

# Review of Palaeobotany and Palynology

## Anthropogenic impacts on vegetation landscapes and environmental implications during the Middle-Late Holocene in the Iberian Central Pre-Pyrenees: an anthracological approach

--Manuscript Draft--

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<b>Abstract:</b>	<p>Cova Colomera is one of the most important archaeological sites to explain early herding activities in the Central Pre-Pyrenees (Iberian Peninsula). Fieldworks have provided a stratigraphy that shows short occupations of the cave by Neolithic and Bronze Age human groups. The sedimentological description has revealed fumiers deposits, that are characteristic of husbandry activities. In this paper, we provide the anthracological results based on 1,117 charcoal fragments. The results allow to characterise the Mediterranean vegetation landscape and its transformation, from a local perspective, related to climatic changes and anthropogenic activities. Climate changes and human activities have played a significant role in Mediterranean landscapes dynamics. However, the incidence or impact of both agents on the vegetation landscape occurred unequally among the Mediterranean region. The anthracological results from Cova Colomera suggest that the Central Pre-Pyrenees was dominated by an oak forest ecosystem, with sub- and supra-Mediterranean deciduous taxon and coniferous forest during the Middle Holocene. This ecosystem remained more or less stable during the Late Holocene, although evergreen oak showed a slight increase, and coniferous forest showed a slight decrease. The orographic characteristics of the Central Pre-Pyrenees were able to maintain temperate and humid conditions, with less impact of aridity events recorded in Mediterranean environments. From a diachronic point of view, the herding activities of Neolithic human and Bronze Age human groups do not appear to have affected highly the landscape development of the Central Pre-Pyrenees. Human activities were probably not intensive in terms of forest clearing or land use.</p>
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<b>Opposed Reviewers:</b>	
<b>Response to Reviewers:</b>	We have corrected and reviewed all the reviewer's comments, and we have provided

an answer or comment to each request. We sincerely believe that both reviewers have contributed to enrich our research. We would like to make some general comments. Firstly, about the quality of the pictures, we send all figures in high quality (TIFF format), although the quality seems poor in the generated pdf. In the other hand, we have modified the order of the discussion in section 4.2 and we have also improved the section 4.1, as the second reviewer suggested. Finally, we have improved the English idiomaticity throughout the manuscript, as a native Englishman has corrected the grammar mistakes and the style.



Tarragona, January 27th, 2022

Dear Editor,

We are submitting a revised version of the manuscript entitled “**Anthropogenic impacts on vegetation landscapes and environmental implications during the Middle-Late Holocene in the Iberian Central Pre-Pyrenees: an anthracological approach**”, co-authored by Bàrbara Mas, F. Xavier Oms and Ethel Allué, for publication. The submission includes the manuscript, 2 tables and 7 figures.

We have corrected and reviewed the manuscript according to all the two reviewer’s comments. We attach a document with all the answers and comments, the clean version of the manuscript, and the manuscript with control changes. We sincerely believe that the reviewer’s suggestions have contributed to enriching our first draft. As reviewer 2 suggested, a native English speaker has corrected the English language of the manuscript. We have edited, also, Figures 1 and 6 and Table 2, and, finally, we have improved the Abstract and the highlights.

Hence, we consider this paper as appropriate for submission to the Review of Palaeobotany & Palynology

We hope you find our work suitable and interested for its publication

We look forward to hearing from you.

Sincerely,

Bàrbara Mas

A handwritten signature in blue ink, appearing to be "Bàrbara Mas", written over a light blue grid background.

We have corrected and reviewed all the reviewer's comments, and we have provided an answer or comment to each request. We sincerely believe that both reviewers have contributed to enrich our research. We would like to make some general comments.

Firstly, about the quality of the pictures, we send all figures in high quality (TIFF format), although the quality seems poor in the generated pdf. In the other hand, we have modified the order of the discussion in section 4.2 and we have also improved the section 4.1, as the second reviewer suggested. Finally, we have improved the English idiomaticity throughout the manuscript, as a native Englishman has corrected the grammar mistakes and the style.

Reviewer comments:

Reviewer #1: The paper submitted by Bàrbara Mas and co-authors to Review of Palaeobotany and Palynology presents new anthracological data that show regional forest transformations in the Central Pre-Pyrenees (Iberian Peninsula) during the Middle to Late Holocene. The study provides a complete anthracological sequence at Cova Colomera (Mont-rebei Gorge, Central Pre-Pyrenees). This paper is a very nice illustration of the interest of palaeobotany to contribute to the development of such scientific themes. This impressive contribution will be very appreciated by the scientific community, among them researchers working on Holocene. The paper fit well with the standards of Review of Palaeobotany and Palynology. The text is well organized, very easy to read and the topic is clearly developed. Therefore, I strongly recommended publication in RPP with only minor revisions.

I suggest only a few minor changes:

**Line 31: Replace semicolon by coma after 2007.**

Done

**Line 193: Write in italics *Acer*, *Fraxinus*, *Juniperus* and *Prunus*.**

Ok. Probably, a M.Word's mistake.

**Line 200: Write in italics *Sorbus* and *Crataegus*.**

Done. Probably, a M.Word's mistake

**Line 204: Use the same criteria with the numbers, or dot or coma. See 1.117 and 1,038.**

Done, thanks!

**Line 357: Add coma after Médail.**

Done.

**Line 362: Delete dot after m a.s.l.**

Done.

## **FIGURES AND TABLES**

**Figure 6 and Table 2. Write the first p of Phillyrea in capital letters.**

Done.

Reviewer #2: General comments

The title is very ambitious. Consider adapting it to the data presented in this study. The data is mainly from one cave site, Cave Colomera that was discontinuously used from the Early Neolithic to the Middle Bronze Age. The anthracological information from the cave is not integrated in a comprehensive manner with other anthracological data from the area in order to present what the title implies. Some sites are mentioned throughout the text but in a rather random manner. Sites with relevant data are pointed in figure 1 but they are not mentioned in the caption. Neither are their anthracological data synthesized in the text so that to create an anthracological record for the area in order to discuss anthropogenic impact and vegetation change.

The discussion is in general difficult to follow. I suggest a reorganization based on

1. Clear presentation of the anthracological characteristics of Cave Colomera, vegetation types, specific importance of certain taxa, interpretation of the anthracological diagram
2. Synthesis of other anthracological data from the area that show differences/similarities through time between hinterland and coastal areas
3. Broader climate changes of the Holocene and how can these be correlated to the anthracological data from archaeological sequences. This part is challenging and should be touched upon with caution, due to the discontinuity of the archaeological record
4. Anthropogenic involvement: Firstly it is necessary to discuss the case of the cave, what uses of the vegetation, how continuous or discontinuous these were and what does the anthracological data reveal for the local area. In continuation the broader area can be discussed making a clear differentiation between cave sites for animal penning and other open air sites.

In the conclusions some issues appear rather controversial, maybe it is a matter of the use of the English language (see next)

It is necessary that a native English speaker corrects and does the editing of the manuscript

**For the references and citations: in general when there are 2 surnames in the references they should both be used in the citations in the text**

We have made changes in the discussion according to the suggestions of the reviewer, this has helped to clarify the organization on the different subjects we are discussing. Although the discontinuity of the sequence, Cova Colomera is one of the most complete in the area recorded to date. We consider that although this paper focus on Cova Colomera offers a broader perspective on the analyses considering the title according to the content. In this aspect, the bias of Middle Neolithic data and the evidence of shorts occupations have been included in the discussion. We have edited the English of the manuscript to correct and clarify some misleading sentences in the discussion.

### **Abstract**

In the first paragraph:

**"The anthropogenic footprint" would be the result; Maybe the authors mean human activities?**

Yes, we have changed it.

**In the abstract it should be specified the time range of the study, Middle and Late Holocene is too long. Please specify at least which millennia after Early, Late Neolithic, Early, Middle Bronze Age. Transformation in landscape changes? not understandable In the second paragraph: Subsequently to what? In the part of the paragraph before subsequently specify to what period you refer to. In some specific places? This is too vague, please clarify what you mean**

We have improved this section according with the suggestions.

### **In the main text**

**Line 18: Late instead of late**

Done.

**Line 23 to 25: The whole sentence needs to be changed and corrected**

Done.

**Line 27: several proxies, mainly pollen and charcoal? Which 3ret he proxies?**

We have revised and changed the sentence.

**Line 29: give time range for the Early Holocene**

Done.

**Line 34: give time range for Middle Holocene**

Done.

**Line 42: fumiers are related to human activities such as stabling animals? I think it is the result of stabling animals. What other activities could be involved?**

You are right. The expression was probably inaccurate. We have corrected it

**Line 50: Chabal 1999 does not exist in references, maybe Chabal et al 1999 or Chabal 1997**

Done. Chabal et al., 1999.

**Line 51: Kabukcu and Chabal 2021 not 2020, change also in references**

Done.

**Line 57: local dynamics could be relevant. Can you please explain what you mean in relation to the diversity at a regional scale?**

Done. We have changed the sentence.

**Line 62: because of the possibility of connecting near sites? Check English**

Done.

**Line 66: from Early Neolithic to middle Bronze Age: give time ranges at least in millennia**

Done,

**Lines 68-70: assess the impact of what? vegetation change? Its causes? It is not clear to me what the sentence means**

Done. We have changed the sentence and included more details.

**Lines 92-93: The northern slope of the range, the Tremp-Graus basin,**

Better, thanks!

**Line 96: in a local area? Locally?**

We have corrected it.

**Lines 99-105: I think the vegetation of the Ager area should go directly after the description of that part of the range. That would directly facilitate comparison**

We agree. Done.

**Line 101: the area is located in biome? Maybe better "The biome of the area...."**

It's better, thanks

**Line 103: in a local area? Locally?**

Done.

**Line 117: a gallery? Maybe the authors mean a chamber?**

Done, it was a translation mistake.

**Line 137: a narrow concentration? Is it a layer? Maybe the authors mean a thin layer/concentration?**

We have improved the sentence.

**Line 139: part of their diet? You mean leaf fodder? And also how do you know this is a Holocene layer? Which layer is it? Is there a date? What is the material culture?**

Done. We have improved the sentence.

