

Holocene dryness and human occupation in Brazil during the “Archaic Gap”

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Abstract

An overview of the archaeological data produced over the last decades for Brazil, coupled with a background of recent paleoenvironmental studies, suggests that during the mid-Holocene vast areas of Central Brazil ceased to be occupied by human groups. Independent data from dated human skeletons, rock-shelter stratigraphy, and chronology of open-air sites converge to support the inference that these areas were depopulated or altogether abandoned. Paleoenvironmental data suggest that dryness events constitute the major cause behind the observed trends. This phenomenon expands the already perceived notion that climatic stresses had a major role in the shaping of human settlement patterns in marginal environments, such as deserts and high-altitude settings.

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Introduction

The occurrence of dry climatic periods during the Early and Mid-Holocene in South America, related respectively to the Younger Dryas and to changes in the Earth's precession, is a phenomenon recognized by several authors (e.g., Absy et al., 1991; Baker et al., 2001; Grimm et al., 2001; Grosjean et al., 2001; Ledru et al., 1996, 2002; Melo et al., 2001; Sifeddine et al., 2003). The consequences of these events on the human occupation, at least in the Andean region, have recently been acknowledged (Grosjean et al., 1997; Nuñez et al., 2001) with a solid corpus of data showing abandonment of entire areas by humans due to dry conditions. However, the analyses achieved so far tend to restrict the influence that such climatic variables would have over humans, focusing on marginal environments such as deserts or high-altitude settings. In this paper, we try to put the problem of human migrations and regional abandonment in a broader perspective, by compiling archaeological data mainly originating from Brazil (at low-altitude settings), and by discussing palaeoenvironmental evidence gathered outside the Andes. We deal with two sources of archaeological information,

both coupled with paleoenvironmental background. On one hand, we present new data gathered from our research in the Lagoa Santa region in Central Brazil, with main focus on the Paleoindian occupation. On the other hand, and under this perspective, we analyze data published by Brazilian and other South American researchers over the last decades.

Dry periods during the Holocene in Brazil

Recent paleoenvironmental data coming from Brazil are finally shedding some light on the question of the climatic trends that occurred during the Holocene. Of course, these trends show considerable differences depending upon the area investigated, as well the resolution of paleoenvironmental reconstructions. In this paper we will address two regions: Central/Southeastern and Southern Brazil. There are still few paleoclimatic studies for Northeastern Brazil (Behling et al., 2000; Ledru et al., 2002), and the available information does not allow regional generalizations. The same can be said about Northern Brazil, where both paleoenvironmental and archaeological data are extremely scattered across a vast region.

Central/Southeastern Brazil

In the case of Central Brazil, and based on pollen records, some authors believe that a very dry Last Glacial Maximum

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(LGM) and Late Glacial period (since 19,000 ^{14}C yr B.P., or 22,540 cal yr B.P.) was followed by an increase in moisture beginning ca. 6000–5000 ^{14}C yr B.P. (6850–5710 cal yr B.P.), leading to modern climatic conditions (Barberi et al., 2000; Ferraz-Vicentini and Salgado-Laboriau, 1996; Salgado-Laboriau et al., 1997, 1998). In the same region, however, other researchers found evidence of a somewhat different scenario, with a dryer and cooler LGM followed by a cool and moist Late Glacial period between ca. 10,000 and 8500 ^{14}C yr B.P. (11,440–9490 cal yr B.P.), followed again by an arid period between ca. 8500 and 4000 ^{14}C yr B.P. (9490–4460 cal yr B.P.), and a trend towards modern climatic conditions since then (Behling, 2002; Ledru, 1993; Ledru et al., 1996; Martin et al., 1997; Servant et al., 1993). The different climatic interpretations can potentially be explained by many factors: problems in comparability of pollen data due to different research methods, problems of chronology related to the interpolation of ^{14}C dates or to radiocarbon reservoir effect (Auler et al., in press; Ferraz-Vicentini and Salgado-Laboriau, 1996; Geyh et al., 1999; Ledru and Mourguiart, 2001; Salgado-Laboriau, 1997; Sylvestre et al., 1999), or even to variations in localized differential moisture gradients due to microclimatic/orographic factors (Behling and Hooghiemstra, 2001; Nimer, 1989).

