A Good Place to Live: Plants and People at the Santa Elina Rock Shelter (Central Brazil) from Late Pleistocene to the Holocene

Rita Scheel-Ybert and Caroline Bachelet

The Santa Elina rock shelter (Central Brazil) was recurrently occupied from the Late Pleistocene to the Late Holocene. We compare sets of previously published anthracological analyses with new data to reconstruct the landscape, vegetation, and climate over the several thousand years of occupation, providing information on firewood management from about 27,000 to about 1500 cal BP. Laboratory analyses followed standard anthracological procedures. We identified 34 botanical families and 84 genera in a sample of almost 5,000 charcoal pieces. The Leguminosae family dominates the assemblage, followed by Anacardiaceae, Bignoniaceae, Rubiaceae, Euphorbiaceae, and Sapotaceae. The area surrounding the shelter was forested throughout the studied period. The local landscape was formed, as it is today, by a mosaic of vegetation types that include forest formations and open cerrado. *Some regional vegetation changes may have occurred over time. Our data corroborate the practice of opportunistic firewood gathering in all periods of site occupation, despite a possible cultural preference for some taxa. The very long occupation of Santa Elina may be due not only to its attractiveness as a rock shelter but also to the continuously forested vegetation around it. It was a good place to live.*

Keywords: landscape, paleoecology, prehistory, anthracology, archaeobotany, Central Brazil

O sítio Santa Elina foi recorrentemente ocupado desde o final do Pleistoceno até o Holoceno. Este artigo compara dados de análises antracológicas previamente publicadas a dados inéditos visando reconstruir paisagem, vegetação e clima e fornece informações sobre economia de combustíveis entre cerca de 27.000 e 1500 cal aP. As análises de laboratório seguiram protocolos antracológicos padronizados. Foram determinadas 34 famílias e 84 gêneros botânicos em uma amostra de quase 5.000 fragmentos de carvão. A família Leguminosae domina a assembleia, seguida por Anacardiaceae, Bignoniaceae, Rubiaceae, Euphorbiaceae e Sapotaceae. Os resultados demonstram que a área ao redor do abrigo se manteve continuamente florestada nos últimos 30 mil anos. A paisagem do entorno caracterizava-se por um mosaico vegetacional incluindo formações florestais e cerrado aberto, como é hoje. Algumas mudanças climáticas podem ter ocorrido ao longo do tempo. O trabalho corrobora a prática de coleta oportunista de lenha em todos os períodos de ocupação do sítio, ainda que possa ter havido preferência cultural por algumas espécies. A longa ocupação do sítio Santa Elina pode estar associada ao atrativo do local como abrigo rochoso, mas também à vegetação continuamente florestada ao seu redor. Em outras palavras, era um bom lugar para se viver.

Palavras-chave: paisagem, paleoecologia, pré-história, antracologia, arqueobotânica, Brasil Central

There are places in the world in which it is good to live; there always have been. The Santa Elina rock shelter, in Central Brazil, is one such place. It was recurrently occupied by several groups of hunter-gatherers from the Late Pleistocene to the Late Holocene (Vialou et al. 2017; Vilhena-Vialou 2005, 2011; Vilhena-Vialou and Vialou 2019). They left behind almost a thousand paintings and drawings, in many colors, representing images from geometric signs to highly realistic figurative animals and humans (Vialou 2005)—making this one of the most impressive rock art sites in Brazil. These hunter-gatherers also left remains of their lithic industry, adornments, braided fibers, basketry, and many ecofacts, such as plant remains in a perfect state of preservation (Vilhena-Vialou 2005). Many extinct megafaunal remains were

Rita Scheel-Ybert (scheelybert@mn.ufrj.br, corresponding author) and **Caroline Bachelet** ■ Museu Nacional, Universidade Federal Rio de Janeiro, Departamento de Antropologia, Laboratório de Arqueobotânica e Paisagem, Quinta da Boa Vista, São Cristóvão, 20940-040, Rio de Janeiro RJ, Brazil

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found in the lower levels, before 10,000 cal BP, some in clear association with material culture (Vialou et al. 2017; Vilhena-Vialou 2003, 2011).

The site, thoroughly excavated, yielded dates ranging from around 1500 to 27,000 cal BP (Vialou et al. 2017). Exceptionally good preservation of plant remains is restricted to the late Holocene levels. Combustion structures and dispersed charcoal occur throughout the stratigraphy. Some of the hearths, large and dense, were reused several times (Bachelet and Scheel-Ybert 2017; Vilhena-Vialou 2005).

The possibility of people living in South America before 12,000 BP remains contentious. Nevertheless, research in various fields has provided growing evidence of the existence of pre-Terminal Pleistocene sites and of multiple independent, geographically uneven migration routes into South America (cf. Araujo and Ferreira 1996; Boëda et al. 2014; Bueno et al. 2013; Dillehay et al. 2008; Moreno-Mayar et al. 2018). The antiquity of the Santa Elina shelter was carefully analyzed in a recent article, in which the authors argued for the crucial significance of the site in understanding the earliest period of known prehistoric settlement in South America (Vialou et al. 2017).

Anthracology may contribute to this debate, because the analysis of charcoal assemblages may allow us to discriminate between fires of natural or anthropogenic origin (Scheel-Ybert 2018). In addition, it provides data on vegetation changes and aspects of plant uses that are key to understanding past ways of life.

In this article, we present the latest results of anthracological analysis of dispersed and concentrated charcoal from throughout the stratigraphic record of Santa Elina. We aim to reconstruct the landscape, vegetation, and climate over the several thousand years of occupation and to provide information regarding firewood management.

Environmental and Archaeological Backgrounds

The Santa Elina rock shelter is situated in Mato Grosso state, Central Brazil (15°27′28″S, 56°46′93″W, 290 m asl), on the southeastern side of the Serra das Araras range, at the base of a rocky massif, on the northeastern face of one of its ridges (Figure 1). The region is located at the confluence of two major river basins: Paraná/Paraguay and Tocantins/Araguaia. Cuiabá River, a main tributary of the Paraguay River, runs through the range about 30 km east of the shelter (Aubry 2005; Vialou et al. 2017).

The climate is warm tropical (Aw in the Köppen classification), with a well-marked dry season from May to September. This region is located within the *cerrado* biome, characterized by a mosaic of plant formations distributed according to climate, substrate, topography, and human action. It comprises park and gramineous-woody savannas (*campo limpo*, *campo sujo*, *campo rupestre*), wooded savannas (*cerrado* stricto sensu, *veredas*), and forest formations (deciduous, semi-deciduous, and riparian forests, as well as *cerradão*—which is a typical local dry forest; Coutinho 2002; Rizzini 1997).

The geological, climatic, and environmental characteristics of the Serra das Araras make for a unique landscape. Thick vegetation thrives thanks to a variety of subsoils, developed because of the regional hydrological network (Ceccantini 2005). The local landscape comprises patches of deciduous and semi-deciduous forests, *cerrado*, riparian forests, and anthropogenic areas (deforested areas, pastures, habitations). The rocky massif where the shelter is situated is presently surrounded by deciduous and semi-deciduous forests, whereas *cerrado* formations and riparian forests occur in the adjoining plains. Deciduous and semi-deciduous forests are characterized by taxa such as *Aspidosperma* sp., *Inga edulis*, *Enterolobium* sp., *Qualea* sp., and the like; *cerrado* formations are characterized by *Aspidosperma macrocarpon*, *Curatella americana*, *Casearia sylvestris*, *Guazuma ulmifolia*, and so on; riparian forests are characterized by *Tapirira obtusa*, *Hirtella gracilipes*, *Anadenanthera colubrina*, *Ficus guianensis*, and the like (Ceccantini 2005).

