



Early Holocene human skeletal remains from Santana do Riacho, Brazil: implications for the settlement of the New World

Walter Alves Neves^{a*}, André Prous^b, Rolando González-José^c, Renato Kipnis^d, Joseph Powell^e

^a *Laboratório de Estudos Evolutivos Humanos, Departamento de Biologia-IB, Universidade de São Paulo, C.P. 11461, 05422.970 São Paulo, SP, Brazil*

^b *Museu de História Natural, Universidade Federal de Minas Gerais, C.P. 1035, 31080.010 Belo Horizonte, MG, Brazil*

^c *Sección de Antropología, Facultad de Biología, Universitat de Barcelona, Av. Diagonal, 645, 08028 Barcelona, Spain*

^d *Laboratório de Estudos Evolutivos Humanos, Departamento de Biologia-IB, Universidade de São Paulo, C.P. 11461, 05422.970 São Paulo, SP, Brazil*

^e *Department of Anthropology and Maxwell Museum of Anthropology, University of New Mexico, Albuquerque, NM 87131-1086, USA*

Received 16 May 2002; accepted 28 April 2003

Abstract

In this study we compare the cranial morphology of several late Paleoindian skeletons uncovered at Santana do Riacho, Central Brazil, with worldwide human cranial variation. Mahalanobis Distance and Principal Component Analysis are used to explore the extra-continental morphological affinities of the Brazilian Paleoindian sample. Santana do Riacho is a late Paleoindian burial site where approximately 40 individuals were recovered in varying states of preservation. The site is located at Lagoa Santa/Serra do Cipó, State of Minas Gerais. The first human activities in this rockshelter date back to the terminal Pleistocene, but the burials are bracketed between circa 8200 and 9500 BP. The collection contains only six skulls well-enough preserved to be measured. The Santana do Riacho late Paleoindians present a cranial morphology characterized by long and narrow neurocrania, low and narrow faces, with low nasal apertures and orbits. The multivariate analyses show that they exhibit strong morphological affinities with present day Australians and Africans, showing no resemblance to recent Northern Asians and Native Americans. These findings confirm our long held opinion that the settlement of the Americas was more complicated in terms of biological input than has been widely assumed. The working hypothesis is that two very distinct populations entered the New World by the end of the Pleistocene, and that the transition between the cranial morphology of the Paleoindians and the morphology of later Native Americans, which occurred around 8–9 ka, was abrupt. This, in our opinion, is a more parsimonious explanation for the diversity detected than a long, local microevolutionary process mediated by selection and drift. The similarities of the first South Americans with sub-Saharan Africans may result from the fact that the

* Corresponding author. Fax: 55-11-3091-7553

E-mail addresses: waneves@ib.usp.br (W.A. Neves), aprous@dedalus.lcc.ufmg.br (F. Prous), rgonzalez@porthos.bio.ub.es (R. González-José), rkipnis@ib.usp.br (R. Kipnis), jpowell@unm.edu (J. Powell).

non-Mongoloid Southeast Asian ancestral population came, ultimately, from Africa, with no major modification in the original cranial *bau plan* of the first modern humans.

© 2003 Elsevier Ltd. All rights reserved.

Keywords: Peopling of the Americas; Paleoindians; South America; Brazil; Principal components analysis; Mahalanobis distances; Lagoa Santa; Burials; Skeletal analysis

Introduction

In the last decade, new models about the origins and the biological affinities of the first Americans have been suggested (see Powell and Neves, 1999; Steele and Powell, 2002 for reviews). One of the most interesting and debated issues is that new studies show a cranial morphology for terminal Pleistocene and Early Holocene populations in the Americas outside the range of variation of modern Amerindians, both in North and South America (Jantz and Owsley, 2001). While in North America the early human remains are, in general, but not exclusively, more similar to South Asians, Ainu/Polynesians or Europeans (Steele and Powell, 1992, 1994, 1999; Chatters et al., 1999; Brace et al., 2001; Jantz and Owsley, 2001), in South America they are closer to Australians and sub-Saharan Africans (Neves and Pucciarelli, 1989, 1990, 1991; Munford et al., 1995; Neves et al., 1998, 1999a,b). Although this information has been available in the specialized literature since the late 1980s (Neves and Pucciarelli, 1989), due attention to these findings by the mainstream academic community is recent, post-dating crucial challenges to the prevailing “Clovis first/Clovis-like” model (Roosevelt et al., 1996; Adovasio and Pedler, 1997; Dillehay, 1997; Meltzer, 1997; Meltzer et al., 1997; Kipnis, 1998).

The cranial morphology of a female skeleton of great antiquity (>11,000 BP) found at Lapa Vermelha IV in the Lagoa Santa region of Central Brazil, also contributed significantly to the increased attention of physical anthropologists and archaeologists to the biological origins of the Native Americans. The individual found at Lapa Vermelha IV, also known as “Luzia”, is considered to be the oldest human remains ever found in the New World (Laming-Emperaire, 1979; Prous,

2001). As in other South American Paleoindians, “Luzia” presents a cranial morphology common today among Australian aboriginals and sub-Saharan Africans (Neves et al., 1998, 1999a,b).

In spite of the fact that other early South American skeletons also show a different cranial morphology when compared to later Amerindians (Neves and Pucciarelli, 1989, 1990, 1991; Steele and Powell, 1992, 1994), it has been suggested that “Luzia” could be an aberrant individual (Dillehay, 2000; Roosevelt et al., 2002), because, in principle, the biological and cultural origins of the first Americans are presumed to be found among northern Asians. In order to test the idea that the cranial morphology of “Luzia” is an anomalous case when compared to other South American Paleoindians, we investigate in this work the cranial morphology of several individuals recovered from Santana do Riacho, a late Paleoindian burial site located near the Lagoa Santa region (Fig. 1).

Well-dated early skeletal remains are rare in the New World, particularly in North America, where specimens consist of isolated individuals found in widely separated geographic regions (Steele and Powell, 1994; Chatters et al., 1999; Jantz and Owsley, 2001). In South America many skeletons are putatively assumed to be of Late Pleistocene/Early Holocene age, but most of these skeletons were never accurately dated, either by precise stratigraphic association, or by directly dating human bone collagen. The human skeletons recovered at Santana do Riacho are an exception. The radiocarbon dating of charcoal in good stratigraphic association with human burials, together with direct dating of human bone collagen, indicates a burial event during the Early Holocene (ca. 9500 BP, see below). The Santana do Riacho material is therefore important for those interested

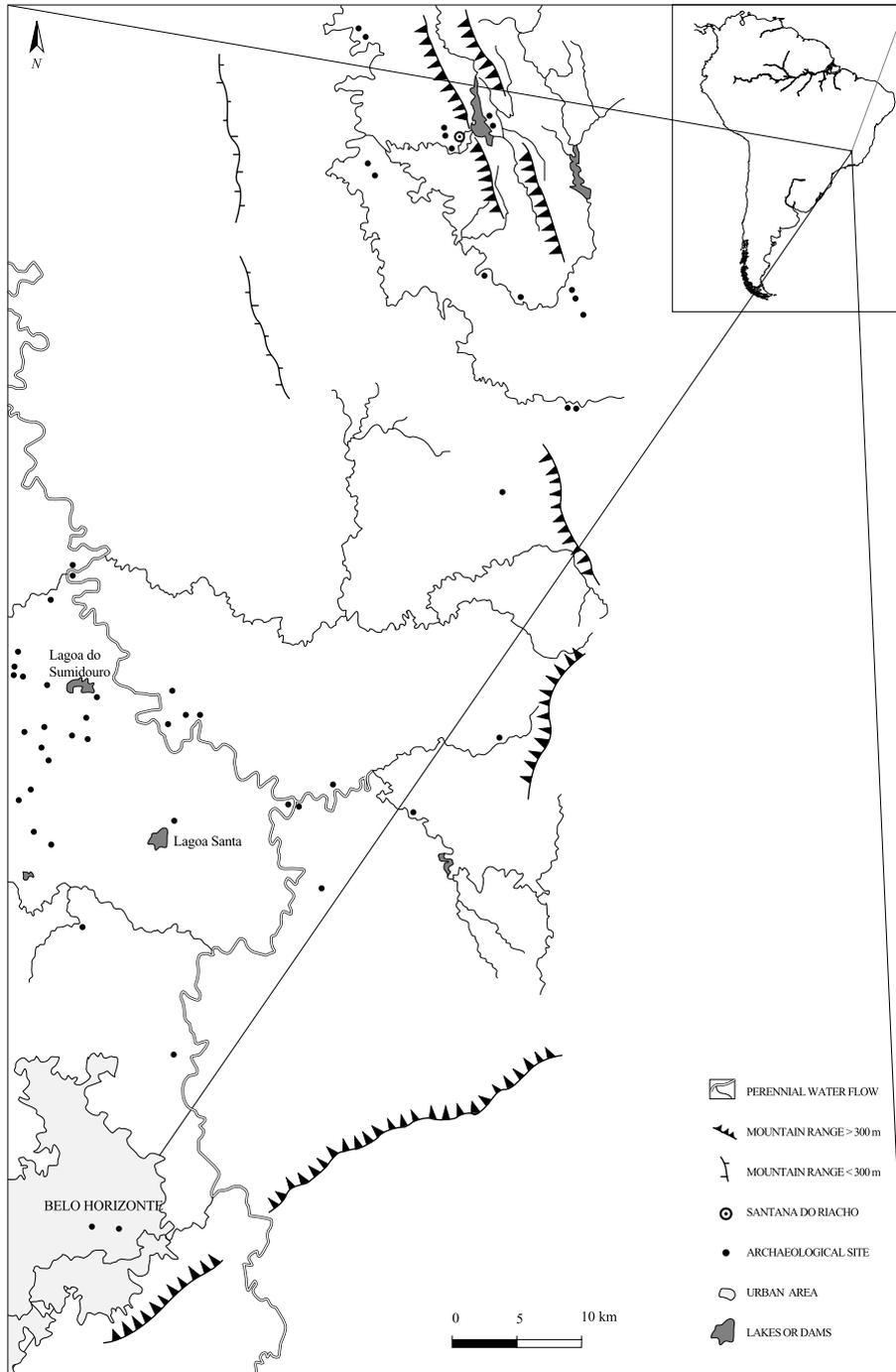


Fig. 1. Lagoa Santa plateau with archaeological site distribution (adapted from Malta and Köhler, 1991).

in the study of the biological characteristics of the first Americans and their implications for the settlement of the continent.

Before presenting the skeletal data and analyses, we discuss, in the next section, the information about the archaeological and the chronological contexts of Santana do Riacho.

The archaeological and chronological context

Geographical setting

The rockshelter of Santana do Riacho is located in the *Serra do Cipó* region (Fig. 1). The *Serra do Cipó* is the easternmost portion of the Lagoa Santa Plateau. The region is dominated by *cerrado* vegetation with *cerradão* formation widespread through the area, and gallery forest along watercourses (Brandão, 1992/93). The climate at Lagoa Santa is warm and seasonally dry in the winter and moist and warm in the summer. Average annual rainfall is 1562 mm, unevenly distributed throughout the year. Spring and summer rainfall (September–February) account for 70% of all precipitation. Mean annual temperature is 20.6°C. February is the warmest month with mean temperature of 22.8°C, and July being the coldest month with mean temperature of 17.2°C (Ratisbonna, 1976).

Lagoa Santa is characterized by its karstic relief formed on the limestone formation known as *Sete Lagoas*. Santana do Riacho, a rockshelter formed by the falling of quartzite blocks from the base of a cliff, is located at the boundary between the *Sete Lagoas* limestone formation associated with the *Bambu* group of Silurian age and the quartzite *Espinhaço* supergroup (Malta and Köhler, 1991). The archaeological site is found in the structural/lithologic limits between two major geological units: (1) *Córrego dos Borges* Formation, which is formed by medium-grain quartzite intercalated with thin levels of metapelites and conglomeratic lenses, belonging to the *Espinhaço* supergroup, is characterized by the alternation of metasediments of psammitic/pelitic character; and (2) *Macaúbas* Group which is characterized by three units: (a) quartzites, (b) tillites and associated sediment, and

(c) quartzite, micaceous quartzites, metasiltite, phyllite, and green schist (Karfunkel et al., 1991).

