

Chapter 23

Early Human Occupation of Lagoa Santa, Eastern Central Brazil: Craniometric Variation of the Initial Settlers of South America

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ABSTRACT

The karstic region of Lagoa Santa (eastern central Brazil) has been highly important for discussions about the tempo and mode of human dispersal in the Americas, owing to the high density of late-Pleistocene/early-Holocene sites and hundreds of human skeletons recovered from the local rockshelters. In this chapter we highlight the importance of the Lagoa Santa region by 1) briefly reviewing the two centuries of research history in the region, including the work conducted by our team in the past 15 years; 2) discussing the biological characteristics of the Lagoa Santa population, via multivariate analyses of its cranial morphological affinities with a series representing modern human morphological diversity worldwide; and 3) discussing how these biological characteristics have been used to contribute to the discussion of origins of biological diversity of past and present Native American groups. Our analyses support previous results that members of the Lagoa Santa populations shared a distinct morphological pattern from the one observed among most modern Native Americans, indicating a high diachronic morphological diversity across the continent. However, there is still no consensus on how this diversity originated with different models that have been proposed in the past decade.

KEYWORDS: Settlement of the Americas, Multivariate analyses, Morphological affinities, Biological diversity

Introduction

Despite centuries of research on the topic, the processes surrounding the time and mode of the human settlement of the Americas have proven hard to elucidate, as can be easily at-

tested by the contributions of this volume and the hundreds of scientific articles dedicated to the topic in the past 25 years. Within the vast realm of unsolved questions that still surround the settlement of the Americas, some deal specifically with the origins of the biological variation seen among

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past and present Native Americans and their implications for the processes of human dispersion into the continent.

The biological diversity of Native Americans across time is a direct result of dispersion wave(s) into the continent and of the way that populations interacted with each other and with the landscape of the continent. Consequently, the study of the biological diversity of extinct and extant Native American populations can contribute significantly to the discussion about the ways in which human beings occupied the continent in the past and can then be contrasted with the results and discussions originated by disciplines such as archaeology and linguistics.

Studies dedicated to analyzing the biological diversity of Native American populations can be divided broadly into two categories: studies that estimate the biological diversity and characteristics of living Native American populations; and studies that infer biological characteristics from human remains associated with past populations. The first group mostly comprises studies of the molecular diversity seen in mitochondrial DNA (e.g., Schurr 2004; Bonato and Salzano 1994; Kemp and Schurr 2010; Bodner et al. 2012; Fagundes et al. 2008; Kitchen et al. 2008; Perego et al. 2009; Tamm et al. 2007; Torroni et al. 1992, 1993), Y chromosome (e.g., Schurr 2004; Zegura et al. 2004) and autosomic DNA (e.g., Reich et al. 2012; Wang et al. 2007). Although very prolific in the past 25 years (see Kemp and Schurr 2010, for a good review), molecular studies have generated conflicting models for the settlement of the continent with regards to the number of migration waves into the continent, the existence of continuous gene flow with NE Asia during the Holocene, the timing of the initial colonization event, the effective size of the population that initially colonized the continent, as well as the expansion strategy and routes taken by initial settlers. This lack of consensus probably derives from the facts that molecular studies estimate events that happened many generations before the individuals studied and that only a small percentage of the total Native American populations have been analyzed so far.

The second group of studies has focused on the more straightforward strategy of analyzing the biological diversity seen in remains from past populations. Most of the studies falling into this category study the morphological characteristics of past human remains, especially the skull (e.g., Jantz and Owsley 2001; Neves and Hubbe 2005; Neves and Pucciarelli, 1989, 1991; Powell and Neves 1999; Azevedo et al. 2011; González-José et al. 2003, 2005a, 2008; Hubbe et al. 2010, 2011; Seguchi et al. 2011) and dentition (e.g., Powell 2005; Turner 1986; Greenberg et al. 1986), with some recent work focusing on postcranial characteristics (e.g., Auerbach

et al. 2012; Jantz et al. 2010). Molecular studies of past individuals have been slowly increasing in frequency as well (e.g., Demarchi et al. 2001; Gilbert et al. 2008a, b; Kemp et al. 2007, 2009), but to date they are mostly restricted to fairly recent samples (Raff et al. 2011). Although the study of past human remains is clearly the best approach to reconstruct the biological characteristics of Early Americans, such enterprise is challenged by the lack of well-preserved human remains in the continent, especially when the initial millennia of the human presence in the New World is considered.

Despite the fact that human presence in the continent is now safely attested by archaeological sites at least since 12.5 ¹⁴C kyr BP (Dillehay 2009, Dillehay et al. 2008, Goebel et al. 2008), no human remains dated to more than 11.5 ¹⁴C kyr BP are known to date (e.g., Waguespack 2007; Feathers et al. 2010). Consequently, studies dealing with the biological characteristics of these early remains describe groups that lived in the Americas at least 1,000 years after its initial occupation. Moreover, the vast majority of the reported early remains in the continent are composed of few individuals, some very fragmented, which renders impossible any attempt to understand

the population structure of these groups. In Figure 23.1 we illustrate the most important sites containing early remains in South America, and Table 23.1 lists the approximate number of individuals represented in each site as well as its chronological range.

Only two regions in the entire continent have individuals recovered from early contexts in sufficient quantity to estimate intra-population variability, from which we can then reliably extrapolate the characteristics of the Early American groups. The first is a series of skeletons recovered from limestone rockshelters in the Bogotá Savannah, central Colombia. This material has been covered in detail by Neves et al. (2007a) and represents ~20 skeletons, collected from only a handful of sites, dated to 11.5–6.5 kyr BP.

The second region is Lagoa Santa, in central Brazil, which has been studied over the past 180 years and has generated over 100 individuals dated to 11.5–7.5 ¹⁴C kyr BP. To date, Lagoa Santa is the single region in the continent that allows a good assessment of the biological characteristics within early-Holocene populations. Consequently the Lagoa Santa material has called the attention of scholars worldwide since the late 19th century (Hansen 1888; Hrdlička 1912; Imbeloni 1938; Lund 1842, 1845; Rivet 1908; Ten Kate 1885; Lacerda and Peixoto 1876, among others). Recently Lagoa Santa has been included in a great variety of studies of the cranial morphology of this population in the context of worldwide variation and its implications for the peopling of the Ameri-

“Fica, portanto, provado por estes documentos, em primeiro lugar —que a povoação do Brasil deriva de tempos muito remotos, e indubitavelmente anteriores aos tempos históricos.

A questão que se offerece naturalmente agora é saber quem foram esses antiqüísimos habitantes do Brasil? de que raça eram? qual era o seu modo de vida, a sua perfeição intelectual?”

“[It is, thus, proved by these documents in the first place—that the settling of Brazil dates to very remote times, undoubtedly prior to historic times.

The question that offers itself naturally now is to know who these ancient inhabitants of Brazil were? which race did they belong to? what was their life style, their intellectual perfection?”

