

Early Holocene human skeletal remains from Sumidouro Cave, Lagoa Santa, Brazil: History of discoveries, geological and chronological context, and comparative cranial morphology

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Received 4 May 2005; accepted 20 July 2006

Abstract

In this work, we present new evidence supporting the idea that the first Americans were very distinct from late and recent Native Americans and Asians in terms of cranial morphology. The study is based on 30 early Holocene specimens recovered from Sumidouro Cave (Lagoa Santa region, central Brazil) by Peter Lund in 1843. Sumidouro is the largest known collection of Paleoindian skulls deriving from a single site. Six different multivariate statistical methods were applied to assess the morphological affinities of the Sumidouro skulls in comparison to Howells' worldwide extant series and late archaic Brazilian series (Base Aérea and Tapera). The results show a clear association between Sumidouro and Australo-Melanesians and none with late Asian and Amerindian series. These results are in accordance with those of previous studies of final Pleistocene/early Holocene human skulls from South, Central, and North America, attesting to a colonization of the New World by at least two different, succeeding biological populations: an early one with a cranial morphology similar to that found today in the African and Australian continents, and a later one with a morphology similar to that found today among northeastern Asians.

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Keywords: Paleoindians; Paleoamericans; Karst; First Americans; Multivariate analysis

Introduction

Since the work of Hrdlička (1912), the idea that all Native American human populations, past and present, can be accommodated in a single biological population (classically known as Mongoloid) predominates in the literature (Jantz and Owsley, 2001). However, comparative multivariate analyses on crania carried out during the last 15 years by several authors, in North (Steele and Powell, 1992, 1993, 2002; Jantz and Owsley, 2001; Powell and Neves, 1999), Central (González-José et al., 2005), and South America (Neves and Pucciarelli, 1989, 1991; Neves et al., 1999a,b, 2003, 2004, 2005; Hubbe

et al., 2004; Neves and Hubbe, 2005), have revealed that at least two distinct biological populations entered the New World during the Pleistocene/Holocene transition. This dual occupation is perceived only when the cranial morphology of the first Americans, known in the archeological literature as Paleoindians, is taken into account. In South America the dual occupation is easily detected because, in contrast to North and Central America, early human skeletons abound at least in one region, the Lagoa Santa karst, where approximately 80 measurable human skulls, now dated to the Pleistocene/Holocene transition, have been recovered since the nineteenth century.

As one of us (WAN) has formally suggested elsewhere (Munford et al., 1995), cranial variation across time in South America strongly supports the idea that the New World was occupied by two morphologically distinct populations coming

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from Asia. The older one is characterized by long and narrow neurocrania, low and projecting faces, and low and wide orbits and noses; the later one is characterized by short and wide neurocrania, high and retracted faces, and high and narrow orbits and noses. The first pattern predominates today in Australia and sub-Saharan Africa, while the second pattern is variably represented in eastern Asia, especially in its northern region, and in the Americas (Howells, 1995). Since the transition between these two patterns in South America seems to have been abrupt, a “two main biological components model” has been proposed by Neves et al. (1999c) as a formal way of expressing this scenario.¹

In this work, we present new evidence supporting the idea that the cranial morphology of the first Americans was distinct from that of late and recent Native Americans and Asians. Our study is based on 30 early Holocene specimens recovered from Sumidouro Cave, Lagoa Santa region, central Brazil. Now that the specimens from Sumidouro are contextualized in time, they are a key material for those interested in the biology of the first Americans. This assemblage is the largest collection of early American skulls from a single site (single environment), providing the opportunity to consider a population and its variation with reference to worldwide variability. Previous work on the subject was either discriminatory in focus by assigning single specimens to groups (Neves et al., 1999a,b, 2005; Hubbe et al., 2004), or based on a few individuals from other sites (Neves and Pucciarelli, 1989, 1991; Neves et al., 2003, 2004; González-José et al., 2005; Steele and Powell, 1992, 1993, 2002; Jantz and Owsley, 2001).

History of discoveries

The Danish naturalist Peter W. Lund, known as the father of Brazilian paleontology, was the first to explore the caves and rock-shelters of Lagoa Santa. His work, carried out in the field between 1833 and 1843, identified at least 800 fossil-bearing caves in the region (Piló and Auler, 2002), 60 of which were intensively explored by him. Among the caves he explored, Sumidouro (literally “swalet”) was by far the most important due to the fact that it was the only cave where human skeletal remains were found in abundance associated with megafaunal fossils (Lund, 1844, 1845; Holten and Sterll, 1999). Only after scrutinizing the fossil deposits of the subterranean chambers of Sumidouro in detail did Lund reluctantly propose that the human bones found in the cave were associated with remains of extinct megafauna (Lund, 1844)—a difficult decision for a convinced catastrophist directly influenced by Cuvier.

Two main conclusions were reached by Lund after his excavations at Sumidouro. First, because humans were coeval with the megafauna in Lagoa Santa, the occupation of the New World must have been much older than previously thought. Second, the association between the humans and megafauna strongly undermined catastrophism. To the best of our knowledge, Lund was the first naturalist who dared to suggest such a scenario for the occupation of the American continent. Until the discovery of the first Clovis sites in North America in the beginning of the twentieth century (Howard, 1936), Lund’s ideas were strongly rejected by most of his colleagues in Europe and the United States.

The early chronology suggested by Lund (1844) for the human remains from Sumidouro was based primarily on two indicators: first, the human skeletons he found exhibited the same degree of fossilization as the megafaunal remains; and second, both were found in the same sedimentary deposits within the cave. Both indicators were seriously questioned by his critics, mainly Hrdlička (1912), who never accepted an ancient antiquity for the Sumidouro material.

The major issues raised by Lund’s critics (including Hrdlička) can be summarized as follows. First, the fossilization rate at Sumidouro was very rapid (Lund himself concluded so), and consequently, the degree of fossilization could not be used to infer the antiquity of the human bones. Second, since the main entrance to the cave is, in fact, a very active swalet, the water activity within the inner chambers should be very intense. This turbulence could have redeposited and mixed fossils from very different periods. The debate concerning the real antiquity of the material from Sumidouro took exactly 160 years to be resolved (Piló et al., 2004) in favor of Lund’s interpretations.

The repercussions of the morphological studies carried out on the best-preserved human skulls found at Sumidouro during the second half of the nineteenth century and the first decades of the twentieth century were astonishing. In brief, physical anthropologists involved in these studies can be classified into two groups. One, which constituted the majority (e.g., Lacerda and Peixoto, 1876; Ten Kate, 1885; Hansen, 1888; Rivet, 1908; Imbeloni, 1938), suggested that the cranial morphology of the Sumidouro specimens could not be accommodated within the range of variation of Amerindian populations, calling for a special explanation, such as the entrance of two very different human populations into the New World. The second group was represented mainly by Ales Hrdlička [see also Kollmann’s (1884) study, which was based on only five skulls], who argued that the cranial morphology of these specimens required no special explanation, as it could be accommodated within the known range of Native American variation. Since both groups used typological strategies in approaching the problem (due to the fact that descriptive comparison was the only tool available to them at that time), it is difficult to understand why Hrdlička’s explanation became so predominant until very recently (for some suggestions, see Jantz and Owsley, 2001). The application of modern quantitative methods of morphological comparison to the Sumidouro crania may shed light on an important question still

¹ In fact, the first time this model was suggested in the literature by Neves et al. (1996), it was named the “four migration model” to contrast it with the “three migration model” proposed by C.G. Turner and collaborators in the beginning of the 1980s (Greenberg et al., 1986). However, with the evidence generated by molecular biological studies indicating that “sinodont/mongoloid” populations entered the New World in a single migration, Neves et al.’s model was renamed the “two main biological components model” in the late 1990s.

open in physical anthropology, a question completely obliterated during the second half of the twentieth century by the monolithic nature of the Clovis-first model.

Geological and chronological context

Sumidouro Cave is one among hundreds of caves recorded in the Lagoa Santa karst, located approximately 30 km from Belo Horizonte, the state capital of Minas Gerais (Fig. 1). The cave developed in the southern portion of a limestone outcrop at the margins of Sumidouro Lake, one of the largest permanent water bodies in the region. It contains approximately 650 meters of corridors and chambers, remaining completely under water during most of the year (Piló et al., 2004, 2005).

Two separate entrances could have been used in prehistoric times to access the subterranean passages and chambers of Sumidouro Cave (Fig. 2). One, located in the northern portion of the outcrop, lies by the lake and functions as an expressive swalet. Today, this entrance is mostly blocked due to a recent fall of limestone blocks caused by dynamite explosions. Another entrance, a dry window, is called the southern entrance and is located on top of a slope, 7 m above the lake level and the swalet. This was certainly the main entrance of humans into the cave (Piló et al., 2004, 2005).

According to Piló et al. (2005), several diagnostic features and the close relationship between the cave and the lake strongly suggest a genesis by floodwater. Floodwater caves associated with lakes abound in Lagoa Santa (Auler, 1995). Episodically (once every 30 or 40 years currently), the entire cave is dry, except for a few remaining small inner bodies of static water. The two chambers that have been excavated (the Lund and Diniz² chambers) are located in the southern part of the cave, being easily accessed by the southern entrance in very dry years (Fig. 2). Lund himself had to wait several years to have access to the chamber he explored. While abundant sedimentary deposits are found in the southern portion of the cave, where the paleontological deposit is located, the northern portion is primarily devoid of sediment, probably because of the water flowing into the swalet (Piló et al., 2005).

Lund (1845) recognized two main sedimentary deposits at Sumidouro: a reddish sediment at higher levels in the cave and a yellowish clay at lower areas. According to him, the reddish layer would correspond to the original fill, while the yellowish clay would be this original reddish sediment intensively reworked by floodwater. The yellowish package could be divided into two subunits, a higher one, described by him as yellowish clay with small dark spots of manganese and iron, and a lower one, described as a yellowish-gray clay.

For Lund, the absence of lacustrine snail shells in the reddish sediment and an abundance of these shells in the lower yellowish sediments were a strong inspiration for his ideas

about the formation of the two main sedimentary deposits he found within Sumidouro. Besides these old sedimentary packages, recent flood events deposited in the floor of the cave a dark organic (“humus”) layer also rich in aquatic snail shells.

Fossilized megafaunal remains were found in the three ancient sedimentary levels (reddish, yellowish, and yellowish gray), while human fossils occurred only in the yellowish sediments. Lund collected a large amount of nonhuman and human bones in the dark organic sediments as well, and also at the bottom of a small lake present in the chamber. However, he realized that these fossils should be treated as secondary depositions due to water having eroded the original sediments.

As already mentioned, both the reddish sediment and the two yellowish layers were fossiliferous according to Lund. He believed that, although they were at the top of the sequence, the few animal fossils found in the reddish layer were older than those found in the lower yellowish deposits because the fossil assemblage present in the latter would be a mix of the original bones present in the reddish fill plus more recent fossils brought into the cave by later floods (Lund, 1845).