Santana do Riacho's wall presents the lithologic contact between the quartzitic rocks of the *Espinhaço* Group and the tillites of the *Macaúbas* Group. The shelter is 80 m long, with a quartzite wall in the back and two dejection cones on each side forming a semi-amphitheater. The floor is formed by fallen blocks, surrounded by sand, quartzite fragments, and laterite debris, originating from the lateral cones, and covered by sandy sediments (Köhler et al., 1991).

The archaeological site consists of two major platforms with a ten-meter difference in level between them (Fig. 2). Test pits and excavations, covering 100 m², were conducted in these two areas of the rockshelter. The first human occupation dates back to 11,960 ± 250 BP, and from then on it was occupied throughout the Holocene up to modern times (Prous, 1980/1981).

Excavation history

During the second half of the 19th Century, the Lagoa Santa region was explored by the Danish naturalist Peter W. Lund, who found several caves and rockshelters containing extinct fauna and human remains (Lund, 1842, 1844; Couto, 1950). In the late 1960s the French archaeologist Annette Laming-Empeire, the coordinator of the French-Brazilian Archaeological Mission, began working in the Lagoa Santa region. In 1974 Laming-Empeire decided to extend the research area to *Serra do Cipó*, north of Lagoa Santa (Prous, 1991). Her reasoning for this was that she was frustrated by the stratigraphic problems found at Lagoa Santa (i.e., disturbance by previous excavations). By changing area, she was hoping to find undisturbed archaeological sites. Santana do Riacho, first visited by Laming-Empeire and one of the authors (AP) in 1976, matched her expectations of a fairly intact archaeological site. The location was well-known to local inhabitants because of the extraordinary prehistoric paintings along its wall. Excavations (Fig. 3) began that year, and during the following three years the research team conducted four more months of

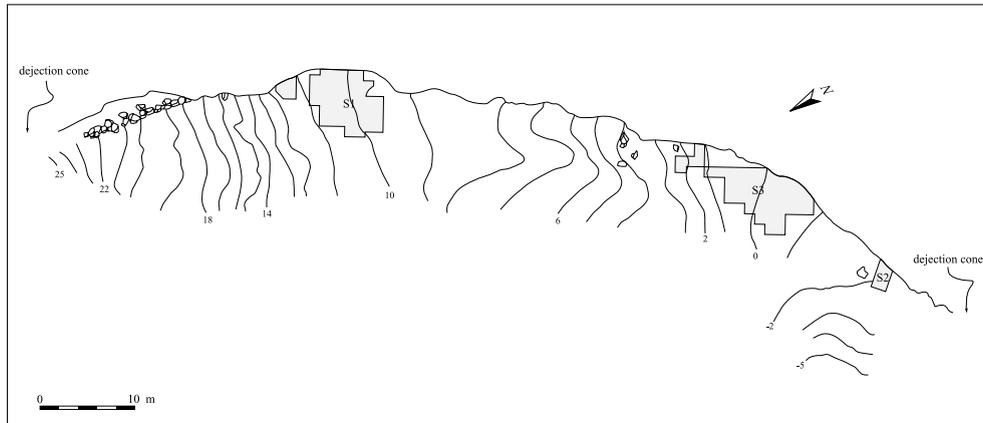


Fig. 2. Topography and archaeological excavation areas at Santana do Riacho. Contour interval in meters (adapted from Köhler et al., 1991).

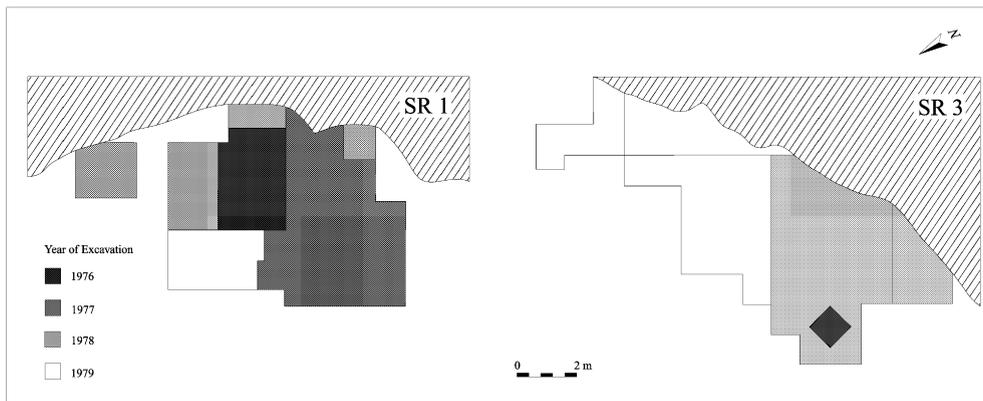


Fig. 3. Chronological sequence of excavations at Santana do Riacho (adapted from Prous, 1991).

fieldwork (one in 1977, two in 1978, and one in 1979).

In 1976 three small test pits (S1, S2 and S3; Fig. 2) were excavated and revealed lithic-rich archaeological deposits and human burials. The testing was performed in areas with gentler slope with the assumption that the 1970s floor relief was similar to past relief in the shelter; therefore, those areas would have been more attractive for human activities. Two of the test pits (S1 and S2) were located at the extremities of the shelter, close to the dejection cones. A third test pit (S3) was located in between S1 and S2. The locations of the excavations were designed to assess the differential spatial

distribution of archaeological material. Also, the tests were positioned under the prehistoric paintings with the expectation that the excavations would reveal artifacts and/or features associated with the painting activities, thus providing the possibility of dating some of the rock art (Prous et al., 1991).

The S1 and S3 test excavations revealed the thickest deposits with rich archaeological material, and it was decided to extend the excavations in those two areas. The excavation areas are referred to as SR1 and SR3, which are extensions of the S1 and S3 test pits, respectively. The other test excavation (S2) revealed a thin sedimentological

package containing archaeological material, and was not excavated further. During the following two years, extensive excavations of SR1 and SR3 were undertaken (Figs. 2 and 3). Excavation followed stratigraphic levels guided by natural strata. Four major natural stratigraphic units were identified in all test pits and subsequent excavations. We will focus on SR1 because all the Early Holocene burials were found in this area, and it has a consistent stratigraphy.

Stratigraphy-SR1

Prous et al. (1991:67) expected that the testing and excavation of SR1 area would reveal thick deposits, and because of its proximity to the dejection cone (Fig. 2), might have distinguishable occupational floors. Excavation followed the *décapage* method, a system of careful horizontal scraping with the side of a trowel following natural, or cultural, stratigraphy while maintaining standardized horizontal units within which artifacts, features, and organic remains can be plotted three-dimensionally. Sieves of 5- and 2-mm mesh were used to recovered material not piece-plotted.

Each stratum corresponds to a phase or sedimentological process (Prous et al., 1991). In general, the sediment associated with the archaeological layers is sand, the source of which could be the dejection cone, eolian, anthropic, or from local lithology. Unfortunately, there were no further geomorphological studies to understand the formation of each stratum. Therefore, we do not know the exact origin of the sediment for the different time periods. The strata were divided into archaeological levels, and each received a number corresponding to the stratum (e.g., 1, 2, 3) and its location within the stratum (e.g., upper, middle, lower). The subdivisions of the strata were intended to represent different archaeological occupations, but, as Prous et al. (1991) acknowledge, they probably grouped several occupations spanning years, decades, or even centuries owing to the lack of sediment compactness, some degree of vertical mobility of material, and lack of 'sterile' levels between archaeological levels.

All of the strata could be recognized along the excavation (Fig. 4), but specific archaeological levels were not present in some of the excavation units (1 × 1 m) because of animal and human perturbations (Prous et al., 1991). The thickness of the Holocene sediment varies greatly in SR1. The northern area of the excavation had 70 cm of sediment representing the last 8000 years, while the central part had only 30 cm for the same period. Description of each stratum, as presented by Prous (1980/81; Prous et al., 1991) follows:

Stratum 0 (ca. 2800 BP-present) - Sediment is dark in color, charcoal rich (up to 5% of its volume), with great quantities of archaeological material. The surface contains modern dry cattle manure and charcoal, probably from recent hearths and fires. This stratum was not subdivided because there were no features to suggest different archaeological levels, apparently because of cattle trampling on the surface. At the base of this stratum, close to the talus, lie large blocks (up to 80 cm in height) fallen from the ceiling.

Stratum 1 (ca. 2800 BP-ca. 4500 BP) - Characterized by a great number of archaeological features, hearths, post-holes, and clusters of artifacts. The sediment matrix has a light gray color, but it is brown under the fire hearths. It also contains sandy lenses formed by the disintegration of tillite blocks in fire hearths. This stratum varies in thickness from 30 cm in the excavation's northern part, where it was subdivided into three levels (upper, middle, and lower), to 15 cm in the southern area where the middle level was not recognized during excavation. Some of the hearths penetrated older levels. Radiocarbon dating obtained from charcoal samples from this stratum are: 2875 ± 50 BP for the contact between stratum 0 and 1, 3990 ± 70 BP for a fire hearth associated with level 1/upper and 4340 ± 70 BP for another hearth associated with level 1/lower.

Stratum 2 (ca. 4500 BP and ca. 8000 BP) - Characterized by the presence of a sediment with a homogeneous brown color due to burning, few preserved structures, and the archaeological material seems to have been moved horizontally and vertically by trampling. Thickness of this stratum varies from 20 cm along the northern and southern part of the excavation area to 15 cm in

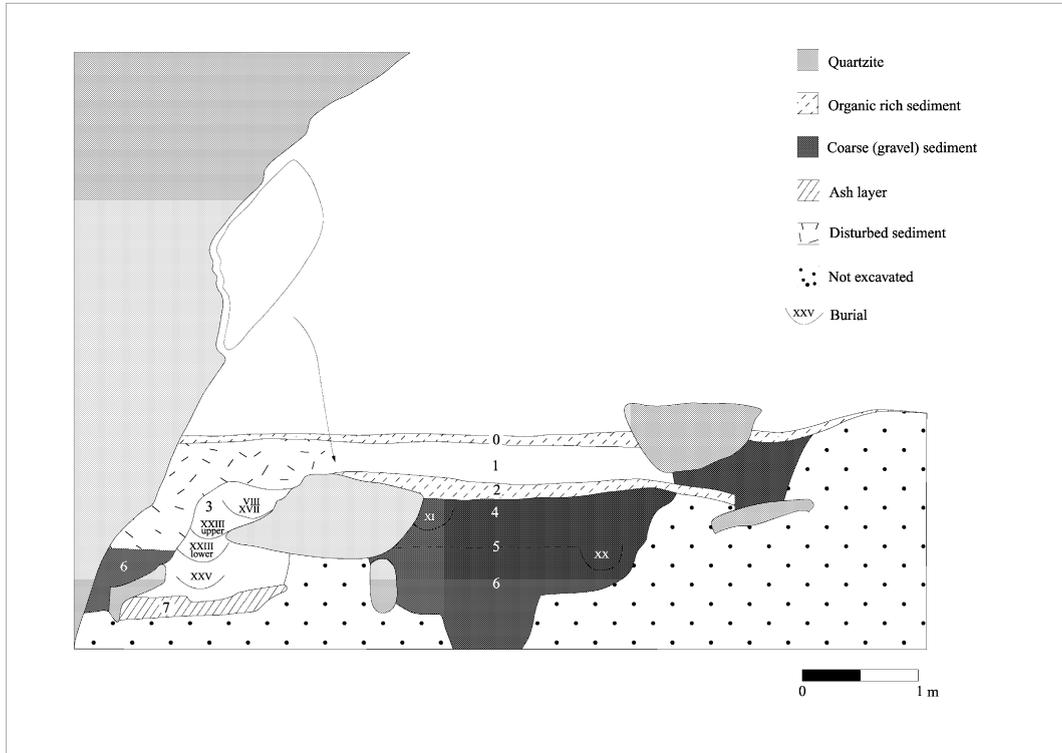


Fig. 4. Profile of excavation area SR1 with burial locations projected against it (adapted from Prous et al., 1991). Arabic numbers refer to stratigraphic levels.

the center. A subdivision of upper and lower levels was guided by the presence of ‘sterile’ sediment in between. Contact between stratum 1 and 2 is not well defined.

