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# $^{14}C$ data and the early colonization of Northwest South America: A critical assessment

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A R T I C L E I N F O

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A B S T R A C T

The aim of this paper is to make a critical appraisal of the available $^{14}C$ dataset from Northwest South America (Colombia) corresponding to the Pleistocene/Holocene transition (ca. 12,000–8000 $^{14}C$ years BP). The first step in the study was to assemble from both published and unpublished sources an exhaustive database of $^{14}C$ dates ($n = 85$), recording data regarding the environmental setting and spatial coordinates of each site, stratigraphic provenance of the dated samples, material used for dating, and $^{14}C$ dating method. After the application of different filtering procedures based on outlier detection techniques, the database was subsequently reduced ($n = 77$). Using uncalibrated and calibrated dates, some spatial and temporal trends in data distribution were investigated in order to illustrate both the strengths and weaknesses of the available database. It is concluded that three main features that characterize the $^{14}C$ dataset from Northwest South America, namely the very high percentage of $^{14}C$ measurements made on charcoal, the almost total disregard of bone as a target sample for dating, and the extremely low percentage of AMS dates, partially affect both its reliability and comparability. It is suggested that, in order to use $^{14}C$ dates as data to make reliable inferences about the timing, pattern, process and tempo of early exploration and colonization of the study area, work at two different levels would be profitably carried out. In the short term, it would be advisable to develop an extensive and exhaustive program aimed at redating, with AMS and new sample selection criteria, the more significant archaeological assemblages attributable to the Pleistocene/Holocene transition. In the medium to long term, it would be necessary to implement new research projects specifically aimed at obtaining original information about early human settlement in different geographical areas of the Colombian territory.


## 1. Introduction

Northwest South America, which roughly corresponds to the current Colombian territory (Fig. 1), is an area from where substantial evidence about Pleistocene human settlement has been recovered (e.g. Correal and van der Hammen, 1977; Hurt et al., 1977; Correal, 1986; Ardila, 1991; Niuwenhuis, 1998, 2002; Gnecco, 2000, 2003; Aceituno, 2001, 2007; Mora and Gnecco, 2003; Gnecco and Aceituno, 2006; Aceituno and Loaiza, 2007; López, 2008; Aceituno et al., 2013). Despite this fact, research about the early peopling of this ample and ecologically diverse territory has never reached the necessary momentum. As a consequence, there are very few research projects specifically aimed at obtaining information about the timing, pattern, process and tempo of early exploration and colonization.

In order to lay down the foundations for future research on the subject, there is an urgent need to critically review a number of issues regarding evidence about early peopling. Chief among such issues is the evaluation of the available chronological framework based on $^{14}C$ dates obtained at different archaeological contexts attributable to the Pleistocene/Holocene transition (ca. 12,000–8000 BP). The aim of this paper is to undertake such a critical review, trying to identify the potential weaknesses of the existing $^{14}C$ database, as reviewed by December 2013, corresponding to the targeted time period and suggesting some guidelines for further research. To introduce the problem, we will begin

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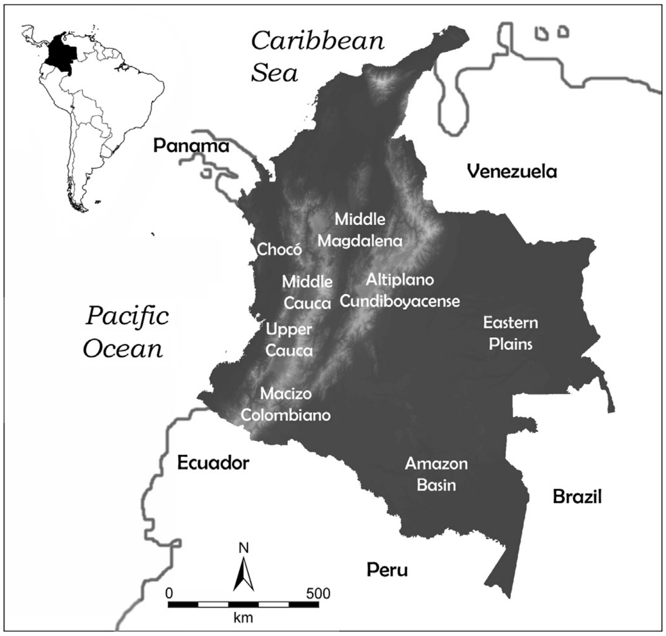


**Fig. 1.** Map of Northwest South America showing the main ecogeographic regions mentioned in the text.

first with a description of the environmental evolution of Northwest South America during the Pleistocene/Holocene transition, followed by a brief overview of the archaeological research about the early peopling of this area.

## 2. Northwest South America: environmental settings at the Pleistocene/Holocene transition

From a physiographic point of view, the northwest portion of the South American subcontinent is a highly diverse area (Fig. 1). Whereas the Ecuadorian Andes in the south form a continuous mountain chain, the Colombian Andes split into three branches of different geological origin, the Western, Central and Eastern Cordillera, which delimit two wide intermountain river valleys: the Magdalena and the Cauca (Domínguez, 1988). At both sides of the Andes lie lowland areas covered with tropical rainforest: the narrow strip along the Pacific coast and the vast Amazon River basin (Domínguez, 1988). To the north of the latter, extends a large plain covered with grasses, forested along the rivers. The rest of the area is made up of rolling savannahs, particularly along the Colombia's Caribbean coast. Near the equator, the physiographic variants produce a dramatic climate variation along an altitudinal gradient. Differences in solar exposure, rainfall, and soils make a vertical mosaic of markedly different and narrow tiers, except in the Amazon and eastern plains where the ecosystems are substantially wider (Gnecco and Aceituno, 2006).

Available palynological, glaciomorphological and diatom evidence allows the reconstruction of the predominant environmental conditions during the last 18,000 $^{14}$C years (van der Hammen and González, 1960; van der Hammen, 1974, 1992; van der Hammen and Hooghiemstra, 1995; Colinvaux, 1997; Marchant et al., 2001, 2002, 2004; Vélez et al., 2006; Delgado, 2012a). The most conspicuous pattern that currently emerges is that Northwest South America suffered repeated environmental changes of variable intensity over time, inferred from temperature, moisture and rainfall fluctuations as indicated by different climate proxies. Such fluctuations may have had the potential to cause significant ecological modifications resulting from climate-dependent chorological changes affecting vegetal and animal communities. Recent pollen-based biome reconstructions by Marchant et al. (2001, 2002, 2004) show that, during the Last Glacial Maximum (LGM) (ca. 18,500–17,500 BP), the lowlands were dominated by grass savannahs, cool mixed forests, and tropical seasonal forests. At mid to highland settings, a shift from tropical seasonal forests to cool evergreen forests and cool mixed forests has been registered, while at locations above 2500 masl there has been a marked increase of the cool grassland–shrub biome. In general terms, the vegetation at this period reflects cold and dry conditions.

For the early Lateglacial, between 15,500 and 14,500 BP, the paleoenvironmental record from mid-lower elevations suggests that the cool mixed forest biome became more widespread. Cool mixed forest and cool evergreen forest biomes were recorded at lower altitudes. The low altitude localities exhibited at that time the same biomes than today such as grassland savannah, cool mixed forest and tropical seasonal forest. Overall, the aforementioned conditions suggest the existence of a cold and dry climate. In summary, the LGM and the earliest part of the Lateglacial was a very cold and dry time period, in which some of the investigated localities had very slow sedimentation rates (Marchant et al., 2002).

Between 12,500 and 11,500 BP, biome reconstructions reveal environmental conditions relatively similar to those of the previous period, although with an increased spread of cool evergreen forest biomes at mid altitudes, thus revealing some climatic amelioration. This is related to the Guantiva Interstadial (ca. 12,500–11,000 BP), which is characterized by the increasing of average annual temperature (2 C° lower than today) and effective precipitation, as well as altitudinal movements of the upper forest line (van der Hammen and Hooghiemstra, 1995). In the Sabana de Bogotá (Eastern Cordillera), for instance, there was an expansion of the forest over the *páramo* (i.e. the ecosystem between the upper forest line and the permanent snow line characterized by valleys and plains with a variety of lakes, peat bogs and wet grasslands intermingled with shrublands and forest patches; Hofstede et al., 2003), which was represented by *Alnus* and vegetation typical of marsh environments such as lower bushes of the genera *Myrica* and *Symplocos*. At Fúquene lake and surrounding areas, the presence of *Dodonaea*, a pioneer of bare soil, is a good indicator of this climatic trend (van der Hammen, 1974, 1992:45), which has correlatives in other areas of Colombia (Marchant et al., 2002).

The end of the Guantiva Interstadial was marked by the return of colder and drier conditions associated with the onset of the El Abra Stadial (ca. 11,000–10,000/9500 BP). Average annual temperatures during the E1 Abra Stadial were 4–6 C° lower than today according to pollen data (van der Hammen and Hooghiemstra, 1995) or 2°–3 C° lower than today according to stable isotope ($\delta^{13}$C) data (Boom et al., 2001, 2002; Mora and Pratt, 2002). The upper forest line during this stadial was some 400–500 m lower than during the Guantiva Interstadial and some 600–800 m lower than today (van der Hammen and Hooghiemstra, 1995). Lowered atmospheric $pCO_2$ and reduced rainfall during this period may have contributed both to a lower forest line and the colonization of the tropical Andes by $C_4$ grasses despite prevailing cooler temperatures (Mora and Pratt, 2002).

