



Mid-Holocene local vegetation dynamics and human impact at Los Castillejos, Andalusia, Spain: evidence from charcoal analysis

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Abstract

From the anthracological study of considerable quantities of charcoal recovered from the excavation of the settlement at Los Castillejos de Montefrío, a synthesis was made of the vegetation dynamics during Recent Prehistory of the area, from the middle of the sixth millennium BC to the beginning of the second millennium BC. The vegetation dynamics mark four anthracological phases over this sequence. From the Late Neolithic (end of the fifth millennium BC) the influence of different activities such as livestock raising, burning and agriculture become evident in the development of the natural vegetation, altering species composition and appearance frequency. The last anthracological phase, MF4, spanning the second half of the third millennium BC, saw the regeneration of the tree vegetation as certain former activities ceased, indicating the environmental singularity of this enclave within the context of the southern Iberian Peninsula.

Keywords Neolithic · Chalcolithic · Charcoal analysis · Anthracology · Palaeoenvironment · South-eastern Iberian Peninsula

Introduction

A great part of human subsistence has been based on plants, whether consuming them as food or using them as fuel, construction materials, or tools etc. This dependence on vegetation has signified a constant demand for herbaceous as well as woody plants, with resulting considerable modification of plant communities as human populations exploited and exerted various pressures on the environs of settlements. Such pressure diminishes and sometimes eliminates indigenous species in favour of opportunistic plants or the introduction of new species. The anthracological data have served to redefine and reconstruct the palaeoethnobotanical model of each prehistoric community at the same time as aiding palaeoecological interpretations of the results.

The use of wood for fires and in order to construct buildings as well as to make tools and utensils was a daily feature

of both prehistoric and pre-industrial societies. The main source of energy was firewood, whether used directly in fires or specifically to produce charcoal. The carbonized remains of plants used for such ends are studied in Anthracology, together with the remains of construction and tools burnt in natural conflagrations or in the context of human-induced fires related to prehistoric settlements. These traces provide not only valuable environmental information but also clues concerning the management of the vegetation by human communities. In the present study, we seek to reconstruct the landscape that existed around the site of Los Castillejos and to elucidate the way in which the environment was managed and, in some cases, transformed.

Archaeological site, present-day climate and geographical setting

The municipality of Montefrío is situated in the north-west of the province of Granada, near the borders of the provinces of Córdoba and Jaén. Geographically, it lies in the region of Los Montes, within the Betic System, the main mountain range of the southern Iberian Peninsula.

The settlement of Los Castillejos, part of the group of archaeological sites known as Las Peñas de los Gitanos (Montefrío, Granada; 37°20'05"N, 3°58'01"W), occupies a

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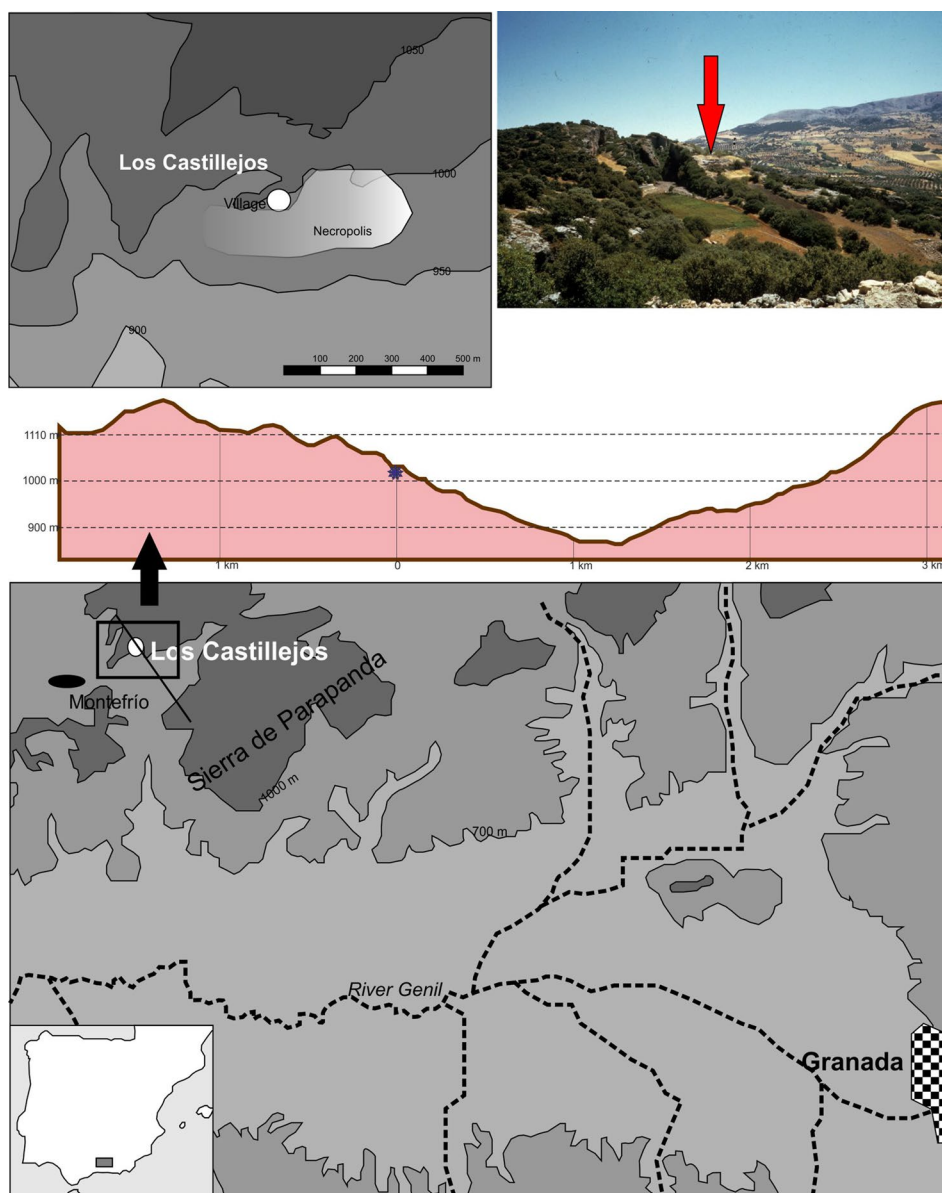
small calcareous massif formed by corridors and mesas at different heights. The megalithic necropolis is situated in the lowest corridors and the prehistoric settlement of Los Castillejos lies on a mesa (plateau) at 1,050 m a.s.l., and at the south borders the Sierra de Parapanda which rises to 1,601 m a.s.l. The site of Los Castillejos is located at the western end of this massif, which shows evidence of occupation from the end of the Early Neolithic to the Roman period (Fig. 1).

This set of archaeological sites has been the subject of publications and scientific studies since the middle of the 19th (Góngora 1868; Gómez-Moreno 1905, 1907; Mergelina 1941–1942, 1945–1946; Leisner and Leisner 1943; Tarradell 1952). In the early 1970s, the Department of Prehistory of the University of Granada launched an excavation project at

Los Castillejos and began several surveys to delineate and characterize the different phases of occupation of the site, focussing especially on prehistoric occupation (Arribas and Molina 1979a, b). Between 1991 and 1994, new excavations helped redefine and broaden the stratigraphic sequence of the site, characterized by different phases and periods (Afonso et al. 1996; Ramos et al. 1997; Cámara et al. 2005, 2016), which served as the temporal reference for our work.