Recent research tends to differentiate this part of Brazil into two climatic zones: the “core” savanna area would show the trend of increasing moisture during the Holocene, whereas the “peripheral” area, towards the East and the South, would show more oscillations in moisture, probably due to incursions of Antarctic polar fronts (Barberi, 2001:145) and periods of aridity in the Late Holocene due to increasing ENSO activity or to a northward shift of the ITCZ (De Oliveira et al., 1999:335). This subdivision seems more in accordance than the earlier views with the climatic complexity that probably existed in this vast area during the Holocene, and which can be appreciated in the recent compilation carried out by Ledru et al. (1998). However, the issue is far from being settled. Most of the palynological records from Central Brazil supporting the “increasing Holocenian moisture” model suffer from insufficient chronological control (Barberi, 2001; Barberi et al., 2000; De Oliveira, 1992; Salgado-Laboriau et al., 1998; Stevaux, 2000). On the other hand, paleoenvironmental studies (palynological or otherwise) supporting the hypothesis of a peak in moisture around 8000 ^{14}C yr B.P. (8970 cal yr B.P.) followed by dryness in the mid-Holocene and a return of moisture in the Late Holocene, tend to show better chronological controls (Alexandre et al., 1999; Behling, 1998; Gouveia et al., 2002; Ledru, 1993; Melo et al., 2001; Rodrigues-Filho et al., 2002; Turcq et al., 1997, 2002; Vernet et al., 1994).

Southern Brazil

Several palynological studies were carried out in recent years for the southern states, and the picture seems to point towards and increasing climatic amelioration throughout the Holocene. Several palynological records (Behling, 1995, 1997; Behling and Negrelle, 2001; Behling et al., 2001, 2004, 2005) suggest that the LGM and Late Glacial period were very dry

and cold, with expansion of grasslands where today a variety of forest ecosystems occurs (Behling, 2002). The Late Glacial period, however, was probably somewhat warmer than the LGM. During the Holocene, changes toward wetter conditions started around 6000 ^{14}C yr B.P. (6850 cal yr B.P.) in Southeastern Brazil, and even later in Southern Brazil, around 3000 ^{14}C yr B.P. (3210 cal yr B.P.—Behling, 2002). The coastal area was moister, probably due to orographic factors, as is the case in Volta Velha (Behling and Negrelle, 2001) where an incipient rain forest started to develop around 12,300 ^{14}C yr B.P. (14,250 cal yr B.P.). In the southern highlands, early and mid-Holocene climate was probably marked by a long dry season, preventing the expansion of *Araucaria* forests. Only in the Late Holocene, after about 1500–1000 ^{14}C yr B.P. (1360–940 cal yr B.P.), the annual dry season became shorter, as suggested by *Araucaria* expansion (Behling, 1997, 2002; Behling et al., 2001). Climate in Southern/Southeastern Brazil is strongly affected by the Antarctic polar fronts (Garreaud, 2000), and the increased moisture could be related to shifts in this system.

Humans enter the scenario: the “Archaic Gap” at Lagoa Santa

The Lagoa Santa region, a karstic area encompassing several counties near the city of Belo Horizonte, State of Minas Gerais (Fig. 1), is perhaps one of the most widely known archaeological settings of Brazil, and a key area for understanding the peopling of the Americas (Walter, 1948, 1958; Araujo et al., 2003). After so many decades of research in the area, it is striking that dates accounting for the majority of burials in the Lagoa Santa region cluster around two peaks: between 10,000 and 8000 ^{14}C yr B.P. (11,380 cal yr B.P. and 8970 cal yr B.P.), and between 2000 and 1000 ^{14}C yr B.P. (1940 and 940 cal yr B.P.) (Table 1, Fig. 2). There is, accordingly, a period of 6000 years during which human burials were practically absent in sheltered areas. We called this the “Archaic Gap” (Araujo et al., 2003). We generated some evidence suggesting the advent of dryer climatic conditions coincident with the “gap.” A core sample extracted from the bottom of the temporary doline lake near the Cerca Grande outcrop revealed two discrete dark organic levels, the upper one at 50 cm depth, the lower at 210 cm. We interpreted these levels as the result of two discrete periods of permanent water in the lake, hence two periods of higher humidity. The age obtained for the upper organic level was 2800 ± 40 ^{14}C yr B.P. (2900 ± 100 cal yr B.P.), and for the lower level 9680 ± 230 ^{14}C yr B.P. ($10,960 \pm 590$ cal yr B.P.).

A late discrete episode of high humidity in the Lagoa Santa region was also confirmed by a core sample extracted by us from the temporary doline lake near the Sumidouro outcrop. Two organic levels, found at 115 cm and 275 cm depth, were dated to 1570 ± 70 ^{14}C yr B.P. (1460 ± 140 cal yr B.P.) and 2630 ± 40 ^{14}C yr B.P. (2759 ± 34 cal yr B.P.), respectively. This suggests that the local lakes, mainly the doline lakes, could have been more permanent during certain periods in the past, when compared to modern times. As such, they could have



Figure 1. Archaeological sites (numbers) and paleoenvironmental studies (letters) cited in the text. 1 = Lagoa Santa; 2 = Santana do Riacho; 3 = Lapa do Boquete and Lapa dos Bichos; 4 = Lapa do Dragão; 5 = Lapa Pequena; 6 = Gruta do Gentio II; 7 = Lapa do Varal; 8 = GO-JA-01; 9 = MT-GU-01; 10 = Santa Elina; 11 = BA-RC-28; 12 = Abrigo do Pilão; 13 = Gruta do Gavião. A = Lagoa dos Olhos, Lagoa Santa; B = Lago Silvana and Dom Helvécio; C = Lago do Pires and Água Preta de Baixo; D = Salitre; E = Serra Negra; F = Cromínia; G = Águas Emendadas, Lagoa Bonita, and Lagoa Feia; H = Icatu Dunes; I = Toca da Boa Vista; O = Fazenda do Pinto; P = Serra Rio do Rastro; Q = Morro da Igreja; R = Serra Boa Vista; S = Volta Velha; T = Serra Campos Gerais; U = Paraná River; V = Rio Claro; W = Botucatu; X = Anhembi; Y = Jaguariúna.

been very attractive places for more permanent and denser human settlement, in a region otherwise limited by water supply for humans, animals, and vegetation.

