PATTERNS OF HUMAN OCCUPATION DURING THE EARLY HOLOCENE IN THE CENTRAL EBRO BASIN (NE SPAIN): A RESPONSE TO THE 8200-YR B.P. CLIMATIC EVENT

P. González-Sampériz^{1*}; P. Utrilla²; C. Mazo²; B. Valero-Garcés¹; MC. Sopena²; M. Morellón¹; M. Sebastián²; A. Moreno¹ & M. Martínez-Bea²

¹ *Instituto Pirenaico de Ecología-CSIC, Avda. Montañana 1005, Apdo 202, 50080 Zaragoza, Spain;* ² *Dpto. de Ciencias de la Antigüedad (Prehistoria), Universidad de Zaragoza, C/ Pedro Cerbuna 12, 50009 Zaragoza, Spain,*

* Author for correspondence (e-mail: pgonzal@ipe.csic.es)

Abstract

The Central Ebro River Basin (NE Spain) is the most northern area of truly semi-arid Mediterranean climate in Europe and prehistoric human occupation has been strongly influenced by these unique environmental conditions. The Bajo Aragón region (SE Ebro River Basin) was intensively populated during the Early Holocene (9400 – 8200 cal. yr B.P.) but the settlements were abandoned abruptly at around 8200 cal. yr B.P. Modern climate conditions single out this region due to the harsh environment, characterized by the highest absolute summer temperatures of the Ebro River Basin. We propose that this “archaeological silence” was caused by the regional impact of the global abrupt 8.2 ka cold event. Available regional paleoclimate archives demonstrate the existence of an aridity crisis 8200 years ago that interrupts the humid Early Holocene. That environmental crisis would have forced hunter-gatherers groups from the Bajo Aragón to migrate to regions with more favourable conditions (i.e. more humid mountainous areas) and only return in the Neolithic. Coherently, archaeological sites persist during this crisis in the nearby Iberian Range (Maestrazgo) and the North Ebro River area (Pre-Pyrenean mountains and along the northwestern Ebro Basin).

Keywords: Abrupt climate change, Central Ebro River Basin, Holocene, Migration, Hunter-Gatherers, Aridity, Archaeology.

Introduction

Prehistoric and historic societies around the world, particularly those located in semi-arid areas, have been highly vulnerable to abrupt climatic changes, with numerous examples of widespread abandonment, migrations and even cultural collapses. For example, the Eastern Sahara occupation during the Holocene humid period: Hoelzmann et al., 2001; the Neolithic migrations that occurred in Europe: Turney and Brown, 2007 and the population decreases in the North American Great Plains during the Altithermal period of the Middle Holocene: Meltzer, 1999. In several cases, environmental crises caused by increased aridity have been considered a main trigger in civilization collapse, as the Akkadian Empire, the Argaric Culture and the Maya Civilization, although other possible socio-economic factors have also been considered: Cullen et al., 2000, Carrión et al., 2007; Haug et al., 2003, respectively. The Ebro River Valley (NE Spain) has a long history of human occupation (Utrilla, 2002; Montes et al., 2006) and because of the harsh environmental conditions that characterize this Mediterranean area it provides several examples of the complex interplay of climate and human societies. In addition, this region includes the Bajo Aragón area, an ecologically “fragile” area characterized by a strong water deficit (López-Martín et al., 2007).

The Holocene (last 11.5 ka) has been classically considered a climatically stable episode, especially when compared with the last glacial period. However, there is increasing evidence of significant climate variability at suborbital scales during the present interglacial at a global scale (Mayewski et al., 2004). In the Iberian Peninsula several sites document large climate variability during the Holocene and particularly the strong impact in vegetation communities and hydrology during the Early Holocene (Ramil-Rego et al., 1998; Sanchez-Goñi and Hannon, 1999; Carrión, 2002; Pla and Catalán, 2005; González-Sampériz et al., 2006; Davis and Stevenson, 2007; Morellón et al., 2008).

The 8.2 ka event is one of the most significant climate crisis of the last 11.5 kyrs and was globally identified as a short cold and arid period (Alley and Agustsdottir, 2005; Rohling and Pälike, 2005). This event appears to have been generally cooler over much of the Northern Hemisphere, and it is also characterized by: i) a widespread aridity in low latitudes (de Menocal et al., 2000; Gasse and Van Campo, 1994); ii) enhanced seasonality (Baldini et al., 2002); and iii) dry northerly winds influence in the western Mediterranean (Frigola et al., 2007). Although many new paleoclimate records have contributed to reconstruct the climate variability associated to this event (see

compilation in Mayewski et al., 2004), the forcing mechanisms remain under discussion (Bauer et al., 2004; Rohling and Pälike, 2005). Global climate models (GCM) show that colder conditions in the north Atlantic would translate into more arid conditions in the continental areas of the Mediterranean region, including the Iberian Peninsula (Wiersma and Renssen, 2006). In this sense, it is not difficult to imagine how ecosystems could have been easily destabilized in the Central Ebro Basin during short climate crises, with great consequences for the already scarce vegetation, fauna and humans during the Prehistory.

