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¹⁴C data and the early colonization of Northwest South America: A critical assessment

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ABSTRACT

The aim of this paper is to make a critical appraisal of the available ¹⁴C dataset from Northwest South America (Colombia) corresponding to the Pleistocene/Holocene transition (ca. 12,000–8000 ¹⁴C years BP). The first step in the study was to assemble from both published and unpublished sources an exhaustive database of ¹⁴C dates ($n = 85$), recording data regarding the environmental setting and spatial coordinates of each site, stratigraphic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 ¹⁴C 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 ¹⁴C dataset from Northwest South America, namely the very high percentage of ¹⁴C 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 ¹⁴C 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.

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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 ¹⁴C 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 ¹⁴C 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 ($2\text{ }^{\circ}\text{C}$ 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 El Abra Stadial were $4\text{--}6\text{ }^{\circ}\text{C}$ lower than today according to pollen data (van der Hammen and Hooghiemstra, 1995) or $2\text{--}3\text{ }^{\circ}\text{C}$ lower than today according to stable isotope ($\delta^{13}\text{C}$) 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 González, 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*, *Propaopus*, and *Eremotherium*), and American horses (genus *Equus*) coexisted, in certain areas, with still living fauna including cervids (genera *Odocoileus* and *Mazama*), xenarthrans (genus *Dasybus*), 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 paleo-environmental 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 lower levels of Tequendama I, where two hearths were ¹⁴C 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 palmaria 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, ¹⁴C 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.

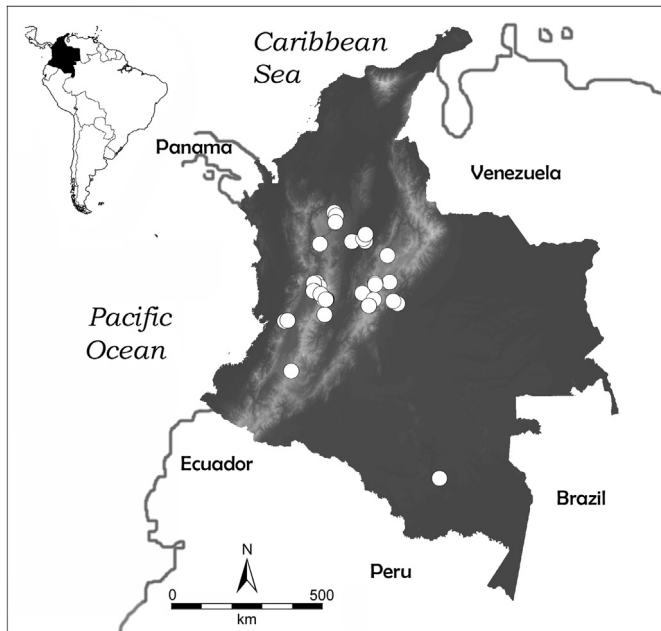


Fig. 2. Map of the study region showing the distribution of the archaeological sites mentioned in the text and in Table 1.

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 $12,910 \pm 60$ BP; Salgado, 1998) and a date from El Abra II (GrN-5556 $12,400 \pm 160$ 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	PIII01-52	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)
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 Antiojo	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	PIIIO-P-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

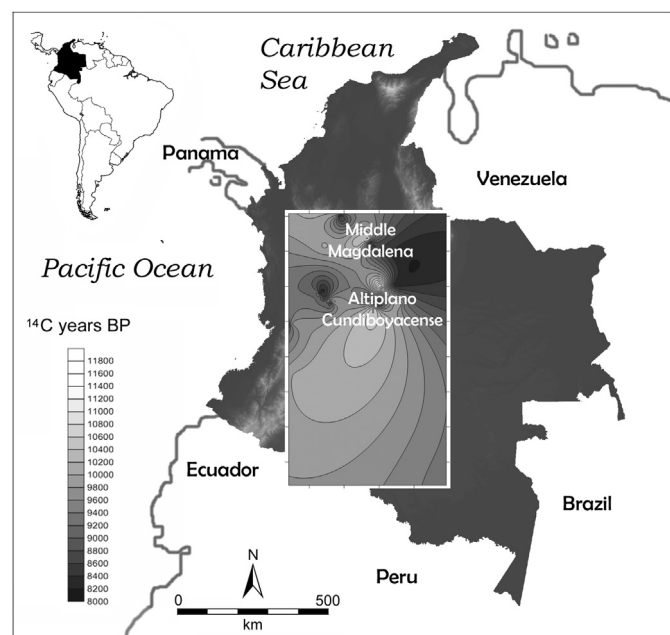


Fig. 3. Raster surface map (kriging algorithm), superimposed to the map of the study region, showing the spatio-temporal trends in the distribution of the earliest ^{14}C date registered at each archaeological site.

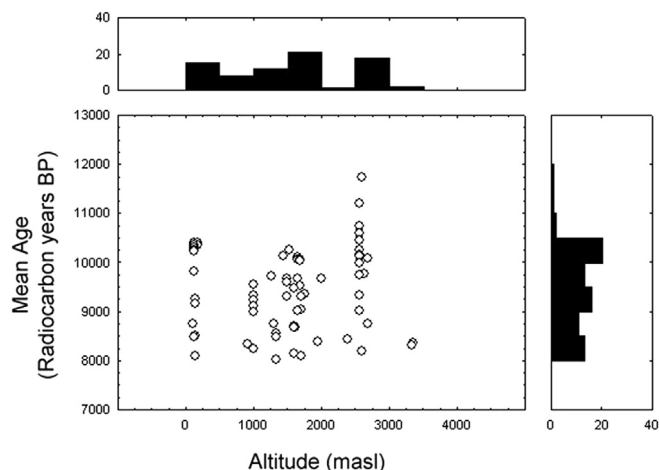


Fig. 4. Scatterplot with histograms showing the distribution of uncalibrated ^{14}C dates from Northwest South America against the altitude of the respective archaeological sites.

