Human-landscape interactions in the Conquezuela-Ambrona Valley (Soria, continental Iberia): from the early Neolithic land use to the origin of the current oak woodland

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Abstract

The sedimentological, geochemical and palynological analyses performed in the Conquezuela palaeolake (41º11’N; 2º33’W; 1124 m a.s.l.) provide a detailed, multiproxy palaeoenvironmental reconstruction in one of the key areas of inner Iberian Neolithic colonization. Combined with archaeobotanical and archaeological data from well-dated settlements along the Conquezuela-Ambrona Valley we investigate how environmental conditions may affect both socio-economic adaptations and livelihood strategies of prehistoric communities. The first evidences of early Neolithic occupation in the valley ca. 7250-6450 cal yr BP (5300-4500 BC) coincided with the onset of a period (7540-6200 cal yr BP, 5590-4250 BC) with higher water availability and warmer climate as alluvial environments were substituted by carbonate-wetland environments in the basin. The Conquezuela record supports an early Neolithic colonization of the inner regions of Iberia favored by warmer and humid climate features and with preferential settlement patterns associated to lakes. The maximum human occupation of the valley occurred during the mid-late Neolithic and Chalcolithic (6200-3200 cal yr BP, 4250-1250 BC) as evidenced by the high number of archaeological sites. Although a number of hydrological oscillations have been detected during this period, the intense landscape transformation at basin-scale, leading to a deforested landscape was largely a consequence of widespread farming and pastoral practices. Socio-economic activities during Bronze, Iron and Roman times modified this inherited landscape, but the second largest ecosystem transformation only occurred during Mediaeval times when a new agrarian landscape developed with the expansion of stockbreeding transhumance. The current vegetation cover characterized by patches of holm and marcescent oaks and fields reflects an intense human management combining both extensive herding with agrarian activities in order to transform the previous forested landscape into a dehesa-like system.

Key words: Human-Environment interaction, Neolithic, Palynology, Archaeobotany, Multiproxy reconstruction, Continental Iberia

1. Introduction

Modes and rates of early agriculture spread and the onset of the cultural landscapes at Mediterranean-scale have grabbed the attention of the European archaeological scene during the last decade (Pinhasi et al., 2005; Cortes Sánchez et al., 2012; Zapata et al., 2013; Mercuri, 2014). Since the pioneering study carried out by Sokal et al. (1991), combined phylogenetic analysis and detailed archaeobotanical works have clearly identified first traces of agriculture in the early Holocene (Coward et al., 2008) and related them with the onset of humid climate conditions (Willcox et al., 2009; Haldorsen et al., 2011). Nowadays, it is well-accepted that the European Neolithisation process followed a demic diffusion model originated at the Fertile Crescent (Coward et al., 2008), firstly spreading across southern Levant and eastern Mediterranean islands (Vigne et al., 2012) and reaching the westernmost areas at ca. 7350 cal yr BP (5400 BC) (Zilhão, 2001; Bocquet-Appel et al., 2009). This wave of advance was characterized by the introduction of new crop varieties (Fuller et al., 2014), livestock domestication (Zeder, 2008) and forest clearance, modifying, at least locally, the landscape physiognomy and vegetation structure.

In geographical terms, the early adoption of Neolithic agriculture in the Iberian context followed the previously explained east-west pattern, although controversy exists regarding the timing (Zilhão, 2001). In Mediterranean coastal environments, numerous evidences demonstrate that agriculture was early adopted (Antolín and Buxó, 2011; Cortes Sánchez et al., 2012; Morales et al., 2013; Zapata et al., 2013; Antolín et al.; in press). However, continental areas have been relatively less studied and the paradigm that inner Iberia followed a marginal and secondary colonization has been widely accepted. Recent studies have changed this traditional view and seriously questioned the whole chronological framework of the Iberian Neolithisation (Rojo-Guerra et al., 2006; Alday, 2011; Zilhão, 2011; Utrilla et al., 2013). Particularly, radiocarbon dates performed in short-lived pulse and cereal samples (e.g., Peña-Chocarro et al., 2005a,b; Stika, 2005; Rojo-Guerra et al., 2006, 2008) revealed the presence of Neolithic settlements dispersed in inner Iberia as soon as ca. 7350 cal yr BP (Rojo-Guerra et al., 2008 and references therein).

Multiproxy-based studies provide an unambiguous evidence revealing traces of agricultural and landscape management (López-Merino et al., 2010; Di Rita and Melis, 2013; Revelles et al., in press), but clear evidences for an intense and early landscape transformation in inner Iberia during Neolithisation are still scarce (Carrión et al., 2010 and references therein). Terrestrial archives (particularly lakes) provide integrated reconstructions at a basin-scale of past land use changes and vegetation dynamics (e.g., Morellón et al., 2011; Rull et al., 2011; Corella et al., 2013) and allow a better constrain of the environment where past cultures took place (Cañellas-Boltà et al., 2013). Comparison between changes in arboreal pollen frequencies and synchronous increase in charcoal particles help to evaluate anthropogenic deforestation processes (e.g., Gil-Romera et al., 2008; Morales-Molino et al., 2011). In addition, when archaeobotanical and plant macrofossils are available from nearby, well-dated archaeological settlements, human-induced landscape transformations are easier to infer (Sadori et al., 2010). In fact, the integrated interdisciplinary collaboration including palaeoenvironmental and archaeological research is crucial to achieve a better understanding of human-environment interactions and to explore possible feedbacks between settlement patterns and climate variability (González-Sampériz et al., 2009; Fiorentino et al., 2013; Mercuri et al., 2015; Montes et al., in press).

In this paper we reconstruct the palaeoenvironmental history of the Conquezuela-Ambrona Valley (Soria, Northern Iberian Plateau; Figure 1) during the last 13000 cal yr BP based on the Conquezuela palaeolake record. The region has been intensively surveyed from an archaeological (Shipman and Rose, 1983; Falguères et al., 2006; Terradillos-Bernal and Rodríguez, 2012), palaeobotanical (Ruiz-Zapata et al., 2003) and palaeontological (Villa et al., 2005) point of view. The first human occupations in this area occurred during the Acheulean industrial complex, Mid Pleistocene (ca. 350,000 cal yr BP, Villa and D'Errico, 2001; Falguères et al., 2006; Santoja and Pérez-González, 2010). However, the environmental conditions during the first postglacial settlements are not well-constrained. In this contribution we document and date the first evidence of human-induced landscape transformation in a continental area of the Iberian Peninsula, applying a multiproxy strategy to a lacustrine record. Comparison with local archaeobotanical data allowed us to test possible environmental and/or socio-economic processes involved in the cultural changes during the onset of the Neolithic and the relationships between climate conditions and vegetation dynamics up to Mediaeval times.