In this paper we present a detailed compilation of the radiocarbon –dated settlements located in the Ebro Basin between 11.5 – 6.5 cal ka B.P. and analyze the relationship between their occupation patterns and the climate evolution reconstructed from available regional palaeoenvironmental sequences. Our results point to the cal. 8.2 ka arid event (Alley et al., 1997) as the main cause for the dramatic cessation of the use of the sites identified at the Bajo Aragón during the end of the Epipaleolithic or Mesolithic culture. The region will not be re-occupied intensively until the beginning of the Neolithic, when a new economic activity (agriculture, pastoralism) would allow the subsistence in this particular region.

Present-day environment: climate and vegetation

The climate in the Central Ebro River Basin is Mediterranean with strong continental influences resulting in very hot summers, cold and relatively dry winters, strong dry NW winds and low rainfall due to the rain-shadow effect of the Iberian Range (Capel Molina, 1981; García-Vera, 1996). Specifically, this region is the northernmost region of truly semi-arid climate in Europe. In fact, the Bajo Aragón area shows the maximum absolute temperatures in the area with more than 45°C (López Martín et al., 2007) next to the greatest evapotranspiration index of the region with an annual water deficit of more than 800 mm and only 300 mm of annual precipitation (Fig.1).

The present landscape in the Central Ebro Basin (including the Bajo Aragón) is an herbaceous-shrubly land, mostly dedicated to agriculture. Steppe vegetation cover is generally open, leaving small patches with xerophyte shrubs, *Pinus halepensis*, *Quercus coccifera* and *Juniperus thurifera* as the main arboreal taxa. Nitrophilous and gypsophilous plants are also abundant (Molero et al., 1986; Longares, 1997). In contrast, the North Ebro area sustains forested landscapes dominated by conifers (*Abies*

alba, *Pinus uncinata*, *Pinus sylvestris*) or broad-leaf angiosperms (*Quercus pubescens*, *Quercus robur*, *Fagus*, *Corylus*, *Betula*, *Acer*, *Tilia*, *Sorbus*). The Prepyrenean foothills (southeastern of the North Ebro area) and the Iberian Range (Maestrazgo) have a more Mediterranean influence and vegetation is dominated by diverse types of conifers depending the altitude and the substrate and *Quercus ilex-rotundifolia* or *Q. faginea-pubescens* with dense shrub land (Blanco et al., 1997).

Cultural chronology during the Early Holocene

Archaeological information for the Early Holocene in the Ebro Basin shows important population density only in specific areas (Utrilla, 2002, 2005; Montes et al., 2006). For example, 14 archaeological sites are located in the Bajo Aragón during the period known as “Recent Mesolithic” or “Epipaleolithic Geometric culture” (cal. 9-8 ka B.P.). Despite the high number of settlements known in the whole Ebro Basin, only 40 of them have dated occupation levels between 11-6.5 cal ka B.P. For this study we consider the available radiocarbon dates (228) associated to these 40 sites (Tables 1 and 2, additional information). The dates have been converted into calendar ages using the calibration curve from CalPal-2007-HULU (Weninger et al., 2007; Weninger & Jöris, in press).

A diagram with the probability of occupation based on the available dates on eight archaeological sites is shown in Figure 2. The settlements located in the North Ebro (Axoste, Mendandia and Forcas I and II) do not reflect any occupation change around 8000 cal yr B.P. On the contrary, the sites located in the Bajo Aragón (Angel 1 and 2, Los Baños, Botiquería dels Moros and Pontet) were abandoned at this time. The settlement of Mas Nou in Maestrazgo Mountains shows its first occupation just after 8000 cal B.P. Based on this complete archaeological compilation, a large migration of people from the Bajo Aragón to more humid mountain areas occurred at around 8000 cal B.P. (Figs. 3a and 3b).

Although erosion of the archaeological record cannot be ruled out as a factor contributing to the observed “silence”, the high number of sites documented in this study, and their location in different geomorphological settings point towards regional-scale processes (migration) more than to site-specific processes (erosion).. Besides, the stratigraphy of the sites represented in Fig.2 clearly shows that the intervals without human occupation always correspond to archaeologically sterile levels (without industry, fire, fauna or human traces) but not to hiatus (lack of sediment) as a

consequence of erosion processes. The archaeological levels are always *in situ* and, in addition, the abandonment is correctly reflected in the stratigraphy because is bounded by fertile archaeological levels at top and bottom layers. So, the inherent problem in archaeology that relates erosion and archaeological material displacement known as “apparent archaeological contexts” (Bernabeu et al., 1999) cannot be applied to this area.

Most of the settlements located in the Bajo Aragón were re-occupied after 700 years (from 7300 cal. yr B.P. on) when the Neolithic culture was well developed in the whole region (Fig.3c). Nevertheless, one site, Botiquería dels Moros shows sporadic occupation at 7670 cal. yr B.P., only 500 years after the abandonment of the area. However, the archaeological material found in this level (no pottery, mainly lithic industry) is poor, and the cultural adscription is not clear pointing to a short occupation (only 6-20 cm depth), probably as a knapping site (Utrilla et al., 1998; Barandiarán and Cava, 2000).

