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ARTICLE

New Data from Pedra Pintada Cave, Brazilian Amazon: Technological Analyses of the Lithic Industries in the Pleistocene–Holocene

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Abstract
For many years, the existence of ancient human settlements in the Amazon was deemed impossible, particularly those as old as 12,000 BP as found in Pedra Pintada Cave in Monte Alegre, in the state of Pará, by Anna Roosevelt and colleagues in the 1990s and by Edithe Pereira's team in 2014. In this article, we present the results of the technological analyses of the bifacial tools found in the cave, focusing on raw materials, techniques, shaping and retouching methods, and technical procedures. The analyses indicate careful knapping, with no mistakes, in hundreds of flakes in the shaping and retouching phases, as well as fragmented tools with flaws. Whenever possible, we compare the results to the data published by Roosevelt and colleagues in 1996 from the same site.

Resumen
Durante muchos años se consideró imposible la existencia de antiguos asentamientos humanos en la Amazonia como los encontrados en el yacimiento de cueva de Pedra Pintada en Monte Alegre, estado de Pará, por Anna Roosevelt y sus colegas en la década de 1990 y por el equipo de Edithe Pereira en 2014. En este artículo, presentamos los resultados inéditos de análisis tecnológicos de artefactos bifaciales: materias primas, técnicas, métodos de conformación, retoque y procedimientos técnicos. Los resultados indican una talla cuidadosa, sin errores, observada en cientos de lascas relacionadas con las fases de conformación y retoque, además de herramientas fragmentadas defectuosas. Siempre que fue posible, los resultados se compararon con los datos publicados por Roosevelt y colegas, procedentes del mismo yacimiento.

Keywords: Amazon; lithic technology; chaîne opératoire

Palabras clave: Amazonia; tecnología lítica; cadenas operativas

For many years, the model that posited the arrival of human groups through the northern parts of the Americas has dominated scientific debate, with little attention given to Latin American and European voices. It seems like researchers had little interest in searching for other possibilities, as if the truth had already been established (Dillehay 1992; Lavallée 1995; Meltzer 1989). But science is dynamic, and certainties tend to weaken. Discoveries in North America from the 1950s and for the following few decades did not go earlier than the 12,000 BP paradigm, yet research done in the rest of the Americas indicated occupancies before that period or contemporary to it, especially in the southern tip of the continent (Emperaire et al. 1963). In the following decades, there were many studies in South America indicating an earlier arrival there (Bueno et al. 2013; Chauchat et al. 2016:24; Dillehay 2008:31; Osorio et al. 2017; Ravines 1967; Roosevelt et al. 1996; Santoro and Chacama 1984) and in the United States and Canada (Halligan et al. 2016; Haynes 2015; Jenkins et al. 2012; Waters and

Stafford 2007; Waters et al. 2011). A model of American antiquity was developing, with well-accepted dates that precede the limits of the Pleistocene–Holocene transition. These studies show lithic industries and ways of life distinct from those observed in Clovis and Folsom occupancies.

Brazilian archaeology has contributed to the development of this model by providing a very specific array of ancient bone remnants that have been studied both physically and genetically (Bonatto and Salzano 1997; Moreno-Mayar et al. 2018; Sutter 2021) and an array of ^{14}C dates accepted by the scientific community that put certain occupancies at a similar or previous moment than that of the Clovis site. These ancient occupancies are found all over Brazil in the following states—Minas Gerais: Bibocas II (Sousa et al. 2020), Lapa do Boquete (Rodet 2006), Lapa Vermelha IV (Prous 2019); Pará: Gruta da Capela (Magalhães et al. 2016); Goiás: Serranópolis (Rodet et al. 2019), and Piauí: Toca do Meio (Guidon 1986), notably in the Amazon. There is a great collection of dates stemming from excavations done in Monte Alegre, Pará, by Anna Roosevelt and colleagues (1996) and, more recently, by Edithe Pereira (Pereira and Moraes 2019), confirming that local occupancy occurred earlier than 12,000 cal BP (Table 1).

Table 1. Pedra Pintada Cave's Dating List during Stratigraphy.

Layer	Pickling	Lab. Code	^{14}C years ± σ BP	$\delta^{13}C$	Cal years BP ± 2σ	Period
Surface	—	—	—		—	Late Holocene
X	A	—	—		—	
IX	B	Beta-434984	1720 ± 30	−26.9 ‰	1700–1655 1615–1530	
VIII	C	Beta-434985	590 ± 30		625–605 560–520	
	C-2	—	—		—	
VII	D	—	—		—	
	D-2	—	—		—	
	E	Beta-434986	3080 ± 30		3345–3160	
	F	Beta-475219	3990 ± 30	−26.5 ‰	4450–4285	Middle Holocene
VI	F-2	Beta-475220	5890 ± 30	−24.6 ‰	6860–6669	
		Beta-434987	8050 ± 30		9005–8770	Initial Holocene
	G	—	—		—	
V	H	—	—		—	
	I	Beta-434988	10,100 ± 40	−27.5 ‰	11,765–11,390 11,375–11,360	
	J	—	—		—	Pleistocene–Holocene
	J-2	Beta-434989	10,260 ± 40	−25.9 ‰	12,030–11,765	
	J-3	Beta-434990	10,360 ± 40	−26.0 ‰	12,390–12,330 12,295–12,215 12,160–11,980	
IV	J-4	—	—		—	
III	K	Beta-434991	10,430 ± 40	−24.0 ‰	12,425–12,040	
II	L	—	—		—	
I	L-2	Beta-434992	10,310 ± 30	−25.8 ‰	12,050–11,955 11,855–11,850	
		Beta-434993	10,290 ± 40	−23.3 ‰	12,050–11,820	

Note: The dates of the northwest sector of the site confirm its occupation since about 12,425–12,040 years cal BC (Pereira and Moraes 2019:337, adapted from Duarte-Talim 2019:502). Calibration by BetaCal3.21: HPD, method: SHCAL13.

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This discussion also relates to the Amazon's lowlands, which have received less attention than the uplands, the Andes. Seen either as a green hell or as a paradise, the Amazon region was considered between 1950 and 1970 to be unable to sustain great civilizations, a view based, among other aspects, on ecological determinism and neoevolutionism (Carneiro 2007; Clement et al. 2015; Gross 1975; Lathrap 1970; Lowie 1948; Meggers and Evans 1961; Steward 1948). For decades, these preconceptions permeated and limited the understanding of the populations who occupied, transformed, and domesticated one of the largest tropical rainforests in the world. These early researchers assumed that populations suffered from protein insufficiency, which could not sustain large groups dependent on hunting and gathering; did not have access to lithic raw materials that would enable the production of tools suited to their needs; lacked local production of elaborate unifacial and bifacial tools; and did not have the ability to produce elaborate ceramics. Systematic works assessed these assumptions and disproved them in research that highlighted the antiquity of the occupancies and the presence of ceramic production (Roosevelt et al. 1991, 1996), domestication and handling of plants (Balée 1989; Shock and Santos 2016), production of fertile lands for horticulture (anthropogenic dark earth) and agriculture (Kämpf and Kern 2005), a complex social (and spatial) organization, and elaborate imagery (Carneiro 2007). The Amazon is now seen as a viable and habitable place in which human groups settled, adapting themselves in a dialectical relation of exchange in which they become an integral part of the forest (Balée 1989; Franchetto and Henckenberg 2001; Magalhães et al. 2016; Neves 2012).

However, although ceramics, vegetal remains, forest management, and the creation of fertile lands have been studied systematically, the lithic industries have not. Almost everything related to technological choices in lithic industries is unknown, such as the following: Which rocks and minerals did they use to produce their tools? Which technical procedures and techniques were chosen? Was there a good level of skill and know-how in the removals? Which parts of the *chaînes opératoires* were left on the site? Are they elaborate or simple *chaînes opératoires*? And what do the answers to these questions teach us about the ancient inhabitants of the Americas?

The most elaborate productions in the Brazilian lithic industries result from bifacial flaking. In the Amazon, bifacial tools have been found from the more ancient levels of occupation to the surface, within or out of context. Several regions in the Brazilian Amazon have well-excavated contexts in which ancient sites (11,000–8000 BP) contain points and fragments or even remains of the bifacial production; these include the Serra dos Carajás, between 9000 and 10,000 BP (Duarte-Talim 2019:669–671; Magalhães et al. 2016) and Monte Alegre, between 11,100 and 8000 BP (Pereira and Moraes 2019; Roosevelt et al. 1996), in Pará. In addition, an array of elaborate bifacial points of distinct morphologies and technologies—indicating high levels of knapping control—were found out of context along the Tapajós, Negro, Branco, Amazonas, Tocantins, and Xingu Rivers in the northern and southern parts of the state of Roraima and in the southern state of Pará (Hilbert 1998; Figure 1; Supplemental Figure 1).