Strata 3 and 4 (ca. 8000 BP and ca. 10,000 BP) - These strata are actually one stratum that was perforated by intrusive human burials. Stratum 3 is defined as the archaeological layer containing the human burials, and stratum 4 is the same archaeological layer without the burials (Fig. 4). The human burials are not necessarily contemporaneous. The sediment of stratum 4, immediately underneath level 2, is characterized by a light beige sandy matrix with gravel rocks of various sizes. The human burials were filled with sediment and archaeological material. Gravel and small rocks were placed on top of the burials in order to seal them. Some of the burials cut through older ones and/or through stratum 4. Archaeological material

in stratum 4 is rare, and the stratum varies in thickness from 60 to 80 cm.

Strata 5 and 6 (ca. 10,000 BP and ca. 12,000 BP) - Both strata lack archaeological material and in some areas were cut through by burials from later occupations. The sedimentary matrix of stratum 5 is the same as stratum 4 (sandy with gravel and different sized rocks) characterized by yellow color, and the sediment of stratum 6 is characterized by coarse-grained sand.

Stratum 7 (ca. 12,000 BP and ca. 18,000 BP) - The matrix of this stratum is the same yellow sediment as in strata 5 and 6, and it is characterized by the presence of many large blocks from the shelter’s wall and ceiling. The stratum was subdivided into three levels. The upper level has an ash lens of what could be a fire hearth. The ash lens has a radiocarbon date of $11,960 \pm 250$ BP on top of which a large wall slab fell between 12,000

Table 1
Uncalibrated radiocarbon dates ($\pm 1\sigma$) from Santana do Riacho, excavation area SR1

Zone/Square	Stratum Level	Date (yrs. BP)	Laboratory ^a and no.	Material dated	Radiometric Method
G 74	1 upper	2875 \pm 50 ^b	CDTN 1038	Charcoal	Standard
D 79	1 upper	3360 \pm 70	CDTN 1047	Charcoal	Standard
G 72	1 middle/upper	3990 \pm 70	GIF 4510	Charcoal	Standard
G 73	1 lower	4340 \pm 70	GIF 4509	Charcoal	Standard
–	Burial IV	8150 \pm 150	GIF 5087	Charcoal	Standard
H 74	2 base	8185 \pm 110	CDTN 1039	Charcoal	Standard
–	Burial XX	8,280 \pm 40	BETA 162014	Human bone collagen	AMS
–	Burial XXIII	8230 \pm 150	GIF 5088	Charcoal	Standard
DE 72	2 base	8381 \pm 280	CDTN 1044	Charcoal	Standard
–	Burial XIII	9460 \pm 110	GIF 4508	Charcoal	Standard
C 71	7	11,960 \pm 250	GIF 5089	Charcoal	Standard
–	Burial Va	12,760 \pm 70 ^c	BETA 96759	Human bone collagen	AMS
EF 71-72	8	18,000 \pm 1000 ^d	CDTN 1045	Charcoal	Standard

^aBeta Analytic (USA), Gif sur Yvette (GIF, France) and Centro de Desenvolvimento da Tecnologia Nuclear (CDTN, Belo Horizonte).

^bRadiocarbon date younger than expected, potential contamination by roots.

^cRadiocarbon date older than expected.

^dAnthropic origin of charcoal sample is questionable, probably from natural fires (Prous and Fogaça, 1999:27).

and 11,000 BP. The middle level is archaeologically sterile, and in the lower level charcoal was found, which yielded a date of 18,000 \pm 1000 BP, but the origin of which (i.e., anthropic or natural) is not known.

Table 1 and Fig. 5 show the results of radiocarbon dating 11 charcoal samples and 2 human bone collagen samples for SR1. Most of the dates are consistent, with increasing age as one goes down the sequence. Samples from Stratum 0 of SR1 were all contaminated by humic acids from modern roots, and could not be dated accurately (Chausson and Delibrias, 1992/93). Similarly, three other dates of human bone samples, dating from ca. 2000 and 7800 BP and reported elsewhere (Dillehay, 2000: 309–310) must be seen as minimum dates. Because none of these samples provided good collagen for dating, Beta Analytic provided dates based on floating carbon molecules found in the acid washes of the pretreatment of the samples. These molecules are a mixture of carbon released from collagen and carbon released from later humic acids. There are clearly two clusters of dates (Table 1 and Fig. 5), one associated with Stratum 1, between 2875 and 4340 BP, and another related to the base of Stratum 2 and the set

of burials of Stratum 3 around 8150 and 9460 BP.

Until recently, the dating of Stratum 7 at Santana do Riacho has been assumed to be among the earliest evidence for a human presence in Central Brazil at around 12,000 BP, because one charcoal sample from this Stratum yielded a radiocarbon date of 11,960 \pm 250 BP (Table 1). The dated material came from an ash and charcoal layer (Fig. 4), and stratigraphically associated with this layer were crystal quartz flakes, processed ochre fragments, and a small stone covered with pigment. It is acknowledged now that the associated archaeological material might be intrusive, maybe pertaining to Stratum 4, and, although improbable, the ash and charcoal could have been derived from natural fire (Prous and Fogaça, 1999:27).

Prehistoric remains

The main lithic industry at Santana do Riacho is characterized by an expedient flaked lithic assemblage mainly of quartz, which is locally available within a 1–2 km radius from the site (Prous et al., 1991). Other raw materials far less utilized at Santana do Riacho are quartzite, flint,

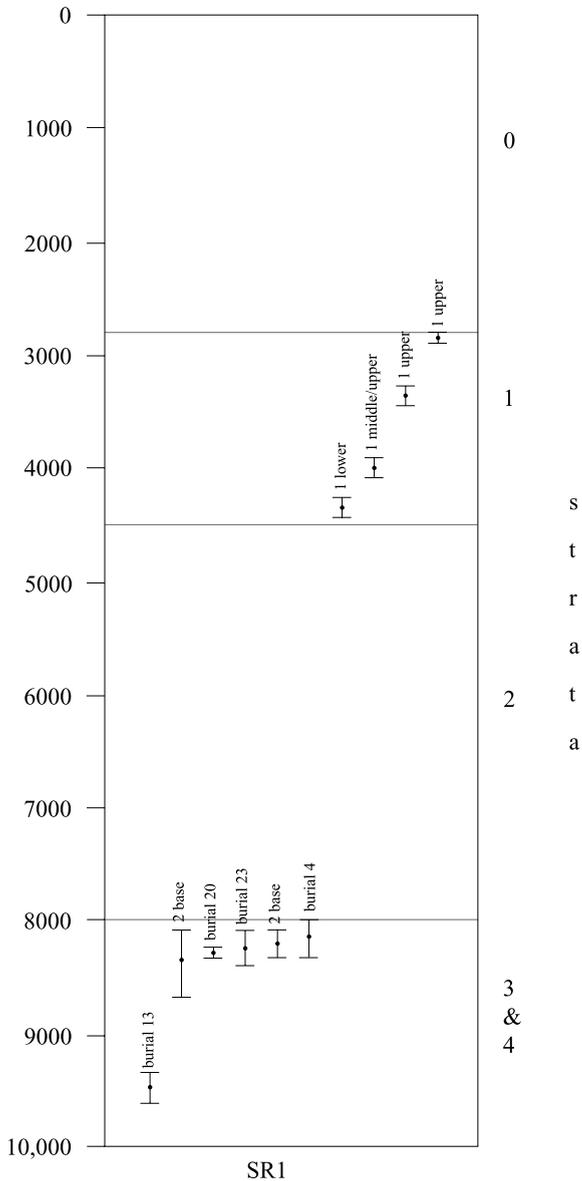


Fig. 5. Uncalibrated radiocarbon dates ($\pm 1\sigma$) from untested archaeological occupations at Santana do Riacho (left y-axis). Horizontal lines define stratigraphic levels (right y-axis) based on excavation area SR1.

chalcedony, and jasper. Quartzite is found at the site and surroundings, but flint, jasper, and chalcedony are not. The closest known source for flint is 40 km from Santana do Riacho. Jasper and chalcedony are also exotic, and are not found less than 60 km from Serra do Cipó.

Formalized artifacts include side scrapers, end-scrapers, nosed scrapers, borers, and *limaces*. A few fragments of bifacial artifacts (10 quartz pieces), probably projectile points, were also found. Several utilized flakes were also recovered from the excavation. Quartz tools, cores, and *débitage* (mainly byproduct of flint-knapping using anvil stones) were present in relatively great quantities. The flint assemblage, rare in the most recent occupations, increases in quantity as one goes back in time. The significant increase in the use of flint as raw material for producing artifacts suggests that the Early Holocene populations at Santana do Riacho had greater access to flint than later inhabitants of the site. This might imply greater mobility or exchange networks.

Use-wear analysis of a sample of the lithic collection showed conclusive evidence of wood-working on 4 of 69 analyzed quartz scrapers, and two other scrapers showed evidence of hide or pigment processing. Twenty-five other scrapers also had evidence of use, but the use-wear did not show a distinguishable pattern. The other 35 analyzed tools did not have clear indication of use (Lima, 1991:277).

Despite the low acidity of the sediments, botanical remains (not including non-identified charcoal fragments) at Santana do Riacho are not abundant; only 306 plant remains were recovered from SR1. Although most of the botanical material from SR1 is found inside a hearth dated to ca. 2800 BP (Resende and Prous, 1991), Stratum 3 shows a relatively great diversity of plant remains (Resende and Prous, 1991:99). Domesticated species (e.g., *Zea mays*) are only found in Stratum 1. In older strata (i.e., strata 2, 3, and 4) the botanical remains include nuts and wild fruits (e.g., coconuts such as *Astrocaryum* sp. and *Cocos coronata*, and pequi fruit-*Caryocar brasiliense*).

Animal remains at Santana do Riacho are more frequent than the botanical remains, 1197 skeletal elements were recovered from SR1. The faunal assemblage is characterized by a diversity of taxa with predominantly small-size vertebrates such as cavy, rock cavy, turtle, and a significant presence of medium-size mammals, mainly deer. Noteworthy is the absence of remains of extinct animals

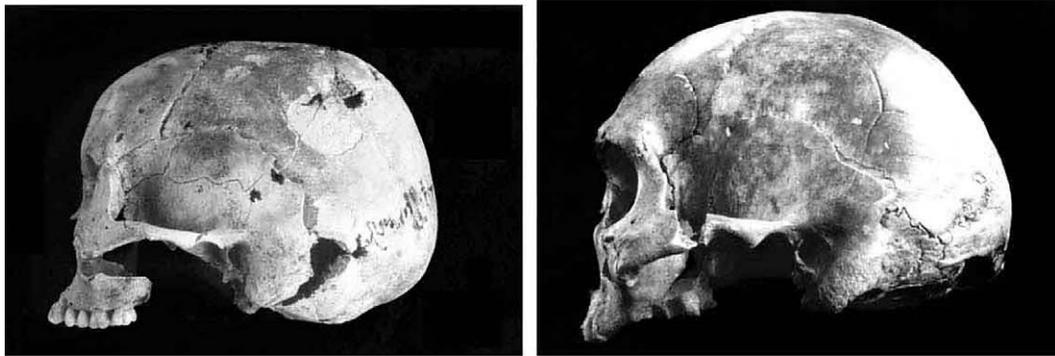


Fig. 6. Lateral view of two of the most intact crania from Santana do Riacho, SR1XXII (left, female) and SR1III (right, male).

associated with human occupation. A detailed taphonomic study of the faunal assemblage from Santana do Riacho has shown that human agency is responsible for most of the faunal remains retrieved during excavation. Analysis of the faunal assemblages indicate that there are no statistical differences in taxonomic abundance (i.e., richness, evenness, and diversity) between the terminal Pleistocene, Early Holocene and Middle Holocene levels from Santana do Riacho (SR1). This suggests that hunting strategies were consistent, despite environmental changes during the terminal Pleistocene and first half of the Holocene (Kipnis, 2002).