Environmental changes during the Early Holocene

Numerous paleoclimate reconstructions show a more positive water balance in the lakes and an increase in forest formations in NE Spain caused by cool temperatures and / or higher precipitation during the Early Holocene (around 11,500 to 7000 yr B.P.) (Montserrat, 1992; Davis, 1994; Valero-Garcés et al., 2000, 2004; González-Sampériz, 2004a; González-Sampériz et al., 2006, 2008; Davis and Stevenson, 2007; Morellón et al.; 2008). Higher lake levels observed throughout the Mediterranean region during this period have also been explained as a result of cooler temperatures and/or higher precipitation (Harrison and Digerfeldt, 1993; Roca and Julià, 1997; Giralt et al., 1999; Reed et al., 2001). The vegetation cover of NE Spain during with the Early Holocene reflects humid conditions: from maximum of mesophytes in the Pyrenees (i.e., Tramacastilla: Montserrat, 1992; El Portalet: González-Sampériz et al., 2006), Pre-Pyrenees (i.e., Peña 14 archaeological site: González-Sampériz, 2004a; Estanya Lake: Morellón et al., 2008), Iberian Range (i.e., Ojos del Tremedal: Stevenson, 2000) and North Ebro (i.e., Velate: Peñalba, 1989) to more extensive Mediterranean forest formations (coniferous and evergreen *Quercus*) and scarce steppe land proportions in lowlands of the Central Ebro Basin (i.e., La Playa: González-Sampériz et al., 2008).

Several sedimentary sequences have provided local palaeoenvironmental information about the Early Holocene, although none presents a continuous record up to

the Middle Holocene (Valero-Garcés et al., 2000, 2004; González-Sampériz et al., 2008). Most sequences come from archaeological sites with discontinuous records (López-García, 1992; González-Sampériz, 2004b) or playa-lake sediments where *hiati* are common (Davis, 1994; Valero-Garcés et al., 2000, 2004; González-Sampériz et al., 2008). In a recent study, Davis and Stevenson (2007) interpret two playa-lake records from Hoya del Castillo (HdC) and Laguna Guallar (LG) (Fig.1) as possible candidates for “sedimentary continuity” and “high resolution” pollen analysis. Although the authors claimed that the dating and the resolution are enough to pinpoint the 8.2 event, the reconstructions are based on only 3 radiocarbon dates from HdC, one from LG, and two tie points based on pollen content (*Ephedra* curve) without considering the sedimentation rate differences and pollen-sampling resolution (every 4 cm in LG and every 8 cm in HdC). The chronological model does not seem robust enough to support a centennial scale reconstruction in these playa-lake records. However, in spite of the limitations, playa lake records are in some areas the only palaeoclimatological records, although the difficulties to achieve robust chronologies and the inherent problems related to the sedimentation processes (erosion) greatly hamper the identification of short and abrupt events as the 8.2 cal. ka B.P. (González-Sampériz et al., 2008).

Only regional lacustrine archives of the Ebro River Basin may provide the needed high-resolution reconstructions. Lake Redó (LR), El Portalet (EP) and Estanya Lake (EL) cores represent, at this moment, the only three long sequences in the region (Fig. 1) with a robust chronology based on 10 radiocarbon dates from LR, 13 from EP and 17 from EL and they have been analysed following a multiproxy approach that could show the effects of the 8.2 cal. yr event in climate, palaeohidrology and vegetation at a regional scale (Plá and Catalán, 2005; González-Sampériz et al., 2006; Morellón et al., 2008).

Lake Redó caryophyte cysts altitude anomaly curve shows a warming trend during the Early Holocene interrupted by a cold spell around 8,200 cal yrs B.P. (Plá and Catalán, 2005). Although this event appears embedded in a warm, local fluctuation, the age matches the cold 8.2 event in the GISP2 record (Fig. 4b and 4g). El Portalet pollen record shows a rapid *Juniperus* response - a decrease in the pollen percentages indicative of more arid conditions- to all abrupt changes identified during the Lateglacial and the Early Holocene, including the 8.2 cal. ka event, (Fig. 4c) (González-Sampériz et al., 2006). The mesophytes pollen curve of this site, mainly composed by *Betula* and *Corylus*, also reflect a decrease trend after its maximum development during

the Early Holocene. The Estanya Lake record clearly shows an increase in water availability during the Early Holocene, after 9500 cal. yrs B.P. In addition, an increase in water salinity represented by higher sulphur values (gypsum deposition) (Fig. 4d) occurred around 8200 cal yrs B.P. (Morellón et al., 2008).

Other continental records in Spain also reflect the 8200 cal yr B.P. event. Fluvial deposits in several Iberian watersheds document large floods between ca. 11200-9000 cal. yr B.P. and a period without floods between ca. 8400–7600 cal. B.P. (Benito et al., 2003, Macklin et al., 2006; Thorndycraft and Benito, 2006) in agreement with the more humid conditions of the Early Holocene and the aridity crisis related to the 8.2 event (Fig. 4e).

Available western Mediterranean marine records also show a distinctive Early Holocene signature. The geochemical composition of the IMAGES core (MD99-2343) located offshore Menorca (Balearic Islands), Frigola et al. (2007) points to abrupt events during the Holocene related to the intensity of Mediterranean deep water formation and the amount of particles derived from fluvial transport. The percentage of K as an indicator of clays transported by the rivers clearly decreases from 9500 to 7700 cal yr B.P., reaching the minimum at the 8.2 ka event (Fig 4f). In addition, the Si/Al ratio, considered a proxy for deep currents intensity, marks the most prominent peak of the last 11 kyrs at the 8.2 ka event (Fig. 4f).

Therefore, the globally cold 8.2 ka event (GISP2 ice core, Fig. 4e) appears in northeastern Spain as a cold short phase in altitude (LR) but as a dry event in most records from the whole studied area (EP, EL, MD99-2343).