The human fossils (approximately 30 individuals), however, were not added to the yellowish deposit by the action of the flowing water coming from the swalet. Lund preferred the hypothesis that the human bodies were actively discharged through the dry southern entrance, which gives direct and easy access to the two chambers he, and later Helio Diniz, explored.

The hypotheses put forward by Lund to explain how megafaunal and human bones were introduced into Sumidouro were based on the fact that, while animal fossils were very fragmentary and completely disarticulated, several parts of human skeletons were still in anatomical position, and most of the skulls were entirely preserved. If the human skeletons had entered the cave through the swalet, as the animal bones did, they would have been completely disarticulated, with the skulls severely fragmented (Lund, 1845).

As emphasized by Piló et al. (2005: 756): “Although Lund’s conclusions gained a few supporters [...] many [especially Hrdlička] claimed that the geological context would not allow any definite conclusion concerning the contemporaneity between man and extinct mammals [...]. Because none of these scholars visited the cave, their judgment of the depositional context of Sumidouro Cave was entirely based on Lund’s report, adding no new information to this complex and important paleoanthropological site.”

In order to test Lund’s hypotheses, two of us (LBP and WAN) participated in a detailed sedimentological investigation in the Lund and Diniz Chambers, the only loci in the cave where remnants of the old sedimentary assemblages can still be found. The main goals pursued during the field work within Sumidouro cave were: (1) to generate a detailed map of the cave, plotting the areas excavated by Lund and Diniz (such a map was never elaborated by earlier researchers); (2) to understand the details of the huge operation carried out by Lund in the locus excavated by him; (3) to observe, understand, and critically assess the stratigraphic sequence suggested by

² Helio Diniz, a local amateur archaeologist, also undertook intensive excavations at Sumidouro in 1959. Unfortunately, nothing was published by him. His collection, including half a dozen human skulls, is now housed at a private museum in Lapinha, Lagoa Santa region. So far, this collection has been inaccessible to us.

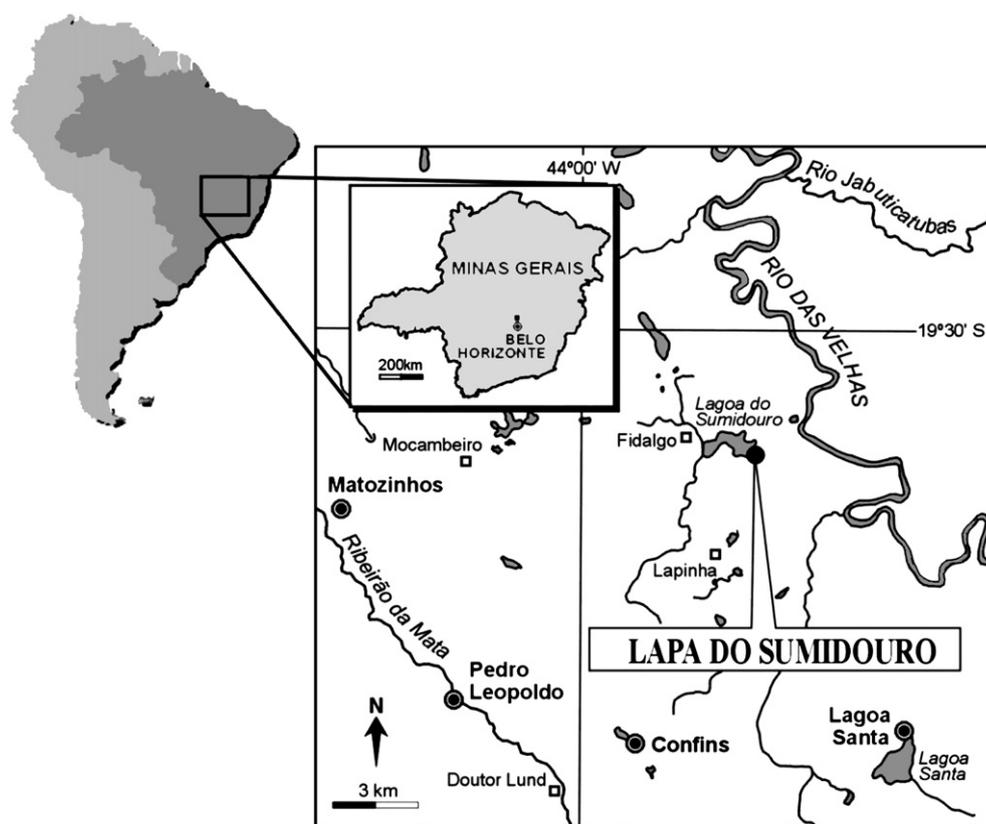


Fig. 1. Geographic location of Sumidouro Cave (Lapa), Minas Gerais State, Brazil.

him; (4) to locate and collect well-contextualized organic and inorganic debris that could be dated; (5) to understand the characteristics of the water flow along the inner passages and chambers of the cave; and (6) to find potential locations still intact to be eventually excavated in the future. The field work was carried out in 2001 and 2002, taking advantage of a severe regional drought that exposed the cave completely.

The detailed results and interpretations derived from our work at Sumidouro can be found in Piló et al. (2004, 2005). Lund's hypothesis about the genesis of the original sedimentary packages within the cave was not confirmed. The yellow sediments are not the product of in situ reworking of the reddish fill by water flow. Both sediments can also be found on top of the outcrop with the reddish layer (rich in hematite) covering the yellow one (rich in goethite). They entered the cave in this sequence through vertical fissures in the cave ceiling. The color differences cannot be accepted as the product of the action of water over time. Reddish soils cannot grade into yellowish ones because hematite does not change into goethite as a result of hydration.

None of the human and animal bones found in situ by us in the interior of the cave were amenable to dating. No collagen was preserved in these samples, probably as a result of the oscillation of the water table within the chambers for millennia. In fact, the Sumidouro material is characterized by general lack of collagen. Several samples of animal and human bones and teeth submitted by Kim Aaris-Sorensen (curator of the Lund collection) for AMS dating did not preserve collagen.

Although no absolute date could be generated for the Sumidouro fossil material, we were able to demonstrate that the fossils from the yellowish sediments (where human and megafaunal remains were found together) are older than 8 ka (calibrated). A fragment of yellowish breccia (Breccia 789; Fig. 3) covered by a thin layer of cristalline calcite was collected by Lund and incorporated into his geologic collection. Lund (1844) described that only one layer of calcite was found by him at Sumidouro. As can be seen in Table 1, two $^{230}\text{Th}/^{234}\text{U}$ series corrected dates obtained from the cristalline calcite itself generated an interval of age from 7674 ± 456 to 8150 ± 450 BP.

A small piece of charcoal and several small aquatic shells encrusted in the calcite generated AMS C-14 calibrated intervals of 8530–8370 BP and 10220–9920 BP, respectively. A sample of charcoal still adhered to a human postcranial bone (Breccia 247) was dated to a calibrated interval of 8540–8390 BP, while a shell inserted into a human auditory meatus (Breccia 321) was dated to a calibrated interval of 8530–8200 BP. A fragment of the same calcite adhered to a human parietal was recently dated to a similar age.

The convergence of these different sources of dating to between 8000 and 8500 calibrated years BP is remarkable if we consider the dynamic nature of sediment and bone deposition in the inner chambers of Sumidouro. Interestingly enough, this age is congruent with the fact that the peak of human occupation in Lagoa Santa occurred between 9500 and 7500 BP, with most of the organized cemeteries being established in the local rock shelters from 8500 to 7500 BP (Araujo et al., 2005).

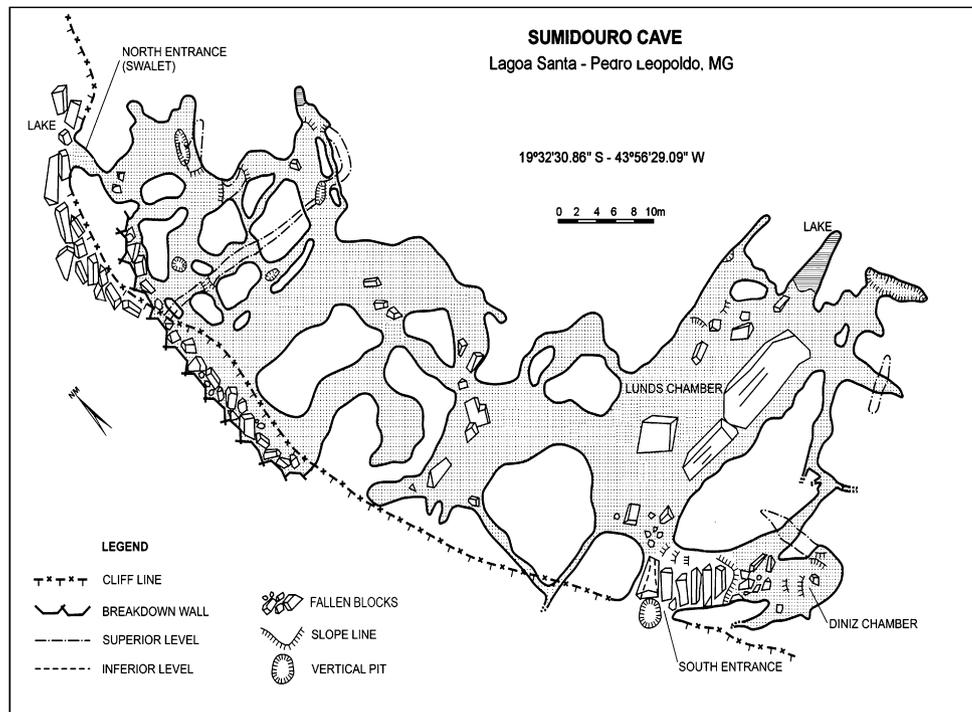


Fig. 2. Plan-view map of Sumidouro Cave.

Material and methods

A total of 31 measurable human skulls now constitute the Sumidouro collection. The measurements of these skulls are provided in [Tables 2](#) (males) and [3](#) (females). These skulls are housed in three different institutions in Brazil and Europe and exhibit different degrees of completeness (see [Table 4](#) for the detailed institutional location of the material and its degree of integrity). As can be seen in [Table 4](#), the great majority of the specimens are housed at the Zoological Museum of the University of Copenhagen, Denmark. The Brazilian specimen is housed at Instituto Histórico e Geográfico do Rio de Janeiro,

while another specimen is part of the hominid collection of the Natural History Museum, London.

Almost the entire fossil collection gathered by Lund in Lagoa Santa, totaling 12,000 animal bones and 15 well-preserved human skulls, was donated by him to Christian VIII, King of Denmark. Curatorial work carried out by one of us (WAN) in September 2002 and September 2004 resulted in the refitting of 15 new measurable crania (although not as complete as the others). The skull housed in Rio de Janeiro was also a direct donation from Lund, while the one at the Natural History Museum in London was sold by Peter Clausen as part of a collection of fossils from Lagoa Santa and elsewhere in central Brazil. Peter Clausen, also Danish, was a fossil dealer who introduced Peter Lund to the Lagoa Santa caves. In return, Lund presented him with, among other things, one of the human specimens he recovered from Sumidouro ([Holten and Sterll, 1999, 2000](#)).