In the Sabana de Bogotá, the forest partially disappeared and was replaced by the low bushes of the *subpáramo*, with many open *páramo* grasslands of the family Compositae (van der Hammen and Gónzalez, 1960; van Geel and van der Hammen, 1973; van der Hammen, 1974, 1978). According to van der Hammen and Hooghiemstra (1995), the Guantiva-El Abra interval is the regional equivalent to the European Allerød–Younger Dryas sequence. Around 10,000 BP the climate ameliorated again, with a sudden rise in average annual temperature that increased evaporation and caused lakes and swampy areas to dry (van der

Hammen, 1992). The biome reconstructions for the 9500–8500 BP interval reveal that there was a notable expansion of mesic biomes (Marchant et al., 2002). At higher elevations, cool mixed forest spread at the expense of the cool grassland–shrub biome. Below 2570 masl, the cool grassland–shrub biome formed an association with the cool evergreen forest. At lower altitudes, tropical seasonal forest and tropical rain forests biomes were present, although some increasing in the extent of grass savannah and tropical seasonal forest was detected. According to Marchant et al. (2002, 2004) this interval was clearly characterized by warmer and wetter conditions than those of the last part of the Lateglacial.

Changes in the chorology and composition of animal communities during the Pleistocene/Holocene transition are difficult to establish, as most of the archaeological and paleontological records come from undated or non-stratified contexts. This particularly affects the knowledge of relevant aspects regarding Pleistocene megafauna, whose interactions with humans appear to be poorly documented (Correal, 1981, 1993; van der Hammen, 1986; Piperno and Pearsall, 1998; van der Hammen and Correal, 2001; Correal et al., 2005). Available evidence shows that extinct mammals including *proboscidean gomphotheres* (genera *Haplomastodon*, *Stegomastodon*, and *Cuvieronius*), xenarthrans (genera *Gliptodon*, *Propraopus*, *and Eremotherium*), and American horses (genus *Equus*) coexisted, in certain areas, with still living fauna including *cervids* (*genera Odocoileus* and *Mazama*), xenarthrans (genus *Dasypus*), lagomorphs (genus *Sylvilagus*), caviomorphs (genera *Cavia* and *Cuniculus*), and cricetids. However, the timing of megafaunal extinction and the role of humans in the process have yet to be determined.

## 3. Archaeological research about early human settlement in Northwest South America

As in other areas of the Andes, archaeological research in Northwest South America traditionally focused on the archaeological record of past agricultural communities. As a consequence, research interest in the problem of the early peopling of the Colombian territory did not emerge until the 1960s, when Reichel-Dolmatoff (1965) reported several findings of lithic artifacts across the Colombian territory and stressed the importance of investigating a deeper past by indicating the most promising geographic areas for the search of preceramic cultures. He and the Dutch geologist T. van der Hammen, who since the 1950s had been devoted to the investigation of Pleistocene and Holocene paleoenvironmental conditions in the Eastern Cordillera, *were pioneers in the design* and implementation of a coherent plan for paleoindian research (Reichel-Dolmatoff, 1997). The research, focused on the Sabana de Bogotá (Eastern Cordillera), was continued by van der Hammen along with the Colombian archaeologist G. Correal and the American archaeologist W. Hurt. Between 1967 and the early 1970s, two contexts of Late Pleistocene age were investigated: El Abra II and Tequendama I. At El Abra II, a rockshelter near the town of Zipaquirá (Cundinamarca), few lithic flakes and expedient unifacial tools belonging to the so-called "Abriense industry" or "edge-trimmed tool tradition" (Hurt, 1977; Correal, 1986) were recovered at the lower levels (7 and 8) in association with faunal remains of still living species. Several charcoal samples, mostly small flecks mixed with dark soil particles, were selected for dating, yielding Late Pleistocene and Early Holocene ages (Correal et al., 1969; Hurt et al., 1977; Correal, 1986). At Tequendama (Soacha, Cundinamarca), Correal and van der Hammen excavated a group of rockshelters. In the lowers levels of Tequendama I, where two hearths were $^{14}C$ dated yielding Late Pleistocene ages, these scholars found faunal remains similar to those found at El Abra II but associated with artifacts of a different technology which were labelled as "Tequendamiense industry". At Tequendama, the Tequendamiense artifacts characterized by the use of *allochthonous* materials and the presence of scrapers, thinned flakes and a projectile point appear spatially close to Abriense artifacts (Correal and van der Hammen, 1977). Beginning in 1979, G. Correal excavated Tibitó (Tocancipá, Cundinamarca), an open air site where a number of Abriense stone tools were recovered associated with bone remains of proboscideans (*Haplomastodon* sp. and *Cuvieronius hyodon*), American horse (*Equus* sp.) and deer (*Odocoileus virginianus*). A sample of bone yielded a Late Pleistocene age (Correal, 1981). At the Sabana de Bogotá, further investigations in sheltered and open air sites including Sueva I, Gachalá, Galindo I, Neusa, and Checua lead to the discovery of contexts characterized by the presence of Abriense artifacts and faunal remains of still living species, with chronologies ranging from 12,000 to 8000 BP.

During the 1980s and the early 1990s, several sites were excavated in the Colombian southwest whose findings were actively integrated into the discussion regarding early human settlement. At the Calima region (Western Cordillera), a sub-Andean valley about 1600 masl, two open air sites of Early Holocene age—El Sauzalito and El Recreo—have artifact assemblages composed by simple unifacial flakes, hoes, hand stones, hammers, and anvils (Salgado, 1988–1990). At the Popayán Plateau (Central Cordillera) the San Isidro site (~1600 masl) has, at a level attributable to the Pleistocene/Holocene boundary, a lithic assemblage composed by thousands of chert artifacts including unretouched and retouched flakes, lanceolate bifaces and handstone tools which is not associated with faunal remains (Gnecco, 1994, 2000, 2003). In addition to the artifacts, charred seeds of *Persea* spp. and *Erythrina* and starch grains from cf. *Xanthosoma*, cf. *Ipomea*, cf. *Manihot* and cf. *Maranta arundinacea* were also identified, as well as other grasses and legumes (Piperno and Pearsall, 1998:200).

Contemporary with the investigations in the Colombian southwest, archaeological research in the Amazon basin led to the discovery of Peña Roja, an open air site on the middle Caquetá River dated at the beginning of the Early Holocene (Cavelier et al., 1995). At this site, the lithic assemblage was composed by unifacial flakes, choppers, drills, handstone, milling stone, hammers and anvils (Cavelier et al., 1995). Thousands of charred seeds and macro-remains belonging to different genera of palmae were also recovered at this site (Morcote et al., 1998), along with phytoliths of *Lagenaria* spp., *Calathea allouia* and *Cucurbita* spp. (Gnecco and Mora, 1997; Piperno and Pearsall, 1998), indicating the importance of the vegetal resources among early Amazonian people.

During the last decade, some important early sites like Nare, La Palestina 1 and 2, San Juan de Bedout, and Peñones de Bogotá were explored and subsequently excavated in the lowlands of the Middle Magdalena river valley (for a synthesis, see López, 2008). At these stratified open air sites, $^{14}C$ dated between ca. 10,400 and 8500 BP, simple flakes, plane-convex scrapers and triangular fishtail projectile points with straight, oblique or rounded wings, and long thin tail, made either on chert or quartz were found, with no association with faunal or botanical remains.

More recently, at the Middle Cauca and the Middle Porce river valleys (Central Cordillera, ca. 1650–2100 masl), a number of stratified open air sites whose occupation dates back, in some cases, to the Late Pleistocene were found (Tabares and Rojas, 2000; Rodríguez, 2002; Cano, 2004; Castillo and Aceituno, 2006; Aceituno and Loaiza, 2007; Santos, 2010). At sites such as El Jazmín (Middle Cauca) (Aceituno and Loaiza, 2007) and La Morena (Middle Porce) (Santos, 2010) the lithic technology—primarily consisting of simple flakes, axes, hoes, hand stones and milling bases—is clearly oriented to the exploitation of vegetal resources, something that is not verified in contemporary sites of the Altiplano Cundiboyacense and the Middle Magdalena River valley.

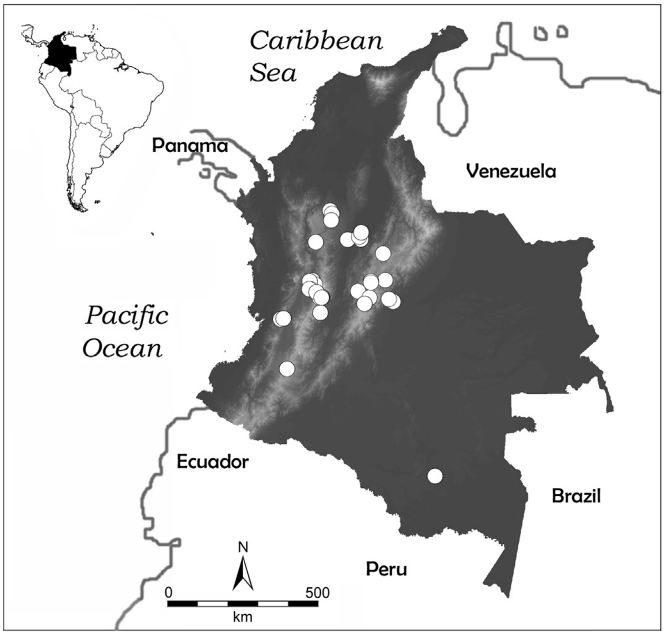


**Fig. 2.** Map of the study region showing the distribution of the archaeological sites mentioned in the text and in Table 1.