Several species belonging to these formations can be used for food, medicine, crafts, construction, charcoal production, and firewood (Lorenzi 2002; Lorenzi and Matos 2008). The diversity of plant resources—fruits, flowers, seeds, and underground storage organs—available throughout the

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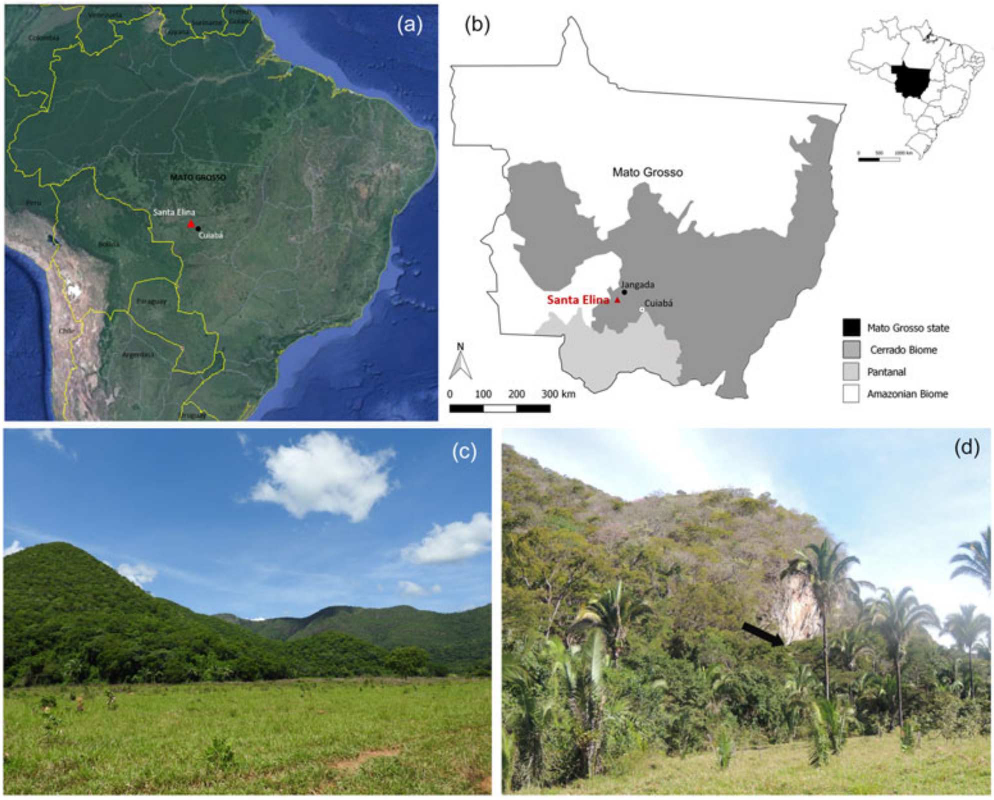

Figure 1. Location and general view of the study area. (a) General location of the site (base map adapted from Google Earth); (b) location of the site in Brazil, the Mato Grosso State, and distribution of the major regional biomes; (c) general overview of the Serra das Araras in the studied region; (d) view of the location of the Santa Elina rock shelter (at the base of the rock wall that appears in the center of the photograph, as indicated by the arrow). Map and photographs by Caroline Bachelet. (Color online)

year makes this area attractive not only to humans but also to animals, several of which were hunted (Pacheco 2008).

The shelter, formed between two precambrian dolomitic limestone walls, is between 3 and 4 m wide and about 20 m long. The floor slopes slightly to the north and east. The space between the two walls is filled with sand and fallen blocks. To the south is a large rock wall 50 m high, 60 m long, and with a negative inclination of 70°. The shelter is fully protected from the weather, providing favorable conditions for human settlement that were largely exploited (Vilhena-Vialou 2005).

This site was excavated between 1984 and 2004 in two contiguous areas totaling 80 m^2 (Sector East/Sector West). Several human groups are thought to have occupied the shelter in succession. Most were hunter-gatherers, but cultivators did at least visit the site in more recent times, as attested by rare ceramic sherds and a maize cob retrieved from the surface layer and dated to 400 ± 50 BP (Vilhena-Vialou and Vialou 2019). Three main periods of occupation were identified in the stratigraphy (Pacheco 2008; Vialou et al. 2017; Vilhena-Vialou 2003, 2005, 2011; Vilhena-Vialou and Vialou 2019):

(1) The upper archaeological layers (stratigraphic unit I: SU-I), or Holocene levels, exhibit a detailed chronology between 7000 and 1500 cal BP of a series of uninterrupted and well-stratified occupations. The sediments, fine and powdery, are formed primarily of ash. The preservation of plant

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remains is exceptional. There are many wooden posts, probably the remnants of habitational structures and other uses. Numerous combustion features are rich in charcoal and sometimes contain fruits and other plant remains, stone tools, and adornments. Lithic artifacts and colorants are very frequently found; the latter have been associated with rock art and body paintings. Animal remains, although not very conspicuous, include fish, reptiles, amphibians, birds, mammals, and invertebrates.

(2) The intermediate archaeological layers (stratigraphic unit II: SU-II), or Pleistocene/Holocene transition levels, are dated from 12,000 to 7000 cal BP. The sediments are sandy; noncharred plant remains are rare. The material culture is characterized by a rich lithic industry, combustion features, and dispersed charcoal. Animal remains are similar to those of SU-I in frequency but include extinct faunal remains of *Glossotherium* in the lower levels.

(3) The lower archaeological layers (stratigraphic unit III: SU-III), or Pleistocene levels, are dated to the Late Pleistocene (22,500 ± 500 BP–23,120 ± 260 BP). The sediments are sandy and stony; plant remains are scarce. Many *Glossotherium* megafauna remains were retrieved, frequently in direct association with lithic artifacts. The material culture is characterized by lithic and microlithic industries; in addition, there are two modified osteoderms, probably adornments. Plant remains are restricted to few dispersed charcoal fragments. Animal remains are fewer than in SU-II and much less diverse, suggesting that human occupation during this period was sparse and sporadic.

Previous Studies on Plant Remains

Exceptionally well-preserved plant remains were retrieved from the more recent levels at Sector West, dated between about 6000 and 1500 BP. In addition to charcoal, wood and bamboo posts, leaves, fibers, basketry, artifacts, fruits, and seeds were found. Several studies were aimed at proposing interpretations of plants uses; most were conducted by G. Ceccantini and collaborators (e.g., Ceccantini 2002; Ceccantini and Fernandez 2005; Ceccantini and Gussella 2001; Gussela 2003).