2. Site description

The Conquezuela palaeolake (41º11'N; 2º33'W; 1124 m a.s.l.; Figure 2A) is located in the eastern fringe of the Iberian Northern Plateau, among the headwaters of the Duero, Tajo and Ebro River basins (Figure 1). The Conquezuela Basin sits on Upper Triassic claystones (Keuper facies) bounded by Triassic sandstones to the north and Jurassic and Cretaceous sandstones and marls to the south (Terradillos-Bernal and Rodríguez, 2012). The formation of the Conquezuela Basin was likely favored by karstification processes affecting the Upper Triassic formation since the Early Pleistocene. Active karstic, weathering and denudation processes culminated with the development of the endorheic Conquezuela-Ambrona Basin, later captured by the Masegar River, a tributary of the Jalón River (Pérez-González et al., 1997; Falguères et al., 2006). While the eastern Ambrona sector was captured by the Jalón River drainage basin and progressively eroded by fluvial incision, the western Conquezuela sub-basin remained a semi closed-basin, only fed by small creeks and with an ephemeral outlet to the northeast (Figure 2A).

Low annual rainfall values and large thermal amplitude define the regional climate as continental Mediterranean type. The mean annual temperature (Valdelcubo station, 1103 m a.s.l.) is 10.8 ºC, with large daily and monthly oscillations, and the precipitation (annual average 471 mm) follows the typical Mediterranean pattern with maximum values during spring and autumn. Annual potential evapotranspiration rate is relatively high (up to 656 mm) and there is negative water balance at least from June to September.

The vegetation landscape in the Conquezuela-Ambrona Valley has been noticeably modified in order to expand agrarian activities (Figure 2B). Main crops are cereals but also sunflowers and flax have been extensively cultivated (Stika, 2005). The natural vegetation belongs to the current mesomediterranean bioclimatic belt, and includes

Quercus rotundifolia and *Q. faginea* communities along with *Juniperus communis*, *Cistus laurifolius*, *Thymus zygis*, *T. vulgaris*, *T. mastichinia* and *Lavandula pedunculata*. Siliceous soils developed on the Upper Triassic sandstones (Buntsandstein Formation) support patches of *Quercus pyrenaica* with a shrubland composed of *Crataegus monogyna*, *Rosa canina* and *Prunus spinosa*. Thorny scrubs such as *Genista scorpius*, *G. pumila* and *Erinacea anthyllis* dominate the more degraded and open areas. Sparse *Pinus nigra* stands are located in the eastern sector of the basin and some *P. sylvestris* and *P. pinaster* reforestations are also present (Figure 2B). Regarding the hydroseral communities, *Typha* sp. and *Phragmites australis* predominate, although some species of the genus *Scirpus*, *Epilobium* or *Ranunculus* are also visible. Diverse tree stands formed by *Populus alba*, *Ulmus minor* or *Salix* sp. are also found in the palaeolake surroundings.

The Ambrona-Conquezuela Basin has a large number of Neolithic and Chalcolithic sites (Stika, 2005; Rojo-Guerra et al., 2010) (Figure 2C). There is no archaeological evidence pointing to a previous regional Mesolithic occupation. Neolithic settlements are chronologically placed in two different phases; 1) four sites belong to the early Neolithic period (7250-6450 cal yr BP, 5300-4500 BC) and they had been archaeobotanically studied in detail by Stika, (2005), and 2) complex megalithic tombs wide spreading along the valley belong to the mid-late Neolithic (6450-4950 cal yr BP, 4500-3000 BC) (Rojo-Guerra et al., 2010). Finally, during the Chalcolithic (4950-3950 cal yr BP, 3000-2000 BC), an exponential increase in the number of settlement occurred (Figure 2C).

3. Material and methods

In 2010, a 206 cm-long core was retrieved from the Conquezuela palaeolake area using a Van Walt/Eijkelkamp mechanical drilling machine. The core was split lengthwise, and sedimentary units and facies described following Schnurrenberger et al. (2003) criteria. Images were obtained using a digital Color Line Scan Camera attached to the Avaatech XRF Core Scanner.

XRF measurements at 1 cm resolution were obtained with an Avaatech XRF Core Scanner using two different settings: 10-s count times, 10 kV X-ray voltage, and an X-ray current of 1000 μA for light elements (Al, Si, S, Cl, K, Ca, Ti, V, Mn and Fe) and 25-s count times, 30 kV voltaje and 2000 μA for heavy elements (Ni, Cu, Zn, Ga, As, Rb, Br, Y, Zr and Pb). Element concentrations are not directly available but the obtained intensity values in counts per second (cps) can be used to estimate relative concentrations. In addition, 79 samples for total organic carbon (TOC), total inorganic carbon (TIC) and total nitrogen content (TN) were analyzed in the IPE-CSIC laboratory of Zaragoza, with LECO SC 144 DR and VARIO MAX CN elemental analyzers. TOC and TIC values are expressed in percentages.

58 samples for pollen and non-pollen palynomorphs (NPPs) were taken every 2-3 cm and prepared at the IPE-CSIC. In addition, 12 moss samples (labeled as CQM) were collected in order to characterize the modern pollen rain-vegetation relationship in the Conquezuela palaeolake surroundings (Figure 2B). Laboratory procedure follows standard chemical method (Moore et al., 1991) with HF (40%), HCl (37%), KOH (10%) and Thoulet solution (density = 2.0). Acetolysis was performed on moss samples.

Pollen identification was supported by the reference collection from IPE-CSIC, determination keys and photo atlases (Reille, 1992). The pollen sums range from 108 to 449 grains with an average and standard deviation of 337 and 97 respectively. A total of 110 palynomorph taxa were identified. *Pinus pinaster/halepensis* pollen type was differenced from *Pinus nigra/sylvestris* type following the suggestions of Carrión et al. (2000). *Spirogyra* algae as well as the Type 128 palynomorph were recognized based on specific literature (van Geel, 1978; Carrión and van Geel, 1999). Palynological results are expressed as percentages, excluding hygrophytes, hydrophytes, ferns and NPPs from the pollen sum. A stratigraphically constrained cluster analysis by the method of incremental sum of squares (Grimm, 1987), has been applied to the terrestrial pollen dataset in order to establish pollen zones. CONISS analysis was performed in Psimpoll v.4.27 (Bennett, 2009).

The pollen rain-vegetation relationship was explored aiming to define the real presence of oaks in our fossil spectra. We defined palynologically the oak communities in the near vicinity of the palaeolake by applying a Bray Curtis dissimilarity coefficient to our 12 modern pollen samples. We used a paired, UPGMA clustering method to the surface pollen data. UPGMA dendrogram has been constructed in R software (*Vegan* package, R Core Team, 2012).

The Conquezuela palaeolake depth-age model is based on 9 AMS ^{14}C samples obtained from bulk sediment and performed using *Clam* software package (Blaauw, 2010).

4. Results

4.1. Sedimentary sequence

Visual description, smear slides microscopic observation and geochemical analyses (XRF elements and ratios together with TOC, TIC and atomic TOC/TN) allowed characterization of sedimentary facies and sedimentological units in the Conquezuela sequence. From base to top, four main sedimentary units have been defined (Figure 4).

UNIT-4 (206-153 cm depth) is composed of massive, carbonate and siliciclastic gravels and sands, with a very low organic content (TOC < 1%). Geochemically, this unit is characterized by the highest Zr/Rb ratio coherent with the coarser and detrital nature of the sediments, and the lowest Sr/Ti also indicative of dominance of allochtonous siliciclastic minerals. Both, sedimentary and geochemical features point to deposition in an alluvial setting.