Rock shelters, archaeological “Gaps,” and paleoenvironments in Brazil

The recognition of the “Archaic Gap” at Lagoa Santa led us to search for possible correlates in adjacent areas. A survey of the Brazilian archaeological literature from the last two decades resulted in a picture that seems to corroborate a broader pattern of human regional abandonment during the early and mid-Holocene in several places. Most examples come from rock shelters, which have a greater probability of being repeatedly visited by prehistoric populations, and

which allow for comparisons across the same stratigraphic profile. We will now try to integrate the archaeological and paleoenvironmental data, taking into account the potentials and shortcomings of the different methods and approaches. Our main working hypothesis is that paleoclimatic changes were responsible for the patterns observed in the archaeological record of Central/Northern Brazil, also influencing the patterns of human occupation observed in other portions of the country. Specifically, water availability, with its direct and indirect impacts on human beings, could be thought of as a factor of major importance in this regard. We also suggest that archaeological sites in themselves can be good proxies of paleoenvironmental stress, adding new information to the corpus of paleoenvironmental data gathered by other fields of investigation. For space reasons, we will not

Table 1
Dated human remains from Lagoa Santa region

Skeleton number	Site	Lab code	¹⁴ C yr B.P.	¹³ C/ ¹² C ‰
MN-815	Amoreira	Beta 161657	7070 ± 40	NA
BL-K10 No.13 ^a	Boleiras	Beta 159243	7560 ± 110	-25.0
MN-1390	Boleiras	Beta 155659	8300 ± 50	-20.8
MN-1389	Boleiras	Beta 155658	8420 ± 100	-17.9
BL-K12 No.14 ^a	Boleiras	Beta 159244	8360 ± 50	-25.4
BL-K10 No.12 ^a	Boleiras	Beta 159242	8820 ± 150	-25.0
MN-627	Carrancas	Beta 161656	7970 ± 40	-21.8
MN-1365 ^a	Cerca	Beta 84444	1100 ± 50	-25.0
	Grande VI			
MN-1363 ^a	Cerca	Beta 84443	1280 ± 50	-25.0
	Grande VI			
MN-1346 ^b	Cerca	Beta 84442	6470 ± 60	-21.8
	Grande VI			
MN-1329	Cerca	Beta 161666	8230 ± 50	-20.8
	Grande VI			
MN-1369	Cerca	Beta 161668	8240 ± 40	-25.7
	Grande VI			
MN-1384 ^a	Cerca	Beta 84446	9130 ± 60	-25.0
	Grande VII			
MN-856	Lapa do Caetano	Beta 155657	2200 ± 50	-21.8
MN-865	Lapa do Caetano	Beta 161660	1760 ± 40	NA
MN-902	Lapa Mortuária	Beta 161661	1800 ± 40	-19.2
MN-847	Lapa Mortuária	Beta 161659	7190 ± 50	-19.1
MN-923	Lapa Mortuária	Beta 161662	8290 ± 40	-19.2
MN-928	Lapa Mortuária	Beta 161663	8350 ± 40	-19.4
MN-834	Lapa Mortuária	Beta 161658	8810 ± 50	-18.6
MN-932	Lapa Mortuária	Beta 161664	1770 ± 40	-19.3
MN-933	Lapa Mortuária	Beta 161665	1970 ± 40	-19.8
LVIV-Sep 1 ^b	Lapa Vermelha IV	Beta 84439	9330 ± 60	-24.9
UFMG-HW-15 ^b	Lagoa Santa (region)	Beta 108187	6660 ± 50	-33.4
	Lagoa Santa (region)	Beta 108186	7250 ± 60	-26.4
SRIACHO-VA	Santana do Riacho	Beta 96759	12,760 ± 70	-33.2
SR1-Sep Vb ^b	Santana do Riacho	Beta 104291	2310 ± 50	-22.7
SRIACHO-II ^b	Santana do Riacho	Beta 96758	5350 ± 60	-29.2
SRIACHO-XXII ^b	Santana do Riacho	Beta 96760	5680 ± 70	-28.3
SR1- Sep VII ^b	Santana do Riacho	Beta 104292	7820 ± 60	-26.5
SR1-XX	Santana do Riacho	Beta 162014	8280 ± 40	-24.9
MNH-HW294	Lapa da Lagoa Funda	Beta 165379	7870 ± 40	-25.3
Sep IV ^a	Santana do Riacho	Gif 5087	8150 ± 150	NA
Sep XXII ^a I	Santana do Riacho	Gif 5088	8230 ± 150	NA
Sep XIII ^a	Santana do Riacho	Gif 4508	9460 ± 110	NA

^a Associated charcoal.