Climate and Humans during the 8.2 event in the Central Ebro Basin

Abrupt climate changes conducive to large changes in water availability have caused a concomitant reduction of archaeological sites in several regions. Thus, Lateglacial and Holocene human occupation of the Puna de Atacama Desert in Chile follows the alternation of dry / wet periods (Núñez et al., 2002). Particularly significant is the “silencio arqueológico”, a period without human occupation that has been related to the well-documented Mid Holocene aridity crisis in the Chilean Altiplano (Grosjean et al., 2005). In Europe, the transition between the Bronze-Iron Age in the Netherlands was associated to a cold and humid period around 2650 yr B.P. that also caused an important migration to higher altitudes due to the expansion of wetlands in low areas (van Geel et al., 1996).

In the Bajo Aragón the influence of climatic conditions on the human occupation appears as a very plausible explanation for the ‘archaeological silence’ between 8000-7300 cal. yrs B.P. Contrarily to this situation, the settlements located in the North Ebro persisted, likely due to more favourable conditions. In addition, new occupations occur in the Maestrazgo area at about this time (Olaria et al., 2005; Fernández-López de Pablo, 2006) supporting the hypothesis that Bajo Aragón hunter-gatherers migrated to more humid habitats in the southern Iberian Range mountains. The existence of an exclusive style of “Levantine rock art” in the Maestrazgo, that it is exactly the same than in the Bajo Aragón (Utrilla, 2005; Utrilla & Martínez Bea, 2006), supports the migration and cultural connections from both areas.

The Bajo Aragón would be definitively re-occupied during the Neolithic, after 7300 cal. yr B.P. The new Neolithic Culture permits a better “adaptation” to the ecologically fragile environment with the use of fire and deforestation practices to facilitate agriculture expansion and grazing. However, despite the proliferation of settlements overall the Ebro Basin, population density in the Bajo Aragón was lower than during the Early Holocene.

Conclusions

Following a dramatic abandonment of archaeological settlements in the Bajo Aragón (NE Spain), people migrated to more humid areas (North Ebro and Maestrazgo) between ca. 8.190-7.670 cal. ka B.P. The reduced extent of human settlements around 8000 cal. yr B.P. is synchronous with the sharp transition from wet-temperate to more arid climate identified as the 8.2 cal. ka B.P. event. The impact of this short and abrupt climate change in the population of these environmental fragile areas was large enough to cause the abandonment of the region till Neolithic times. This collapse of widespread occupation (“archaeological silence”) reflects environmental stress and likely caused human migrations, changes in habitat types and in the economy. An important decrease in water availability affected the vegetation resources and implied the subsequent animal migration, basis for the hunter-gatherer type of life. During that time, people occupied alternative habitats considered as ecological refuges where appropriate resources for them remained available in the overall harsh environment.

As in other historic or prehistoric times in different geographic locations, this period of abrupt climate change occurred during the Early Holocene forced the hunter-

gatherer human communities of the central Ebro Basin to look for new habitat areas and to change their subsistence patterns and culture.

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Figure captions

Fig.1. A) Location map of the Ebro Basin with all the archaeological settlements (dots) and palaeoenvironmental sites (stars) cited in the text. Currently, the Bajo Aragón area has a harsh continental climate with: B) the highest absolute maximum temperatures of Aragón region (included in the Ebro Basin), reaching more than 45°C in summer; and C) one of the three highest evapotranspiration index areas of the Iberian Peninsula (more than 800 mm). The Bajo Aragón area is encircled in Fig.1B and C.

Archaeological settlements: **1.** *Fuente Hoz*, **2.** *Kampanoste*, **3.** *Kampanoste Goikoa*, **4.** *Mendandia*, **5.** *Atxoste*, **6.** *La Peña de Marañón*, **7.** *Peña Larga*, **8.** *Los Cascajos*, **9.** *Cueva Lóbrega*, **10.** *Abauntz*, **11.** *Aizpea*, **12.** *Zatoya*, **13.** *Paternanbidea*, **14.** *Paco Pons*, **15.** *Peña*, **16.** *Legunova*, **17.** *Chaves*, **18.** *Huerto Raso*, **19.** *Puyascada*, **20.** *Forcas I*, **21.** *Forcas II*, **22.** *Balma Margineda*, **23.** *Moro de Olvena*, **24.** *Parco*, **25.** *Moli de Salt*, **26.** *Riols*, **27.** *Filador*, **28.** *Costalena*, **29.** *Pontet*, **30.** *Botiquería dels Moros*, **31.** *Vidre*, **32.** *Los Baños*, **33.** *Angel 1*, **34.** *Angel 2*, **35.** *Toros de Cantavieja*, **36.** *Cova de las Bruixes*, **37.** *Cova Fosca*, **38.** *Mas Nou*, **39.** *Cabezo de la Cruz*, **40.** *Cueva del Gato*, **41.** *Lampara*, **42.** *Revilla*, **43.** *Mas Cremat*.

Palaeoenvironmental sites: **EP:** *El Portalet*, **T:** *Tramacastilla*, **LR:** *Lake Redó*, **EL:** *Estanya Lake*, **LG:** *Laguna Guallar*, **LP:** *La Playa*, **HY:** *Hoya del Castillo*.

