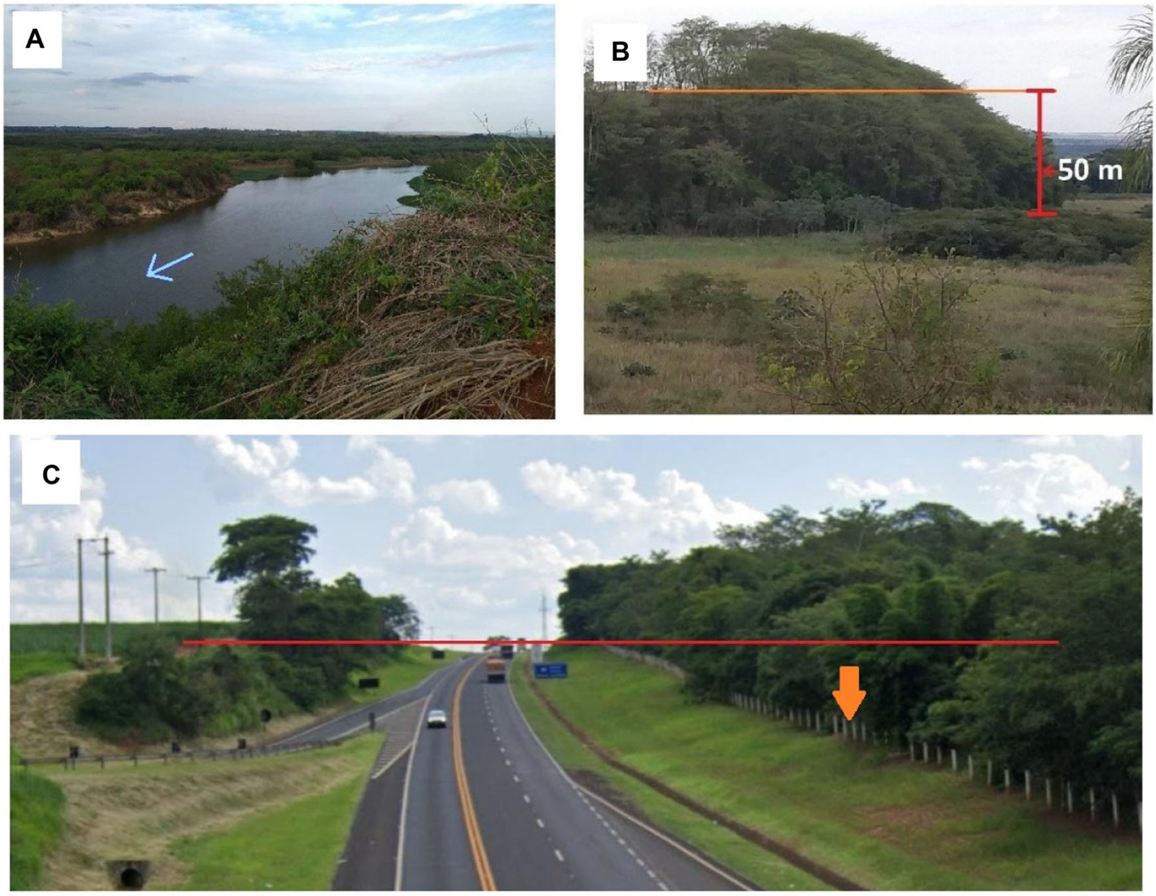

Figure 5. Photos of the main landscape units: (A) alluvial plain and Mogi-Guaçu River seen from the adjacent hillslopes, with two units separated by an abrupt 40 m vertical scarp: photo taken facing north, with a blue arrow pointing towards the current river flow; (B) detail of passage between hillslopes and alluvial plain marked by an abrupt topographic break of 50 m: photo taken facing east; (C) hillslopes, cut up to 7 m by highway and parallel pipeline works, on the right, during the opening of which the site was discovered. The line in red indicates the projection of the slopes' surface from the segment not covered by the artificial cuts. The orange arrow points to the location of excavation unit 1-2018: photo was taken facing south. Source: P. Cheliz and Google Street VIew. [Color figure can be viewed at wileyonlinelibrary.com]

The dimensions of the flakes are predominantly less than 30 mm long, 28 mm wide and 12 mm thick; 19% of them have no cortex, 23% have less than 25% cortex, and 20% exhibit 25% (or more) cortex. A small number of them (<10) are twice as long as they are wide, thus making it possible for them to be considered as blade-like flakes (Fig. 13A). The quartz flakes show significant differences in relation to those of other raw materials, as detailed in the Supplementary Materials 9 and 10. Among the main differences in the unipolar quartz flakes, cortical platforms and hard percussion predominate, while in sandstone and flint unipolar flakes, the smooth platform is the most common, and soft percussion predominates. Among the total flakes from the site, 15 can be considered as *façonnage* flakes (Supplementary Materials 9 and 10). Of these, 74% are silicified sandstone with smaller dimensions; on average, 15 mm long, 20 mm wide and 4 mm thick, and associated with soft percussion.

The technological attributes of the formal instruments identified on the surface (Fig. 13B and 13C), in addition to those already pointed out by Galhardo (2010, 2016), are described in Tables 3 and 4. The stemmed point does not appear to be finished since the body is too wide and long, with irregular active edges. The broken area highlights the presence of a chemical alteration patina, a pattern that is also present in some artefacts found in the older layers of early (>10 ka) Brazilian archaeological sites, such as those found in the Lagoa Santa area (Moreno de Sousa & Araujo, 2018) or at the Bastos site (Correa, 2017). A similar surface alteration patina was also present on the deeper artefacts of UE1-2018 (Fig. 11D).

Discussion

Transformations of the physical environment over time

The integration of physical data and artefacts allows us to interpret that the human occupation of the Rincão I site took place on palaeosurfaces formed amid successive colluvium deposits. The textural and petrographic characteristics of samples from the UE1R-2018 profile are compatible with the hypothesis that colluviums originated from the São Bento Group rocks close to the archaeological site (UNESP, 1982; Cheliz, 2016, 2023). The evidence is the similarity between the São Bento Group sandstones described nearby (Gesicki, 2007) and the colluvium, as for mineralogical composition (prevalence of quartz, Fig. 9), granulometry, sorting degree and rounding of the coarse fraction. The abundant reddish fine fraction (Fig. 9), in turn, can be influenced by both the products of alteration of igneous rocks (Serra Geral Formation) and the clay-ferruginous cement of the São Bento Group sandstones (Gesicki, 2007).