Burial pattern

The excavations of SR1 at Santana do Riacho revealed 28 burials, containing approximately 40 individuals (Junqueira, 1992/93; Prous, 1992/93; Neves and Cornero, 1997). All but one burial dates to between 8200 and 9500 BP, the exception is one individual who was probably buried between 10,000 and 11,000 BP (Prous, 1992/93:23).

Preliminary analyses of the human osteological material from Santana do Riacho (Fig. 6) were reported by Alvim (1992/93), Radicchi (1992/93), and Souza (1992/93a,b) before the material was appropriately cleaned, and their results must be viewed with caution.

After appropriate curation, led by one of us (WAN) in 1994/1995, 40 individuals of different sexes and ages were recognized (21 adults, 18

sub-adults, 1 with age undetermined; of the adults, 9 were males, 8 females, and 4 of undetermined sex). The corpses were buried in shallow graves preferentially established around the fallen block of stratum IV (Fig. 7). The burial activities at this locus were so intense that several burials were damaged when a pit was dug to bury a new individual. When this happened, the disturbed bones were placed on the top of the new grave. Only three bodies were interred away from the central block.

All individuals were interred in fetal and lateral position. Some adults were probably wrapped in hammocks before being laid down. The ribs and right leg of the individual in burial 16 was partially enclosed by a textile manufactured by the twined technique (Lara and Moresi, 1991). This technique is commonly used among modern Native communities in Brazil to manufacture hammocks (Riberio, 1986, 1988). While some of the burials were devoid of any preserved funerary artifacts, others showed several associated items, including wood-bead necklaces and lithic tools, such as hammers, red or yellow stained borers, scrapers, and more commonly, quartz flakes. Bone instruments were rarely used as funerary items: three bone point fragments (burial IV), two fragments of a bone spatula (burial II inf.), one worked deer horn fragmented (burial XXIII), and one fragment of a fishing hook (burial XVIII).

In some of the graves, small charred fragments of pequi fruit (*Caryocar brasiliensis*) were deposited with the body as a result of food refuse.

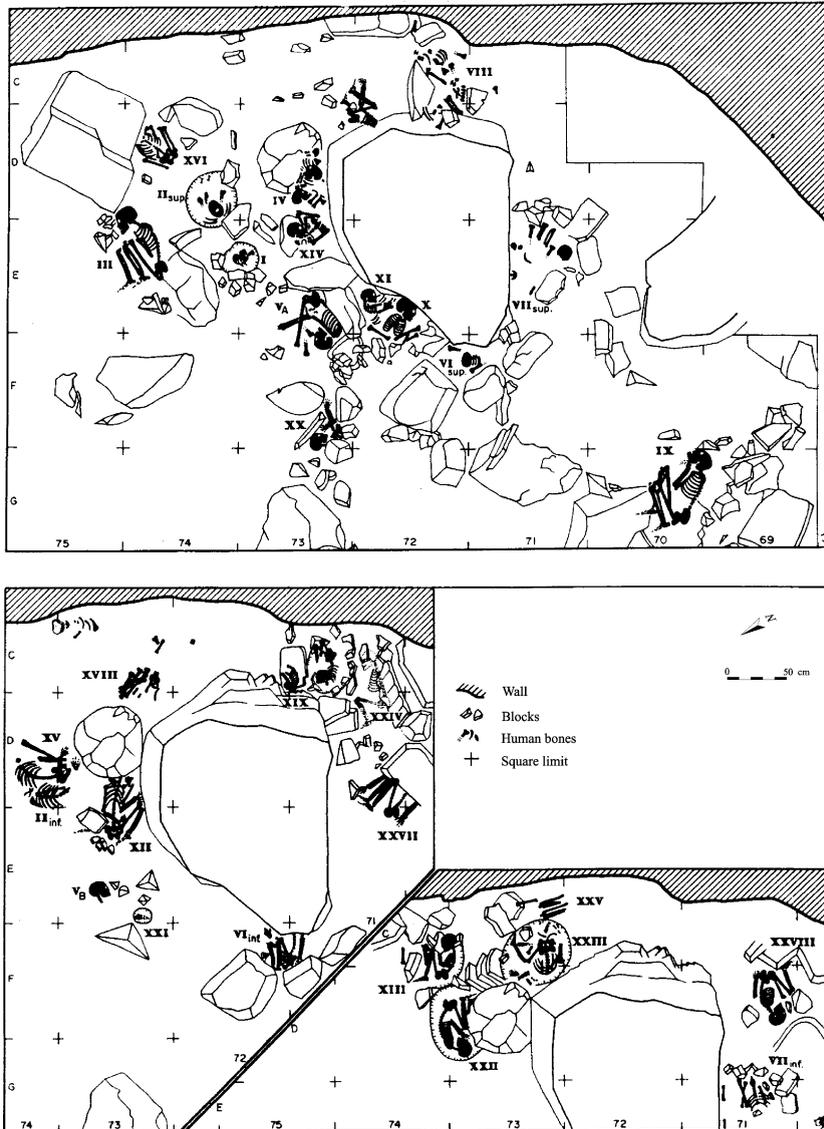


Fig. 7. Three different excavation-events of the human burials from Stratum 3 at SR1 (adapted from: Prous, 1992/93).

Since this species fruits only in the summer, these specific burials (burials I inf. II sup, VIII, XIII, XVII, XVIII, XXII, XXIII. Resende and Prous 1991) were most probably interred during the rainy season.

Some of the infants were directly covered by red pigment extracted from lateritic formations, easily found on the top of the cliff where the shelter is located.

After the bodies were laid down in the graves, they were covered by a mixture of sediment, charcoal and ash. Some of these charcoals and ashes were still hot, causing extensive burning marks on some of the bones. The early population of SR1 used to lay down gravels and blocks of quartzite on the top of the graves. Sometimes, the blocks were also used to make the lateral walls of the graves. Red pigments were extensively spread over these blocks.

Similar funerary practices have been described in other archaeological sites of Lagoa Santa, where skeletons dating between 11,000 and 8000 BP have been found (Walter, 1948, 1958; Hurt and Blasi, 1969; Laming-Emperaire et al., 1975).

Material and methods

The skeletal remains found in SR1 are stored at the Natural History Museum of the Federal University of Minas Gerais, Belo Horizonte, Brazil, under the responsibility of Prof. André Prous. They represent the best sample of late Paleoindian skeletons available in the New World for the study of the biological affinities and the life styles of the early Americans.

Of the 40 individuals found in SRI, only six skulls could be measured. These six individuals are bracketed in time between 8200 and 9500 years ago, being of late Paleoindian¹ antiquity. With the exception of the skeletal collection recovered from Sumidouro cave, by P.W. Lund, in the 19th Century, comprising 23 well preserved undated skulls, the human remains from SRI represents the largest collection of measurable skulls recovered from a single site in the Lagoa Santa region and from any Paleoindian site in the Americas. Unlike other collections of early skeletons from South America, the SR1 human skeletal remains are well dated and archaeologically contextualized (see above). Judging from the similarities of the graves, they represent the burial activities of the same population during approximately 1500 years.

In order to compare the cranial morphology of the population of Santana do Riacho with other populations around the world, cranial measurements were taken on all six skulls, following the criteria and landmarks described by Howells

(1973). All measurements were taken by one of us (WAN) in 1996. Table 2 presents the values of the 50 measurements taken in the 6 skulls, as well as the means and standard deviations for males and females separately. Since the skulls exhibit different degrees of preservation, missing values are common. The measured skulls were compared to 19 populations studied by Howells². These populations are used extensively by physical anthropologists in comparative studies because they represent the main core of human cranial variation in the world.

The assessment of the extra-continental morphological affinities of the SR1 population was performed by two different methods. The first approach was a Principal Components Analysis (PCA) performed upon the three best preserved specimens (SR1Va, SR1XXII, and SR1II) and based on 38 size-corrected craniometric variables (Table 3). The number of variables used was limited by the number of missing values from the three SR1-specimens. Thus, we selected a dataset in which, 22 out of 114 measurements (18.4%) were estimated by multiple regression substitution. The computation of the principal components and the related statistics was done via the covariance matrix in order to represent the variance contribution of each variable to the PCs. Males and females were analyzed separately. Individual data were size-corrected using the Q-mode geometric mean method proposed by Darroch and Mosimann (1985). The mean PCA score of each modern reference sample was computed, and the centroid was plotted in a three-dimension scatterplot representing variation on PCs 1, 2 and 3. The PC scores for each SR1 specimen were also represented in this scatterplot.

In order to confirm or refute the PCA analysis based on means, Mahalanobis Distances (D^2) were calculated between the most complete Paleoindian individuals and reference populations using a pooled within-sample covariance matrix estimated

¹ Although the term “Paleoindian” is normally employed in the literature, mainly in North America, to refer specifically to Late Pleistocene hunter-gatherers, we will apply this nomenclature to the early Holocene occupation of Santana do Riacho, because the biological population, the technology, and the settlement-subsistence pattern during the early Holocene period are exactly the same as those of the Late Pleistocene in Lagoa Santa.

² Howells’ populations used as comparative samples: Norse (NOR), Zalavar (ZAL), Berg (BER), Teita (TEI), Dogon (DOG), Zulu (ZUL), Australia (AUS), Tasmania (TAS), Tolai (TOL), Peru (PER), Arikara (ARI), Santa Cruz (SCR), Ainu (AIN), North Japan (NJP), South Japan (SJP), Hainan (HAI), Moriori (MOR), Mokapu (MOK), Eastern Island (EAS).