Issues involving the arrival of human groups in the Americas and their dispersal and settlement in distinct territories can be approached from at least two perspectives. The first, which has been widely disseminated, is anchored in debates about different entrance routes traveled by human groups along land; for example, the Bering Strait, East Coast, or sailing from the west (Erlandson 2013). Determination of the routes traveled is based on the ancient dating of excavations and whether the sites present stratigraphic mixtures. The second way to approach the arrival debate is through interpretive analyses of the material culture—in this case, the lithic industries, an indelible testimony of the passage of human groups. The technologies represented by the tools and their byproducts—*restes de débitage*: all pieces, such as flakes and fragments produced during the knapping action, that are left unused—combined with the contexts represented by the rocks and minerals used, food remains left in campfires, rupestrian paintings, and engravings form a cohesive and reliable set of data that allows an effective framework to be constructed for the Americas' first inhabitants. Current environmental information about site surroundings and consistent dates complement this framework.

This article uses the second approach. We present a techno-economic study of the elaborate *chaînes opératoires* of bifacial production found in the more ancient levels of the excavations conducted in

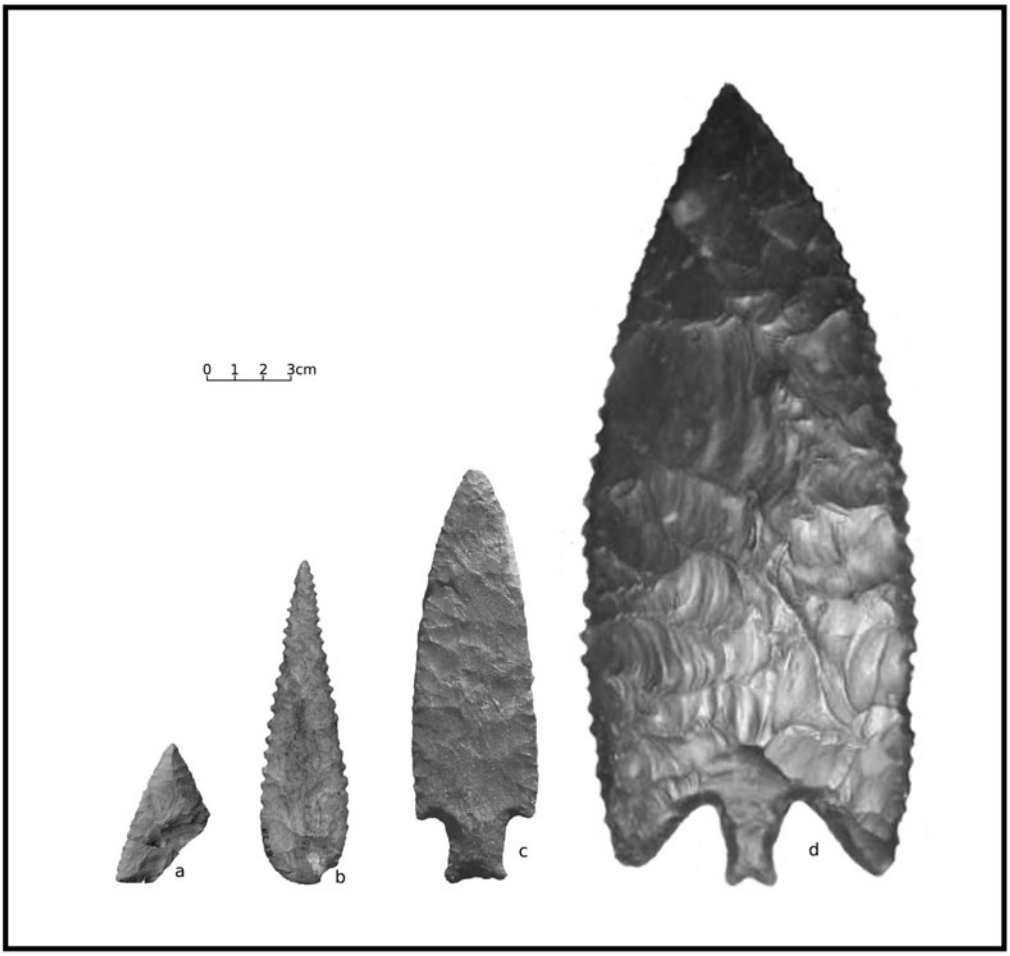

Figure 1. Bifacial pieces and points of Amazon: (a) Caverna da Pedra Pintada, Monte Alegre, Pará (photograph by Maria Jacqueline Rodet); (b) blank from the Negro River, Marabá, Pará (photograph by Claide Moraes); (c) blank from the Tocantins River, Pará (photograph by Luydy Fernandes); (d) Xingu River, Pará (photographer unknown).

2014 at the Pedra Pintada Cave site by Pereira and her team (Duarte-Talim 2019; Pereira and Moraes 2019). These occupancies are related to the 500-year transition from the Pleistocene–Holocene to the early Holocene periods: layer IV dating from 12,390 to 12,330 cal BP and layer V dating from 11,375 to 11,360 cal BP. Whenever possible, we compare the results to the data published by Roosevelt and colleagues (1996), even when they did not include all the technological elements that we do.

Environmental Context and Site Presentation

The Pedra Pintada Cave site, also known as Gruta do Pilão, is in the Monte Alegre municipality in Pará State, Brazil (Figure 2). A cavity that developed in a sandstone massif, it has a northwest–southeast opening with a big, bright, dry, airy room (Figure 3). To the northwest, a sinuous corridor fit into cracks leads to the highest part of the grotto, where there is a smaller opening that is almost parallel to the first one (Parque Estadual Monte Alegre 2009:131). The great entrance of the cave is surrounded by thick vegetation, but the small entrance, because of its high location (4 m higher than the main entrance; Silveira et al. 1984), provides a view above the canopy of the immediate surroundings; one can even see the mighty Amazon River, which is a far distance away. Although archaeological remains have only been found in the big room and two corridors (paintings in shaded areas), the site's inhabitants certainly traversed all the cave's sectors, the higher part being a suitable observation post.

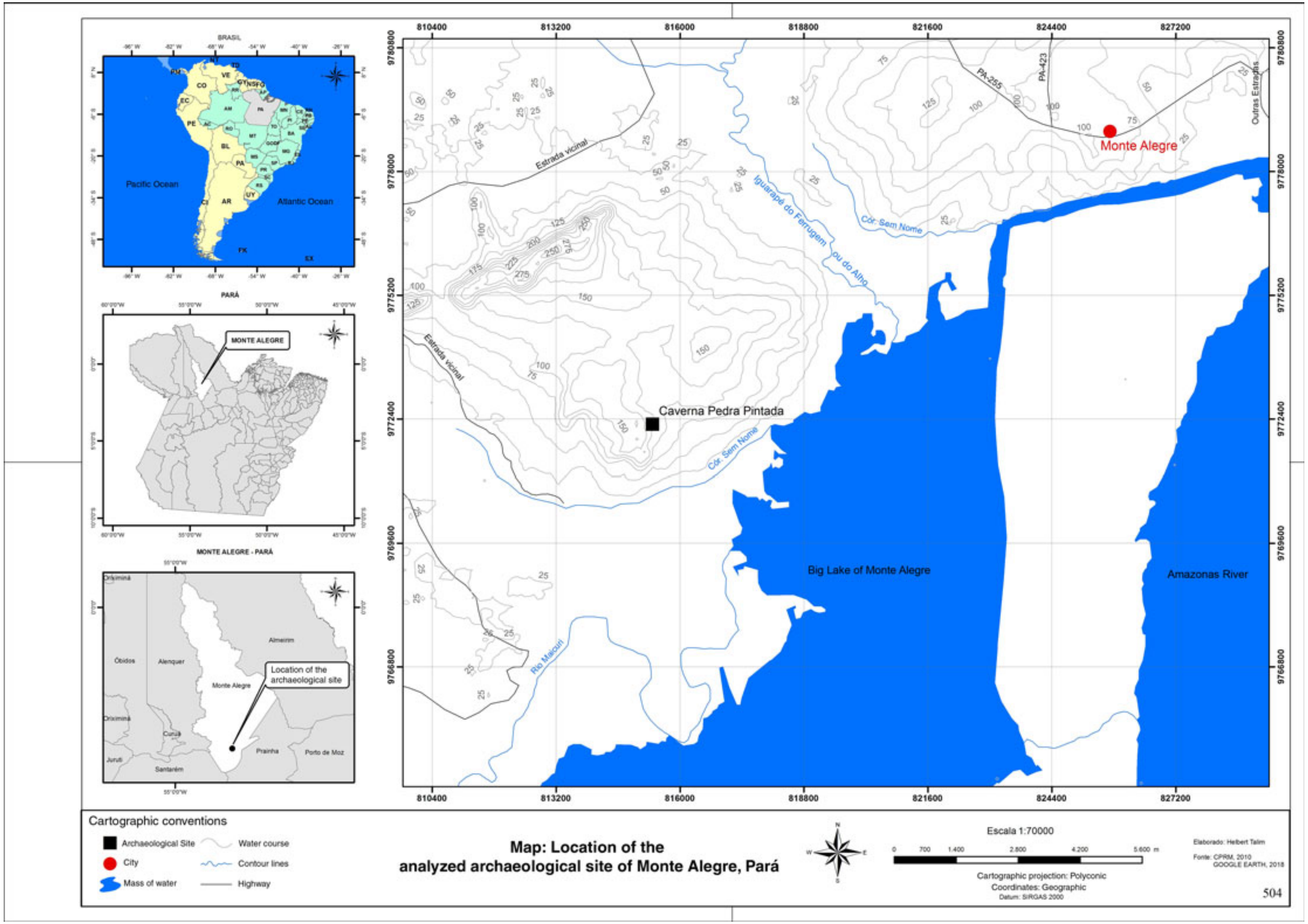

Figure 2. Site location map (produced by Helbert Talim, with Duarte-Talim 2019). (Color online)