The original 17 measurable skulls were numbered by [Hansen \(1888\)](#) SH-01 to SH-17. He conducted the most comprehensive study to date of Lund's human collection. The newly reconstructed crania were numbered WN-01 to WN-15 by the senior author. Specimen SH-12 disappeared from the Zoological Museum around 1940. The Sumidouro human skeletal remains housed at the Zoological Museum of Copenhagen³

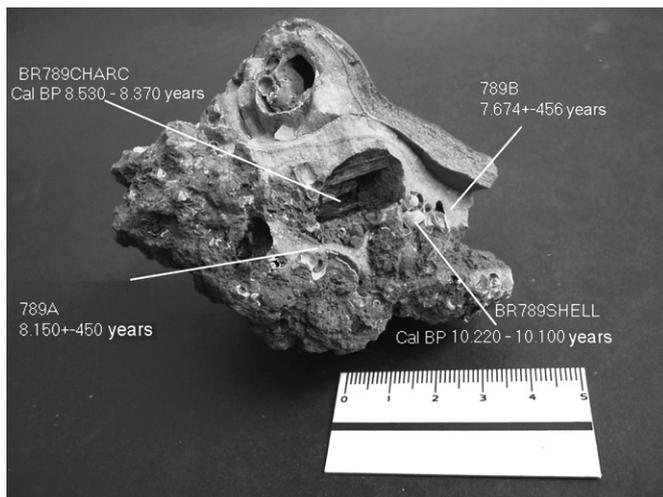


Fig. 3. Fragment of Breccia-789 from Sumidouro showing where samples were taken for dating (ZMUC collection).

³ The Danish collection also includes a single individual uncovered by Lund at Lapa da Escrivânia (dated by AMS to 7650 ± 80 BP), the anatomical parts of which were put together by Patricia Soto-Heim (Soto-Heim, 1994), and two very recent skulls, one found on the surface of Cerca Grande and another found on the surface of an unknown local cave. These two recent skulls cannot be used to characterize the cranial morphology of the early population of Lagoa Santa.

Table 1
Dates generated for Sumidouro based on calcite (breccia) and organic material

Laboratory sample	²³⁸ U (ppb)	²³² Th (ppt)	²³⁴ U (measured)	[²³⁰ Th/ ²³⁸ U] (activity)	[²³⁰ Th/ ²³² Th] (ppm)	Age (uncorrected)	Age (corrected)
Sumc-01	135.9	372.7	354.6	0.2025	12.0	17,563 ± 173	11,459 ± 3.07
789A	211.6	11257.5	767.1	0.1409	43.7	9,021 ± 114	8,150 ± 450
789B	289.5	15688.6	767.0	0.1339	40.8	8,561 ± 101	7,674 ± 456

Sample	Laboratory reference	Radiocarbon age (years BP)	Calibrated age (years BP)
789 CHARC	Beta-172186	7,650 ± 50	8,530–8,370
789 SHELL*	Beta-172187	8,960 ± 50	10,220–10,100 and 10,090–9,920
ZMUCBR247	Beta-174730	7,680 ± 40	8,540–8,390
ZMUCBR321	Beta-174732	7,590 ± 80	8,530–8,200

* These dates are probably exaggerated due to the reservoir effect common in mollusk shells.

also include many well-preserved postcranial elements from Sumidouro, which unfortunately cannot be matched among themselves or with the skulls.

Specimen SH-17 was not included in the quantitative analysis presented here because it is a statistical outlier. Besides presenting a completely different cranial morphology when compared to all other specimens, this skull also exhibits completely different taphonomic characteristics. For instance, SH-17 does not have sediments accumulated within its braincase or permeating the trabecular area in the exposed parts of the skull. In addition, the interior of the braincase does not show a patina of great age but instead appears fresh, a feature very different from the other skulls in the collection. This is clearly an intrusive individual that was probably discharged into the cave much later than the other specimens. The uniqueness of SH-17 was also noticed by previous physical anthropologists (Ten Kate, 1885; Rivet, 1908). In summary, a total of 30 individuals (16 males and 14 females), all adults, were included in our quantitative analysis.

Howells' protocol (Howells, 1973, 1989, 1995) was used as the standard for the measurements in order to allow for comparison with other world populations. All skulls were measured by the senior author. Males and females were analyzed separately.

Extensive quantitative analysis was performed to compare the cranial morphology of the Sumidouro sample with Howells' world populations plus two coastal archaic Brazilian series (Tapera and Base Aérea; Table 5) that were added to increase the size of the South American sample.

The following analyses were conducted to explore Sumidouro's morphological affinities based on its central tendency and internal variation: (1) principal components analysis (PCA) on centroids; (2) PCA on individuals; (3) canonical variates analysis (CVA); (4) Mahalanobis distances expressed through multidimensional scaling; (5) principal coordinate analysis based on heritability corrected data ($h^2 = 0.55$); and (6) Mahalanobis distance, posterior probability, and typicality probability between each individual from Sumidouro to the centroids of the comparative samples. Although the first procedure is redundant with the second, the PCA on centroids was included, because in this case, all individuals from Sumidouro contributed to the calculation of its means, irrespective of the

degree of integrity of the specimen. In addition, this was the only analysis in which missing values did not need to be replaced.

All analyses were performed on four subsets of the data: males with and without size correction and females with and without size correction. Size correction (also known as Q-standardization) was performed by dividing each variable of each skull by the geometric mean of all variables of the same specimen (Darroch and Mosimann, 1985). With the exception of the first analysis (PCA based on centroids), which took into account all individuals from Sumidouro, the remaining analyses were based on the 17 (9 males and 8 females) best-preserved skulls and on the best-represented variables (27 for males and 22 for females). Even with the most complete skulls, replacement of missing values was necessary in some cases. The replacement was performed by regressing the global mean of a specific variable on the variables present in the specimen with missing data. In total, males had 92.2% of original values for the 27 variables used, while females had 84.7% of the 22 variables used. All analyses generated similar results. Due to their redundancy, only analyses 1, 2, 4, and 6, based on size-corrected data, are presented here.

Results

Figure 4 (males, shape only) shows the position of the Sumidouro centroid in the morphospace defined by PC1 and PC2. Sumidouro shows a clear morphological affinity with Australo-Melanesians (Australia and Tasmania) and sub-Saharan Africans (Zulu and Teita).

In the distribution of the samples in the morphospace of Figure 5 (females, shape only), also defined by PC1 and PC2, Sumidouro is strongly associated with Australo-Melanesians, as well as with Easter Islanders and Eskimos. It is important to recall that, according to Howells (1973, 1989, 1995), Easter Islanders are the most "Australo-Melanesic" population of Polynesia.

It is also important to emphasize that, in Figures 4 and 5, the two Brazilian late archaic samples (Tapera and Base Aérea) occupy a position opposite to Sumidouro, a region of the morphospace also occupied by late Asian and American native populations.

Table 2
Individual measurements of Sumidouro male specimens (in millimeters)

	SH 01	SH 02	SH 03	SH 04	SH 05	SH 09	SH 11	SH 13	SH 16	WN 01	WN 04	WN 05	WN 06	WN 08	WN 10	WN 11
Glabello-occipital length (GOL)	194	185	191	182	183	182	197	184	180	—	—	—	—	—	—	—
Nasion-occipital length (NOL)	190	180	186	179	180	180	191	180	177	—	—	—	—	—	—	—
Basion-nasion length (BNL)	—	—	98	102	93	98	110	—	102	—	—	—	—	—	—	—
Basion-bregma height (BBH)	—	—	134	137	132	139	141	—	139	—	131	—	—	—	—	—
Maximum cranial breadth (XCB)	130	128	132	128	129	129	140	131	131	—	136	—	—	—	—	—
Maximum frontal breadth (XFB)	115	113	110	114	110	114	117	110	113	—	—	—	—	—	—	—
Bistephanic breadth (STB)	113	110	110	114	109	114	117	110	111	—	—	—	—	—	—	—
Bizygomatic breadth (ZYB)	—	—	135	140	127	134	—	—	134	—	—	—	—	—	—	—
Biauricular breadth (AUB)	—	121	118	126	120	119	128	112	123	—	—	—	—	—	—	—
Minimum cranial breadth (WCB)	—	73	69	73	71	73	79	—	72	—	—	—	—	—	—	—
Biauricular breadth (ASB)	—	114	111	113	112	113	113	107	108	—	—	—	—	—	115	110
Basion-prosthion length (BPL)	—	—	96	—	91	93	—	—	95	—	—	—	—	—	—	—
Nasion-prosthion height (NPH)	70	63	67	—	57	65	—	—	61	—	—	—	57	—	—	—
Nasal height (NLH)	47	47	45	50	45	47	—	—	49	49	—	—	45	—	—	—
Orbit height (OBH)	34	38	31	33	32	35	—	—	33	32	—	34	33	—	—	—
Orbit breadth (OBB)	43	39	40	40	39	41	—	—	40	43	—	37	39	—	—	—
Bijugal breadth (JUB)	—	—	113	119	114	116	—	—	117	—	—	—	—	—	—	—
Nasal breadth (NLB)	—	—	22	24	24	25	—	—	25	—	—	—	23	—	—	—
Palate breadth, external (MAB)	—	66	58	63	—	62	—	—	64	—	—	—	48	—	—	—
Mastoid height (MDH)	19	—	26	27	22	24	—	—	20	23	—	22	—	—	—	—
Mastoid breadth (MDB)	14	—	11	16	12	16	16	14	12	15	19	15	—	—	—	—
Bimaxillary breadth (ZMB)	—	—	95	103	95	103	—	—	100	—	—	—	90	—	—	—
Zygomaxillary subtense (SSS)	—	—	23	22	17	24	—	—	22	—	—	—	—	—	—	—
Bifrontal breadth (FMB)	—	—	98	103	97	103	101	—	101	—	—	—	—	—	—	—
Naso-frontal subtense (NAS)	—	—	14	17	13	15	19	—	15	—	—	—	—	—	—	—
Biorbital breadth (EKB)	—	—	96	100	98	101	—	—	99	—	—	—	—	—	—	—
Dacryon subtense (DKS)	—	—	8	7	9	10	—	—	8	—	—	—	—	—	—	—
Interorbital breadth (DKB)	27	26	21	27	25	26	28	23	26	29	—	—	21	—	—	—
Naso-dacryal subtense (NDS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Simotic cord (WNB)	10	—	—	10	7	—	7	—	10	—	—	—	7	—	—	—
Simotic subtense (SIS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Malar length, inferior (IML)	—	—	46	50	30	37	—	—	50	—	—	—	—	—	—	—
Malar length, maximum (XML)	—	—	62	66	41	52	—	—	64	—	—	—	—	—	—	—
Malar subtense (MLS)	—	—	12	16	8	11	—	—	18	—	—	—	—	—	—	—
Cheek height (WMH)	24	23	24	27	22	23	—	—	23	26	—	—	21	—	—	—
Supraorbital projection (SOS)	9	7	8	10	7	9	7	8	7	7	—	5	8	—	—	—
Glabella projection (GLS)	5	5	2	3	3	3	5	4	4	5	—	3	4	—	—	—
Foramen magnum length (FOL)	—	—	39	39	39	35	37	—	40	—	—	35	—	—	—	—
Frontal cord (FRC)	116	110	110	111	111	112	124	109	110	112	—	111	106	—	—	—
Frontal subtense (FRS)	25	25	25	26	26	26	28	21	21	23	—	25	24	—	—	—
Nasion-subtense fraction (FRF)	57	47	49	52	46	48	56	53	46	54	—	48	52	—	—	—
Parietal cord (PAC)	121	109	115	114	122	110	108	140	117	131	—	—	—	104	—	—
Parietal subtense (PAS)	26	24	21	26	28	22	22	34	26	30	—	—	—	19	—	—
Bregma-subtense fraction (PAF)	72	48	64	62	60	64	54	61	62	61	—	—	—	57	—	—
Occipital cord (OCC)	—	—	110	97	95	104	107	—	94	—	—	—	—	—	108	—
Occipital subtense (OCS)	—	—	40	25	27	31	34	—	25	—	—	—	—	—	29	—
Lambda-subtense fraction (OCF)	—	—	64	44	45	49	53	—	51	—	—	—	—	—	61	—
Vertex radius (VRR)	—	121	121	127	124	128	131	121	130	—	—	—	—	—	—	—
Nasion radius (NAR)	—	92	93	96	91	91	104	93	96	—	—	—	—	—	—	—
Subspinale radius (SSR)	—	102	98	97	93	94	—	—	98	—	—	—	—	—	—	—
Prosthion radius (PRR)	—	108	101	—	98	100	—	—	100	—	—	—	—	—	—	—
Dacryon radius (DKR)	—	86	80	83	80	80	—	81	84	—	—	—	—	—	—	—
Zygo-orbitale radius (ZOR)	—	85	83	85	81	80	—	—	83	—	—	—	—	—	—	—
Frontal-malare radius (FMR)	—	81	78	82	79	79	87	85	82	—	—	—	—	—	—	—
Ectoconchion radius (EKR)	—	77	74	78	74	72	—	—	76	—	—	—	—	—	—	—
Zygomaxillare radius (ZMR)	—	79	76	79	76	72	—	—	78	—	—	—	—	—	—	—
Molar alveolus radius (AVR)	—	87	—	—	—	82	—	—	84	—	—	—	—	—	—	—
Bregma radius (BRR)	—	116	121	123	120	124	128	127	126	—	—	—	—	—	—	—
Lambda radius (LAR)	—	107	115	106	110	113	111	106	115	—	—	—	—	—	—	—
Ophistion radius (OPR)	—	—	47	47	44	44	46	—	45	—	—	—	—	—	—	—
Basion radius (BAR)	—	—	16	19	15	18	16	—	15	—	—	—	—	—	—	—