The colluvium sediments from which palaeosol 2C1 (Fig. 7) originated would have remained exposed for a long time, as

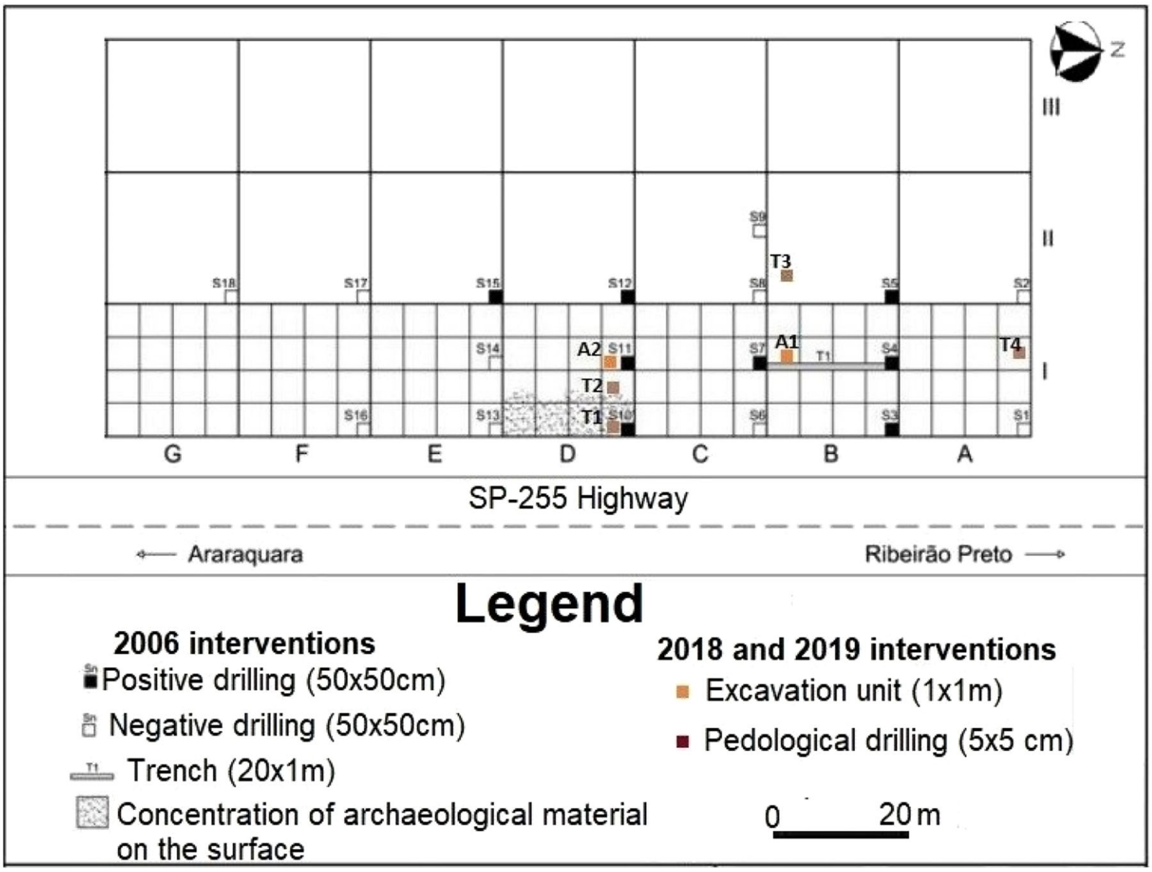

Figure 6. Map of excavations. Positive and negative drillings refer to a register of lithic artefacts or the lack of artefacts, respectively. Adapted from Zanettini Arqueologia (2006). [Color figure can be viewed at wileyonlinelibrary.com]

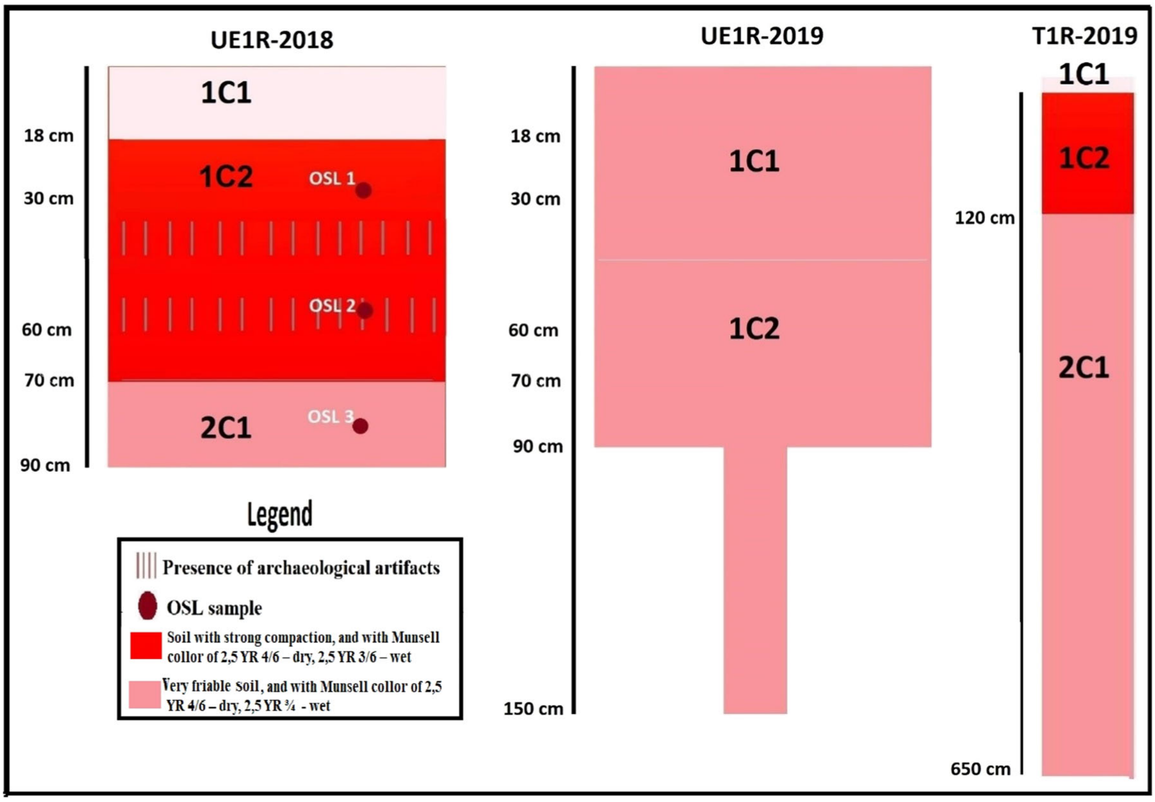

Figure 7. Synthesis of pedological data from excavation units A1 (UE1R-2018), A2 (UE1R-2019) and T3 (T1R-2019). The UE1R-2018 profile is also highlighted in the photo in Fig. 2E. [Color figure can be viewed at wileyonlinelibrary.com]