## 4. The $^{14}$C database

### 4.1. Data quality assessment and calendar calibration

In order to approach the spatial and temporal distributional pattern of $^{14}$C dates from our study area, we begin by assembling from both published and unpublished sources an exhaustive dataset corresponding to the Pleistocene/Holocene transition. For the purpose of this study, all $^{14}$C dates were taken at face value due to the difficulties for an individual-based assessment of each date imposed by the lack of sufficient information, in most of the original reports, about relevant issues like sample selection criteria, pre-treatment protocols, and correction for isotopic fractionation. A total of 85 $^{14}$C dates allegedly associated with evidence of human activity at 41 archaeological sites were collected from the existing literature for further analysis. The archaeological sites consist of both open air settings (36/41 or 87.8%) and rockshelters (5/41 or 12.2%). The whole sample was examined in search of outliers, either mild or extreme, on the basis of the calculation of the median, the interquartile range, and the outlier coefficient (established at 1.5 or one and a half times the length of the interquartile range) of the complete distribution of measured $^{14}$C ages. This procedure allowed to detect two mild outliers consisting in a date from El Jordán (Beta-111972 12,910 ± 60 BP; Salgado, 1998) and a date from El Abra II (GrN-5556 12,400 ± 160 BP; Correal et al., 1969; Hurt et al., 1977), that were consequently rejected. The rationale for this decision was to ensure the coherence (i.e. the unity or internal cohesion) of the sample, under the premise that a continuous or quasi-continuous distribution of $^{14}$C dates is more reliable as a signal of a colonization phase than a highly punctuated one. A second screening step consisted of the elimination of all those $^{14}$C dates with exceedingly high sigma values (i.e. laboratory uncertainty), recognized on the basis of an outlier detection analysis performed as described above. Six extreme values were detected, five of them corresponding to El Abra II (Beta-2134 10720 ± 400 BP; I-6363 9050 ± 470 BP; Beta-2135 8810 ± 430 BP; Beta-2137 8760 ± 350 BP; GrN-82 8670 ± 400 BP; Correal et al., 1969; Hurt et al., 1977), one to Tequendama I (GrN-6539 10920 ± 250 BP; Correal and van der Hammen, 1977), and the remaining one to Peña Roja (GX-17395 9125 ± 250 BP; Cavelier et al., 1995). The resulting dataset was thus composed of 77 $^{14}$C dates from the same 41 archaeological considered first (Table 1; Fig. 2). In this sample, the one on which all further analyses were carried out, the materials used for dating were charcoal (70/77 or 92.2%), bone (1/77 or 1.3%), seeds (1/77 or 1.3%), unspecified organic (1/77 or 1.3%), phytoliths (1/77 or 1.3%), and undetermined (2/77 or 2.6%). The $^{14}$C methods used for dating were beta-counting (63/77 or 81.8%) and accelerator mass spectrometry (AMS) (14/77 or 18.2%). Decade by decade, the pace of publication of $^{14}$C dates was as follows: 15 in the 1970s (19.5%), 8 in the 1980s (10.4%), 17 in the 1990s (22.1%), 23 in the 2000s (29.9%), and 14 in the current decade (18.2%). No statistically significant differences between the number of dates published in consecutive decades were observed (test of difference between percentages, two sided distribution, $\alpha = 0.05$).

**Table 1**
$^{14}$C dates from Northwest South America at the Pleistocene/Holocene transition.

| N° | Site | Altitude (masl) | Sample | Code | $^{14}$C date | Sigma | Technique | Setting | Region[c] | References |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tibitó | 2590 | bone | GrN-9375 | 11740 | 110 | B–C[a] | open air | Altiplano CB | Correal (1981) |
| 2 | El Abra II | 2570 | organic | GrN-5941 | 11210 | 90 | B–C | rockshelter | Altiplano CB | Hurt et al. (1977) |
| 3 | Tequendama I | 2566 | charcoal | GrN-6270 | 10730 | 105 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 4 | Tequendama I | 2566 | charcoal | GrN-6505 | 10590 | 90 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 5 | Tequendama I | 2566 | charcoal | GrN-6731 | 10460 | 130 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 6 | Nare | 175 | charcoal | Beta-146798 | 10400 | 60 | AMS[b] | open air | Middle Magdalena | López (2008) |
| 7 | Nare | 175 | charcoal | Beta-70040 | 10400 | 40 | AMS | open air | Middle Magdalena | López (2008) |
| 8 | La Palestina 2 | 130 | charcoal | Beta-40855 | 10400 | 90 | B–C | open air | Middle Magdalena | López (2008) |
| 9 | Nare | 175 | charcoal | Beta-70040 | 10350 | 60 | B–C | open air | Middle Magdalena | López (2008) |
| 10 | San Juan de Bedout | 130 | charcoal | Beta-40852 | 10350 | 90 | B–C | open air | Middle Magdalena | López (1989) |
| 11 | La Palestina 2 | 130 | charcoal | Beta-123566 | 10300 | 70 | B–C | open air | Middle Magdalena | López (2008) |
| 12 | PIII0I-52 | 1524 | charcoal | Beta 205293 | 10260 | 50 | AMS | open air | Central Cordillera | Otero and Santos (2006) |
| 13 | La Palestina 2 | 130 | charcoal | Beta-123565 | 10260 | 70 | B–C | open air | Middle Magdalena | López (2008) |
| 14 | Tequendama I | 2566 | charcoal | GrN-6210 | 10250 | 95 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 15 | La Palestina 2 | 130 | charcoal | Beta-40854 | 10230 | 80 | B–C | open air | Middle Magdalena | López (2008) |
| 16 | Tequendama I | 2566 | charcoal | GrN-7114 | 10150 | 150 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 17 | Tequendama I | 2566 | charcoal | GrN-7113 | 10140 | 100 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |

**Table 1** (*continued* )

| N° | Site | Altitude (masl) | Sample | Code | $^{14}$C date | Sigma | Technique | Setting | Region[c] | References |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | El Guatín | 1440 | charcoal | Beta-325213 | 10130 | 50 | AMS | open air | Central Cordillera | Restrepo (2013) |
| 19 | Tequendama I | 2566 | charcoal | GrN-6732 | 10130 | 150 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 20 | El Jazmín | 1650 | charcoal | Ua-24497 | 10120 | 70 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2007) |
| 21 | Sueva I | 2690 | charcoal | GrN-8111 | 10090 | 90 | B–C | rockshelter | Altiplano CB | Correal (1979) |
| 22 | La Morena | 1650 | charcoal | Beta-245566 | 10060 | 60 | B–C | open air | Central Cordillera | Santos (2010) |
| 23 | San Isidro | 1690 | charcoal | Beta-65878 | 10050 | 100 | B–C | open air | Central Cordillera | Gnecco (2000) |
| 24 | San Isidro | 1690 | seed | Beta-93275 | 10030 | 60 | AMS | open air | Central Cordillera | Gnecco (2000) |
| 25 | Tequendama I | 2566 | charcoal | GrN-6730 | 9990 | 100 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 26 | La Palestina 1 | 130 | charcoal | n.d. | 9820 | 115 | B–C | open air | Middle Magdalena | CAIN-OCENSA (1997) in López (2008) |
| 27 | El Jordán | 2640 | charcoal | Beta-116764 | 9760 | 160 | B–C | open air | Central Cordillera | Salgado (1998) |
| 28 | Tequendama I | 2566 | charcoal | GrN-7115 | 9740 | 135 | B–C | rockshelter | Altiplano CB | Correal and van der Hammen (1977) |
| 29 | 66PER001 | 1270 | charcoal | Beta-121972 | 9730 | 100 | B–C | open air | Central Cordillera | Cano (2004) |
| 30 | La Morena | 1650 | charcoal | Beta-245564 | 9680 | 60 | B–C | open air | Central Cordillera | Santos (2010) |
| 31 | Salento 24 | 2000 | charcoal | Beta-146613 | 9680 | 100 | B–C | open air | Central Cordillera | Tabares and Rojas (2000) |
| 32 | Sauzalito | 1500 | charcoal | Beta-23476 | 9670 | 150 | B–C | open air | Western Cordillera | Bray et al. (1988) |
| 33 | Sauzalito | 1500 | charcoal | Beta-23476 | 9670 | 100 | B–C | open air | Western Cordillera | Bray et al. (1988) |
| 34 | Sauzalito | 1500 | charcoal | Beta-23475 | 9600 | 110 | B–C | open air | Western Cordillera | Bray et al. (1988) |
| 35 | Sauzalito | 1500 | charcoal | Beta-23475 | 9600 | 100 | B–C | open air | Western Cordillera | Bray et al. (1988) |
| 36 | La Trinidad Corte I | 1000 | charcoal | CEDAD LTL 4267A | 9542 | 50 | AMS | open air | Central Cordillera | Restrepo (2013) |
| 37 | San Isidro | 1690 | charcoal | Beta-65877 | 9530 | 100 | B–C | open air | Central Cordillera | Gnecco (2000) |
| 38 | La Selva Risaralda | 1600 | charcoal | Beta-87188 | 9490 | 110 | B–C | open air | Central Cordillera | Rodríguez (2002) |
| 39 | Gachalá | 1758 | n.d. | GrN-8448 | 9360 | 45 | B–C | rockshelter | Altiplano CB | Correal (1979) |
| 40 | El Abra II | 2570 | charcoal | GrN-5661 | 9340 | 40 | B–C | rockshelter | Altiplano CB | Hurt et al. (1977) |
| 41 | La Trinidad Corte II | 1000 | charcoal | CEDAD LTL 4845A | 9333 | 65 | B–C | open air | Central Cordillera | Restrepo (2013) |
| 42 | El Abra II | 2570 | charcoal | GrN-5746 | 9325 | 100 | B–C | rockshelter | Altiplano CB | Hurt et al. (1977) |
| 43 | La Pochola | 1700 | charcoal | LTL-4223A | 9312 | 55 | B–C | open air | Central Cordillera | Aceituno ms. |
| 44 | Sauzalito | 1500 | charcoal | Beta-8.441 | 9300 | 100 | B–C | open air | Central Cordillera | Bray et al. (1988) |
| 45 | Sauzalito | 1500 | charcoal | Beta-18441 | 9300 | 100 | B–C | open air | Western Cordillera | Bray et al. (1988) |
| 46 | Peña Roja | 141 | charcoal | Beta-52964 | 9250 | 140 | B–C | open air | Amazon Basin | Cavelier et al. (1995); Gnecco (2000) |
| 47 | Génova | 1000 | charcoal | Beta-355217 | 9230 | 40 | AMS | open air | Central Cordillera | Restrepo (2013) |
| 48 | La Montañita | 1000 | charcoal | Beta-355214 | 9230 | 50 | AMS | open air | Central Cordillera | Restrepo (2013) |
| 49 | Peña Roja | 141 | charcoal | Beta-64602 | 9160 | 90 | B–C | open air | Amazon Basin | Cavelier et al. (1995); Gnecco (2000) |
| 50 | Sitio 045 | 1000 | charcoal | Beta-72375 | 9120 | 90 | B–C | open air | Central Cordillera | Castillo and Aceituno (2006) |
| 51 | La Pochola | 1700 | charcoal | LTL5436A | 9047 | 45 | B–C | open air | Central Cordillera | Aceituno ms. |
| 52 | El Abra II | 2570 | charcoal | Beta-5710 | 9025 | 90 | B–C | rockshelter | Altiplano CB | Hurt et al. (1977) |
| 53 | El Jazmín | 1650 | charcoal | Beta-95061 | 9020 | 60 | B–C | open air | Central Cordillera | INTEGRAL (1997) |
| 54 | Sitio 021 | 1000 | charcoal | Beta-114687 | 8990 | 80 | B–C | open air | Central Cordillera | Castillo and Aceituno (2006) |
| 55 | El Recreo | 110 | charcoal | Beta-26018 | 8750 | 160 | B–C | open air | Western Cordillera | Herrera et al. (1992) |
| 56 | Nuevo Sol | 1291 | charcoal | Beta-306257 | 8740 | 50 | AMS | open air | Central Cordillera | Restrepo (2013) |
| 57 | Galindo I | 2689 | charcoal | GrN-16346 | 8740 | 60 | B–C | open air | Altiplano CB | Pinto (2003) |
| 58 | La Selva | 1600 | charcoal | X-23803 | 8712 | 60 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2015) |
| 59 | La Selva | 1600 | charcoal | X-23805 | 8704 | 56 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2015) |
| 60 | La Pochola | 1611 | charcoal | Ua-24498 | 8680 | 55 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2007) |
| 61 | La Selva | 1600 | charcoal | Ua-24499 | 8680 | 60 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2007) |
| 62 | La Selva | 1600 | charcoal | X-23804 | 8674 | 61 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2015) |
| 63 | 39 El Recreo Cancha | 1341 | charcoal | Beta-285871 | 8550 | 60 | B–C | open air | Central Cordillera | Herrera et al. (2011) |
| 64 | Peña Roja | 141 | n.d. | Beta-64601 | 8510 | 110 | B–C | open air | Amazon Basin | Llanos (1997) |
| 65 | 39 El Recreo Cancha | 1341 | charcoal | Beta-290954 | 8480 | 40 | AMS | open air | Central Cordillera | Herrera et al. (2011) |
| 66 | Peñones de Bogotá | 116 | charcoal | Beta-181064 | 8480 | 40 | AMS | open air | Middle Magdalena | López (2008) |
| 67 | Salento 21 | 2391 | charcoal | Beta-146609 | 8430 | 100 | B–C | open air | Central Cordillera | Tabares and Rojas (2000) |
| 68 | El Antojo | 1950 | charcoal | Beta-93154 | 8380 | 90 | B–C | open air | Central Cordillera | INTEGRAL (1997) |
| 69 | Neusa | 3350 | charcoal | Beta-21060 | 8370 | 90 | B–C | rockshelter | Altiplano CB | Rivera (1991) |
| 70 | PIIIOP-59 | 920 | charcoal | Beta 231479 | 8340 | 40 | AMS | open air | Central Cordillera | Cardona et al. (2007) |
| 71 | Parámo de Peña Negra | 3340 | charcoal? | GrN 12068 | 8320 | 80 | B–C | open air | Altiplano CB | Herrera et al., 1992 |
| 72 | La Chillona | 1000 | charcoal | Beta-325216 | 8240 | 40 | AMS | open air | Central Cordillera | Restrepo (2013) |
| 73 | Checua | 2600 | charcoal | A-03 | 8200 | 110 | B–C | open air | Altiplano CB | Groot (1992) |
| 74 | San Germán II | 1600 | charcoal | CSIC-1987 | 8136 | 65 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2007) |
| 75 | La Pochola | 1700 | charcoal | Ua-24499 | 8095 | 55 | B–C | open air | Central Cordillera | Aceituno and Loaiza (2007) |
| 76 | Peña Roja | 141 | phytoliths | UCR-3419; CAMS-27728 | 8090 | 60 | AMS | open air | Amazon Basin | Piperno and Pearsall (1998) |
| 77 | 39 El Recreo Cancha | 1341 | charcoal | Beta-283582 | 8030 | 80 | B–C | open air | Central Cordillera | Herrera et al. (2011) |