^b Minimum age (acid washes).

explore the details of changes in lithic industry and subsistence patterns; more details can be found in Prous and Fogaça (1999).

The sites discussed below are shown in Figure 1. Numbers in brackets correspond to their locations.

The archaeological records at Lagoa Santa [1] (Araujo et al., 2003; Hurt and Blasi, 1969; Laming-Emperaire et al., 1975), and Santana do Riacho [2] (Chausson and Délibrias, 1993; Kipnis, 2002; Prous, 1991) suggest a decrease in human occupation between ca. 7500 and 2000 ¹⁴C yr B.P. (8340–1940 cal yr B.P.), and between ca. 8000 and 4000 ¹⁴C yr B.P. (8970–4490 cal yr B.P.), respectively, based both on abundance of sites and occupation of rock shelters. The nearest corresponding paleoenvironmental data come from Lagoa Santa, Lagoa dos Olhos, Lago Silvana, and Lago do Pires. These data strongly support a climatic explanation for the decrease in the prehistoric occupation of the two areas. De Oliveira (1992) has found a high frequency of charcoal from around 7500 ¹⁴C yr B.P. (8340 cal yr B.P.-interpolated age) in the sediments at Lagoa dos Olhos. According to the author, this suggests the occurrence of natural fires due to a dryer climate. At Lagoa Santa, Parizzi (1993) detected very poorly preserved pollen in lake sedimentary levels dated to 5020 ± 50 ¹⁴C yr B.P. (5860 ± 60 cal yr B.P.). The author suggested that the damage of the pollen grains may have been a consequence of dryer conditions. According to Parizzi (1993), the landscape in the Lagoa Santa region during the mid-Holocene was predominantly open, with much more grass than arboreal species.

For the Late Holocene, Parizzi (1993) has found that between circa 3000 and 1800 ¹⁴C yr B.P. (3210 and 1780 cal yr B.P.) (interpolated age), 32% of the pollen grains pertain to arboreal species, in marked contrast to what she found for the mid-Holocene. The author argues that this indicates the presence of exuberant vegetation in the region due to elevated year-round humidity during this period. De Oliveira (1992) also found evidence of cold and humid weather for Lagoa dos Olhos between ca. 4000 (interpolated age) and 1320 ¹⁴C yr B.P. (4490–1260 cal yr B.P.), based on paleopalynological studies of lake sediment. The record at Lago do Pires (Behling, 1998) shows a deeper chronology, where it is possible to observe an increase in moisture that starts somewhere between 8800 and 7500 ¹⁴C yr B.P. (9810–8340 cal yr B.P.), followed by dryer mid-Holocene conditions, as detected at Lagoa Santa and Lagoa dos Olhos. At Lagoa Silvana (Rodrigues-Filho et al., 2002), it is possible to observe the transition from the dry late Glacial to the moister Early Holocene around 8500 ¹⁴C yr B.P. (9510 cal yr B.P.). The same trend was observed at Salitre (Ledru, 1993), 280 km from Lagoa Santa towards the West.

There are no paleoenvironmental data for the northern portion of Minas Gerais State and, therefore, the correlation is restricted to the archaeological sites. However, the pattern seems to follow the trend already observed in the central region. Prous (Prous, 1997) suggests that an increase in the number of “mocó” bones (rock cavy—*Kerodon rupestris*) found at rock shelters in Northern Minas Gerais reflects an increase in aridity during the mid-Holocene.

Archaeological data at Lapa do Boquete [3] (Fogaça, 2001) and Lapa do Dragão [4] (Prous et al., 1997:152) also suggest decrease in human occupation. At Boquete, the decrease in occupation spans from ca. 7000 to 2000 ¹⁴C yr B.P. (7830 to 1940 cal yr B.P.). At Dragão there seems to be a gap from 10,000 to 5000 ¹⁴C yr B.P. (11,380 to 5700 cal yr B.P.) or, if