Wooden posts occur in all stratigraphic levels of SU-I (Ceccantini and Fernandez 2005). Nearly a hundred of them were found in situ, some measuring up to 60 cm. Two parallel rows of posts were distributed on each side of the shelter over a length of 11 m. Posts in both rows are situated in two different stratigraphic levels: one double alignment is between SU-I-1b and SU-I-2, and another one is between SU-I-2 and SU-I-3. In addition to a few sparse posts, a third alignment occurs perpendicularly to the first ones, "closing" them at their western end; this third alignment is situated between SU-I-1b and SU-I-2 (Kamase 2005; Vilhena-Vialou and Vialou 2019). The analysis of 59 posts identified 21 taxa in 15 dicotyledonous families (*Astronium* sp., *Tapirira* sp. [Anacardiaceae], *Adenocalymna* sp., *Tabebuia* sp. [Bignoniaceae], *Protium* sp., Burseraceae indet [Burseraceae], *Cecropia* sp. [Cecropiaceae], *Terminalia* sp. [Combretaceae], *Sloanea* sp. [Elaeocarpaceae], *Apuleia* sp., *Hymenaea* sp., *Inga* sp., *Myrocarpus* sp. [Leguminosae], *Trichilia* sp. [Meliaceae], *Ficus* sp. [Moraceae], Myrtaceae indet, *Randia armata* [Rubiaceae], *Magonia pubescens*, *Talisia* sp. [Sapindaceae], *Guazuma ulmifolia*, *Pterygota* sp. [Sterculiaceae]), and two genera of bamboo (*Guadua* sp., cf. *Merostachys*). *Guadua* is by far the most common material used (found in 39% of the posts), followed by *Astronium* (8.5%) and *Tabebuia* (5%). All other taxa are found in only one or two posts. Both high- (*Hymenaea*, *Astronium*, *Apuleia*, *Tabebuia*, *Terminalia*, *Talisia*) and low-density woods (*Ficus*, *Protium*, *Tapirira*, *Pterygota*, *Trichilia*, *Guadua*) were used. Ecological features suggest that wood was mostly obtained from deciduous and semi-deciduous forests (Ceccantini and Fernandez 2005). Vilhena-Vialou and Vialou (2019) interpret the aligned posts as being part of a shelter, possibly covered with palm leaves; some posts might also have supported structures such as platforms or shelves.

Many leaves/leaflets of palms and other species were excavated from SU-I (Vilhena-Vialou and Vialou 2019). Leaves of a Marantaceae appeared isolated, sometimes fragmented but often stacked, and also as the wrappings of small packages of unknown contents that were tied with braided fibers (Scheel-Ybert and Solari 2005).

A variety of artifacts produced from plant materials were found throughout the living space. Most were concentrated in SU-I-1a and SU-I-1b (dated from ca. 2000–1500 cal BP), but they occur up to SU-I-3 (ca. 4000 cal BP; Blanchot and Amenomori 2005). Basketry, penile sheaths, sandals, braided fibers, cords, strings, complex knots (some typical of festive armbands), and indeterminate artifacts were produced from palm leaves. Histological analysis of 24 of these artifacts revealed a predominant use of *Attalea eichleri* (42% of artifacts) and *Astrocaryum* sp. (12.5%; Gussela 2003). Fourteen of 50 fragments of braided strings and possible adornments and necklaces were identified. They were produced from palm (*Bactris glaucescens*), *Hibiscus* sp., and bromeliads fibers (Blanchot and Amenomori 2005; Vilhena-Vialou and Vialou 2019). Analysis of weaving, braiding, twisting, folding, and knotting techniques suggested that these artifacts might be associated with Bororo material culture (Taveira 2005).

Many coils of unbraided fibers were retrieved from all SU-I stratigraphic levels in different units. Initially interpreted as possible raw material for braided artifacts, histological analysis determined that the analyzed samples were actually woody liana stems of the genus *Aristolochia*. These forest plants, with a strong and unpleasant scent, are widely cited in the literature for their various properties. Despite their toxicity, *Aristolochia* species are used as medicine in various parts of the world for many purposes, they have attested antiophidic properties and are used as repellents and amulets against snakes, and they have ritual uses (Ceccantini and Gussella 2001). This plant may have been used for any or several of these purposes on this site. The abundance of *Aristolochia* stems suggests that it was culturally important for the site dwellers for at least the last 6,000 years.

A resin fragment of *Hymenaea courbaril* (SU-I-1b) may also have been used medicinally. This resin, extracted from the bark or fruit of the tree, is traditionally used to treat various disorders, including pain, bone fractures, diarrhea, parasites, bronchitis, inflammation, and snake bites (Scheel-Ybert and Solari 2005).

Well-preserved fruits and seeds occurred in various contexts at SU-I: dispersed in sediments, concentrated in features, and associated with hearths, they were the subject of two separate analyses. All samples come from unsystematic collections retrieved manually during the excavations. Gussela (2003) analyzed 624 samples of plant material collected in several field seasons between 1986 and 2002. All fruits and seeds larger than 0.5 cm and presenting diagnostic characteristics were analyzed ($n = 7{,}814$). Scheel-Ybert and Solari (2005) analyzed 70 fruits and seeds, along with other noncharred plant remains collected during the 1995 excavation.

Both studies yielded quite similar results. Gussela (2003) identified nine taxa from seven different families (Arecaceae, Anacardiaceae, Apocynaceae, Combretaceae, Humiriaceae, Leguminosae, Phytolaccaceae); Scheel-Ybert and Solari (2005) identified 12 taxa, also from seven families (Arecaceae, Apocynaceae, Bignoniaceae, Humiriaceae, Lecythidaceae, Leguminosae, Sterculiaceae; Figure 2). Variations in the relative proportions between the different analyses may be due to unsystematic sampling —this also explains the few taxa identified. Quantitative results should thus be taken with caution; there may be an underrepresentation of smaller and less conspicuous fruits/seeds and an overrepresentation of those most valued by field archaeologists.

Only the five most frequently observed taxa are common to both studies: Arecaceae (palms), *Dipteryx alata*, *Hymenaea courbaril*, cf. *Humiria* sp., and *Aspidosperma* sp. With the exception of the last taxon, they all produce edible fruits or seeds. In addition, a noncharred wood fragment retrieved in 1995 attests to the existence in the area of *Spondias* sp. (Anacardiaceae), the fleshy fruits of which are highly appreciated still today (Scheel-Ybert and Solari 2005).

In both samples, legumes and palms are the most important plants, both in species diversity and in number of specimens. These two families account for most of the food items identified, especially *D. alata*, *H. courbaril*, and palms.

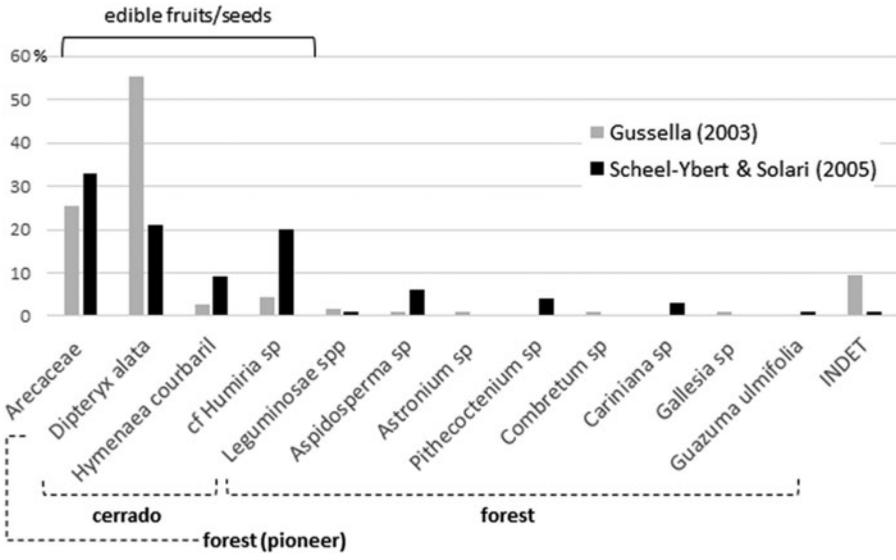

Figure 2. Synthesis of the carpological analyses performed by Gussella (2003) and Scheel-Ybert and Solari (2005) for the Santa Elina rock shelter. Among the palms, Scheel-Ybert and Solari (2005) identified three species (21% *Orbignya oleifera*/babaçu, 9% *Acrocomia aculeata*/bocaiúva, and 3% *Scheelea phalerata*/acuri), while Gussella (2003) left all remains at the family level; the histogram was constructed on family level to allow comparability.