—Peter W. Lund (1842:84)

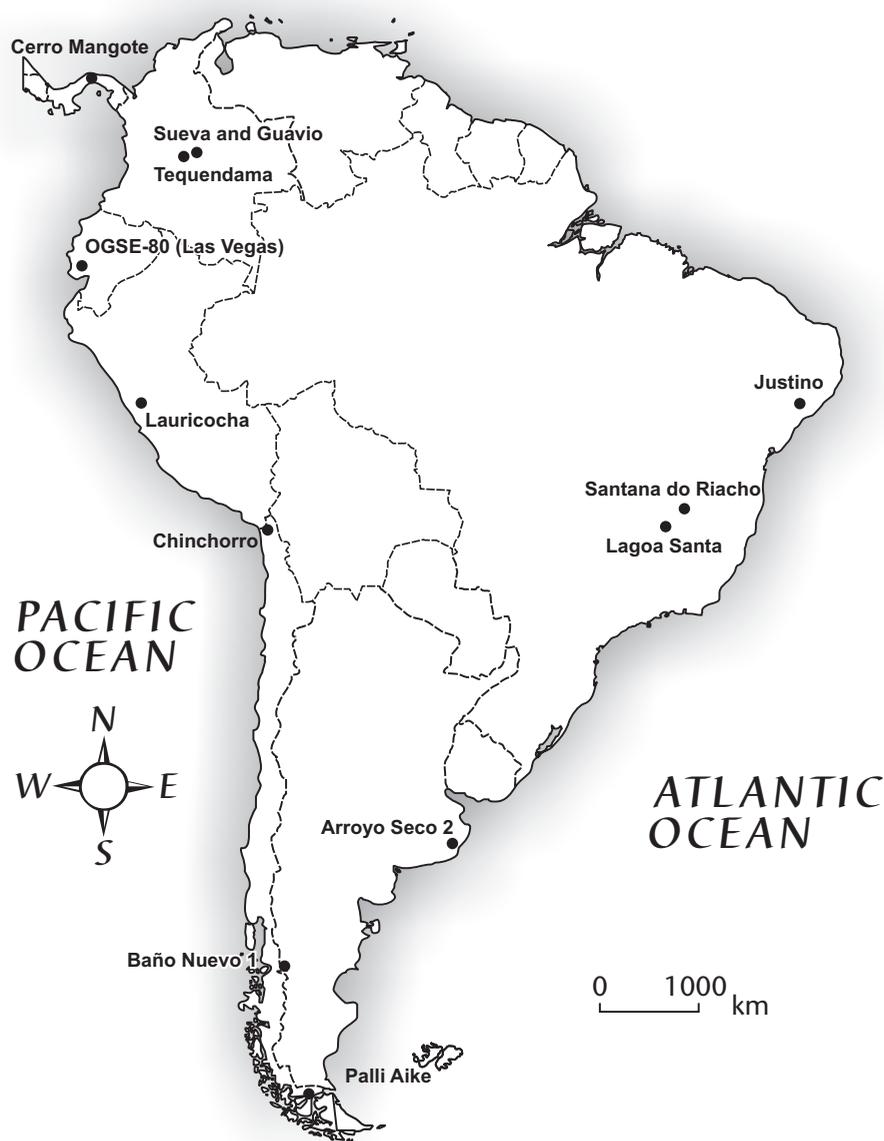


Figure 23.1 Geographic location of the most important early sites with skeletal remains in South America.

cas (e.g., Neves and Hubbe 2005; Neves and Pucciarelli 1989, 1991; Azevedo et al. 2011; González-José et al. 2003, 2008; Neves et al. 2003, 2007a,b; Pucciarelli et al. 2006), as well as studies dealing with aspects of their life-style (Da-Gloria 2012; Mendonça de Souza 1995; Neves and Corneiro 1997; Neves and Piló 2003; Prous and Fogaça 1999; A. Hubbe et al. 2009), and its implication for the peopling of the Americas. For the past 13 years, the lead author has coordinated an extensive new archaeological and paleontological project in the region, recovering over 30 new early burials as well as associated cultural artifacts in well-contextualized archaeological contexts.

These two larger series (Sabana de Bogotá and Lagoa Santa) are complemented by some scattered individuals of early age in NE Brazil (Bernardo and Neves 2010; Hubbe et al. 2007), SE Brazil (Neves et al. 2005), Argentina (Neves et al. 1999), Chile (Arriaza et al. 2008; Passig et al. 1986), as well as

a few individuals in North America (Waguespack 2007; Jantz and Owsley 2001).

In light of the preponderance of Lagoa Santa as the best-represented collection of Early American populations in the continent, this chapter will present a general description of archaeological background and history of discoveries of the region, complementing it with new data generated by our own research in the past decades, followed by a formal analysis of the morphological affinities of the best-preserved skulls from different sites excavated in the region since the 1830s. As we will demonstrate, analyzing this material further supports the hypothesis that the populations that inhabited the continent share a cranial morphological pattern different from that of late Native American groups, which suggests that the biological diversity seen nowadays in the continent was not present among American groups until mid-Holocene.

Table 23.1 Details of the most relevant South American sites with early human remains.

Site	Country	Number of Individuals	Chronology (¹⁴ C yr BP)	Reference
Cerro Mangote	Panamá	12	~6800	McGimsey III 1956, 1958
Sueva	Colombia	1	10,100	Neves et al. 2007a
Guavio 1	Colombia	8	~9400	Neves et al. 2007a
Tequendama	Colombia	26	~9000–6000	Neves et al. 2007a
OGSE-80 (Las Vegas)	Ecuador	> 65	~8200–6600	Stoothert 1983
Lauricocha	Peru	11	> 9500	Cardich 1964
Chinchorro sites	Chile/Peru	> 60	~9000–3000	Arriaza 2008
Baño Nuevo 1	Chile	5	~8800	Mena and Reyes 2001
Palli Aike	Chile	1	> 7800	Neves et al. 1999
Santana do Riacho	Brazil	> 30	~11,900–8400	Neves et al. 2003
Justino	Brazil	5	~8900	Vergne and Amâncio 1992
Lagoa Santa	Brazil	> 300	~11,500–7000	Neves and Hubbe 2005
Arroyo Seco 2	Argentina	45	7800–4500	Politis 2008

Lagoa Santa Archaeological Record

The karstic region of Lagoa Santa (Figure 23.2) derives its importance for the studies of early humans in the continent from the long history of paleontological and archaeological excavations of its caves and rockshelters and the relatively well preserved archaeological packages dated to the beginning of the Holocene. The region became famous during the 19th century thanks to the systematic work of the Danish naturalist Peter Lund, who explored hundreds of caves in the region between 1835 and 1844 and intensively excavated 60 of them (Lund 1844, 1845; Holten and Sterll 1999). Lund was primarily interested in the Quaternary fauna deposits in the region and, based on his findings, described several new genera and species of extinct mammals that inhabited the region in the past. However, in the context of this book his most significant contribution was the discovery of human remains associated with extinct megafauna specimens inside Sumidouro cave (literally “swallet cave”). The Sumidouro remains, recently dated to a minimum age of ~8500 cal yr BP (Neves et al. 2007b), were among the first evidence of an older date for the presence of human beings in the continent and quickly became a major topic of discussion among European and American scholars (e.g., Hansen 1888; Hrdlička 1912; Rivet 1908; Lacerda and Peixoto 1876), being frequently included in a primitive human “race,” the Lagoa Santa Man (Hansen 1888; Lacerda and Peixoto 1876).