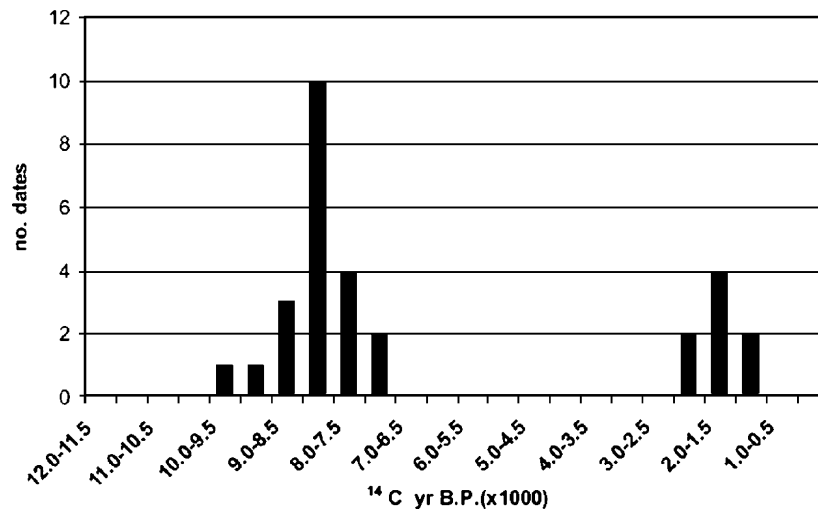


Figure 2. Frequency of ^{14}C ages for human skeletons from Lagoa Santa region, 500-yr intervals (uncalibrated).

some dubious¹ dates are dismissed, until as late as 2000 ^{14}C yr B.P. (1940 cal yr B.P.). The same can be said for data coming from Lapa Pequena [5] (Bryan and Gruhn, 1978), about 350 km North of the Lagoa Santa region, suggesting a decrease in human occupation between 7000 and 530 ^{14}C yr B.P. (7830–534 cal yr B.P.), in good agreement with data coming from Lapa do Varal [7] (8300 to 2600 ^{14}C yr B.P. [9370–2740 cal yr B.P.]), Boqueirão Soberbo (8200 to 1300 ^{14}C yr B.P. [9210–1260 cal yr B.P.]), and Barreirinho rock shelters (7600 ^{14}C yr B.P. [8390 cal yr B.P.]—present ?) (Dias Jr., 1991), all located 80 km to the North.

In the northwestern portion of Minas Gerais, Gruta do Gentio II [6] (Bird et al., 1991; Dias Jr., 1991; Machado, 1990) was first occupied ca. 10,000 ^{14}C yr B.P. (11,380 cal yr B.P.), and the authors suggest a decrease in occupation between ca. 7000 and 3500 ^{14}C yr B.P. (7830–3740 cal yr B.P.). For Lapa do Foice the same occurs between ca. 7500 and 3500 ^{14}C yr B.P. (8340–3740 cal yr B.P.: Dias Jr., 1991). These interpretations are not in agreement with the paleoenvironmental interpretation for Vereda de Águas Emendadas (Barberi et al., 2000), about 150 km NW. At that location, the authors found a “drastic decrease in concentration and diversity of palynomorphs from ca. 21,000 yr BP (outside of the calibration range) until 7220 ± 50 yr BP” (8000 ± 80 cal yr B.P.) (op. cit.: 241), followed by an increase in moisture with a peak ca. 5600 ^{14}C yr B.P. (6340 cal yr B.P.). At Lagoa Bonita, 10 km away from Águas Emendadas, data gathered by Barberi (2001) seem to match more closely with the archaeological scenario, with evidence of aridity between 19,000 and 13,000 ^{14}C yr B.P. (22,540–15,640 cal yr B.P.) (based on a sedimentation hiatus) followed by an increase in moisture but in an oscillatory manner. From 13,000 to 8400 ^{14}C yr B.P. (15,640–9450 cal yr B.P.), there was a savanna vegetation, followed by a dryer period between 8400 and 6300 ^{14}C yr B.P. (9450–7220 cal yr B.P.). The lake was completely dry ca. 7900 ^{14}C yr B.P. (8690

cal yr B.P.) (extrapolated age). Although the interpretation for ca. 6300–3200 ^{14}C yr B.P. (7220–3420 cal yr B.P.) is of a wetter climate following the first appearance of *Mauritia* pollen, the core showed other evidence of dryness ca. 5300 ^{14}C yr B.P. (6030 cal yr B.P.). Modern conditions were established after 3200 ^{14}C yr B.P. (3420 cal yr B.P.).

In our view, two main factors could be responsible for the discrepancy in interpretation between these two nearby studied areas: either microclimatic differences induced by the presence of a mountain range between the two areas, or problems related to the interpolation of dates. At Águas Emendadas, for example, there is an interpolation between $21,400 \pm 100$ ^{14}C yr B.P. (outside of the calibration range) and 7220 ± 50 ^{14}C yr B.P. (8000 ± 80 cal yr B.P.), missing the interval where we would expect the Early Holocene moisture peak; and again, between 7220 ± 50 and 2600 ± 60 ^{14}C yr B.P. (between 8000 ± 80 and 2740 ± 70 cal yr B.P.), introducing uncertainty regarding the hypothesis of increasing moisture up to 5600 ^{14}C yr B.P. (6340 cal yr B.P.).