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.

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 ($11,740 \pm 110$ BP and $11,210 \pm 90$ 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

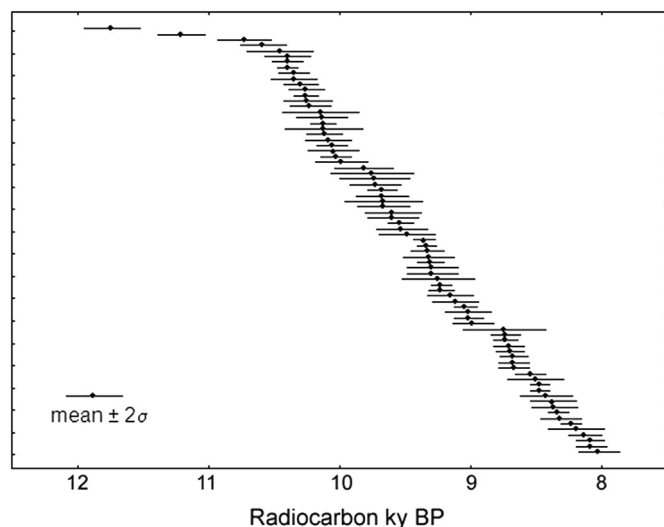


Fig. 5. Range plot displaying error bars (2 sigmas) corresponding to ^{14}C dates of the Pleistocene/Holocene transition from Northwest South America.

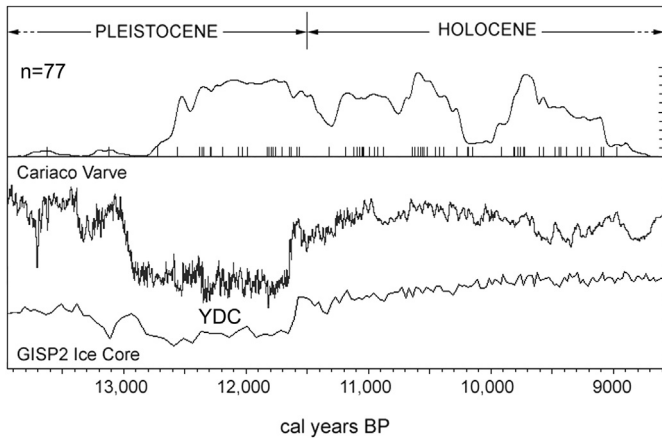


Fig. 6. (Top) summed probability distribution plot of calibrated ages (2 sigmas) from Northwest South America; (bottom) paleoclimate proxies: GISP2 $\delta^{18}\text{O}$ (Meese et al., 1997) and Cariaco Varve Greyscale (Hughen et al., 1998). YDC = Younger Dryas Chronozone.

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 less 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

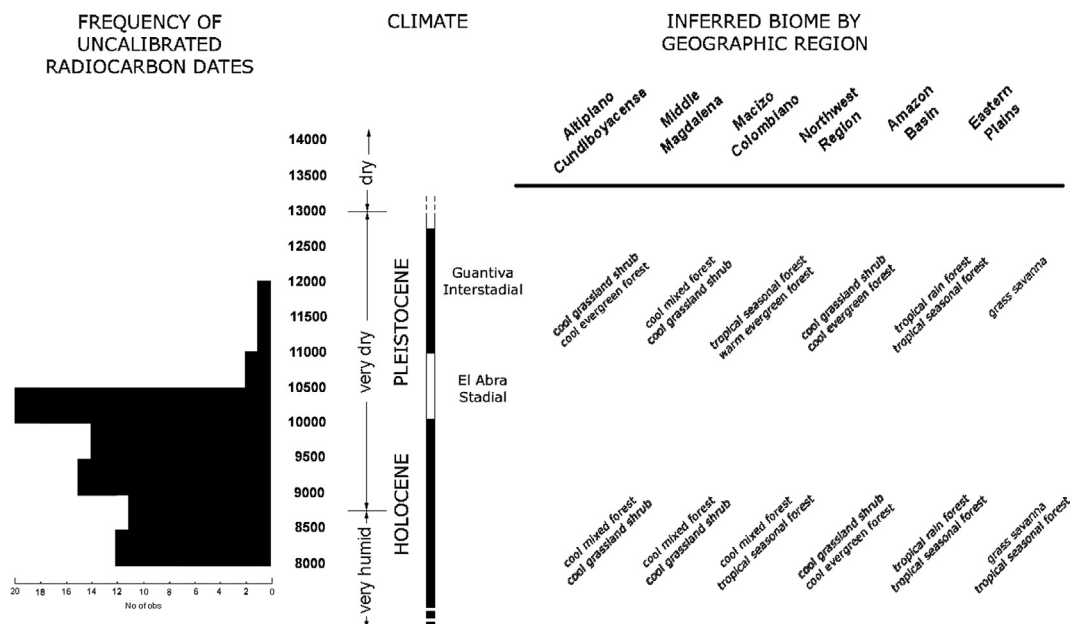


Fig. 7. Histogram of uncalibrated ^{14}C dates against a paleoenvironmental chart (by region) of Northwest South America at the Pleistocene/Holocene transition.

“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 $11,740 \pm 110$ and $10,460 \pm 130$ 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 redetermine 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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