Fig.2.- Diagram of calibrated dates for eight selected archaeological sites from North Ebro (Mendandia, Axoste and Forcas) and South Ebro Basin (grouped in Bajo Aragón - Ángel, Los Baños, Botiquería dels Moros and Pontet- and Maestrazgo areas -Mas Nou-) between the 11000-6500 cal yr B.P. interval. The settlements of the Bajo Aragón are affected by a dramatic abandonment marked by the band at 8.2 cal ka B.P. referenced at the GISP2 ice core (Grootes and Stuiver, 1997). The Mas Nou site, in the Maestrazgo Mountains (Iberian Range), shows its first occupation when the Bajo Aragón is abandoned.

The fertile (occupation) and sterile (abandoned) archaeological levels of every settlement are also indicated by a grey band below each site. The corresponding cultural adscription is shown at the bottom of the diagram (**Ancient Mesolithic:** Az- *Azilian*, Em/SA- *Epipalaeolithic microlaminar or Sauveterrian*, MD- *Mesolithic with Denticulates*; **Recent Mesolithic:** MG- *Mesolithic with geometrics*; and **Neolithic:** NA- *Ancient Neolithic*).

Fig.3.- Chronological and cultural periods in the Ebro Basin (modified from Utrilla & Martínez-Bea, 2006): 3a) between 11000-8200 cal yr B.P. (dense human occupation); 3b) between 8200-7700 cal yr B.P. (abandonment of the Bajo Aragón: “*Archaeological Silence*”; continuous occupation in North Ebro areas and onset of the occupation in the Maestrazgo Mountains); 3c) between 7700-6500 cal yr B.P. (re-occupation of the Bajo Aragón and new development overall the Ebro Basin).

Fig.4.- Interval 11,500 to 6,500 cal yr B.P. comparison between:

- A) probability curves of Archaeological Occupation (%) for Northern Ebro Basin, Bajo Aragón and Maestrazgo regions (this study) and
- a suite of regional palaeoenvironmental records: B) *LR-Lake Redó* record of crysophytes altitude anomaly (meters) (Plá and Catalán, 2005); C) *EP-El Portalet* Peatbog record *Juniperus* and Mesophytes pollen percentages (%) (González-Sampériz et al., 2006); D) *EL-Estanya Lake* record Sulphur (S) content (counts per second, cps) (Morellón et al., 2008); E) *Paleoflood episodes* in the Iberian Peninsula (based in Thorndycraft and Benito, 2006); F) Minorca Drift record (*Core MD99-2343*, Mediterranean Sea) Potassium (K) percentage (%) and Silicon/Aluminium (Si/Al) ratio (Frigola et al., 2007) and G) *Greenland GISP2* ice core oxygen isotope curve (Grootes and Stuiver, 1997).

A grey band marks the 8.2 cal ka B.P. event as referenced at the GISP2 ice core (Grootes and Stuiver, 1997)

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Additional information in attached link

Table 1. Early Holocene available radiocarbon dates (11-6.5 ky cal B.P.) from archaeological settlements of the North Ebro area (NE Spain).

Table 2. Early Holocene available radiocarbon dates (11-6.5 ky cal B.P.) from archaeological settlements of the South Ebro area (NE Spain).

Table 1. Early Holocene available radiocarbon dates (11-6.5 ky cal B.P.) from archaeological settlements of the North Ebro area (NE Spain).

(0 = AD 1950). *P* (68%). *CalPal 2007*, *HULU curve*.

Archaeology: **Mag/AZ**, Magdalenian/Azilian; **Em**, Epipalaeolithic microlaminar; **MD**, Mesolithic with Denticulates; **MG**, Mesolithic Geometric; **NA**, Ancient Neolithic; **N**, Neolithic

Dated material: **B**, Acorn; **C/cc**, Charcoal; **Cl**, Cerealia seed; **H/hh**, Bones (**hum**-humans, **dom**-animal)

Archaeological site Level	Ref. Lab.	Date C14	σ	cal B.P.	σ	Culture	Remain
Abauntz							
2r	GrN-21010	5820	40	6620	60	N	C
c	I-11537	6910	450	7770	430	NA	hh
d	Ly-1964	9530	300	10860	410	Mag/Az	hh
Peña de Marañón							
d inf.	BM-2363	7890	120	8760	170	MG	H
Aizpea							
III (b alt)	GrN-18421	6370	70	7310	80	NA	hh
II (b med/alt.)	GrA-799	6600	50	7500	50	MG	H
II (b med/alt.)	GrN-16622	6830	70	7680	70	MG	hh
I (b med.)	GrN-16621	7160	70	7990	70	MG	hh
I (b bas.)	GrN-16620	7790	70	8580	90	MG	hh
Atxoste							
IIIb1	GrN-9789	6220	60	7130	90	NA	H
IIIb2	Sin datos	6710	50	7580	50	MG	H
IIIb2	GrA-13415	6940	40	7770	50	MG	H
IV	Sin datos	6970	40	7810	60	MG	H
IIIb2	Sin datos	7140	50	7960	40	MG	H
IV	GrA-13418	7340	50	8150	80	MG	H
IV	GrA-13469	7480	50	8290	70	MG	H
V	GrA-13447	7810	40	8590	40	MD	H
V	GrA-13472	7830	50	8630	70	MD	H
V	GrA-13448	8030	50	8900	100	MD	H
IV	Sin datos	8080	50	8980	110	MD	H
VI	GrA-15700	8510	80	9500	50	MD	H
VI	GrA-15699	8760	50	9770	110	MD	H
VI (Hogar)	GrA-13473	8840	50	9950	150	MD	H
E2	Sin datos	9510	150	10840	230	Em	H
VII	GrA-15858	9550	60	10910	140	Em	H
E	Sin datos	9650	150	10970	210	Em	H
E2	Sin datos	9820	150	11270	300	Em	H
Balma Margineda							
3a (f1)	Ly-3288	6640	160	7520	140	NA	C
3b (f3)	Ly-2839	6670	120	7550	90	NA	C
3/4	Ly-3290	6820	170	7690	150	NA	C
3b (f3)	Ly-3289	6850	160	7720	140	NA	C
4 sup.	Ly-3291	8210	180	9130	250	MD	C
4 sup.	Ly-2840	8390	150	9330	170	MD	C
4 base	Ly-2841	8530	420	9560	540	MD	C
4/5	Ly-3892	8850	120	9920	200	MD	C
5/6	Ly-4402	8960	120	10030	180	Em	C
4 base	Ly-4401	8970	120	10040	180	MD	C