One of the most extensively excavated rock shelters in Central Brazil, called GO-JA-01 rock shelter [8] (Schmitz et al., 1989) was first occupied ca. 10,500 ^{14}C yr B.P. (12,430 cal yr B.P.), and shows a possible gap in human occupation between 6700 and 1000 ^{14}C yr B.P. (7830–940 cal yr B.P.). The closest paleoenvironmental study was undertaken at Cromínia (Salgado-Laboriau, 1997), 300 km NE from the rock shelter, too distant to warrant correlations. However, it is worth noting that in Cromínia at 6680 ± 90 ^{14}C yr B.P. (7540 ± 150 cal yr B.P.) are attested the lowest concentrations of algae remains and pollen grains, and high concentrations of charcoal particles (Salgado-Laboriau et al., 1997, 219).

In Western Mato Grosso State, MT-GU-01 [9] (Abrigo do Sol rock shelter) was almost totally excavated (Miller, 1987). The stratigraphy shows a gap between 5800 and 300 ^{14}C yr B.P. (6600 – 390 cal yr B.P.), with a continuous prior occupation possibly beginning 14,500 ^{14}C yr B.P. (17,370 cal yr B.P.). This rock shelter is the westernmost site of our sample. However, lack of paleoenvironmental studies nearby precludes any comparison.

¹ Some of the samples were dated at a Brazilian lab and were considered not very reliable.

In Bahia State, the two sites under examination are far away from each other (about 350 km), and few paleoenvironmental studies are available. BA-RC-28 rock shelter [11] (Barbosa, 1991) shows an apparent gap between 6800 and 2000 ^{14}C yr B.P. (7640–1940 cal yr B.P.). This site is relatively close (ca. 100 km) to the already mentioned Lapa do Boquete and Lapa do Dragão, and seems to follow the same chronology of abandonment. Abrigo do Pilão rock shelter [12] (Bryan and Gruhn, 1993) shows a gap between 8800 and 860 ^{14}C yr B.P. (9810–750 cal yr B.P.). The closest paleoenvironmental data come from Toca da Boa Vista (Auler and Smart, 2001), located 150 km NE, and from the Icatu River (De Oliveira et al., 1999), 150 km NW. There is evidence from Toca da Boa Vista of a wet climate until 9000 ^{14}C yr B.P. (10,190 cal yr B.P.), in agreement with the archaeological data. The Icatu data suggest moisture between 11,000 and 8900 ^{14}C yr B.P. (13,000–9960 cal yr B.P.), followed by an increase in aridity with a semi-arid peak between 6800 and 6200 ^{14}C yr B.P. (7070–7640 cal yr B.P.), which also agree with the archaeological data. There is a discrepancy only in the late-Holocene, when Icatu paleoclimatic data suggest an increase in moisture between 6200 and 4500 ^{14}C yr B.P. (7070–5250 cal yr B.P.).

Southern Brazil: no Gaps?

Southern Brazil, considered here as the southern portion of São Paulo State and the States of Paraná, Santa Catarina and Rio Grande do Sul, is very heterogeneous in terms of archaeological research and results. Rio Grande do Sul, Santa Catarina and Paraná are fairly well known. In contrast, huge portions of São Paulo lack even a single piece of archaeological information. Overall, the region does not contain many well-dated rock shelters, and the kind of comparison carried out for the other regions of the country is thus hampered. Distribution of sites across the landscape suggest that Paleoindians were present since at least ca. 11,000 ^{14}C yr B.P. (13,000 cal yr B.P.) at both the northern and southern extremes of the region (Rio Grande do Sul and Central São Paulo: Beltrão et al., 1986; Dias and Jacobus, 2003; Dias and Jacobus, 2001; Miller, 1987). In São Paulo, the only site within the 11,000–10,000 ^{14}C yr B.P. (13,000–11,380 cal yr B.P.) range is Alice Böer (Beltrão et al., 1986), with bifacial projectile points placing it in closer affiliation with the southern industries. Rock shelters in the eastern portion of the state and relatively close to the sea, were first occupied (Collet, 1985; De Blasis, 2001) by 9800 ^{14}C yr B.P. (11,200 cal yr B.P.). The inland portion of São Paulo shows dates ranging from 7000 ^{14}C yr B.P. (7830 cal yr B.P.) to the present date (Vialou, 1984). Due to the poor archaeological data for the state, it is not possible to know if there is actually a gap between ca. 9800 and 7000 ^{14}C yr B.P. (ca. 11,200–7830 cal yr B.P.). In environmental terms, São Paulo could be regarded as a transitional area between Central Brazil and the Southern Region, and therefore, the lack of data frustrates any attempt to understand past human settlement strategies in this important region during the mid-Holocene.

Paraná State shows a continuous record of human occupation since 7000 ^{14}C yr B.P. (7830 cal yr B.P.) (Chmyz, 1983),

and the same can perhaps be said for Santa Catarina. Rio Grande do Sul, the better-studied region, shows a continuous archaeological record from 11,000 ^{14}C yr B.P. (13,000 cal yr B.P.) to the present (Noelli, 2000).