Biogeographically, the zone belongs to the Mediterranean and within the chorological typology to the Betic province. The main woody vegetation is classified in the association *Paeonio coriaceae-Querceto rotundifoliae* S. The presence of *Pistacia lentiscus* and *Olea europaea* suggests the thermophilous facies of this association (Rivas Martínez 1988; Valle 2004). The main woody species is

Fig. 1 Location of the archaeological site of Los Castillejos and the adjacent megalithic necropolis, within the Granada area (Southeast of Andalusia, Spain). The black line through the site indicates the line of the topographic section of the area. In this section the situation of the village is indicated by a star



Quercus rotundifolia (*Q. ilex* ssp. *rotundifolia*) which normally attains a medium height. In the shrub layer *Q. rotundifolia* is also important but with *Q. faginea* (Portuguese oak) where considerable shade is present.

Materials and methods

The charcoal samples were systematically collected by hand and also from 571 sediment samples for flotation. Approximately 9,164 l of sediment were floated (Rovira 2007, p 82), which enabled the recovery of numerous ecofacts that were then studied by different specialists. Analyses were made of seeds and fruits (Rovira 2007), fauna (Riquelme 1997) and land snails (Yanes et al. 2011). In addition, a study of stable isotopes of seeds (Araus et al. 1997a; Aguilera et al. 2008) was made, as well as an archaeomagnetic study of the ceramics which also provides environmental information (Nachasova et al. 2007).

The anthracological analysis at Los Castillejos de Montefrío included a total of 10,574 fragments from the excavation of Cut 6 during the excavation campaign of 1991–1994. The different charcoal samples were grouped into 25 stratigraphic phases, which in turn were grouped into nine cultural periods that spanned the Early Neolithic to the Early Bronze Ages (Table 1), according to the chronology proposed by the excavators, based on 25 ¹⁴C dates (Arribas and Molina 1979a, b; Afonso et al. 1996; Ramos et al. 1997; Cámara et al. 2005, 2016). The chronology ranges between 5325–5220 and 2000–1800 cal BC.

The reconstruction that follows is based on the interpretation of the anthracological diagram (Fig. 2), which is made up of the charcoal found scattered throughout the archaeological strata (9,589 fragments analysed), excluding those recovered in the numerous hearths identified (906 fragments) and in the postholes (79 fragments), which were evaluated independently. Table 1 lists the taxa identified in each of the 25 stratigraphic phases studied and their relative as well as absolute frequencies. In addition, the frequencies are indicated for the unidentified fragments (Indeterminate) and the charcoal that could not be determined due to its poor state (Undeterminables). This last mentioned includes charcoal with knots, vitrified, calcium concretions etc. The final two rows of the table show the total number of charcoal fragments analysed and the number of taxa identified, which, in turn, provide an indication of the floristic richness of each set of samples. The relative percentage frequencies that appear in this table are used in preparing the anthracological diagram (Fig. 2). In Phase 24 (Early Bronze Age) only 33 fragments were studied, so they have not been represented graphically.

The anatomical identification of charcoal usually reaches the species level, although in many cases it remains in the genus or family (Table 1; Fig. 2). In the case of genus, it has been opted to denominate them generically with sp. in the diagram. Sometimes, one taxon represents two species, as in the case of *Quercus ilex-coccifera*, which potentially includes *Q. ilex* (holm oak) and *Q. coccifera* (kermes oak), or two genera such as *Salix-Populus*, which encompass willow and poplar. Evergreen *Quercus* includes the fragments having intermediate anatomical characteristics between *Q. ilex-coccifera* and *Q. suber* (cork oak), possibly belonging to hybrid species that are so frequent in the areas where *Q. ilex* and *Q. suber* coexist. Also, the distinction between different species of deciduous *Quercus* is difficult, being aggravated by the ease with which these species hybridize. Fragments of *Q. faginea* were identified on the basis of a single row of large spring vessels with diameters of 160–300 µm.

The taxa in Fig. 2 are arranged with the main taxon *Q. ilex-coccifera*, placed in the first position, followed by the rest of the taxa listed alphabetically, apart from the riverbank species which are placed in the last columns. The values with less than 1% frequency are represented by squares, while in the last column on the right-hand side are the taxa that appear occasionally.

Results

Quantitative analysis

Because there are two phases in which relatively little charcoal was recovered—138 pieces in Phase 3 and 70 in Phase 6—we show the number of charcoal fragments analysed and the number of taxa identified per phase (Fig. 3), in order to determine whether the latter was a function of the former. These graphs suggest that the number of taxa is not a function of the number of charcoal fragments analysed. Phase 16a, for instance, with 1,297 fragments analysed, was not the phase with the most taxa identified, and Phase 24, with 33 fragments, did not have the least number of taxa. Figure 3b shows different segments or steps with a similar number of taxa determined.

A first section corresponds to the first five phases, belonging to the Ancient Neolithic. The number of taxa ranges between 12 and 13, except for Phase 4, which has 21. After Phase 6, with only three determined taxa, in relation to a period of population hiatus or mixture (Cámara et al. 2016), there is the second section that corresponds to the Middle Neolithic. At this time the number of determined taxa decreases by up to 9 taxa on average, indicating a floristic poverty. At this time the number of determined taxa decreases up to nine on average, indicating floristic poverty. The third section is composed