indicated not only by the OSL age difference of around 3 ka in relation to the 1C2 sediments above (Table 1, and Supplementary Material 7), but also by the asymmetry between these two horizons in the concentration of phosphorus (Supplementary Material 2). This allows the characterisation of the 2C1 horizon as a palaeosol. In soil horizon 1C2 (Fig. 7), at least two colluvium depositional events are represented, as can be inferred from: (i) the difference between the OSL ages collected from 25 and 55 cm (Table 1, and Supplementary Material 7); (ii) the distribution of archaeological lithic artefacts near those OSL samples along two small (<6 cm) vertical ranges (Fig. 7) separated by a relatively large (>10 cm) vertical distance, which allows us to conclude that each set of artefacts represents a different palaeosurface; and (iii) the contrasting compaction degree of the materials below and above 50 cm (Supplementary Material 2). The relatively short exposure time of the palaeosurface between these two depositional events and/or the similarity and continuity of the pedological process

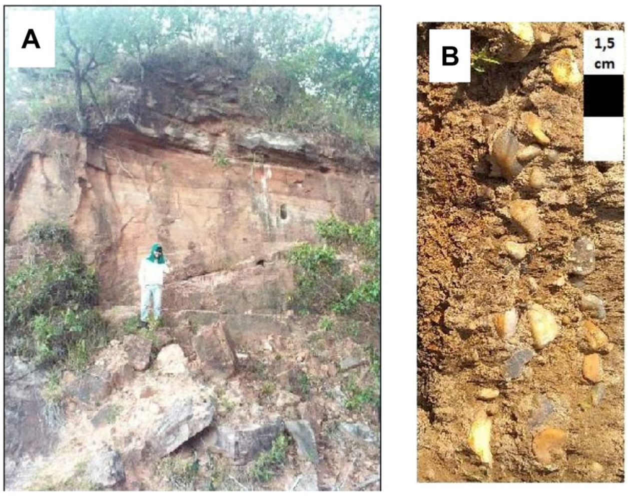

Figure 8. Potential sources of raw materials for lithic artefacts in the vicinity of the Rincão I site: (A) outcrop of Botucatu Formation sandstone, in the scarps of Santa Lúcia, in which angular fragments (>30 cm) of igneous rocks (associated with Serra Geral Formation) and sandstone are also found; (B) pebbles associated with alluvial plain. Source: P. Cheliz. [Color figure can be viewed at wileyonlinelibrary.com]

would have contributed to the associated deposits' appearance as a single soil horizon, in a similar way to that documented by Neto (2003). Also, the fact that the UE1-2018 profile is in a hillslope truncated by a deep artificial cut (between 1.8 and 5 m, Figs. 4 and 5C) means that previously existing younger overlying sediments were removed. This helps to understand why Late Pleistocene deposits (20.3 ka according to CAM – Table 1; 15.5 ka according to MAM – Supplementary Material 7) are today found so close to the surface (<85 cm).

The semivertical cliff that currently marks the outer limit of the floodplains adjacent to the Rincão I site and the recognition of an abandoned meander next to it (Figs. 4 and 5B) show that the slopes were also sectioned by the Mogi-Guaçu River, which was then further south. This would have occurred at a time when the river ran about 4 m above its current level, as suggested by the difference in altitude between the abandoned meanders (Figs. 4 and 5B) in the alluvial plain near the Rincão I site and the present Mogi-Guaçu River. This process took place after the formation of the colluvium deposits of the Rincão I site (i.e. after 11.2 ka according to the CAM, or 5.5 ka according to the MAM; Table 1 and Supplementary Material 7), since those deposits were also truncated by the palaeochannel (Fig. 4). Subsequently, there was the abandonment of the river meander that cut these hillslopes, the northward migration of the channel to its current position and the vertical incision of 4 m. This interpretation agrees with the formation of an alluvial plain, within the last 10 ka, that was about 4 m above the current one, as identified by Celarino (2011) in the Mogi-Guaçu River 7 km east of the Rincão I site. Additionally, this interpretation is consistent with the dominant Holocene trends of fluvial incision and landscape transformations detected in the alluvial plains of numerous other rivers located in the Paraná Sedimentary Basin (e.g. Ab'Saber, 1994; Dias, 2015; Celarino, 2015; Lupinacci and Souza, 2019; Macedo et al., 2020, Cheliz and Giannini, 2020; Breda, 2021; Cheliz et al., 2021).

The insertion of artefacts in the sediments and soils

The distribution of the artefacts recovered in UE1-2018 demonstrates similarities with those found in the 2006 investigations. Both present concentrations of artefacts at the