**Line 144: Veraza and Veraza-Ferrières cultures. Not all readers are familiar with local /regional sequences. Can you provide chronologies for these cultures?**

Table 1 shows the dates of archaeological layers. These two cultures constitute two horizons of ceramic assemblages. As this article does not discuss ceramics, reference is made to paper that includes the ceramic material.

**Line 160: why is it 3.1? there is no 3.2, please change**

It's true. Thanks!

**Line 163: a previous work**

Done.

**Lines 164-166: the results from both studies should be included in Table 2. There should be correlation between what is written here, what is shown in the diagram (Figure 6) and what is included in table 2**

You are right. We have included the analysis of 300 samples from silo EE1 (Oms et al., 2009) in Table 2.

**Line 168: maintaining the arrangement of the facies (Z-Z1)? What does this mean? Please explain. Also in the same line place the mesh size together with the flotation method used**

Done, we have changed and improved the sentence.

**Line 169: why is it mentioned here the method for the small-mammal remains? irrelevant? Or maybe more wood charcoal was collected from those samples? Please clarify and organize**

We have clarified the reference.

**Line 174: are they saturation curves? See Kabukcu and Chabal 2021. Why were they established? Later on they are used to refer to the taxonomic variability of layers. Is this why they are used for in anthracology? See also below comment for figure 5**

We have clarified the reference. It was a language translation mistake.

**Line 176: analysis**

Done.

**Lines 186 to the end of section: check English language and clarify what taxa you define. What does "are regrouped in terms of species" "mean?"**



We have clarified this section.

**Line 193, 197 and 200: Acer, Juniperus, Fraxinus, Prunus, sorbus, Crataegus not bold but Italics**

Done,

**Line 199: but for the discrimination between Amygdalus and Prunus spinosa see the criteria established in Scweingruber 1990, 643**

Yes, we have deleted Amygdalus in our assemblage because we have not observed ring-porus wood character in *Prunus* samples. However, we have followed your recommendation and the description of Prunus type has been improved.

**Line 199: Rosaceae/Maloideae not capital**

Done.

## **RESULTS**

**Line 204: 1117 recovered? Maybe 1117 studied and 1038 identified**

Done.

**Line 205: 22 woody species? Here and throughout the text replace species by taxa. Not all identified material corresponds to species**

Done.

**Line 206: of the current sub-Mediterranean climatic type. I think this is interpretation and it should go in the discussion where it should be integrated in the description of the conditions in the study area in the past relative to the presence of the identified taxa**

We have clarified the sentence.

**Line 206: what is ubiquity of frequency? There is no ubiquity analysis of the taxa in this study**

We have clarified the sentence.

**Line 209: The curves in Figure 5 were obtained to show taxa richness in different layers? What is the purpose of accumulation curves?**

To explain the anthracological assemblage richness of Cova Colomera. In the discussion, the diversity of taxa is explained.

**Lines 213-218: this is inaccurate, the woody taxa listed are deciduous and evergreen and to my knowledge Fagus sylvatica is neither thermo nor meso-Mediterranean**

It's true. Done.

**Line 218: Rosaceae/Maloideae**

Done. ,

**Line 222 and 224: shrubby is interpretation. How can it be known that these small trees had a shrubby form? And how can it be known that junipers were shrubby and not tree-like?**

You are right. We have changed these lines.

**Lines 232-235: Other taxa..... not continuously". If the sentence describes the presence of taxa in one layer and this is what is shown in Table 2 how can "continuity" be perceived. This could only be possible through comparison of consecutive layers**

It was an editingmistake. We have changed it.

**Line 237-238: Please explain in the caption what the curves show in relation to the results and the anthracological method in general? Or otherwise clarify in the methods section**

Done.

**Line 244: boxwood**

Done.

## **DISCUSSION .1.**

**Line 269: is Arbutus sub-Mediterranean?**

We have changed it with "circum-Mediterranean".

**Line 276: Why is it holm oak here and elsewhere evergreen Quercus? Also which are the associate elements? They should be named. And shouldn't there be Arbutus and Rhamnus/Phillyrea among them?**

We have clarified and improved it.

**Lines 280-289: what are Mediterranean forests? All information about Mediterranean, sub-mediterraenan and Atlantic should be explained. However, it would be preferable to make all the necessary comparisons in relation to what is depicted in figure 2. I believe it serves better the purposes of the manuscript than other general descriptions. All the section needs thorough revision. Which are the taxa typical of the Holm oak forest? In cases the same taxa appear as deciduous, sclerophyllous (i.e. Arbutus) sub-mediterranean, or Mediterranean.**

We have improved this section.

**Line 289: what are percentages of ubiquity value? Relative frequency of fragment counts per layer/per period are presented in Table 2 and figure 5**

We have clarified the sentence.

**Line 290: what is a secondary position?**

We have clarified and improved this section.

**Lines 292-294: What are the results from the study of small vertebrates. If it is mentioned it should be explained to show how it supports the anthracological results**

We have improved this explanation.

**Line 305: starting with "however" it should correlate with something. What is it? Is it something about the changes of the Late Holocene seen through other proxies? If so these should be described first and then make the comparison with the Bronze Age at Cave Colomera**

We have reorganized and improved this section.

**Line 316: what ubiquity values and in comparison to what? Other anthracological results from Iberia?**

Translation Language mistake. Done and clarified.

**Line 305-335: Revise and organize the data so that they are meaningful**

We have reorganized and improved this section.

**Line 337: how can you discuss about the 8.2 event? It is not represented in your sequence**

We have not discussed the 8.2 event. We have only used it as a starting point for explaining the Middle-Holocene scenario.

**Line 338-339: this is not seen in the anthracological sequence. Which are the xerophilous shrubs that start to expand? Arbutus, Pistacia, Phillyrea are not present, Quercus evergreen increases slightly. Contrary to that Quercus deciduous shows increasing trend throughout**

We have reorganized, clarified and improved this section.

## **DISCUSSION .2.**

**Line 361: specify in which period of the Middle Holocene you refer because later on you compare with the Early Bronze Age (line 367).**

Done. We were referring to the Middle-Late Holocene.

**Line 362-364: I do not understand the comment. What is wood consumption? Fuel? Timber? And are these the only means that may affect the vegetation of an area? What about animal herding, forest fires for pasture, woodland management for leaf fodder, etc. Please explain what you mean.**

We have improved this section,

**Line 370: Ros 1995 a or b**

Thanks, is 1995b

**Line 391-392: How does this observation correlate with the uses of wood distinguished through the anthracological study?**

Several of the taxa identified are recurrent in ovicaprine diets. This point has already been discussed.

**Line 399: what wood? of juniperus and boxwood?**

Thanks for the observation, is boxwood. Done.

**Line 408-409: from the Early Neolithic to the Middle Bronze Age**

Done

**From 408 to the end the information relates to the characteristics of the broader area but this is not clearly structured. From the specific uses of the taxa at Cave Colomera the focus turns to vegetation dynamics from the Middle to the Late Holocene in the Pre-Pyrenees without a clear definition of what has to be compared.**

We have improved this section. We compare, from a local point of view, the dynamics of vegetation with the low impact of human activities.

**Line 411: how permanent is defined? Can the anthracological data show that? How could the exploitation be permanent if the archaeology of the caves shows long periods of no use?**

This is a translation mistake, we were referring to reiterated or recurrent exploitation.

**Line 419: mixed oak taxa?**

We changed this sentence for oak taxa.

**Line 427: Diaz Polo et al. 2014?**

Done.

**Line 430: "with any differences"? Maybe "with no differences"**

Done

**Line 440: the retreat of conifers only briefly mentioned in the discussion**

We have improved this question,

**Line 444-445: at the local scale of Cave Colomera the expansion of xerophytic shrubs and Quercus is not obvious**

True, we have improved this sentence.

**Line 451-452: to conclude: is there evidence of some pressure in inland areas in the Neolithic? How should "incipient pressure" be understood? "No pressure" or "the beginning of pressure"? I understand the second but in the discussion the arguments are against it**

We have improved this sentence.

**Line 456: what is the specialized selection pattern of forest resources? How is it justified in the discussion? An in particular about herding at Cave Colomera?**

We have improved this sentence.

## **References**

**Allue 2009, not found in references**

**Badal 1999, not found in references**

Both references are et al. Thanks for your observation. We have corrected the reference in text.

## **Figures – Tables**

**Figure 1: consider using subepoch without hyphenation as in Walker et al. 2019, Journal of Quaternary Science 34(3): 173-186 <https://doi.org/10.1002/jqs.3097> you**  
**In the caption the names of the sites should be mentioned and correlated with the numbers. If no mention to the sites is made what is the point of numbering them? Some sites are mentioned in the text and it would be useful to see which and where they are located. Also, the time range of the Middle and Late Holocene is long. To which part of the Late Holocene do the sites correspond. Consider adapting the caption of figure 1 to include all this information e.g. for the Lower Holocene the sites correspond only to the 2nd millennium BC**

We have modified the figure and included the name of the sites, reference and archaeological period in the caption.

**Figure 2: The quality is not good, but I am not sure if this is due to low resolution conversion for the pdf file. It should be very clear and probably used to make comparisons instead of using other general information (see also comment for lines 280-289)**

The poor quality is due to the generation of the pdf. All figures in this paper were sent in tiff format and at high resolution.

**Figure 4: Please explain in the caption what is c facies (layers base) = layers base**

**of what? Of fumier? tf facies (indeterminate origin) = indeterminate origin relative to what?**

These acronyms correspond to the excavation methodology of a fumier, and identify the origin and composition of different layers, according to the study by Angelucci and others (2009). Given the confusion that this can generate, we have improved the caption of the figure.

**Figure 5: explain what does it show? Is it a saturation curve or an accumulation curve? See the discussion in Kabukcu and Chabal 2021, 12-13**

We have improved this section.

**Figure 6: The first column from left should be Cultural Period instead of Age. In Table 2 it is Archaeological Period**

Done, we changed as Archaeological Period.

**Second column from left should be Identified fragments, what is determined?**

Agree. We have changed for Identified fragments.