UNIT-3 (153-95 cm depth) groups light-colored carbonate-rich massive to banded silts. These sediments are characterized by a decreasing grain-size trend (lower Zr/Rb values), lower siliciclastic content (low Al, Si values) and increasing carbonate content (higher Ca/Ti, Sr/Ti ratios and TIC percentages). This unit represents the onset of sedimentation in a shallow lake still with low bioproductivity but high rates of carbonate production in the palustrine belt.

UNIT-2 (95-44 cm depth) is composed of organic and carbonate-rich silts. The unit is characterized by an increase in organic matter and a decrease in atomic TOC/TN ratio, indicative of the change from land-based vascular plants (values around 18-20) to mainly algal dominance (values 11-13) (Meyers and Lallier-vergés, 1999). This unit can be divided into three sub-units. Sediments in SUB-2C (95-80 cm depth) have higher siliciclastic content, although with increasing values of Ca/Ti and Fe/Mn ratios (Figure

4). During SUB-2B (80-60 cm depth), this trend is reverted with a marked reduction in the carbonate content (Ca/Ti) and an increase in fine siliciclastics (Al, Si). In SUB-2A (60-44 cm depth) carbonate content rise again (Figure 4). The sediment variability in UNIT-2 is common in wetland-shallow lake settings, where a mosaic of depositional environments occurs. Changes in carbonate content in the sediments are associated to better development of littoral paludal environments, commonly related to a decrease in lake level.

UNIT-1 (44-0 cm depth) is composed of organic-rich silts with the highest percentages of TOC (up to 5 %) and the lowest values of TOC/TN ratio (up to 10). Besides, maximum values of the fine siliciclastic fraction are attained in this unit (high Si and Al and low Zr/Rb), carbonate content are the lowest (Figure 4). These sediments were deposited in a wetland dominated by organic productivity with limited palustrine carbonate forming processes. The top 15 cm interval shows evidence of modern soil processes and bioturbation.

4.2. Chronological model

The depth-age model for Conquezuela palaeolake sequence (Figure 3) is based on 9 AMS ^{14}C samples obtained from bulk sediment (Table 1) and calibrated using the latest INTCAL13 curve (Reimer et al., 2013) implemented in *Clam*, software package for classical, non-Bayesian, age modeling (Blaauw, 2010). The sedimentary record (from ca. 13000 to 540 cal yr BP) shows a highly variable sedimentation rate (Figure 3). A sedimentary hiatus likely occurs within UNIT-4, between the two lowermost dates. Abrupt sedimentological changes in UNIT-4 (Figure 4) and the null pollen preservation (see further details below), also suggest a major hiatus covering the Lateglacial and early Holocene periods. The sedimentation rate increases during UNIT-3, reaching up to 14.45 yr cm^{-} and greatly decreases in UNIT-2 (ca. 114 yr cm^{-}). The top UNIT-1 has an intermediate accumulation rate, ca. 21.74 yr cm^{-} (Figure 3) as a response to a rapid organic accumulation in the wetland (Figure 4). Periods of higher sedimentation rate correspond to phases of dominant carbonate (UNIT-3) or organic (UNIT-1) production in the wetland-lake complex.

4.3 Pollen sequence

According to the CONISS analysis, 5 main vegetation zones (CQ) have been defined and roughly follow the units established by the sedimentological sequence. Pollen, spore and NPP preservation and diversity was good except in sedimentary UNIT-4. The summary pollen diagrams are plotted in the Figures 5A and 5B.

CQ-5 (206-145 cm depth, 13020-7540 cal yr BP, UNIT-4): 13 samples have been analyzed in this section; however none of them contains enough pollen to be included in the diagrams.

CQ-4 (145-99 cm depth, 7540-6200 cal yr BP, UNIT-3): The highest frequencies of *Pinus nigra/sylvestris* type (> 60%) together with the continuous presence of *Juniperus*, *Quercus faginea/pyrenaica* type and *Quercus ilex/coccifera* type characterize the pollen assemblage of this period (Figure 5A). The first Cerealia type record is found at ca. 7380 cal yr BP while Fabaceae, Cichorioideae or Asteraceae appear but still showing low values. Hygro-hydrophytes, *Spirogyra*, as well as Type 128 palynomorph, attain the lowest frequencies of the whole sequence while *Glomus* peaks are recorded (Figure 5B).

CQ-3 (99-64 cm depth, 6200-3200 cal yr BP, SUB-2C, SUB-2B): The frequency of anthropogenic-related indicators increase at the same time of a remarkable and long-term decrease in *Pinus nigra/sylvestris* type (Figure 5A). Cichorioideae attach the highest frequencies, followed by Chenopodiaceae, Brassicaceae, Fabaceae, Polygonaceae and Lamiaceae, denoting a progressive landscape opening (Figure 5A). *Juniperus*, *Quercus faginea/pyrenaica* type and *Quercus ilex/coccifera* type are also continuously recorded. Overall, both mesophytes and Mediterranean taxa do not attain high frequencies. Hygro-hydrophytes, *Spirogyra* algae and Type 128 do not show marked changes with respect to the previous trend (Figure 5B).

CQ-2 (64-40 cm depth, 3200-930 cal yr BP, SUB-2A): A partial recovery in the arboreal pollen is recorded, *Pinus nigra/sylvestris* type being the main favored taxon. *Pinus pinaster/halepensis* type also increase and *Juniperus* is continuously recorded. Anthropogenic-related indicators, however, remain high and probably well-represented locally (Figure 5A). Towards the end of the zone a progressive increase in Cyperaceae and *Juncus* is observed, synchronous to the development of *Spirogyra* and the Type 128 palynomorph (Figure 5B). Sordariales shows an exponential increase.

CQ-1 (40-16 cm depth, 930-540 cal yr BP, UNIT-1): Arboreal pollen presents minimum values as a consequence of *Pinus nigra/sylvestris* type decrease. However, *Pinus pinaster/halepensis* type, *Juniperus*, *Quercus faginea/pyrenaica* type and *Quercus ilex/coccifera* type report slight increases (Figure 5A). Cerealia type, Fabaceae and *Trifolium* type are well represented, paralleling other nitrophilous and ruderal taxa like *Artemisia*, Cichorioideae, Asteraceae, Chenopodiaceae, Brassicaceae, *Plantago*, *Urtica* and Polygonaceae that reveal a noticeable expansion (Figure 5A). *Olea* and

Juglans report continuous frequencies. An exponential increase is observed in Cyperaceae that is followed by *Juncus*, *Myriophyllum alterniflorum* type, *Spirogyra* and Type 128 (Figure 5B). Sordariales reach their highest values together with *Glomus*. The change observed in the hygro-hydrophyte assemblage is also highlighted by the sedimentological and geochemical proxies defined in UNIT-1.

4.4. Modern pollen-vegetation relationship

The 12 moss polsters collected from the surroundings of the Conquezuela-Ambrona Valley (Figure 2B) reveal different pollen spectra in comparison to the fossil assemblages, especially regarding the frequencies acquired by both evergreen and marcescent oaks. The results of the cluster analysis separate two main groups of moss samples (Figure 6).