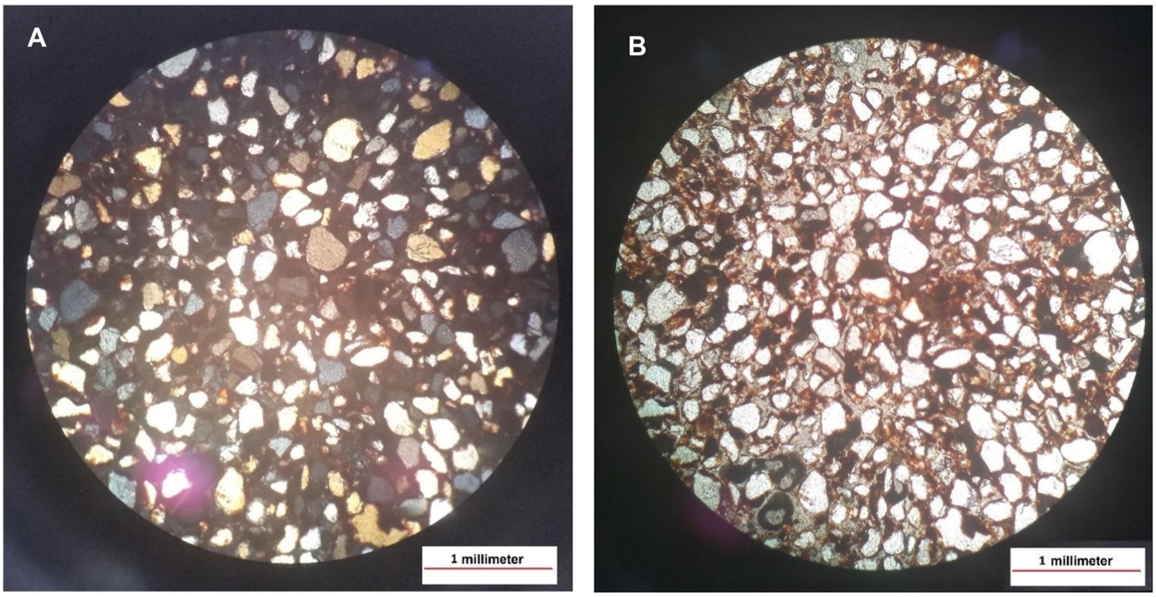

Figure 9. Thin section photomicrographs of a soil sample collected at the 1C2 horizon of UE1-2018: (A) cross-polarised light; (B) plane-polarised light. [Color figure can be viewed at wileyonlinelibrary.com]

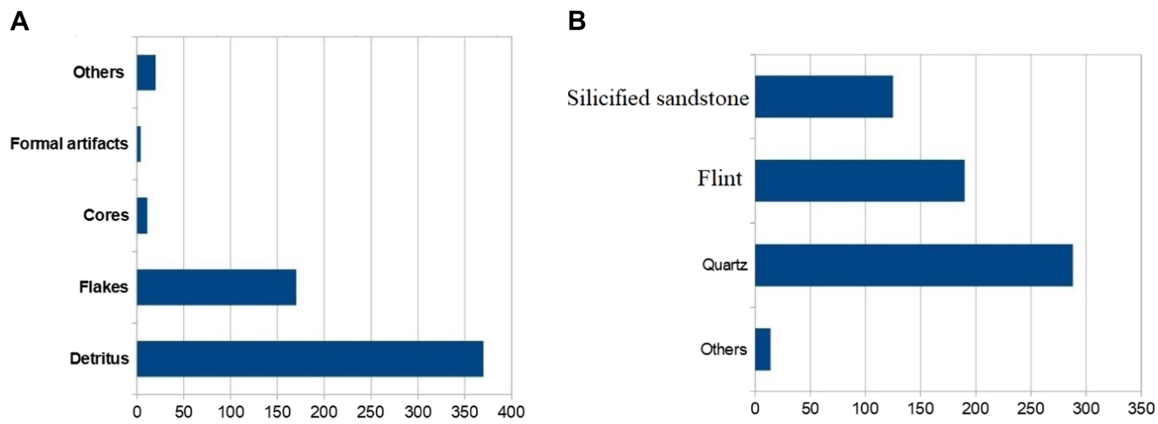

Figure 10. Types (A) and predominant raw materials (B), among the artefacts recovered in the 2006 and 2018 excavations. Source: integration of Galhardo (2010) and 2018 excavation data. [Color figure can be viewed at wileyonlinelibrary.com]