Table 1 Results of charcoal analysis of Los Castillejos, southern Spain

Cultural period	Early Neolithic						Middle Neolithic					Late Neolithic I			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Stratigr. phases	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	n/%	
<i>Acer</i> sp.						1/1.4	2/1			2/0.6	2/0.71		3/0.3	1/0.1	
<i>Arbutus unedo</i>	8/2.8	5/2.5	7/5.1	16/2.5	1/1.2		8/4	14/6.3	63/8.3	15/4.7	22/7.8	4/1.3	126/13.9	102/12.2	
<i>Cistus</i> sp.				1/0.2				1/0.5	1/0.1		8/2.9		1/0.1		
Fabaceae	5/1.7	10/5.1	9/6.5	9/1.4	2/2.3		3/1.4	1/0.5		1/0.3	1/0.4		1/0.1	2/0.2	
<i>Fraxinus</i> sp.	3/1.1	6/3	3/2.2	33/5.3	2/2.3		3/1.4	5/2.3	4/0.5	5/1.6	2/0.7			4/0.5	
<i>Juniperus</i> sp.	9/3.1	4/2		6/1	3/3.5		1/0.5			13/4		24/7.7	28/3.1	3/0.4	
<i>Olea europaea</i>	13/4.5	4/2	3/2.2	18/3	1/1.2		1/0.5						8/0.9	16/1.9	
<i>Phillyrea</i> sp.		1/0.5	1/0.7	1/0.2				1/0.5	4/0.5				2/0.2	3/0.4	
<i>Pinus halepensis</i>		1/0.5		4/0.6	1/1.2							11/3.5	183/20.2	218/26.1	
<i>Pinus</i> sp.									1/0.5				2/0.2	6/0.7	
<i>Pistacia lentiscus</i>	2/0.7		1/0.73	4/0.6	1/1.2								13/1.4	/	
<i>P. terebinthus</i>	1/0.3			1/0.2							2/0.7	4/1.3	22/2.4	16/1.9	
<i>Pistacia</i> sp.				2/0.3									2/0.2		
<i>Populus</i> sp.			2/1.4	1/0.2				1/0.5							
<i>Quercus</i> deciduous	14/4.9	11/5.5	8/5.8	23/3.7	2/2.3		11/5.4	1/0.5	2/0.3				6/0.7	5/0.6	
<i>Q. faginea</i>	13/4.5	2/1	7/5.1	10/1.6			7/3.4		23/3.1	10/3.1	7/2.5	10/3.2	20/2.2	36/4.3	
<i>Q. ilex-coccifera</i>	153/53.9	114/57.6	65/47.1	349/56.3	54/62.8	54/77.1	144/70.2	181/83	631/83.7	266/83.1	229/81.5	238/76.5	464/51.2	391/46.9	
<i>Quercus</i> evergreen	35/12.3	13/6.6	16/11.6	68/1	3/3.5			2/0.9	5/0.6	2/0.6	5/1.8	4/1.3			
<i>Q. suber</i>	4/1.4			13/2.1	1/1.2			1/0.5	2/0.2			3/1	1/0.1	0/0	
<i>Quercus</i> sp.	6/2.1	9/4.6	5/3.6	24/3.9											
<i>Salix</i> sp.				3/0.4		2/2.9			4/0.5			8/2.6			
<i>Salix/Populus</i>				1/0.2	5/5.8			1/0.5							
<i>Tamarix</i> sp.									1/0.1					2/0.2	
<i>Viburnum tinus</i>				1/0.2											
<i>Vitis</i> sp.															
Indet.	4/1.4	3/1.5	1/0.7	4/0.6		1/1.4	6/2.9	1/0.5	2/0.3			1/0.3	6/0.7		
Undet.	14/4.9	15/7.6	10/7.2	28/4.5	10/11.6	12/17.1	19/9.3	7/3.1	12/1.6	6/1.9	3/1.1	4/1.3	18/2	29/3.5	
Sum	284	198	138	620	86	70	205	218	754	320	281	311	906	834	
N° of Taxa	13	12	12	21	12	3	9	12	11	8	9	9	16	14	

of nine stratigraphic phases that culturally go from the Late Neolithic I to the Late Copper I. The number of taxa increases to 16 on average, indicating increased flora from this time. The last section is composed of four stratigraphic phases that go from the Late Copper II to the Ancient Bronze. In this section there is an oscillation in the number of determined taxa, although in the two central phases the number (15) is similar to the previous phase.

This first quantitative assessment of the taxa identified indicates that the floristic richness varied considerably over the cultural periods represented in the records, provided that the samples studied come from charcoal scattered throughout the excavated area and not related to specific activities. Therefore, the different defined sections indicate stages or phases in the development of the surrounding vegetation of Los Castillejos de Montefrío.

Qualitative analysis

Qualitatively, the percentage representation of the main taxa also varies considerably. These two variables, i.e., taxa

present and percentage representation, enabled four anthracological phases to be distinguished (Table 2). These phases are indicated in Fig. 2 and denoted by MF (for Montefrío), followed by an Arabic numeral. Subphases are indicated by lowercase letters and broken lines. The main features of the anthracological phases are now described.

Anthracological phase MF1

This phase includes the first five stratigraphic phases, corresponding to the Early Neolithic, and hence relating to the earliest occupation at the site. These phases span some 400 years, during which the vegetation used as fuel by the settlers of Los Castillejos remains relatively constant.

In this phase there is an absolute predominance of *Quercus*, both evergreen (*Q. ilex-coccifera*, *Q. suber* and evergreen *Quercus*) and deciduous (*Quercus* deciduous and *Q. faginea*) that would be distributed in a mosaic throughout the territory. The former would occupy the driest areas, while the latter occupy the valley bottoms or areas with cooler soils. Meanwhile on the riversides the riparian

Table 1 (continued)

Cultural period	Late Neolithic II		Early Chalcolithic		Middle Chalcolithic		Late Chalcolithic I			L Chal. II	Early Bronze
	15 n/%	16a n/%	16b n/%	17 n/%	18 n/%	19 n/%	20 n/%	21 n/%	22 n/%	23 n/%	24 n/%
<i>Acer</i> sp.		11/0.9	4/0.9	5/1.2	10/4.2	2/1	14/4.1	29/13.9	2/0.6	1/0.3	
<i>Arbutus unedo</i>	17/7.9	86/6.63	42/9	54/12.6	36/15.1	39/18.8	98/29	29/13.9	51/14.1	27/7.8	1/3
<i>Cistus</i> sp.	1/0.5	13/1	1/0.2	1/0.2	1/0.4	2/2	22/6.5		4/1.1	4/1.2	
Fabaceae		7/0.5	5/1.1	1/0.2	2/0.8	1/0.5	3/0.9	1/0.5		2/0.6	
<i>Fraxinus</i> sp.	1/0.5	9/0.7	8/1.7	7/1.6	10/4.2	4/1.9	28/8.2	15/7.2	16/4.4	7/2	
<i>Juniperus</i> sp.	1/0.5	1/0.1		1/0.2							
<i>Olea europaea</i>	9/4.2	18/1.4		3/0.7	10/4.2	8/3.8	2/0.6		2/0.6	44/12.8	4/12.1
<i>Phillyrea</i> sp.	1/0.5	1/0.1	3/0.6	3/0.7	7/2.9	3/1.4	2/0.6			5/1.4	
<i>Pinus halepensis</i>	38/17.7	387/29.8	175/37.3	120/27.9	31/13	31/14.9	2/0.6	5/2.4	16/4.4	2/0.6	2/6.1
<i>Pinus</i> sp.	5/2.3	15/1.2	4/0.9	1/0.2	2/0.8		1/0.3		4/1.1		
<i>Pistacia lentiscus</i>	3/1.4	30/2.3	10/2.1	4/0.9	1/0.4	4/1.9	1/0.3	1/0.5	3/0.8	2/0.6	
<i>P. terebinthus</i>	3/1.4			1/0.2	1/0.4					1/0.3	
<i>Pistacia</i> sp.		1/0.1	1/0.2		1/0.4						
<i>Populus</i> sp.			1/0.2								
<i>Quercus</i> deciduous	3/1.4	10/0.8	8/1.7	4/0.9	7/2.9	9/4.3	16/4.7	11/5.3	29/8	18/5.2	
<i>Q. faginea</i>	5/2.3	55/4.2	17/3.6	30/7	14/5.9	19/9.1	33/9.8	37/17.8	106/29.4	111/32.2	5/15.2
<i>Q. ilex-coccifera</i>	118/54.9	593/45.7	154/32.8	169/39.3	92/38.7	73/35.1	91/26.9	99/47.6	114/31.6	99/28.7	19/57.6
<i>Quercus</i> evergreen		3/0.2	2/0.4		2/0.8	2/2			2/0.6	2/0.6	
<i>Q. suber</i>											
<i>Quercus</i> sp.		6/0.5	18/3.8	14/3.2	4/1.7	2/2	14/4.1	6/2.9	1/0.3	10/2.9	
<i>Salix</i> sp.											
<i>Salix/Populus</i>						1/0.5			2/0.6		
<i>Tamarix</i> sp.											
<i>Viburnum tinus</i>											
<i>Vitis</i> sp.									1/0.3		
Indet.	1/0.5	5/0.4	1/0.2	2/0.5		1/0.5	1/0.3			1/0.3	
Undet.	9/4.2	46/3.6	15/3.2	10/2.3	7/2.9	7/3.4	10/2.9	4/1.9	8/2.2	9/2.6	2/6.1
Sum	215	1,297	469	430	238	208	338	208	361	345	33
N° of Taxa	13	17	16	16	17	15	14	9	15	15	5

Number of charcoal fragments studied and frequencies of percentages of the taxa in the 24 stratigraphic phases defined

vegetation consisted mainly of *Fraxinus* (ash), with *Salix* (willow) and *Populus* (poplar) appearing in the latter phases of this period.