The **first cluster** comprises pollen types corresponding to the samples collected from open and degraded areas (samples CQM-11, CQM-3, CQM-12, CQM-10, CQM-8, and CQM-9) where an open, patched thorny scrubland of *Genista scorpius*, *G. pumila* and *Erinacea anthyllis* dominate (Figure 2B). Overall, Poaceae, anthropogenic and nitrophilous indicators like Cerealia type, Asteraceae, *Cirsium/Carduus* type, Chenopodiaceae and *Plantago* characterize the pollen assemblage. Shrubs like *Juniperus*, *Genista*, *Cytisus/Ulex* type and heliophytes such as *Cistus* and *Helianthemum* are also well represented. *Quercus faginea/pyrenaica* type and *Quercus ilex/coccifera* type do not present high values. Although sparsely recorded and confined to the eastern sector of the Conquezuela-Ambrona Valley (Figure 2B), *Pinus* *nigra/sylvestris* values are well recorded in the samples collected from the open environments.

The **second cluster** (samples CQM-4, CQM-6, CQM-7, CQM-1, CQM-2, and CQM-5) indicates noticeable frequencies of *Quercus faginea/pyrenaica* type and *Quercus ilex/coccifera* type, followed by *Olea* and shrubs like Rosaceae, *Prunus* type and Lamiaceae (Figure 6). This assemblage defines well the landscape where the moss samples were collected, comprising diverse patches of *Quercus rotundifolia*, *Q. faginea* and *Q. pyrenaica* along with diverse shrubs such as *Rosa canina*, *Crataegus monogyna*, *Prunus spinosa* and *Lavandula pedunculata*, as shown in the Figure 2B. In these moss samples, *Pinus nigra/sylvestris* type does not present high frequencies whereas Poaceae, anthropogenic and nitrophilous indicators are almost absent (samples CQM-4, CQM-6, CQM-7) (Figure 6)**.**

5. Discussion

The sedimentological, geochemical and palynological analyses carried out in the Conquezuela palaeolake provide a detailed reconstruction of the landscape evolution in one of the most representative areas of the Neolithic colonization in inner Iberia (Rojo-Guerra et al., 2008). Comparison of the carpological research carried out by Stika, (2005) from the nearby La Lampara and La Revilla settlements and our pollen results (Figure 5A) helped to characterize the land use changes developed in the region since the early Neolithic. The occurrences of a large number of well-dated archaeological sites in the Ambrona-Conquezuela Valley also allow discussing the links between environmental factors and human settlement patterns since the first postglacial occupations. Overall, six phases in the landscape evolution have been established.

5.1 Pre-Neolithic alluvial environment in the Conquezuela-Ambrona Valley (13000 to 7540 cal yr BP)

Coarse siliciclastic sediments at the base of the sequence indicate a dominant alluvial environment in the basin during the Lateglacial and early Holocene (ca. 13000- 7540 cal yr BP). Alluvial fans from the basin margins developed and reached the coring site and the center of the basin. Unfortunately, the lack of a coherent chronological model for this interval (Figure 3) and the absence of pollen remains prevent further interpretation of landscape characteristics during this period.

5.2 Early Neolithic settlements, pinewoods and first traces of landscape management (7540-6200 cal yr BP, 5590-4250 BC)

The mid Holocene (7540-6200 cal yr BP, 5590-4250 BC) landscape in the Conquezuela-Ambrona Valley was characterized by a conifer forest, mainly composed of *Pinus sylvestris* and/or *Pinus nigra* stands with juniper (Figure 5A). More than 1600 needle fragments were discovered in La Peña de la Abuela settlement (Figure 2B) (Stika, 2005) and also the anthracological data collected from archaeological sites suggest local pinewoods dominance (Carrión and Badal, 2005). Radiocarbon dates performed on *Pinus nigra/sylvestris* type charcoal remains revealed that montane pine was the main collected taxon near La Lámpara settlement (Figure 2C) at least between 7136±33 and 6608±35 yr BP (7965-7500 cal yr BP, 6015-5550 BC) (Figures 7 and 8B) (Table 2). The complete dominance of *Pinus nigra/sylvestris* type in the Conquezuela palaeolake pollen record noticeably differs from other continental Mediterranean regions where *Quercus ilex* together with *Quercus faginea* types were the main spread communities during this period (Carrión et al., 2001). However, montane pinewoods dominance even during the most humid and thermal Holocene phases, is not limited to our study area. It has been well-documented by means of pollen and macrofossil data in numerous sequences located along the Central Range (Franco-Múgica et al., 1998; Rubiales et al., 2007; Rubiales and Génova, in press), northern Iberian Range (Peñalba, 1994; García Antón et al., 1995; García-Amorena et al., 2011) or in the Albarracín Range (Stevenson, 2000; Aranbarri et al., 2014). A modeling approach carried out by Benito Garzón et al. (2007) coupled with the results obtained by Cheddadi et al. (2006), highlights a broader distribution of *Pinus sylvestris* in the Iberian Peninsula for the mid Holocene, especially at the meso- and supramediterranean belts. Pinewood persistence in continental Iberia throughout the whole Holocene responds to pine ecophysiological traits as distribution is defined by complex soil-related autoecological aspects and the lack of potential competitors (Rubiales et al., 2010). The vegetation around Conquezuela palaeolake seems to have followed a similar pattern revealing a new example of pinewood resilience in inner Iberia.

Regarding hydrological fluctuations, the progressive change in both sedimentological and geochemical indicators in the Conquezuela sequence at the top of UNIT-4 revealed the development of carbonate-producing lake environments at least since ca. 7540 cal yr BP (5590 BC) (Figure 4). This depositional change from alluvial to lacustrine reflects a significant increase in the local water-table and a more positive water balance in the basin. In particular, the decrease in Zr/Rb, the coeval increase in TIC, Ca/Ti and Sr/Ti ratios illustrate the establishment of a carbonate lake (Figure 4). Carbonate formation in the palustrine belt could have been favored by the increase in temperatures. The lower

Al and Si values suggest a runoff decrease. At a regional scale, slightly higher lake levels compared to the onset of the Holocene have been also registered in other Mediterranean-climate sequences like Lake Estanya (Morellón et al., 2009) or Villarquemado palaeolake (Aranbarri et al., 2014) (Figure 1), as a possible effect of southern penetration of westerlies (Vannière et al., 2011).

The archaeobotanical remains described by Stika, (2005) in several Ambrona sites revealed the oldest cultivated cereals in continental Iberia dated between 7240 and 7010 cal yr BP (5290 and 5060 BC). *Triticum monococcum* (einkorn) and *T. dicoccum* (emmer) dominated the overall crop spectrum, but also some *Hordeum vulgare* (barley) remains were identified in La Lámpara and La Revilla settlements (Figure 8C). The first appearance of Cerealia type in the Conquezuela pollen sequence occurred at ca. 7380 cal yr BP (5430 BC) although it is just a presence not indicative of significant agricultural activities (Figure 5A). The limited presence of pollen grains in the sequence, however, is to be expected because of the cereal pollen production strategy, since some genera are autogamous (e.g., *Hordeum* or *Triticum*) and their large pollen size (> 40 µm) greatly hampers the surface area distribution (Fyfe, 2006). Palynological data demonstrate that cereal presence is not continuously recorded far from cultivated fields (Mercuri et al., 2013a). In the Ambrona-Conquezuela Valley, early agricultural practices seem to have been confined in the eastern areas, next to La Lámpara and La Revilla settlements (Figure 2C), but not necessarily around the palaeolake.