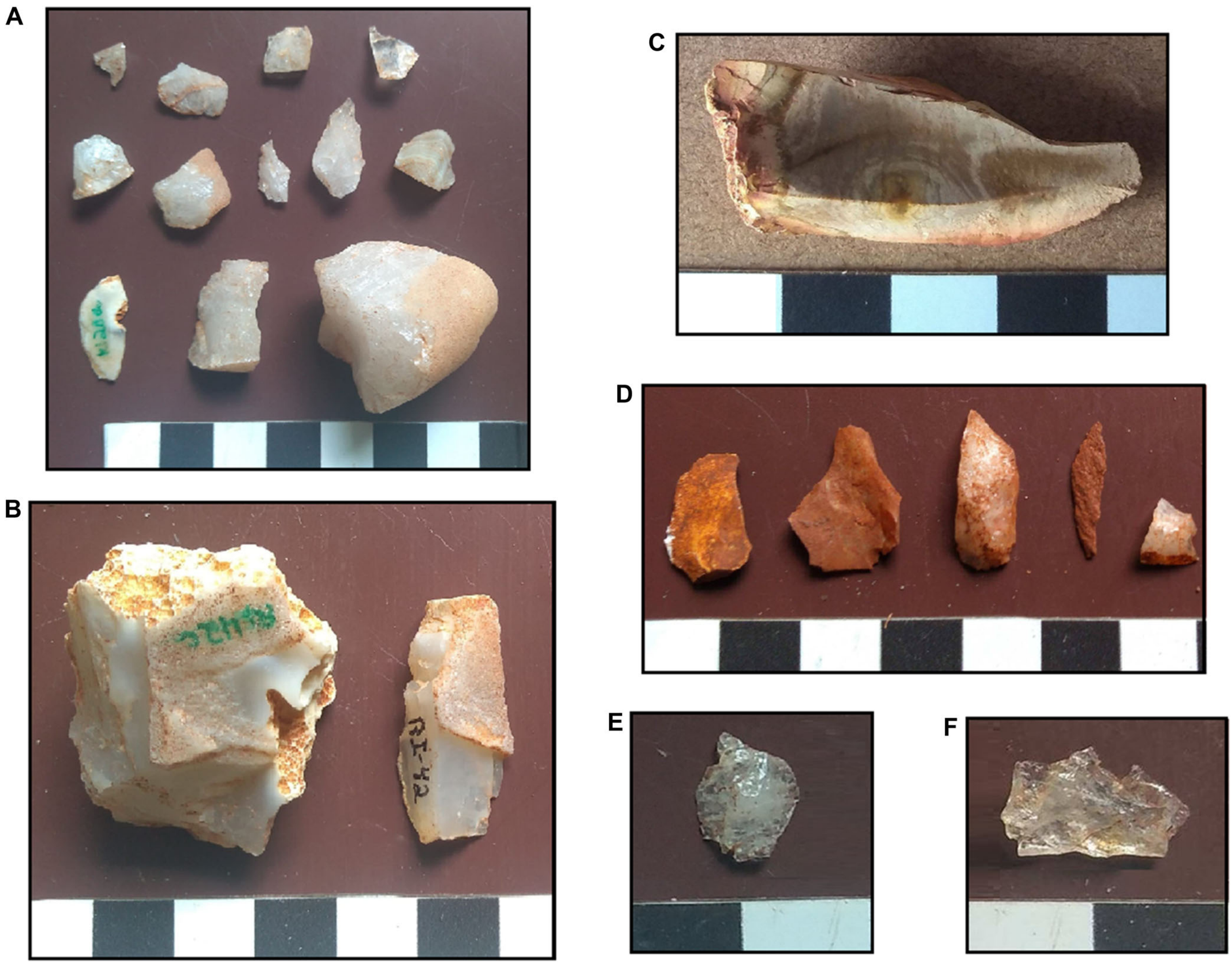

Figure 11. Types of artefact: (A) flakes and detritus of quartz (Trench 1-2006, B area, depth of 50–60 cm); (B) core and flake with preserved cortex of fluvial pebble (Trench 1-2006, D block, 40–50 cm); (C) detritus of flint (UE1-2018, 30–40 cm); (D) flakes and detritus of flint and quartz (UE1-2018, 50–60 cm), with a white chemical alteration patina in the artefact at the left corner of the photo; (E) and (F) flakes of quartz (E: Trench 1-2006, O block, 100–110 cm; F: Trench 1-2006, H block, 70–80 cm). [Color figure can be viewed at wileyonlinelibrary.com]

same depth interval (Fig. 12). In the case of the 2006 trench (adjacent to UE1-2018), this depth interval extends horizontally for 20 m (Fig. 12), which is not compatible with the occurrence of large post-depositional vertical movements affecting the artefacts, such as those described by Araujo (1995) as frequent in open-air archaeological sites in tropical and subtropical areas. Two of the sediment samples used to obtain the OSL ages were taken from UE1-2018 profile segments (25 cm and 55 cm) within this depth interval containing artefacts belonging to the two different colluvium deposits in the 1C2 horizon (Fig. 7). These OSL-dated sediments were therefore more likely deposited after the onset of local human occupation. Artefacts were also identified between 60 and 80 cm in five of the 18 blocks of the 2006

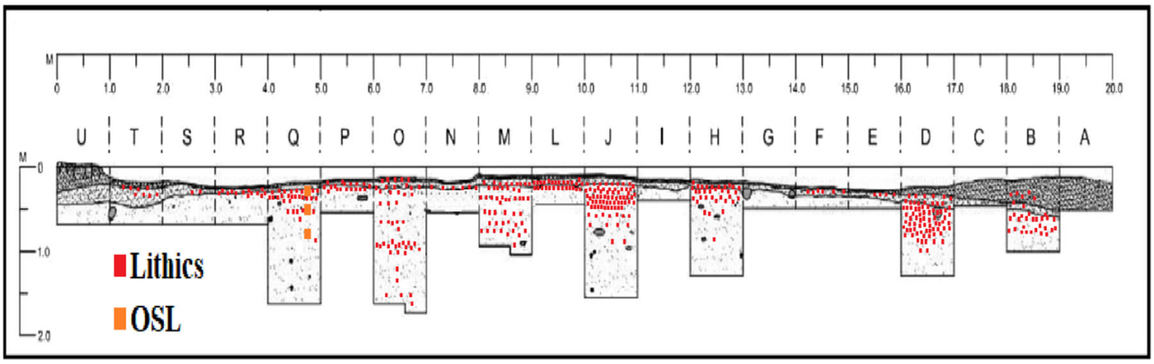

Figure 12. Distribution of artefacts and projection of OSL samples from the adjacent 2018 excavation unit in the 2006 trench. Source: adapted from Zanettini Arqueologia (2006). [Color figure can be viewed at wileyonlinelibrary.com]

trench (Figs. 11F and 12), which are below the 55 cm sediment OSL sample collected in the UE1-2018. The position of these deeper artefacts is consistent with the interpretation that the sediments from this OSL sample were deposited at a time when human presence would have already begun on the site.

However, it should be noted that both in the interventions of Zanettini Arqueologia (2006) and UE1-2018 (Fig. 7), the vertical position of the artefacts was controlled by means of artificial layers of 10 cm, and not by the exact individual measurement of each piece. Simultaneously, the age obtained at 55 cm at the UE1-2018 profile (17.2 ± 1.6 ka according to CAM, 13.3 ± 1 ka according to MAM – Tables 1 and Supplementary Material 7) conflicts with the most accepted human occupation models for south-southeast Brazil (Bueno et al., 2013; Moreno de Sousa, 2019). According to these models, São Paulo State is usually considered to be one of the most recently occupied areas, with maximum ages close to the Pleistocene–Holocene boundary (Araujo and Correa, 2016; Troncoso et al., 2016; Santos and Cheliz, 2019; Cheliz et al., 2021; Moreno de Sousa, 2019). Sites with similar Late Pleistocene ages are rare in South America, where no more than five areas are known to have records of human occupation before 15 ka. Of such areas, those present in the Brazilian territory (Santa Elina and Serra da Capivara – Vialou et al., 2017; Parenti et al., 2018; Boeda et al., 2021a, 2021b) are located at lower latitudes than the Rincão I site, and are not consensually accepted as vestiges of Late Pleistocene human presence. Some researchers (e.g. Sutter, 2020; Coutouly, 2021) have suggested that the lithics found in the deeper levels of such sites could not be considered indisputable evidence of anthropic presence, while others (e.g. Boeda et al., 2021a, 2021b; Vialou et al., 2017) conclude that human presence prior to 15 ka was securely demonstrated.

The third sediment sample of UE1-2018 dated by OSL, with 20.3 ± 2.1 ka by CAM, and 15.5 ± 1.3 ka by MAM, was collected from the 2C1 horizon at a depth of 85 cm (Table 1 and Supplementary Material 7). Below this depth, artefacts were not found in the 2018 excavation, but in the 2006 trench (Figs. 11E and 12), where they appear between depths of 80 and 150 cm with a sparse distribution (Fig. 12), which is compatible with the occurrence of post-depositional disturbances (Araujo, 1995). However, the differential distribution of the pieces' raw materials along the vertical cuts (exclusive registration of quartz pieces deeper than 80 cm) is not consistent with the concept of intense post-depositional movements, since it is not expected that these movements are selective in relation to the lithological types of artefacts.

The site occupation model suggested by Zanettini Arqueologia (2006) assigned great importance to this vertical segmentation of the types of archaeological raw materials. According to the authors, flaking sequences aimed exclusively at the quartz pieces would have prevailed in an earlier period of occupation of the site, represented by the sparse lithics below 80 cm. In a second period, represented by the artefacts above 80 cm, the quartz flaking techniques would have coexisted with another flaking sequence, made from sandstone and flint. Indeed, the characterisation of the flakes (supplementary material 9) points out contrasts between quartz and sandstone or flint regarding several major flake attributes; this is consistent with the idea that different flaking sequences were intended for those different raw materials.