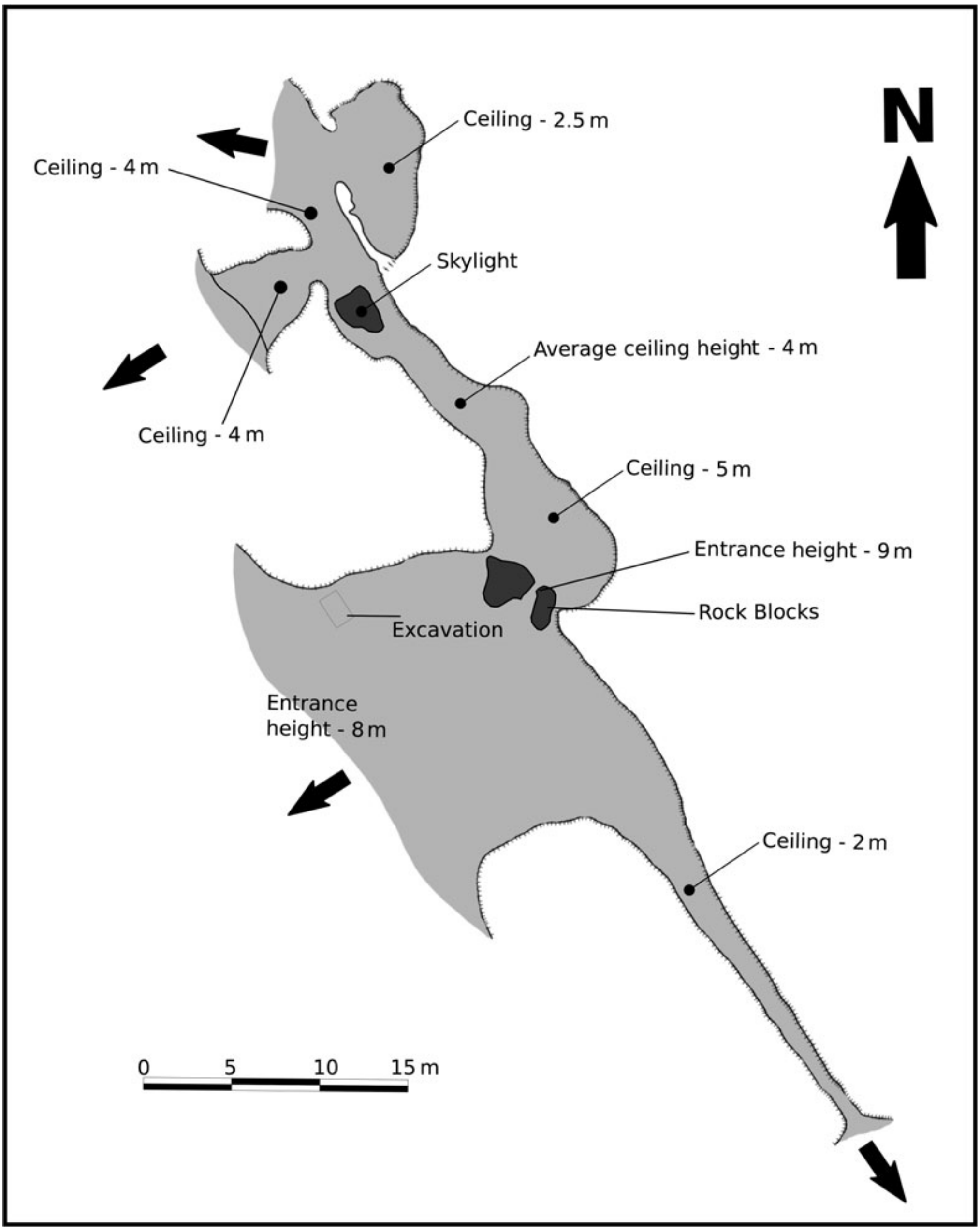

Figure 3. Caverna da Pedra Pintada sketch showing the location of excavated areas (modified from Silveira et al. 1984).

An attractive element of the grotto's entrance is its microclimate, which is much cooler than the surrounding environment (in the hot season, from September to December, the daily average temperature is higher than 33°C). In contrast to the tropical heat of Amazonian Cerrado's vegetation, which creates a high thermal presence and makes bodies sweat continuously, the entrance of the cave is well aired and has a constant breeze. This phenomenon may be related to the location of the higher opening, above the forest canopy, which channels the breeze that comes from the Amazon River (situated 10 km away, in a straight line, from the entrance to the cave), producing a lower temperature at its entrance than in the surroundings.

The environmental context of Monte Alegre differs from that of the Amazon rainforest. Geologically, Monte Alegre's low flatlands are the opposite of the rugged topography of low plateaus that reach up to 220 m of altitude (Domo de Monte Alegre). Originating from a magmatism of the Mesozoic period, the region has a huge variety of rocks (gneisses, granites, amphibolites, sandstones, shales, and quartzes; Parque Estadual Monte Alegre 2009:110–117), many of which were the basis of the lithic industries. This rocky substrate supports vegetal typologies not only of the tropical rainforest but also of the Cerrado forest (Parque Estadual Monte Alegre 2009:138–147), with plants that are typical of the savannahs. There are large, medium, and small-sized mammals and several species of amphibians, reptiles, and snakes (Parque Estadual Monte Alegre 2009:148–154). The lakes and rivers are rich in species of fish. An immense variety of bird and insect species populate the forests and certainly were part of the material and symbolic universe of earlier human groups.

The archaeological site was excavated in the 1990s (11 m^2, southeast sector, with depths of 2.25 m) under Roosevelt's supervision (Roosevelt et al. 1996) and in 2014 (6 m^2, northwest sector, with depths of 2.5 m) under Pereira's coordination (Barreto and Moraes 2014). The lithic vestiges exhumed in Pereira's excavation are presented in this article.

Ten archaeological layers were defined through granulometry, sediment color, and the presence or absence of archaeological remains. In layers VI and IV, sandstone blocks protected and sealed the more ancient levels of the occupancies (Figure 4). Even using different field methodologies, Pereira's team was able to relate the layers from the two excavated areas. The dozens of radiocarbon dates produced in the two sectors are in the same chronological interval (Table 1).

Both excavations had a complex stratigraphy, with the individualization of several occupancies, lithic industries, and ceramics showing differences over time and between the two excavated sectors. Bone fragments of diversified fauna, shells, seeds and burned barks of plants from the distinct Amazonian environments were observed (Shock and Santos 2016). Radiocarbon dates of the northwest excavation were obtained from charred seeds, and wooden parts were retrieved from structured campfires.

Methods and Analyses

Studies of lithic industries are based on the technological analysis developed by the French School (Inizan et al. 2017; Pelegrin 1986; Perlès 1987; Tixier 2012). This school, as well as the Anglo-Saxon School (Binford 2001; Bradley et al. 2010; Hodder 2001), has served as the basis for analysis in South America (Mioti et al. 2003; Moreno de Sousa and Okumura 2018; Rodet et al. 2019). Both schools analyze the hierarchical organization of the technical resources according to time and space, facilitating an understanding not only of the tools but also of the byproducts of their productions and the possible connections between them. The fundamental concept is that of a *chaîne opératoire*, which allows a wide reconstruction of human technical behaviors from a paleoethnological perspective (Leroi-Gourhan 1965). Understanding the tools from the choice of raw materials until the finished or abandoned object and considering the production phases—the choice and formatting of the core, removal of the flake to be used (the flake-blank), shaping, retouching, and resuming, in certain cases—enable determinations of what was made within the site, what was brought into the site, and what may have been taken to other places.