Human responses to climate variability during the Neolithic have been widely reported in the Mediterranean Basin (Roberts et al., 2011 and references therein). Recently Fiorentino et al. (2013) concluded that variations in agricultural practices were directly related to changes in the precipitation regime, with drastic reduction of occupation linked to recurrent arid spells. Changes in the human livelihood strategies and cultural trajectories seem to have been coincident to major climate changes at the circum-Mediterranean Basin (Mercuri et al., 2011). Although taking into account that the Neolithisation process is a really complex cultural period with many abiotic, biotic and social factors intrinsically involved, early Neolithic colonization of the inner regions of Iberia seems to have occurred under warm and humid climate conditions with settlement patterns commonly associated to large water bodies.

5.3. Pinewoods deforestation, landscape management and hydrological variability during the mid-late Neolithic and Chalcolithic (6200-3200 cal yr BP, 4250-1250 BC)

The human impact near the Conquezuela palaeolake landscape increased during this phase (6200-3200 cal yr BP, 4250-1250 BC), considerably modifying the vegetation physiognomy. Pinewoods were cleared in order to obtain new farmlands, but probably also for building purposes (Figure 5A) (Carrión and Badal, 2005). Anthracological data reveal that the montane pine still was the main exploited taxon between 5308±31 and 4773±29 ^{14}C yr BP (6085-5520 cal yr BP, 4135-3570 BC) (Table 2) (Carrión and Badal, 2005). This is coherent with the Conquezuela palaeolake pollen signal of a long-term use of pine wood (Figures 8A and 8B). Some pine wood remains presented wood-working activity. Montane pine was probably chosen for supporting structures like beams and posts, due to its high wood durability and density (Ntinou et al., 2013). In fact, the mid-late Neolithic period (6450-4950 cal yr BP, 4500-3000 BC) in the Conquezuela-Ambrona Valley was characterized by the development of semicircular funerary structures demanding large amount of fuel for combustion and crematory practices (Rojo-Guerra et al., 2005, 2010). All the radiocarbon dates were correlated with the high amount of Bell-Beaker pottery fragments discovered along the numerous archaeological settlements of the area (Figure 2C) (Morán-Dauchez, 2006).

Weeds like *Atriplex* sp., *Chenopodium* cf. *album* (Chenopodiaceae), *Heliotropium* cf. *europaeum* (Boraginaceae), *Polygonum aviculare* (Polygonaceae), *Fallopia convolvulus*, and *Descurainia sophia* (Brassicaceae) have been identified as the common plants growing in the nearby fertile arable lands, at least during the early Neolithic (Stika, 2005). During this period also the Conquezuela pollen spectra included Chenopodiaceae, Polygonaceae and Brassicaceae curves (Figure 5A). Cereals continued to be poorly represented in our pollen results. As seen in the previous phase, only isolated grains were identified, those were not cultivated in the lake surroundings. Fabaceae seem not to be especially abundant in the pollen assemblages, neither in the archaeobotanical finds (Stika, 2005). The Neolithic levels of Los Cascajos open-air settlement (Figure 1) reported similar conclusions (Peña-Chocarro et al., 2005a) while in La Vaquera cave only few finds of *Lens* sp. (lentil) and *Vicia sativa* (common vetch) were recovered from the post-Neolithic layers (López García et al., 2003) (Figure 1). The explanation for the relatively reduced crop diversity in the settlements located along the Conquezuela-Ambrona Valley may be attributed to the harsh environmental conditions and the low fertility soils. This contrasts with the broad spectrum of legumes produced by the early Neolithic sites located in the Iberian Mediterranean coast (Antolín et al., in press), northern Africa (Morales et al., 2013), or the Pyrenees (Lancelotti et al., 2014).

The exponential rise in Cichorioideae characterizing the Conquezuela palaeolake sequence during the mid Holocene deserves a special mention (Figure 5A). Despite high Cichorioideae pollen frequencies in Mediterranean archaeological contexts have been traditionally associated to human presence, recently, it has been clearly identified as pasture indicator, revealing traces of animal breeding and grazing areas where no apparent pollen re-deposition, concentration or preservation issues are present (Florenzano et al., 2015). Modern pollen analogues performed in continuously grazed areas show simultaneous, local occurrence of Cichorioideae, Asteraceae or *Cirsium* type in the pollen results (Mazier et al., 2006) similar to the assemblage recorded in the Conquezuela palaeolake (Figure 5) but also in the surface moss polsters (Figure 6). This is coeval to the rise of nitrophilous and ruderal taxa like *Plantago* and *Urtica* (Mercuri et al., 2013b) and of *Glomus*, commonly associated with trampled areas (Abel-Schaad and López-Sáez, 2012). These characteristics, continuously recorded in our study during the late Neolithic and Chalcolithic (Figure 5A), were followed by peaks in Sordariales, pointing to pastureland management of the nearby areas. Animal husbandries in intensive Neolithic farming systems like those found in Conquezuela-Ambrona Valley, have been linked to both production and traction as well as to woodland clearing practices (Antolín et al., 2014). The zooarchaeological data retrieved from La Peña de la Abuela and La Sima sites (Figure 2C) reveal the presence of a local husbandry dominated by ovicaprine herding with occasional remains of *Bos* sp. and *Sus* sp. (Liesau and Montero, 2005). Economic activities centered on pastureland management and cereal farming, along with large-scale woodland deforestation and animal production, suggests a specialized economy, a common feature in Neolithic societies (Antolín et al., 2014).

Sedimentological and geochemical indicators from Conquezuela palaeolake sequence reveal recurrent hydrological oscillations in a wetland setting from carbonate-producing to more detrital depositional environments during the 6200-3200 cal yr BP (4250-1950 BC) interval (Figure 4). Carbonate formation (higher Ca/Ti, Sr/Ti, TIC) and frequent oxidation processes (higher Fe/Mn) continue to be dominant during SUB-2C (until ca. 5120 cal yr BP, 3170 BC), highlighting the abundance of palustrine environments in a relatively shallow lake. By contrast, this trend is slightly reverted during SUB-2B (5120-3200 cal yr BP, 3170-1950 BC), with the simultaneous increase in detrital input (Si, Al) along with the coeval decrease in carbonate proxies (Ca/Ti, Sr/Ti, TIC). This short period of augmented runoff could be related to an increase in precipitation or changes in the forest cover in the watershed as shown by the pollen diagram (decrease in pine, numerous pollen indicators of watershed disturbance) (Figure 4).

The long-term hydrological variability recorded in Conquezuela palaeolake from a carbonate lake to an organic-dominated wetland reflect a water table lowering that matches the general western Mediterranean palaeoenvironmental history, with higher lake levels during the early Holocene and a general aridity increased towards the mid Holocene (Magny et al., 2012). Well-dated hydrological and palynological sequences evidenced a remarkable shift in the precipitation regime toward more seasonal conditions that started during the second half of the Holocene (Di Rita and Magri, 2009; Sadori et al., 2011; Magny et al., 2012; Magri et al., 2015). Roughly, broadleaves trees start losing their dominance at the Iberian-scale (Carrión et al., 2010 and references therein) while pinewoods and sclerophytes spread in continental Mediterranean environments (Carrión and van Geel, 1999; Aranbarri et al., 2014). Similarly, Lake Estanya (Morellón et al., 2009), Basa de la Mora (Pérez-Sanz et al., 2013) and

Villarquemado palaeolake (Aranbarri et al., 2014) (Figure 1) reported a trend toward lower lake levels after ca. 5000 cal yr BP. Atmospheric mechanisms explaining pronounced and recurrent droughts in the western and central Mediterranean Basin, has been presumably linked to the southward migration of the ITCZ (Di Rita and Magri, 2009; Vannière et al., 2011).