Table 2
Sex, age and craniometric values for the SRI skeletons analyzed in this study

Sex	Male			Female				Mean	S.D.
	Burial Number	II*	Vb**	III*	Va*	VIIIa***	XXII**		
Age (years old)	35–39	Adult-undetermined	Mean	20–24	20–24	35–39	15–19	Mean	S.D.
GOL	196	–	196	–	177	–	171	174	–
NOL	190	–	190	–	174	–	169	171.5	–
BNL	108	–	108	–	93	–	–	93	–
BBH	134	–	134	–	123	–	–	123	–
XCB	125	–	125	–	122	–	±118	120	–
XFB	108	–	108	–	101	–	–	101	–
STB	108	–	108	–	98	–	–	98	–
ZYB	±134	–	134	–	–	–	±120	120	–
AUB	±122	–	122	112	114	–	–	113	–
WCB	73	–	73	–	61	–	–	61	–
ASB	±112	±104	108	100	102	–	±105	102.3	2.5
BPL	103	–	103	–	–	–	–	–	–
NPH	72	–	72	–	–	–	54	54	–
NLH	55	–	55	–	–	–	42	42	–
OBH	35	31	33	–	–	–	30	30	–
OBB	45	–	45	–	–	–	34	34	–
JUB	±120	–	120	–	–	–	±104	104	–
NLB	±27	–	27	–	26	–	±20	23	–
MAB	–	–	–	62	60	±50	±58	57.5	5.3
MDH	32	22	27	20	20	17	22	19.75	2.1
MDB	15	15	15	11	11	13	10	11.25	1.3
ZMB	±106	–	106	–	–	–	–	–	–
SSS	–	–	–	–	–	–	–	–	–
FMB	106	–	106	–	95	–	–	95	–
NAS	19	–	19	–	14	–	–	14	–
EKB	±100	–	100	–	–	–	–	–	–
DKS	–	–	–	–	–	–	–	–	–
DKB	26	–	26	–	–	–	–	–	–
NDS	–	–	–	–	–	–	–	–	–
WNB	8	–	8	–	–	–	6	6	–
SIS	–	–	–	–	–	–	–	–	–
IML	40	38	39	–	–	36	29	32.5	–
XML	57	52	54.5	–	–	52	45	48.5	–
MLS	12	9	10.5	–	–	8	7	7.5	–
WMH	27	24	25.5	–	–	23	–	23	–
SOS	9	–	9	–	5	–	5	5	–
GLS	5	–	5	–	2	–	–	2	–
FOL	34	37	35.5	32	34	–	–	33	–
FRC	114	–	114	–	104	–	106	105	–
FRS	26	–	26	–	25	–	22	23.5	–
FRF	47	–	47	–	45	–	45	45	–
PAC	118	–	118	–	111	–	115	113	–
PAS	24	–	24	–	22	–	28	25	–
PAF	60	–	60	–	62	–	59	60.5	–
OCC	97	93	95	90	93	–	90	91	1.7
OCS	35	30	32.5	27	30	–	26	27.7	2.1
OCF	52	34	43	37	37	–	41	38.4	2.3
VRR	–	–	–	–	114	–	–	114	–
NAR	–	–	–	–	92	–	–	92	–

Table 2 (continued)

Sex	Male		Mean	Female				Mean	S.D.
	Burial Number	II*		Vb**	III*	Va*	VIIIa***		
Age (years old)	35–39	Adult-undetermined		20–24	20–24	35–39	15–19		
FMR	–	–	–	–	83	–	–	83	–
BRR	–	–	–	–	113	–	–	113	–

*Sex determination based on skull, pelvis and long bones indicators.

**Sex determination based on skull indicators.

***Sex determination based on the robusticity of long bone indicators.

Table 3

Main characteristics of the first 15 Principal Components with eigenvalues of the covariance matrix

PC	Males			Females		
	Eigenvalue	Percentage Explained	Cumulative Percentage	Eigenvalue	Percentage Explained	Cumulative Percentage
1	0.0246	21.4	21.4	0.0237	21.4	21.4
2	0.0166	14.4	35.8	0.0151	13.6	34.9
3	0.0119	10.4	46.2	0.0117	10.5	45.4
4	0.0092	8.0	54.2	0.0098	8.8	54.2
5	0.0061	5.3	59.5	0.0064	5.8	60.0
6	0.0054	4.7	64.2	0.0053	4.8	64.8
7	0.0046	4.0	68.2	0.0043	3.9	68.6
8	0.0039	3.4	71.6	0.0036	3.3	71.9
9	0.0034	3.0	74.6	0.0031	2.8	74.7
10	0.0029	2.5	77.1	0.0029	2.6	77.4
11	0.0028	2.4	79.5	0.0027	2.4	79.8
12	0.0025	2.2	81.7	0.0026	2.4	82.1
13	0.0023	2.0	83.6	0.0021	1.9	84.1
14	0.0021	1.8	85.5	0.0019	1.7	85.8
15	0.0018	1.6	87.0	0.0018	1.6	87.4

from Howells' data, as described by Van Vark and Schafsma (1992). Squared Mahalanobis distance between a specimen and a reference sample was computed as

$$D_{1,j}^2 = (x_1 - x_j)' P_w^{-1} (x_1 - x_j),$$

where x_1 represents the vector of values for individual i , x_j is the mean vector for population j and P_w represents the pooled within-sample covariance matrix (Powell and Neves, 1999; Jantz and Owsley, 2001). The squared Mahalanobis distances were used to obtain a typicality probability of each Paleoindian individual, as suggested by Albrecht (1992). Calculations were performed pooling

sexes by first centering data on sex-specific means, according to Jantz and Owsley (2001). This standardization procedure was preferred to the Darroch and Mossiman size correction, since in the later case the inverted pooled covariance matrix became near singular. Since size differences are usually related to sex, this is an alternative way to explore shape weighting size differences. We used the same 38 variables that were already used in the PCA analysis. Alternatively we computed the Mahalanobis distances using a reduced set of 17 variables (GOL, NOL, XCB, ASB, NLB, MDH, MDB, SOS, FRC, FRS, FRF, PAC, PAS, PAF, OCC, OCS, OCF), which were present in the three specimens, thus avoiding missing values

Table 4
Eigenvectors for the first three principal components

Cranio-metric dimension	Males			Females		
	PC1	PC2	PC3	PC1	PC2	PC3
Glabello-Occipital Length (GOL)	-0.343	-0.126	0.099	-0.343	0.059	-0.162
Nasio-Occipital Length (NOL)	-0.296	-0.120	0.126	-0.298	0.058	-0.190
Basion-Nasion Length (BNL)	-0.197	0.052	0.093	-0.153	-0.180	-0.072
Basion-Bregma Height (BBH)	-0.043	-0.096	0.276	-0.051	-0.100	-0.284
Maximum Cranial Breadth (XCB)	0.404	0.053	-0.026	0.382	0.043	-0.042
Maximum Frontal Breadth (XFB)	0.368	-0.193	-0.075	0.341	0.290	0.011
Bizygomatic Breadth (ZYB)	0.003	0.290	-0.241	0.069	-0.205	0.309
Biauricular Breadth (AUB)	0.174	0.318	-0.155	0.223	-0.208	0.224
Minimum Cranial Breadth (WCB)	0.128	0.082	-0.139	0.149	0.024	0.158
Biasterionic Breadth (ASB)	0.106	0.106	-0.040	0.118	0.003	0.042
Nasion-Prosthion Height (NPH)	0.048	0.170	0.014	0.069	-0.147	0.051
Nasal Height (NLH)	0.025	0.136	-0.007	0.049	-0.112	0.010
Bijugal Breadth (JUB)	-0.062	0.190	-0.208	-0.026	-0.131	0.276
Nasal Breadth (NLB)	-0.073	-0.021	-0.050	-0.071	0.016	0.039
Palate Breadth (MAB)	-0.033	0.103	-0.104	-0.020	-0.080	0.125
Mastoid Height (MDH)	-0.018	0.059	0.045	0.030	-0.035	0.004
Mastoid Width (MDB)	-0.017	0.057	0.028	0.005	-0.053	-0.006
Orbit Height Left (OBH)	0.022	0.070	0.002	0.034	-0.073	0.006
Orbit Breadth Left (OBB)	-0.041	0.036	-0.056	-0.030	-0.044	0.066
Simotic Cord (WNB)	-0.014	-0.034	-0.053	-0.029	0.059	0.020
Bifrontal Breadth (FMB)	-0.091	0.013	-0.194	-0.082	-0.010	0.204
Nasio-Frontal Subtense (NAS)	-0.043	-0.007	-0.035	-0.057	0.005	0.045
Malar Length Inferior (IML)	-0.162	0.041	-0.112	-0.165	-0.097	0.146
Malar Length Maximum (XML)	-0.089	0.078	-0.108	-0.084	-0.118	0.138
Malar Subtense (MLS)	-0.023	0.007	-0.013	-0.034	-0.021	0.019
Supraorbital Projection (SOS)	-0.021	-0.005	-0.023	-0.033	0.010	0.022
Glabella Projection (GLS)	-0.036	0.052	-0.010	-0.022	-0.049	0.029
Bistephanic Breadth (STB)	0.524	-0.376	0.073	0.443	0.427	-0.130
Nasion-Bregma Chord (FRC)	-0.022	-0.087	0.124	-0.013	0.044	-0.198
Frontal Subtense (FRS)	0.033	-0.204	0.026	-0.002	0.161	-0.076
Nasion-subtense Fraction (FRF)	0.010	0.028	0.005	-0.013	0.002	-0.025
Bregma-Lambda Chord (PAC)	-0.214	-0.436	-0.176	-0.308	0.439	0.056
Parietal Subtense (PAS)	-0.020	-0.144	-0.113	-0.060	0.158	0.106
Bregma-Subtense Fraction (PAF)	-0.044	-0.401	-0.123	-0.181	0.393	0.020
Lambda-Opisthion Chord (OCC)	0.013	0.117	0.531	0.050	-0.232	-0.481
Occipital Subtense (OCS)	-0.054	0.072	0.162	-0.022	-0.059	-0.142
Lambda-Subtense Fraction (OCF)	0.078	0.113	0.510	0.137	-0.201	-0.402
Foramen Magnum Length (FOL)	0.024	0.007	-0.046	0.006	-0.001	0.040

In brackets: measurement abbreviations after Howells (1973).

replacement. In order to simplify computations, modern reference groups were pooled in seven regional areas (East Asia, Americas, Australia, Europe, Africa, Polynesia, and South Asia).

Results

Table 3 presents the amount of information retained by the PCA analysis of the three most

complete specimens. As can be seen, in the case of males, the first five PCs explain 59.5% of the initial variation, while in the case of the females this figure reaches 60%.

Table 4 presents the correlation between the initial factored variables and the first three PCs generated for males and females. In general, for both sexes, the great positive values of PC1 indicate a morphology characterized by wide and

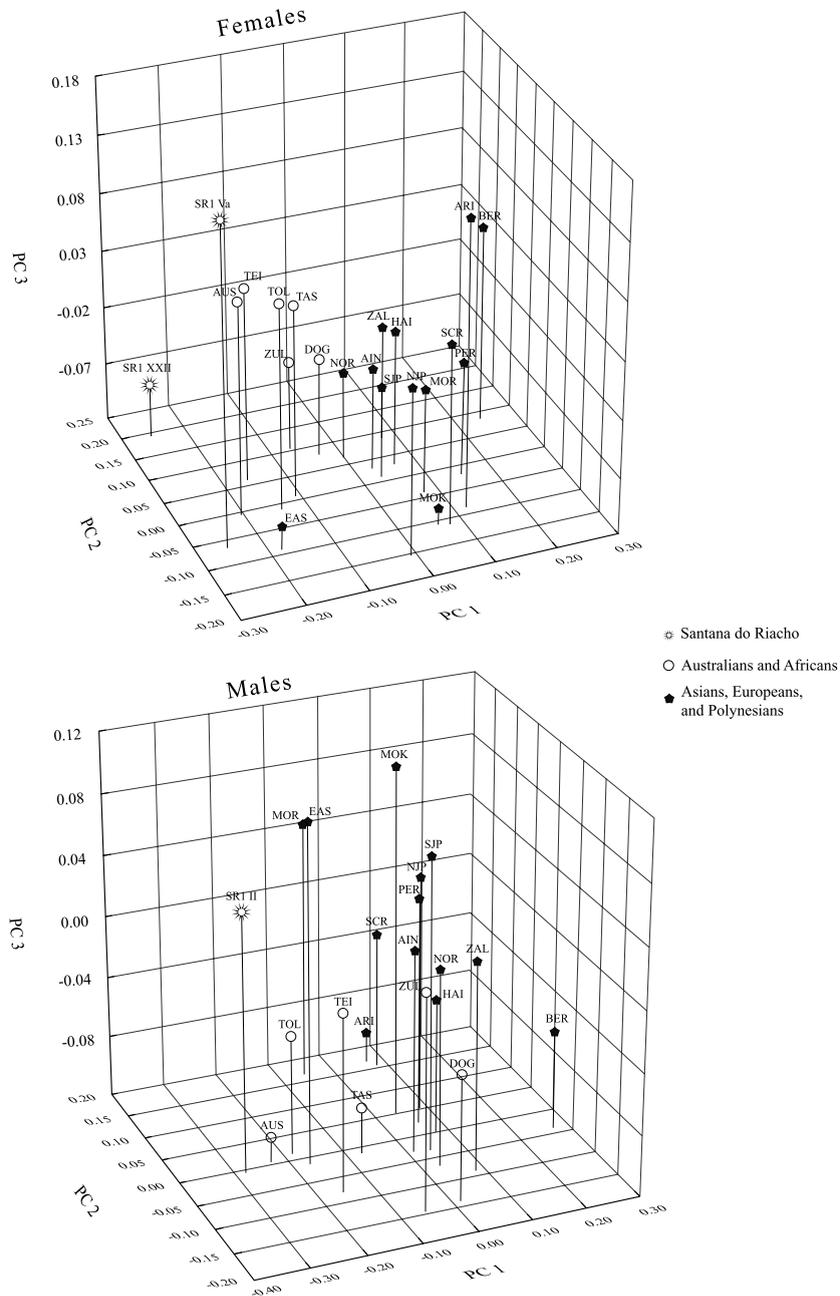


Fig. 8. Graphic representation of Principal Components Analysis for female and male individuals.

rounded neurocrania with tall faces, orbits and noses, while negative values stand for narrow neurocrania with low faces, orbits and noses. While PC1 reflects a similar pattern for both sexes,

opposite loadings on PC2 and PC3 tend to show some degree of sexual dimorphism.