Every technical act is full of cultural intentions, possessing a strict relation to all the knowledges that have been acquired, memorized, and transmitted (Pelegrin 1986). The fashioning of lithic objects is related to possible gestures and techniques, with the groups searching in their social memories for the ones that had been culturally selected (Rodet et al. 2019): these memories are cultural mental images on which the knappers may rely in the absence of the object itself. It is crucial to identify all the morpho-technological concepts of a certain society and their ways of doing things (their preferences). Doing so isolates different moments and distinct occupancies or populations, which then allows comparison of the technologies applied.

Thus connected, the byproducts and tools enable us to comprehend the intents of the production left at the sites. Raw materials play an important role in this analysis. Understanding how they were obtained and how they got to the sites, the distance and quality of the outcrop, and the existence of

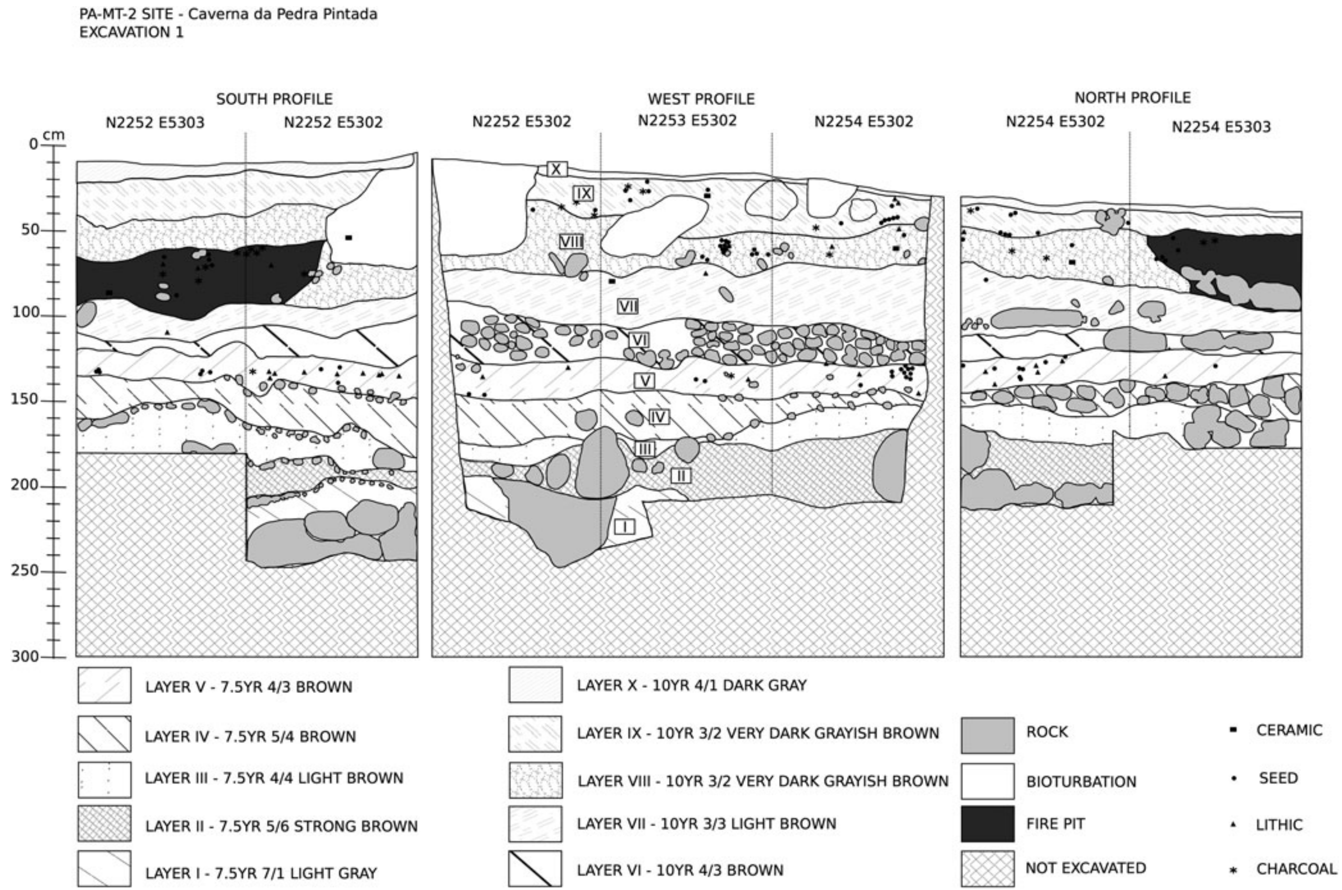

Figure 4. Excavation profile; our study focuses on the ancient's levels (modified from Pereira and Moraes 2019).

raw material reserves (Tixier 2012) is crucial to comprehending the technological choices made by ancient occupations.

Another fundamental concept underlies this framework: the distinct levels of skill and know-how (*savoir-faire*; Pelegrin 1986) observed in the knapping remnants. Expert knappers tend to execute flawless knappings or with few mistakes, with no hesitation: they apply the proper strategies, perform the appropriate movements, and obtain results adapted to their goals. Novices, in contrast, leave in the archaeological register actions that may more or less reflect their level of experience; if they do not have full mastery of knapping, they may repeat the same mistake, removal after removal, because they cannot predict or correct a mistake. Knowing the technical procedures for preparing the striking platform is not enough: sometimes the blows are executed at bad angles and with poorly conceived or poorly planned movements, resulting in pieces that deviate from what was expected (Chauchat and Pelegrin 2004:110). Moving from the novice level to the expert level requires a long path of intellectual and practical learning, with different aspects having different visibilities in the archaeological record (Bradley et al. 2010; Pigeot 1987).

In this study we analyzed all the byproducts, remnants, and tools, particularly their qualitative aspects: the raw materials, phases of the *chaînes opératoires*, methods, techniques, mistakes, and knapping errors.[1] We compared the flakes to each other and to the tools and cores by analyzing the following elements: morphology, inclination and depth of scars, presence/absence of platform preparation, technique, orientation of scars, presence/absence of lip and bulb, and knapping angles. The very large amount of millimetric flakes that we retrieved were not part of this study.

The raw materials were analyzed with X-ray diffraction, using destructive methods at the X-ray diffraction laboratory (LABD) at the Universidade Federal do Pará's Geoscience Institute [2] and using nondestructive methods at the Manuel Teixeira da Costa Research Center at the Universidade Federal de Minas Gerais's Geoscience Institute.[3] The radiocarbon dates were obtained with ^{14}C from exhumed charcoal of combustion structures and charred seeds, using conventional methods and AMS, by the Beta-Analytics laboratory (Table 1).

We used descriptive statistics to synthesize sets of values, which enabled us to visualize global changes in lithic sets over time (Guedes et al. 2015). The sets related to each layer were taken as a sample, from which we calculated the frequency of qualitative and quantitative variables and their percentages. The graphical representation is based on Inizan and colleagues (2017).

Results

The Bifacial Collection

The number of lithic pieces exhumed from the Pleistocene–Holocene transition and the Early Holocene from the northwest part of the excavation (6 m^2)—not including the millimetric flakes—totaled 6,291, including tools (whole and fragmented), flakes and fragments of flakes, and thermal fragments (Table 2). The raw materials were of good quality for knapping, with fine granulometry (silexites,[4] chalcedonies, volcanic rocks, and silicified grayish sandstones, as well as rock crystal quartz; Supplemental Figures 2 and 3).

Of these lithic pieces, 5,742 were found in layers IV and V (Table 1). Of these, 3,174 (55%) can be directly related to bifacial production (Table 3), with dihedral and prepared platforms and opposing scars. The collection is in excellent taphonomic condition, with cutting edges and readable technological stigmata.

The byproducts indicate the presence of distinct *chaînes opératoires*, whether simple or elaborate, pointing to the existence of several classes of utensils that correspond to different functional domains, such as hunting, fishing, dismembering of animals, leatherworking, and the gathering and treatment of plants. Studies of the Brazilian lithic industries support the presence of elaborate, lengthy *chaînes opératoires* encompassing various knapping phases and techniques; these techniques are related to intermediate and final mental images, with specific procedures of higher or lower predictability that require the use of different methods based on a certain level of know-how (Pelegrin 1986:29–30). In contrast, some flakes, fragments, or blocks receive a few retouches in specific places, aimed at righting stretches of the edge and making the piece more suitable for its desired purpose (Rodet et al. 2019).

Table 2. Quantitative Presentation of the Studied Collection.

Layer	Tool	Core and Core-Flake	Flake	Flake Fragment	Termic Fragmment	Doubt	Natural	Total
I			6	11				17
II			9	11	3	4	4	31
III	10		57	76	15	3		161
IV	8	1	152	183	11	69	14	438
V (Pleistocene–Holocene)	71	5	1,452	2,019	328	141	9	4,025
V (initial Holocene)	11		555	518	180	13	2	1,279
VI	4	4	81	182	45	10	14	340
Total								6,291

Table 3. Quantitative Presentation of the Material Related to Bifacial Production.