In the Conquezuela-Ambrona Valley, anthropogenic impact clearly affected the surrounding vegetation structure, hampering to easily discern its natural dynamic. Long-term disturbed landscapes like those inferred by the Conquezuela palaeolake record likely represent locally-induced land use changes. Nevertheless, the background trend towards an arid climate (Carrión et al., 2010; Sadori et al., 2011) may have also contributed buffering the regional vegetation replacement and therefore, both anthropogenic and climate variables should be considered as possible drivers.

5.4. Pinewoods recovery and long-term lake lowering (3200-930 cal yr BP, 1950 BC-1020 AD)

After 3200 and till 930 cal yr BP (1950 BC-1020 AD) montane pinewood recovered (Figure 5A), although the lack of archaeobotanical remains and macrofossil evidences make it difficult to discern if pines were located near the lake or in the surrounding mountains. Pollen sequences relatively close to the Conquezuela palaeolake, like Somolinos tufa Lake (Currás et al., 2012) or Pelagallinas peatbog (Franco-Múgica et al., 2001a) (Figure 1), also showed the presence of pinewoods during the late Holocene, occasionally punctuated by human-induced deforestation processes linked to increased fire-activity and contemporaneous rise in ruderal and nitrophilous elements.

Nevertheless, a trend towards oak dominated open woodland, shaping the present landscape, was progressively appreciable in many different sequences during pre-Roman (Uzquiano et al., 2012) and Roman times (Moreno et al., 2008; Currás et al., 2012).

In the Conquezuela palaeolake sequence, woodland recovery may have been related to a change in the local settlement pattern towards more-strategically positioned elevations. In addition, a demographic reduction or large-scale migration pattern may have also caused a lower human impact in the regional vegetation. Post-Chalcolithic sites significantly reduced in number along the Conquezuela-Ambrona Valley and those found were located at higher altitudes (Morán-Dauchez, 2006).

Although it is not possible to define the spatial distribution of communities and human activities using exclusively regional palynological proxies, the coeval increase in Cerealia type and the rise in arboreal pollen, mainly *Pinus nigra/sylvestris* type, suggest different pollen source areas reaching the basin. Cereal-based agriculture continued or even spread in the Conquezuela palaeolake surroundings (Figure 5A). Ruderals, nitrophilous taxa and indicators of pastoral activities (Cichorioideae, Asteroideae, *Cirsium/Carduus* type, some Fabaceae, *Trifolium* type, Chenopodiaceae, Polygonaceae) still predominated locally, although in lower frequencies than during the mid-late Neolithic and Chalcolithic periods (Figure 8A). This may partially reflect the reforestation of wide areas by montane pinewoods, previously dedicated to extensive herding management (Figure 5A), and therefore, partial abandonment of pastureland activities. In fact, *Plantago* and Sordariales did not attain the high values previously recorded.

Although a lowering lake level trend started at the base of UNIT-2 (ca. 5800 cal yr BP, 3850 BC), changes in sedimentation patterns at the base of SUB-2A (around 3200 cal yr BP, 1950 BC) suggest a decreasing lake level conducive to development of paludal environments where carbonate production and organic accumulation increased while siliciclastic supply to the lake slightly decreased (Figure 3). The onset of UNIT-1 brought a larger hydrological shift, with the definitive colonization of the basin by vegetation and the concomitant development of dense sedge and reed communities (*Juncus*, Cyperaceae and overall, hygro-hydrophytes) (Figure 5B).

The reduction or even absence of Iron Age, pre- and Roman-period sites in the Conquezuela-Ambrona Valley was directly associated with changes in the settlement patterns towards defensive positions instead of climatically-induced adaptations. Population migration towards urban areas likely represented a social and economic change in an urban livelihood, especially under the Roman Hispania (i.e. Occilis, current town of Medinaceli), leading reforestation processes occur in the previous disturbed rural areas.

5.5. Agrarian landscape development between 930-540 cal yr BP (1020-1410 AD) in the Conquezuela- Ambrona Valley

Forest communities presented the minimum values of the whole sequence during this period (Figure 5A), while an agrarian landscape expanded in the area. Cereal fields widespread as deduced by the continuous and high values of Cerealia type. Overall, the same trend was followed by ruderals and nitrophilous taxa like Chenopodiaceae, Brassicaceae, Fabaceae, *Trifolium* type and Polygonaceae (Figures 5A and 8A). Additionally, regional sequences, like the nearby Somolinos tufa lake (Currás et al., 2012) but also in many continental records like Taravilla Lake (Moreno et al., 2008), Espinosa del Cerrato (Franco-Múgica et al., 2001b), Lake Arreo (Corella et al., 2013), Lake Montcortès (Rull et al., 2011) or Lake Estanya (Morellón et al., 2011) (Figure 1), showed a continuous Cerealia type curve with values up to >3 % since Roman times, indicating that the agricultural intensification occurred simultaneously at a regional scale. In general, cereal-based agricultural landscape in both Northern and Southern Iberian Plateaux, as well as in the Ebro Valley, were more intensively developed during Mediaeval times, being barley (*Hordeum vulgare*) and free-threshing wheat (*Triticum aestivum/durum*) the main produced crops (Alonso, 2005; Vigil-Escalera et al., 2014).

The rise in arboricultural pollen indicators was also remarkable (Figure 5A). Although walnut pollen is discontinuously recorded since 5330 cal yr BP (3380 BC) and therefore demonstrating its native character (Carrión and Sánchez-Gómez, 1992), the coeval increase of olive groves likely represent a regional cultivation especially during post-Roman times. The synchronous increase in *Olea* and *Juglans* together with *Castanea* and *Vitis* in the pollen assemblages have been defined as a clear marker for tracing human pressure in Mediterranean environments (Abel-Schaad and López-Sáez, 2012; Kouli, 2012; Mercuri et al., 2013a). Nevertheless, a detailed archaeobotanical research is needed in order to detect the local exploitation of economic valuable taxa and infer changes in the local production systems.

The exponential rise in Sordariales along with the contemporaneous increase in Poaceae, *Plantago*, *Urtica*, *Glomus* chlamydospores and moderate Cichorioideae values suggests pasturelands management in the watershed (Figures 5A and 5B). It is well-known that Mesta system played a major role in Castilian rural territories since the 13th century (Rodríguez-Picavea, 2010). Protected under the Crown of Castile, woodlands were leaved at service of transhumant livestock shaping the forested landscape into open pasturelands (Valbuena-Carabaña et al., 2010).

The change towards a vegetated wetland environment with limited open-water areas is recorded by the expansion of sedges and meadows that densely colonized the basin (Figure 5B). The simultaneous increase in TOC and atomic TOC/TN curves coeval to the spread of diverse hygro-hydrophyte taxa like *Juncus* or Cyperaceae indicate the development of an environment conducive to organic-rich silt deposition and peat accumulation (Figures 4 and 5B). The continuous lake-infilling is also well-demonstrated by the expansion of *Spirogyra* that commonly grows under shallow and stagnant waters (van Geel, 1978). However, the persistence of submerged aquatic plants (i.e. *Myriophyllum alterniflorum* type, *Potamogeton*) and NPPs like Type 128 indicative of eutrophic waters (van Geel, 1978) (Figure 5B), may reflect a fragmented depositional environment with small ponds near the coring site.