Interfaces between human groups and the physical environment during the early occupation

In the time indicated by OSL ages, the settlement area of the Rincão I site was favourable for human occupation, as the hillslopes were sufficiently high to keep the human groups protected from the floods of the Mogi-Guaçu River, without being far from the river plains. It is estimated from the geomorphological context (Fig. 4) that the river would have been no more than 1.5 km from the site. Thus, the human groups could have access to the resources it offers: water, opportunities to hunt or pebbles to be used as a source of raw materials to make artefacts. The climate, however, would have been different from the current one, in at least part of the occupation period. A study of pollen in the river terraces of the Mogi-Guaçu River, less than 7 km from the site, concludes that the climate before 10 ka ago was drier and with grassland vegetation dominant (Souza, 2010; Souza et al., 2013). According to same study, between 10 and 2 ka, a rise in humidity favoured forest vegetation types, but conditions were still drier than the present. Palynological data obtained by Aviles et al. (2019) in São Paulo State also suggest the time between 25 and 13 ka as being of grassland dominance, under a climate drier than today. Similarly, a palaeohydrological study by Turcq et al. (1997) in an area located 10 km east of the site infers the predominance of a drier climate between 15 and 10 ka than the current one, followed by a more humid phase between 10 and 6 ka. Additionally, Cheliz et al. (2021), based on a geomorphological and pedological study in an area 50 km south of the Rincão I site, indicate the period between 12.4 and 10 ka as being drier than today.

The abundance of river pebble cortex in the site artefacts suggests that at least some of these pieces were flaked from pebbles collected from the nearby alluvial plains (secondary sources of supply – Luedtke, 1979; Church, 1994; Batalla, 2018), as also previously suggested by Galhardo (2010). In support of this interpretation, the lithological characterisation of the pebbles from the nearby alluvial plain carried out in the

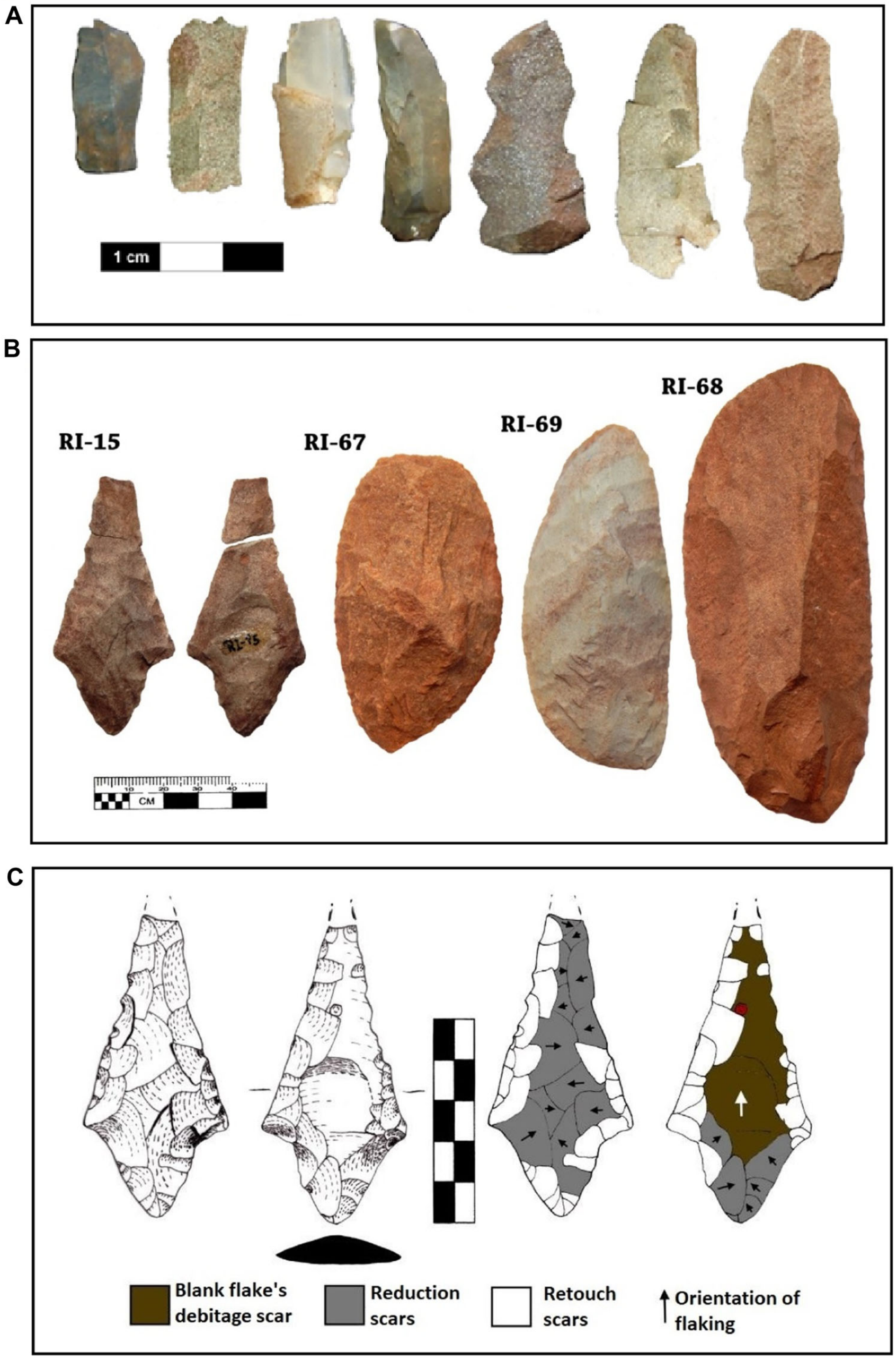

Figure 13. Artefacts from the Rincão site: (A) blade-like flakes; (B) point (both sides) and *lesmas* specimens (upper faces); (C) technical drawing of the point. Photos and drawings of the points and *lesmas* were done by the third author, and flake compositions were adapted from photos from Zanettini Arqueologia (2006). [Color figure can be viewed at wileyonlinelibrary.com]

present work showed an abundance of quartz and flint; the same raw materials that compose the artefacts of the Rincão I site. The hypothesis that human groups transported rocky clasts from the alluvial plains to the hillslopes is strengthened by the absence of natural rock fragments in the excavation unit with no artefacts (UE1-2019, Fig. 7). The geological literature, in fact, does not describe a significative presence of fragments of flint and quartz larger than 2 mm amid the sedimentary units (sandstones of São Bento Group) from which the colluviums supposedly originated (Meaulo, 2005; Gesicki, 2007). Additionally, the pedological survey T1R-2019 (Fig. 7) did not document the presence of bedrock over depths of up to 6.5 m, which seems to make the hypothesis by Batalla (2018) that early human groups could have obtained raw materials by excavation unlikely in the case of the Rincão I site.