	Tool			Flake			Flake Fragment			Total		
Layer	*n*	Bifacial	%	*n*	Bifacial	%	*n*	Bifacial	%	*n*	Bifacial	%
IV	8	—	0	155	47	30	183	105	57	346	152	43
V	82	5	6	2,065	1,175	56	2,537	1,793	70	4,684	2,973	63
Total										5,030	3,125	62

Note: Relation of bifacial products, related to the total of pieces (*n*) on layers IV and V.

In the ancient levels of Caverna da Pedra Pintada, the simple *chaînes opératoires* are represented by the production of flake-blanks by direct hard percussion, percussion on anvil (bipolar percussion), and organic percussion; these flake-blanks then are transformed unifacially by peripheral retouches or used without transformation. The most elaborate *chaînes opératoires* are represented by unifacial and bifacial pieces and by polished tools. The techniques used in the removal of the initial flake could not be identified because of their subsequent transformation.

Pereira and Moraes (2019) recovered characteristic vestiges of bifacial knapping dating between 12,050 to 11,820 cal BP and 9005 to 8770 cal BP. However, the great majority of these vestiges were found in layers IV and V, dating between 12,295–12,215 cal BP and 11,765–11,390 cal BP (layers IV and V), an interval of about 500 years. The techno-morphological analyses of vestiges from this period indicate very specific elements of the production of bifacial pieces carried out on endogenous and exogenous rocks with fine and very fine granulometry—volcanic rocks, silexites, chalcedony, silicified sandstones—and rock crystal quartz (Figure 5).

In this period, the raw materials were knapped with different techniques: tangential organic percussion, direct hard percussion, or splitting (over an anvil; Supplemental Figure 4). High-quality raw materials were knapped mainly with tangential organic percussion (1,897 of 2,219 pieces; 86%) and always after persistent abrading (Supplemental Figure 5). Pressure was sometimes applied, and some sectors of the bifacial piece present parallel scars, at most 1 cm wide, with concentrated negative bulbs (Figure 6).

Pieces in layers IV and V exhibit a homogeneity in raw material choices and in knapping control, with a near-absence of technological mistakes in the byproducts (hinged termination[5]; Supplemental Figure 6).

Characteristics of the Analyzed Collection

The most frequent types of flakes are shaping and retouch flakes, reflecting the bifacial production that took place on site. There are 3,120 pieces (1,222 unbroken flakes and 1,898 fragments of

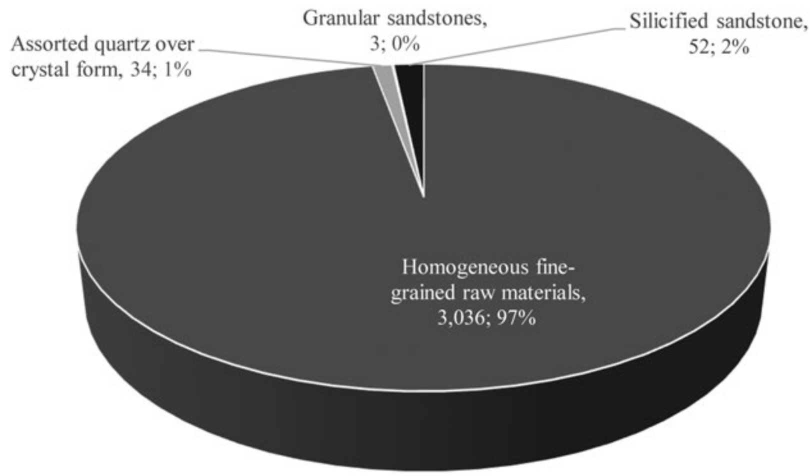

Figure 5. Graph with the raw materials used in the analyzed collection.

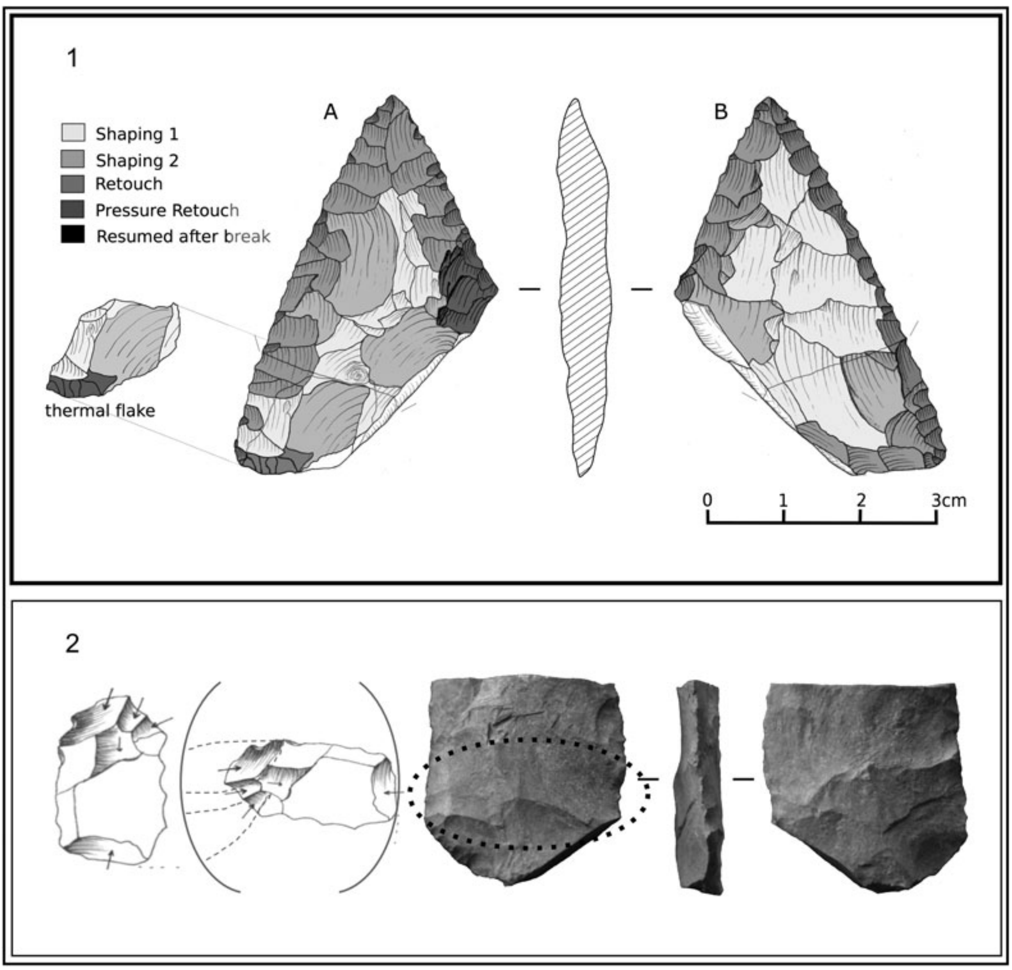

Figure 6. Bifacial piece: (1) main phases of bifacial production represented by different colors (drawing and photos by Claide Moraes); (2) hypothetical reconstitution of a bifacial shaping removal (drawings by Sérgio B. Medeiros).

flakes) with these types of flakes; they make up 63.17% of the total number of flakes from this period ($n = 4{,}939$; Table 3). Most are of small size, with most lengths between 0.5 cm and 3 cm and widths between 0.5 cm and 2.8 cm; the flakes are usually longer than wider, with varying thicknesses between <0.1 cm and 0.4 cm (Supplemental Figure 6). They follow a very standardized form and have very few mistakes (27 flakes of 1,222 unbroken flakes), meaning that less than 3% of bifacial shaping and retouching flakes present hinged termination (Supplemental Figure 7). These pieces are also systematically abraded. Very specific stigmata (Bradley et al. 2010; Chauchat and Pelegrin 2004) confirm the relation of these flakes to a bifacial shaping phase, based on the type of platform and its preparation, profiles, thickness, diacritical organization, and technique. Flakes that cross from one side to the other side of the piece can be considered as overshot (*couvrant*; Aubry et al. 2008; Bradley 2016; Bradley et al. 2010), but some flakes stop around the midline of the piece.

A significant number of platforms on unbroken flakes are dihedral (393 [32.71%]; Supplemental Figure 8), showing remains of the tool's two worked faces; they are systematically abraded and usually blunted (Figure 7). The flake profiles are oblique or slightly curved; at times, they are flat in the middle and slightly curved at the distal area, which may correspond to the shaped piece's morphology. The lower faces are bulb free. This kind of flake is typical of the shaping of flattened bifacial pieces (Figure 7). They are made during a specific phase in the work when the volume of the piece has yet to be determined. Only those flakes that surpass the center of the piece and then elongate can truly reduce the volume of the surface (thinning the piece), which, during the knapping, tends to concentrate on the central part of the tool. The accumulation of central volume is a result of removals originated from the edges toward the center.