Table 3
Individual measurements of Sumidouro female specimens (in millimeters)

	SH 06	SH 07	SH 08	SH 10	SH 14	SH 15	SH 17*	WN 02	WN 03	WN 07	WN 09	WN 12	WN 13	WN 14	WN 15
Glabella-occipital length (GOL)	181	176	185	179	174	172	166	190	174	—	—	—	—	—	—
Nasion-occipital length (NOL)	—	172	180	177	172	169	164	185	172	—	—	—	—	—	—
Basion-nasion length (BNL)	—	—	97	—	91	92	—	—	—	—	—	—	—	—	—
Basion-bregma height (BBH)	134	—	136	—	126	130	—	—	—	—	—	—	—	—	—
Maximum cranial breadth (XCB)	131	123	131	132	127	124	136	134	120	131	—	—	—	—	—
Maximum frontal breadth (XFB)	—	105	116	110	106	107	110	110	—	—	—	—	—	—	—
Bistephanic breadth (STB)	—	105	113	108	105	107	110	109	—	—	—	—	—	—	—
Bizygomatic breadth (ZYB)	—	—	—	—	—	—	124	—	—	—	—	—	—	—	—
Biauricular breadth (AUB)	108	113	121	127	108	115	119	—	—	—	—	—	—	—	—
Minimum cranial breadth (WCB)	82	70	71	80	71	69	71	86	—	—	—	—	—	—	—
Biasterionic breadth (ASB)	113	106	113	111	110	94	104	—	87	—	—	106	—	—	—
Basion-prosthion length (BPL)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nasion-prosthion height (NPH)	—	63	—	64	—	—	53	—	—	—	—	—	—	63	—
Nasal height (NLH)	—	47	—	47	—	—	41	—	—	—	—	—	—	46	—
Orbit height (OBH)	—	35	34	33	—	—	31	—	—	—	—	—	—	33	—
Orbit breadth (OBB)	—	36	39	39	—	—	36	—	—	—	—	—	—	38	—
Bijugal breadth (JUB)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nasal breadth (NLB)	—	25	27	25	—	—	—	—	—	—	—	—	—	25	—
Palate breadth, external (MAB)	—	—	63	70	—	—	58	—	—	—	—	—	—	—	60
Mastoid height (MDH)	—	14	24	—	—	—	—	—	—	—	17	—	—	—	—
Mastoid breadth (MDB)	14	8	13	17	14	8	13	—	—	—	12	—	—	—	—
Bimaxillary breadth (ZMB)	—	—	—	—	—	—	90	—	—	—	—	—	—	—	—
Zygomaxillary subtense (SSS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bifrontal breadth (FMB)	—	—	—	100	—	94	91	—	91	—	—	—	—	98	—
Naso-frontal subtense (NAS)	—	—	—	13	—	11	—	—	14	—	—	—	—	13	—
Biorbital breadth (EKB)	—	—	—	—	—	—	93	—	—	—	—	—	—	—	—
Dacryon subtense (DKS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Interorbital breadth (DKB)	—	—	26	25	24	22	23	25	24	—	—	—	—	24	—
Naso-dacryal subtense (NDS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Simotic cord (WNB)	—	—	—	—	—	—	7	—	—	—	—	—	—	7	—
Simotic subtense (SIS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Malar length, inferior (IML)	—	—	—	—	—	—	49	—	—	—	—	—	—	—	—
Malar length, maximum (XML)	—	—	—	—	—	—	60	—	—	—	—	—	—	—	—
Malar subtense (MLS)	—	—	—	—	—	—	10	—	—	—	—	—	—	—	—
Cheek height (WMH)	—	24	24	—	—	—	19	—	—	—	—	—	—	24	23
Supraorbital projection (SOS)	5	5	6	6	7	6	5	6	5	—	—	—	—	5	—
Glabella projection (GLS)	—	2	3	3	2	2	2	5	1	—	—	—	—	2	—
Foramen magnum length (FOL)	—	—	38	—	—	31	—	—	—	—	—	—	—	—	—
Frontal cord (FRC)	—	104	113	115	107	106	104	113	100	—	—	—	—	—	—
Frontal subtense (FRS)	—	24	26	23	24	26	23	24	23	—	—	—	—	—	—
Nasion-subtense fraction (FRF)	—	51	51	56	46	49	44	44	44	—	—	—	—	—	—
Parietal cord (PAC)	112	107	113	124	108	116	100	118	105	111	—	—	112	—	—
Parietal subtense (PAS)	24	22	22	29	24	27	21	25	24	29	—	—	—	—	—
Bregma-subtense fraction (PAF)	60	64	61	63	55	60	54	60	58	61	—	—	—	—	—
Occipital cord (OCC)	99	—	101	—	—	93	—	—	—	—	—	—	—	—	—
Occipital subtense (OCS)	30	—	33	—	—	26	—	—	—	—	—	—	—	—	—
Lambda-subtense fraction (OCF)	44	—	51	—	—	47	—	—	—	—	—	—	—	—	—
Vertex radius (VRR)	126	114	127	131	123	122	125	—	—	—	—	—	—	—	—
Nasion radius (NAR)	—	90	94	94	90	89	88	—	—	—	—	—	—	—	—
Subspinale radius (SSR)	—	90	—	99	—	—	93	—	—	—	—	—	—	—	—
Prosthion radius (PRR)	—	94	—	105	—	—	95	—	—	—	—	—	—	—	—
Dacryon radius (DKR)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Zygo-orbitale radius (ZOR)	—	80	—	84	—	—	—	—	—	—	—	—	—	—	—
Frontal-malare radius (FMR)	—	79	85	77	76	81	80	—	—	—	—	—	—	—	—
Ectoconchion radius (EKR)	—	73	—	72	—	—	76	—	—	—	—	—	—	—	—
Zygomaxillare radius (ZMR)	—	74	—	79	—	—	75	—	—	—	—	—	—	—	—
Molar alveolus radius (AVR)	—	76	—	87	—	—	82	—	—	—	—	—	—	—	—
Bregma radius (BRR)	121	111	125	129	116	118	120	—	—	—	—	—	—	—	—
Lambda radius (LAR)	106	104	111	110	109	100	110	—	—	—	—	—	—	—	—
Ophistion radius (OPR)	46	—	46	—	—	40	—	—	—	—	—	—	—	—	—
Basion radius (BAR)	16	—	15	—	13	15	—	—	—	—	—	—	—	—	—

* Not used in the analyses because of its late intrusive nature.

Table 4
General information about the cranial specimens from Sumidouro

Institutional reference	Sex	Housing institution	Number of Howells variables taken	Percentage of completeness*
SH-01	Male	ZMUC-DN	22	36.07
SH-02	Male	ZMUC-DN	35	57.38
SH-03	Male	ZMUC-DN	57	93.44
SH-04	Male	ZMUC-DN	55	90.16
SH-05	Male	IHGB-BR	57	93.44
SH-06	Female	ZMUC-DN	19	31.15
SH-07	Female	ZMUC-DN	35	57.38
SH-08	Female	NHM-UK	37	60.66
SH-09	Male	ZMUC-DN	58	95.08
SH-10	Female	ZMUC-DN	37	60.66
SH-11	Male	ZMUC-DN	34	55.74
SH-13	Male	ZMUC-DN	23	37.70
SH-14	Female	ZMUC-DN	26	42.62
SH-15	Female	ZMUC-DN	33	54.10
SH-16	Male	ZMUC-DN	59	96.72
SH-17	Female	ZMUC-DN	42	68.85
WN-01	Male	ZMUC-DN	15	24.59
WN-02	Female	ZMUC-DN	15	24.59
WN-03	Female	ZMUC-DN	15	24.59
WN-04	Male	ZMUC-DN	4	6.56
WN-05	Male	ZMUC-DN	9	14.75
WN-06	Male	ZMUC-DN	15	24.59
WN-07	Female	ZMUC-DN	3	4.92
WN-08	Male	ZMUC-DN	3	4.92
WN-09	Female	ZMUC-DN	2	3.28
WN-10	Male	ZMUC-DN	4	6.56
WN-11	Male	ZMUC-DN	1	1.64
WN-12	Female	ZMUC-DN	1	1.64
WN-13	Female	ZMUC-DN	1	1.64
WN-14	Female	ZMUC-DN	12	19.67
WN-15	Female	ZMUC-DN	2	3.28

Institutional abbreviations are as follows: ZMUC-DN, Zoological Museum of University of Copenhagen, Denmark; IHGB-BR, Instituto Histórico e Geográfico do Rio de Janeiro, Brazil; NHM-UK, Natural History Museum, London, England.