6 sup.	Ly-2842	9250	160	10480	200	Em	C
6L	Ly-3884	9900	110	11430	180	Em	C
Chaves							
Ia	CSIC-381	6120	70	7020	110	NA	C
b (muerto)	GrA-26912	6230	45	7140	90	NA	H
Ia	CSIC-379	6230	70	7130	100	NA	C
Ia	GrN-13603	6260	100	7160	130	NA	C
Ia	GrN-13605	6330	70	7270	80	NA	C
Ia	GrN-13602	6330	90	7260	110	NA	C
Ia	GrA-28341	6380	40	7330	60	NA	B
Ib	CSIC-378	6460	70	7370	60	NA	C
Ib	GrN-13604	6490	40	7400	50	NA	C
Ib	GrN-12683	6650	80	7530	60	NA	C
Ib	GrN-12685	6770	70	7630	50	NA	C
Filador							
2	AA-13411	8150	90	9130	120	MD	C
2	OxA-8658	8515	50	9510	30	MD	C
7	ICEN-495	9130	230	10280	330	Em	C
4	UBAR-284	9460	190	10770	280	Em	C
5/6	AA-13412	9988	97	11520	190	Em	C
7	UBAR-257	9830	160	11290	310	Em	C
4	AA-8647	10020	80	11550	180	Em	H
Forcas I							
VII	GrN-17784	9360	140	10630	230	Az/Em	C
IX	GrN-17785	9715	75	11050	150	Az/Em	C
Forcas II							
VIII	GrN-22689	6680	190	7560	170	NA	C
VI	GrN-22688	6900	45	7740	50	NA	C
V	GrN-22687	6970	130	7810	120	NA	C
V	Beta 60773	6940	90	7790	90	NA	C
IV	Beta 59995	7090	340	7950	320	MG	C
II	GrN-22686	7240	40	8070	60	MG	C
Ib	CAMS-5354	8650	70	9650	90	MD	C
Fuente Hoz							
II (lecho 16)	I-12084	6120	280	6970	310	NA	C
III (lecho 23)	I-12778	7140	120	7980	130	MG	C
III (lecho 21)	I-12083	7840	130	8710	190	MG	C
III (lecho 23)	I-13496	7880	120	8750	170	MG	C
III (lecho 28)	I-12985	8120	240	9020	310	MD	C
Huerto Raso							
b (base)	GrA-21360	6310	60	7240	60	NA	C
Kanpanoste							
Lanhs	GrN-22440	7620	70	8440	70	MD	hh
Lanhi (base)	GrN-22442	7920	100	8790	150	MD	hh
Lanhi (med.)	GrN-22441	8200	70	9180	110	MD	hh
Kanpanoste Goikoa							
III	GrN-20214	6360	70	7300	80	MG	hh
III	GrN-20289	6550	260	7410	250	MG	hh
III inferior	GrN-20215	7620	80	8440	70	MD	hh
III inferior	GrN-20455	7860	330	8780	380	MD	hh
Legunova							
1	GrA-24292	8200	50	9160	90	MD	C
1	GrA-22086	8250	60	9240	110	MD	C
2	GrA-24294	8800	60	9890	160	MD	C