[a] Beta Counting.
[b] Accelerator Mass Spectrometry.
[c] Altiplano Cundiboyacense.

Due to the lack of sufficient contextual information, no attempts to associate $^{14}$C dates from any particular site through the calculation of pooled means were made prior to calibration. The calendar calibration of the putative conventional $^{14}$C dates was performed using CALPAL_A (Cologne Radiocarbon Calibration & Palaeoclimate Research Package), a software package that allows the simultaneous processing of a large bulk of data and the comparison of the summed probability distribution with paleoclimatic curves from different proxies. The calibration curve chosen in this study was the CalPal-2007-Hulu (Weninger and Jöris, 2008), which produces results that are identical—for all practical purposes—to the recently published and internationally recommended INTCAL09-calibration (Bradtmöller et al., 2012).

### 4.2. Spatial and temporal trends in $^{14}$C data

The geographic patterning of early dates was assessed by means of a raster surface map using the kriging algorithm. We used XYZ coordinate data where X and Y are, respectively, the longitude and latitude of each archaeological site and Z is the value corresponding to the earliest $^{14}$C date registered at each site. As Fig. 3 shows, the earliest sites are distributed in the Altiplano Cundiboyacense (Eastern Cordillera) and the Middle Magdalena River basin. To the west, the occupation of the Middle and Western Cordillera and of the Cauca River valley seems to have been a later phenomenon. To the east, the only early site discovered so far in the Amazonas Basin, Peña Roja, has a record of occupation that begins at the Early Holocene.

Radiocarbon dates corresponding to the Pleistocene/Holocene transition come from sites distributed at three main altitudinal floors: 0–500 masl, 1000–2000 masl, and 2500–3000 masl (Fig. 4). It is remarkable that the two oldest dates, both exceeding 11,000 BP, were registered at sites corresponding to the third altitudinal floor, at about 2600 masl (Tibitó and El Abra, Altiplano Cundiboyacense). The occupation of the lowest floor, mainly represented at the Middle Magdalena River basin, seems to begin later, at around 10,500 BP, at Nare, La Palestina 2, and San Juan de Bedout. The second floor, located between 1000 and 2000 masl in the Central and Western Cordillera, has a record of occupation that seems to begin slightly later, around 10,100 BP.

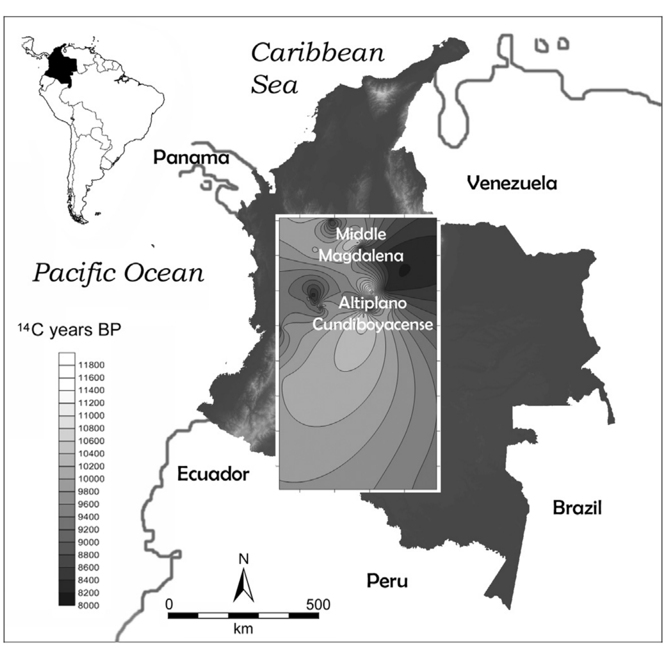


**Fig. 3.** Raster surface map (kriging algorithm), superimposed to the map of the study region, showing the spatio-temporal trends in the distribution of the earliest $^{14}$C date registered at each archaeological site.

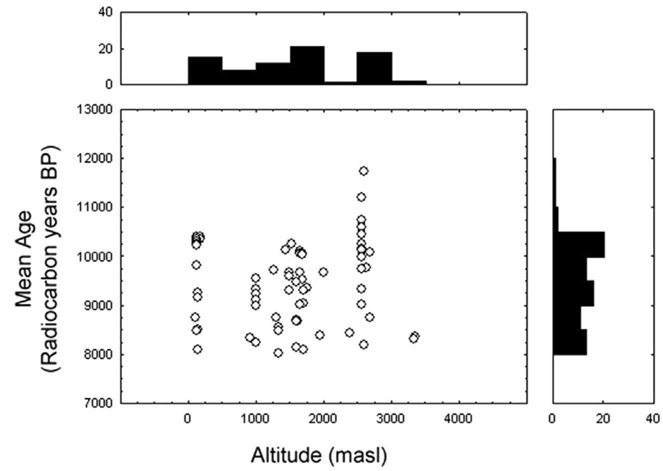


**Fig. 4.** Scatterplot with histograms showing the distribution of uncalibrated $^{14}$C dates from Northwest South America against the altitude of the respective archaeological sites.