* Based on the total number of measurements taken by Howells (61).

Table 6 presents the correlations among the original variables and the first two principal components extracted (based on the sample centroids) for both sexes. In the case of males (shape only), the first principal component shows high positive correlations ($r > 0.50$; $p < 0.01$) with variables describing neurocranial breadth (XCB, XFB, ZYB, AUB, ASB), facial height (NPH, NLH, WMH), orbital height (OBH), bizygomatic breadth (JUB), and alveolar breadth (MAB). The first principal component also shows high negative correlations ($r < -0.50$; $p < 0.01$) with some variables describing cranial length (GOL, BPL), inferior malar length (IML), and alveolar prognathism (SSR and PRR). The second principal component shows high positive correlations ($r > 0.50$; $p < 0.01$) with bizygomatic breadth (ZYB), glabellar projection (GLS), and subnasal radius (SSR), and high negative correlations ($r < -0.50$; $p < 0.01$) with cranial length (GOL, NOL, PAC, PAF), frontal breadth (XFB, FMB), interorbital breadth (DKB, WNB), and frontal subtense (FRS).

In the female analysis (shape only), high positive correlations ($r > 0.50$; $p < 0.01$) can be seen between the first

Table 5
Reference populations used and their geographical location

Sample	Geographic region	Number of males	Number of females
Base Aérea	Late archaic America	12	12
Tapera	Late archaic America	28	30
Eskimo	North America	53	55
Arikara	North America	42	27
Santa Cruz	North America	51	51
Peru	South America	55	55
Teita	Africa	33	50
Dogon	Africa	47	52
Zulu	Africa	55	46
Egypt	Africa	58	53
Bushman	Africa	41	49
North Japan	Asia	55	32
South Japan	Asia	50	41
Ainu	Asia	48	38
Buriat	Asia	55	54
Anyang	Asia	42	—
Hainan	Asia	45	38
Australia	Australo-Melanesia	52	49
Tasmania	Australo-Melanesia	45	42
Tolai	Australo-Melanesia	56	54
Norse	Europe	55	55
Zalavar	Europe	53	45
Berg	Europe	56	53
South Maori	Polynesia	10	—
North Maori	Polynesia	10	—
Mokapu	Polynesia	51	49
Easter Island	Polynesia	49	37
Moriori	Polynesia	57	51
Andaman	South Asia	35	35
Philippines	Western Pacific	50	27
Guam	Western Pacific	30	—
Atayal	Western Pacific	29	18
Total		1417	1198

principal component and neurocranial breadth (XCB, XFB, AUB, ASB), facial height (NPH, NLH), and orbital height (OBH), and high negative correlations ($r < -0.50$; $p < 0.01$) with supraorbital projection (SOS) and alveolar prognathism (SSR and PRR). The second principal component of this analysis shows high positive correlations ($r > 0.50$; $p < 0.01$) with glabellar projection (GLS) and high negative correlations ($r < -0.50$; $p < 0.01$) with cranial length (GOL, NOL, FRC, PAC, PAF), upper facial breadth (FMB), interorbital breadth (DKB), and nasion and frontal subtenses (NAS, FRS).

Figure 6 (males, shape only) shows the position of the Sumidouro centroid and sample dispersion (95% confidence ellipse) in the morphospace defined by PC1 and PC2. The Australo-Melanesians occupy the center of the ellipse. North Maori, Eastern Islanders, and Eskimo are found within the South American Paleoindian dispersion as well.

In the distribution of the samples in the morphospace of Figure 7 (females, shape only), the well-defined position of Sumidouro in the inferior right quadrant of the graph attests to its close morphological relationship with Australo-Melanesians. Note that the few outliers found among the Sumidouro specimens can be found near sub-Saharan Africans. In these

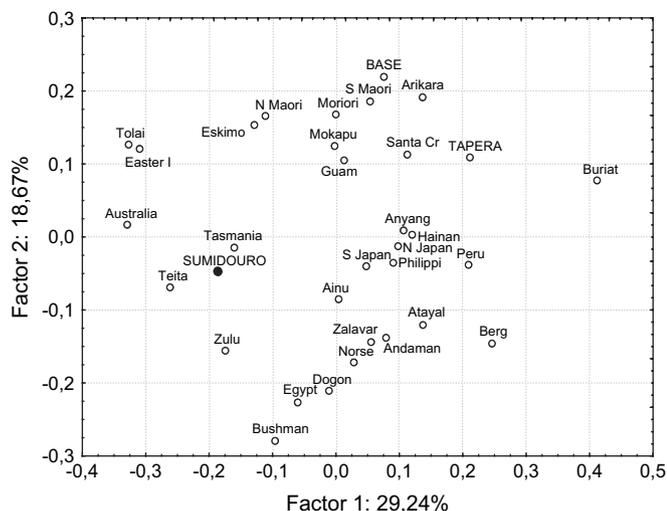


Fig. 4. Morphological affinities among the series centroids (males, shape only), as illustrated by the first two principal components. The percentages associated with each axis are the amount of variation explained by each principal component. In this analysis, series with higher values on the first PC have wider and shorter neurocrania, high faces and orbits, low prognathism, and wide alveolar regions. Series with high values on the second PC have shorter neurocrania, narrower frontals and interorbital regions, wider faces, and higher glabellar and nasal projections.

analyses (Figures 6 and 7), the two Brazilian late archaic samples (Tapera and Base Aerea) again appear closer to the Amerindian samples and in a distant position from Sumidouro.

Table 7 presents the correlations among the original variables and the first two principal components extracted (based on Sumidouro's individuals) in these analyses. In the case of males (shape only), the first principal component presents

Table 6

Correlations between the first two principal components and the original variables used in the analyses based on sample centroids

Variable	Male shape		Female shape	
	PC 1	PC 2	PC 1	PC 2
ASB	0.6726	-0.3524	0.7414	-0.2713
AUB	0.8601	0.3574	0.8423	0.3697
AVR	-0.3104	0.4914	-0.4248	0.3148
BBH	0.2077	0.1302	0.2038	-0.0681
BNL	-0.3393	0.0650	-0.0772	-0.2189
BPL	-0.6137	0.0533		
DKB	-0.1099	-0.6439	-0.1895	-0.5190
DKR	-0.2007	0.0464		
DKS	-0.3574	-0.2453		
EKB	0.0762	-0.4763		
EKR	-0.0779	0.2622	-0.0951	0.2171
FMB	-0.0902	-0.5447	-0.0293	-0.6031
FMR	-0.1767	0.2521	-0.1609	0.2387
FOL	0.3339	-0.3770	0.3892	-0.2302
FRC	0.3630	-0.4198	0.4923	-0.5537
FRF	0.4728	0.0014	0.3791	-0.2641
FRS	-0.1216	-0.7525	-0.0312	-0.7478
GLS	-0.2105	0.6029	-0.4269	0.6080
GOL	-0.4835	-0.5993	-0.4050	-0.7685
IML	-0.6416	0.1890		
JUB	0.5919	0.3657		
MAB	0.5232	0.0974	0.3445	0.0025
MLS	0.0623	0.0095		
NAR	-0.3183	0.0093	-0.1888	-0.1965
NAS	-0.3078	-0.3515	-0.0892	-0.5210
NLB	-0.1070	-0.2698	-0.1527	-0.4230
NLH	0.6661	0.4500	0.6728	0.2935
NOL	-0.3082	-0.6838	-0.1830	-0.8261
NPH	0.6654	0.3680	0.6158	0.3298
OBH	-0.0486	-0.1491	0.1782	-0.2404
OBH	0.5636	0.3534	0.5316	0.2496
OCC	0.3287	0.1061	0.4307	-0.0619
OCF	0.1424	0.1737	0.4403	0.2003
OCS	-0.0853	-0.0682	-0.0688	-0.1823
PAC	-0.3501	-0.7318	-0.3122	-0.7541
PAF	-0.0855	-0.7943	-0.0812	-0.8034
PAS	0.0039	-0.3877	-0.1060	-0.2489
PRR	-0.5259	0.3819	-0.5367	0.1309
SOS	-0.3934	0.0368	-0.5382	-0.0516
SSR	-0.6397	0.5984	-0.6042	0.3017
SSS	-0.2174	0.3870		
WMH	0.5832	0.4839	0.4343	0.4978
WNB	-0.0684	-0.5629		
XCB	0.8719	-0.3478	0.9200	-0.2066
XFB	0.7915	-0.5295	0.8814	-0.3158
XML	0.0191	0.4553		
ZMB	0.4835	0.2572	-0.4847	0.2437
ZMR	-0.3879	0.2848		
ZOR	-0.3743	0.0422	-0.3735	0.0508
ZYB	0.6777	0.5620		

Values in bold are the highest correlations for each PC.