Scheel-Ybert and Solari (2005) identified three palm species (*Orbignya oleifera*, *Acrocomia aculeata*, and *Scheelea phalerata*; Figure 2), all of which produce edible fruits/seeds and palm hearts, as well as fibers or leaves widely used in basketry. *S. phalerata* leaves are appreciated as shelter coverings, and *A. aculeata* and *O. oleifera* have medicinal properties.

Among the other carporemains is *Pithecoctenium crucigerum*, a woody liana typical of forest edges and clearings, whose large fruits are currently used as toys or for crafting. *Cariniana* sp. and *Albizia niopoides* are typical forest species whose fruits are appreciated by animals. *Astronium* sp., *Combretum* sp., *Gallesia* sp., *D. alata*, and *H. courbaril* are recognized for their medicinal properties (Gussela 2003; Scheel-Ybert and Solari 2005).

Gussela's (2003) analysis, covering the entire SU-I, demonstrates a wide temporal and spatial distribution of fruits and seeds. Before 4000 yrs BP, the record shows a smaller number of species, with increased diversity after about 2000 yrs BP. Scheel-Ybert and Solari's (2005) analysis also verified a higher diversity after about 2000 yrs BP. Nevertheless, higher diversity does not necessarily reflect variation in the patterns of plants uses, because it could be a result of collection and preservation biases.

Materials and Methods

Standard archaeological methods enabled the careful removal of anthropogenic sediments over different field seasons. Charcoal samples were collected following two different methods: (1) charcoal and carporemains concentrated in combustion features and associated deposits were sampled by hand picking and dry sieving (all field seasons), and (2) dispersed macroremains in the sediments were systematically sampled by dry sieving (1990, 1995, and 1997 seasons; Scheel-Ybert and Solari 2005). All the plant material (charcoal, fruits/seeds, wood, leaves, artifacts, and so on) was sorted in the field and subsequently forwarded to different specialists. Anthracological analyses were carried out at ISEM UMR 5554, Institut des Sciences de l'Evolution de Montpellier (Scheel-Ybert and Solari 2005) and in the Museu Nacional in Rio de Janeiro, reported in this article.

In the laboratory, large samples of charcoal from SU-I were subsampled, whereas samples from SU-II and SU-III were analyzed in their entirety. All charcoal fragments larger than 3 mm were analyzed in each sample/subsample. Charcoal pieces were manually split according to the three fundamental wood sections (transverse, tangential longitudinal, and radial longitudinal) and analyzed under reflected light brightfield/darkfield microscopes. Taxonomic determination was performed by referring to the specialized literature (e.g., Détienne and Jacquet 1983; Fedalto et al. 1989; Mainieri and Chimelo 1989) and to the reference collection of the Laboratory of Archaeobotany and Landscape of the Museu Nacional in Rio de Janeiro (Scheel-Ybert 2016). Wood and charcoal anatomy databases, especially InsideWood (2004; Wheeler 2011) and Anthrakos (Scheel-Ybert et al. 2014), were consulted as well.

In this article, we compare the following four datasets:

(1) SU-I-1 to SU-I-3: 59 samples of dispersed charcoal from four archaeological layers of Sector West (squares 32–40 A–D); spanning about 4000–1500 cal BP (results published in Scheel-Ybert and Solari [2005] and Bachelet and Scheel-Ybert [2017])
(2) SU-I-4 to SU-II-1: five samples of dispersed charcoal from two archaeological layers of Sector East (squares 23–24 A–B); dated between about 8000 and 7000 cal BP (unpublished analysis performed by Rita Scheel-Ybert)
(3) SU-II-2 concentrated (SU-II-2_C): eight samples from combustion structures of Sector East (squares 21–23 A; results published in Bachelet and Scheel-Ybert [2017] but reinterpreted here); the F7 combustion structure was directly dated to 9340 ± 70 BP
(4) SU-II-2 to SU-III-4: 40 samples of dispersed charcoal from two archaeological layers of Sector East (squares 20–24 A–Z and 26–28 A–C); dated at around 11,000 and 27,000 cal BP, respectively (unpublished analysis performed by Caroline Bachelet)

Results

The four datasets compared in this article span the occupation of Santa Elina. We analyzed 4,695 charcoal pieces in 113 samples, covering all the surface and stratigraphy of the site (Table 1). Approximately 15% of these pieces correspond to non-identifiable pieces (knots, bark, tiny stems, poorly preserved, or vitrified fragments), 80% were taxonomically identified to the family or genus level ($n = 3{,}758$), and 5% remain undetermined. Fragments of charred palm endocarps were identified in several samples from SU-I and SU-II. Those fragments are not considered here because their numbers are not significant due to prior separation of most of the carpological remains from these samples. The importance of palms as food items has already been well established by previous studies (Gussela 2003; Scheel-Ybert and Solari 2005).

Dataset SU-II-2_C comprises the conjugation of anthracological results from concentrated charcoal in eight combustion features (Bachelet and Scheel-Ybert 2017). Concentrated charcoal remains usually represent a brief period of use and contain the remnants of only one or a few charring events, thus forming species-poor assemblages that provide only paleoethnobotanical information (Scheel-Ybert 2018). Nevertheless, the analysis of multiple-use features (such as F4 and F8 are likely to be; Bachelet and Scheel-Ybert 2017) or of a large number of features or both may allow paleoecological interpretations and the identification of firewood acquisition practices as well (cf. Scheel-Ybert 2018). In the present case, the large numbers of features and of charcoal pieces analyzed, associated with high species diversity and with results that are consistent with the dispersed charcoal, help ensure that our interpretation is reliable.

In our analysis of the entire sample, we identified 34 botanical families—32 dicotyledons and 2 monocotyledons—and 84 genera, of which only one is a monocotyledon; 28 taxa remain undetermined. The Leguminosae family is dominant, both in the number of taxa ($n = 41$) and in the frequency of charcoal pieces (51% of all identified fragments). Subfamilies Caesalpinioideae and Mimosoideae are in the large majority (10 genera each, compared to only 3 from Papilionoideae); 28 Leguminosae types remain identified to the family level.

The Leguminosae family is followed, in frequency of charcoal pieces, by the Anacardiaceae

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Table 1. Characterization of the Samples Analyzed in the Present Study.

Anthraco-zone	Stratigraphic unit	Level/ code *	Conventional age BP (^{14}C)	Calibrated age (cal yrs BP)	# Samples	Nt	Ni	Nsp	Nfam
1	SU-III-4		23,120 ± 260	27,770–26,778	7	67	60	19	13
	SU-III-3				9				
2	SU-II-2		9790 ± 20	11,233–11,146	25	1,023	806	54	43
	SU-II-2_C**	F1, F2, F3, F4, F5, F6, F7, F8	9340 ± 70	10,672–10,267	8	429	354	36	23
3	SU-II-1a		7050 ± 55	7948–7704	3	87	87	14	8
	SU-I-4		6040 ± 70	7146–6661	2	88	88	15	8
4	SU-I-3	L4	3560 ± 50	3961–3641	7	252	217	23	13
	SU-I-2	L3	2660 ± 50	2853–2499	13	537	458	34	17
	SU-I-1b	L2	1890 ± 20	1832–1724	3	373	310	29	18
	SU-I-1a	L1	1770 ± 60	1818–1521	36	1,839	1,580	48	23
				TOTAL:	113	4,695	3,960	112	34

Note: Definition of anthraco-zones, stratigraphic units, chronology, number of subsamples, total number of charcoal pieces analyzed (Nt), number of charcoal pieces that could be determined (Ni), number of identified taxa (Nsp), and number of families (Nfam).
* Code adopted by Bachelet and Scheel-Ybert (2017) in correspondence to stratigraphic unit code.
** Concentrated charcoal from SU-II-2: synthesized results for all the combustion features analyzed in Bachelet and Scheel-Ybert (2017); the date provided was obtained directly from feature F7.