Regarding the temporal pattern of distribution of the $^{14}$C dates corresponding to the Pleistocene/Holocene transition, both the uncalibrated and the calibrated sets (2 sigma) exhibit the same features (Figs. 5 and 6), i.e. a weak and punctuated signal before 11,000 BP and a stronger and continuous signal after that date, particularly in Late Pleistocene times. The only date from Tibitó and the earliest date from El Abra II (11,740 ± 110 BP and 11,210 ± 90 BP, respectively) are disconnected from the rest of the dates, notwithstanding the fact that they do not behave as outliers in a statistical sense. This makes these samples obvious candidates for redating in order to confirm or reject the estimated $^{14}$C ages.

In terms of the environmental scenario in which the early peopling of Northwest South America occurred, if the two pre-11,000 BP dates are accepted, then the colonization of the study area likely began at the Guantiva Interstadial, a period in which the Altiplano Cundiboyacense had relatively warm and humid

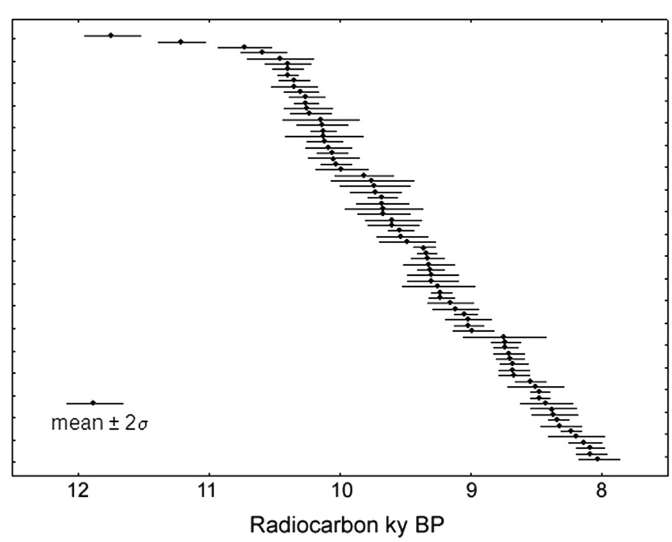


**Fig. 5.** Range plot displaying error bars (2 sigmas) corresponding to $^{14}$C dates of the Pleistocene/Holocene transition from Northwest South America.

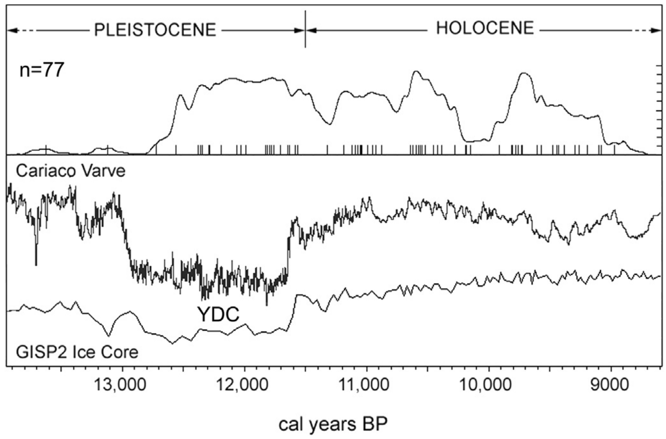


**Fig. 6.** (Top) summed probability distribution plot of calibrated ages (2 sigmas) from Northwest South America; (bottom) paleoclimate proxies: GISP2 $\delta^{18}O$ (Meese et al., 1997) and Cariaco Varve Greyscale (Hughen et al., 1998). YDC = Younger Dryas Chronozone.

conditions that allowed the spread of a cool grassland/shrub biome and an ascendant movement of the upper forest line (Fig. 7). If both dates are deemed provisionally dubious, then the colonization process began during the El Abra Stadial, contemporary with the Younger Dryas Chronozone (12,900–11,600 cal BP; Newby et al., 2005) (Fig. 7). In either case, it was during this cold pulse when the colonizing population first reached an indisputably clear archaeological visibility represented by a diversity of contexts deposited at different environmental settings in the Altiplano Cundiboyacense and the Middle Magdalena River valley.

## 5. Discussion

In the last decade, there is a growing recognition that $^{14}C$ dates, beside their usefulness for establishing the temporal position of past specific events, can be used as data to discuss a number of archaeological problems (Rick, 1987). In particular, datasets collected from large geographic areas are important sources of information about population processes such as demographic change and spatial dispersal (see, among others, Housley et al., 1997; Anderson and Faught, 2000; Bocquet-Appel and Demars, 2000; Gkiasta et al., 2003; Gamble et al., 2004; Michczyńska and Pazdur, 2004; Barrientos and Perez, 2005; Chamberlain, 2006; Hamilton and Buchanan, 2007; Buchanan et al., 2008, 2011; Riede, 2009; Collard et al., 2010; Peros et al., 2010; Steele, 2010; Wilmshurst et al., 2011; Bamforth and Grund, 2012; Bradtmöller et al., 2012; Williams, 2012; cf. Surrovell and Brantingham, 2007; Delgado, 2012b; Barrientos and Masse, 2014). In this line of research a major concern is, or should be, the quality of the databases in terms of some critical archaeological (e.g. associational, stratigraphic) and chronometric (e.g. pre-treatment and measurement) criteria (Waterbolk, 1971; Pettitt et al., 2003; Vermeersch, 2005).

In the case of Northwest South America, there are some practical difficulties in thoroughly assessing, on a case by case basis, the quality of the $^{14}C$ dates due to the generalized incompleteness of the bibliographic sources regarding relevant issues including sample selection criteria, degree of association between dated samples and the archaeological phenomena they are intended to represent (i.e. sample-event association), pre-treatment protocols, correction for isotopic fractionation (in the case of the only bone sample dated so far), and $^{14}C$ measurement techniques and protocols. Notwithstanding this fact, some considerations can be made regarding the dataset as a whole.

Firstly, it is quite remarkable the overwhelming majority of $^{14}C$ dates obtained on charcoal samples and the almost null representation of dates obtained on bone. Both kinds of materials, used as samples for dating, have advantages and problems. On the one side, charcoal is often preferred over bone due to (i) the higher vulnerability of the latter to contamination with substances such as humic and fulvic acids, polyphenols, polysaccharides, lignins, and degraded collagen, (ii) the decay of collagen with time, and (iii) the much least complex pre-treatment required by charcoal samples compared with bone collagen (Stafford et al., 1987; Jöris et al., 2003). On the other side, the main advantages of bone collagen over charcoal reside in the facts that (i) the former is a short-lived material whereas wood charcoal can be affected by the so-called

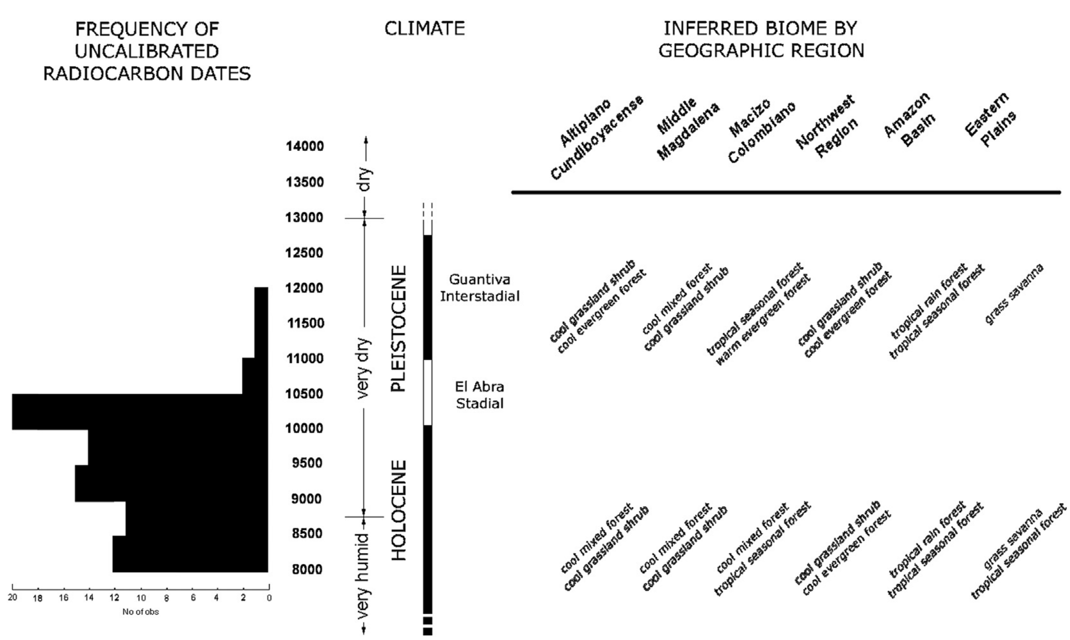


**Fig. 7.** Histogram of uncalibrated $^{14}C$ dates against a paleoenvironmental chart (by region) of Northwest South America at the Pleistocene/Holocene transition.

"old wood effect" (Taylor, 1987; Bowman, 1990) and (ii) bone (both faunal and human) usually has, compared to charcoal, a higher reliability as a marker of human activity, particularly when an adequate knowledge of taphonomic factors and processes operating at each locality is available (Gutiérrez, 2004; Borrero, 2008, 2009). Moreover, most of the problems regarding bone contamination have been overcome due to refinements in pre-treatment techniques (Hedges and Van Klinken, 1992; Yuan et al., 2000; Bronk Ramsey et al., 2004) and the increasing use of AMS dating over the last 30 years (Gillespie et al., 1984; Gowlett, 1987). The latter is a method based on the counting of $^{14}C$ atoms instead of $^{14}C$ decay (beta particles) that requires very small samples (i.e., less than a milligram, approximately a thousand times less material than is required from beta-counting methods; Currie, 2004; Gowlett, 1987) and allows, when necessary, for the dating at the molecular level (i.e. individual bone collagen amino acids) (Stafford et al., 1987; Stafford, 1990), thus enhancing the suitability and reliability of bone as sample for $^{14}C$ dating. In general terms, then, a dataset composed by $^{14}C$ dates obtained mostly on bone samples with good taphonomic control can be considered (all other things being equal) as having a stronger sample-event relationship than a one like ours, mostly composed by dates obtained on charcoal.