Lund’s collection, currently housed at the Museum of Natural History in Copenhagen, is to date the largest collection of Quaternary fauna and early human remains recovered from Lagoa Santa. Lund’s work certainly inspired many new researchers to explore the caves and rockshelters of the region during the following centuries. Of special interest to this chapter is the work of the French-Brazilian mission (Laming-Emperarie 1979, Prous and Fogaça 1999), who recovered the oldest evidence of human presence in the region: the skeleton of a young female recovered from Lapa Vermelha IV, a 14-m-deep fissure filled with sediment and fauna remains, but with scant evidence of formal human presence. Nicknamed “Luzia” by the lead author, the skeleton was not recovered

from a burial context; probably the body was discarded into the fissure in the past. The skeleton was originally dated to 11.4–16.4 cal kyr BP (Laming-Emperaire 1979), based on its stratigraphic position between charcoal concentrations. Although the skeleton did not preserve enough collagen to be directly dated, new OSL dates agree with the date range of this skeleton, suggesting a range of 12.7–16.0 cal kyr BP (Feathers et al. 2010). Although only one individual, the skeleton from Lapa Vermelha IV is currently one of the oldest skeleton remains in the Americas and attests to the presence of human beings in the region of Lagoa Santa at least since the final millennia of the Pleistocene.

Besides the French-Brazilian mission, other research teams during the 20th century excavated a great number of caves and rockshelters containing evidence of early human occupations, and generated a relevant collection of early human skeletons. Hurt and Blasi (Hurt 1960, 1964; Hurt and Blasi 1969) excavated the Cerca Grande complex, which yielded 17 burials dated to 9500–8000 ¹⁴C yr BP. Finally, Harold Walter led a team of amateur archaeologists who excavated many different sites, recovering early human remains from Lapa Mortuaria and a great number of skeletons from different sites in the region (see Neves and Hubbe, 2005 for a complete list of well-preserved skulls from Lagoa Santa and Strauss, 2010 for a discussion of their chronology).

Since 1999, the main author has led a long-term archaeological project in the Lagoa Santa region, which focused on

- 1) generating an absolute chronological frame for the collections excavated in the past;
- 2) excavating new sites with modern archaeological techniques; and
- 3) looking for evidence of early human groups outside the local rockshelters.

During its execution period, all institutions and museum housing Lagoa Santa collections in Brazil and abroad were visited and bone samples were collected for AMS dating. Despite the overall poor preservation of collagen that characterizes the osteological remains from the region, the absolute

chronology has been significantly improved (see Neves and Hubbe 2005 for the complete list of new dates). Over this decade of work, we systematically excavated two rockshelters with deep archaeological packages (Araujo et al. 2008); in one of them, Lapa do Santo, was found a high concentration of human burials. To date 32 burials dated to 9200–7000 ¹⁴C yr BP have been recovered from Lapa do Santo. They show a wide array of burial practices; a significant number of them show evidence of complex secondary ritual manipulation of human remains (Strauss 2010, 2011, 2012; Strauss et al. 2011a, 2011b).

The new chronological context for the Lagoa Santa burial shows that Pleistocene individuals are quite rare, and only the individual from Lapa Vermelha IV (Luzia) has been dated to before the Holocene. Despite the presence of Pleistocene dates at the bottom of the archaeological record in the rock-

shelters (e.g., Araujo et al. 2008), the systematic use of these spaces as burial ground did not start before ~9000 ¹⁴C yr BP, which suggests a possible shift in the cultural background of groups living or moving across the region around this date.

During the last 13 years, the permanent lakeshores of the region were prospected. Evidence of human presence recovered in the form of lithic artifacts dated to around 8300 ¹⁴C yr BP (Araujo and Feathers 2008; Araujo et al. 2013), suggests a possible increase in the logistical use of the regional resources by populations that established themselves in Lagoa Santa at the beginning of the Holocene. Inside the rockshelters, the pattern of secondary burials described in Lapa do Santo contradicts the notion that early groups of Lagoa Santa used expeditious and homogeneous burial practices (Strauss 2010, 2011, 2012; Strauss et al. 2011a, 2011b). In fact, the burials recovered from this site show a complex rit-

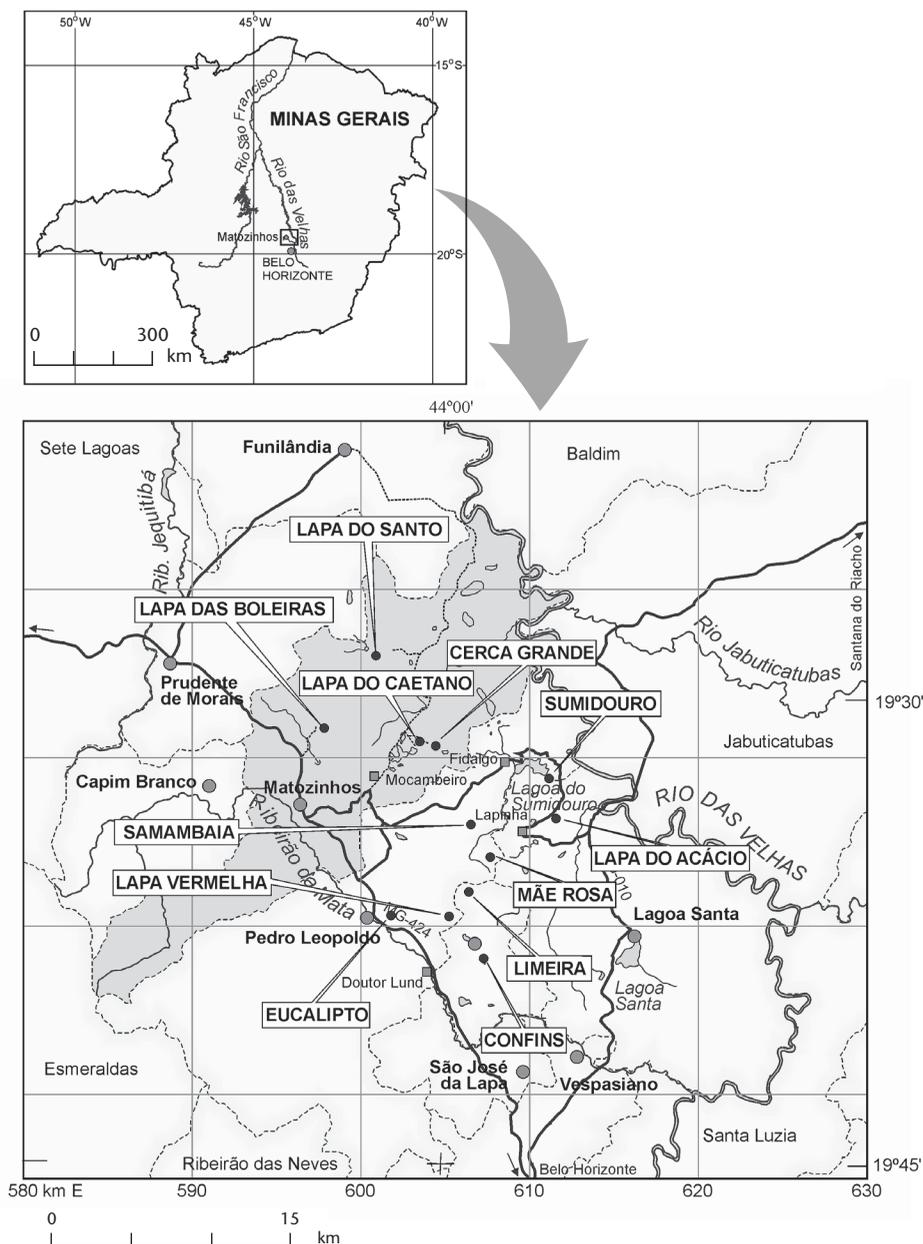


Figure 23.2 Geographic location of the most important early archaeological sites in the Lagoa Santa region.

ual processing of the dead, frequently dichotomizing cranial and postcranial remains by organizing bundles of the latter (sometimes from more than one individual) around or inside opened skull cases (Strauss 2010).