The appearance of *Q. suber* and a minor curve of *Arbutus unedo* (strawberry tree) indicate that in a karstic area siliceous plants can become established, so long as there is a decalcification of the substrate (Varo et al. 1977; Torres et al. 2002). The presence of *A. unedo* with low percentages of 1–5%, with a similar representation of juniper (*Juniperus* spp., possibly *J. oxycedrus* or *communis*), shrubby legumes and the occasional appearance of *Pinus halepensis* (Aleppo pine) in three phases reflects the openness of some areas, where *Cistus* spp. (rockroses) occasionally grow. In the same areas or on the sunnier slopes they could appear in a series of species that typify warm climates, such as *Olea europaea* (olive), *Phillyrea* sp. and *Pistacia lentiscus* (mastic tree), with a small appearance curve, together with the occasional appearance of *Viburnum tinus*.

Anthracological phase MF2

Anthracological Phase 2 encompasses six stratigraphic phases that can be assigned to the Middle Neolithic, from 6 to 11 (Figs. 2, 3), although in the calibrated chronology these correspond to a chronological period of only 1 century, between 5000 and 4900 cal BC.

In this phase, after a first period that corresponds to the levelling of the surface occupied after abandonment, where only three taxa have been determined (Archaeological Phase 6), only three complete records appear. There is a significant increase of *Quercus ilex-coccifera* and a somewhat smaller one of *A. unedo*. However, *Fraxinus* sp. decreases its representation, while *Q. faginea* maintains it.

This finding implies the floristic impoverishment of the overall vegetation present in the surroundings, some taxa disappearing completely (notably *P. halepensis* and *Pistacia lentiscus*) or appearing only occasionally (e.g. *Olea europaea*, *Pistacia terebinthus*, *Q. suber*). The presence of *Fraxinus* and the occasional appearance of *Populus* and *Salix*

could indicate that the water courses were smaller and more unstable.

The increase of *A. unedo* could signify an opening of *Q. ilex* woodlands in certain areas, accompanied by a minor surge in the presence of *Cistus* sp. However taxa that in the previous phase had small percentages, such as *Juniperus* and Fabaceae, diminished in appearance, becoming almost negligible. The group formed by species such as *Olea oleaster* (wild olive), *Pistacia lentiscus*, *Phillyrea* and *Viburnum tinus*, of the previous phase, disappeared or appeared occasionally in one or two phases, as also reflected in the disappearance of *P. halepensis*. However, *Acer* sp. (maple) makes their appearance for the first time in the diagram.

Anthracological phase MF3

This phase covers nine stratigraphic phases, corresponding to several cultural periods from the Late Neolithic I to the Late Chalcolithic I. It presents a significant rise in the number of taxa identified in each of the stratigraphic phases (Figs. 2, 3). Also, the different distribution percentage of each taxon is indicative, causing each to have significant curves throughout Phase 3. Within this phase when calibrated dates span a broad time period, between 4200 and 2600 BC, and present a similar floristic composition, certain temporal subdivisions or subphases can be distinguished.

1. *Subphase 3a* Stratigraphic phase 12, defined as the first time of Late Neolithic I occupation, after a population hiatus of 700 years that spanned almost the entire fifth millennium BC (Cámara et al. 2016, p 31), presented a number of taxa determined that was similar to that of the anthracological phase MF2 (Fig. 3b). However, the different distribution of the percentages of some taxa, together with the appearance of the curve of *P. halepensis* caused this phase to be somewhat different from the previous phase.

Although the charcoal used in the anthracological analysis came from the charcoal scattered throughout the excavated area, it might be deduced that the origin of the fragments is determined by the use of several documented areas of combustion (Cámara et al. 2016, p 75). In this case, the anthracological spectrum would be reflecting only the species used as fuel in a few fires.

The main species used was *Q. ilex* and/or *Q. coccifera* (kermes oak), which presented a percentage similar to that of the previous phase. There was a significant reduction in the presence of *A. unedo* while *Juniperus* sp., *Salix* sp. and *P. halepensis* appear significantly. Therefore, the vegetation expressed by the anthracological analysis had characteristics and a composition similar to those in the previous phase, although the appearance of *P. halepensis* in a significant

percentage (3.5%) reflects that something had changed in the surroundings.

2. *Subphase 3b* The second time period includes the stratigraphic phases 13 and 14 of the Late Neolithic I, 15 and 16a of the Late Neolithic II, and 16b of the Early Chalcolithic. In the calibrated chronology, these anthracological subphases represent a time interval of some 1,000 years, encompassing practically the entire fourth millennium BC.

The floral richness of this period becomes high again, after the dip of anthracological Phase 2. The taxa are almost the same as those of MF1, although the significant presence of *Acer* sp. and the disappearance of *Q. suber* (save for the sporadic appearance in Phase 13) should be pointed out. This would indicate that a species preferring the cold replaced one that preferred warm conditions. However, the most characteristic feature of this subphase is that the proportion of major taxa changed appreciably with respect to the previous phases. The protagonist is Aleppo Pine in correspondence with the decline detected in the percentages of *Q. ilex-coccifera* and *A. unedo*. These frequencies reflect that the *Q. ilex* woodland reduced its presence in the surroundings. The disappearance of a part of *Q. ilex* is taken advantage of, on the one hand, by *A. unedo*, which develop along the edge of the forest, and on the other by the Aleppo pine, a tree that tolerates poorer soils and requires stronger sunlight. The causes for the patterns of these species is also related to the surge in agricultural activity and animal husbandry, which, as we will see later, is a consequence of the different strategies in the socioeconomic management in the setting of Las Peñas de los Gitanos.

The species of the shadier formations were present (*Q. faginea*, deciduous *Quercus* and *Acer* sp.), although the riverbank species declined, with the sporadic appearance of *Fraxinus* sp. and occasionally *Populus* sp. and *Tamarix* sp., indicating that the water courses were not voluminous, or that these formations were present and their wood was not burnt.

3. *Subphase 3c* A third period extends from phases 17 of the Early Chalcolithic to phases 18 and 19 of the Middle Chalcolithic, corresponding roughly in calibrated dates to the first half of the third millennium BC (Cámara et al. 2016, p 26). At this time the vegetation represented was basically the same, though the main taxa had different trends in the preceding period. The decrease of *Q. ilex-coccifera* continues, and this is exploited by *Arbutus unedo* to increase its presence.

However, the curve of *P. halepensis* clearly decreases in correspondence with the increase of *A. unedo*, reflecting a different environment management, as discussed below.

In this subphase, the species from the wetter or shadier areas prospered, with upward curves of *Q. faginea* and deciduous *Quercus* together with more-or-less stable *Acer* sp. and *Fraxinus* sp.

Anthracological phase MF4

This phase covers the last five stratigraphic phases of the sequence of the site, which culturally stretches from the Late Chalcolithic I to the Early Bronze Age. In calibrated dates, this phase occupies the second half of the third millennium and the beginning of the second millennium BC (Cámara et al. 2016, p 26).