Secondly, less than 20% of the dates were obtained with AMS, which is a very low figure considering that more than 70% of the dates were published well after the inception and popularization of this method in the late 1980s. This suggests that, in order to fulfil the weight requirements of traditional beta-counting methods (5–20 g), most of the wood charcoal samples used for dating were likely a composite of flecks, which increases the uncertainty about the effect of the old wood problem and the overall strength of the sample-event relationship.

Thirdly, almost the 40% of the $^{14}C$ dates that yielded Pleistocene ages were obtained in the 1970s. While alone is not enough to cast doubt on the reliability of such dates, it raises questions about the comparability between them and those more recently obtained dates owing to the advances experienced by $^{14}C$ dating over the last decades, particularly regarding pre-treatment protocols. It is significant that the five oldest dates in our database, with $^{14}C$ ages ranging between 11,740 ± 110 and 10,460 ± 130 BP, belong to this group (Table 1). They come from the three classic early sites of the Sabana de Bogotá (Altiplano Cundiboyacense): Tibitó, El Abra II, and Tequendama I. While the lower levels from El Abra II and Tequendama I have been repeatedly dated, both cases exhibiting a considerable dispersion of the estimated $^{14}C$ ages, Tibitó has only a single date, the only one in our database obtained from a bone sample (Correal, 1981). As it is widely recognized, the age of any single event cannot be considered as reliably established on the basis of a single $^{14}C$ date, it being necessary to have a number of dates in statistical agreement (Geyh and De Maret, 1982). In the case of Tibitó, there is an even more pressing need to redate the archaeological level, as the only available date places it as the oldest site in the region yet discovered.

On the basis of the above considerations, we believe that the spatial and temporal trends in $^{14}C$ data discussed in this paper have to be taken with caution until there is more and better information. In the near future, however, such an improvement is unlikely to occur due to the near absence of research projects specifically aimed at obtaining novel information about the early peopling of Northwest South America. The current lack of a critical mass of local archaeologists interested in this problem is a major impediment for the rapid growth of such an important area of scientific research. In this context, the development of an extensive and exhaustive program aimed at redating, with AMS and new sample selection criteria, the more significant archaeological assemblages attributable to the Pleistocene/Holocene transition appears as a much desirable and accomplishable goal in the short term. This may also contribute to augment the degree of comparability between the Colombian database and those from other regions of South America, particularly the Southern Cone, where AMS dating, taphonomic control, bone as preferred sample, and calendar calibration of large datasets are becoming established as standard procedures (e.g. Rubinos Pérez, 2003; Gutiérrez, 2004; Barrientos and Perez, 2005; Borrero, 2008, 2009; Steele and Politis, 2009; Barrientos and Masse, 2014). Interregional comparisons at the continental level are relevant in order to detect differences in the date of initial colonization and subsequent occupation patterns as well as to estimate dispersal rates, which are important tools for the understanding of the demographic and socio-ecological properties of early South American populations.

## 6. Concluding remarks

Archaeological work carried out during the last five decades in Northwest South America allowed the recovery of substantial evidence about human settlement during the Pleistocene/Holocene transition, key to understanding the early human entry into the area and the subsequent dispersal through the subcontinent. However, it is clear that new archaeological evidence and more reliable radiometric dating are necessary in order to expand and refine our current knowledge about such important issues as biocultural diversity, economic strategies, and rate and pathways of population dispersal of the first settlers. In this context, work at two different levels would be profitably carried out: (i) in the short term, it would be advisable to develop an extensive and exhaustive program aimed at redating—with AMS and new sample selection criteria—the more significant archaeological assemblages attributable to the Pleistocene/Holocene transition, particularly those that yielded very old dates like El Jordán and El Abra II; (ii) in the medium to long term, it would be necessary to implement new interdisciplinary research projects specifically aimed at obtaining original information from different geographical areas. Undoubtedly, the whole enterprise would require higher levels of funding, scholarly cooperation, and academic involvement than that which characterized research about the early peopling of the Colombian territory.

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## References

Aceituno, F.J., 2001. Ocupaciones tempranas del bosque tropical subandino en la Cordillera Centro-Occidental de Colombia (Unpublished PhD dissertation). Facultad de Geografía e Historia, Universidad Complutense de Madrid, Madrid.

Aceituno, F.J., 2007. Poblamiento y variaciones culturales en la región Andina del noroccidente de Suramérica en la transición Pleistoceno/Holoceno. In: Bayón, C., Pupio, A., González, I., Flegenheimer, N., Frére, M. (Eds.), Arqueología de las Pampas. Sociedad Argentina de Antropología, Buenos Aires (Buenos Aires), pp. 15–38.

Aceituno, F.J., Loaiza, N., 2007. Domesticación del bosque en el Cauca Medio Colombiano entre el Pleistoceno final y el Holoceno medio. In: British Archaeological Reports, International Series, vol. 1654. Archaeopress, Oxford.

Aceituno, F.J., Loaiza, N., 2015. The role of plants in the early human settlement of Northwest South America. Quaternary International 363, 20–27. http://dx.doi.org/10.1016/j.quaint.2014.06.027.