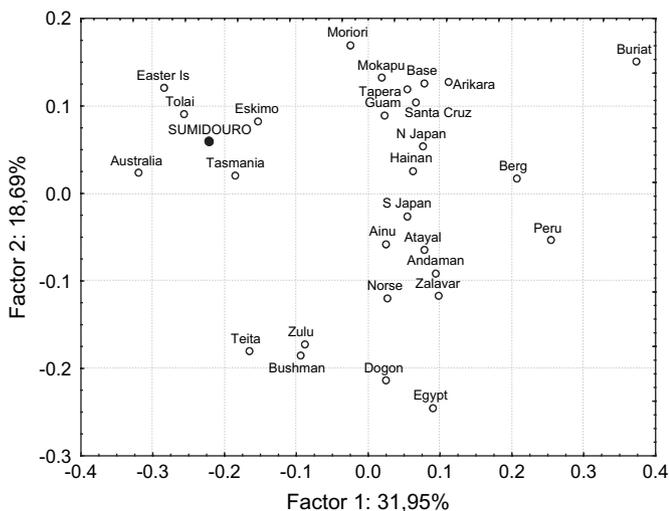


Fig. 5. Morphological affinities among the series centroids (females, shape only), as illustrated by the first two principal components. The percentages associated with each axis are the amount of variation explained by each principal component. In this analysis, series with higher values on the first PC have wider neurocrania, high faces and orbits, and low prognathism. Series with high values on the second PC have shorter neurocrania, narrow frontals and interorbital regions, high glabellar projections, and small nasion and frontal projections.

high positive correlations ($r > 0.50$; $p < 0.001$) with cranial breadth (XCB, XFB, AUB, WCB) and with nasal and orbital height (NLH and OBH), and high negative correlations ($r < -0.50$; $p < 0.001$) with supraorbital projection (SOS) and parietal length (PAC). The second principal component shows high positive correlations ($r > 0.50$; $p < 0.001$) with mastoid breadth (MDB) and glabellar projection (GLS), and

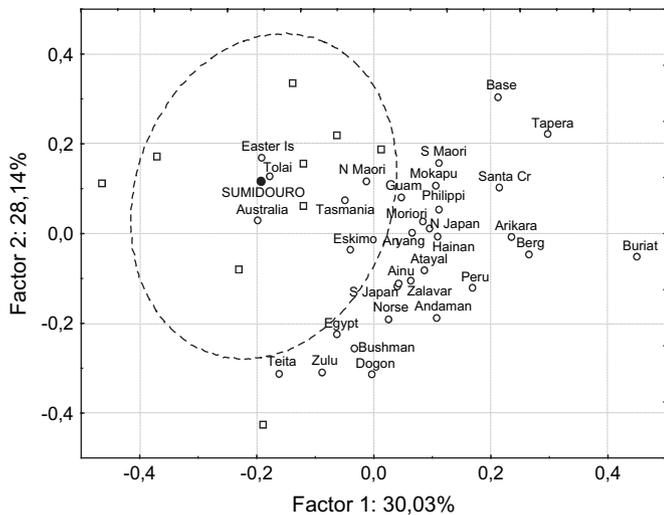


Fig. 6. Morphological affinities among the series (males, shape only), as illustrated by the first two principal components. The squares represent Sumidouro individuals and the ellipse represents their 95% confidence dispersion. The percentages associated with each axis are the amount of variation explained by each principal component. In this analysis, individuals or series with higher values on the first PC have wider neurocrania, shorter parietals, high noses and orbits, and small supraorbital projections. High values on the second PC indicate shorter and narrower neurocrania, narrower orbits, wider mastoids, higher glabellar projections, and smaller nasion and frontal projections.

high negative correlations ($r < -0.50$; $p < 0.001$) with cranial length (GOL, NOL, FRC, PAF), cranial breadth (XCB, XFB), orbital breadth (OBB), frontal subtense (FRS), and nasion radius (NAR).

In the case of the females (shape only), the first principal component shows a high positive correlation ($r = 0.79$;

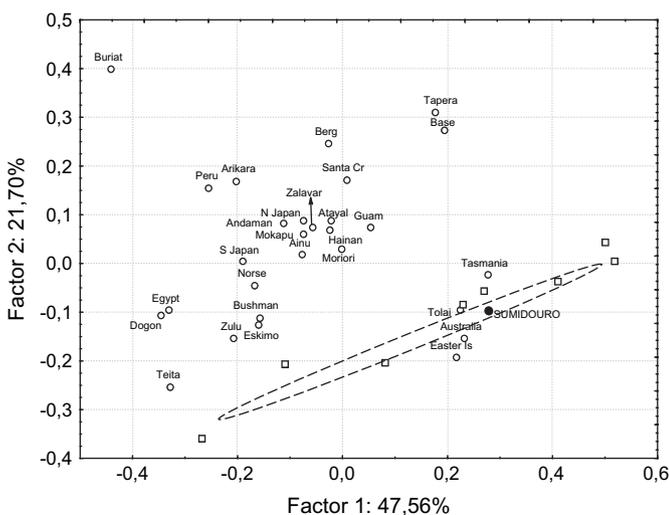


Fig. 7. Morphological affinities among the series (females, shape only), as illustrated by the first two principal components. The squares represent Sumidouro individuals and the ellipse represents their 95% confidence dispersion. The percentages associated with each axis are the amount of variation explained by each principal component. In this analysis high values on the first PC are associated with shorter and narrower neurocrania; smaller nasion, frontomale, and frontal projections; and high glabellar projections. Individuals or series with high values on the second PC tend to have shorter neurocrania and wider skull bases.

Table 7

Correlations between the first two principal components and the original variables used, taking into account the dispersion of the Sumidouro individuals

Variable	Male shape		Female shape	
	PC 1	PC 2	PC 1	PC 2
ASB	0.2916	-0.4932	-0.4811	0.4441
AUB	0.8322	-0.1950	-0.7253	0.4630
DKB	-0.4448	0.0201	-0.0651	-0.4818
DKR	-0.0184	-0.4268		
FMR	-0.2627	-0.1808	-0.5165	-0.3638
FRC	0.1660	-0.6600	-0.8792	-0.0123
FRF	0.1422	-0.1317	-0.5813	-0.0618
FRS	-0.0309	-0.6016	-0.5183	-0.3152
GLS	-0.0421	0.6819	0.7911	0.1110
GOL	-0.4066	-0.7676	-0.7281	-0.5965
MDB	0.0987	0.6803	0.4401	0.3877
NAR	-0.1292	-0.5095	-0.7485	-0.4558
NLH	0.7465	-0.1140		
NOL	-0.3083	-0.8525	-0.8140	-0.4806
OBB	-0.0180	-0.6173		
OBH	0.5227	-0.0735		
PAC	-0.6205	-0.4445	-0.3701	-0.5793
PAF	-0.4133	-0.5730	-0.4377	-0.5647
PAS	-0.4188	-0.0450	-0.0249	-0.2299
SOS	-0.5830	0.3249	0.3879	-0.3875
WCB	0.5798	0.1486	0.1191	0.5554
WMH	0.4207	0.1607		
XCB	0.7353	-0.6009	-0.8440	0.4593
XFB	0.6259	-0.6231	-0.8792	0.3130

Note: The values in boldface are the highest correlations for each PC.

$p < 0.001$) with glabellar projection and high negative correlations ($r < -0.50$; $p < 0.001$) with cranial length (GOL, NOL, FRC, FRF), cranial breadth (XCB, XFB, AUB), frontal subtense (FRS), and nasion and frontomale radii (NAR and FMR). The second principal component shows a high positive correlation ($r = 0.56$; $p < 0.001$) with minimum cranium breadth (WCB) and high negative correlations ($r < -0.5$; $p < 0.001$) with some variables associated with neurocranial length (GOL, PAC, PAF).

Table 8 lists the Mahalanobis distances between Sumidouro and the comparative samples for both sexes. In the case of males, the smallest distance is with Tolai, an Australo-Melanesian series. In the case of females, the closest comparative population is from northern Japan.

The complete distance matrix (not shown) was analyzed using multidimensional scaling to generate the graphs seen in Figures 8 and 9. Figure 8 (males, shape only) shows Sumidouro occupying the same area of the morphospace (lower right) as the three Australo-Melanesian series. In Figure 9 (females, shape only), the late Paleoindian sample appears intermediate to Australo-Melanesians and sub-Saharan Africans. It is clear that, when the complete distance matrices are taken into account, northern Japan is far from the target population, the same being true of Base Aérea and Tapera. In the two graphs, they are among the farthest populations from Sumidouro, being in the same general area occupied by late Amerindians.

The results obtained on individual assignment (Mahalanobis distance, posterior probability, and typicality probability)

Table 8
Mahalanobis distance between the Sumidouro centroid and the reference samples

Sample	Male shape	Female shape
Ainu	31.4578	18.4252
Andaman	31.2569	29.3782
Anyang	26.6103	
Arikara	48.6802	37.9730
Atayal	22.1981	15.6137
Australian	32.0274	27.2933
Base Aérea	35.7053	37.2537
Berg	46.8990	34.1502
Buriat	65.2959	52.4277
Bushman	38.0046	28.6386
Dogon	33.8777	25.2388
Easter Island	27.8956	24.4149
Egypt	37.9956	31.7324
Eskimo	41.7515	29.9221
Guam	26.3747	18.7234
Hainan	28.7870	16.2982
Mokapu	33.5652	30.9665
Moriori	46.4194	35.7875
North Japan	31.1430	14.9893
North Maori	41.2277	
Norse	32.7037	30.2034
Peru	31.2837	32.6190
Philippines	26.0290	
South Japan	24.9158	16.1272
South Maori	39.8428	
Santa Cruz	31.4940	30.3914
Tapera	43.0339	38.0308
Tasmania	34.2925	30.8944
Teita	28.0876	24.6207
Tolai	20.8904	15.7655
Zalavar	33.9137	24.3624
Zulu	26.2198	17.6576

are summarized in Table 9. For males (shape only) 55.6% (5/9) of the individuals are assigned to southern Asian series, 11.1% (1/9) to an Australo-Melanesian series, 11.1% (1/9) to Teita, an African series, 11.1% (1/9) to Easter Island, and 11.1% (1/9) to Santa Cruz.

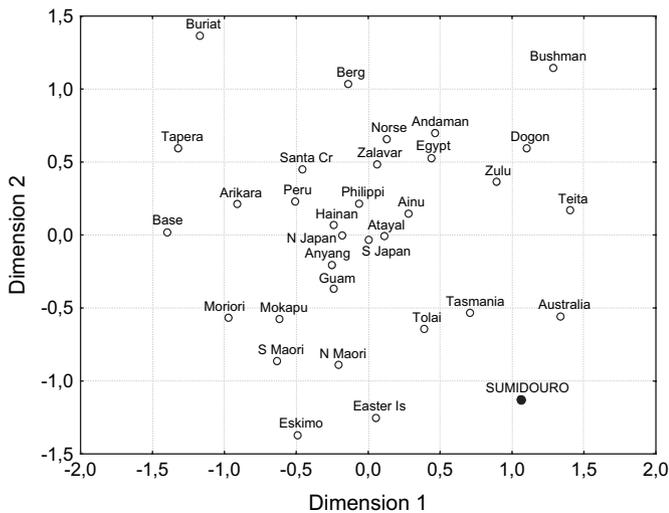


Fig. 8. Multidimensional scaling (stress = 0.1806167) based on Mahalanobis distances between centroids (males, shape only).