At the floristic level, the number of taxa diminishes. As in the foregoing anthracological phase, several periods could be distinguished based mainly on the variations in the frequency of appearance of the different taxa.

1. Subphase MF4a encompasses stratigraphic phase 20. Qualitatively, the data identified were almost the same as in the previous phase, changing chiefly in the percentages of distribution of the taxa. The most significant of these periods was the near disappearance of *P. halepensis*, with only two fragments determined. This was combined with a sharp increase in *A. unedo*, in correlation with the decline of *Q. ilex-coccifera*, which had the least representation of the entire sequence.

The apparent degradation of the *Q. ilex* woodland, with the greater development of *A. unedo*, was accompanied by the appearance of a significant percentage of *Cistus*, which apparently spread into the spaces left open by *Q. ilex*. The increase of *Fraxinus* together with the equal representation of deciduous *Quercus*, *Q. faginea* and *Acer*, species that would occupy the same growth areas, would indicate that these areas are regenerating.

2. Subphase MF4b spans the last two stratigraphic phases, 21 and 22 that were defined as the Late Chalcolithic I. The most noteworthy trends of this period were:

The disappearance of *Phillyrea* sp. and the near disappearance of *Olea europaea* and *Pistacia lentiscus*, warm-climate species, signalling a relative harshening of the climate, with lower temperatures that almost cause these species to disappear.

The marked spike in *Q. faginea* next to the maintenance of the deciduous *Quercus* curve.

3. Subphase MF4c covers the last two stratigraphic phases of the archaeological sequence, defined as the Late Chalcolithic II (FE 23) and Early Bronze (FE 24). In this anthracological subphase the species preferring warmer climatic conditions underwent variations. *Olea* significantly increases its presence, while *Phillyrea* appears next to *Pistacia lentiscus*, reflecting the recovery of the temperatures. The species from the wetter zones maintained their numbers.

Discussion

The palaeoenvironmental sequence evidenced by the anthracological analysis showed four successive images of the vegetal landscape surrounding the site. A synthetic table of the climatic and vegetation dynamics has been made along with the inferred economic dynamics for the site. The last column indicates the forest management of the surrounding vegetation carried out by the inhabitants of Los Castillejos (Table 2). The anthracological phases described above represent periods having certain vegetation stability. However, some fluctuations can be observed in the representation of certain plant species. Therefore, the phases and subphases defined are not fixed images. The change in these plant formations is constant, corresponding both to environmental conditions as well as to economic management by the human settlement at Los Castillejos.

A palaeoenvironmental assessment

During the last glacial period there is some palynological evidence that many areas of Andalusia acted as refuges for many tree and shrub species (Fierro et al. 2011). Moreover, a clear anticipation of Holocene vegetation is observed, even with tardiglacial chronology. Citing just a few palynological studies, this change occurred around 15,000 years BP in Cueva de la Carihuela (Píñar, Granada: Carrión 1990, 1992; Carrion et al. 1998; Fernández et al. 2007), in Siles at 12,100 years BP (Sierra de Segura, Jaén: Carrión 2002) and in Padul at 13,000 years BP (Granada: Pons and Reille 1988). After the Holocene Optimum (7,500–5,000 cal BP), pollen sequences from Sierra de Baza (Carrión et al. 2007) and Sierra de Gádor (Carrión et al. 2003) demonstrate an aridifying climate change (Yll et al. 1994; Burjachs et al. 1997; Pantaleón-Cano et al. 2003) that manifests itself in a progressive xerophytisation of the landscape. From this period, human occupation has played a determining role in shaping Iberian landscapes as we know them since the mid-Holocene (Carrión et al. 2010).

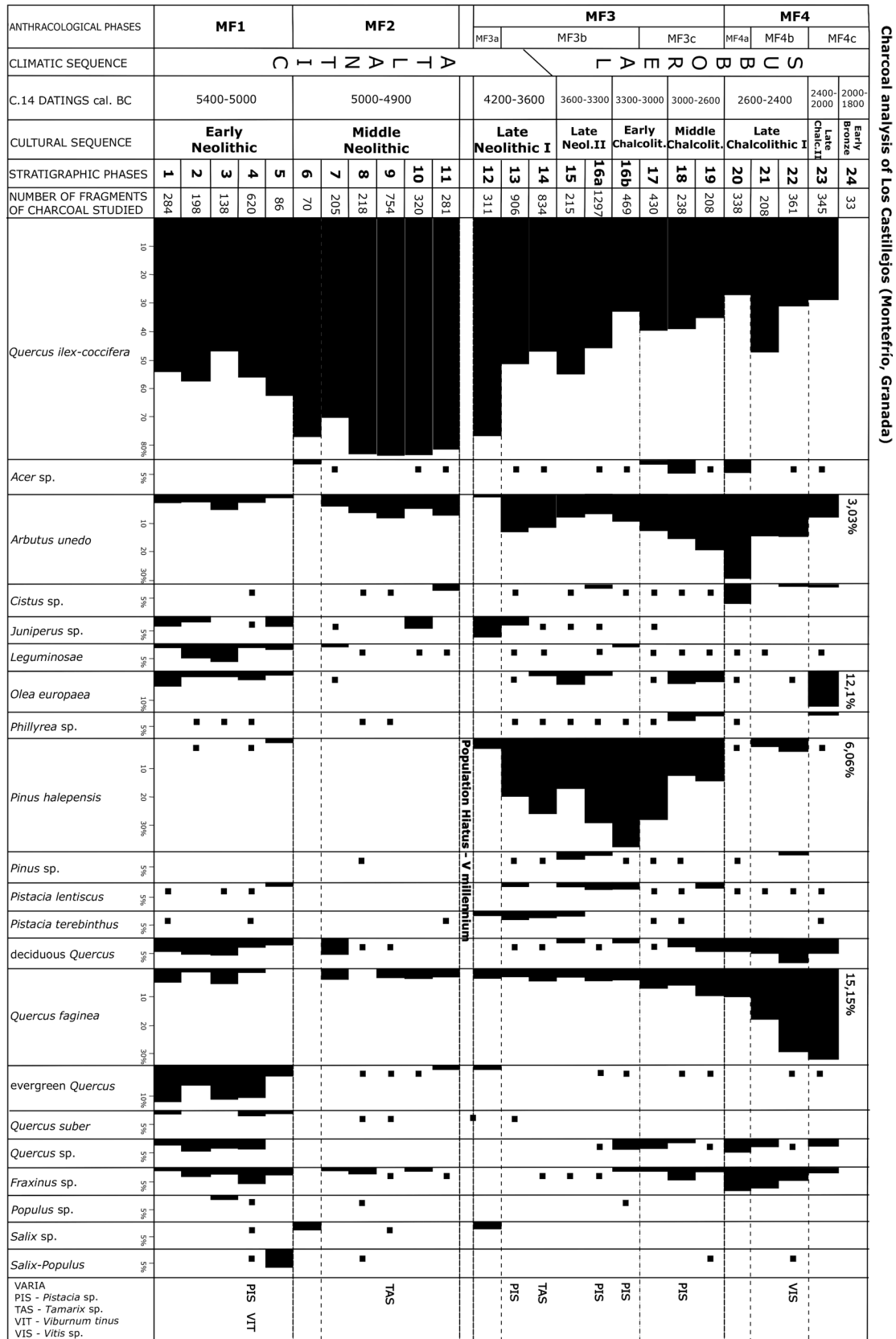
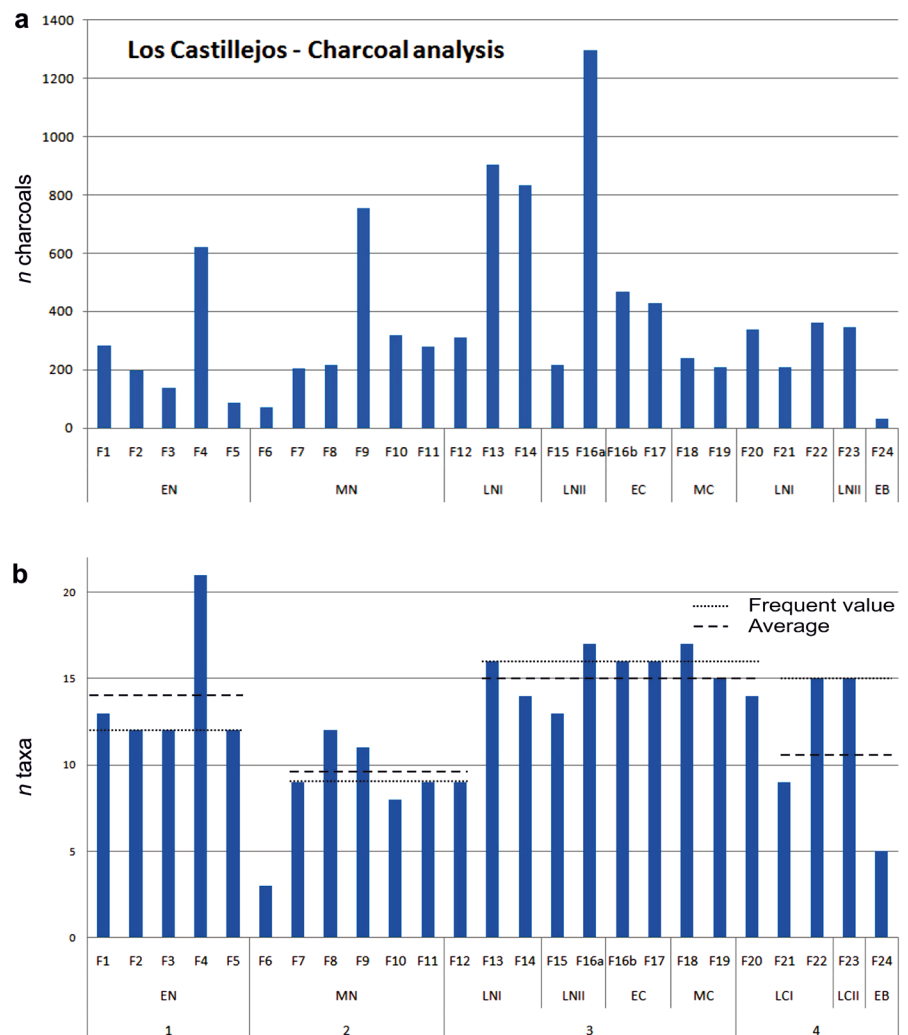