Climate conditions during Mediaeval times have been recently inferred to be dry and warm at Iberian-scale (Moreno et al., 2012). This caused a prominent change in both hydrological and vegetation dynamics and probably allowed the spread of many cultivars (e.g., *Olea*). The development of agrarian practices and the potential role of climate changes, however, should be analyzed carefully and when possible using a high-resolution and multiproxy approach.

In the uppermost 15 cm sediment corresponding to the last 500 years, bioturbation processes and agricultural practices notably disturbed the sediment. Therefore pollen and geochemical analyses have not been taken into account (Figures 4 and 5A). In 1959, the wetland was drained in order to expand agrarian activities and to eradicate possible malarial-ridden swampy areas.

5.6. A human-induced origin of the current mixed oak woodlands?

One of the most conspicuous features of the Conquezuela vegetation history is the reduced spread of evergreen and mascescent oak forest throughout the last ca. 7540 cal yr BP (Figure 5A), especially during the mid Holocene, when sclerophyllous woodland is well recorded in continental Mediterranean Iberia (Carrión et al., 2010; Aranbarri et al., 2014 and examples therein). In fact, pollen-based reconstructed vegetation along the Holocene record noticeably differs from the current landscape, where diverse *Quercus rotundifolia*, *Q. faginea* and *Q. pyrenaica* communities dominate in the more-protected upland areas of Conquezuela basin (Figure 2B). To understand the dynamics of oak populations in the past, we have performed a palynological analysis on modern moss samples to evaluate how current vegetation is represented in the pollen rain at basin-scale. Overall, the pollen spectra obtained from the moss polsters yielded a noticeable variability amongst them. This might be partially explained by the degree of openness in where the samples were collected (Figure 6). As expected, both *Quercus ilex/coccifera* and *Q. faginea/pyrenaica* types are better represented in *Quercus*-dominated dense patches, but they reveal a completely different pollen signature in those samples collected from more open areas. Overall, *Pinus nigra/sylvestris* type attains higher values (Figure 6), whereas *Quercus* pollen frequencies show values similar to our fossil spectra (< 10%) (Figure 5A) and to those results obtained from previous palynological works carried out along the Conquezuela-Ambrona Valley (Ruiz-Zapata et al., 2003).

So, different questions related to the origin of current oak woodland remain unresolved: 1) is the current vegetation the result of a cultural landscape where oak woodland was favored for economic purposes? If so, since when?; 2) is it possible that climate variability occurred during the last 500 years buffered a regional-scale landscape transformation? If so, how?; or 3) is it the sparse presence of oak pollen in the palaeoenvironmental sequence related only to statistical facts or also to pollen productivity and dispersal?.

Regarding the third question, a detailed study focused on oak's PPE (Pollen Productivity Estimates) is needed (Bunting et al., 2004), but this will be the subject of future work.

In relation to natural climate variability, the modern spread of drought-tolerant holm oaks in the area seems not to be directly linked to recent climatic change. Despite the increase in temperatures recorded in the Mediterranean Basin during the last decades (Giorgi et al., 2004), centennial *Quercus* individuals compose the current oak woodland in the area. In addition, it is well-known that during the last 500 years climate in the Iberian Peninsula has been generally more humid and colder (Morellón et al., 2012) in comparison to the previous drier and warmer Mediaeval period (Moreno et al., 2012). Besides, regional pollen records covering this period report pine and broadleaved forest expansion (Moreno et al., 2008; Corella et al., 2013; Pérez-Sanz et al., 2013), synchronous to minor glacier fluctuations (García-Ruíz et al., 2014) and sharp decreases of evergreen *Quercus* pollen frequencies (Pérez-Sanz et al., 2013), chronologically-placed within the Little Ice Age Period. Therefore, climate as a single driver is not able to explain the vegetation change from pine to oak communities in the Conquezuela-Ambrona Valley area during the last centuries, and other variables have to be considered.

The replacement of pinewoods by evergreen *Quercus* communities is not common in the Iberian palaeonvironmental literature, although some records have evidenced the complex interplay between anthropogenic-origin activities and Mediterranean woodland opening, triggered by punctual perturbations such as an increased fire disturbance (Gil-Romera et al., 2010). For example in Navarrés, located in eastern Iberia (Figure 1), palynological data reveal a prominent substitution of *Pinus* by more fine-prone *Quercus* especies as Kermes oak (*Quercus coccifera*) triggered by intermittent episodes of anthropogenic-origin fire activity (Carrión and van Geel, 1999; Gil-Romera et al., 2010). Similar conclusions were obtained from the recently published Neolithic site of Les Ascusses (Figure 1), where a slight decrease in *Pinus pinea* is observed followed by the expansion of evergreen *Quercus* and the pyrophilous NPP *Chaetomium* (Tallón-Armada et al., 2014). In the nearby Somolinos tufa Lake, Currás et al. (2012) report a long-term substitution of *Pinus* by *Quercus ilex* type and linked with the maximum presence of macrocharcoal in the sediment, chronologically placed within the Muslim conquest.

Additionally, both evergreen and marcescent oaks, the dominant taxa in current vegetation landscape of Conquezuela area, are strong re-sprouters and they formed multi-stemmed tree forests after recurrent coppicing (Figure 6, photo from CQM6). Thus, expansion of both *Quercus* types is granted after disturbance, quickly recolonizing cleared landscapes (Pons and Pausas, 2006). Nevertheless, it is not possible confirm that fire disturbances have been the origin of current oak formation.

In any case, in the Conquezuela palaeolake it is likely that recent oak woodlands expansion was mainly favored by human activities, shaping the landscape into a dehesa-like ecosystem. In this kind of human-made environment, typical of the Iberian Mediterranean landscape, economical activities are integrated with the scattered trees that are viewed as an important part of the system (Joffre et al., 1999). The oak-dominated woodland may have persisted under a controlled landscape management combining cultivars and arable lands with more extensive activities like animal husbandry or accord production.

Final remarks

The sedimentological, geochemical and palynological proxies performed in the Conquezuela palaeolake sequence, combined with the archaeological surveys and archaeobotanical research carried out in the nearby Ambrona Valley, have helped to define six main phases of landscape transformation between 13000 and 540 cal yr BP for a continental region of inner Iberia.

1) A basin-scale alluvial environment persisted during the Lateglacial and early Holocene (ca. 13000-7540 cal yr BP).

2) The development of a wetland-shallow lake environment ca. 7540 cal yr BP (5590 BC) marks the onset of a phase of positive hydrological balance that concurs with the higher temperature and humid conditions reconstructed in many Mediterranean Iberian sites for the mid Holocene. These favorable climate features coincide with the beginning of the Neolithisation in the area. The regional vegetation landscape was composed of a dense montane pine forest, also supported by the anthracological results obtained from the nearby early Neolithic site of La Lámpara. During this period, first clear but scattered agricultural (Cerealia type) and nitrophilous indicators (*Plantago*, Brassicaceae, Polygonaceae, *Urtica*) appeared in the pollen sequence as reported in the archaeobotanical finds.