(10%), Bignoniaceae (6%), Rubiaceae (5%), Euphorbiaceae (5%), Apocynaceae (1%), Sapotaceae (1%), and Annonaceae (1%); besides a high frequency of Bambusoideae (bamboos) and Arecaceae (palm stems). In the number of taxa, the Leguminosae family is followed by Rubiaceae ($n = 10$), Anacardiaceae ($n = 6$), Euphorbiaceae ($n = 4$), Sapotaceae ($n = 3$), and Malvaceae ($n = 3$). The most important dicotyledon genera are *Anadenanthera* spp. (Leguminosae, 15% of the charcoal pieces), *Parapiptadenia* sp. (Leguminosae, 9%), *Astronium* sp. (Anacardiaceae, 7%), *Inga* spp. (Leguminosae, 6%), *Tabebuia* spp. (Bignoniaceae, 6%), *Croton* sp. (Euphorbiaceae, 5%), *Cassia* spp. (Leguminosae, 4%), and *Piptadenia* sp. (Leguminosae, 3%).

The analysis of the anthracological results allowed the definition of four "anthraco-zones" (Figures 3 and 4; Table 1). They do not match the abovementioned four datasets but are ordered chronologically.

Anthraco-Zone 1 (AZ-1)

This zone corresponds to the earlier occupation of this site, dated at about 27,000 cal BP (SU-III-3, SU-III-4). A very low plant diversity (19 taxa from 13 families) reflects the low number of fragments available, the lowest in the entire sample. The small charcoal sample can be explained by taphonomic issues (poor preservation) and also by less intensive fire use, possibly associated with the episodic occupation of the site during this early period.

AZ-1 is dominated by the families Leguminosae, Lauraceae, Rubiaceae, and Sapotaceae (Figures 3 and 5). There are no relevant genera in AZ-1; most taxa are only identified at the family level.

The vegetation is very poorly represented in this zone. This is due both to the insufficient sample number, which does not reliably represent the surrounding landscape (cf. Chabal 1997; Scheel-Ybert 2018), and to the large number of undetermined specimens (ca. 40% of the sample). Nevertheless, the high frequency of Lauraceae associated with the presence of *Alchornea* (a typical riparian forest plant) does point to a forested environment.

Anthraco-Zone 2 (AZ-2)

This zone corresponds to dispersed and concentrated charcoal from mid SU-II, dated between about 11,000 and 10,000 cal BP (SU-II-2, SU-II-2_C). High plant diversity (36–54 taxa

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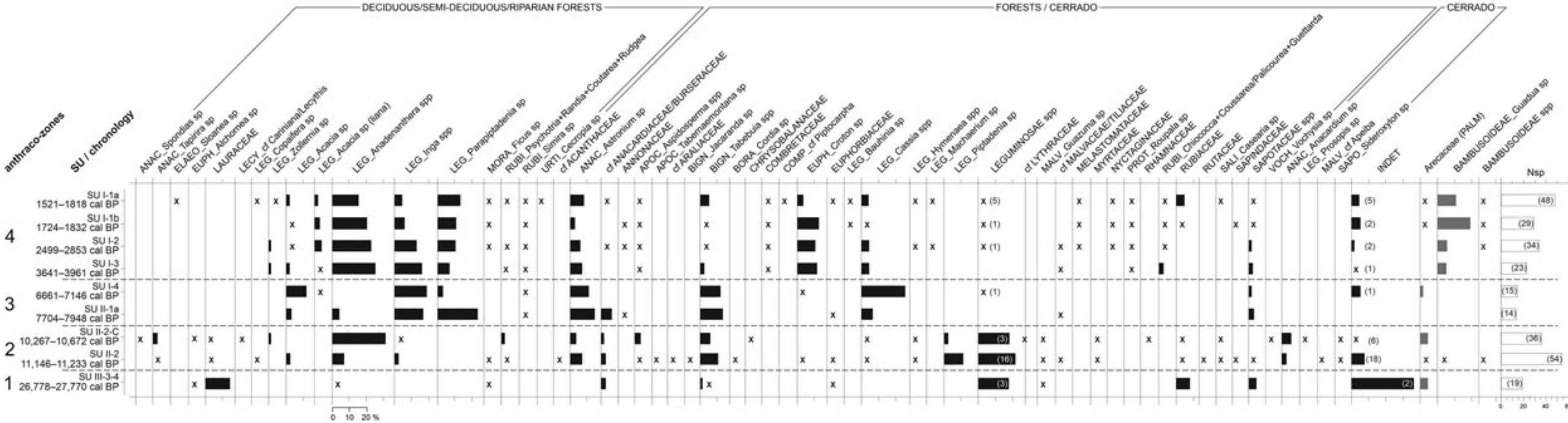

Figure 3. Anthracological diagram for the Santa Elina rock shelter. The presence of taxa with frequencies under 2% is indicated with an "x." The number of anatomical types for Leguminosae and for undetermined types is given in parentheses. The number of taxa identified at each level (Nsp) is given in the last histogram. Histograms in gray indicate taxa that were not included in the anthracological sum. (A full-size version of this diagram is included as Supplemental Figure 1.)

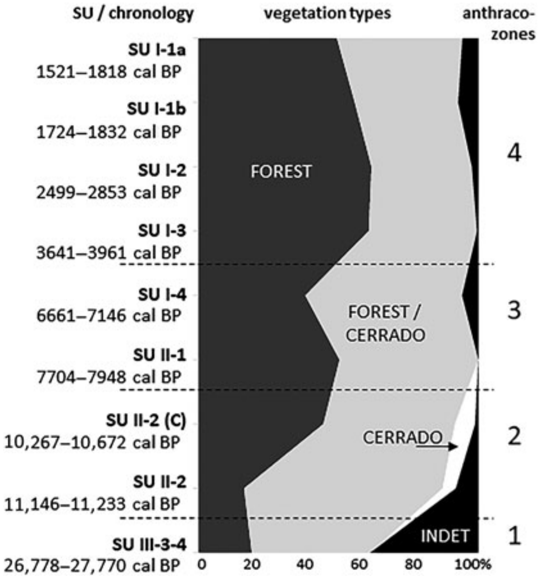

Figure 4. Summary charcoal diagram for the Santa Elina rock shelter.

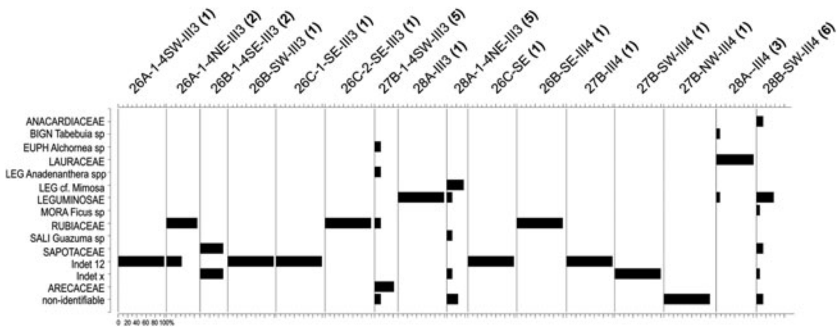

Figure 5. Histograms indicating the taxonomic composition of the Unit I samples analyzed from the Santa Elina rock shelter. The number of taxa in each sample is given in parentheses after the sample code.

per level, 23–43 families) indicates a reliable representation of the surrounding vegetation (cf. Chabal 1997; Scheel-Ybert 2004, 2018).