The project in Lagoa Santa also excavated paleontological sites and systematically dated megafauna remains of the region, whereby it was able to show a significant chronological overlap between human groups and extinct megafauna species. At least the saber-tooth cat (*Smilodon* sp.) and one type of ground sloth (*Catonyx cuvieri*) survived into the Holocene (Neves and Piló 2003). That no evidence of direct interaction between human and megafauna species has been reported for the region (A. Hubbe et al. 2009, 2012, 2013), suggests that these hunter-gatherers were not focusing on large preys. The fauna assemblage recovered from the Lagoa Santa archaeological records is strongly dominated by deer (*Mazama* sp.) with a minor participation of medium-size and small mammals (armadillos, wild pigs, and rodents), as well as birds, lizards, and snails. The specialization toward smaller fauna is supported by the absence of a lithics industry intended for hunting big game. The local lithic assemblage is composed primarily of small flakes and micro-flakes made of quartz, with only minor changes in technology observed over more than 3000 years of occupation of the local rockshelters (Araujo et al. 2008). The diet of these populations appears to have included a larger proportion of cariogenic items (rich in carbohydrates) than in typical hunter-gatherer populations, which resulted in unusually high prevalence of dental caries among the local groups (Da-Gloria 2012; Neves and Cornero 1997; Neves and Kipnis 2004).

Until recently, we believed that Lagoa Santa was occupied by groups with similar biological, technological, and cultural characteristics until the region was abandoned during the mid-Holocene (between 6000 and 3000 cal yr BP) owing to the onset of a drier period that affected most of South America (Araujo et al. 2005), to be settled again after 3000 cal yr BP by groups showing no cultural resemblance to the early population of the region. New findings in Lapa do Santo, however, have shown that the dynamics of local human occupation were probably more complex, since the site presents evidence of intense human occupation during the middle Holocene (see Araujo et al. 2012, for a review on this topic)

In summary, the early archaeological sites of Lagoa Santa show the presence, by the end of the Pleistocene, of humans who progressively increased their use of the landscape and developed a specific cultural tradition that clearly reflects their adaptation towards the surrounding landscape. The local cultural development, reflected in their technology, treatment of the dead, and even in dietary practices, contrasts sharply with the typical image of Early American groups elsewhere in the continent and favors the idea that by the beginning of the Holocene the Americas were occupied by diversified groups that developed specific and unique ways to handle the landscape around themselves (Dillehay 2008).

From a biological standpoint, the Lagoa Santa remains

present a cranial morphological pattern that contrasts with the morphological diversity seen in the continent during the late Holocene. This morphological pattern is not unique to Lagoa Santa and has been described in different regions of the Americas, such as Colombia (Neves et al. 2007a), Chile (Neves et al. 1999), Mexico (Neves et al. 2003), SE Brazil (Neves et al. 2005), and NE Brazil (Bernardo and Neves 2010; Hubbe et al. 2007). North American remains also appear to differ from late Native Americans (Jantz and Owsley 2001), although these remains, with the exception of Kennewick Man (Chatters et al. 1999), were never directly contrasted with the morphological variation of early South Americans. At the present moment, almost all the skeletal remains older than 7000 cal yr BP in South and Meso America share the same morphological pattern, differing considerably from the morphological variation that characterizes the actual Native American populations (for an exception to this pattern see Bernardo and Neves 2010). Differing theories about the typical morphological pattern of Early American groups and the process by which the actual morphological diversity of Native Americans developed have lately stirred vigorous debate, especially in view of the implications for the manner and route by which humans colonized the continent (e.g., Neves and Hubbe 2005; Azevedo et al. 2011; González-José et al. 2008; Hubbe et al. 2010).

Here, we present an analysis of the morphological affinities among the largest sites of the Lagoa Santa region, comparing them with morphological variation observed worldwide. Our intention is to demonstrate that

- 1) the cranial morphological variation of Lagoa Santa populations falls within the levels observed for modern population across the planet, and therefore Lagoa Santa remains probably represent a biological population, albeit spanning almost 3,000 years; and
- 2) the morphological pattern seen among the Lagoa Santa population did not vary significantly among the different groups of the region, which supports the idea that morphological variation seen among Early American populations was low compared with what is observed among late-Holocene populations and recent Native Americans.

Materials

Despite the fact that the Lagoa Santa region produced hundreds of early-Holocene burials, only a few sites, Cerca Grande complex, Sumidouro Cave, and Lapa do Santo, have enough individuals for a site-specific analysis of the morphological variation of local populations. The morphological affinities of Cerca Grande and Sumidouro individuals have been previously explored (Neves et al. 2004, 2007b, respectively), but the individuals from Lapa do Santo have not yet been analyzed, and neither were the three sites compared with one other. Consequently, this chapter presents the first analysis of morphological variation among series from different sites from the Lagoa Santa region dated to the early Holocene.

Cerca Grande The individuals included in this series come from three different rockshelters (Cerca Grande 5, 6 and 7) excavated by Hurt and Blasi during the 1960s (Hurt 1960, 1964; Hurt and Blasi 1969). Their excavations in Cerca Grande Rockshelter 5 yielded five human skeletons, one very fragmented. Rockshelter 6 produced 11 burials, although much of the large original burial area had already been destroyed by mining activities. Rockshelter 7 produced only one human burial (Hurt and Blasi 1969). All the burials were similar: The graves were very shallow (maximum 60 cm in depth), and the bodies were hyper-flexed. No funerary goods were present, and in some cases small stone slabs surrounded or covered the graves (Hurt and Blasi 1969). This was believed to be the regular funerary pattern found in the late-Paleoindian sites of Lagoa Santa (Prous 1991) until our detailed excavations of Lapa do Santo demonstrated a new level of complexity in the region (Strauss 2010, 2011, 2012; Strauss et al., 2011a, 2011b). Radiocarbon dates for some of the sites place the human occupation between 9500 and 8000 ¹⁴C yr BP (Neves et al., 2004). From all the human remains recovered, only five relatively well preserved skulls could be reconstructed, and they compose the individuals included in our analyses.

Sumidouro The Sumidouro Cave was explored in 1842 and 1843 by Lund, who took advantage of a severe drought in the region to access the Sumidouro chambers, normally under the water level of the Sumidouro lagoon. Lund recovered from the cave many fossil remains of extinct megafauna species and the remains of more than 30 human skeletons, which he later concluded came from the same stratigraphic package and thus were contemporaneous (Lund 1845; Neves et al. 2007b). Although no collagen was preserved in these skeletons, we were able to generate minimum ages of 8500 cal yr BP for the stratigraphic package where they were found (Neves et al. 2007b; Piló et al. 2004, 2005). The human skeletons apparently were not in formal burials and most probably belong to individual bodies that were discarded into the cave from a secondary entrance above the main chamber. No cultural artifacts have been found associated with the skeletons (Neves et al. 2007b). The Sumidouro collection is today housed in the Natural History Museum of Copenhagen, with the exception of two skulls. One skull was given by Lund to the Instituto Histórico e Geográfico do Rio de Janeiro; the other was sold by Clausen to the Natural History Museum of London. We included in our analysis the 13 most complete skulls recovered by Lund from Sumidouro.