The flakes' upper faces present negatives in the same direction of the flake itself, with a slight axis deviation or even negatives that are opposites, indicating removals originating from opposite edges (Figure 7). The reading of scar organization on the surfaces of the pieces, combined with experimental knapping of bifacial pieces done at Universidade Federal de Minas Gerais's Museu de História Natural e Jardim Botânico (UFMG) by Jacques Pelegrin (CNRS, France), confirms a diacritic sequence that structures itself from the edges toward the center in a clockwise or counterclockwise manner; in the cases of the more flattened pieces, this knapping is intended to reduce the central volume in a parallel morphological balance between the tool's two faces.

Tangential organic percussion is the only technique observed on the bifacial production of flake platforms. According to Tixier (2012), this technique allows the removal of thin flakes, which are sometimes wide and invasive and have sharp edges. The fracture principle is conchoidal, and the hammer's gesture and nature are responsible for the stigmata left on the pieces (Pelegrin 2000; Rodet and Alonso 2004). Fracture with tangential organic percussion is produced by touching the outer edge of the striking platform with the less convex part of the hammer. The hammer does not directly initiate the fracture, which is caused by the gesture of whipping the flake off. The softness level of the hammer acts directly on the lip's highlight (100% of bifacial flakes have a lip), indicating that the fracture does not occur immediately (bending initiation)[6].

Within this knapping context, it is crucial that the future platform be well prepared: all roughness must be eliminated, and the edge of the striking platform must be rounded to increase its resistance. Sharp edges risk cracking when taking the blow, deviating part of the power imposed by the hammer and causing a mistake. Abrading and blunting, two characteristic technical procedures applied at this phase, allow mistake-free removals (1,114 flakes [93.6%] with platform treatment and 78 flakes [6.3%] without any platform treatment; Supplemental Figure 5). Abrading relates to a persistent longitudinal movement from the edge toward the flaking surface using a soft sandstone pebble, which removes the roughness that may absorb part of the power imposed by the blow. It is complemented by blunting: systematic polishing of a few millimeters at the outer edge. This is done with fine sandstone abraders in a transverse movement to the knapping axis. This very smooth area, with no unevenness, makes it easier to initiate the fracture (Pelegrin 1986). Another procedure observed on the flakes encircles the platform with small removals around it. Reducing the platform concentrates the power of the blow, making it easier to initiate the fracture, and, at the same time, isolates the platform so that there are no mistakes during the percussion (Bradley et al. 2010:67).

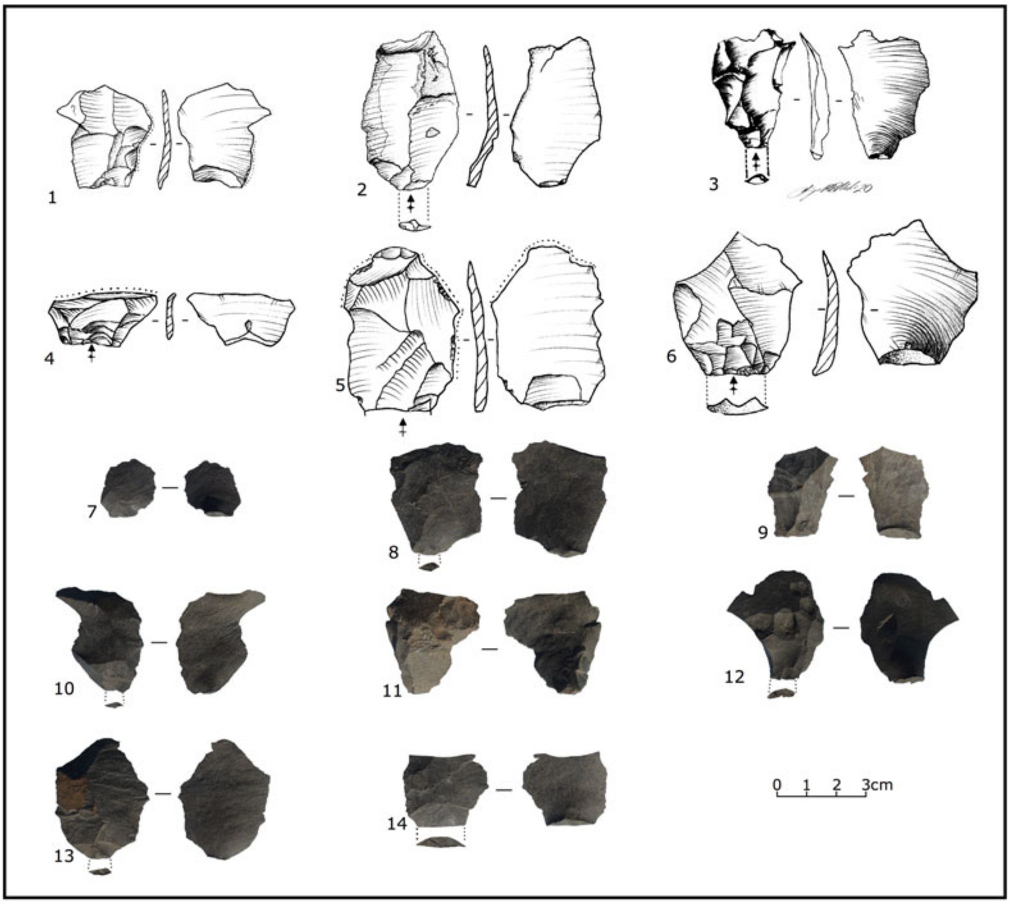

Figure 7. Flakes directly related to the shaping of bifacial tools: (1) layer J, N2253-L5303; (2) and (5) layer I, N2254-L5303; (3) and (6) layer J-3, N2253-L5303; (4) layer J-3, N2252-L5302; (7), (8) and (14) layer J, N2252-L5303; (9) and (12) layer J, N2254-L5303; (10) layer N, N2254-L5302; (11) layer J, N2253-L5302; (13) layer J, N2253-L5303 (drawings by Sérgio B. Medeiros, with Duarte-Talim 2019; photographs by Maria Jacqueline Rodet and Déborah Duarte-Talim).

In the layers IV and V collection, a meticulous griding and blunting can be observed while preparing the platform, contributing to the scarcity of hinged terminations (Supplemental Figure 7): this can indicate a technical norm, which in turn can reflect a high level of knapping control (Duarte-Talim 2019:657–658; Rodet and Duarte-Talim 2016). The people who knapped and left the byproducts on the northwestern sector were certainly experienced and had a high level of know-how. From the large number of standardized flakes with no mistakes, one could expect that finished objects would be standardized and with few mistakes. Surprisingly, the bifacial tools abandoned in the site (Table 2) show fractures, negatives of very deep withdrawals that unbalance the lateral symmetry, and negatives of hinged terminations.

The final-phase retouch flakes follow the same general rules: small flakes (sizes close to 0.5 cm × 0.6 cm × 0.1 cm and to 0.7 cm × 0.5 cm × 0.2 cm) are removed mainly by organic percussion or, less frequently, by hard direct percussion. The platforms are dihedral or smooth, with abrading. Thin and short, these flakes are aimed at making the final adjustments to the edges. Part of the retouching is made with pressure, as indicated by the small, parallel, and ensuing negatives left on the edges of the tools' cutting edges.

Some bifacial shaping and retouching flakes, with sharp edges (with angles close to 20°–30°, 40°–50°, or 60°–70°), present macro-traces of use on one of the edges or on all available edges (31 flakes). Micro-removals on the upper face of the flake-blank and micro-serrated and rounding of the edge's sharpness suggest ramified *chaînes opératoires* (Perlès 1987) in which a shaping or retouching flake was directly used as a tool (Duarte-Talim 2019:274).

The most elaborate tool exhumed in the excavation is a bifacial piece fragmented during the knapping (5.2 cm × 2.4 cm × 0.7 cm). In its present technical state, it is triangular and has a slightly asymmetric volume between the two faces (Figure 6). Made on a fine-grained, homogeneous raw material with a small inclusion, it presents brightness and thermic cupulas (see Supplemental Text 1 for a description of the other bifacial pieces).

At least two production phases can be perceived: Phase 1, reflecting a high level of know-how, and Phase 2, indicating a lower level of knapping control. Two parallel and opposite surfaces exhibit a first series of partial invasive negatives. These larger negatives reveal very light mistakes of the hinged termination, indicating good knapping control on this phase. In Phase 2, there are smaller but mostly marked hinged negatives that interrupt, on both faces, the negatives of the first shaping phase (lower degree of control).