3) Hydrological oscillations characterize the period between 6300 and 3200 cal yr BP (4350 and 1250 BC), alternating carbonate-, organic- and detrital-rich depositional sub-environments. The frequency and diversity of anthropogenic-related indicators attained the maximum representation at the expenses of the locally-confined montane pine, stressing a noticeable human pressure in the vegetation landscape, intensified by broader climate conditions.

4) The dominance of carbonate-rich wetland environments during the period 3200-930 cal yr BP (1250 BC-1020 AD) highlights a progressive infilling of the lake basin, where more-organic conditions paralleled the expansion of diverse hydroseral communities. Pinewoods recovered during this period at regional-scale as a result of climate and socio-economic changes, whereas anthropogenic-related indicators still remained high in the palaeolake surroundings denoting a marked change in the patterns of settlement.

5) After 930 cal yr BP (1020 AD) the basin was definitively colonized by sedges and a peat-like environment was established. Woodlands attained the minimum representation while the presence of olive groves and walnut cultivars suggests arboricultural practices during Mediaeval times, next to the cereal fields. Mesta system and the well-known Mediaeval rural livelihood may have acquired especial relevance explaining the vegetation landscape during this phase.

6) The modern landscape, defined by intercalated holm oak and marcescent oak patches, is probably result of intense human management in order to transform the previous vegetation landscape into a dehesa-like system, combining both extensive herding with agrarian activities. The timing of this vegetation landscape in the Conquezuela surroundings remains still unknown.

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Figures and tables caption

Figure 1. Location of the Conquezuela palaeolake in the Iberian Peninsula (shown by a star). The sites cited in the discussion are also included; 1) La Vaquera Cave (López-García et al., 2003); 2) Espinosa del Cerrato (Franco-Múgica et al., 2001b); 3) Pelagallinas peatbog (Franco-Múgica et al., 2001a); 4) Somolinos tufa Lake (Currás et al., 2012); 5) Quintanar de la Sierra (Peñalba, 1994); 6) Lake Arreo (Corella et al., 2013); 7) Ambrona archaeological site (Stika, 2005); 8) Los Cascajos archaeological site (Peña-Chocarro et al., 2005a); 9) Ojos del Tremedal (Stevenson, 2000); 10) Taravilla Lake (Moreno et al., 2008); 11) Villarquemado palaeolake (Aranbarri et al., 2014); 12) Les Ascusses sequence (Tallón-Armada et al., 2014); 13) Navarrés (Carrión and van Geel, 1999); 14) Basa de la Mora (Pérez-Sanz et al., 2013); 15) Lake Estanya (Morellón et al., 2011) and 16) Lake Montcortès (Rull et al., 2011).

Figure 2. (A) Geological setting and (B) main vegetation communities in the Conquzuela-Ambrona Valley. The location of modern moss polster (CQM) are included. C) Neolithic and Chalcolithic period archaeological sites surveyed along the Conquzuela-Ambrona Valley. Data have been modified from Morán-Dauchez, (2006). Most important archaeological settlements cited in the text are also shown and follow 1) La Lámpara; 2) La Revilla; 3) La Sima; 4) La Peña de la Abuela and 5) La Tarayuela.

Figure 3. Depth-age model for the Conquezuela palaeolake based on lineal interpolation of ^{14}C data (Table 1), obtained using the *Clam* software (Blaauw, 2010). The grey envelope shows the 95% confidence interval. Sedimentological units have been also included.

Figure 4. Main sedimentological units, selected XRF curves and ratios and elemental geochemical analysis (TOC, TIC and atomic TOC/TN) for the Conquezuela sequence. XRF intensities are expressed in counts per second (cps) and TOC and TIC values in percentages.

Figure 5. (A) Summary pollen diagram for trees, shrubs and herbs for the Conquezuela palaeolake sequence. Mesophytes comprises *Betula*, *Corylus*, *Tilia*, *Alnus*, *Salix*, *Populus*, *Ulmus*, *Celtis*, *Fraxinus*, *Juglans*, *Fagus*, Deciduous *Quercus*, *Quercus faginea/pyrenaica* type, *Buxus*, *Cornus*, *Myrtus*, *Vitis*, *Hedera* and *Smilax*. Mediterranean taxa englobes *Quercus ilex/coccifera* type, *Quecus suber*, *Pistacia*, *Rhamnus*, *Thymelaea*, *Phillyrea*, *Olea*, Oleaceae and *Arbutus*. Anthropogenic indicators and ruderals group is composed of Cerealia type, *Artemisia*, Cichorioideae, Asteroideae, *Cirsium/Carduus* type, *Centaurea*, Chenopodiaceae, Caryophyllaceae, *Plantago*, Brassicaceae, Fabaceae, *Trifolium* type, *Lotus* type, Boraginaceae, *Urtica*, *Rumex*, *Euphorbia*, *Papaver*, Geraniaceae, Malvaceae, Polygonaceae, *Asphodelus* and *Linum*. Xerophytic and thorny scrubland includes *Juniperus*, Rosaceae, *Prunus* type, *Ribes*, *Genista*, *Cistus*, *Helianthemum*, *Ephedra distrachya* type, *Ephedra fragilis* type, Lamiaceae and *Teucrium*. (B) Summary pollen diagram for hygrophytes, hydrophytes and NPPs. Hygro-hydrophytes group comprises *Ranunculus*, *Juncus*, Cyperaceae, *Typha/Sparganium* type, *Typha latifolia* type, *Thalictrum/Alisma* type, *Myriophyllum alterniflorum* type, *Myriophyllum spicatum/pectinatum* type, *Potamogeton*, *Utricularia*, *Nuphar*, *Nymphaea* and *Callitriche*. Dots represent percentages <0.5%. Sedimentological units have been also included.

Figure 6. Summary pollen diagram obtained from surface moss polsters collected around Conquezuela palaeolake surroundings (Figure 2B).

Figure 7. Distribution of radiocarbon dates performed on *Pinus nigra/sylvestris* type macrofossils retrieved from archaeological settlements located along the Conquezuela-Ambrona Valley (Figure 2C). Charcoal identification and SEM images have been obtained from Carrión and Badal, (2005). Radiocarbon dates follow Rojo-Guerra et al. (2006).

Figure 8. Main vegetation composition obtained from the Conquezuela-Ambrona Valley (8A) and comparison with local anthracological (8B) and archaeobotanical data (8C). Cultural phases described in the text have been also introduced. Pollen-based ecological groups are defined in the Figure 5A caption. Charcoal identification and SEM images have been obtained from Carrión and Badal, (2005). Carbonized plant remains follow Stika, (2005).

Table 1. Radiocarbon dates (AMS) for the Conquezuela sequence obtained from bulk sediment.

Table 2. Radiocarbon dates performed on *Pinus nigra/sylvestris* type macrofossils retrieved from archaeological sites located along the Conquezuela-Ambrona Valley (Figure 2B). All dates were calibrated with Calib v. 7.0 (Stuiver and Reimer, 1993). The LA, SI, PA and TA abbreviations refer to La Lámpara, La Sima, La Peña de la Abuela and La Tarayuela sites, respectively.