Lapa do Santo As mentioned in the previous section, Lapa do Santo is a large rockshelter excavated by us since 2001. To date, 32 early-Holocene burials have been recovered from the site, representing the largest collection of contextualized human burials not only in Lagoa Santa but also in the entire continent. Highly diversified funerary practices question the previous notion of simplicity in the treatment of the dead by early Lagoa Santa groups (Strauss 2010, 2011, 2012; Strauss

et al. 2011a, 2011b). In terms of lithics technology, however, Lapa do Santo shows the same type of non-specialized industry that comprises chiefly small quartz flakes and very few formal instruments. The site shows evidence of a diet composed mainly of small and medium-size mammals, although the analysis of the skeletal remains suggests a larger intake of carbohydrates (cariogenic food items) than expected from typical hunter-gatherers (Da-Gloria 2012). We included in our analyses the seven best-preserved adult skulls.

Reference Series To analyze the morphological affinities of the Lagoa Santa series in relation to world-wide morphological variation, we included 20 series from the Howells database (Howells 1973, 1989, 1996) and series from early- and mid-Holocene Colombia (Neves et al. 2007a). Colombia, which yielded a series from Sabana de Bogotá, is the only other region in the Americas with enough individuals to support population analysis (i.e., not composed of isolated individuals). The Howells series, on the other hand, each composed of at least 50 individuals from the same geographic region, have been widely used in the past as comparative material and represent well the morphological diversity of modern human populations worldwide. The number of individuals in each series, including those from Lagoa Santa, and the dates available for the early sites are listed in Table 23.2.

Methods

The morphological analyses were based on linear craniometric measurements taken from each skull, following the protocol proposed by Howells (1973, 1989). All early South American samples were measured by the lead author (WAN) to minimize inter-observer error. To maximize the number of individuals included in the analyses, we used only 22 of the 61 measurements proposed by Howells (Table 23.3), in this way minimizing the missing measurements in the early skulls. Table 23.3 also shows the averages and standard deviations of the measurements for each of the early South American samples. In the final database, we replaced the missing values (see Table 23.2 for details) by means of multiple regressions (see Hubbe et al. 2011 for details).

The morphological affinities between series have been explored by a combination of methods. Initially, we calculated the intra-population variation for each of the Lagoa Santa independently and then for all Lagoa Santa sites together. Within-group variability was estimated here using coefficient of variation (CV). For each series, CV was calculated as the standard deviation divided by the mean of each variable. CVs were then averaged for all 22 variables. The CVs for Lagoa Santa sites were then compared with those for the early Colombian series and the Howells reference populations to determine to what extent the early series grouped together here can be considered a valid biological population.

To gauge morphological affinities we performed two analyses. First, Mahalanobis D^2 distances (Mahalanobis 1936) were calculated between series. The relationship between series given by the resulting matrix was then graphi-

Table 23.2 Series included in the morphological affinity analyses.

Series	Region/Chronologic Affiliation	n	Missing Value (%)	Reference
Lapa do Santo	Early Lagoa Santa	7	10.4	This chapter
Cerca Grande	Early Lagoa Santa	5	9.1	Neves et al. 2004
Sumidouro	Early Lagoa Santa	13	12.2	Neves et al. 2007b
Early Colombia	Early Colombia	14	1.0	Neves et al. 2007a
Archaic Colombia	Archaic Colombia	34	2.8	Neves et al. 2007a
Peru	South America	110	-	Howells 1973, 1989
Arikara	North America	69	-	Howells 1973, 1989
Santa Cruz	North America	102	-	Howells 1973, 1989
Buriat	NE Asia	109	-	Howells 1973, 1989
Atayal	East Asia	47	-	Howells 1973, 1989
Hainan	East Asia	83	-	Howells 1973, 1989
Northern Japan	East Asia	87	-	Howells 1973, 1989
Southern Japan	East Asia	91	-	Howells 1973, 1989
Australia	Australo-Melanesia	101	-	Howells 1973, 1989
Tasmania	Australo-Melanesia	87	-	Howells 1973, 1989
Tolai	Australo-Melanesia	110	-	Howells 1973, 1989
Berg	Europe	109	-	Howells 1973, 1989
Norse	Europe	110	-	Howells 1973, 1989
Zalavar	Europe	98	-	Howells 1973, 1989
Bushman	Sub-saharan Africa	90	-	Howells 1973, 1989
Dogon	Sub-saharan Africa	99	-	Howells 1973, 1989
Teita	Sub-saharan Africa	83	-	Howells 1973, 1989
Zulu	Sub-saharan Africa	101	-	Howells 1973, 1989
Mokapu	Polynesia	100	-	Howells 1973, 1989
Moriori	Polynesia	108	-	Howells 1973, 1989
Easter Island	Polynesia	86	-	Howells 1973, 1989

cally represented through a Ward's Hierarchical Cluster (Ward 1963), which combines series into clusters that minimize intra-cluster variation while maximizing inter-cluster variation. Second, morphological affinities were also represented in the first two principal components (PCs) extracted from the covariance matrix between series. PCs were calculated from the covariance matrix instead of the correlation matrix, since the size correction procedure adopted here (see below) standardizes the variance of the variables to a large degree (Roseman and Weaver 2004). In this way, we are able to compare results from a dimension-reduction analysis (Principal Components Analysis), where only the major axis of variation between series is represented, with a distance matrix analysis (Wards Cluster), which considers the totality of the differences between the groups, weighted in this case by the covariance between variables. Details on the analyses procedures and rationale can be found in Hubbe et al. (2011).

Prior to the analyses, size and sexual dimorphism were removed by transforming the raw measurements into z-scores within each sex and then pooling sexes together. After sexes were pooled together, a second z-score was calculated for each individual, following Relethford (1994). Sexes had to be pooled together to maximize the number of individuals in the early series; for all series, however, the proportion of males and females is roughly similar, which insures that sexual dimorphism is not biasing our analysis. All analyses were performed using Statistica 7 (Statsoft Inc).

Results

Table 23.4 shows the CVs of Lagoa Santa, early Colombia, and the Howells series. Coefficients of variation range from 9.0 to 11.7%, and the Lagoa Santa collections fall within the variation of recent human populations, which favors the idea that, despite the time span represented by each of the series, secular trends are not inflating within-series variation to a point where they could not be considered valid biological populations.

Figures 23.3 and 23.4 summarize the results of the morphological affinity analyses among the series. Figure 23.3 shows the Ward's Cluster based on the Mahalanobis distance matrix between the series. The length of the branches shows the relative distance between series. In this case, it is clear that all early series from Lagoa Santa share a similar morphological pattern. This pattern is closely associated with the morphology of Easter Island, which appears in the same cluster of Early Americans, and of Australo-Melanesians in a neighbor cluster. It is noteworthy that Early Americans are not closely associated with the late-American series included in the analysis.

A very similar result is observed in Figure 23.4, when the morphological affinities according to the first two Principal Components are considered. In this analysis the first Principal Component separates Early Americans, Australo-Melanesians, sub-Saharan Africans, and Polynesians from late Americans, Asians, and Europeans. Positive values in this PC (e.g., the Early American series) have narrow neurocrania

(XCB), short faces (NPH, WMH) with short noses (NLH) and orbits (OBH) and long parietals (PAC, PAF) (Table 23.5). On the higher end of the first PC, the second PC separates Lapa do Santo, Easter Island, and Australo-Melanesians from the other Early American series and sub-Saharan Africans. High values on the second PC are correlated with narrow and projected frontals (XFB and FRF, respectively) and wide orbits (OBB).