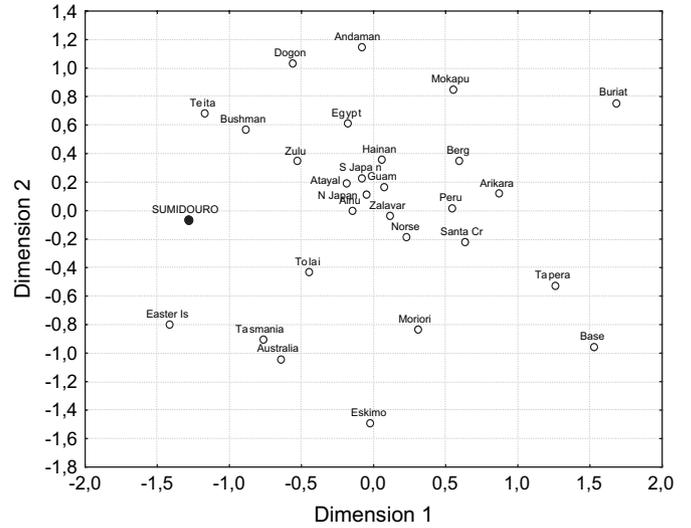


Fig. 9. Multidimensional scaling (stress = 0.2082259) based on Mahalanobis distances between centroids (females, shape only).

According to the posterior probabilities (also shown in Table 9), with the exception of two cases (SH-09 and SH-16), there is at least a 45% chance for the association between the Sumidouro individuals and their closest reference series. On the other hand, when typicality probabilities are taken into account, only four specimens (SH-01, SH-05, SH-11, and SH16) have probabilities higher than 5% of belonging to their closest reference sample. The remaining ones are significantly distinct from their closest sample. This is expected because none of the comparative samples included in the analyses can be said to represent the real population the first Americans came from.

Females show similar tendencies: 25% (2/8) of the individuals are assigned to southern Asian series, 25% (2/8) to sub-

Table 9
Mahalanobis distances (D^2), posterior probabilities (PP), and typicality probabilities (Typ) between Sumidouro individuals and their closest reference series

Individual	Closest series	D^2	PP	Typ
Males				
SH01	Australian	31.9293	0.7548	0.2347
SH02	Santa Cruz	57.5967	0.6213	0.0005
SH03	Teita	47.1040	0.8919	0.0096
SH04	Guam	42.4796	0.4665	0.0295
SH05	Atayal	28.3509	0.8327	0.3931
SH09	Atayal	47.7510	0.2992	0.0082
SH11	Easter Island	32.9469	0.6468	0.1988
SH13	Andaman	138.1391	0.6084	0.0000
SH16	Atayal	38.8613	0.2503	0.0652
Females				
SH06	Atayal	96.0421	0.6842	0.0000
SH07	Eskimo	51.0825	0.3287	0.0004
SH08	Easter Island	36.0441	0.5637	0.0300
SH10	Atayal	28.9505	0.3939	0.1463
SH14	Zulu	36.3045	0.4711	0.0282
SH15	Hainan	29.7619	0.3827	0.1244
WN02	Australia	49.2265	0.9115	0.0007
WN03	Teita	37.0772	0.9632	0.0232

Table 10
Number of incorrect classifications for seven of Howells male series, based on Mahalanobis distances

Series tested	Geographic region	Number of skulls	Incorrect classifications	Series considered as the same geographic region
Norse	Europe	54	31 (57.4%)	Zalavar and Berg
North Japan	East Asia	55	31 (56.4%)	Hainan, Ainu, Anyang and South Japan
Mokapu	Polynesia	51	13 (25.5%)	South Maori, North Maori, Easter Island, and Moriori
Australia	Australo-Melanesia	52	11 (21.2%)	Tasmania and Tolai
Arikara	America	42	28 (66.6%)	Peru, Santa Cruz, and Eskimo
Teita	Africa	33	10 (30.3%)	Egypt, Dogon, and Zulu
Philippines	Western Pacific	50	38 (76.0%)	Atayal and Guam

Saharan African series, 12.5% (1/8) to Australia, 12.5% (1/8) to Easter Island, 12.5% (1/8) to Eskimo, and 12.5% (1/8) to Hainan. According to the posterior probabilities (Table 9), there is at least a 30% chance for the association between the tested individuals and their closest reference series. However, when typicality probabilities are considered, only two specimens (SH-15 and SH-10) can formally be considered (typicality probabilities higher than 0.05) as part of their closest sample (i.e., Hainan and Atayal, respectively).

Taken together, the assignments of the specimens from Sumidouro do not contradict what was found in the preceding analyses. Few individuals were assigned to northeastern Asian or recent Amerindian samples.

In order to assess the legitimacy of using individual classifications to explore population affinities, seven of Howells' male samples, representing seven different geographic regions (Howells, 1989), were submitted to the same discriminant analysis as applied to Sumidouro and using the same variables. As can be seen in Table 10, which presents the results of this exercise, misclassifications are not unusual, depending on the population being tested (ranging from 21.2% to 76.0%), even when complete skulls are used. These results show the problem with classifying only a few individuals from a sample to assess the morphological affinities of a human group. Williams et al. (2005) arrived at a similar conclusion. However, the small number of variables (12) included in their analysis may partially explain the unsuccessful results they obtained.

Discussion and conclusions

With the exception of SH-17, the remaining 30 human fossil skulls recovered by Peter Lund at Sumidouro, Lagoa Santa region, in 1843, can now be assigned to the early Holocene, as is the case for many other human skeletal remains found later in the region (e.g., Neves et al., 1998, 2003, 2004). This important collection represents the best existing series of well-preserved early American skulls from one site. Although unsuitable for paleodemographic analysis (because children and adolescents are strongly underrepresented), and poor in terms of postcranial elements, the human fossil remains from Sumidouro are certainly of special significance to those interested in the issue of the first Americans.

The comparative multivariate analyses carried out in this work demonstrate that the specimens from Sumidouro share

with other early material from Lagoa Santa and from elsewhere in South and Central America a single morphological pattern, currently referred to in the literature as Paleoamerican (Jantz and Owsley, 2001). Their morphology is characterized by long and narrow neurocrania, low and projecting faces, with low and wide orbits and noses. Similar morphologies can be found today only among Africans and Australo-Melanesians, and in the past among the first modern humans (Lahr, 1995, 1996; Neves et al., 1999a,b). On the other hand, present-day east Asians and Amerindians exhibit a cranial morphology (Lahr, 1995, 1996) very distinct from the Paleoamerican one, and from the first modern humans.

In the face of the results presented here, Hrdlička's (1912) argument that all Native American groups share one single biological ancestral population in the Old World can be seriously questioned, at least as far as Howells' recent Native American samples can be said to represent Amerindian variability as a whole. Together with several of Hrdlička's contemporaries and predecessors (e.g., Imbeloni, 1836; Rivet, 1908), we think that, when the cranial morphology of the first Americans is taken into account, the best explanatory scenario is that the New World was settled in ancient prehistoric times by at least two different biological populations: an early one with a cranial morphology found today in Africa and Australia, and a later one, with a cranial morphology similar to that prevailing today in northeastern Asia.

In principle, a local microevolutionary process cannot be peremptorily denied to explain the change from one morphology to the other. Powell and Neves (1999) explored this possibility by modeling different scenarios of demography and degree of genetic drift among the first Americans. They concluded that, under very stringent conditions, the cranial morphology of late and living Amerindians could have evolved in the Americas from the cranial pattern observed in Paleoindians. However, we believe that a local-evolution hypothesis is very difficult to sustain for three reasons. First, the same cranial changes would have had to have occurred in the Americas and in east Asia at approximately the same time, which is very unlikely. Second, at least in South America, the transition appears to have been abrupt. Finally, human cranial morphology is known today to respond adaptively only to extreme environmental conditions (Roseman and Weaver, 2004; Roseman, 2004). In other words, the two-components hypothesis is much more parsimonious than the local-evolution one.

Another piece of information that goes against the local-evolution hypothesis is the fact that Paleoamericans exhibit a dental pattern much more similar to Sundadonts than to Sinodonts (Powell and Neves, 1998). The evolution from the former to the latter is well documented in east Asia (Turner, 1990). This implies that at least two different (skeletal elements skull morphology and dental anatomy) would have evolved in parallel in Asia and in the New World, which makes the local-evolution hypothesis much less probable.

Our results strongly contradict those obtained by Seguchi et al. (2005), which were based on the individual classification of five skulls said to come from Sumidouro (indeed, a recent specimen and one not from Sumidouro were inadvertently included in their analysis; Neves and Velutini, 2004). Seguchi et al. (2005: 187) found that there is a stronger morphological affinity between Lagoa Santa and “prehistoric Jomon of Japan, recent Patagonia/Tierra del Fuego of South America; present day Mexico, Peru, and Archaic Americans of Windover and Indian Knoll of North America, than with our Australian sample.” As we demonstrated here using a pilot test involving individual classifications of Howells’ world samples (for similar results, see Williams et al., 2005), the use of a small number of skulls in this kind of approach may generate unreliable results. The similarities of the results obtained in all the analyses performed by us, based on the whole Sumidouro sample (and not biased by specimens of unknown provenience in Lund’s collection), show a clear association with Australo-Melanesians.

The detection of an “Australo-Melanesian” pattern of cranial morphology in the Americas (especially in South and Central America; for a case in North America, see Powell and Neves, 1999) can be easily explained without involving any sort of transoceanic crossings. As we have emphasized since the inception of our work on the subject (Neves and Pucciarelli, 1989, 1991, 1998), northern Asia can be easily maintained as the point of departure of the Paleoamericans (for a misconstrual of our ideas, see Roosevelt et al., 2002; Fiedel, 2004). It has been amply demonstrated that during the late Pleistocene, Asia was also occupied by humans with a cranial morphology similar to that seen among the first South and Central Americans. The cranial morphology that predominates today in east Asia (and in the Americas) is certainly a late evolutionary phenomenon dated to the Pleistocene/Holocene transition (Kaminga and Wright, 1988; Cunningham and Jantz, 2003). As was the case in Asia, this new morphology also became predominant in the Americas in a short period of time. In the case of east Asia, agriculture has been pointed out as the main reason behind the successful spread of it. In the case of the Americas, the question still remains to be investigated.

Acknowledgements

The research reported here was funded by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) through Grants 99/00670-7, 04/01321-6 to Walter Neves, a doctoral scholarship given to Mark Hubbe (Process 04/01253-0), and a postdoctoral scholarship given to Luís Beethoven Piló

(Process 00/14917-3). The senior author also held a research scholarship from CNPq (Brazilian National Science Foundation) (Process 305918/85-0). Our deepest gratitude goes to the curators who facilitated our access to the human skeletons from Sumidouro: Kim Aaris-Sorensen (Zoological Museum of University of Copenhagen), Chris Stringer (Natural History Museum, London), and Cybelle Ipanema (Historic and Geographic Institute, Rio de Janeiro). Robert Kruszynski, Knud Rosenlund, and Abdi Hedayat were of extreme help during our museum operations. João Paulo Vezzani Atui was also of much help during data handling and processing. Thanks to Augusto Auler, Federal University of Minas Gerais, Belo Horizonte, who actively participated in the field work at Sumidouro, and to Astolfo Araujo and Renato Kipnis, with whom we share the Lagoa Santa Paleoanthropological Project. This paper is dedicated to Harold Walter, Anibal Mattos, and Arnaldo Cathoud, founders of the Academy of Science and Letters of Minas Gerais, for their brave defense of Lund’s idea.