**For the Early Neolithic the total identified fragments in Table 2 are 447. Why 446 in Figure 6?**

Done, the correct are 447.

**For the Late Neolithic the total identified in Table 2 are 401. Why 402 in figure 6?**

Done, the correct are 401.

**For the Early Bronze Age there is a huge difference in total identified between Table 2 (57) and figure 6 (344)**

In Table 2 only the results of the new anthracological analysis were included, while in the diagram in figure 6 the published results of silo EE1 (Oms et al, 2009) were included. We agree with your comments and have included in Table 2 the results of Oms et al, (2009).

**Phillyrea with P capital.**

Done

**Add sp. to Tilia?**

It's true! Done

**Hedera helix ssp?**

We have changed to *Hedera helix*

**What is the significance of the colours? It should be explained. As I understand it the red are the thermophilous ones and the orange the more temperate? But is it really like that for Tilia (red) and Arbutus (orange)?**

Done.

**Figure 7. Nice synthetic figure but poor quality**

The poor quality is due to the generation of the pdf.

**Table 2. Capital P for Phillyrea. Why ROSACEAE/MALOIDEAE in capital? Please change**

Done.

**Change determined with identified**

Agree. Done.

**Have the % been calculated based on the totals? I believe they should be calculated on the basis of the total identified (cf. Chabal 1997)  
In the caption of Table 2: what does "Absolute (n) and relative frequencies (%) of charcoals fragments analyzed with species recorded."? Do the author(s) mean "Absolute and relative frequencies of taxa based on fragment counts"  
An as elsewhere, species should be replaced by taxa**

We have changed and improved the caption.

1 **Anthropogenic impacts in vegetal landscapes and environmental implications**  
2 **during the Middle-Late Holocene in the Iberian Central Pre-Pyrenees: an**  
3 **anthracological approach**

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17 **Keywords**

18 Landscape transformations; Anthracology; Cova Colomera; Middle-Late Holocene;  
19 Northeastern Iberian Peninsula

20

21 **1. Introduction**

22 The impact of general Holocene climate dynamics was unequal in past  
23 Mediterranean landscapes. Mainly in the first stages of the Holocene (11.7 ka years BP



24 to 4.2 ka years BP), the influence of climatic agents on landscape transformation was  
25 more evident than the impact of human activities. However, since the Middle-Late  
26 Holocene Boundary (4.2 ka years BP), discerning which of the two agents, natural  
27 factors or the anthropogenic footprint, was the main contributor to landscape  
28 transformation, or whether it was a combination of both, is controversial or less obvious  
29 ~~Mainly, from the Early Holocene, natural changes in landscapes and a period of~~  
30 ~~predominantly anthropogenic change are difficult to discern until the Late Holocene~~  
31 (see Jalut et al., 2000; Roberts et al., 2011). ~~Past-Holocene Mediterranean vegetation~~  
32 ~~woodland history and landscapes changes landscapes and their transformation during~~  
33 ~~the Holocene~~ have been studied using a several proxies~~palaeoecological proxy, mainly~~  
34 pollen and charcoal data (see e.g. Jalut et al., 2009; Woodbridge et al., 2018; Roberts et  
35 al., 2019; Picornell-Gelabert et al., 2020), ~~mainly pollen and charcoal data~~. According to  
36 the available palaeobotanical sequences in the NE Iberian Peninsula, at the end of the  
37 Late Pleistocene and the beginning of the Early Holocene, deciduous oak forest,  
38 broadleaf trees and pine forests were dominant in the area (Riera-Mora and Esteban-  
39 Amat, 1994; Burjachs et al., 1997; Riera et al., 2007; Allué et al., 2007, 2017; Carrión  
40 et al., 2010a; Pérez-Obiol et al., 2011; Fletcher et al., 2012; Revelles et al., 2015, 2018;  
41 González-Sampéritz et al., 2017; Allué and Mas, 2020; Mas et al., 2021).  
42 ~~Subsequently~~Further, during the Middle Holocene sub-epoch (8.2 ka years BP to 4.2 ka  
43 years BP), warmer and more humid climatic conditions prevailed as precipitation  
44 regimes increased, favoring the expansion of deciduous forests and the retreat of pine  
45 forests and grasslands (Badal et al., 1994; Jalut et al., 2009; Allué et al., 2012;  
46 González-Sampéritz et al., 2017). Simultaneously, from the Early Holocene,  
47 Neolithisation throughout the Mediterranean involved agricultural expansion and  
48 herding associated with the development of a sedentary lifestyle. Herding activities are

49 evidenced in archaeological sites by fumier deposits, which have been documented from  
50 the Early Neolithic to the Iron Age (see Angelucci et al., 2009). Fumiers are the result  
51 of ~~human activities, such as~~ stabling animals (usually flocks of goat and sheep) within  
52 the entrance areas of caves and rock-shelters. The deposits are mainly derived from the  
53 combustion of organic waste, such as the accumulation of animal dung. Plant material  
54 in this type of deposit has different origins related to such human practices as foddering,  
55 animal beds, fuel, refuse or fencing (Brochier, 1983, 1991, 1996; Polo-Díaz et al., 2014,  
56 2016; Burguet-Coca et al., 2020).

57 Anthracology, besides being an important proxy for detecting different past local  
58 landscapes, is also able to identify changes in human-forest relationships in terms of  
59 wood exploitation and consumption (see Chabal, 1992; ~~Chabal et al.,~~ 1999; Kabukcu,  
60 2018; ~~Asouti and Kabukcu, 2021;~~ Kabukcu and Chabal, 2021; ~~Asouti and Kabukcu,~~  
61 ~~2021~~). Anthracological data available for the NE Iberian Peninsula during the Middle  
62 Holocene and the Late Holocene sub-epochs (i.e. Senabre and Socias, 1993; Heinz and  
63 Vernet, 1995; Ros, 1995a, ~~1995b;~~ 1996, 1998; Piqué, 1999, 2005; Allué, 2007, 2010;  
64 Martín and Piqué, 2008; Allué et al., 2009; Vila and Piqué, 2012; Antolín et al., 2013;  
65 Alcolea, 2017; Daura et al., 2019) indicate that the configuration and distribution of  
66 vegetation landscapes were diverse at regional scale. ~~As,~~ and as consequence, ~~research~~  
67 ~~based on a local approach may be relevant to reconstructing the regional variability,~~  
68 ~~dynamics could be relevant~~ (Figure 1).

69 PLACE HERE FIGURE 1. ~~Location of Cova Colomera and~~  
70 ~~archaeological~~Archaeological sites with available Middle-Late Holocene  
71 anthracological data ~~in the~~from NE Iberian Peninsula. Early Neolithic: 1) La Draga  
72 (Piqué, 2005); 2) Cova d'en Pau III (Ros, 1996; Piqué, 2005); 3) Cova 120 (Ros, 1995a;  
73 Piqué, 2005); 4) Bauma del Serrat Pont (Piqué, 2005); 5) Plansallosa (Ros, 1995a;

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74 Piqué, 2005); 6) Cova de l'Avellaner (Ros, 1996); 10) Cova del Toll (Mas and Allué,  
75 2020); 11) Cova del Frare (Ros, 1996); 12) Cova Bonica (Daura et al., 2019); 13) Can  
76 Sadurní (Antolín et al., 2013); 15) La Serreta (Allué, 2010); 17) Cova de la Guineu  
77 (Allué et al., 2009); 18) Camp del Colomer (Piqué et al., 2015); 19) Bauma Margineda  
78 (Heinz, 1995); 20) Coves del Fem (Alcolea, 2017); 23) Cova Colomera (in this paper);  
79 25) Barranc d'en Fabra (Ros, 1996); 26) Cova del Vidre (Alcolea, 2017). Late  
80 Neolithic-Chalcolithic: 3) Cova 120 (Ros, 1995a; Piqué, 2005); 4) Bauma del Serrat  
81 Pont (Piqué, 2005); 7) La Prunera (Piqué, 2005); 14) Santa Maria dels Horts (Senabre  
82 and Socias, 1993); 17) Cova de la Guineu (Allué et al., 2009); 21) Cova Gran de Santa  
83 Linya (Allué, unpublished); 22) Auvelles (Martín and Piqué, 2008); 23) Cova Colomera  
84 (in this paper); 24) Roques del Sarró (Vila and Piqué, 2012). Early Bronze age: 8)  
85 Institut Manlleu (Ros, 1995b); 9) Can Roqueta (Piqué, 1999); 10) Cova del Toll (Mas  
86 and Allué, 2020); 16) Mas d'en Boixos (Allué, 2007); 17) Cova de la Guineu (Allué et  
87 al., 2009); 23) Cova Colomera (in this paper). Middle Bronze age: 21) Cova Gran de  
88 Santa Linya (Allué, unpublished); 23) Cova Colomera (in this paper); 27) Genó (Vila  
89 and Piqué, 2012); 28) Punta Farisa (Ros, 1998).

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90 The Central Pre-Pyrenees (southern Pyrenees, Iberian Peninsula) is remarkable for ~~its~~  
91 ~~evidence of herding~~herding's evidence activities ~~in the NE Iberian Peninsula~~, as  
92 documented at Cova Colomera (see Bergadà and Oms, 2021; Martín and Oms, 2021),  
93 and also ~~because of the possibility of connecting near~~in other archaeological sites with  
94 available anthracological data (i.e. Polo-Díaz et al., 2016; Burguet-Coca et al., 2020). A  
95 new anthracological sequence from a fumier deposit in Cova Colomera (Serra del  
96 Montsec, Central Pre-Pyrenees), with human occupations from the Early Neolithic to  
97 the Middle Bronze Age (mid-6<sup>th</sup> millennium cal BC to 3<sup>th</sup> millennium cal BC), has  
98 focused on a diachronic perspective in order to understand the role of anthropogenic

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99 activities and climate change in the transformation of local environments and shaping  
100 the cultural landscape. ~~Therefore, the main objectives are to understand vegetation~~  
101 ~~change and its causes, and thus to estimate the impact that the Neolithisation process~~  
102 ~~may have had on vegetation landscapes. Therefore, the main goals are to comprehend~~  
103 ~~vegetation change and its causes, and thus assess its impact on landscapes during the~~  
104 ~~Neolithisation process.~~

105

### 106 **1.1. Geographical area and landscapes**

107 The study area is located in the Montsec range, in the Central Pre-Pyrenees  
108 ~~(southern Pyrenees, Iberian Peninsula)~~, between the Tremp-Gaus and Ager drainage  
109 basins. This range, rising through the passage of the Pre-Pyrenees towards the Ebro  
110 basin, is formed by Cretaceous bioclastic limestones. The topography is the result of a  
111 series of monoclinical mountain ranges along 40 km, in an area of 186.96 km<sup>2</sup>, oriented  
112 from west to east. Three rivers, Boix River, Noguera Pallaresa River and Noguera  
113 Ribagorçana River, cut through the ridge from north to south. When crossing the  
114 Montsec range, these water courses have eroded and shaped narrow gorges and routes,  
115 like Pas Nou, Terradets and Mont-rebei. At some points, the range exceeds 1600 m a.s.l.  
116 in its central sector (e.g., Sant Alís is at 1676 m a.s.l.) and loses height towards its ends.