Fig. 2 Anthracological diagram of Los Castillejos, with the percentage representation of the results, cultural phases, absolute chronology and anthracological phases

Fig. 3 **a** Number of charcoal fragments analysed by archaeological phase; **b** number of taxa identified per archaeological phase and frequent value and average for anthracological period are also indicated (*EN* Early Neolithic, *MN* Middle Neolithic, *LNI* Late Neolithic I, *LNII* Late Neolithic II, *EC* Early Chalcolithic, *MC* Middle Chalcolithic, *LCI* Late Neolithic I, *LCII* Late Chalcolithic II, *EB* Early Bronze)



Within this Andalusian palaeoenvironmental sequence, defined by palynology (Fierro et al. 2011), the anthracological diagram of Los Castillejos begins at the moment of maximum expansion of vegetation. The anthracological phase 1 defines vegetation composed of evergreen species (*Q. ilex/coccifera*, *Q. suber* and evergreen *Quercus*) and lauroides (*A. unedo* and *Phillyrea* sp.) together with thermophilic species (*Olea europea*, *Phillyrea* sp. and *Pistacia lentiscus*) and local deciduous trees (*Q. faginea* and deciduous *Quercus*). These types of vegetation have been described today in hills and valley areas of Western Andalusia (Asensi and Diez 1987). We find formations of *Q. canariensis*, *Q. suber* and *Q. ilex* that develop under thermomediterranean (T 13 to 17 °C, m –1 to –4 °C, M 9 to 14 °C) and mesomediterranean parameters (T 17 to 19 °C, m 4 to 10 °C, M 14 to 18 °C; T = mean annual temperature, m = average of the lowest temperatures of the coldest month, M = average of the highest of the coldest month) with subhumid-humid-hyperhumid ombroclimates (from 600 mm to more than

1,600 mm) (Rivas Martínez 1988). These formations overlap each other, resulting in ecotones of difficult interpretation (Valle 2004, p 216). In these formations we find a preforest border and the first replacement step composed of *A. unedo*, *Phillyrea angustifolia* and *Pistacia lentiscus*, while in the most shaded areas *Viburnus tinus* appears (Rivas-Martínez 1988). Therefore the climatic parameters that indicate these formations correspond to a temperate climate with enough moisture corresponding to the maximum humidity detected in the archaeomagnetism of ceramics from the site (Nachasova et al. 2007) around the second half of the sixth millennium BC.

In the second anthracological phase there was a loss of floristic variety (Fig. 3), passing from an average of 12–9 taxa, and more significantly still, *Quercus* spp. and riparian vegetation declined together with almost the complete disappearance of *Q. suber* and thermophilous vegetation. The thermophilous species such as the *Pistacia lentiscus*, *Phillyrea*, and *Olea oleaster*, as well as *Q. suber*, had a

Table 2 Synthetic table with the climatic, vegetation and economic dynamics, together with the forest management of the four anthracological phases defined in Los Castillejos

Phase	Climate dynamics	Vegetation dynamics	Economic dynamics	Forest management
MF1	Subhumid-humid-hyperhumid ombroclimate Thermomediterranean belt	Lauroid and evergreen vegetation with thermophilic species and local deciduous	Dominance of sheep and goats Cereal farming	Exploitation of all the strata and groups of vegetation
MF2	Cold episode—dry ombroclimate Meso-Middle belt	Disappearance of thermophilic species	Cattle, sheep, goats and pigs	Holm oak exploitation
MF3	Subhumic-humic ombroclimate Lower Mesomediterranean belt	Decrease of evergreens Increase of pine	Livestock: cattle, increase of pigs, horse Agricultural intensification: cereals, legumes and flax Harvest of wild olive and wild grape	Cutting of holm oaks Fires in open pastureland
MF4	Subhumid-humid-hyperhumid ombroclimate Middle-Lower Mesomediterranean belt	Decrease of Lauroids Expansion of deciduous and thermophilic species	Livestock: cattle, highest increase of pigs Farming: cereals and legumes	Exploitation of wet areas and riparian forest

clear thermomediterranean bias, poorly tolerating frost, as in the case of *Q. suber* (López 1982; Blanca et al. 2009). The disappearance of these species indicates a harsher climate, turning cold.