Los Cascajos							
Estructura 183	Ua-16024	6185	45	7090	70	NA	H
Estructura 497	Ua-24426	6230	50	7140	90	NA	H
Estructura 551	Ua-24428	6435	45	7360	50	NA	C
Mendandia							
I	GrN-22740	6440	40	7370	40	NA	hh
II	GrN-22741	6540	70	7450	70	NA	hh
III sup	GrN-22742	7180	45	8000	40	NA	hh
III sup	GrN-19658	7210	80	8050	80	NA	hh
III inf.	GrN-22743	7620	50	8440	50	MG	hh
IV	GrN-22745	7780	40	8550	50	MD	hh
IV	GrN-22744	7810	50	8600	60	MD	hh
V	GrA-6874	8500	60	9500	40	Em	hh
Molí del Salt							
Sup	Beta-173335	8040	40	8910	100	MD	H
Moro de Olvena							
Cámara superior	GrN-12119	6550	130	7440	110	NA	C
Paco Pons							
2	GrA-19294	6010	45	6860	60	NA	C
2	GrA-19295	6045	45	6900	60	NA	C
Parco							
IAB-40	CSIC-279	5790	190	6630	220	N	hh
EE1	GrN-20058	6120	90	7010	130	NA	C
IAB-39	CSIC-281	6170	70	7070	90	NA	cc
IAB-38	CSIC-280	6450	230	7300	240	NA	hh
Paternanbidea							
Enterramiento 2 (A)	GrA-13675	5960	40	6800	60	NA	H
Enterramiento 1	GrA-13673	6090	40	6970	60	NA	H
Peña 14							
a	GrN-25094	7660	90	8470	80	MG	C
b	GrN-25999	8000	80	8850	130	MD	C
b	GrN-25998	8000	90	8850	140	MD	C
b	GrN-25097	8340	130	9300	150	MD	C
b	GrN-25098	8780	110	9860	200	MD	C
Peña Larga							
IV	I-14909	5830	110	6640	130	NA	hh
IV	I-15150	6150	230	7010	260	NA	hh
Puyascada							
II	CSIC-384	5930	60	6770	80	N	C
Riols							
a1	GrN-13976	6040	100	6920	140	N	C
Zatoya							
I	Ly-1397	6320	280	7160	290	NA	hh
Ib	Ly-1398	8150	220	9060	300	E	C
Ib	Ly-1457	8260	550	9270	670	E	C

Table 2. Early Holocene available radiocarbon dates (11-6.5 ky cal B.P.) from archaeological settlements of the South Ebro area (NE Spain).

(0 = AD 1950). *P* (68%). *CalPal* 2007, *HULU* curve.

Archaeology: **Mag/AZ**, Magdalenian/Azilian; **Em**, Epipalaeolithic microlaminar; **MD**, Mesolithic with Denticulates; **MG**, Mesolithic Geometric; **NA**, Ancient Neolithic; **N**, Neolithic

Dated material: **B**, Acorn; **C/cc**, Charcoal; **CI**, Cerealia seed; **H/hh**, Bones (**hum**-humans, **dom**-animal)

Archaeological site Level	Ref. Lab.	date C14	σ	cal B.P.	σ	Culture	Remain
Abrigo de Ángel 1							
10 sup (<8b)	GrA-21555	5820	110	6630	130	NA	H
8c (U28)	GrA-27274	7435	45	8270	60	MG	C
U8	Unknow	7950	300	8870	360	MG	Unknow
8c (U8-11)	GrA-27278	7955	45	8830	120	MG	C
8d (U8 inf.)	GrN-15518	8060	270	8970	330	MD	C
U8	Unknow	8070	160	8970	240	MD	Unknow
8d (U13)	GrN-15520	8150	170	9070	250	MD	C
8d (U13)	GrN-15519	8210	210	9120	280	MD	C
8d	GrA-22826	8390	60	9400	70	MD	C
9 (U13)	GrA-27275	9200	50	10380	80	Unknow	C
Abrigo de Ángel 2							
2b	GrN-22836	8310	60	9310	100	MD	C
Botiquería dels Moros							
6	GrA-13268	6040	50	6890	70	NA	H
8	GrA-13270	6240	50	7150	90	NA	H
4	GrA-13267	6830	50	7670	50	EG/NA	H
2	Ly-1198	7550	200	8370	210	MG	cc
2	GrA-13265	7600	50	8410	40	MG	H
Bruixes (C. de les)							
III	Ly-4269	6460	140	7360	130	NA	C
Cabezo de la Cruz							
UE 1351	GrN-29134	7130	130	7960	140	MG	C
UE 1397	GrN-29135	7150	70	7970	70	MG	C
Costalena							
C3 (med/alt.)	GrA-10949	6310	170	7270	260	NA	hh
C3 (alt.)	GrN-14098	6420	250	7270	260	NA	hh
Cova del Vidre							
II hogar	Beta-58934	6180	90	7080	120	NA	C
Cova Fosca							
Z: -9 a-15	Beta-148993	5820	40	6620	60	NA	C
Z: -34 a -48	Beta-148996	5850	70	6660	90	NA	C
Z: -45 a-57	Beta-148997	5870	80	6690	100	NA	C
Z: -15 a -41	Beta-148994	5980	70	6830	90	NA	C
Z: -45 a-83	Beta-148999	5980	70	6830	90	NA	C
Z: -118 a -120	Beta-149005	6070	80	6960	130	NA	C
Z: -49 a -78	Beta-149000	6080	80	6970	130	NA	C
Z: -120 a -130	Beta-149007	6130	60	7040	90	NA	C
Z: -65 a -79	Beta-149001	6140	90	7030	120	NA	C
Z: -111 a -120	Beta-149004	6150	70	7050	100	NA	C
Z: -119	Beta-149006	6250	80	7150	110	NA	C
Z: -135	Beta-149009	6390	40	7340	60	NA	C