117 ~~The southern slope of the range, the Ager Basin, is characterized by longer~~  
118 ~~summer drought and, therefore, drier climate conditions. Ager basin~~ Locally, the area is  
119 under the influence of a sub-Mediterranean climate type, although with a continental  
120 trend (*sensu* Carreras and Ferré, 2014). Climatic conditions of sub-Mediterranean  
121 climate type are differentiated from the general Mediterranean regime by cooler  
122 temperatures and higher rainfall, while a short and irregular summer drought may occur  
123 in some years (see Jalut et al., 2000). The mean annual rainfall ranges from 400 to 600

124 mm with the maximum precipitation occurring in autumn (October with mean  
125 precipitations of around 40 mm) and a minimum in summer (July with precipitations of  
126 less than 13 mm). The mean annual temperature oscillates between 11 and 13°C, with a  
127 maximum of 31°C in July and a minimum of 0°C in January (Meteocat data 2020 from  
128 Camarasa municipality) (Figure 2). The biome of the area is characterized by  
129 Mediterranean forests, woodlands and scrub, which belongs to the Iberian  
130 sclerophyllous and semi-deciduous forests (Dinerstein et al., 2017). In a local area,  
131 holm-oak forests (*Quercus ilex* subsp. *ilex*) and Aleppo pine forests (*Pinus halepensis*)  
132 expand

133 The northern slope of the range, ~~(Tresp-Graus Basin)~~ is rainier and shadier,  
134 and consequently the climate is more temperate and could present a Eurosiberian trend.  
135 The biome is characterized by a temperate broadleaf and mixed forest, which belongs to  
136 the Pyrenees conifer and mixed forest ecoregion (Dinerstein et al., 2017). ~~In a local~~  
137 ~~area~~ Locally, beech forest and oak forests are predominant (*Quercus faginea*, *Quercus*  
138 *cerroides* and *Quercus pubescens* with the presence of *Acer* sp. and *Buxus*  
139 *sempervirens*). Likewise, in the higher areas of the range, pine forests expand (*Pinus*  
140 *nigra* subsp. *salzmanii* and *Pinus sylvestris*). ~~However, the southern slope of the range~~  
141 ~~(Ager Basin) is characterized by longer summer drought and, therefore, drier climate~~  
142 ~~conditions. The area is located in a biome characterized by Mediterranean forests,~~  
143 ~~woodlands and scrub, which belongs to the Iberian sclerophyllous and semi-deciduous~~  
144 ~~forests (Dinerstein et al., 2017). In a local area, holm-oak forests (*Quercus ilex* subsp.~~  
145 ~~*ilex*) and Aleppo pine forests (*Pinus halepensis*) expand.~~

146 PLACE HERE FIGURE 2. A) Map of forest communities in the study area, according  
147 to the vegetation series of Spain (Rivas-Martínez, 1987); B and C) Principal bioclimatic  
148 variables in the NE Iberian Peninsula. “Mean annual Temperature” (B) and “Mean

149 annual Precipitation” (C) according to Ministerio de Agricultura, Pesca y Alimentación  
150 (Spanish government), by geostatistical interpolation methods from actual AMET data  
151 (<http://wms.mapama.es/sig/Agricultura/CaractAgroClimaticas/wms.aspx?>).

152

## 153 2. Cova Colomera cave

154 Cova Colomera is located in the Mont-rebei gorge, Serra del Montsec (Central Pre-  
155 Pyrenees, NE Iberian Peninsula). The cave is located 670 m a.s.l., 150 m above the left  
156 bank of the Noguera Ribagorçana river, a tributary of the Segre River (Oms et al., 2008,  
157 2009a) (Figure 3). The cave entrance is 70 m high and 30 m wide, and leads to a ~~gallery~~  
158 ~~chamber~~ about 180 m long and 10-12 m wide (Oms et al., 2013).

159 PLACE HERE FIGURE 3. 3D Location map of Cova Colomera, at N42°4'40.892",  
160 E0°40'54.487" (WGS 84).

161 From 2005 to 2011, an interdisciplinary team from the Seminari d'Estudis i  
162 Recerques Prehistòriques (SERP-UB) excavated the cave, allowing the description of  
163 the stratigraphic sequence (Oms et al., 2015). Two 26 m<sup>2</sup> test pits were excavated during  
164 the fieldwork: one in the eastern sector of the cave, “Colomera Est (CE)”, and the  
165 second, “Colomera Vestíbul (CV)”, in the highest sector of the cave entrance. The CV  
166 test pit revealed thin stratigraphic layers up to the top of a carbonate crust. Under the  
167 crust, a series of overlapping anthropogenic structures (silos, hearths, post-holes) were  
168 documented. Six Holocene ~~and one Late Pleistocene~~ archaeological layers ~~and a Late~~  
169 ~~Pleistocene one~~ were registered in CE test pit (Table 1).

170

171 PLACE HERE TABLE 1. Compilation of published radiocarbon and calibrated dates  
172 from the Holocene sequence ~~in~~of the Cova Colomera test pit CE.

173

174 Lower unit CE15 (CE15a, b and c), corresponding to the Pleistocene, was not  
175 anthropic in origin, but many micro- and macrofauna remains were recovered from the  
176 excavation and sediment sieving (López-García et al., 2010). The Pleistocene unit was  
177 separated from the Holocene sequence by a ~~narrow concentration~~thin concentration of  
178 boxwood leaves and white-colored branches, that corresponds to Holocene's top unit,  
179 layer CE14 (7163-6964 cal. years BP). ~~Plant-Boxwood~~ remains, such as branches and  
180 leaves, were documented in a primary position, which have been interpreted as a bed for  
181 the herd or part of their diet (i.e. Oms et al., 2013; Bergadà and Oms, 2021). Layers  
182 CE14 (~~7163-6964 cal. years BP~~), CE13 (7164-6909 cal. years BP) and CE12 (7146-  
183 6737 cal. years BP) are ascribed to a late phase of the regional Early Neolithic (Oms et  
184 al., 2008, 2009a, 2010, 2013, 2015). Layers CE10 (5305-5041 cal. years BP) and CE9  
185 (4863-4621 cal. years BP) are ascribed to the Late Neolithic, with horizons associated  
186 with the Veraza and Veraza-Ferrières cultures respectively (Oms et al., 2010, 2015). In  
187 turn, EE1 (4084-3839 cal. years BP, 4086-3896 cal. years BP) is an Early Bronze Age  
188 silo-shaped negative structure cutting through the Early Neolithic layers (Oms et al.,  
189 2009b, 2010, 2015). Lastly, the layer CE8 (3579-3395 cal. years BP, 3561-3400 cal.  
190 years BP) corresponds to the Middle Bronze Age. All Holocene layers correspond to an  
191 *in-situ* sedimentary facies of fumier type (*sensu* Brochier, 1983, 1991, 1996), which  
192 formed by a continuous accumulation of preserved fumier deposits. Therefore, the  
193 eastern sector of the cave (CE) would correspond to an area related to herd stabling and  
194 husbandry practices (Oms et al., 2008; Bergadà and Oms, 2021; Martín and Oms, 2021)  
195 (Figure 4).

196

197 PLACE HERE FIGURE 4. A: Cave plan; B: Stratigraphic profile and grid-square  
198 (2008-2009) of the Cova Colomera test pit CE (Oms et al., 2013; modified). According  
199 to Angelucci and others (2009), *c facies* relates to the accumulations of charcoal  
200 fragments and *ff facies* refers to silt with abundant ash and varied color, sometimes with  
201 platy structure and moderate cementation.