These results show that there was not much morphological diversity among Lagoa Santa populations during the first millennia of the Holocene, and that the distinct morphological pattern exhibited by these groups is not a product of sample bias or poor representation of the morphological characteristics of Early American groups as a result of small samples.

Discussion

Our intention in this chapter is to highlight the importance of the early South American remains to the discussion surrounding the biological origins of late-Pleistocene/early-Holocene human groups in the continent. Accordingly, this chapter was not intended to serve as a hypothesis test, but rather as an ex-

ploratory analysis that examines discussions and conclusions that have been presented by other recent articles and lines of evidence. The present discussion will show how the results presented here can be tied to the knowledge currently available on the peopling of the New World and will thus highlight the reasons for the lack of consensus concerning the current hypotheses about how humans colonized the continent.

The results presented here corroborate previous studies (Neves and Hubbe 2005; Neves and Pucciarelli 1989, 1991; Hubbe et al. 2010, 2011; Neves et al. 2004, 2007b) that show that early Lagoa Santa groups share a morphological pattern different from what is seen among recent Native American groups. Moreover, the analyses shown here demonstrate that this morphology is not a product of sampling biases, as suggested in the past (Van Vark et al. 2003), and indeed represent a common pattern even among different groups from the Lagoa Santa region. This is in accordance with our latest studies that suggest they share the same morphology as late-Pleistocene populations in other parts of the planet (Hubbe et al. 2011), and suggest that there has been an increase in morphological (and biological) diversity in the continent during the Holocene.

Current consensus holds that cranial morphology is largely defined by stochastic evolutionary processes (e.g., Relethford 1994; Roseman 2004; Harvati and Weaver 2006), with selective adaptation being restricted to extreme regions or localized anatomical regions in the skull (e.g., Harvati and Weaver 2004; González-José et al. 2005b; Hubbe et al. 2009). Consequently, cranial morphology has been widely used to reconstruct phylogenetic histories among human populations. It is thus understandable that the means by which cranial morphological diversity in South America increased in the past have major implications for our understanding of the processes of human dispersion into and within the continent in the past. The cause of diversity of cranial morphology has been a point of major debate in the past.

This increase of morphological diversity during the Holocene and the appearance of a new morphological pattern in the continent, closely resembling the morphology seen in East Asian groups by the end of the Holocene, has been attributed variously to multiple dispersion waves into the continent (Neves and Hubbe 2005; Hubbe et al. 2010; Neves et al. 2007a,b), to local micro-evolutionary processes (Powell 2005), or to continuous gene flow with Asia during the Holocene (Azevedo et al. 2011; González-José et al. 2008). Defendants of the first scenario argue that the differences between early and late morphological pattern are so large that they cannot be explained only by local micro-evolutionary forces. Under this scenario, the morphological pattern of Early Americans represents the morphology present in the planet by the end of the Pleistocene and was brought into the New World by the initial settlers crossing the Bering Strait. A new morphological pattern, similar to the one seen among recent East Asian groups, was brought into the Americas by a second wave of dispersion (but not necessarily only one discrete migration) that largely replaced the early pattern, al-

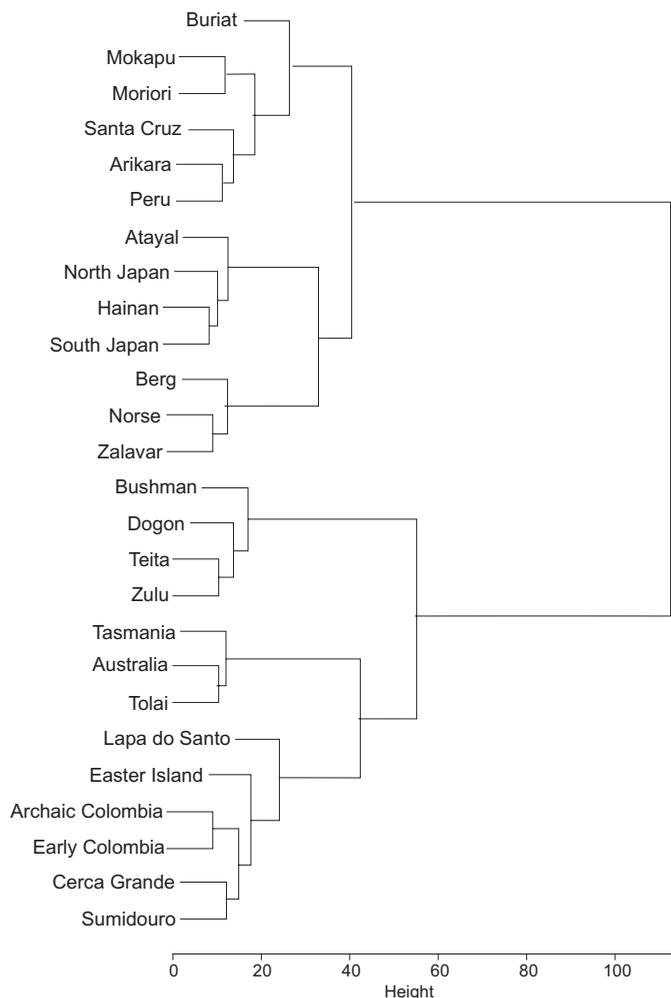


Figure 23.3 Morphological affinities among series according to the Ward's Cluster based on Mahalanobis Distances.

Table 23.3 Craniometric measurements and descriptive statistics (in mm) for the early South American series included in this study.