Attributes of the physical environment suggest that despite the proximity of the alluvial plain, obtaining suitable pebbles for flaking was challenging. These attributes include: (1) the dispersion of pebbles amid the sandy sediments of the Mogi-Guaçu River; and (2) the low abundance of rock fragments in the alluvial plain with dimensions greater than 3 cm, which is the average dimension of the formal artefacts of the site.

Sandstone pebbles of the alluvial plains are significantly weathered, but some of the sandstone artefacts from the

Table 2. Distribution of archaeological artefacts in UE1-2018R

Depth and pedological horizon	Number of artefacts	Observations
0–10 cm (1C1)		
10–20 cm (1C1 and 1C2)		
20–30 cm (1C2)		OSL (11.4 ka years)
30–40 cm (1C2)	8	Includes one flake of quartz and one flint piece with a fire scar. All pieces were found between 38 and 40 cm in the northeastern corner of the UE1-2018
40–50 cm (1C2)	16	Includes one flake of quartz and one flake of flint, all pieces were found between 40 and 44 cm in the northeastern corner of the UE1-2018
50–60 cm (1C2)	5	Includes two flakes of flint. All pieces were found between 55 and 60 cm. OSL (17.2 ka years)
60–70 cm (1C2)		
70–80 cm (2C1)	1	Lithic detritus (no bulb or platform)
80–90 cm (2C2)		OSL (20.3 ka years)
Other depths (Drilling before opening of the 1 × 1 m excavation unit)	Two between 22 and 36 cm Two between 36 and 44 cm	Includes a couple of flint cortical detritus with scars that seem associated with anvil (bipolar) percussion (Fig. 11)
Total	34	

Table 3. Technological attributes identified in the Rioclarense stemmed point (RI-15) of the Rincão 1 site

Attributes	Features
Raw material	Silicified sandstone
Total length	>73 mm (broken tip)
Total width	35 mm
Total thickness	6 mm
Width/thickness proportion	5.8/1
Body length	>52 (broken tip)
Stem length	23 mm
Active edges length	>60 (broken tip)
Shoulders width	36 mm
Neck width	24 mm
Stem width	20 mm
Body thickness	6 mm
Neck thickness	6 mm
Stem thickness	6 mm
Body shape	Triangular
Active edges lineation	Irregular
Shoulders shape	Straight
Neck lineation	Obtuse
Stem shape	Ovate
Body section shape	Plano-convex
Stem section shape	Elliptical
Blank type	Flake
Reduction method	Bifacial
Reduction technique	Percussion
Retouch method	Bifacial
Retouch technique	Pressure
Body scars organisation	Selective trespassed
Stem scars organisation	Parallels with median ridge

Rincão I site are not. Thus, it is suggested that human groups also obtained their raw materials from sources other than the fluvial pebbles. There are two possible sources. The first are the so-called primary supply sources (Luedtke, 1979; Churh, 1994; Batalla, 2018), represented by sandstone outcrops of the Botucatu Formation, of known use in lithic industries in the south and southeast of Brazil (Araujo, 1992; Araujo & Correa, 2016; Batalla, 2018; Batalla et al., 2019; Cheliz et al., 2020). The second are secondary sources out of the alluvial plains, such as the block fragments of sandstone from cliffs, 10 km south of the Rincão I (e.g. Santa Lúcia scarps, Figs. 3 and 8A). Although more distant than the areas of occurrence of alluvial pebbles, these sandstone blocks are within 5–10 km, which has been associated with the usual daily range of human hunter-gatherer groups (e.g. Higgs and Vita-Finzi, 1972).

Unlike most other artefacts on the site, the reduction flakes, *lesmas* and stemmed point present predominant raw materials other than quartz and flint. Some 75% of the reduction flakes and all formal instruments at the Rincão I site are made of silicified sandstone. This raw material, in pieces larger than 3 cm, could have been removed directly from rock outcrops *in situ* or the aforementioned sandstone fragments found on hillslopes. Alternatively, they could have come from the rare, but supposedly less weathered larger pebbles on the floodplains. All of these alternatives necessarily imply an effort to obtain the sandstone (>3 cm) greater than what was spent to obtain the fragments of quartz and flint from the alluvial plains. This greater difficulty could help to explain the development of flaking sequences considered to be of greater complexity as those linked to the reduction flakes and formal plano-convex artefacts. Since sandstone raw material larger than 3 cm was more difficult to obtain, more complex procedures would have been reserved for it than those commonly registered in quartz and flint artefacts.

In addition to the works of Galhardo (2010, 2016), the results obtained here from the analysis of the stemmed point and the plano-convex instruments (*lesmas)* (Tables 3 and 4) characterise technical attributes similar to those of the Rioclarense lithic industry, as defined by Moreno de Sousa (2019). The analysis of the Rincão I site in the context of its physical environment is also similar to that of other known sites (i.e. Alice Boer and Caetetuba) of the aforementioned lithic industry. These environments are characterised as being located in the foothills and on hillslopes with low–intermediate altitudes in relation to the dominant Cuestas geomorphological domain (Almeida, 1964), close to river channels, and a few kilometres from areas with slopes above 30° with rocky outcrops that can provide sources of raw materials (Cheliz et al., 2020).

While at the Rincão I site the raw material for the pedunculated point and the plano-convex unifaces (*lesmas*) is exclusively silicified sandstone, at the other sites of the Rioclarense lithic industry, the predominant raw materials are flint, for the pedunculated points, with smaller amounts of quartz, flint and sandstone, for the *lesmas* (Troncoso et al., 2016; Moreno de Sousa, 2019). This distinctive feature of the Rincão I site may have resulted from an adaptation of its lithic

Table 4. Technological attributes identified in the plano-convex artefacts (*lesmas*) of the Rincão 1 site

Attributes	RI-67	RI-68	RI-69
Raw material	Silicified sandstone	Silicified sandstone	Silicified sandstone
Total length	87	137	130
Total length	50	57	45
Total thickness	21	21	15
Width/thickness proportion	2.4/1	2.7/1	3/1
Lesma general shape	Ovate	Ovate	Ovate
Central section shape	Plano-convex	Plano-convex	Plano-convex
Reduction scars maximum legth	30	—	30
Reduction scars organisation	Parallels with median ridge	Parallels with median ridge	Parallels with median ridge
Orientation of the blank flake	Vertical	Vertical	Vertical
Median ridge bulb scars	Absent	Absent	Absent
Faceting scars in the opposite face	Absent	Absent	Absent
Bulb removal from the blank flake	Present	Absent	Absent
Active edges number	4	4	4

industry to the raw materials available in the area. Although there is an abundance of flint in the surroundings in the form of river pebbles, they have average dimensions smaller than usual in pedunculated points and plano-convex artefacts associated with the Rioclarense industry (Moreno de Sousa, 2019). Therefore, due to restrictions in obtaining flint pebbles of a size large enough to make instruments with the typical dimensions of the Rioclarense industry, the use of sandstone was required.