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### 203 3. Materials and methods

204

#### 205 3.1. Anthracological analysis

206

207 Anthracological analysis of Middle and Late Holocene archaeological layers at  
208 Cova Colomera is based on the study of 1.117 charcoal fragments. A previous~~ly~~ work  
209 consisted of the anthracological identification of 300 fragments from EE1 silo (Oms et  
210 al., 2009b), but in the present study, this assemblage has been completed with the  
211 identification of an additional 60 fragments. To recover the archaeobotanical remains,  
212 all the excavated sediment (from 2005 to 2011) was manually floated using bucket  
213 flotation, maintaining the ~~spot heights~~arrangement measurements (in 5 cm ranges~~Z-Z<sub>1</sub>)~~  
214 of the sedimentary facies, and using a 0.2 mm mesh sieve. ~~To recover the small-~~  
215 ~~mammal remains, the sediment was water sieved with two superimposed meshes of 5~~  
216 ~~and 0.5 mm (García López et al., 2010).~~

217

218 Identification and quantification were performed according to the standard  
219 methodology used in anthracological studies (see Kabukcu and Chabal, 2021~~0~~; Asouti



220 and Kabukcu, 2021). The charcoal remains have been quantified in number of  
221 fragments per taxon and, to evaluate the optimal sample size of the layers, the  
222 accumulation curves were established (Chabal, 1997; Kabukcu and Chabal, 2021)~~to~~  
223 ~~evaluate the homogeneity of the sample, and taxonomic saturation curves were~~  
224 ~~established (Chabal, 1997).~~ Anthracological analyses was accomplished using reflected  
225 light microscopy, both light- and dark-field (Olympus BX41) with magnifications of  
226 x50, x100, x200 and x500. The identification was based on anatomical features  
227 described in the atlas of European woods (Schweingruber, 1990) and was supported by  
228 the reference collection of modern charcoal at the IPHES (Institut Català de  
229 Paleoecologia Humana i Evolució Social), Tarragona (Spain). The unidentifiable  
230 charcoal fragments were assigned to broader categories based on their anatomical  
231 features. Undetermined fragments were classified as Undetermined angiosperm or  
232 Undetermined conifer. Fragments that retained some distinguishable anatomical feature,  
233 but did not allow attribution to species level, were numbered (e.g., Indeterminate  
234 angiosperm 1). Anthracological analysis does not always allow charcoal fragments to be  
235 discriminated to species level (Chabal, 1992, 1997; Chabal et al., 1999), and therefore  
236 in those cases other taxonomic groups were used (types, cf., genera or species). These  
237 specific taxa identified in the anthracological sample were regrouped (e.g.,  
238 *Populus/Salix*; *Pinus sylvestris* type includes *Pinus sylvestris/nigra*; and *Quercus* sp.  
239 evergreen includes *Quercus ilex* and *Q. coccifera*), since the anatomical distinction  
240 between two or more species is not possible (Schweingruber, 1990). ~~Some genera, such~~  
241 ~~as *Acer*, *Fraxinus*, *Juniperus* and *Prunus* only occasionally display differences in~~  
242 ~~specific anatomical criteria, therefore~~ Undefined species “sp” of some genera have been  
243 grouped, such as *Acer* sp., *Fraxinus* sp., *Lonicera* sp., and *Juniperus* sp. are regrouped in  
244 terms of species “sp”, usually accepted by anthracological researchers Some species of

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245 ~~the same genus have distinct specific anatomical criteria that may constitute different~~  
246 ~~categories or types. Some of the characters allow certain species to be regrouped into~~  
247 ~~different types~~ (Heinz and Barbaza 1998; Alcolea, 2017; Allué et al., 2018a). Based on  
248 Heinz and Barbaza (1998), ~~for European woods from the Mediterranean basin, the~~  
249 ~~genus~~ *Prunus* can be classified ~~into three types, which depend on the number of cells~~  
250 ~~wide in the rays. The rays of Prunus type 1 have no more than two cells (includes~~  
251 ~~Prunus avium/padus). Prunus type 2 has three or four cells wide in rays (includes~~  
252 ~~Prunus spinosa/mahaleb), and Prunus type 3 has more than five cells wide (includes~~  
253 ~~Prunus spinosa), as Prunus type 2, including Prunus spinosa/mahaleb, and Prunus type~~  
254 ~~3 corresponding to Prunus spinosa/amygdalus.~~ Finally, the family  
255 ~~Rosaceae/Maloideae~~ **ROSACEAE/MALOIDEAE** corresponds to several species,  
256 including, for example, *Sorbus* and *Crataegus*, that do not always share the same  
257 ecological adscription.

258  
259 **4. Results**

260 ~~The anthracological record from Cova Colomera has been. A total of 1.117~~  
261 ~~charcoal fragments, and were recovered at Cova Colomera and 1,038 of them were~~  
262 ~~identified (Table 2A and 2B). Accumulation curves show an optimal sample size~~  
263 ~~analysed in all layers (Figure 5). The charcoal record shows a wide diversity of taxa,~~  
264 ~~including broadleaves and lianas, such as Acer sp (maples), Arbutus unedo (strawberry~~  
265 ~~tree), Buxus sempervirens (boxwood), Clematis vitalba (Traveller's joy), Corylus~~  
266 ~~avellana (common hazel), Fagus sylvatica (common beech), Fraxinus sp. (ash), Hedera~~  
267 ~~helix (ivy), Lonicera sp. (honeysuckle), Pistacia lentiscus (lentisk), Populus/Salix~~  
268 ~~(poplar/willows), Prunus type 2 and type 3 (plums), Quercus sp. evergreen and sp.~~  
269 ~~deciduous (evergreen and deciduous oaks), Rhamnus alaternus/Phillyrea (buckthorn),~~

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270 ~~Rosaceae/Maloideae (rosales and pomes), Indeterminate angiosperm and cf. *Sambucus*~~  
271 ~~(elderberry), and conifers, such as *Pinus sylvestris* type (scot's pine and black pine),~~  
272 ~~*Taxus baccata* (yew) and *Juniperus* sp. (juniper). The taxa richness remains more or~~  
273 ~~less homogeneous throughout the sequence, although taxa variability was higher in the~~  
274 ~~Late Neolithic layers, especially in Layer CE9.~~

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275 ~~Throughout the sequence, 22 woody species are identified, of the current sub-~~  
276 ~~Mediterranean climatic type. The ubiquity of taxa frequencies remains more or less~~  
277 ~~homogeneous in the sequence, although species variability is higher in the Late~~  
278 ~~Neolithic layers. The recorded species are more variable in Layer CE9, compared to the~~  
279 ~~other layers (Figure 5). The most represented taxa in all archaeological layers are~~  
280 ~~*Quercus* sp. deciduous (oak), *Buxus sempervirens* (box) and *Acer* sp. (maple). Conifer~~  
281 ~~trees and shrubs are also well represented, including *Pinus sylvestris* type (Scots pine),~~  
282 ~~*Juniperus* sp. (junipers) and *Taxus baccata* (English yew). Other woody taxa are less~~  
283 ~~frequent, like deciduous trees belonging to thermo and meso-Mediterranean taxa, such~~  
284 ~~as *Arbutus unedo* (strawberry tree), *Clematis vitalba*, *Corylus avellana* (common hazel),~~  
285 ~~*Fagus sylvatica* (common beech), *Fraxinus* sp. (ash), *Hedera helix* (ivy), *Lonicera* sp.~~  
286 ~~(honeysuckle), *Pistacia lentiscus* (lentisk), *Populus/Salix* (aspen/willow), *Prunus* sp.,~~  
287 ~~evergreen — *Quercus* — (holm oak), — *Rhamnus* — (buckthorns) — and~~  
288 ~~ROSACEAE/MALOIDEAE.~~

289 ~~PLACE HERE TABLE 2A. Middle Holocene anthracological record from Cova~~  
290 ~~Colomera.~~

291 ~~PLACE HERE TABLE 2B. Late Holocene anthracological record from Cova~~  
292 ~~Colomera.~~

293 ~~Anthracological results for Cova Colomera by archaeological layers. Absolute (n) and~~  
294 ~~relative frequencies (%) of charcoal fragments analyzed with species recorded.~~

295 Early Neolithic layers CE12, CE13 and CE14 ~~are showed domination of~~  
296 ~~dominated by shrubby *Buxus sempervirens* boxwood,~~ with *Quercus* sp.  
297 ~~deciduous~~ deciduous oak and *Pinus sylvestris* type subsequently. ~~*Acer* sp. Maple and~~  
298 ~~*Juniperus* sp. maintain continuously~~ shows low values in the three Early Neolithic layers  
299 (no more than 8.5%). Nevertheless, the shrubby ~~In the other hand,~~ *Juniper* increases in  
300 the CE13 layer, although it displays a low presence in the subsequent CE14 layer.  
301 Sporadic fragments ( $\leq 5\%$ ), ~~of other taxa~~ such as *Arbutus unedo*, *Corylus avellana*,  
302 ~~*Quercus* sp. evergreen oak,~~ *Pistacia lentiscus*, *Prunus* sp., *Rhamnus*  
303 *alaternus/Phillyrea*, Rosaceae/Maloideae and *Taxus baccata* ~~are were~~ present ~~in~~  
304 ~~different layers~~ (Table 2A). In the same way, ~~*Buxus sempervirens* boxwood,~~ *Quercus* sp.  
305 ~~deciduous~~ deciduous oak and *Pinus sylvestris* type ~~are were~~ continued to  
306 ~~domined~~ dominant in the Late Neolithic layers CE9 and CE10. However, ~~*Acer* sp. maple~~  
307 has higher recorded values compared to the previous period, mainly detected in CE10  
308 layer. ~~Also, juniper shows a decreased~~ In this layer, *Juniperus* sp. decreases. Other taxa,  
309 such as *Fraxinus* sp., *Lonicera* sp., *Pistacia lentiscus*, *Populus/Salix*, *Prunus* sp.,  
310 ~~evergreen oak~~ *Quercus* sp. ~~evergreen,~~ *Rhamnus alaternus/Phillyrea*, Indeterminate  
311 angiosperm 1, *Taxus baccata* and cf. *Sambucus* ~~are were~~ also present, ~~although not~~  
312 ~~continuously~~. Likewise, *Taxus baccata* and *Prunus* sp. ~~are were~~ documented in both  
313 layers.

314 PLACE HERE FIGURE 5. ~~Taxonomic saturation~~ Taxon accumulation curves ~~for of~~ the  
315 Holocene layers ~~from of~~ Cova Colomera.

316 Early Bronze Age silo EE1 shows high values of ~~*Quercus* sp. deciduous oak.~~  
317 Furthermore, and *Buxus sempervirens* boxwood and *Pinus sylvestris* type pine, are well  
318 represented (Table 2B). Sporadic fragments of other taxa ( $\leq 5\%$ ), such as ~~*Acer* sp. maple,~~  
319 ~~*Fraxinus* sp. ash, *Juniperus* sp. juniper, and *Quercus* sp. evergreen~~ evergreen oak are

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320 ~~were~~ also ~~documented~~identified. Finally, Middle Bronze Age layer CE8 ~~is~~was  
321 characterized by a dominant presence of ~~*Quercus* sp. deciduous~~deciduous oak and  
322 ~~*Buxus sempervirens*~~boxwood although, compared to the older layers, the values of  
323 ~~boxwood~~ have decreasedwas lower. Likewise, scarce appearances of *Acer* sp. *Corylus*  
324 *avellana*, *Fagus sylvatica*, *Fraxinus* sp., *Hedera helix*, *Pinus sylvestris* type, *Prunus* sp.,  
325 ~~*Quercus* sp. evergreen~~evergreen oak, Rosaceae/Maloideae and *Taxus baccata* have been  
326 ~~documented~~identified.