On surface A, the outlining of the point's end, a particularly fragile area, is well controlled: a sequence of small, standardized negatives, elongated and shallow (0.7 cm × 0.5 cm / 0.7 cm × 0.2 cm / 0.6 cm × 0.3 cm) and made with pressure, outline the tip morphology. The remaining edges indicate poor pressure control: the small negatives are abrupt, and there are hinged terminations (0.2 cm × 0.3 cm; 0.1 cm × 0.4 cm; 0.3 cm × 0.2 cm). On the meso-proximal portion of the same surface, the vestigial negatives from Phase 2 are deep and have hinged terminations, creating an unbalanced area in comparison to the rest of the piece. Small thermic cupula positives are present on the bifacial piece, showing that the piece had thermal contact after the knapping.

On surface B, the apical part, just like the rest of the cutting edges, is formed by sequences of small negatives whose morphology tends to be quadrangular (0.3 cm × 0.3 cm; 0.4 cm × 0.4 cm) with abrupt pressure and largely revealing hinged terminations. On the meso-proximal part of this surface, the removals are hinged and are a little deeper (Phase 2), creating a thicker volume at the center. An ineffective attempt to remove this area—a poorly prepared edge removal using poorly controlled power—caused the transversal-torse fracture and fragmented the piece, as indicated by the small negative with a perverse fracture (Crabtree 1972). From the breakage, a few short negatives with marked negative bulbs and hinged terminations can be observed (resumed after break; Supplemental Figure 3). This piece may have been knapped by knappers with varying levels of experience and technical ability. The transverse fracture could have been avoided with good preparation of the striking point.

In summary, the lithic remains of the Caverna da Pedra Pintada present mostly very well-controlled shaping flakes (without mistakes and with prepared platforms), whereas the fragments of bifacial pieces reflect at least one phase with poor knapping control (the marked presence of hinged termination).

It was possible to reconstitute only the shaping and retouching phases of the bifacial *chaîne opératoire*. The first phases may have been deposited elsewhere in the cave or at other sites (outcrop or production sites). Bifacial tools, which would have been produced by knapping, are also absent, with only fragmented ones being recovered (Figure 8).

Nor are hammers present at the excavated sector. However, experimental studies conducted since the end of the 1960s (Bordes and Crabtree 1969; Newcomer 1976; Tixier 2012) clearly demonstrate the use of deer antlers as a benchmark material for organic tangential percussion. Although our own experience indicates that hammers made from wood or bone could also have been used (Chauchat and Pelegrin 2004; Rodet and Alonso 2004), one must note that big marsh deer (*Blastocerus dichotomus*), the largest deer species in Latin America, were present near the cave (Ramos 2004; Rodet et al. 2019).

Thus, the technological study of ancient flakes originating from 6 m^2 of the excavated area shows that there was a targeted choice of quality raw materials to use to fashion specific tools, which were produced systematically for 500 years by experienced knappers. A detailed knowledge of technical procedures led to the production of elaborate *chaînes opératoires* characterized by a high level of know-how. Although the flakes were of high quality and with few mistakes, the set of tools demonstrate a lower skill level.

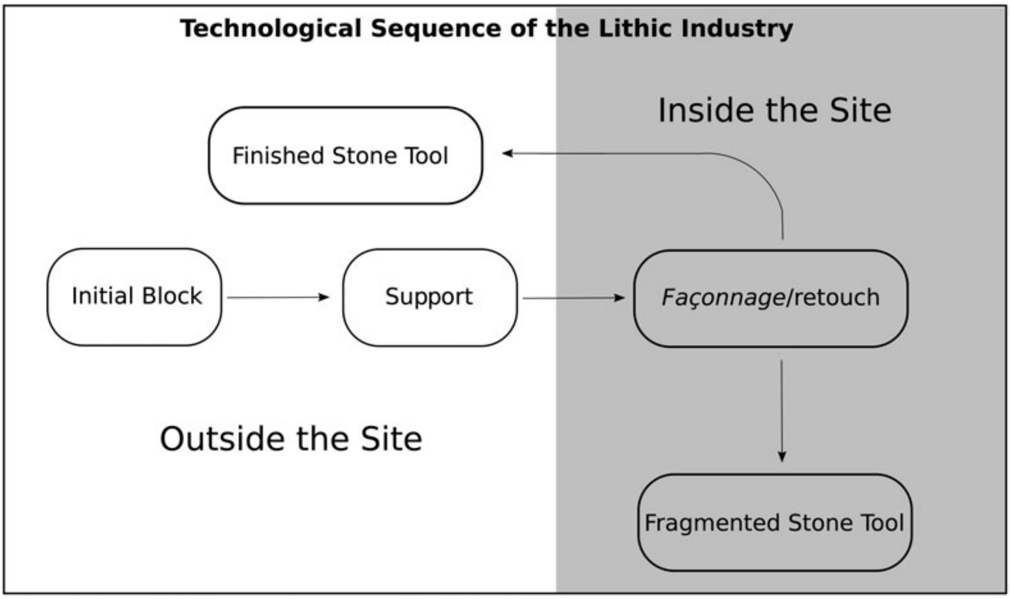

Figure 8. Technological sequence of the lithic industry: the first phases were made in another site; inside the site we find the final phases and fragmented tools.

Discussion

In the Monte Alegre region, despite extensive prospecting, excavations, and dating work (Duarte-Talim 2019; Pereira and Moraes 2019; Roosevelt et al. 1996), the Caverna da Pedra Pintada remains the only archaeological site with proven ancient occupations.

Certainly, the excavated 6 m^2 are not representative of the range of activities that took place in the cave's large, sheltered room, which has an area of at least 150 m^2, nor in the external parts and other entrances of the grotto. Nevertheless, a great amount of lithic material was exhumed from the excavation, which provides relevant information about human occupations. The southeastern excavation produced different results—flat-convex unifacial artifacts and the systematic use of quartz and a fine-grained material (chalcedony) to produce bifacial pieces—yet these data confirm those of the northeastern excavation. Thus, even though the excavated area is small, the meticulous and systematic control of the natural stratigraphy, combined with the large number of byproducts, enabled us to gather coherent and important information for understanding activities performed in the grotto.

According to the technological analyses, the pieces arrived on site in their preformed state because the shaping flakes show no natural surfaces (only two flakes with cortex). The first phases probably took place where the raw materials were found. It is the *chaîne opératoire* that enables an understanding of which and when distinct places with specific features—raw materials, types of plants and animals—were connected systematically. After finding raw materials and performing the first phases of knapping, the workers would shape the previously worked preforms, which are lighter, in the excavated area. The finished tools would then be taken somewhere else to be used. In any case, the bifacial pieces that were finished, fragmented in use, or were in distinct technical states that would prove their in situ usage are not present in the recovered remains of either of the two excavations. Initial flakes or blocks from which tools are made also could not be identified: no flakes larger than 6.5 cm that could have been used for that purpose were found at the excavation. Nor were plaquettes or cores found in these raw materials (Figures 8 and 9). Thus, our hypotheses must be considered with some caution, especially given the excavations to site area ratio.

Given the wide variety of available raw materials, a rigorous selection seems to have occurred. The knappers knew which rocks were of sufficient quality to produce bifacial pieces with no flaking