Craniometric measurements	$\bar{X} \pm s$				
	Lapa do Santo	Sumidouro	Cerca Grande	Early Colombia	Archaic Colombia
Glabello-occipital length (GOL)	182.85 ± 8.61	183.63 ± 6.97	181.40 ± 4.39	182.71 ± 7.54	184.40 ± 6.88
Nasio-occipital length (NOL)	180.14 ± 8.64	179.72 ± 6.33	177.60 ± 4.82	180.42 ± 6.60	181.54 ± 6.17
Maximum cranial breadth (XCB)	129.85 ± 6.66	130.11 ± 4.33	128.80 ± 3.70	129.85 ± 3.93	129.59 ± 6.07
Maximum frontal breadth (XFB)	113.42 ± 6.75	112.18 ± 3.55	106.80 ± 2.77	107.71 ± 2.36	108.92 ± 6.05
Nasion-prosthion height (NPH)	66.19 ± 4.19	64.62 ± 3.21	61.13 ± 5.55	67.07 ± 4.23	67.11 ± 5.51
Nasal height (NLH)	49.08 ± 3.76	47.93 ± 1.93	46.49 ± 3.80	49.50 ± 2.78	49.60 ± 3.57
Orbit height (OBH)	33.86 ± 1.95	33.56 ± 1.75	33.20 ± 0.83	33.82 ± 2.07	33.89 ± 1.63
Orbit breadth (OBB)	40.81 ± 1.64	39.63 ± 1.95	38.99 ± 0.70	38.57 ± 1.85	37.02 ± 1.87
Mastoid Height (MDH)	21.89 ± 5.87	23.70 ± 4.45	24.43 ± 1.79	24.46 ± 3.14	24.93 ± 3.31
Mastoid Breadth (MDB)	13.00 ± 3.16	13.16 ± 2.93	12.70 ± 1.78	11.21 ± 1.39	11.50 ± 1.88
Bifrontomallare breadth (FMB)	99.57 ± 4.75	100.631 ± 4.82	98.55 ± 2.42	97.02 ± 3.45	96.11 ± 4.32
Nasion Subtense (NAS)	17.00 ± 1.52	15.60 ± 2.63	14.41 ± 3.57	14.28 ± 1.81	14.47 ± 2.07
Interorbital breadth (DKB)	24.28 ± 2.42	25.62 ± 2.17	22.16 ± 2.49	22.62 ± 1.75	23.07 ± 1.82
Cheek height (WMH)	23.22 ± 2.44	24.01 ± 1.53	21.80 ± 2.16	23.42 ± 2.70	22.601 ± 1.68
Supraorbital subtense (SOS)	7.857 ± 1.34	7.23 ± 1.42	6.00 ± 1.41	5.78 ± 1.31	5.08 ± 1.58
Glabella subtense (GLS)	3.71 ± 0.95	3.46 ± 1.19	2.80 ± 1.09	2.14 ± 1.167	1.82 ± 1.192
Frontal cord (FRC)	112.58 ± 7.79	111.84 ± 4.86	109.20 ± 2.167	108.53 ± 2.83	111.55 ± 4.52
Frontal subtense (FRS)	25.64 ± 2.46	24.76 ± 1.58	26.00 ± 1.87	23.35 ± 2.53	25.70 ± 2.43
Frontal fraction (FRF)	49.48 ± 3.28	50.92 ± 3.86	45.80 ± 3.03	46.42 ± 3.54	46.61 ± 4.25
Parietal cord (PAC)	114.66 ± 8.21	115.92 ± 7.04	115.60 ± 9.42	112.17 ± 8.60	116.82 ± 7.80
Parietal subtense (PAS)	23.92 ± 2.38	25.00 ± 3.02	24.20 ± 3.89	22.57 ± 2.97	24.99 ± 3.68
Parietal fraction (PAF)	51.14 ± 6.64	61.15 ± 5.58	61.00 ± 7.38	58.78 ± 5.01	60.87 ± 6.02

though groups sharing a similar morphology with the early groups have been reported during mid Holocene in Colombia (Neves et al. 2007a) and late Holocene in Baja California (González-José et al. 2003), Patagonia (Lahr 1995) and Central Brazil (Atuí, 2005; Bernardo et al. 2011).

The second scenario developed to explain morphological diversity observed across time in the Americas assumes that the morphological changes can be explained by local

changes over time. This scenario has received some support from dental morphological studies (Powell 2005), but is considered less parsimonious than multiple migrations from Asia or continuous gene flow with Asia in studies that test which scenario best accounts for morphological diversity in the continent (Azevedo et al. 2011; Hubbe et al. 2010).

The third and most recent scenario proposed to explain morphological diversity in the continent assumes that early

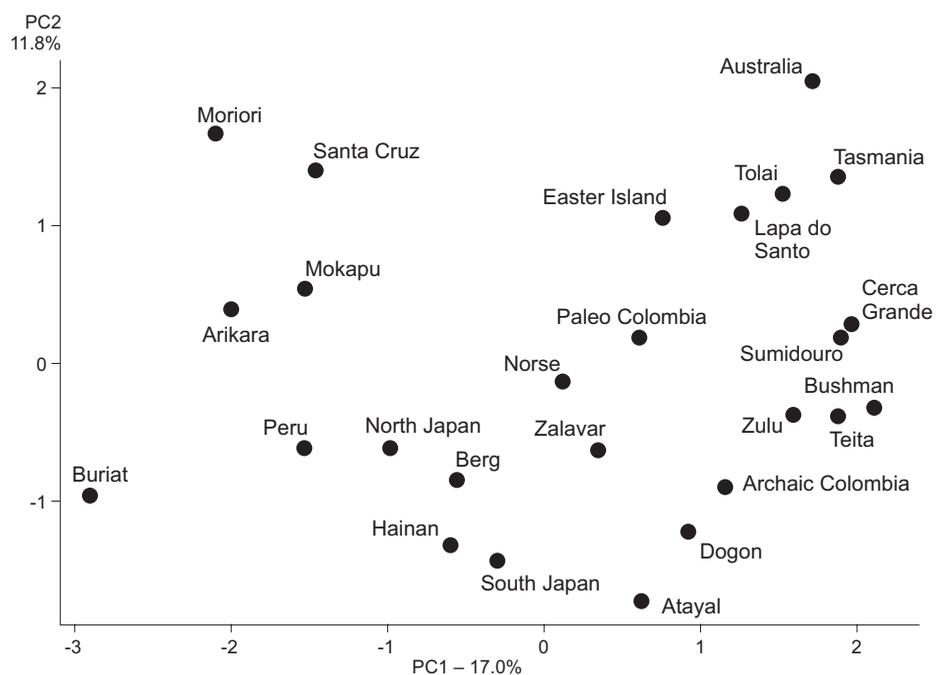


Figure 23.4 Morphological affinities among series according to the first two Principal Components.

Table 23.4 Mean coefficient of variation for each of the series included in the analysis (ordered from lowest to highest).

Series	Region/ Chronologic Affiliation	Coefficient of Variation
Moriari	Polynesia	0.089671
Australia	Australo-Melanesia	0.089821
Santa Cruz	North America	0.090625
Tolai	Australo-Melanesia	0.091451
Hainan	East Asia	0.092124
Atayal	East Asia	0.092824
Zalavar	Europe	0.093703
Easter Island	Polynesia	0.094076
Tasmania	Australo-Melanesia	0.094529
Sumidouro	Early Lagoa Santa	0.095715
Berg	Europe	0.096703
Arikara	North America	0.096913
Norse	Europe	0.097402
Mokapu	Polynesia	0.098547
Cerca Grande	Early Lagoa Santa	0.098621
Peru	South America	0.099821
Zulu	Sub-saharan Africa	0.100737
Southern Japan	East Asia	0.101761
Early Colombia	Early Colombia	0.101987
Lapa do Santo	Early Lagoa Santa	0.102684
Northern Japan	East Asia	0.102688
Buriat	NE Asia	0.103563
Bushman	Sub-saharan Africa	0.109824
Dogon	Sub-saharan Africa	0.111019
Teita	Sub-saharan Africa	0.115373
Archaic Colombia	Archaic Colombia	0.116858

populations that entered the continent already possessed high levels of morphological diversity and that continuous gene flow between American and NE Asian groups shaped the morphological diversity of American groups across time (Azevedo et al. 2011; González-José et al. 2008). This proposal overlaps with the dual-dispersion model by assuming that the diversity observed in the continent depends on the influx of extra diversity from outside the continent. The difference between these scenarios is thus the nature by which this influx occurred; the first scenario defends more discrete migrations, the second maintains that gene flow was constant and continuous between Asia and America throughout the Holocene.