It is also noteworthy that the currently known sites linked to the Rioclarense industry are associated exclusively with occupational ages prior to 7 ka ago (Troncoso et al., 2016; Moreno de Sousa, 2019; Araujo et al., 2021). In the case of the Caetetuba site, the initial occupation related to the Rioclarense industry would be earlier than 10 ka (Troncoso et al., 2016; Moreno de Sousa, 2019). However, records of this lithic industry are not known in Brazil before 11.5 ka, an age similar to the most recent one obtained for Rincão I site deposits, according to the OSL CAM date (sample OSL1, 25 cm deep; Table 1). This lithic industry is considered to be well-established in 8 ka, a time near the one indicated by the OSL-MAM date for the OSL 1 Rincão I sample (supplementary material 7).

Conclusions

Human occupation at the Rincão I site took place on hillslopes, less than 1.5 km from the floodplains of the Mogi-Guaçu River, in southeast Brazil (São Paulo State). The choice of this location allowed human groups access to the resources offered by the river plain; simultaneously, it preserved them from the adverse effects of flooding in the river system, which then flowed at least 4 m higher than today. In addition, the relatively elevated location (30 m higher than the river plain) of the hillslopes would allow a broad view of the surroundings, permitting the monitoring of the approach of possible threats (such as large predators) or other human groups.

The flaking sequences combined the use of primary and secondary sources for the supply of raw materials. Primary sources correspond to sandstone taken from outcrops on hillslopes up to 10 km from the site. Secondary sources are represented by fluvial gravel of quartz, flint and sandstone, taken from alluvial plains up to 1.5 km from the site, and scattered fragments of sandstone on hillslopes up to 10 km away. The major primary and secondary sources of sandstones were more commonly used in the production of reduction flakes and instruments associated with the Rioclarense lithic industry. Meanwhile, the alluvial plain secondary sources of quartz and flint were used in the production of other types of artefact, which are dominant in the stratigraphy of the site.

The archaeological records of the Rincão I site occur amid soils originating from the weathering of sandy colluviums with OSL ages between 20.3 and 5.5 ka. We interpret that at least some of the artefacts found adjacent to or lower than the dating samples were flaked before the deposition of the sediments that have been OSL dated. The main reasons for this interpretation are: the horizontal continuity along 20 m of the depth interval with artefact concentration (30–60 cm, the same interval as the intermediate OSL 2 sample), and vertical segmentation of the artefacts in terms of their raw materials, i.e. only quartz artefacts found between 80 and 150 cm, and quartz, flint and sandstone artefacts coexisting above 80 cm. This pattern of artefact distribution is poorly compatible with the intense processes of vertical remobilisation of the archaeological pieces after their deposition.

The OSL ages are consistent with the local palaeopedological and geomorphological context. Indeed, the deposits, soils and processes of relief transformation documented here are similar to those previously recorded during the same period in other parts of southeast Brazil and even in non-archaeological areas of the Mogi-Guaçu River basin. However, these ages are partially controversial from the point of view of models currently in vogue for human settlements in southeastern South America. According to these models, the study area is in a sector among the most recently occupied, attributed to the Early Holocene or Pleistocene–Holocene boundary. The Rincão I site and its surroundings are therefore a favourable place for further archaeological, geomorphological and palaeoenvironmental investigations, which should include: seeking additional tests for the hypothesis of Late Pleistocene early human settlement; and the refinement of the environmental characterisation and chronological record of past anthropic occupation.

Contributor roles

PMC: conceptualisation, data curation (geomorphological, pedological, sedimentological, petrographic, OSL and archaeological data), formal analysis (geomorphological, sedimentological, pedological, sedimentary, archaeological, petrographic and OSL analyses), funding acquisition, investigation, methodology, project administration, visualisation, writing—original draft, review & editing; **PCFG**: data curation (petrographic data), formal analysis (sedimentological, geomorphological, petrographic and OSL analyses), resources, methodology, writing—review & editing; **JCMS**: data curation (archaeological data), formal analysis (archaeological analysis), investigation, methodolohy, visualisation, writing—review & editing; **FSBL**: data curation (pedological and geomormorphological data), formal analysis (pedological and geomorphological data), investigation, methodology, writing—review & editing; **JAR**: data curation (archaeological data), investigation, methodology, visualisation, writing—review & editing; **GSM**: data curation (archaeological data), formal analysis (archaeological data), investigation, methodology, visualisation, writing—review & editing; **FNP**: formal analysis (OSL and geomorphological analysis), resources, methodology, writing—review & editing; **TDM**: data curation (OSL data), formal analysis (OSL analysis), methodology, writing—review & editing; **RAR**: data curation (archaeological data), formal analysis (archaeological analysis), resources, investigation, methodology, writing—review & editing; **DG**: data curation (archaeological data), formal analysis (archaeological data), methodology, writing—review & editing.

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Data availability statement

All the data analyzed in the present work are available: 1- in the article itself or in its supplementary materials, 2 - in the cited references, which are publicly accessible.

Supporting information

Additional supporting information can be found in the online version of this article.

Supplementary material 1. OSL protocol.

Supplementary material 2. Macromorphology characterization of the Excavation Unit 1-2018.

Supplementary material 3. Chemical characterization of the EU1-2018.

Supplementary material 4. Granulometric characterization of the EU1-2018.

Supplementary material 5. Complementary date from OSL I.

Supplementary material 6. Complementary date from OSL II.

Supplementary material 7. Alternative OSL ages (minimum age model).

Supplementary material 8. Detailed description of UE1-2018 lithics artifacts.

Supplementary material 9. Details of the flakes of the Rincão I site, segmented according to the different raw materials.

Supplementary material 10. Meaning of terms of supplementary material 9.

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