Z: -180	CSIC-356	7100	70	7920	70	-	C
Z: -182	CSIC-357	7210	70	8050	80	-	C
Z: -184	CSIC-353	7640	110	8450	100	-	C
Z: -270	I-9868	8880	200	9950	250	Em/MD	C
Z: -278	I-11313	9460	160	10780	260	Mag/AZ	C
Cueva del Gato							
S.I	GrA-22525	6240	50	7150	90	N	C
Cueva Lóbrega							
N. III	GrN-16110	6220	100	7120	120	N	hh
Lámpara							
Hoyo 1	KIA 6789	6033	34	6880	50	NA	hh (human)
Hoyo 11	KIA 21348	6125	33	7050	80	NA	H
Hoyo 1	KIA 6790	6144	46	7060	80	NA	H (human)
Hoyo 9	KIA 21352	6280	33	7220	40	NA	H
Hoyo 1	UtC-13346	6280	50	7210	50	NA	Cl
Hoyo 1	KIA 4780	6390	60	7330	60	NA	C
Hoyo 18	KIA 21347	6407	34	7350	50	NA	H
Hoyo 13	KIA 16571	6608	35	7510	40	NA	C
Hoyo 9	KIA 16579	6610	32	7510	40	NA	C
Hoyo 13	KIA 16574	6729	45	7600	40	NA	C
Hoyo 9	KIA 16575	6744	33	7610	30	NA	C
Hoyo 13	KIA 16566	6835	34	7670	30	NA	C
Hoyo 9	KIA 21350	6871	33	7710	40	NA	H
Hoyo 18	KIA 16577	6915	33	7750	40	NA	C
Hoyo 9	KIA 16569	6920	50	7760	60	NA	C
Hoyo 18	KIA 16570	6956	39	7790	50	NA	C
Hoyo 9	KIA 16578	6975	32	7810	50	NA	C
Hoyo 9	KIA 16580	6989	48	7830	70	NA	C
Hoyo 9	KIA 16568	7000	32	7850	50	NA	C
Hoyo 18	KIA 16581	7075	44	7910	50	NA	C
Hoyo 16	KIA 16573	7108	34	7930	40	NA	C
Hoyo 9	KIA 16576	7136	33	7970	30	NA	C
Los Baños							
2b3sup	GrA-21550	7350	60	8170	90	MG	C
2b3inf	GrA-21551	7550	50	8360	40	MG	C
2b3 general	GrN-24300	7570	100	8370	110	MG	C
2b1	GrA-21552	7740	50	8520	60	MG	C
2b1	GrN-24299	7840	100	8710	170	MG	C
2b1	GrA-21556	8040	50	8900	100	MD/MG	C
Mas Nou							
1	Beta-136678	6560	130	7450	110	NA	C
2b	Beta-170713	6760	40	7620	30	NA	H
1	Beta-136676	6800	70	7650	60	NA	H
1	Beta-136677	6900	70	7750	70	NA	H
3	Beta-170715	6920	40	7760	50	MG	H
3	Beta-170714	6910	40	7750	50	MG	H
fosa	Unknown	7010	40	7860	60	MG	H
Pontet							
c inf.	GrN-14241	6370	70	7310	80	NA	C
e	GrN-16313	7340	70	8170	100	MG	C
Revilla							
Estructura 8	KIA 13943	5642	96	6450	110	NA	C
Estructura 4	UtC-13348	6120	60	7030	100	NA	Cl
Estructura 12	KIA 21353	6156	33	7070	70	NA	H (dom.)

Estructura 12	KIA 21349	6158	31	7070	60	NA	H
Estructura 13	KIA 21354	6177	31	7080	60	NA	H (dom.)
Estructura 2	KIA 21346	6202	31	7100	60	NA	H (dom.)
Estructura 2	UtC-13350	6210	60	7120	90	NA	Cl
Estructura 13	KIA 21355	6230	30	7150	80	NA	H
Estructura 16	UtC-13294	6240	50	7150	90	NA	Cl
Estructura 4	KIA 21359	6245	34	7180	60	NA	H
Estructura 12	UtC-13295	6250	50	7160	80	NA	Cl
Estructura 2	UtC-13269	6250	50	7160	80	NA	Cl
Estructura 14	KIA 21357	6271	31	7210	40	NA	H
Estructura 4	KIA 21351	6289	31	7220	40	NA	H
Estructura 9	UtC-13347	6313	48	7240	50	NA	Cl.
Estructura 4	KIA 13936	6335	46	7270	60	NA	C
Estructura 4	KIA 21356	6355	30	7290	30	NA	H (dom.)
Estructura 14	KIA 21358	6365	36	7320	50	NA	H
Estructura 2	KIA 13932	6385	35	7340	50	NA	C
Estructura 4	KIA 13937	6405	36	7350	50	NA	C
Estructura 4	KIA 13942	6415	36	7360	50	NA	C
Estructura 8	KIA 13945	6446	39	7370	40	NA	C
Estructura 5	KIA 13948	6449	37	7370	40	NA	C
Estructura 4	KIA 13938	6449	42	7370	40	NA	C
Estructura 2	KIA 13933	6468	40	7380	40	NA	C
Estructura 4	KIA 13940	6568	37	7480	30	NA	C
Estructura 14	KIA 13946	6691	48	7560	40	NA	C
Estructura 4	KIA 13939	6755	57	7620	40	NA	C
Estructura 2	KIA 13934	6772	47	7630	40	NA	C
Estructura 14	KIA 13947	6809	37	7650	30	NA	C
Estructura 4	KIA 13935	6983	45	7830	70	NA	C
Estructura 8	KIA 13944	7014	37	7870	50	NA	C
Estructura 4	KIA 13941	7165	37	7990	30	NA	C
Toros de Cantavieja							
a1	GrA-24791	5880	50	6710	50	NA	H