The graphic results of the PCA (Fig. 8) show that the worldwide populations used as

Table 5

Squared Mahalanobis distances (D^2), typicality probabilities (Tp) and posterior probabilities (Pp) of each cranium relative to seven regional groups (pooled from Howells' reference populations). A data set of 38 variables listed in Table 3 was used. Bold indicates highest typicality probability for a column

Burial Number	II			Va			XXII*		
	D^2	tp	pp	D^2	tp	pp	D^2	tp	pp
East Asia	58.4	0.018	0.047	44.4	0.221	0.108	129.8	0.000	0.001
America	64.1	0.005	0.013	44.1	0.229	0.112	112.1	0.000	0.397
Australia	43.4	0.252	0.648	34.5	0.634	0.309	130.1	0.000	0.001
Europe	53.7	0.047	0.121	48.3	0.122	0.059	110.9	0.000	0.600
Africa	61.8	0.009	0.022	36.4	0.542	0.264	140.0	0.000	0.000
Polynesia	52.9	0.054	0.140	49.6	0.098	0.048	132.1	0.000	0.000
South Asia	66.1	0.003	0.008	45.0	0.203	0.099	129.2	0.000	0.001

*Note that the typicality probabilities of this individual are extremely low.

Table 6

Squared Mahalanobis distances (D^2), typicality probabilities (Tp) and posterior probabilities (Pp) of each cranium relative to seven regional groups (pooled from Howells reference populations). A data set of 17 variables was used. Bold indicates highest typicality probability for a column

Burial Number	II			Va			XXII*		
	D^2	tp	pp	D^2	tp	pp	D^2	tp	pp
East Asia	28.6	0.039	0.046	19.2	0.315	0.147	42.8	0.001	0.040
America	31.7	0.016	0.020	23.8	0.126	0.059	35.5	0.005	0.409
Australia	14.5	0.630	0.746	13.6	0.694	0.324	36.3	0.004	0.319
Europe	28.6	0.038	0.045	23.5	0.133	0.062	40.1	0.001	0.096
Africa	32.0	0.015	0.018	16.3	0.504	0.235	49.8	0.000	0.003
Polynesia	25.1	0.091	0.108	26.6	0.064	0.030	43.3	0.000	0.033
South Asia	32.1	0.015	0.018	19.4	0.304	0.142	40.0	0.001	0.099

*Note that the typicality probabilities of this individual are extremely low.

comparative samples tend to form three main groups of morphological affinities. The first group is formed by Australians and Africans, the second is formed by Asians, Europeans and recent Native Americans, and the third is formed by Polynesians, which occupies an intermediate position between the two former groups. SR1 clusters with the group formed by Africans and Australians. This means that these South American Paleoindians present a cranial morphology characterized by long and narrow neurocrania, low and narrow faces, with low nasal apertures and orbits.

Table 5 presents the results of the Mahalanobis distance performed upon SR1 II, SR1 Va and, SR1 XXII and using 38 variables. Test performed after 17 variables, that is a data set without missing values, is

shown in Table 6. With the exception of SR1 XXII, which shares no clear affinities with modern reference samples, the individuals from SR1 exhibit a strong association to Australians. This pattern of distances is consistent either using a set of 38 variables with missing values replacement or a set of 17 variables without replacement.

It is worth mentioning that, in the case of SR1 XXII, the typicality probabilities (TP) across-the-board are low. Since the idea of TP is to determine the probability of a skull falling within the multivariate normal distribution of one of the reference groups, low TPs across-the-board indicate, in accordance with Albrecht (1992), that the individual cannot be said to be a member of any of the reference groups.

Additionally, the three fragmentary skulls were tested for similarity with reference samples using their limited number of measurements. In those cases, the SR1 specimens fitted also the morphological patterns of Australians and Africans (results not shown). These results, however, must be viewed with caution since analyses were based on few metric variables.

Discussion and conclusions

As Jantz and Owsley (2001) have appropriately emphasized, using cranial morphological patterns or tendencies to explore inter-population biological affinities is a productive and legitimate exercise to infer the origins, spreading and diversification of human evolutionary lineages. Recent results presented by Sparks and Jantz (2002) also indicate a relatively high genetic component of the head and face diameters despite environmental differences during development, contrary to what Boas (1912) found in his original study. Harding (1990), Relethford and Blangero (1990), Relethford (1994), and Relethford and Harpending (1994) have also demonstrated that cranial morphology, as characterized by metric traits, are capable of revealing genetic patterns in human populations in time and space. The fact that some populations are preferentially more similar to others does not mean that the resulting clusters represent fixed and invariable racial types.

Cavalli-Sforza et al. (1994) have demonstrated the same is true when genetic markers are used. The cluster analysis they generated based on genetic distances among several local populations showed an almost perfect match between inter-population similarity and geographic proximity (not to mention linguistic affiliation). Their results attest to the fact that although within population variation is immense, this does not preclude one population from being more similar to other specific populations, and that this pattern of preferential similarity has a geographical coherence.

As the studies of Harding (1990) and Relethford and Harpending (1994) have demonstrated, information derived from comparative cranial

morphological investigations applied to late *Homo sapiens* can help in the understanding of our recent biological history. Accordingly, we assume that elaborating on the cranial morphological differences between early and late Native Americans, and how these differences can be understood in relation to a broader geographic scale, can be important in advancing our knowledge about the settlement of the New World.

The results obtained from the analyses of the Santana do Riacho skeletons show that Luzia's peculiar morphology is not unique in the New World. As a matter of fact, all Paleoindian skeletal samples assessed so far indicate that the first South Americans were markedly different in terms of cranial morphology when compared to late North Asians and Amerindians. Powell and Neves (1998) have also shown that their dentition cannot be classified as sinodont (*sensu* Turner, 1983).

The nature of the transition between the cranial morphology of the Paleoindians and the morphology of the later Native Americans is still a matter of contention (Powell and Neves, 1999; Steele and Powell, 2002). For South America, one of us (WAN) has been advocating that this transition was abrupt (Munford et al., 1995; Neves et al., 1996, 1999a).

In a comprehensive analysis of native cranial variation through time in South America (from early Holocene to historical times), Munford et al. (1995) and Neves et al. (1996, 1999a) have detected a general cranial *bau plan* characterized by long and narrow neurocrania, low, narrow and projecting faces that was suddenly replaced by one characterized by short and wide neurocrania, high, wide and retracted faces. The abrupt morphological change, which occurred around 8–9 Ka, suggests that a new population arrived in South America at that time. This, in our opinion, is a more parsimonious explanation than a long, local microevolutionary process mediated by selection and drift.

The idea of two distinct populations entering the New World by the end of the Pleistocene was recently reinforced by cultural evidence. Based on a comprehensive review of early projectile points found in North America, Dixon (2001) suggested that two major colonizing events occurred in the

Americas. One (circa 13,500 BP) relying on atlatl darts as the primary weapon system, and the other (10,500 BP) relying on the use of bow and arrow.

Recognizing the non-Mongoloid³ affinities of the first South Americans highlights a further problem: Where did these earliest population come from? As we have emphasized elsewhere, an appropriate answer to this question is hampered by our limited knowledge about human evolutionary events in East Asia, and particularly in Northeast Asia during the late Pleistocene (few human fossils are available for this period in the region).

Kamminga and Wright (1988), Wright (1995) and Neves and Pucciarelli (1998) have demonstrated, however, that the Zhoukoudian Upper Cave (UC) cranium 101 display marked similarities with Australo-Melanesians. Cunningham and Wescott (2002) has shown that although highly variable, none of the three specimens from this site (UC 101, UC 102, UC 103) resembles modern Asian populations. Matsumura and Zuraina (1999:333) reported the presence of the “Australo-Melanesian lineage” in Malaysia as late as the terminal Pleistocene. If we consider that UC is dated to between 32,000 BP and 11,000 BP, the fixation of the classical Mongoloid morphology in North Asia could have been a recent phenomenon (terminal Pleistocene/early Holocene), a hypothesis favored by several authors (see Cunningham and Wescott, 2002 for a review).

Accordingly, an Australo-Melanesian-like population present in North Asia by the end of the Pleistocene could have been the source of the first Americans. This would explain the presence of a non-Mongoloid morphology in the New World without invoking a direct transpacific route departing from Australia, as suggested by Rivet (1943).

Lahr (1995) has argued that human diversity in northern Asia was probably higher in the final moments of the Pleistocene than today, at least as far as cranial morphology is concerned. Therefore, non-Mongoloid Asians could have arrived in the

Americas using the Behring Strait as the gate of entry following either the shore of Beringia or a land bridge.

It is recognized that the human population that arrived in Australia around 50,000 BP (Bowler et al., 2003) was the product of an expansive movement out of Africa, following the tropical areas of Southern Asia. This route of expansion represents one of the first offshoots of modern humans out of Africa (Stringer and Andrews 1988; Stringer 1992; Lahr, 1996; Lahr and Foley, 1998). This is why Australians and Africans still form a supra-population unit of morphological affinity (Howells, 1973, 1989; Lahr, 1996). Therefore, the similarities of the first South Americans with Australians are easily explained if we accept that both populations shared a common ancestral population in mainland East Asia (most probably Southeast Asia). A population expansion from Asia to the New World before the Mongoloid traits were fully developed in the Old World was actually predicted more than fifty years ago by Birdsell (1951:63). The similarities of the first South Americans with sub-saharan Africans may result from the fact that the non-Mongoloid Southeast Asian ancestral population came, ultimately, from Africa, with no major modification in the original cranial *bau plan* of the first moderns. Neves et al. (1999c) have already suggested a possible historical connection among early modern humans (Skhul/Kafzeh), UC 101, Paleoindians and recent Africans and Australians based on their cranial morphology.

In order to avoid future misrepresentation of our findings and interpretations (see Roosevelt et al., 2002 for an example), we present below a detailed version of what one of us (WAN) refers to as the “Two Main Biological Components⁴ Model” (see Fig. 9 for a graphic representation of the model):

1. A population that began to expand from Africa around 70 Ka reached Southeast Asia by the middle of the Upper Pleistocene. From

³ The term Mongoloid is used here not as a fixed race or type. Instead, it is used as a supra-population unit of morphological affinity (SPUMA), joining recent North Asians and more recent Native Americans.