In this sense, the appearance bears highlighting in this cold period of the genus *Acer*, which includes several species; *Acer granatensis* (or *A. opalus* ssp. *granatense*) is endemic to North Africa, the island of Majorca, and the southern half of the Iberian Peninsula. In Andalusia, this species occurs in the supramediterranean belt, giving its name to the association Daphno-Aceretum granatense, structured on the basis of *Acer* spp. and *Q. faginea*, frequently mixed, which occupies shady slopes that maintain a certain soil moisture throughout the year, with precipitation that exceeds 600 mm annually. The other species of *Acer* are scarcely represented in eastern Andalusia, except for *A. monspessulanum*, which as a broader distribution area than the former species, living in the mesomediterranean belt, although its ecological requirements are rather similar (López 1982; Blanca et al. 2009). Recently a community of deciduous trees (*A. monspessulanum*, *Pistacia terebinthus*) has been described, severely restricted to karst biotopes: the bases of cliffs and rocky edges in the nearby Sierras del Torcal and Zafarraya, to the south of the site. It develops on meso- and supramediterranean belts under humid-subhumid ombroclimate (in this case between 700–1,020 mm) (Pérez Latorre et al. 2009, 2015). Therefore records for this genus indicate a harshening of the ecological conditions, tending towards more cold and lower humidity.

This period that in the anthracological diagram corresponds to the Middle Neolithic and six stratigraphic phases (Fig. 2), represents a period of only 1 century, although the abandonment of the settlement during the main part of the fifth millennium BC prevent us from knowing its duration. However we speculate that the worsening of the climatic conditions could have provoked the abandonment of the site.

This cold and dry climatic event appears to correspond to the abrupt fall in moisture towards 5000 BC detected in the archaeomagnetic study of the ceramics of the site (Nachasova et al. 2007), after recording maximum values in the second half of the sixth millennium BC.

In the third anthracological phase, which developed in a broad time period during the fourth millennium and the first half of the third, the temperatures and precipitation appeared to recover after the cold and dry episode of the second phase, although the values of the first phase may not be reached. Thus, the thermophilous species again present a minor but constant curve, reflecting a certain rise in temperatures. Similarly, the significant proliferation of *A. unedo* indicates a mild climate, without hard frosts (López 1982). There is a certain recovery of the riparian vegetation, of *Quercus* spp., and of the aforementioned *A. unedo*. This latter species has been described in some locations of the Natural Park of Cazorla (Jaén, Spain), invariably on western slopes, open to the thermal influence that penetrates through the Guadalquivir Valley. It always appears in the lower and middle strips of the mesomediterranean belt, in all cases with a subhumid ombroclimate (Valle et al. 1989, p 54). It has also been described in the southern Iberian Peninsula in two geological areas: the most westerly one, between the chorological provinces Luso-Extremadurensis and Gaditano-Onubo-Algaviense with its siliceous substrate; and the central-oriental one, over mainly carbonate substrates. In all seasons, the Atlantic influence is strong, causing the ombroclimate to be subhumid-humid and the thermotype Thermomediterranean and Mesomediterranean (Torres et al. 2002). Therefore, the contrast with the current vegetation of the area is evident as the presence of *A. unedo* has not been described in the area of Las Peñas de los Gitanos (Guerrero and Rubio 2016). In the nearby Natural Park of the Sierra Subbética, it has been reported in very few

localities (Muñoz and Domínguez 1985; Valle 1993; Triano 2010). The presence of *A. unedo* at this very time is highly significant in the Cueva de los Murciélagos de Zuheros (Córdoba) (Rodríguez-Ariza 2011). Percentages very similar to those of Las Peñas de los Gitanos are recorded in sites of the same area of Andalusia as Cueva del Toro (Rodríguez-Ariza 2004), Polideportivo de Martos and Marroquíes Bajos (Rodríguez-Ariza 2011). All this would support a recovery of moisture in this period.

In this phase, as remarked above, the anthracological analysis detected three subphases, with the change towards the Early Copper Age (c. 3200 BC). At a time prior to this date (3500–3200 BC) the archaeomagnetic study indicated a dry period corresponding in the anthracological diagram (Fig. 2) to the greatest presence of Aleppo pine and the least presence of *Q. ilex* and *A. unedo*. After this dry period, the moisture increased in the archaeomagnetic study, corresponding to Subphase 3c, where there was a progressive increase in the curves of *A. unedo*, *Quercus* spp., and riparian vegetation, together with a significant downturn in the curve of Aleppo pine. Therefore, at this time, again a moisture pulse and also somewhat warmer conditions were reflected in the curve of the thermophilous species.

At the beginning of anthracological Phase 4, for 2 centuries that coincided with the Late Chalcolithic I, a series of climatic fluctuations appear to have taken place, where the most remarkable result was the decline in the thermophilous species such as *Olea oleaster*, *Phillyrea* and *Pistacia lentiscus*. This would indicate a relative fall in temperatures. At the same time, the expansion of the riparian vegetation, with *Fraxinus* as the main representative, together with the progressive proliferation of *Quercus* spp. indicates a gradual increase in precipitation. These trends persisted in the last period corresponding to the Late Chalcolithic II, together with a rise in temperatures, as reflected by the increase in thermophilous species, primarily *O. oleaster*. These climatic fluctuations appear to coincide with those detected by archaeomagnetism of the ceramics for the period 2500–2200 (Nachasova et al. 2007).

In summary, we deduce that the climatic conditions presented in the diagram of Los Castillejos were moister than current conditions in the zone, as also reflected by the isotope analyses made on seeds from this site and others of the south-eastern Iberian Peninsula (Araus et al. 1997a). The diagram (Fig. 2) indicates 4 phases in the vegetation that appear to represent the successive climatic conditions (Table 2). These conditions, however, are not stable, presenting fluctuations noticeable in the advance and recession of certain species and in some cases their appearance and disappearance.

A management evaluation of the setting

The four anthracological phases defined also correspond to a physiognomic composition of the vegetation surrounding

Las Peñas de los Gitanos, characterized by the predominance and appearance or disappearance of plant associations and/or given species that, as discussed above, are subject to environmental influences, but also to the management that different prehistoric populations applied to their surroundings.

The first image provided by the diagram (Fig. 2) in its anthracological Phase 1 corresponds to a *Q. ilex* woodland that has some lauroid species, such as *A. unedo* and *Viburnum tinus*. This *Q. ilex* woodland has certain deciduous species occupying areas of shade or cool soils as in the case of gullies where *Fraxinus*, *Salix* and *Populus* grow, and as also reflected by forest fauna, with the garden dormouse, European bats, the hawfinch, wood and rock pigeons (*Columba palumbus* and *C. livia*) (Riquelme 1997). The presence of junipers and shrubby legumes, possibly broom type, indicate certain open spaces, as also testified to by the remains of red partridge, magpie and lizard (Riquelme 1997). *Phillyrea*, *O. oleaster*, and *Pistacia lentiscus*, of which seeds were also found (Rovira 2007), would have occupied rocky and sunny areas. This floristic composition indicates a variety of ecological niches in the surroundings of the settlement, as indicated by the firewood supply gathered from all of these species. In this woodland environment, the first Neolithic settlers arrived in Las Peñas de Los Gitanos and brought *Triticum aestivum* and *T. durum* (common and durum wheat), *Hordeum vulgare* var. *nudum* (naked barley) and *T. monococcum* (einkorn), together with *Pisum sativum* (pea) and *Vicia faba* (faba bean) (Rovira 2007). These settlers also brought their livestock of sheep and goats, progressively expanding to cattle and pig (Riquelme 1997).