The assemblage is dominated by the families Leguminosae (both in frequency and in the number of taxa), Anacardiaceae, Bignoniaceae, Rubiaceae, Malvaceae, Salicaceae, and Apocynaceae. *Anadenanthera* spp. is the most frequent taxa; *Tabebuia* spp., *Piptadenia* sp., and *Astronium* sp. also appear in significant concentrations. These taxa indicate forest vegetation surrounding the site. Concurrently, taxa strictly associated with *cerrado* formations (*Anacardium* sp., *Prosopis* sp., cf. *Apeiba*, and *Sideroxylon* sp.) attest to their prevalence in the landscape.

Anthraco-Zone 3 (AZ-3)

This zone corresponds to the end of SU-II and the beginning of SU-I, dated from about 8000–7000 cal BP (SU-II-1a, SU-I-4). Despite a drastic change in the nature of the archaeological sediments between SU-II-1a and SU-I-4 (Vialou et al. 2017), the composition of the anthracological assemblage is very similar.

The drastic reduction in plant diversity (14–15 taxa per level, 8 families each) is probably associated with the small number of charcoal pieces available for analysis. As with AZ-1, the fewer charcoal pieces in the sediments might be due to taphonomic issues or less intense human occupation during this period.

The assemblage is dominated by the families Leguminosae, Anacardiaceae, and Bignoniaceae. This zone marks a clear reduction in *Anadenanthera* spp. and in unidentified Leguminosae, with greater concentrations of *Cassia* spp., *Inga* spp., *Parapiptadenia* sp., *Acacia* sp., and *Astronium* sp., and slightly more *Tabebuia* spp.

All the taxa identified are characteristic of the deciduous/semi-deciduous/riparian forest or may occur both in the forest and in *cerrado* formations. Most of the charcoal pieces analyzed exhibit growth rings, pointing to a seasonal climate, with the alternation of dry and rainy seasons. A high proportion of fragments bearing thick bark corroborates the occurrence of a severe dry season or possibly an adaptation to fire or both.

Anthraco-Zone 4 (AZ-4)

This zone corresponds to the more recent occupations analyzed in Sector West, dated to between about 4000 and 1500 cal BP (SU-I-1a, SU-I-1b, SU-I-2, SU-I-3). Plant diversity is very high, especially in SU-I-1a (23–48 taxa per level, 13–23 families). The assemblage is dominated by the Leguminosae family, followed by Anacardiaceae, Euphorbiaceae, Rubiaceae, and Bignoniaceae. *Anadenanthera* spp. is the most frequent taxa in all levels, comprising 21% of all identified fragments in AZ-4. It is followed by *Parapiptadenia* sp., *Inga* spp., *Astronium* sp., *Croton* sp., and *Tabebuia* spp. Charred bamboo pieces (*Guadua* sp.) are extremely frequent. Growth rings and thick barks remain abundant. All taxa identified are characteristic of the deciduous/semi-deciduous/riparian forest or may occur both in the forest and in *cerrado* formations; there is a discrete augmentation in forest taxa compared to AZ-3. The data analyzed here suggest that during this period the shelter was surrounded by a forested environment similar to the present one.

Sample validity was tested through saturation curves (Figure 6). In all samples but AZ-1, the curves tend to stabilize, indicating that at least most of the species used in each level are represented in the charcoal samples. Even in AZ-3, where less than a hundred charcoal pieces were analyzed in each level, saturation curves suggest that the vegetation is reasonably well represented. In evaluating these curves, one must consider that species-area/saturation curves constructed for tropical environments hardly attain asymptotes (Scheel-Ybert 2002). This is true both in phytosociological (e.g., Assunção and Felfili 2004; Felfili and Felfili 2001; Neri et al. 2007) and paleoecological studies (e.g., Ledru 1991; Scheel-Ybert 2000). Therefore, we argue that for all samples larger than 200 identifiable charcoal pieces, the local vegetation is well represented.

Discussion

The Santa Elina rock shelter is a place of strong symbolic value that has been the site of domestic and ritual activities for different cultural groups; it therefore holds important testimonies of past human life in Central Brazil. This site contains data on past landscapes, paleoenvironment, paleoclimate, plant use, and cultural practices, among other features, for approximately the past 30,000 years.

The present work corroborates and complements previous studies. Because of the exceptional conservation of plant remains, especially in the upper layers from the Santa Elina shelter, there have been numerous archaeobotanical analyses, notably in anthracology, carpology, palynology, fiber analysis, and plant craftwork (Bachelet and Scheel-Ybert 2017; Blanchot and Amenomori 2005; Ceccantini 2002; Ceccantini and Fernandez 2005; Ceccantini and Gussella 2001; Chaves 2005; Kamase 2005; Scheel-Ybert and Solari 2005; Taveira 2005). Nevertheless, this is the first time that researchers have analyzed plant material that encompasses the entire stratigraphic record, particularly those from the earlier Pleistocene levels.

Paleoenvironment and Landscape

Similar to previous anthracological results (Bachelet and Scheel-Ybert 2017; Scheel-Ybert and Solari 2005), the taxa identified from throughout the stratigraphic record are typical