Aceituno, F.J., Loaiza, N., Delgado Burbano, M.E., Barrientos, G., 2013. The initial settlement of Northwest South America during the Pleistocene/Holocene transition: synthesis and perspectives. Quaternary International 301, 23–33.
Anderson, D.G., Faught, M.K., 2000. Paleoindian artifact distributions: evidence and implications. American Antiquity 74, 507–513.
Ardila, G., 1991. The peopling of Northern South America. In: Bonnichsen, R., Turnmire, K.L. (Eds.), Clovis Origins and Adaptations. Center for the Study of the First Americans. Oregon State University, Corvallis, pp. 261–282.
Banforth, D.B., Grund, B., 2012. Calibration curves, summed probability distributions, and early paleoindian population trends in North America. Journal of Archaeological Science 39, 1768–1774.
Barrientos, G., Perez, S.I., 2005. Was there a population replacement during the late mid-Holocene in the southeastern Pampas of Argentina? Archaeological evidence and paleoecological basis. Quaternary International 132, 95–105.
Barrientos, G., Masse, B., 2014. The archaeology of cosmic impact: lessons from two Mid-Holocene Argentine case studies. Journal of Archaeological Method and Theory 21, 134–211.
Bocquet-Appel, J.P., Demars, P.Y., 2000. Neanderthal contraction and modern human colonization of Europe. Antiquity 74, 544–552.
Boom, A., Mora, G., Cleef, A.M., Hooghiemstra, H., 2001. High altitude $C_4$ grasslands in the northern Andes: relicts from glacial conditions? Review of Paleobotany and Palynology 115, 147–160.
Boom, A., Marchant, R., Hooghiemstra, H., Sinninghe Damsté, J.S., 2002. $Co_2$- and temperature controlled altitudinal shifts of $C_3$- and $C_4$-dominated grasslands allows reconstructions of palaeoatmospheric $p\mathrm{CO}_2$. Paleogeography, Paleoclimatology, Paleoecology 177, 151–168.
Borrero, L.A., 2008. Extinction of Pleistocene megamammals in South America: the lost evidence. Quaternary International 185, 69–74.
Borrero, L.A., 2009. The elusive evidence: the archaeological record of the South American extinct megafauna. In: Haynes, G. (Ed.), American Megafaunal Extinctions at the End of the Pleistocene. Springer Science, Dordrecht, pp. 145–168.
Bowman, S., 1990. Radiocarbon Dating. University of California Press, Berkeley.
Bradtmöler, M., Pastoors, A., Weninger, B., Weniger, G., 2012. The repeated replacement model – rapid climatic change and population dynamics in late Pleistocene Europe. Quaternary International 247, 38–49.
Bray, W., Herrera, L., Schrimpff, M., 1988. Report on the 1984 Field Season. ProCalima. Archäologisch-ethnologisches Projekt im Westlichen Kolumbien/Südamerika No 5:2–42. Periodische Publikation der Vereinigung Pro Calima, Basel.
Bronk Ramsey, C., Higham, T., Bowles, A., Hedges, R., 2004. Improvements to the pretreatment of bone at Oxford. Radiocarbon 146, 155–163.
Buchanan, B., Collard, M., Edinborough, K., 2008. Paleoindian demography and the extraterrestrial impact hypothesis. Proceedings of the National Academy of Sciences of the United States of America 105, 11651–11654.
Buchanan, B., Hamilton, M., Edinborough, K., O'Brien, M.J., Collard, M., 2011. A comment on Steele's (2010) radiocarbon dates as data: quantitative strategies for estimating colonization front speeds and event densities. Journal of Archaeological Science 38, 2116–2122.
Cano, M., 2004. Los primeros habitantes de las cuencas medias de los ríos Otún y Consota. In: López, C., Cano, M. (Eds.), Cambios Ambientales en Perspectiva Histórica. Ecorregión del Eje Cafetero, vol. I. Universidad Tecnológica de Pereira, Programa Ambiental GTZ, Pereira, pp. 68–91.
Cardona, Luis C., Luis, E. Nieto, Jorge, I. Pino, 2007. Del Arcaico a la Colonia. Construcción del paisaje y cambio social en el Porce Medio. Informe final. Universidad de Antioquia-Empresas de Medellín, Medellín. Unpublished.
Castillo, N., Aceituno, F., 2006. El bosque domesticado, el bosque cultivado: un proceso milenario en el valle medio del rio Porce en el noroccidente Colombiano. Latin American Antiquity 17, 561–578.
Cavelier, I., Rodríguez, C., Herrera, L., Morcote, G., Mora, S., 1995. No solo de la caza vive el hombre: Ocupación del bosque amazónico, Holoceno temprano. In: Cavelier, I., Mora, S. (Eds.), Ámbito y Ocupaciones Tempranas de la América Tropical. Fundación Erigaie, Instituto Colombiano de Antropología, Bogotá, pp. 27–44.
Chamberlain, A.T., 2006. Demography in Archaeology. Cambridge University Press, Cambridge.
Colinvaux, P., 1997. Pleistocene landscapes: the ice-age Amazon and the problem of diversity. The Review of Archaeology 19, 1–10.
Collard, M., Buchanan, B., Hamilton, M.J., O'Brien, M.J., 2010. Spatiotemporal dynamics of the Clovis-Folsom transition. Journal of Archaeological Science 37, 2513–2519.
Correal, G., 1979. Investigaciones Arqueológicas en los Abrigos Rocosos de Nemocón y Sueva. Fundación de Investigaciones Arqueológicas Nacionales, Bogotá.
Correal, G., 1981. Evidencias Culturales y Megafauna Pleistocénica en Colombia. Fundación de Investigaciones Arqueológicas Nacionales, Bogotá.
Correal, G., 1986. Apuntes sobre el medio ambiente pleistocénico y el hombre prehistórico en Colombia. In: Bryan, A.L. (Ed.), New Evidence for the Pleistocene Peopling of the Americas. Center for the Study of the Early Man, University of Main, Orono, pp. 115–131.
Correal, G., 1993. Nuevas evidencias culturales pleistocénicas y megafauna en Colombia. Boletín de Arqueología 8, 3–12.
Correal, G., van der Hammen, T., 1977. Investigaciones arqueológicas en los abrigos rocosos del Tequendama. Biblioteca Banco Popular, Bogotá.
Correal, G., van der Hammen, T., Lerman, J.C., 1969. Artefactos líticos en abrigos rocosos de El Abra, Colombia. Informe preliminar. Revista Colombiana de Antropología 14, 10–46.
Correal, G., Gutiérrez, J., Calderón, K., Villada, C., 2005. Evidencias arqueológicas y megafauna en un salado del tardiglacial superior. Boletín de Arqueología 20, 3–58.
Currie, L.A., 2004. The remarkable metrological history of radiocarbon dating [II]. Journal of Research of the National Institute of Standards Technology 109, 185–217.
Delgado, M.E., 2012a. Paleoecología y poblamiento temprano del Noroccidente de Sur América durante la transición Pleistoceno/Holoceno (ca. 12,000–8000 años $^{14}$C AP). In: IV Simposio Internacional El hombre temprano en América: modelos de poblamiento y aportes desde las territorialidades tropicales. Pereira, Colombia.
Delgado, M.E., 2012b. Mid and late Holocene population changes at the Sabana de Bogotá (northern South America) inferred from skeletal morphology and radiocarbon chronology. Quaternary International 256, 2–11.
Domínguez, C., 1988. El espacio. In: Historia de Colombia, vol. 1. Salvat, Bogotá, pp. 3–35.
Gamble, C.S., Davies, W., Pettit, P., Richards, M., 2004. Climate change and evolving human diversity in Europe during the last glacial. Philosophical Transactions of the Royal Society of London B 359, 243–254.
Geyh, M.A., De Maret, P., 1982. Research notes and application reports histogram evaluation of $^{14}$C dates applied to the first complete Iron Age sequence from west central Africa. Archaeometry 24, 158–163.
Gillespie, R., Hedges, R.E.M., Wand, J.O., 1984. $^{14}$C dating of bone by accelerator mass spectrometry. Journal of Archaeological Science 11, 165–170.
Gkiasta, M., Russell, T., Shennan, S., Steele, J., 2003. Neolithic transition in Europe: the radiocarbon record revisited. Antiquity 77, 45–62.
Gnecco, C., 1994. The Pleistocene/Holocene Boundary in the Northern Andes: an Archaeological Perspective (Unpublished PhD dissertation). Washington University, Department of Anthropology, Saint Louis.
Gnecco, C., 2000. Ocupación temprana de bosques tropicales de montaña. Editorial Universidad del Cauca.
Gnecco, C., 2003. Against ecological reductionism: Late Pleistocene hunter-gatherers in the tropical forests of northern South America. Quaternary International 109–110, 13–21.
Gnecco, C., Aceituno, F., 2006. Early humanized landscapes in Northern South America. In: Morrow, J.E., Gnecco, C. (Eds.), Paleoindian Archaeology: a Hemispheric Perspective. University Press of Florida, Gainesville, pp. 86–104.
Gnecco, C., Mora, S., 1997. Late Pleistocene/Early Holocene tropical forest occupations at San Isidro and Peña Roja, Colombia. Antiquity 71, 683–690.
Gowlett, J.A., 1987. The archaeology of radiocarbon accelerator dating. Journal of World Prehistory 1, 127–170.
Groot, A.M., 1992. Checua: Una secuencia cultural entre 8500 y 3000 años antes del presente. Fundación de Investigaciones Arqueológicas Nacionales, Banco de la República, Bogotá.
Gutiérrez, M.A., 2004. Análisis tafonómicos en el área Interserrana (Provincia de Buenos Aires) (Unpublished PhD dissertation). Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata.
Hamilton, M.J., Buchanan, B., 2007. Spatial gradients in Clovis-age radiocarbon dates across North America suggest rapid colonization from the north. Proceedings of the National Academy of Sciences of the United States of America 104, 15625–15630.
Hedges, R.E.M., Van Klinken, G.J., 1992. A review of current approaches in the pretreatment of bone for $^{14}$C dating by AMS. Radiocarbon 34, 279–291.
Herrera, L., Bray, W., Cardale, M., Botero, P., 1992. Nuevas fechas de radiocarbono para el precerámico de la Cordillera Occidental de Colombia. In: Ortiz-Troncoso, O., van der Hammen, T. (Eds.), Archaeology and Environment in Latin America. Instituut voor Pre- en Protohistorische Acheologie Albert Egges van Giffen, Universiteit van Amsterdam, Amsterdam, pp. 145–163.
Herrera, L., Moreno, C., Peña, O., 2011. La historia muy antigua del municipio de Palestina (Caldas). Proyecto de rescate y monitoreo arqueológico del aeropuerto del café. Centro de Museos-Universidad de Caldas, Asociación Aeropuerto del Café (2005–2011), Manizales.
Hofstede, R., Segarra, P., Mena, P.V., 2003. Los Páramos del Mundo. Global Peatland Initiative/NC-IUCN/EcoCiencia, Quito.
Housley, R.A., Gamble, C.S., Street, M., Pettitt, P.B., 1997. Radiocarbon evidence for the Lateglacial human recolonisation of Northern Europe. Proceedings of the Prehistoric Society 63, 25–54.
Hughen, K.A., Overpeck, J.T., Lehman, S.J., Kashgarian, J.M., Southon, R., Petersson, L.C., 1998. A new $^{14}$C calibration data set for the last deglaciation based on marine varves. Radiocarbon 40, 483–494.
Hurt, W., 1977. The edge-trimmed tool tradition of Northwest South America. In: Cleland, C.E. (Ed.), For the Director. Research Essays in Honor of James B. Griffin, Anthropology Papers, vol. 61. Museum of Anthropology, University of Michigan, Ann Arbor, pp. 268–294.
Hurt, W., van der Hammen, T., Correal, G., 1977. The El Abra Rockshelters, Sabana de Bogotá, Colombia, South America. In: Occasional Papers and Monographs No. 2. Indiana University Museum, Bloomington.
INTEGRAL, 1997. Arqueología de Rescate: Vía Alterna de la Troncal de Occidente Río Campoalegre-Estadio Santa Rosa de Cabal (Informe Final). INTEGRAL S.A., Ministerio de Transporte, Instituto Nacional de Vías, Medellín (Unpublished).
Jöris, O., Fernández, E., Weninger, B., 2003. Radiocarbon evidence of the Middle to Upper Paleolithic transition in southwestern Europe. Trabajos de Prehistoria 60, 15–38.