⁴ We prefer to use the term “biological component” instead of “migration” because we will never know how many migrations were indeed involved in the peopling of the New World.

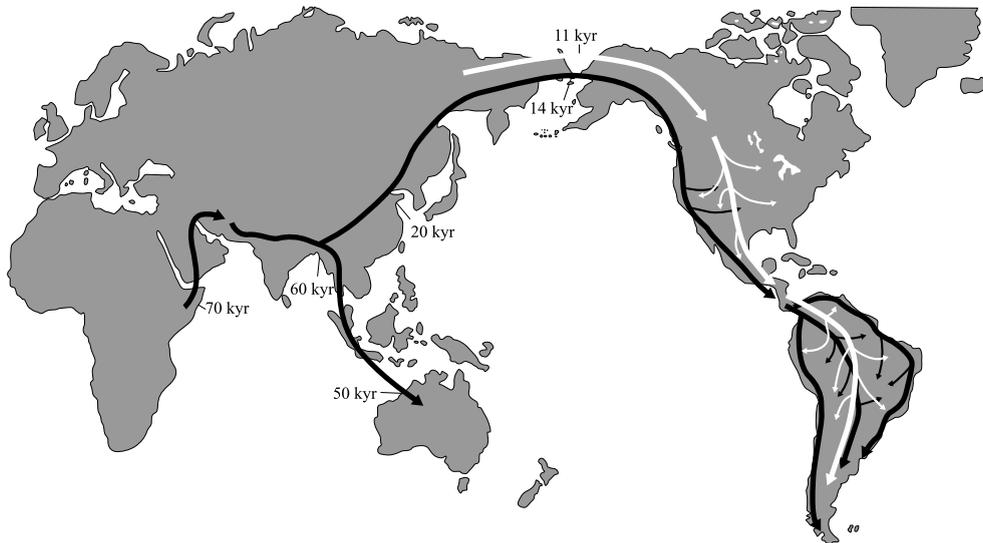


Fig. 9. Two biological component model. Black line represents the non-Mongoloid biological component, and white line represents the Mongoloid component. Dates are to be read as uncalibrated.

Southeast Asia, part of this population took a southern route of expansion towards Australia, where they arrived around 50 Ka (Lahr and Foley, 1998). Sometime between 50 and 20 Ka the same Southeast Asian population took a northern route of expansion along both interior and coastal East Asia (as suggested by Fladmark, 1979), depending on the local climatic conditions. The presence of an “Australo-Melanesian-like” population in East Asia is attested by the human skeletal remains from the Zhoukoudian Upper Cave around 20 Ka (Kamminga and Wright, 1988; Wright, 1995; Neves and Pucciarelli, 1998). A late occupation of the northern zones of East Asia also agrees with the idea that major behavioral change and technological strategies necessary to exploit extreme environments were not in place until ca. 40,000 BP (Whallon, 1989; Klein, 1992, 1995).

2. During most of the late Pleistocene (65–11 Ka) through the beginning of the Holocene Beringia and North America were covered by ice sheets (Hopkins, 1982; McManus et al., 1983; Hoffecker et al., 1993), with no continental ice-free corridors to facilitate human dispersion southward during this time

(Jackson et al., 1997). It is more likely, therefore, that the first settlers (Australo-Melanesian-like) took a coastal route of expansion, as has been suggested by Fladmark (1979), Gruhn (1988, 1994) and Dixon (1999).

3. We postulate a putative time of entry of this “Australo-Melanesian-like” population in the New World around 14 Ka (see also Dillehay, 2000; Dixon, 2001). This population expanded southward in the New World using the Pacific coast. Eventually, when the recession of the ice sheets in North America permitted, this population expanded towards the interior. A rapid expansion along the coast would explain why the Australo-Melanesian cranial *bau plan* of the first settlers was not altered during the expansion into South America. If we see the Australo-Melanesian cranial morphology as the result of selection under tropical climates since its inception in Africa (Lahr, 1996), a relatively fast migration along the Pacific Rim could explain why this “tropical pattern” was not significantly altered by colder climates.
4. At the Panama Isthmus, the coastal expansion trifurcated, with one migration following down the Pacific coast, another the Atlantic coast, and a third one inward into the Amazon basin.

These multiple axes south of Panama would explain the presence of humans in Southern Chile around 12.3 Ka (Dillehay, 1989, 1997), the presence of humans in Lagoa Santa and elsewhere in eastern Central Brazil around 12 Ka (Kipnis, 1998, Prous and Fogaça, 1999), and in the Amazon around 11.2 Ka (Roosevelt et al., 1996). A Pacific and an Atlantic expansion would also explain the presence of Paleoindians with Australo-Melanesian morphology on opposite sides of South America, in eastern Central Brazil and the Colombia Highlands, by the end of the Pleistocene (Neves and Pucciarelli, 1989; 1991; Munford, 1999).

5. When climatic conditions ameliorated in North America, during the terminal Pleistocene and early Holocene (around 11 Ka), a second population entered the Americas. Their cranial morphology was similar to that seen today among Northern Asians and Native Americans.

In this study we compared the cranial morphology of several late Paleoindian skeletons uncovered at Santana do Riacho, Central Brazil, with worldwide human cranial variation. Howells' (1973, 1989) dataset was used as reference samples. Mahalanobis Distance and Principal Component Analysis were used to explore the extra-continental morphological affinities of the Brazilian Paleoindian sample. Both methods of analysis generated similar results indicating a clear affinity between the early Americans and nowadays Australians and Africans. These results confirmed previous findings obtained by one of us (WAN) using other samples of early South American skeletons, including "Luzia", considered one of the earliest known South American human skeletons. Our findings suggest that the first humans to arrive in the New World displayed a cranial morphology very different from that exhibited by late and modern Native Americans. Although microevolutionary processes within the New World cannot be completely ruled out as a possible explanation for the changes of the cranial morphology of the Native Americans through time, the nature of the transition as seen in South America suggests that the New World

was occupied by two different human populations coming from the Old World, a scenario also favored by Jantz and Owsley (2002).

Acknowledgements

We thank the editor and three anonymous reviewers for their generous advice and editorial assistance. This research was possible thanks to a grant received by WAN from The State of São Paulo Research Foundation (FAPESP-Proc. 99/00670-7), a research fellowship awarded to WAN by the National Research Council of Brazil (CNPq-Proc. 305918/85-0), and a post-doctoral fellowship awarded to RK by FAPESP (Proc. 01/06881-1).

References

- Adovasio, J.M., Pedler, D.R., 1997. Monte Verde and the antiquity of humankind in the Americas. *Antiquity* 71, 573–580.
- Albrecht, G.H., 1992. Assessing the affinities of fossils using canonical variates and generalized distances. *Hum. Evol.* 7, 49–69.
- Alvim, M.C., 1992/93. Os antigos habitantes da Serra do Cipó, MG Brasil: estudos morfológicos preliminar. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 107–128.
- Birdsell, J.B., 1951. The problem of the early peopling of the Americas as viewed from Asia. In: Laughlin, W.S. (Ed.), *The Physical Anthropology of the American Indian*. Edward Brothers, Ann Arbor, pp. 1–68.
- Boas, F., 1912. Changes in the bodily form of descendants of immigrants. *Am. Anthropol.* 14, 530–562.
- Bowler, J.M., Johnston, H., Olley, J.M., Prescott, J.R., Roberts, R.G., Shawcross, W., Spooner, N.A., 2003. New ages for human occupation and climatic change at Lake Mungo, Australia. *Nature* 421, 837–840.
- Brace, C.L., Nelson, A.R., Seguchi, N., Oe, H., Sering, L., Qifeng, P., Yongyi, L., Tumen, D., 2001. Old World sources of the first New World human inhabitants: A comparative craniofacial view. *Proc. Natl. Acad. Sci.* 98, 10017–10022.
- Brandão, M., 1992/93. A cobertura vegetal circundante do Grande Abrigo de Santana do Riacho. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 401–408.
- Cavalli-Sforza, L.L., Menozzi, P., Piazza, A., 1994. *The History and Geography of Human Genes*. Princeton University Press, Princeton.

- Chatters, J., Neves, W.A., Blum, M., 1999. The Kennewick Man: A first multivariate analysis. *Cur. Res. Pleist.* 16, 87–90.
- Chausson, Y., Delibrias, G., 1992/93. Datações realizadas no sítio de Santana do Riacho. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 395–400.
- Couto, C.P., 1950. Peter Wilhelm Lund; memória sobre a paleontologia brasileira. Instituto Nacional do Livro, Rio de Janeiro.
- Cunningham, D.L., Wescott, D.J., 2002. Within-group human variation in the Asian Pleistocene: the three Upper Cave crania. *J. Hum. Evol.* 42, 627–638.
- Darroch, J.N., Mosimann, J.E., 1985. Canonical and principal components of shape. *Biometrika* 72, 241–252.
- Dillehay, T.D., 1989. Monte Verde: A Late Pleistocene Settlement in Chile. Volume 1 - Paleoenvironment and Site Context. Smithsonian Institution Press, Washington, D.C.
- Dillehay, T.D., 1997. Monte Verde: A Late Pleistocene Settlement in Chile 2: The Archaeological Context. Smithsonian Institution Press, Washington, D.C.
- Dillehay, T.D., 2000. *The Settlement of The Americas*. Basic Books, New York.
- Dixon, E.J., 1999. *Bones, Boats and Bison. Archeology and the First Colonization of Western North America*. The University of New Mexico Press, Albuquerque.
- Dixon, E.J., 2001. Human colonization of the Americas: timing, chronology and process. *Quarter. Sci. Rev.* 20, 277–299.
- Fladmark, K.R., 1979. Routes: Alternate migration corridors for early man in North America. *Am. Antiq.* 44, 55–69.
- Gruhn, R., 1988. Linguistic evidence in support of the coastal route of earliest entry in the New World. *Man* 23, 77–100.
- Gruhn, R., 1994. The Pacific coast route of initial entry: An overview. In: Bonnicksen, R., Steele, D.G. (Eds.), *Method and Theory for Investigating the Peopling of the Americas*. Center for the Study of the First Americans, Corvallis, pp. 249–264.
- Harding, R.M., 1990. Modern European cranial variables and blood polymorphism show comparative spatial patterns. *Hum. Biol.* 62, 733–745.
- Hoffecker, J.F., Powers, W.R., Goebel, T., 1993. The colonization of Beringia and the peopling of the New World. *Science* 259, 46–53.
- Hopkins, D.M., 1982. Aspects of the paleogeography of Beringia during the Late Pleistocene. In: Hopkins, D.M., Matthews, J.V. Jr., Schweger, C.E., Young, S.B. (Eds.), *Paleoecology of Beringia*. Academic Press, New York, pp. 3–28.
- Howells, W.W., 1973. Cranial variation in man. A study of multivariate analysis of patterns of difference among recent human populations. *Paps. Peabody Mus. Archeol. Ethno.* 67. Harvard University Press, Cambridge.
- Howells, W.W., 1989. Skull shapes and the map. *Craniometric analysis in the dispersion of modern Homo*, *Paps. Peabody Mus. Archeol. Ethno.* 79. Harvard University Press, Cambridge.
- Hurt, W.R., Blasi, O., 1969. O projeto arqueológico “Lagoa Santa”, Minas Gerais, Brasil. *Arquivos do Museu Paraense (NS) Arqueologia* 4, 1–63.
- Jackson, L.E. Jr., Phillips, F.M., Shimamura, K., Little, E.C., 1997. Cosmogenic ³⁶Cl dating of the Foothills erratics terrain, Alberta, Canada. *Geology* 25, 195–198.
- Jantz, R.L., Owsley, D.W., 2001. Variation among North American crania. *Am. J. phys. Anthropol.* 114, 146–155.
- Junqueira, P.A., 1992/93. As estruturas aparentes (2): os sepultamentos do Grande Abrigo de Santana do Riacho—Os sepultamentos da escavação No. III. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 78–87.
- Kamminga, J., Wright, R.S.V., 1988. The upper cave at Zhoukoudian and the origins of the Mongoloids. *J. Hum. Evol.* 17, 739–767.
- Karfunkel, J., Noce, C.M., Köhler, H.C., 1991. A geologia do Grande Abrigo de Santana do Riacho e vizinhanças, Serra do Cipó, Minas Gerais. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 33–41.
- Kipnis, R., 1998. Early hunter-gatherers in the Americas: perspectives from central Brazil. *Antiquity* 72, 581–592.
- Kipnis, R., 2002. *Foraging societies of eastern central Brazil: An evolutionary ecological study of subsistence strategies during the terminal Pleistocene and Early/Middle Holocene*. Ph.D. Dissertation, The University of Michigan.
- Klein, R.G., 1992. The archaeology of modern human origins. *Evol. Anthropol.* 1, 5–14.
- Klein, R.G., 1995. Anatomy, behavior, and modern human origins. *J. World Prehist.* 9, 167–198.
- Köhler, H.C., Malta, I.M., Karfunkel, J., 1991. A geomorfologia da região do Grande Abrigo de Santana do Riacho. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 43–58.
- Lahr, M.M., 1995. Patterns of modern human diversification: Implications for Amerindian origins. *Yearb. Phys. Anthropol.* 38, 163–198.
- Lahr, M.M., 1996. *The Evolution of Modern Human Diversity*. Cambridge University Press, Cambridge.
- Lahr, M.M., Foley, R., 1998. Towards a theory of modern human origins: Geography, demography, and diversity in recent human evolution. *Yearb. Phys. Anthropol.* 41, 137–176.
- Laming-Emperaire, A., 1979. Missions archéologique franco-brésiliennes de Lagoa Santa, Minas Gerais, Brésil: Le grand abri de Lapa Vermelha. *Revista de Pré-história* 1, 54–89.
- Laming-Emperaire, A., Prous, A., Moraes, A.V., Beltrão, M.C.M.C., 1975. Grottes et abris de la region de Lagoa Santa, Minas Gerais, Brésil. *Cahiers d' Archéologie d'Amérique du Sud* 1, 1–97.
- Lara, E.G., Moresi, C.M.D., 1991. Material Textil de Santana do Riacho. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 179–186.
- Lima, M.A., 1991. Indústria lítica de Santana do Riacho: análise funcional de microtraceologia. *Arquivos do Museu*