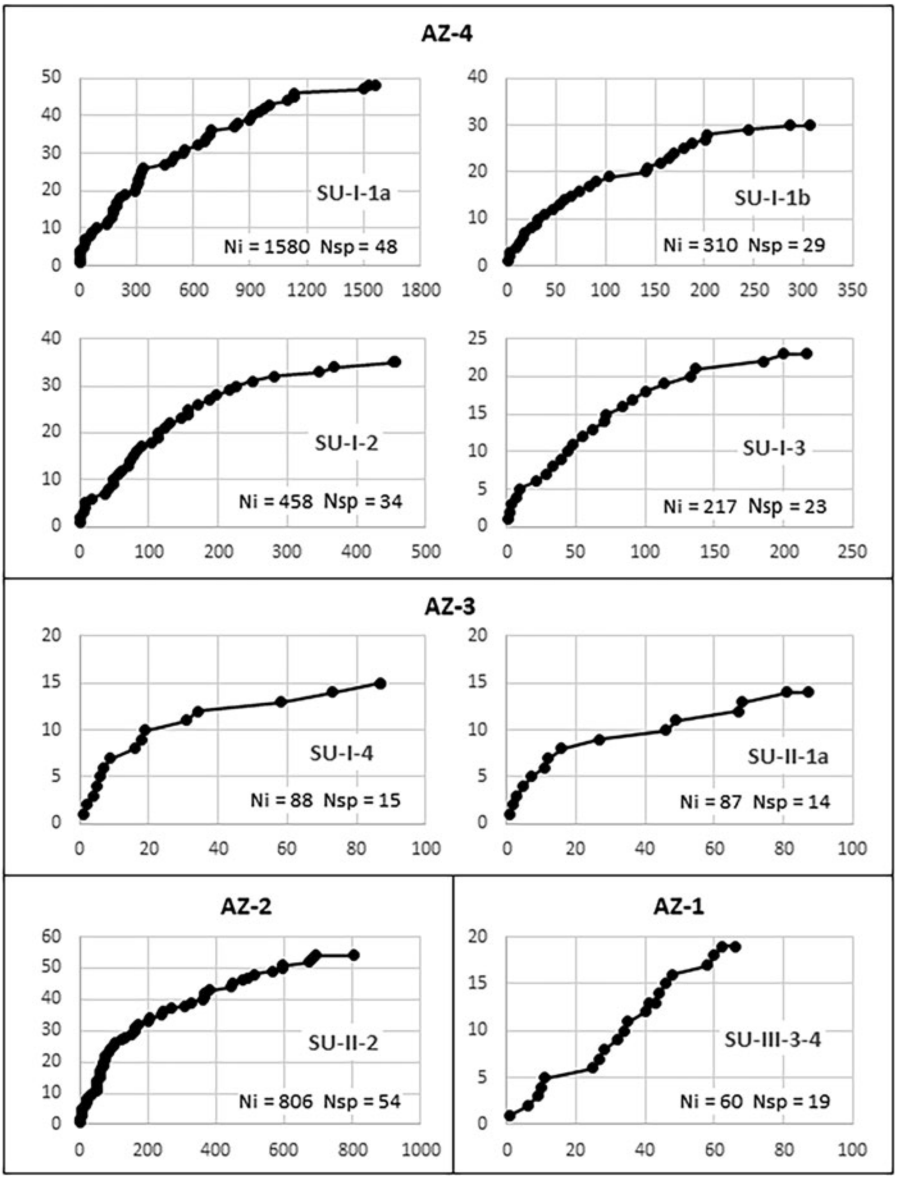

Figure 6. Saturation curves constructed for charcoal samples at different stratigraphic units of the Santa Elina rock shelter. The abscissa (x) shows the number of identified charcoal pieces; the ordinate (y) marks the first time each new species appears in the analysis. Ni = number of identified charcoal pieces; Nsp = number of taxa.

of deciduous/semi-deciduous and riparian forests and the *cerrado*. The proportions of these plants vary over time, suggesting possible vegetation and climatic changes; yet overall, the data suggest that a wooded environment surrounded the site throughout its occupational history.

Species richness in the anthracological samples is usually less than that of modern surveys; however, with the exceptions of AZ-1 and AZ-3, in which too few samples were available for analysis, our samples were consistent with the expected values for modern flora. Analysis of between 217 and 1,580 charcoal pieces per level in AZ-2 and AZ-4 revealed 23–54 taxa from 13 to 43 families (Table 1). For comparison, modern floristic and phytosociological surveys in areas of *cerrado*, *cerradão*, and semi-deciduous forest measuring 0.5, 1, or 100 ha reported between 572 and 2,118 individuals, among which 54–68 genera were identified in 29–38 families (Arruda and Daniel 2007; Camilotti et al. 2011; Maracahipes et al. 2011; Marimon Junior and Haridasan 2005).

Since it was first occupied, the Santa Elina rock shelter has been part of the *cerrado* biome. At about 27,000 cal BP (AZ-1) the site was surrounded by a forested environment. The small charcoal sample does not allow for further climatic inferences, but previous paleoecological studies corroborate the existence of a cold and humid climate in Central Brazil between about 27,000 and 20,000 BP (Salgado-Labouriau et al. 1997). This same study demonstrated a decrease in humidity from about 18,500 BP onward, with a very dry climate until about 11,500 BP (Salgado-Labouriau et al. 1997). During this interval, evidence of human occupation in Santa Elina shelter is scarce or nonexistent (Vialou et al. 2017).

Between about 11,000 and 10,000 cal BP (AZ-2) the occupation resumes; the site was then surrounded by a deciduous/semi-deciduous forested environment. The presence of taxa corresponding to a more open *cerrado* physiognomy suggests a drier climate than that of today. From about 8000 to 7000 cal BP (AZ-3), the site was still surrounded by a deciduous/semi-deciduous forest, but *cerrado* taxa disappear, suggesting a more humid climate than in the previous period. Nevertheless, growth rings and thick barks attest to the continued occurrence of severe dry seasons or possibly of an adaptation to fire. Indeed, the *cerrado* is a fire-prone biome. The open *cerrado* flora is typically pyrophytic; a great number of species are fire tolerant. Thick barks, typical of a high proportion of woody species in the modern flora, provide protection to trees during fire events (Coutinho 1990).

Fire is an ancient and important ecological agent in the *cerrado* (Coutinho 1990). Natural and anthropogenic fires have coexisted in its domain for thousands of years (Miranda et al. 2009): *cerrado* fire events have been recorded in Central Brazil since 32,400 yrs BP (Salgado-Labouriau et al. 1997). Some authors question the human presence in this region before about 11,000 yrs BP (e.g., Schmitz 1990), thus precluding the possibility of human-induced fires before the Holocene, but the chronology of the earlier occupation in Santa Elina pushes back the antiquity of human colonization.

Anthropogenic fires may be accidental or deliberate, slash-and-burn cultivation being the best-known example of the latter. Nevertheless, foragers also used fire as a tool of vegetation management to foster the growth of more palatable food plants, including secondary plants rich in carbohydrates and storage organs (Jones 2012; Piperno and Pearsall 1998). Although there is no evidence that the inhabitants of Santa Elina may have fire-managed the *cerrado*, this possibility cannot be excluded. Could anthropogenic actions have been one of the drivers in the evolution of this biome? Only further studies may tell.

Finally, between about 4000 and 1500 cal BP (AZ-1), the site was surrounded by a deciduous/semi-deciduous forested environment similar to the present one and was exposed to a similar climate. There is a slight increase in the proportion of forest taxa, but no significant environmental or climatic changes can be perceived during this period. The vegetation structure seems to be the same, even if there are some changes in floristic composition.

In summary, the landscape around the shelter probably comprised, as it is today, a mosaic of vegetation types typical to the *cerrado* biome, consisting of patches of forest formations and of wooded, gramineous-woody, and park savannas. The anthracological results corroborate previous paleoecological studies from Central Brazil, all of which attest to colder and drier conditions and more open vegetation types during the Late Pleistocene/Early Holocene (ca. 27,000–10,000 cal BP) followed by a continuous increase in warmth, humidity, and forest expansion from around 8000 cal BP to the present (Gouveia et al. 2002; Ledru et al. 1998, 2006; Parizzi et al. 1998; Salgado-Labouriau et al. 1997). Locally, the area surrounding the shelter itself remained forested, at least during the studied periods, over the past 30,000 years. The anthracological results indicate a drier climate from the Late Pleistocene to the Early Holocene (11,000–10,000 cal BP), followed by increased humidity, associated with forest expansion and likely warmer conditions after about 8000 cal

BP; by 4000 cal BP the present environmental conditions were established.

The aforementioned previous archaeobotanical analyses agree with these results, pointing to a forested environment surrounding the site and the presence of *cerrado* formations in the plains between 6000 and 1500 yrs BP (Bachelet and Scheel-Ybert 2017; Ceccantini 2002; Ceccantini and Fernandez 2005; Ceccantini and Gussella 2001; Scheel-Ybert and Solari 2005). Chaves (2005), in a palynological analysis of seven animal coprolites dated from 4000 to 400 yrs BP, also identified a mix of forested formations and *cerrado*/*cerradão*, suggesting a vegetation similar to the present one.

Carpological analyses also agree with these results, even if the open *cerrado* is better represented in this case (Gussella 2003; Scheel-Ybert and Solari 2005). These analyses show that nonedible fruits/seeds account for the less frequent carpological remains found in the site and that all of them are typically forest plants (Figure 2). Conversely, edible fruits/seeds are by far the most frequent remains; all are associated with open *cerrado* (*D. alata*) formations or to associated riparian forest (*H. courbaril*, *Humiria* sp.), except for palms, which are pioneer plants and occur in forest openings. Nonedible fruits/seeds, which are dispersed by animals or wind, are probably local elements that fell from trees in the surrounding of the shelter or were brought unintentionally with branches collected for ends other than food. Food items, in contrast, were actively targeted in the plains and intentionally brought to the shelter.