López, C., 1989. Evidencias paleoindias en el valle medio del río Magdalena (Municipios de Puerto Berrío, Yondó y Remedios, Antioquia). Boletín de Arqueología 4 (2), 3–23.
Llanos, J.M., 1997. Artefactos de molienda en la región de Medio Río Caquetá-Amazonía Colombiana. Boletín de Arqueología 12 (2), 3–95.
López, C., 2008. Landscape Development and the Evidence for Early Human Occupation in the Inter-andean Tropical Lowlands of the Magdalena River, Colombia. Syllaba Press, Miami.
Marchant, R., Behling, H., Berrío, J., Cleef, A., Duivenvoorden, J., Helmens, K., Hooghiemstra, H., Kuhry, P., Melief, R., Schreve-Brinkman, E., van Geel, B., van Reenen, G., van der Hammen, T., 2001. A reconstruction of Colombian biomes derived from modern pollen data along an altitudinal gradient. Review of Palaeobotany and Palynology 117, 79–92.
Marchant, R., Behling, H., Berrío, J., Cleef, A., Duivenvoorden, J., Hooghiemstra, H., Kuhry, P., Kuhry, R., Melief, R., Schreve-Brinkman, E., van Geel, B., van der Hammen, T., van Reenen, G., Wille, M., 2002. Pollen-based biome reconstructions for Colombia at 3000, 6000, 9000, 12000, 15000 and 18000 $^{14}$C yr ago: Late Quaternary tropical vegetation dynamics. Journal of Quaternary Science 17, 113–129.
Marchant, R., Boom, A., Behling, H., Hooghiemstra, H., Melief, B., van Geel, B., van der Hammen, T., Wille, M., 2004. Colombian vegetation at the Last Glacial Maximum: a comparison of model and pollen-based biome reconstructions. Journal of Quaternary Science 19, 721–732.
Meese, D.A., Gow, A.J., Alley, R.B., Zielinski, G.A., Grootes, P.M., Ram, M., Taylor, K.C., Mayewski, P.A., Bolzan, J.F., 1997. The Greenland Ice Sheet Project 2 depth–age scale: methods and results. Geophysical Research 102 (C12), 26,411–26,423.
Michczyńska, D.J., Pazdur, A., 2004. Shape analysis of cumulative probability density function of radiocarbon dates set in the study of climate change in the late glacial and Holocene. Radiocarbon 46, 733–744.
Mora, G., Pratt, L.M., 2002. Carbon isotopic evidence from paleosols for mixed C3/C4 vegetation in the Sabana de Bogotá basin, Colombia. Quaternary Science Review 21, 985–995.
Mora, S., Gnecco, C., 2003. Archaeological hunter-gatherers in tropical rainforests: a view from Colombia. In: Mercader, J. (Ed.), Under the Canopy: the Archaeology of Tropical Rain Forests. Rutgers University Press, New Brunswick, pp. 271–290.
Morcote, R.G., Cabrera, D., Mahecha, C.E., Franky, C., Cavellier, I., 1998. Las palmas entre los grupos cazadores recolectores de la Amazonia colombiana. Caldasia 20, 57–74.
Newby, P., Bradley, J., Spiess, A., Shuman, B., Leduc, P., 2005. A Paleoindian response to Younger Dryas climate change. Quaternary Science Reviews 24, 141–154.
Nieuwenhuis, C.J., 1998. Unattractive but effective: unretouched pointed flakes as projectile points? A closer look at the Abriense and Tequendamiense artefacts. In: Plew, M.G. (Ed.), Explorations in American Archaeology. Essays in Honor of Wesley R. Hurt. University Press of America, Lanham, pp. 133–163.
Nieuwenhuis, C.J., 2002. Traces on Tropical Tools: a Functional Study of Chert Artifacts from Preceramic Sites in Colombia (PhD thesis from Leiden University. Archaeological Studies Leiden University No. 9). Faculty of Archaeology, University of Leiden, Leiden.
Otero, H., Santos, G., 2006. Las ocupaciones prehispánicas del cañón del río Porce. Prospección, rescate y monitoreo arqueológico. Proyecto hidroeléctrico Porce III. Obras de infraestructura. Informe final. Universidad de Antioquia-Empresas Públicas de Medellín, Medellín. (Unpublished).
Peros, M.C., Muñoz, S.E., Gaweski, K., Viau, A.E., 2010. Prehistoric demography of North America inferred from radiocarbon data. Journal of Archaeological Science 37, 656–664.
Pettit, P., Davies, W., Gamble, C.S., Richards, M.B., 2003. Radiocarbon chronology: quantifying our confidence beyond two half-lives. Journal of Archaeological Science 30, 1685–1693.
Pinto, M., 2003. Galindo, un Sitio a Cielo Abierto de Cazadores-Recolectores en la Sabana de Bogotá. Fundación de Investigaciones Arqueológicas Nacionales, Banco de la República, Bogotá.
Piperno, D., Pearsall, D., 1998. The Origins of Agriculture in the Lowland Neotropics. Academic Press, San Diego.
Reichel-Dolmatoff, G., 1965. Colombia Ancient Peoples and Places. Thames and Hudson, London.
Reichel-Dolmatoff, G., 1997. Arqueología de Colombia: Un Texto Introductorio. Presidencia de la República, Bogotá.
Restrepo, C.A., 2013. Informe de monitoreo arqueológico en el área de influencia del Proyecto de Desarrollo Vial Armenia Pereira Manizales, Autopista de Café. Instituto Nacional de Vías, Autopistas de Café S. A., Pereira (Unpublished).
Rick, J.W., 1987. Dates as data: an examination of the Peruvian preceramic radiocarbon data. American Antiquity 52, 55–73.
Riede, F., 2009. Climate and demography in early prehistory: using calibrated $^{14}$C dates as population proxies. Human Biology 81, 309–337.
Rivera, S., 1991. Neusa 9000 Años de Presencia Humana en el Páramo. Fundación de Investigaciones Arqueológicas Nacionales, Banco de la República, Bogotá.
Rodríguez, C.A., 2002. El Valle del Cauca Prehispánico: Procesos Socioculturales Antiguos en las Regiones Geohistóricas del Alto y Medio Cauca y la Costa Pacífica Colombo-Ecuatoriana. Departamento de Historia, Facultad de Humanidades Universidad del Valle, Santiago de Cali.
Rubinos Pérez, A., 2003. Recopilación y análisis de las fechas Carbono-14 del Norte de Santa Cruz. In: Aguerre, A.M. (Ed.), Arqueología y Paleoambiente en la Patagonia Santacruceña Argentina, pp. 1–25 (Buenos Aires).
Salgado, H., 1988-1990. Asentamientos precerámicos en el alto y medio río Calima, Cordillera Occidental de Colombia. Cespedesia 16–17 (57–58), 139–162.
Salgado, H., 1998. Exploraciones Arqueológicas en la Cordillera Central Roncesvalles–Tolima. Fundación de Investigaciones Arqueológicas Nacionales, Banco de la República, Bogotá. Universidad del Tolima, Fondo Mixto de Cultura del Tolima, Bogotá.
Santos, G., 2010. Diez Mil Años de Ocupaciones Humanas en Envigado Antioquia. El Sitio La Morena. Alcaldía de Envigado, Envigado.
Stafford Jr., T.W., Jull, A.J.T., Brendel, K., Duhamel, R.C., Donahue, D., 1987. Study of bone $^{14}$C dating accuracy at the University of Arizona NSF accelerator facility for radioisotope analysis. Radiocarbon 29, 24–44.
Stafford Jr., T.W., 1990. Late Pleistocene megafauna extinctions and the Clovis culture: absolute ages based on accelerator $^{14}$C dating of skeletal remains. In: Agenbroad, L.D., Mead, J.I., Nelson, L.W. (Eds.), Megafauna and Man: Discovery of America's Heartland, Hot the Mammoth Site of Hot Springs, South Dakota, Inc., Scientific Papers, vol. 1. Northern Arizona University, Flagstaff, pp. 118–122.
Steele, J., 2010. Radiocarbon dates as data: quantitative strategies to estimating colonization front speed and event densities. Journal of Archaeological Science 37, 2017–2030.
Steele, J., Politis, G., 2009. AMS $^{14}$C dating of early human occupation of southern South America. Journal of Archaeological Science 36, 419–429.
Surrovell, T., Brantingham, J.P., 2007. A note on the use of temporal frequency distributions in the studies of prehistoric demography. Journal of Archaeological Science 34, 1868–1877.
Tabares, D., Rojas, E., 2000. Aportes para una Historia en Construcción: Arqueología de Rescate en la Doble Calzada Manizales-Pereira-Armenia. INVIAS-CISAN, Bogotá (Unpublished).
Taylor, R.E., 1987. Radiocarbon Dating: an Archaeological Perspective. Academic Press, Orlando.
van der Hammen, T., 1974. The Pleistocene changes of vegetation and climate in tropical South America. Journal of Biogeography 1, 3–26.
van der Hammen, T., 1978. Stratigraphy and environments of the Upper Quaternary of the El Abra corridor rockshelters (Colombia). Palaeogeography, Palaeoclimatology, Palaeoecology 25, 111–162.
van der Hammen, T., 1986. Cambios medioambientales y la extinción del Mastodonte en el norte de los Andes. Revista de Antropología 2, 27–33.
van der Hammen, T., 1992. Historia, Ecología y Vegetación. Corporación Colombiana para la Amazonia Araracuara, Bogotá.
van der Hammen, T., Correal, G., 2001. Mastodontes en un humedal Pleistocénico en el valle del Magdalena (Colombia) con evidencias de la presencia del hombre en el pleniglacial. Boletín de Arqueología 16, 4–36.
van der Hammen, T., González, E., 1960. Upper Pleistocene and Holocene climate and vegetation of the Sabana de Bogotá (Colombia, South America). Laidse Geologische Mededelingen 25, 261–315.
van der Hammen, T., Hooghiemstra, H., 1995. The El Abra stadial, a Younger Dryas equivalent in Colombia. Quaternary Sciences Review 14, 841–851.
van Geel, B., van der Hammen, T., 1973. Upper Quaternary vegetational and climatic sequence of the Fúquene area (Eastern Cordillera, Colombia). Palaeogeography, Palaeoclimatology, Palaeoecology 14, 9–92.
Vélez, M., Hooghiemstra, H., Metcalfe, S., Willie, M., Berrío, J., 2006. Late Glacial and Holocene environmental and climatic changes from a limnological transects through Colombia, northern South America. Palaeogeography, Palaeoclimatology, Palaeoecology 234, 81–96.
Vermeersch, P.M., 2005. European population changes during Marine Isotope Stages 2 and 3. Quaternary International 137, 77–85.
Waterbolk, H.T., 1971. Working with radiocarbon dates. Proceedings of the Prehistoric Society 37, 15–33.
Weninger, B., Jöris, O., 2008. A $^{14}$C age calibration curve for the last 60 ka: the Greenland-Hulu U/Th timescale and its impact on understanding the Middle to Upper Paleolithic transition in Western Eurasia. Journal of Human Evolution 55, 772–781.
Williams, A.N., 2012. The use of summed radiocarbon probability distributions in archaeology: a review of methods. Journal of Archaeological Science 39, 578–589.
Wilmshurst, J.M., Hunt, T., Lipo, C., Anderson, A., 2011. High precision radiocarbon dating shows recent and rapid initial human colonization of East Polynesia. Proceedings of the National Academy of Sciences of the United States of America 108, 1815–1820.
Yuan, S., Wu, X., Gao, S., Wang, J., Cai, L., Liu, K., Li, K., Ma, H., 2000. Comparison of different bone pretreatment methods for AMS $^{14}$C dating. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 172, 424–427.