When viewed in the light of paleoenvironmental data, the human occupation of Southern Brazil seems to be significantly more unconstrained in terms of moisture/temperature/seasonality than the rest of Brazil. In fact, the region probably showed a milder climate when compared to both Central Brazil (due to water availability) and meridional settings such as the Argentinian Pampas (in this case, due to low temperatures and water availability). The climate became moister and warmer through the Holocene, explaining the region's more stable human occupation, without marked gaps. If the palynological data for Santa Catarina coast can be extrapolated (Behling and Negrelle, 2001), rainforest was starting to develop very early, since 12,300 ^{14}C yr B.P. (14,250 cal yr B.P.), and therefore paleoclimatic conditions were probably suitable for human occupation. The coastal area would therefore be very attractive to Paleoindian groups, as suggested by the early dates already generated for the coastal mountain range ("Serra do Mar"—Collet, 1985).

Out of the shelters: regional patterns inferred from open-air sites in Brazil

Up to this point, we have only dealt with evidence coming from rock shelters that exhibit a very clear pattern of mid-Holocene abandonment or decrease in occupation. Nevertheless, regional comparisons between rock shelters and open-air sites are a good way to test our proposition. Our procedure is to use dates coming from open-air sites in Brazil, and see if we can detect the regional abandonment pattern we advocate, since it is probably very broad. The assumption underlying this analysis is that the frequency of dates in a given region is a proxy measure of the density of human occupation (Rick, 1987).

We deliberately avoided using data from coastal areas, since human occupation in these settings was constrained mainly by sea-level fluctuations, and Early Holocene sites are probably underwater. Also, we did not analyze data from NE Brazil and the Amazon for other reasons: while NE Brazil has a fair number of dated archaeological sites, the paleoenvironmental setting is still far from clear, perhaps due to the extreme climatic/moisture variability already observed by other authors (Auler and Smart, 2001; Nimer, 1989). In the Amazon, on the other hand, the debate over the refugia hypothesis (Colinvaux et al., 2000) led to a greater investment in paleoenvironmental research, but the archaeological scenario is not very clear.

The central states

Here we scrutinize data coming from what we call "the central states" of Brazil. Our database composed of 436 radiocarbon and luminescence dates is drawn mainly on Oliveira and Viana (2000) and Etchevarne (2000). Plotting these dates in bar graphs at 500-yr intervals provides an

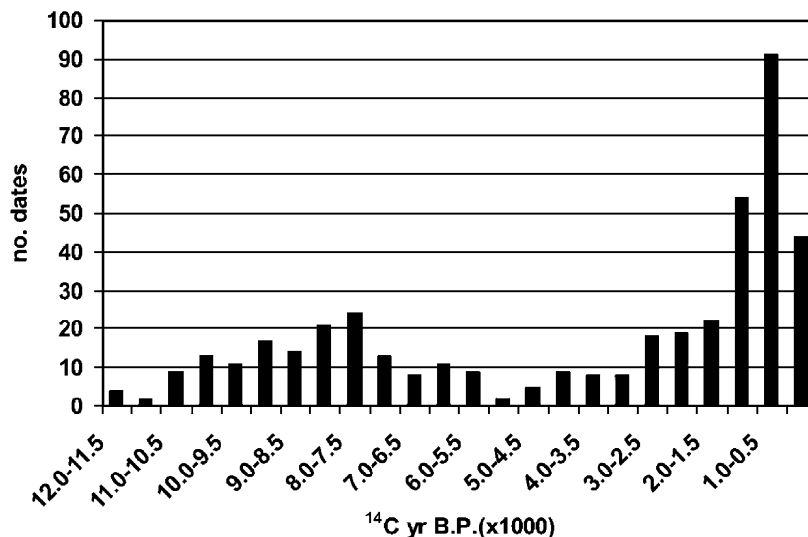


Figure 3. Total frequency of ¹⁴C ages for Central Brazil, 500-yr intervals (uncalibrated).

overview of the pattern occurring in Central Brazil (Fig. 3): two peaks in human occupation, the early one around 8000 ¹⁴C yr B.P. (8970 cal yr B.P.), the later one just before the European arrival, and a period of lesser occupation in between, reaching a minimum at ca. 5000 ¹⁴C yr B.P. (5710 cal yr B.P.). In summary, these data from open-air sites corroborate those coming from the rock shelters, and are in good overall agreement with the paleoenvironmental interpretations for the region.

The southern states

Our database comprises 273 dates for sites in the southern states, and is based mainly on Noelli (2000). The frequency of dates for Rio Grande do Sul (RS-126 dates) is the best sample we have for Southern Brazil, and it seems that there are at least two peaks of dates, an earlier one between 10,500 and 9000 ¹⁴C yr B.P. (12,430–10,190 cal yr B.P.), and another representing an increase ca. 1500 ¹⁴C yr B.P. (1360 cal yr B.P.). However, the two-peaked pattern is not as clear as in the central portion of the country, and indeed, we could postulate a

rather stable early to mid-Holocene population followed by a manifold increase in the Late Holocene. This pattern is better observed if we deal with all 273 dates, as can be seen in Figure 4.