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## 328 5. Discussion

329

### 330 5.1. Vegetal landscape transformation and environmental conditions around 331 Cova Colomera

332 The anthracological results from Cova Colomera have provided key data that  
333 allow us to describe the local-scale environment in the Central Pre-Pyrenees, ~~from~~  
334 ~~the~~during the Early Neolithic to the Middle Bronze AgeMiddle-Late Holocene.  
335 Anthracological analysis of 1.4+17 charcoal fragments from Cova Colomera shows the  
336 taxa diversity and changes in the representativeness of the relative values along the  
337 sequence (Figure 6). Although the anthracological sequence is very homogeneous in  
338 terms of the richness and ubiquity of woody taxa, there is a tendency towards a  
339 predominance and progressive increase of deciduous forest elements. However, a slight  
340 increase of evergreen oaks has been detected in the top of the anthracological  
341 sequence.~~Although the anthracological sequence is very homogeneous in terms of~~  
342 ~~diversity, 22 different woody taxa have been identified.~~

343 PLACE HERE FIGURE 6. Diagram with anthracological results for Cova Colomera.

344 Results from Early Bronze age silo EE1 (Oms et al., 2009b) have been included.

345 In accordance with the anthracological results obtained, the local area of Cova  
346 Colomera remained relatively stable and dominated by forest communities of deciduous  
347 Quereusoaks, with a significant presence of *Buxus sempervirens* and *Acer* sp. This  
348 assemblage of taxa is usually associated with sub- and supra-Mediterranean deciduous  
349 oak formations. The presence of mesophilic taxa such as *Acer* sp., *Prunus* sp.,  
350 Maloideae, *Rhamnus cathartica/saxatilis* and *Buxus sempervirens* would indicate  
351 temperate and humid climatic conditions. Other shrubby vegetation and small trees,  
352 such as *Juniperus* sp. and *Rhamnus/Phillyrea*, could also develop in more open spaces,  
353 indicating the existence of clearances. These opened forest formations under a humid  
354 climate may well correlate with the results from the study of the small vertebrates in the  
355 Holocene layers at Cova Colomera (López-García et al., 2010), which indicates  
356 chorotype of micromammals with mid-European requirements, which currently found at  
357 higher altitudes from the Pyrenes. Sub-Mediterranean thermophilic elements requiring  
358 more humidity, such as *Tilia* and *Pistacia cf. terebinthus*, have been identified in the  
359 silo EE1 at Cova Colomera, dated in the Early Bronze Age, and *Acer* sp. appears  
360 throughout the anthracological sequence. Riverine taxa, such as *Populus/Salix*, and  
361 *Fraxinus* sp., have been documented, although their presence is always low. These  
362 elements are likely to have been part of the riparian vegetation, occupying the river  
363 banks in Montsec mountain range, or in shadier and more humid locations, such as deep  
364 narrow gorges. The other represented subcircum- and sub-Mediterranean small trees,  
365 shrubs and liana, such as *Arbutus unedo*, *Corylus avellana*, *Ilex aquifolium*, *Hedera*  
366 *helix* and *Clematis vitalba* appear in lower frequencies. The occurrence of *Pinus*  
367 *sylvestris* type suggests the presence of conifer forests which suffered a slight decline in

368 the course of the anthracological sequence, mainly during the Middle Bronze Age.  
369 These formations would probably be growing at higher altitudes in some nearby areas  
370 of the Pre-Pyrenees. ~~-Taxus baccata~~ would probably develop in shadier areas. ~~Holm~~  
371 ~~oak~~Evergreen oaks and ~~associated sclerophyllous~~ elements, like ~~Arbutus unedo and~~  
372 ~~Rhamnus alaternus/Phillyrea~~, showed a low relative frequency throughout the  
373 anthracological sequence. However, from a diachronic point of view, a slight increase in  
374 evergreen ~~Quercus sp. oak was~~ detected, especially ~~during in~~ the Middle Bronze Age.  
375 ~~At present~~

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376 Currently, in Northeastern Spain and Southern France, Mediterranean forests  
377 form an ecoregion in transition between the Western European temperate broadleaf and  
378 mixed forest ecoregion and the Iberian sclerophyllous and semi-deciduous forest  
379 ecoregion (Dinerstein et al., 2017). Therefore, Mediterranean forests display ecological  
380 characteristics of Mediterranean, ~~sub-Mediterranean and~~ and Atlantic ~~climate~~vegetation  
381 (Blanco et al., 1997; Carreras and Ferré, 2014). Likewise, the plant community that  
382 includes the holm oak (Quercus ilex) evergreen oak forest and ~~other an evergreen~~  
383 understory of low trees and high shrubssclerophyllous evergreen taxa (such as *Olea*  
384 *europaea*, *Arbutus unedo*, *Rhamnus alaternus/Phillyrea*, *Erica sp.* and *Pistacia lentiscus*)  
385 are also identified as ~~ecoregion~~bioclimatic markers of the ~~Mediterranean climate~~  
386 Mediterranean biome, which currently dominates the area. In this aspect, ~~in the area~~  
387 ~~surrounding Cova Colomera, the Mediterranean taxa typical these sclerophyllous taxa~~  
388 ~~of the holm oak forest~~ display low ~~percentages~~ representation of ubiquity values in  
389 throughout the anthracological ~~record~~sequence of Cova Colomera. ~~The~~  
390 ~~sclerophyllous~~These taxa may have occupied secondary positions in more drier or  
391 sunnier places, probably in deciduous oak forest degradation areas. ~~formations would~~  
392 ~~probably occupy secondary positions in drier or sunnier places, while open and humid~~

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~~deciduous *Quercus* forests could be dominant in the landscape surrounding Cova Colomera. These open forest formations may well correlate with the results from the study of the small vertebrates in the Holocene layers at Cova Colomera (López-García et al., 2010).~~s

In Central Pre-Pyrenees, from the Early-Middle Holocene boundary (8.2 ka years BP event), the deciduous oak forest would occupy a more extensive territory than at present, favored by a temperate and humid climate (Figure 7). Paleoclimate records from Pre-Pyrenean ranges, such as Estanya Lake (Morellón et al., 2008), indicate greater water availability in three periods during the Holocene: Early Holocene: 8.5-8.2 ka year BP and Middle Holocene: 6.7-5.9 ka year BP and 4.9-4.2 ka year BP. Although these periods correspond to more humid conditions in the Mediterranean area, brief arid events also occurred at 8.2 and 7.5 ka year BP (Jalut et al., 2009; Bergadà et al., 2018).

PLACE HERE FIGURE 7. Calibrated radiocarbon dates of Cova Colomera in relation of different climate proxies.

~~However, Sub-Mediterranean thermophilic elements requiring more humidity, such as *Tilia* and *Pistacia cf. terebinthus*, have been identified in the silo EE1 at Cova Colomera, dated in the Early Bronze Age, and *Acer* sp. appears throughout the anthracological sequence. Riverine taxa, such as *Populus/Salix*, and *Fraxinus* sp., have been documented, although their presence is always low. These elements are likely to have been part of the riparian vegetation, occupying the river banks in Montsee mountain range, or in shadier and more humid locations, such as deep narrow gorges.~~

*Taxus baccata* records have very low values in pollen sequences, probably owing to the poor pollination rates and morphology difficulties (Chybicki and Oleksa, 2018), although it is well represented in Middle Holocene anthracological records in the

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417 Northern Iberian Peninsula (see Uzquiano et al., 2015), especially in mid-mountain  
418 areas. ~~Differences in *Taxus baccata* values between anthracological and pollen data~~  
419 ~~Differences in ubiquity values of *Taxus baccata*~~ may correspond to variable humidity  
420 conditions at higher altitudes, which would probably be dominated by coniferous  
421 forests. Additionally, the high relative frequency of *Buxus sempervirens* ~~boxwood~~  
422 Cova Colomera anthracological record is noteworthy. ~~Boxwood~~ is a sub-Mediterranean  
423 taxon, which currently grows in the montane and subalpine zones and in some southern  
424 locations in the Iberian Peninsula, in altitudinal ranges from 26 m. to 2.500 m- a.s.l.  
425 (Bolòs and Vigo, 1984; Carreras and Ferré, 2014). In some places, especially in  
426 disturbed oak forests, ~~boxwood~~ can play a pioneer role and can form extended shrubby  
427 formations, although it is most often associated with undergrowth in the deciduous oak  
428 forest (Rivas-Martínez, 1984; Carreras et al., 2015; Pascual, 2015) and can be  
429 considered an indicator of degraded or cleared areas (Pascual, 2015). In the local area  
430 around Cova Colomera, woodland formed by deciduous oaks and including maple and  
431 ~~boxwood~~ are currently found as part of the forest structure, especially in more temperate  
432 or Eurosiberian areas in the Pyrenees and Pre-Pyrenees, under temperate and humid  
433 climate conditions. ~~The association of the tree taxa~~ ~~These taxa is-are~~ common in Middle  
434 Holocene anthracological sequences ~~in the~~ ~~from~~ NE Iberian Peninsula, including littoral  
435 sites as well as the inner Pre-littoral ranges, such as in Cova del Toll (Mas and Allué,  
436 2020), Cova de l'Avellaner (Ros, 1996), Cova Gran (Allué, unpublished), Cova d'en  
437 Pau III and Plansallosa (Ros, 1996; Piqué, 2005), La Draga (Piqué, 2005), Cova del  
438 Frare (Ros, 1996), Bauma del Serrat Pont and La Prunera (Piqué, 2005).