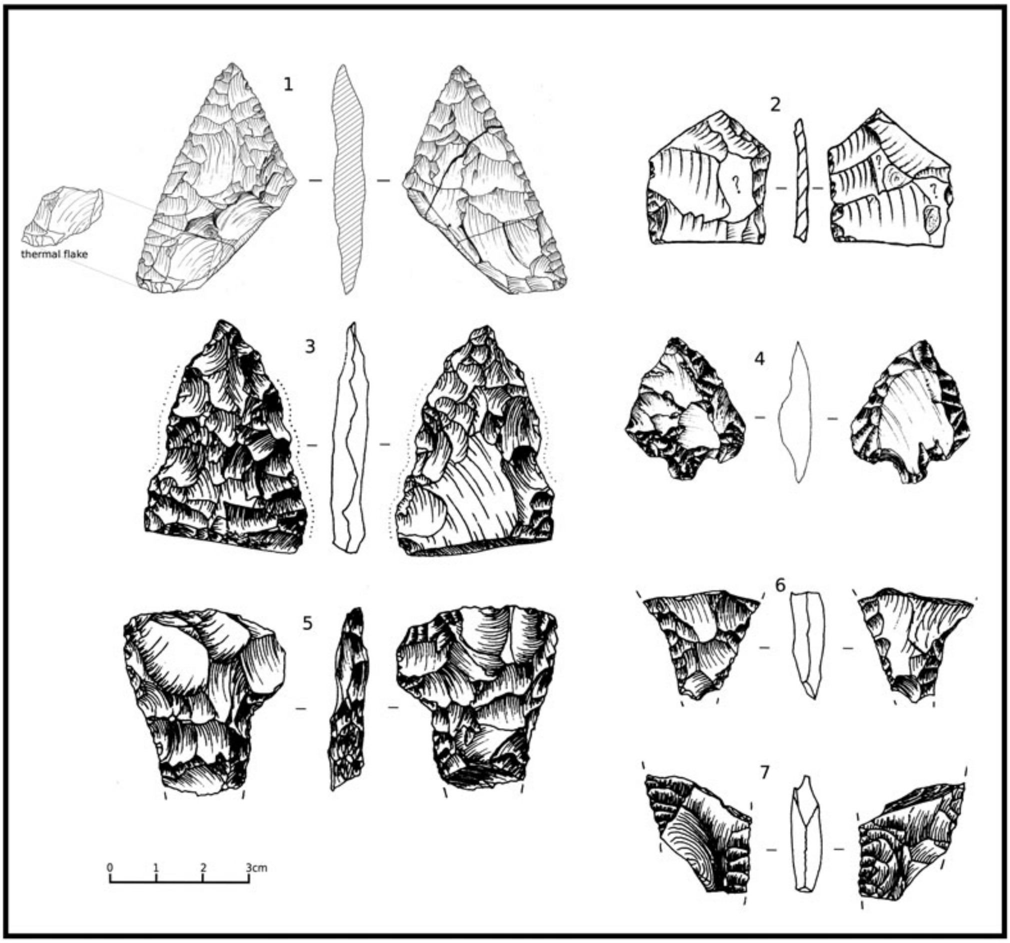

Figure 9. Bifacial tools from excavation areas: (1 and 2) pieces from the northwest area (drawings by Claide Moraes and Sérgio B. Medeiros, with Duarte-Talim 2019); (3–7) pieces from the area excavated by Anna Roosevelt using different raw materials: chalcedony: (3), (5), (6), (7); and (4) quartz (drawings from Roosevelt et al. 1996).

mistakes. This trend was observed in the set of byproducts, but not in all phases of tool production, which supports the hypothesis that the knappers had different skill levels. Outcrops of high-quality raw materials have not been identified yet, but the corresponding rocks have been observed in the geological formations that form the Domo de Monte Alegre, where the site is located. These outcrops may be in the geological Iricoumé Formation, bathed by the Maicuru River, which cuts the region, around 100 km away from the cave (Maurity 2018). Or given the large size of the Domo, they may be much farther away (Duarte-Talim 2019:520).

For about 500 years, the remains of the final production phases were very similar not only in terms of raw materials but also in their dimensions, morphologies, and knapping quality; this is further evidence for a very structured selection of raw materials. However, even though the remains of knapping point to experienced knappers, the few bifacial tools using the same raw materials have phases that indicate very different knapping skill levels. The first phases of the tools indicate thinning with control (without hinged terminations or deep removals), but the final phases exhibit less control, resulting in mistakes, scars over the surface, and breaks. In contrast, the byproducts have very few mistakes, specific preparations of the platforms, and very small flakes.

Spatial analyses of archaeological sites have shown that prehistoric spaces were structured to fit different uses. Nicole Pigeot (1987) suggests that preparation of the initial flake and then fashioning the flakes into tools would occur at other sites than the knapping itself, as in the archaeological site of

Pincevent in France. One possibility is that experienced knappers had structured work areas where production remains can be observed (cores, tools, flakes) that all exhibit a high technical level of knapping. However, novices would make products in different sites.

Anna Roosevelt and colleagues (1996) did not study the remains of production, and so we cannot directly compare our findings. However, their findings seem to indicate the use of quality raw materials, with rock crystal quartz and chalcedony being present in more elaborate productions than other raw materials used in what they called the initial and early periods (Roosevelt et al. 1996).

In the northwest excavation, thousands of small shaping and retouching flakes were exhumed from layers IV and V (Table 1), which correspond to 500 years of occupation, demonstrating that in the 6 m^2 excavated, approximately 6.2 pieces were made per year. These numbers may seem low, but they are only from a small area of the shelter. Still, according to Roosevelt and colleagues (1996:377), the "broad bifacial thinning flakes and fine, narrow, regular retouching flakes are common in all periods." These data can be interpreted in three ways: (1) the characteristics of these flakes indicate that their shaping and retouching phases were carried out inside the cave; (2) these flakes could be part of a ramified *chaîne opératoire* (Perlès 1987); and (3) the flakes could be the result of the knapping of a bifacial core and were intentionally removed to serve as initial flake-blanks (Bradley et al. 2010).

Conclusions

The technological analyses suggest that there have been very well-established groups in the region since the site's first occupation. Knappers would identify where the higher-quality stone outcrops were located and then use them systematically for elaborate production. The knapping remains left, when related to other remains (fruits, seeds, and fauna remains), reflect detailed knowledge of the area. For the period we studied, the groups demonstrate a high level of production know-how, with mental images predetermined. This knowledge would lead to increased well-being of the community as a whole. Such groups may already have been well established in the region before creating a site in the cave.

To better understand the groups' daily lives and the grotto's functions, it is important either to have access to the data produced by the research coordinated by Roosevelt or to study the recovered collections. It is also crucial to continue excavating the surroundings. The multidisciplinary project under Edithe Pereira's direction is conducting systematic excavations near the cave, but thus far its findings have not produced such ancient dates.

Was the grotto part of a network of temporary campsites between hunting areas or repository sites and more permanent sites, where one can see paintings and even burials at more recent levels? Or is the grotto itself a seasonal but well-established campground, systematically used year after year by its occupants?

We do know that the cave was systematically occupied from the end of Pleistocene period until the Late Holocene. The archaeological work done there indicates that, since then, the groups occupying the site have known and made use of surrounding contexts. These results are reinforced by similar findings in South America, confirming that, since a very early age, human groups were present both on the coastal fringe (from Mexico to Patagonia, with the presence of fishtail points, for instance; Suárez and Melián 2021) and the countryside, as in the cave or even in Cerrado regions from the center of Brazil. These stabilized groups range from the northern to the southern ends of the Americas.

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Data Availability Statement. The permanent curation of lithic collection presented here belongs to Museu Paraense Emílio Goeldi, Pará, Brazil.

Competing Interests. The authors declare none.

Supplemental Material. The supplemental material for this article can be found at https://doi.org/10.1017/laq.2023.20.

Supplemental Figure 1. Colored bifacial pieces and points of Amazon: (a) Caverna da Pedra Pintada, Monte Alegre, Pará (photo by M. J. Rodet); (b) blank of Negro River, Marabá, Pará (photo by C. Moraes); (c) blank of Tocantins River, Pará (photo by L. Fernandes); (d) Xingu River, Pará (photographer unknown).

Supplemental Figure 2. (1) Colored bifacial piece: main phases of bifacial production represented by different colors (drawing and photos by C. Moraes); (2) hypothetical reconstitution of a bifacial shaping removal (drawings by S. B. Medeiros).

Supplemental Figure 3. Quantitative Distribution of Raw Materials on Layers I to VI. The most-knapped raw material was homogeneous and fine-grained, followed by assorted quartz over crystal form and, more rarely, by granular sandstone, green rock, and non-identified material.

Supplemental Figure 4. Knapping Techniques Used on Layers IV and V. Most of the flakes were removed by organic percussion, but hard hammer percussion and percussion over an anvil were also used to a lower extent.

Supplemental Figure 5. Types of Platform Treatment on Bifacial Flakes from Layers IV and V. Most flakes received some platform treatment (gridding, blunting, or isolated platform), with flakes without any treatment being rare.

Supplemental Figure 6. Thickness from the Bifacial Flakes from Layers IV and V. The flakes of the analyzed layers are not very thick, which is another characteristic that relates them to bifacial production. Flakes with less than thickness between 0.1 cm and 0.4 cm are common.

Supplemental Figure 7. Types of Accidents over Bifacial Flakes from Layers IV and V. Although we recorded several mistakes in the production of bifacial pieces, it should be noted that (1) distal and tongues breaks occur in very thin pieces (between <0.1 cm and 0.4 cm), probably soon after their removal or even after falling to the ground; (2) bulb deskilling is a stigma that can be related to the technique (organic percussion); (3) the ringed accident is the only one considered to be technological and thus capable of attesting to the level of dexterity of the knappers, which occurs discretely and rarely in the collection (Duarte-Talim 2019).

Supplemental Figure 8. Types of Plataform of Bifacial Flakes from Layers IV and V. Only three types of platforms were observed in the bifacial production flakes, with dihedral platforms being frequent.

Supplemental Text 1. Description of Other Bifacial Pieces from the Northeast Section of Caverna da Pedra Pintada.

Notes

1. The cores are from quartz, mostly related to bipolar debitage.
2. Analyses conducted by Maurity (2018), with diffractograms interpreted by A. S. Leite.
3. Analyses conducted by Maurity (2018), with diffractograms interpreted by A. S. Leite.
4. Siliceous mistake—fine-grained, massive, or stratified—of chemical, biochemical, or volcanic origin (Foucault and Raoult 1984).
5. The hinged termination is a type of technological mistake that makes it possible to measure the degree of knapping control.
6. In contrast, in hard hammer percussion, the shock is concentrated according to the hardness of the two materials. The fracture starts at the impact point (Rodet and Alonso 2004).

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