This lack of consensus in the process of human occupation of the continent is also observed in studies of genetic variation among Native American groups. Largely restricted to recent populations, molecular studies in the past 25 years have proposed from one to three discrete migrations into the continent (Bonatto and Salzano 1994; Fagundes et al. 2008; Perego et al. 2009; Reich et al. 2012; Tamm et al. 2007; Wang et al. 2007; Zegura et al. 2004), sometimes defending continuous gene flow with NE Asia (González-José et al. 2008; Tamm et al. 2007) or even a period of isolation of Proto-Americans (Kitchen et al. 2008; Tamm et al. 2007) from Asia before their dispersion into the New World. This lack of consensus among molecular researchers has hindered attempts to conciliate

morphological and genetic evidence (e.g., González-José et al. 2008; Greenberg et al. 1986). Conclusions are therefore doomed to be short-lived and prone to extensive criticism.

Consequently, although increased morphological diversity and a shift in morphological patterns over time in the Americas suggest an influx of further diversity into the continent, at present it is impossible for us to offer a more definite opinion on whether these phenomena are a product of multiple discrete migrations into the continent or a result of gradual influx introduced by continuous contact and gene flow between NE Asia and North America.

Finally, although we extrapolate our conclusion to the entire American continent, it has to be noted that the Early American series available today come entirely from South America. As argued elsewhere in this volume (Dias and Bueno; Dillehay; Flegenheimer), there is enough archaeological evidence to show that early South American groups do not culturally resemble early North American groups. Consequently, the same might be true of the biological characteristics of early populations in each continent. Our results favor the notion that all early North American, Meso American, and South American groups shared a common morphology, since Lagoa Santa and early Colombia groups show the same morphological pattern seen in other parts of the planet by the end of the Pleistocene. Consequently, the increase in morphological diversity and the late appearance of a new morphological pattern in the continent was a continent-wide event. However, it is possible and reasonable to assume that the processes that

Table 23.5 Correlations between the first two principal components and the craniometric variables included in this study.

	PC1	PC2
Eigenvalue	1.89171	1.574605
% of variance	0.170437	0.118086
Glabella-occipital length (GOL)	0.376349	0.346632
Nasio-occipital length (NOL)	0.304731	0.282694
Maximum cranial breadth (XCB)	-0.57534	-0.36688
Maximum frontal breadth (XFB)	-0.33461	-0.54643
Nasion-prosthion height (NPH)	-0.67036	-0.05943
Nasal height (NLH)	-0.69452	-0.06089
Orbit height (OBH)	-0.54308	0.002459
Orbit breadth (OBB)	-0.05901	0.5337
Mastoid Height (MDH)	-0.27646	0.053939
Mastoid Breadth (MDB)	-0.23185	0.32434
Bifrontomallare breadth (FMB)	0.246123	0.471891
Nasion Subtense (NAS)	0.263655	0.390538
Interorbital breadth (DKB)	0.427717	-0.05776
Cheek height (WMH)	-0.51724	-0.09909
Supraorbital subtense (SOS)	0.413507	0.323255
Glabella subtense (GLS)	0.004826	0.49209
Frontal cord (FRC)	-0.06571	-0.17321
Frontal subtense (FRS)	0.357769	-0.5084
Frontal fraction (FRF)	-0.18112	-0.0452
Parietal cord (PAC)	0.66753	-0.27869
Parietal subtense (PAS)	0.365594	-0.38176
Parietal fraction (PAF)	0.525428	-0.47799

In bold: highest correlations with each principal component

drove this influx of morphological diversity in North America might have been different from those at work in South America. For instance, it is possible that in North America this process was a continuous influx from Asia, whereas in South America the same result could have been achieved by discrete waves of dispersion. This scenario has some support from recent molecular studies that suggest that continuous gene flow with NE Asia was probably restricted to the northern regions of North America (Reich et al. 2012; Tamm et al. 2007). Moreover, the theory of discrete dispersion waves in South America has received some support from molecular studies, which suggest two discrete dispersion waves inside the continent, based on rare mtDNA lineages (Perego et al. 2009) and a much higher degree of diversity between populations in non-Andean native South Americans (Tamm et al. 2007).

However, many other molecular studies refute this idea and defend a single wave of dispersion into South America (Greenberg et al. 1986; Reich et al. 2012; Tamm et al. 2007) or even into the Americas as a whole (e.g., Wang et al. 2007; Zegura et al. 2004). Our intention here is not to corroborate or refute a particular scenario of how populations dispersed across the continent, but rather to highlight the fact that our data about Early American groups are biased by being restricted to South America. Therefore any model built to explain the origins of the first South Americans will not necessarily apply to North America. We believe it is time to consider the possibility that the two sub-continent have distinct human histories, as has been repeatedly demonstrated by the archaeological record (e.g., Dillehay 2008, 2009; Rothhammer and Dillehay 2009; this volume) and other lines of evidence such as linguistics (Nettle et al. 1999) and molecular studies (Wang et al. 2007).

The Paleoamerican Odyssey: Perspectives from the Biology of Early South Americans

The importance of the Lagoa Santa region, with its dozens of late-Pleistocene/early-Holocene sites and hundreds of human burials, to the studies of the characteristics of early human groups in South America cannot be highlighted enough. The human presence in the region during the final millennia of the Pleistocene and early Holocene shows a series of groups adapted to the local environment, with life-style and burial practices remarkably different from those seen in other regions of South and North America. By itself, this shows that the early-Holocene populations in the New World expressed significant cultural diversity between themselves, being one more distinct piece of the mosaic of cultures that were present in the continent (e.g., Dillehay 2000, 2008; Dixon 2001; Arriaza et al. 2008; Goebel et al. 2008). This cultural diversity shows a quick process of differentiation in the initial periods of the human presence in the continent, showing that no matter who came into the Americas or how fast the colonization wave dislocated through the landscape, by 10,000 cal yr BP the continent showed signs of people adapting to their own landscape

and developing clear local traditions that are defined by more than their technological background.

Yet the same cannot be said from their biological characteristics, since as far as cranial morphology is concerned, the early-Holocene populations of the continent show low levels of variation and a morphological pattern that is not the one most widespread among late-Holocene Native American population. This strongly suggests a significant influx of extra morphological (and biological) diversity into the continent during the Holocene, either by continuous gene flow with Asia or by multiple discrete dispersion waves into the continent during this time. Consequently, from the perspective of cranial morphology, a) the actual biological diversity of Native Americans does not derive exclusively from the early Paleoamerican populations that settled the continent, and b) a linear causal connection between early and late populations on the continent should be argued for only when empirical data strongly support it. In other words, our analyses of the Lagoa Santa remains in the past decades (Neves and Hubbe 2005; Hubbe et al. 2010, 2011; Neves et al. 2007b), as well as the ones presented here, add to the growing body of evidence that the processes associated with the settlement and dispersion of human groups across the Americas, far from being either simple or straightforward, instead involved the complex interaction between different cultures and possibly biologically distinct populations during the entire period humans have been occupying the continent.

Acknowledgments

This chapter is dedicated to Peter W. Lund, who opened the doors to this most remarkable evidence about the life of early humans in the continent. Over the past decade hundreds of people—researchers, students, volunteers and workers—helped in the Lagoa Santa project, excavating and generating data, interpreting results, and discussing our findings. Although we cannot list all of them here, their contribution to the project can hardly be overstated. We are also indebted to the curators of all the different institutions that house the Lagoa Santa remains: Natural History Museum of Copenhagen, Natural History Museum of London, Museu Nacional do Rio de Janeiro, Museu de História Natural da UFMG, Instituto Histórico e Geográfico do Rio de Janeiro. This research was funded by FAPESP (99/0191-8 and 04/01321-6), CNPq (300917/2010-4) and the Max Planck Institute for Evolutionary Anthropology.

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