These data are also in very good agreement with the paleoenvironmental scenario proposed for inland Southern Brazil: the climate became moister and hotter through the Holocene, especially after 3000 ¹⁴C yr B.P. (3210 cal yr B.P.), when *Araucaria* forest started to expand (Behling, 1997, 2002; Behling et al., 2001). Therefore, great oscillations in the local population during the mid-Holocene for this portion of Brazil would not be expected.

Statistical comparison between regions

The frequencies presented in Figures 3 and 4 seem fairly different on a visual basis, but a statistical analysis was used to check the results. Since the frequencies did not show a normal distribution, we had to use a non-parametric statistical test. Mann–Whitney's *U* test was considered the most adequate in order to evaluate if the distributions of dates obtained for

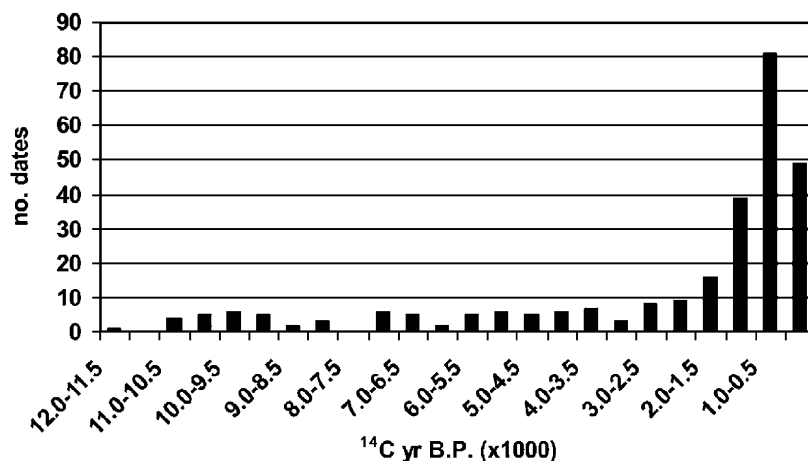


Figure 4. Total frequency of ¹⁴C ages for Southern Brazil, 500-yr intervals (uncalibrated).

Central and Southern Brazil were significantly different. The results [$U = 42113.50$ ($P < 0.000001$)] showed that the pattern of dates is significantly different between the two regions. Two assumptions underlie this analysis: we considered that there was no sample bias, i.e., that all archaeological sites were sampled in a similar and consistent way, and that the rates of generation and decomposition of datable material were also similar.

Discussion

The data gathered from rock shelters and open-air sites in Brazil seem sufficient to suggest that climate had a strong influence on the observed patterns. The consequence for human settlement is that areas with more benign conditions would have been sought, and even disputed, during these periods. In our view, the coastal region of Brazil could be one of these areas, although marine oscillations preclude the identification of Early Holocene archaeological sites.

There are some rock shelters in the interior that constitute exceptions to this picture of Holocene abandonment. Among those in Brazil, we can cite Santa Elina (Vialou et al., 2000), Gruta do Gavião (Silveira, 1994), Toca da Esperança (Martin, 1997), Lapa Vermelha IV (Laming-Emperaire et al., 1975), and Lapa dos Bichos (Kipnis, 2002). All these sites showed continuous occupation during the mid-Holocene, which can be attributed to numerous causes. Local, microclimatic conditions could be a possible answer. However, a detailed diachronic analysis of the artifact distributions may also show a decrease in the mid-Holocene occupation in all or some of these sites. However, these avenues of inquiry are outside the scope of this paper, and the topic deserves much more research.

Conclusions

The Holocene in South America was marked by dry periods that affected the lives of humans in an intelligible way. Ancient populations had to move across vast spaces in order to avoid the consequences of climatic changes. This pattern has already been observed in the Northern Hemisphere (e.g., Weiss and Bradley, 2001) and in the Andean zone (e.g., Nuñez et al., 2002), where aridity and water availability are obvious constraints to human occupation. In this paper, we try to show that this abandonment pattern is much more ubiquitous, affecting humans in extra-Andean settings such as the Brazilian lowlands. For a large area in Central Brazil, comprising about 920,000 km² (slightly larger than the areas of France and Germany together—Fig. 5) evidence of major gaps in human occupation is observable both at rock shelters and in the pattern of dates at open-air sites.

We suggest that humans might be regarded as good paleoenvironmental markers for the Holocene, since their presence seems to be clearly associated with a threshold of water availability, either in a direct manner, or following a set of constraints related to the foodstuff they sought. In this light, we propose that archaeological data should be better explored



Figure 5. Partial map of South America. Dry periods during the Mid-Holocene affected the dashed region, ~920,000 km².

and regarded as a valuable basis for paleoenvironmental inferences.

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