The sowing of cereals and legumes within this forest environment required the deforestation of certain areas with good soils. The creation and extension of these crop fields would have been related to the number of inhabitants of the village, as well as their technical capacity for deforestation. From the anthracological Phase 3 (MF3), the use of fire to transform the landscape is evident. The sudden appearance of new plant formations and species with large percentages indicate that the pressure of the human groups was greater on the surrounding environment. From the Late Neolithic I to the end of the fifth millennium BC, agriculture became established with cereals as the principal species cultivated, together with the growing importance of legumes, such as *Pisum* and *Vicia faba*, and *Linum usitatissimum* (linseed), which reaches a significant presence during the Copper Age (Rovira 2007). This implies a complex agricultural system possibly with crop rotation between cereals and legumes, which enables quicker soil regeneration. In addition, the provision of proteins from the legumes complemented the human diet, based on carbohydrates provided by the cereals (Buxó 1997).

Together with the impact that agricultural activities exerted on the environment, the livestock also posed a source of pressure. The impact of animal husbandry on the vegetation of certain areas is difficult to establish, since many factors are involved directly, such as the composition of the flocks and herds, the number of animals, and the stabling system. Indirect factors would be the production of fires for the creation of pastures.

In Los Castillejos the herds were composed predominantly of bovids, followed by ovicaprids throughout the sequence, which implies a moist forest environment that corresponds to our data. It is remarkable that, in Stratigraphic Phase 20, the largest presence of pigs matches with the smallest of *Q. ilex* and the largest of *A. unedo* and thicket species (Table 2). A large presence of pigs would cause direct damage to the vegetation, consuming fruits of trees and thereby impeding the regeneration of seedlings, in addition to damaging bark by scratching and even killing some trees.

One of the most surprising findings regarding the anthracological analysis of Los Castillejos is the almost sudden appearance of *P. halepensis* at the end of the fifth millennium BC and their persistence during the millennium and half until their new near disappearance in the middle of the third millennium BC, defined by the anthracological Phase 3. This appears to have resulted from the intensification of agriculture and livestock raising mentioned above, for which fire is one of the main tools for the creation and maintenance of crop fields and pastures.

Pinus halepensis, being heliophilous, thermophilous and xerophilous, is well adapted to drought and is one of the most representative trees of semiarid Mediterranean areas, tolerating up to 250 mm of annual precipitation and dry summer periods of 1–5 months (Herranz 2000). However, as mentioned in the previous section, the environmental conditions of the group of taxa identified implies a mild, relatively moist climate and thus the colonization of *P. halepensis* in this environment by itself is not plausible. The use of fire has been mentioned at sites such as Cova de Cendres (Badal 2009a, b) and Marroquíes Bajos (Rodríguez-Ariza 2011), although in this latter site at a slightly later time than in Los Castillejos.

Natural or provoked fires constitute a key ecological factor in the dynamics and structure of many Mediterranean ecosystems. Repeated fires cause periodic perturbation with which Mediterranean species have evolved and to which they have adapted by developing diverse strategies, whether of being capable of surviving the fire, being able to regenerate afterwards, or even needing fire to reproduce. One such species is *P. halepensis*, which has adapted to fire with early fruiting, delayed seed dispersal, and serotinous cones (Herranz 2000). Such strategies are effective when the time lapse between two fires exceeds the period needed for the pine to fruit. For the regeneration of the pine, good

climatic conditions are need for the first 2 years, since fire does not always favour the pine, but rather could help *Q. ilex* or re-sprouting species.

Studies on the recurrences of fires in the Mediterranean area (Pausas 2004) have demonstrated that although the age of first pine cone production in *P. halepensis* is relatively early (a few years), the production of a seed bank sufficiently large to restore the population requires some 15 years (depending on the characteristics of the site).

Current studies on the recurrence of fires in the Mediterranean area (Pausas 2004) have shown that although the age of onset of cone production in *P. halepensis* is relatively early (few years), the seed bank is not large enough to remake the population until approximately 15 years (depending on the characteristics of the place).

Thus, in localities with fires recurring in less than 15 years this pine is eliminated. However, with intermediate recurrence there appears a mixed community of *Quercus* and *Pinus* with more or less abundant shrubbery depending on the fire recurrence. Therefore, fires in the area of Los Castillejos might have occurred at particular intervals, provoked mainly to clean the open areas and encourage the re-sprouting of pasture for livestock.

In the same anthracological Phase 3, there is an inverse relation between *P. halepensis* and *A. unedo*. This trend gives a clue to how the same pre-forest areas or more or less cleared areas are occupied. It is remarkable that in Phase 20, the beginning of MF4, when fires appear to have ceased and *P. halepensis* almost disappeared, *A. unedo* reached its maximum abundance as did shrub species (Fig. 2). The presence of *A. unedo* is indicated throughout recent prehistory of central Andalusia at the sites of Cueva del Toro (Rodríguez-Ariza 2004), Polideportivo de Martos, Marroquíes Bajos, and especially at Cueva de los Murciélagos de Zuheros (Rodríguez-Ariza 2011). At this latter site, it has been suggested that *A. unedo* in MZ3, corresponding to the Neolithic, could represent the peak of forest vegetation in the zone, with a species composition very similar to that of Los Castillejos.

After this Phase 21 (Late Copper Age I, towards 2500 BC), fully in anthracological Phase 4 (MF4), when the presence of *Q. faginea* and the other *Quercus* spp. increases considerably, rising from 14.5% in Phase 20 to 23.1% in Phase 21 and to 37.4% in Phases 22 and 23. Such an increase is somewhat unusual, and thus implies forest regeneration and the recovery of tree species. This may not be only due to the change in the environmental conditions indicated above but also to a change in subsistence strategies. Thus the carpological studies detect in these phases a change in the main species consumed. Again, *Triticum aestivum/ durum* appeared as the most consumed taxon, together with *Hordeum vulgare* (naked), *T. monococcum* and the appearance of *H. vulgare* (hulled), whereas *Vicia*

faba reached greater importance (Rovira 2007). These latter crops could be cultivated successfully in dry fields without irrigation during this period, in contrast to other contemporary sites of the south-eastern Iberian Peninsula (Araus et al. 1997b). In the livestock, bovids again predominate (Riquelme 1997), indicating a moist climate, also evidenced by a strong presence of *Q. faginea*. Therefore, the abandonment of forest-burning practices, together with the change of the species used, both plants as well as animals, may imply that certain areas surrounding the settlement were no longer exploited, especially swales and valley floors, where *Q. faginea* could regenerate in a relative short time (1 or 2 centuries).

The anthracological analysis of Los Castillejos has evidenced an important environmental sequence, which is explained only taking into account the major changes that occurred both in climatic conditions as well as in the economic management of the surroundings. Most of these changes are correlated with the rest of the palaeoenvironmental record compiled at the same site, conveying a similar image of the surroundings. However, some of these changes have no clear correlation with the rest of the prehistoric sites in the region and in the western Mediterranean setting, which shows the environmental singularity of this enclave, indicated by the carbon-isotope and nitrogen study made on cereals from the site (Aguilera et al. 2008), which indicated a slightly wetter and colder climate than the rest of the archaeological sites.

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