439 ~~———According to our results, vegetation transformation dynamics during the Middle-~~  
440 ~~Late Holocene were more or less homogeneous in the Central Pre-Pyrenees. From a~~  
441 ~~local scale, global aridity events would not have affected the vegetation landscape~~

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442 ~~structure, and deciduous oak forests, temperate taxa and montane conifers would have~~  
443 ~~developed well in the area. According to our results, it might be suggested that, in the~~  
444 ~~Central Pre-Pyrenees, the 8.2 and 7.5 ka arid events did not cause major changes in the~~  
445 ~~vegetation cover. However, later, during the Late Holocene, xerophilous shrubs and~~  
446 ~~evergreen *Quercus* sp. began to expand in the landscape near Cova Colomera. Rapid~~  
447 ~~global climate change detected in the 4.2 to 3.8 ka event (Mayewsky et al., 2004) and~~  
448 ~~the aridification trend that affected the Mediterranean basin (Fletcher and Sánchez,~~  
449 ~~2008; Allué et al., 2009; Jalut et al., 2009; Carrión et al., 2010b; Bergadà et al., 2018)~~  
450 ~~could have been ~~more influential~~less influential in forest changes towards~~  
451 ~~Mediterraneanisation of the Central Pre-Pyrenees ~~than former climate events~~. Likewise, a~~  
452 ~~slight increase of the evergreen oak forest was detected in the Middle Bronze Age layer~~  
453 ~~of Cova Colomera. *Taxus baccata*, *Acer* sp. and *Buxus sempervirens* continued to be~~  
454 ~~well represented in Bronze Age layers from Cova Colomera and Cova Gran (Allué,~~  
455 ~~unpublished). However, the vegetation composition deduced from these anthracological~~  
456 ~~assemblages shows a continuing dominance of deciduous oak forests, with montane~~  
457 ~~conifers and temperate taxa.~~

458 ~~Subsequently, during the Late Holocene, *Taxus baccata*, *Acer* sp. and *Buxus*~~  
459 ~~*sempervirens* continued to be well represented in Bronze Age anthracological sequences~~  
460 ~~at Cova Colomera, Cova Gran (Allué, unpublished), Cova del Toll (Mas and Allué,~~  
461 ~~2020) and Institut de Manlleu (Ros, 1995b). The vegetation composition deduced from~~  
462 ~~these anthracological assemblages shows a continuing dominance of mesophilic taxa,~~  
463 ~~with deciduous *Quercus* forests and associated sub-Mediterranean elements, such as~~  
464 ~~*Acer* sp., *Buxus sempervirens* and Rosaceae. Nevertheless, deciduous oak forest and the~~  
465 ~~arboreal vegetation cover retreated slightly, indicating larger clearances. Finally, low~~

466 ~~percentages of sclerophyllous taxa occurred and *Pinus sylvestris* type has also been~~  
467 ~~documented.~~

## 469 **5.2. Anthropogenic impacts: human and environment interactionsinvolvement**

470 The archaeological record at Cova Colomera is associated with short-term  
471 occupations, related to herding activities, like foddering, litter-bedding, etc. (Oms et al.,  
472 2013; Bergadà and Oms, 2021). The systematic burning of these fumier deposits often  
473 provides rich vegetal remains (see Angelucci et al., 2009; Euba et al., 2016; Vergès et  
474 al., 2016; Polo-Díaz et al., 2016; Burguet-Coca et al., 2020), and Cova Colomera is not  
475 an exception. The anthracological sequence shows high taxonomic diversity, including  
476 29 woody taxa. Some of them, could have been part of the herd's fodder diet. However,  
477 we cannot exclude the use of some woody taxa as fuel, such as pine, juniper or yew, or  
478 as objects and tools that were thrown to the fire after their use. Moreover, ovicaprine  
479 herds are a potential agent to reduce undergrowth vegetation. During the winter,  
480 browsing is focused on evergreen and semi-deciduous species, while in spring and  
481 autumn herbaceous grasses are also browsed (Bartolomé et al., 1998; Osoro et al.,  
482 2013). High protein woody species such as *Clematis vitalba*, *Acer opalus*, *Quercus* sp.,  
483 *Pistacia lentiscus* or *Arbutus unedo* are currently consumed by ovicaprine herds in  
484 Mediterranean areas (Rogosic et al., 2006; Bartolomé, 2014). Other taxa such as  
485 junipers and boxwood are rejected by the herds as fodder (Bartolomé, 2014). However,  
486 the boxwood's wood is also of good quality: hard, fine and compact, easy to polish and  
487 dye, and could have been used for manufacturing objects. The wood produces a slow  
488 combustion, a property much appreciated for its use as fuel (Caruso-Ferre and Piqué-  
489 Huerta, 2014). Examples such as the Neolithic settlement of La Draga (Banyoles,  
490 Girona) show the use of boxwood in the production of agricultural tools (Palomo et al.,

491 2011; Piqué et al., 2018). In this sense, archaeological work in some of the phases of the  
492 fumier documented the preservation and accumulation of leaves and branches of  
493 boxwood, possibly for the adaptation of beds or spaces for livestock (Bergadà and Oms,  
494 2021; Oms et al., 2013).

495 Cova Colomera has provided no evidence of human occupation during the  
496 Middle Neolithic, although the cave was used by humans in the Early Neolithic and  
497 from the Late Neolithic to Bronze Age cultural periods. Two possible scenarios can be  
498 discussed. In the NE of the Iberian Peninsula, evidence of occupation by Middle  
499 Neolithic populations has only been documented in burial contexts or in the open-air  
500 settlement of Ca n'Isach (Palau-saverdera, Girona) (Tarrús et al., 2016) while no  
501 evidence of occupation of caves and rock-shelters has been found (see Oms and Martín,  
502 2018). A first hypothesis could be the non-preservation of evidence of human  
503 occupation due to erosion in karst systems and on mountainsides (see Polo-Díaz et al.,  
504 2014; Bergadà et al., 2018). Alternatively, the second hypothesis postulates the  
505 intentional abandonment of caves and rock-shelters due to changes in livestock grazing  
506 practices.

507 Attending to human impact on forest communities in a local scale, from the  
508 Early Neolithic to the Middle Bronze Age, the forest cover does not seem to have  
509 changed significantly in terms of either recovery or degradation. This could indicate that  
510 human groups carried out a reiterated but a non-intensive exploitation of the forests. In  
511 this sense, little evidence of intense human activities on the landscape can be found in  
512 the Iberian Central Pre-Pyrenees, although the exploitation of the plant resources has  
513 been documented since the Upper Pleistocene and Early Holocene (Allué et al., 2012,  
514 2018b). At lower altitudes and similar to Cova Colomera, Neolithic layers or structures  
515 at Les Auvelles (Oms et al., 2019), Cova Gran (Mora et al., 2011) and Forat de

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516 Conqueta (Mora et al., 2009; Allué, 2011) show slight differences and similarities in the  
517 composition of the vegetation landscape. On one hand, the open-air archaeological site  
518 of Auvelles has yielded an anthracological record of oak taxa in which, although  
519 dominated by deciduous oak, evergreen oak is also represented with high ubiquity  
520 values (Martín-Seijo and Piqué, 2008). According to the authors, this assemblage could  
521 be influenced by specific fuel and wood selection patterns. On the other hand,  
522 anthracological data from the cave of Forat de Conqueta and the rock-shelter of Cova  
523 Gran (Allué, unpublished) indicate an assemblage similar to that of Cova Colomera.  
524 Archaeological research identified livestock practices in the Holocene layers of Cova  
525 Gran, especially for livestock enclosure, and interpreted the use of the cave in relation to  
526 the transhumance routes through the southern Pyrenees (Polo-Díaz et al., 2014;  
527 Burguet-Coca et al., 2020; Martín and Oms, 2021), and also in some mountain Pyrenees  
528 areas (Gassiot et al., 2017; Knockaert et al., 2018; Tejedor-Rodríguez et al., 2021). The  
529 forest formations were probably the same in the different Pre-Pyrenees valleys with no  
530 differences related to human pressure causing more open forests in some areas.

531 Profound transformations of natural landscapes into cultural landscapes are  
532 currently the result of human pressure (Butzer, 1989; Quézel and Médail, 2003;  
533 Blondel, 2006; Pérez-Obiol et al., 2011). Humans exploited forest wood resources and  
534 interfered with the natural development and distribution of woody plants for millennia.  
535 However, evidence of the anthropogenic footprint in the landscape during the Middle-  
536 Late Holocene is not homogeneous in the Iberian Peninsula. For example, it seems to be  
537 less intense in mountainous areas (e.g., Carrión et al., 2010b). In these areas above  
538 2.000 m- a.s.l., Neolithic populations could consume more or less wood according to the  
539 functionality and location of settlements (i.e. Obea et al., 2021). Therefore, the  
540 archaeological sites show no evidence of extensive agriculture or substantial

541 modification of the landscapes. In contrast, the transformation of the vegetation  
542 landscape appeared to be more intense in Mediterranean coastal areas (e.g., Riera and  
543 Esteban-Amat, 1994; Revelles et al., 2015). Nevertheless, there is no uncertainty that  
544 anthropogenic activities were important at the local scale particularly in the Late  
545 Holocene. The anthropic impact on landscapes during the Early Bronze Age has also  
546 been interpreted by the increase in microcharcoal particles associated with the  
547 recurrence of fire events in mountain areas (i.e. Carrión et al., 2010b), more intensive  
548 land-use dynamics (Rull et al., 2021) and more specialized fuel gathering patterns (i.e.  
549 Ros, 1995<sup>b</sup>, 1998; Piqué, 1999; Allué, 2007; Allué et al., 2009; Vila and Piqué, 2012;  
550 Obea et al., 2021).