- de História Natural da Universidade Federal de Minas Gerais 12, 275–284.
- Lund, P.W., 1842. Carta escripta de Lagôa Santa ao senhor primeiro secretário do instituto. *Revista do Instituto Histórico e Geográfico Brasileiro* 4, 30–87.
- Lund, P.W., 1844. Carta escripta de Lagôa Santa a 21 de abril de 1844. *Revista do Instituto Histórico e Geográfico Brasileiro* 6, 334–342.
- Malta, I.M., Köhler, H.C., 1991. O cenário geográfico e geológico do planalto de Lagoa Santa. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 3–11.
- Matsumura, H., Zuraina, M., 1999. Metric analysis of an early Holocene human skeleton from Gua Gunung Runthu, Malaysia. *Am. J. phys. Anthropol.* 109, 327–340.
- McManus, D.A., Creager, J.S., Echols, R.J., Holmes, M.L., 1983. The Holocene transgression on the Arctic flank of Beringia. In: Master, P.M., Flemming, N.C. (Eds.), *Quaternary Coastlines and Marine Archaeology: Towards the Prehistory of Land Bridges and Continental Shelves*. Academic Press, New York, pp. 365–388.
- Meltzer, D.J., 1997. Monte Verde and the Pleistocene peopling of the Americas. *Science* 276, 754–755.
- Meltzer, D.J., Grayson, D.K., Ardila, G., Barker, A.W., Dincauze, D.F., Haynes, C.F., Mena, F.N.L., Stanford, S., 1997. On the Pleistocene antiquity of Monte Verde, southern Chile. *Am. Antiq.* 62, 659–663.
- Munford, D. 1999. Estudo comparado da morfologia de populações pré-históricas da América do Sul: Implicações para a questão do povoamento do Novo Mundo. Masters thesis, University of São Paulo.
- Munford, D., MC, 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., Cornero, S., 1997. What did South American paleoindians eat? *Cur. Res. Pleist.* 14, 93–96.
- Neves, W.A., Munford, D., Zanini, M.C., 1996. Cranial morphological variation and the colonisation 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. Modern human origins as seen from the peripheries. *J. Hum. Evol.* 37, 129–133.
- Neves, W.A., Powell, J.F., Ozolins, E.G., 1999b. Extra-continental morphological affinities of Lapa Vermelha IV, Hominid 1: A multivariate analysis with progressive numbers of variables. *Homo* 50, 263–282.
- Neves, W.A., Powell, J.F., Ozolins, E.G., 1999c. Extra-continental morphological affinities of Palli Aike, southern Chile. *Interciência (Venezuela)* 24, 258–263.
- Neves, W.A., Powell, J.F., Prous, A., Ozolins, E.G., 1998. Lapa Vermelha IV, Hominid I: Morphological affinities of the earliest known American. *Am. J. Phys. Anthropol.* 26(Suppl.), 169.
- Neves, W.A., Pucciarelli, H.M., 1989. Extra-continental biological relationships of early South American human remains: A multivariate analysis. *Ciência e Cultura* 41, 566–575.
- Neves, W.A., Pucciarelli, H.M., 1990. The origins of the first Americans: an analysis based on the cranial morphology of early South American human remains. *Am. J. Phys. Anthropol.* 81, 247.
- Neves, W.A., Pucciarelli, H.M., 1991. Morphological affinities of the first Americans: An exploratory analysis based on early South American human remains. *J. Hum. Evol.* 21, 261–273.
- Neves, W.A., Pucciarelli, H.M., 1998. The Zhoukoudian Upper Cave skull 101 as seen from the Americas. *J. Hum. Evol.* 34, 219–222.
- Powell, J.F., Neves, W.A., 1998. Dental diversity of early New World population: Taking a bite out 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.
- Prous, A., 1980/81. Fouilles du Grand Abri de Santana de Riacho (Minas Gerais), Brésil. *Journal de la Société de Americanistes*. N.S 67, 163–183.
- Prous, A., 1991. Histórico das pesquisas no abrigo de Santana do Riacho e nos arredores (Serra do Cipó). *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 61–66.
- Prous, A., 1992/93. As estruturas aparentes (2): os sepultamentos do Grande Abrigo de Santana do Riacho-Os sepultamentos da escavação No. I. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 21–77.
- Prous, A., 2001. Em busca dos primeiros povoados do Brasil. XI Congresso da Sociedade de Arqueologia Brasileira, Resumos. Sociedade de Arqueologia Brasileira, Rio de Janeiro. pp. 30–31.
- Prous, A., Fogaça, E., 1999. Archaeology of the Pleistocene-Holocene boundary in Brazil. *Quatern. Int.* 53/54, 21–41.
- Prous, A., Junqueira, P.A., Malta, I.M., Chausson, Y., 1991. Métodos de escavação, estratigrafia arqueológica e datações. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 67–83.
- Radicchi, R., 1992/93. Estudos dos dentes, maxila e mandíbula dos restos esqueléticos do sítio arqueológico Santana do Riacho (escavação No. I): determinação da idade pelo método radiológico. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 173–187.
- Ratisbona, L.R., 1976. The climate of Brazil. In: *Schwerdtfeger, W. (Ed.), World Survey of Climatology, Volume 12, Climates of Central and South America*. Elsevier, Amsterdam, pp. 219–293.
- Relethford, J.M., 1994. Craniometric variation among modern human populations. *Am. J. Phys. Anthropol.* 95, 53–62.
- Relethford, J.M., Blangero, J., 1990. Detection of differential gene flow from patterns of quantitative variation. *Hum. Biol.* 62, 5–25.

- Relethford, J.M., Harpending, H.C., 1994. Craniometric variation, genetic theory and modern human origins. *Am. J. Phys. Anthropol.* 95, 249–270.
- Resende, E.T., Prous, A., 1991. Os vestígios vegetais do Grande Abrigo de Santana do Riacho. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 12, 87–111.
- Ribeiro, B., 1986. A arte de trançar: dois macorestilos, dois modos de vida. In: Ribeiro, D. (Ed.), *Suma Etnológica Brasileira* 2. Vozes, Petrópolis, pp. 283–313.
- Ribeiro, Berta, 1988. *Dicionário do Artesanato Indígena*. Itatiaia Limitada, Belo Horizonte.
- Rivet, P., 1943. *Les Origines de l'Homme Américain*. Gallimard, Paris.
- Roosevelt, A.C., Costa, M.L., Machado, C.L., Michab, M., Mercier, N., Valladas, H., Feathers, J., Barnett, W., Silveira, M.I., Henderson, A., Sliva, J., Chernoff, B., Reese, D.S., Holman, J.A., Toth, N., Schick, K., 1996. Paleoindian cave dwellers in the Amazon: The peopling of the Americas. *Science* 272, 373–384.
- 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 Science, San Francisco, pp. 159–235.
- Souza, S.M., 1992/93a. Paleodemografia da população do Grande Abrigo de Santana do Riacho, Minas Gerais: uma hipótese para verificação. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 161–171.
- Souza, S.M., 1992/93b. Paleopatologia humana de Santana do Riacho. *Arquivos do Museu de História Natural da Universidade Federal de Minas Gerais* 13/14, 129–160.
- Sparks, C.S., Jantz, R.L., 2002. A reassessment of human cranial plasticity: Boas revisited. *Proc. Natl. Acad. Sci.* 99, 14636–14639.
- 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., 1994. Paleobiology of the first Americans. *Evol. Anthropol.* 2, 138–146.
- Steele, D.G., Powell, J.F., 1999. Peopling of the Americas: a historical and comparative perspective. In: Bonnicksen, R. (Ed.), *Who Were the First Americans? Peopling of the Americas Publication*, Corvallis, OR, pp. 9–120.
- 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 Science, San Francisco, pp. 93–122.
- Stringer, C.B., 1992. Replacement, continuity and the origin of *Homo sapiens*. In: Brauer, G., Smith, F.H. (Eds.), *Continuity or Replacement: Controversies in Homo Sapiens Evolution*. Balkema, Rotterdam, pp. 9–24.
- Stringer, C.B., Andrews, P., 1988. Genetic and fossil evidence for the origin of modern humans. *Science* 239, 1263–1268.
- Turner, C.G. II, 1983. Dental evidence for the peopling of the Americas. In: Shutler, R. Jr. (Ed.), *Early Man in the New World*. Sage Publications, Beverly Hills, pp. 147–157.
- Van Vark, G.N., Scafsma, W., 1992. Advances in the quantitative analysis of skeletal morphology. In: Saunders, S.R., Katzenberg, M.A. (Eds.), *Skeletal Biology of Past Peoples: Research Methods*. Wiley-Liss, New York, pp. 225–257.
- Walter, H.V., 1948. A pré-história da região de Lagoa Santa (Minas Gerais). *Oficinas Gráficas da Papelaria e Tipografia Brasil de Velloso and Cia. Ltda*, Belo Horizonte.
- Walter, H.V., 1958. *Arqueologia da região de Lagoa Santa, Minas Gerais; índios pré-colombianos dos abrigos-rochedos*. Sedegra, Rio de Janeiro.
- Whallon, R., 1989. Elements of cultural change in the Late Palaeolithic. In: Mellars, P., Stringer, C. (Eds.), *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans*. Princeton University Press, Princeton, pp. 433–454.
- Wright, R.V.S., 1995. The Zhoukoudian Upper Cave skull 101 and multiregionalism. *J. Hum. Evol.* 29, 181–183.