References

- Araujo, A.G.M., Neves, W.A., Piló, L.B., Atui, J.P.V., 2005. Holocene dryness and human occupation in Brazil during the “Archaic Gap.” *Quatern. Int.* 64, 298–307.
- Auler, A.S., 1995. Lakes as a speleogenetic agent in the karst of Lagoa Santa, Brazil. *Cave and Karst Sci.* 21, 105–110.
- Cunningham, D., Jantz, R.L., 2003. The morphometric relationship of Upper Cave 101 and 103 to modern *Homo sapiens*. *J. Hum. Evol.* 45, 1–18.
- Darroch, J.N., Mosimann, J.E., 1985. Canonical and principal components of shape. *Biometrika* 72, 241–252.
- Fiedel, S.J., 2004. The Kennewick follies: “New” theories about the peopling of the Americas. *J. Anthropol. Res.* 60, 75–110.
- González-José, R., Neves, W.A., Lahr, M.M., González, S., Pucciarelli, H.M., Martínez, M.H., Correal, U., 2005. Late Pleistocene/Holocene craniofacial morphology in Mesoamerican Paleoindians: Implications for the peopling of the New World. *Am. J. Phys. Anthropol.* 128, 772–780.
- Greenberg, J.H., Turner, C.G., Zegura, S.L., 1986. The settlement of the Americas: a comparison of the linguistic, dental, and genetic evidence. *Curr. Anthropol.* 27, 477–497.
- Hansen, S., 1888. Lagoa Santa Racen. En *Anthropologisk Undersögelse af Jordfundne Menneskelevninger fra Brasilianske Huler. Med et Tillæg om det Jordfundne Menneske fra Pontimelo, Rio de Arrecifes, La Plata.* E Museo Lundii 1, 1–34.
- Holten, B., Sterll, M., 1999. Uma carta reencontrada—relatório conclusivo das escavações feitas em Lagoa Santa pelo naturalista P.W. Lund. *Rev. Inst. Hist. Geogr. Bras.* 160, 371–398.
- Holten, B., Sterll, M., 2000. The Danish Naturalist Peter Wilhelm Lund (1801–80): Research on Early Man in Minas Gerais. *Luso-Brazilian Review* 37. University of Wisconsin Press.
- Howard, E.B., 1936. An outline of the problem of man’s antiquity in North America. *Am. Anthropol.* 38, 394–413.
- Howells, W.W., 1973. *Cranial Variation in Man: A Study by Multivariate Analysis of Patterns of Difference Among Recent Human Populations.* Harvard University Press, Cambridge.
- Howells, W.W., 1989. *Skull Shapes and the Map.* Harvard University Press, Cambridge.
- Howells, W.W., 1995. *Who’s Who in Skulls. Ethnic Identification of Crania from Measurements.* Harvard University Press, Cambridge.
- Hrdlička, A., 1912. *Early Man in South America.* Smithsonian Institution Press, Washington.
- Hubbe, M., Neves, W.A., Atui, J.P.V., Cartelle, C., Silva, M.P., 2004. A new early human skeleton from Brazil: Further support to the “two main biological components model” for the settlement of the Americas. *Curr. Res. Pleistocene* 21, 77–81.

- Imbeloni, J., 1938. Tabla classificatória de los índios: regiones biológicas y grupos raciales humanos de América. *Physis* 12, 229–249.
- Jantz, R.L., Owsley, D.W., 2001. Variation among early North America crania. *Am. J. Phys. Anthropol.* 114, 146–155.
- Kollmann, J., 1884. Schädeln von Lagoa Santa. *Z. Ethnol.* 16, 194–199.
- Lacerda, J.B., Peixoto, R., 1876. Contribuição para o Estudo Anthropologico das Raças Indígenas do Brasil. *Arch. Museu Nac.* 1, 47–76.
- Lahr, M.M., 1995. Patterns of modern human diversification: Implications for Amerindians origins. *Yearb. Phys. Anthropol.* 38, 163–198.
- Lahr, M.M., 1996. *The Evolution of Modern Human Diversity*. Cambridge University Press, Cambridge.
- Lund, P.W., 1844. Carta escripta de Lagôa Santa a 21 de abril de 1844. *Rev. Inst. Hist. Geogr. Bras.* 6, 334–342.
- Lund, P.W., 1845. Notice sur des Ossements Humains Fossiles, Trouvés dans une Caverne du Brésil. *Mém. Societé R. Antiquaires Nord* 49, 77.
- Munford, D., Zanini, M.C., Neves, W.A., 1995. Human cranial variation in South America: Implications for the settlement of the New World. *Braz. J. Genet.* 18, 673–688.
- Neves, W.A., Hubbe, M., 2005. Cranial morphology of early Americans from Lagoa Santa, Brazil: Implications for the settlement of the New World. *Proc. Natl. Acad. Sci. U.S.A.* 102, 18309–18314.
- Neves, W.A., Pucciarelli, H.M., 1989. Extra continental biological relationships of early South American human remains: a multivariate analysis. *Ciênc. Cult.* 41, 566–575.
- Neves, W.A., Pucciarelli, H.M., 1991. The origin of the first Americans: an analysis based on the cranial morphology of early South American human remains. *J. Hum. Evol.* 21, 261–273.
- Neves, W.A., Pucciarelli, H.M., 1998. The Zhoukoudien Upper Cave skull 101 as seen from the Americas. *J. Hum. Evol.* 34, 219–222.
- Neves, W.A., Velutini, W.C., 2004. Curatorial procedures used by Walter Neves in August/September 2004 regarding the skeletal human remains uncovered by Peter W. Lund from Sumidouro and other caves, Lagoa Santa, Brazil. Unpublished manuscript, Zoological Museum of University of Copenhagen, Denmark.
- Neves, W.A., Munford, D., Zanini, M.C., 1996. Cranial morphological variation and the colonization of the New World: Towards a four migration model. *Am. J. Phys. Anthropol.* 22 (Suppl.), 176.
- Neves, W.A., Powell, J.F., Ozolins, E.G., 1999a. Extra-continental morphological affinities of Lapa Vermelha IV, hominid I: a multivariate analysis with progressive number of variables. *Homo* 50, 263–282.
- Neves, W.A., Powell, J.F., Ozolins, E.G., 1999b. Extra-continental morphological affinities of Palli Aike, southern Chile. *Interciência (Venez.)* 24, 258–263.
- Neves, W.A., Munford, D., Zanini, M.C., Pucciarelli, H.M., 1999c. Cranial morphological variation and the colonization of the New World: Towards a four migration model? *Ciênc. Cult.* 51, 151–165.
- Neves, W.A., Prous, A., González-José, R., Kipnis, R., Powell, J., 2003. Human skeletal remains from Santana do Riacho I, Brazil: archeological background, chronological context and comparative cranial morphology. *J. Hum. Evol.* 45, 759–782.
- Neves, W.A., González-José, R., Hubbe, M., Kipnis, R., Araújo, A.G.M., Blasi, O., 2004. Early human skeletal remains from Cerca Grande, Lagoa Santa, Central Brazil, and the origins of the first Americans. *World Archaeol.* 36, 479–501.
- Neves, W.A., Hubbe, M., Okumura, M.M.M., González-José, R., Figuti, L., Eggers, S., Blasis, P.A.D., 2005. A new early Holocene human skeleton from Brazil: implications for the settlement of the New World. *J. Hum. Evol.* 48, 403–414.
- Piló, L.B., Auler, A.S., 2002. Apresentação: bicentenário do nascimento de Peter Wilhelm Lund (1801-1880). *O Carste* 14, 4–7.
- Piló, L.B., Auler, A.S., Neves, W.A., Wang, X., Cheng, H., Edwards, R.L., 2004. Revisitando a Lapa do Sumidouro: Marco paleo-anropológico do Quaternário Americano. *Rev. Bras. Paleontol.* 7, 337–348.
- Piló, L.B., Auler, A.S., Neves, W.A., Wang, X., Cheng, H., Edwards, R.L., 2005. Geochronology, sediment provenance, and fossil emplacement at Sumidouro Cave, a classic late Pleistocene paleoanthropological site in eastern Brazil. *Geoarchaeology* 20, 751–764.
- Powell, J.F., Neves, W.A., 1998. Dental diversity of early New World populations: Taking a bite of the tripartite model. *Am. J. Phys. Anthropol.* 26 (Suppl.), 179–180.
- Powell, J.F., Neves, W.A., 1999. Craniofacial morphology of the first Americans: pattern and process in the peopling of the New World. *Yearb. Phys. Anthropol.* 42, 153–188.
- Rivet, P., 1908. La Race de Lagoa Santa Chez lês Populations Précolombiennes de l'Equateur. *Bull. Mém. Soc. Anthropol. Paris* 9, 209–268.
- Roosevelt, A.C., Douglas, J., Brown, L., 2002. The migrations and adaptations of the first Americans: Clovis and pre-Clovis viewed from South America. In: Jablonski, N.G. (Ed.), *The First Americans: The Pleistocene Colonization of the New World*. California Academy of Sciences, San Francisco, pp. 159–235.
- Roseman, C.C., 2004. Detecting interregionally diversifying natural selection on modern human cranial form by using matched molecular and morphometric data. *Proc. Natl. Acad. Sci. U.S.A.* 10, 12824–12829.
- Roseman, C.C., Weaver, T.D., 2004. Multivariate apportionment of global human craniometric diversity. *Am. J. Phys. Anthropol.* 125, 257–263.
- Seguchi, N., Nelson, A.R., Austin, S., Brace, C.L., 2005. Early South Americans in craniofacial metric perspective: Lagoa Santa. *Am. J. Phys. Anthropol.* 40 (Suppl.), 187.
- Steele, D.G., Powell, J.F., 1992. The peopling of the Americas: the paleobiological evidence. *Hum. Biol.* 63, 301–336.
- Steele, D.G., Powell, J.F., 1993. Paleobiology of the first Americans. *Evol. Anthropol.* 2, 138–146.
- Steele, D.G., Powell, J.F., 2002. Facing the past: a view of the North American human fossil record. In: Jablonski, N.G. (Ed.), *The First Americans: The Pleistocene Colonization of the New World*. California Academy of Sciences, San Francisco, pp. 93–122.
- Ten Kate, H., 1885. Sur les Crânes de Lagoa Santa. *Bull. Soc. Anthropol. Paris* 8, 240–244.
- Turner II, C.G., 1990. Major features of sundadonty and sinodonty, including suggestions about east Asian microevolution, population history, and late Pleistocene relationships with Australian Aborigines. *Am. J. Phys. Anthropol.* 82, 295–317.
- Williams, F.L., Belcher, R.L., Armelagos, G.J., 2005. Forensic misclassification of ancient Nubian crania: Implications for assumptions of humans variation. *Curr. Anthropol.* 46, 340–346.