In this rich and diversified landscape circulated multiple generations of hunter-gatherers (and later potters/cultivators). They ascribed meaning to the different vegetation facies according to each one's usefulness and social meaning. They created paths and probably managed some areas into durable secondary vegetation to ensure that useful plants, including palms, would thrive. Time after time they returned to Santa Elina, where they found protection and comfort.

Ancient Charcoal

In certain conditions, anthracological analysis may help discriminate sedimentary charcoal samples associated with natural fires from archaeological charcoal samples produced by human action. Sedimentary samples generally feature low taxonomic diversity because charcoal deposits occur in situ; therefore, each soil parcel will testify only to the limited number of plants that grew precisely in that spot. In contrast, dispersed archaeological charcoal samples are "synthetic" deposits, which combine remains of many firewood-gathering events, repeated over time, in the different vegetation types existing around the settlement during the occupation; therefore, they exhibit high plant diversity (Scheel-Ybert 2018).

Nevertheless, a higher diversity in archaeological samples depends on long-term occupations; that is, on the occurrence of multiple firewood-gathering events (Chabal 1997; Scheel-Ybert 2018; Théry-Parisot et al. 2010). Short-term occupations produce species-poor assemblages, because they represent the remains of only few firewood-gathering/charring events (Scheel-Ybert 2018).

The anthracological assemblage of the earliest occupation of Santa Elina rock shelter (SU-III), dated at about 27,000 cal BP, consists of a set of 16 samples, each one presenting between one and six taxa (Figure 5). This result is consistent with short-term human occupations, in which case temporary combustion activities would have likely produced these charcoal samples. Yet, we cannot exclude the possibility that this evidence could also have been produced by natural fires.

The archaeological context does nevertheless seem well established (Vialou et al. 2017). These Pleistocene levels are characterized by a large amount of *Glossotherium* remains (cranial fragments, mandible, tooth, long bone, osteoderms, and others). Zooarchaeological analyses clearly indicate that this animal was intentionally transported to the shelter (Figuti 2005). The bones were not in anatomical connection; the archaeological excavations revealed several scattered concentrations of small bones. The presence of modified osteoderms (polished, perforated, and beveled) and lithic and microlithic remains in association with the faunal remains testify to human activities in these Pleistocene levels.

The contemporaneity between the analyzed charcoals and *Glossotherium* remains is clearly established. The *Glossotherium* bone, dated to 27,000 ± 2000 BP (Th/U), was in clear association with three of the charcoal samples analyzed (square 26-C). One microcharcoal dated to 23,120 ± 260 BP (27,818–26,887 cal BP) was associated with four of the samples analyzed (square 27-B), reinforcing their contemporaneity (cf. Vialou et al. 2017; Vilhena-Vialou 2005).

We therefore argue that the charcoal retrieved in this unit was produced in short-term combustion features related to episodic and sporadic human activities, one of which might have involved the butchering of giant sloths.

Firewood Management and Wood Uses

During all periods of occupation of the Santa Elina rock shelter, firewood procurement was largely based on opportunistic gathering, as indicated by the high plant diversity and the good correspondence with the present phytosociology in all studied levels (cf. Bachelet and Scheel-Ybert 2017; Scheel-Ybert and Solari 2005). Similar practices for firewood management were also demonstrated in other regional rock shelters occupations as far as 200 km south of Santa Elina, dated between 6000–200 BP (Bachelet 2013, 2014; Bachelet and Scheel-Ybert 2017).

Nevertheless, some taxa might have been preferred and therefore more frequently selected for firewood; for example, *Anadenanthera* spp. (Bachelet and Scheel-Ybert 2017). Species of this genus are still today among the most frequent in deciduous and semi-deciduous forests (Ceccantini 2005), hence their abundance is not inconsistent with the natural vegetation. Yet, their frequencies in the anthracological record are particularly high, especially in AZ-2 and AZ-4, and a cultural selection cannot be excluded. In the present, the wood of *Anadenanthera* species is used as firewood and for charcoal production, and the plants are also used as medicine and produce entheogenic seeds (Conceição and de Paula 1990; Lorenzi 2002, 2008). Ethnobotanical inquiries in the farms around the site revealed that *Anadenanthera colubrina* and *A. macrocarpa* are by far the two most preferred species for firewood cooking among contemporary farmers (Bachelet and Scheel-Ybert 2017; Scheel-Ybert 1997).

Cultural selection of bamboos (*Guadua* sp. and possibly another species) is also suggested, especially in the more recent occupations. The high frequency of bamboo stems in the shelter, carbonized or not, points to the large use of this material. Bamboos were frequently used as posts (Ceccantini and Fernandez 2005); they may also have been used to produce different utilitarian artifacts. But it is the high frequency of charred remains that stands out. Bamboo pieces are among the most important charred remains at AZ-4 (ca. 4000–1500 cal BP). No evidence of this material was retrieved in AZ-3 (ca. 8000–7000 cal BP), but a few fragments were identified in AZ-2 (ca. 11,000–10,000 cal BP). Today, bamboo is considered a poor-quality firewood because it is fast burning and inclined to bursts. Nevertheless, the great quantity of charred bamboo pieces in dispersed and concentrated charcoal indicates their charring was not accidental. Bachelet and Scheel-Ybert (2017) suggested that it might have been used as kindling and therefore specifically collected for this purpose, but it is also possible that bamboos were mostly collected for other utilitarian uses (such as posts, fences, and other) and that the remains of these activities were secondarily used as kindling.

In addition to the many wood varieties notably used for posts (Ceccantini and Fernandez 2005), wood probably was used by these communities for many purposes that unfortunately are not preserved in the archaeological record, such as a wide range of artifacts, handles, construction material, medicines, and others.

Conclusion

The Santa Elina rock shelter was a good place to live. In addition to the attractiveness of a rock shelter, the permanent forest made this site a sort of vegetation refuge, a protected and pleasant site where people might find shelter from bad weather and from cold and hot days, while having access to particularly rich environments. The open *cerrado* in the plains around the site was largely exploited for food procurement and useful plants, whereas the deciduous/semi-deciduous forest around the shelter provided wood, firewood, and protection from seasonal warmth and aridity.

In all periods of the occupation of this shelter, human groups adopted opportunistic firewood-gathering strategies, probably collecting the deadwood available in the vegetation surrounding the shelter. Opportunistic gathering was probably coincident with cultural selection of some plants, especially *Anadenanthera* (*angico*), which might have been praised and selected as a good firewood in this region for millennia, as suggested by the combination of anthracological and ethnographic results. Bamboos as well were probably subject to cultural selection, especially during the late Holocene, when they were likely used as kindling, as well as posts and material for craftwork (Bachelet and Scheel-Ybert 2017).

The earliest human occupations of Santa Elina rock shelter, during the Late Pleistocene, were probably sporadic and of short duration, as suggested by the extremely low diversity of charcoal deposits. The transition between the Pleistocene/Holocene exhibits an increase in the frequency and intensity of occupation, attested by the high charcoal diversity. It culminates with a very intense occupation of the shelter during the Late Holocene, as indicated not only by the high charcoal diversity but also by the huge quantities of charcoal and plant remains preserved in the upper layers of this site.

This emblematic site of Central Brazil, of rare beauty but also deeply symbolic, is key to our understanding of the first routes of colonization in South America. Most of all, it bears important information on the ways of life of Central Brazilian hunter-gatherers, some of which we have tried to present in this article.

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Data Availability Statement. The data supporting this study are available from the corresponding author upon request.

Supplemental Materials. For supplementary material accompanying this article, visit https://doi.org/10.1017/laq.2020.3.

Supplemental Figure 1. Full-size anthracological diagram for the Santa Elina rock shelter.

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