551 ~~—— Cova Colomera has provided no evidence of human occupation during the~~  
552 ~~Middle Neolithic, although the cave was used by humans in the Early Neolithic and~~  
553 ~~from the Late Neolithic to Bronze Age cultural periods. Two possible scenarios can be~~  
554 ~~discussed. In the NE of the Iberian Peninsula, evidence of occupation by Middle~~  
555 ~~Neolithic populations has only been documented in burial contexts or in the open air~~  
556 ~~settlement of Ca n'Isach (Palau-saverdera, Girona) (Tarrús et al., 2016) while no~~  
557 ~~evidence of occupation of caves and rock shelters has been found (see Oms and Martín,~~  
558 ~~2018). A first hypothesis could be the non-preservation of evidence of human~~  
559 ~~occupation due to erosion in karst systems and on mountainsides (see Polo et al., 2014;~~  
560 ~~Bergadà et al., 2018). Alternatively, the second hypothesis postulates the intentional~~  
561 ~~abandonment of caves and rock shelters due to changes in livestock grazing practices.~~

562 ~~The archaeological record at Cova Colomera is associated with short term~~  
563 ~~occupations, related to herding activities, like foddering, litter bedding, etc. (Oms et al.,~~  
564 ~~2013; Bergadà and Oms, 2021). The systematic burning of these fumier deposits often~~  
565 ~~provides rich vegetal remains (see Badal, 1999; Angelucci et al., 2009; Euba et al.,~~

566 2016; Vergès et al., 2016; Polo-Díaz et al., 2016; Burguet-Coca et al., 2020), and Cova  
567 Colomera is not an exception. The anthracological sequence shows high taxonomic  
568 diversity including 22 woody taxa, which could have been part of the herd's fodder diet.  
569 However, we cannot exclude the use of some woody species as fuel or as objects and  
570 tools that were thrown to the fire after their use. Moreover, ovicaprine herds are a  
571 potential agent to reduce undergrowth vegetation. During the winter, browsing is  
572 focused on evergreen and semi-deciduous species, while in spring and autumn  
573 herbaceous grasses are also browsed (Bartolomé et al., 1998; Osoro et al., 2013). High  
574 protein woody species such as *Clematis vitalba*, *Acer opalus*, *Quercus* sp., *Pistacia*  
575 *lentiscus* or *Arbutus unedo* are currently consumed by ovicaprine herds in  
576 Mediterranean areas (Rogosic et al., 2006; Bartolomé, 2014). Other species such as  
577 *Juniperus* sp. and *Buxus sempervirens* are rejected by the herds as fodder (Bartolomé,  
578 2014). However, the wood is also of good quality: hard, fine and compact, easy to  
579 polish and dye, and could have been used for manufacturing objects. The wood  
580 produces a slow combustion, a property much appreciated for its use as fuel (Caruso-  
581 Ferme and Piqué Huerta, 2014). Examples such as the Neolithic settlement of La Draga  
582 (Banyoles, Girona) show the use of boxwood in the production of agricultural tools  
583 (Palomo et al., 2011; Piqué et al., 2018). In this sense, archaeological work in some of  
584 the phases of the fumier documented the preservation and accumulation of leaves and  
585 branches of *Buxus sempervirens*, possibly for the adaptation of beds or spaces for  
586 livestock (Bergadà and Oms, 2021; Oms et al., 2013).

587 Attending to human impact on forest communities, during the Early Neolithic  
588 and Middle Bronze Age, the forest cover does not seem to have changed significantly in  
589 terms of either recovery or degradation. This could indicate that human groups carried  
590 out a permanent but a non-intensive exploitation of the forests. In this sense, little

591 ~~evidence of intense human impact on the landscape can be found in the Iberian Central~~  
592 ~~Pre-Pyrenees, although the exploitation of the plant resources has been documented~~  
593 ~~since the Upper Pleistocene and Early Holocene (Allué et al., 2012, 2018b). At lower~~  
594 ~~altitudes and similar to Cova Colomera, Neolithic layers or structures at Les Auvelles~~  
595 ~~(Oms et al., 2019), Cova Gran (Mora et al., 2011) and Forat de Conqueta (Mora et al.,~~  
596 ~~2009; Allué, 2011) show slight differences and similarities in the composition of the~~  
597 ~~vegetation landscape. On one hand, the open-air archaeological site of Auvelles has~~  
598 ~~yielded an anthracological record of mixed oak taxa in which, although dominated by~~  
599 ~~deciduous oak, evergreen oak is also represented with high ubiquity values (Martín~~  
600 ~~Seijo and Piqué, 2008). According to the authors, this assemblage could be influenced~~  
601 ~~by specific fuel selection patterns. On the other hand, anthracological data from the cave~~  
602 ~~of Forat de Conqueta and the rock shelter of Cova Gran (Allué, unpublished) indicate~~  
603 ~~an assemblage similar to that of Cova Colomera. Archaeological research identified~~  
604 ~~livestock practices in the Holocene layers of Cova Gran, especially for livestock~~  
605 ~~enclosure, and interpreted the use of the cave in relation to the transhumance routes~~  
606 ~~through the southern Pyrenees (Polo et al., 2014; Burguet Coca et al., 2020; Martín and~~  
607 ~~Oms, 2021), and also in some mountain Pyrenees areas (Gassiot et al., 2017; Knoekaert~~  
608 ~~et al., 2018; Tejedor Rodríguez et al., 2021). The forest formations were probably the~~  
609 ~~same in the different Pre-Pyrenees valleys with any differences related to human~~  
610 ~~pressure causing more open forests in some areas.~~

## 612 **6. Conclusions**

613 The anthracological analysis of Cova Colomera has documented changes in the  
614 vegetation landscape in the Central Pre-Pyrenees, and these are related to specific  
615 climatic dynamics and a low anthropogenic impact, especially as regards herding and



616 livestock management activities. The anthracological sequence shows how the local  
617 area of Cova Colomera, from the Middle to Late Holocene, remained in the long term  
618 dominated by deciduous ~~Quereus oak~~ forest ecosystems associated with sub- and supra-  
619 Mediterranean deciduous formations, while the coniferous forest gradually receded.  
620 According to our results, it seems that in the Central Pre-Pyrenees aridity events did not  
621 cause major changes in vegetation cover, since the environmental conditions in the area  
622 of study included certain particularities that favored the establishment of a temperate  
623 and humid climate. However, during the Late Holocene, ~~xerophytic shrubs and~~  
624 evergreen ~~Quereus oaks~~ began to ~~spread on a local scale~~ show a slight increase, mainly  
625 during the Middle Bronze Age.

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626 The evidence of the anthropogenic footprint on the landscape during the Middle  
627 Holocene is not homogeneous in the NE Iberian Peninsula, as some areas would have  
628 displayed certain particularities. Neolithic human groups who settled in the open air and  
629 took advantage of the caves and rock-shelters to carry out specialized activities were  
630 well aware of the potential of the landscapes. However, the evidence of herding  
631 activities during the Neolithic seems to have left ~~an a slight~~ ~~incipient~~ pressure on the  
632 structure of the different landscapes, especially in inland areas of the NE Iberian  
633 Peninsula, like the Central Pre-Pyrenees. -Therefore, human presence in this area was  
634 probably not intensive. In this sense, we do not observe such intensive exploitation of  
635 forest resources, in contrast to the areas near the coast. Finally, the Bronze Age  
636 populations to which more intensive exploitation of forest resources is attributed on a  
637 regional scale do not seem to be intensive at the local scale of Cova Colomera. The  
638 differences in the intensity of forest exploitation may be due to the different  
639 functionalities of the occupations as well as the different places of settlement. Finally,  
640 during the Late Holocene, Bronze Age populations seem to show a more specialized

641 ~~selection pattern of forest resources, although with differences in intensity, according to~~  
642 ~~the functionality of the occupations and the place of settlement.~~

643

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667

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- Fumier deposits of Cova Colomera are the earliest evidence of herding activities among the Central Pre-Pyrenees (Iberian Peninsula), that related by short occupation periods by Neolithic and Bronze Age human groups.
- The new anthracological data from Cova Colomera shows local peculiarities about the structure of the oak woodland ecosystem, and its slight change, related to climatic dynamics, geographic features and activities of herding management.
- In terms of landscape development, human activities do not appear to have affected highly, in contrast to the areas near the Mediterranean seacoast of the NE Iberian Peninsula.

## Abstract

Cova Colomera is one of the most important archaeological sites to explain early herding activities in the Central Pre-Pyrenees (Iberian Peninsula). Fieldworks have provided a stratigraphy that shows short occupations of the cave by Neolithic and Bronze Age human groups. The sedimentological description has revealed fumiers deposits, that are characteristic of husbandry activities. In this paper, we provide the anthracological results based on 1,117 charcoal fragments. The results allow to characterise the Mediterranean vegetation landscape and its transformation, from a local perspective, related to climatic changes and anthropogenic activities.

Climate changes and human activities have played a significant role in Mediterranean landscapes dynamics. However, the incidence or impact of both agents on the vegetation landscape occurred unequally among the Mediterranean region. The anthracological results from Cova Colomera suggest that the Central Pre-Pyrenees was dominated by an oak forest ecosystem, with sub- and supra-Mediterranean deciduous taxon and coniferous forest during the Middle Holocene. This ecosystem remained more or less stable during the Late Holocene, although evergreen oak showed a slight increase, and coniferous forest showed a slight decrease. The orographic characteristics of the Central Pre-Pyrenees were able to maintain temperate and humid conditions, with less impact of aridity events recorded in Mediterranean environments. From a diachronic point of view, the herding activities of Neolithic human and Bronze Age human groups do not appear to have affected highly the landscape development of the Central Pre-Pyrenees. Human activities were probably not intensive in terms of forest clearing or land use.

1 **Anthropogenic impacts on vegetation landscapes and environmental implications**  
2 **during the Middle-Late Holocene in the Iberian Central Pre-Pyrenees: an**  
3 **anthracological approach**

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13

14 **Keywords**

15 Landscape transformations; Anthracology; Cova Colomera; Middle-Late Holocene;

16 Northeastern Iberian Peninsula

17

18

19 **1. Introduction**

20 The impact of general Holocene climate dynamics varied among past

21 Mediterranean landscapes. Above all in the first stages of the Holocene (11.7 ka BP to

22 4.2 ka BP), the influence of climatic agents on landscape transformation was more evident

23 than the impact of human activities. However, it is more controversial, or less obvious,  
24 which of the two agents, natural factors or the human activities, has been the main  
25 contributor to landscape transformation since the Middle-Late Holocene Boundary (4.2  
26 ka BP), or indeed whether it has been a combination of both (see Jalut et al., 2000; Roberts  
27 et al., 2011). Holocene Mediterranean woodland history and landscape changes are here  
28 studied using a palaeoecological proxy, mainly pollen and charcoal data (e.g., Jalut et al.,  
29 2009; Woodbridge et al., 2018; Roberts et al., 2019; Picornell-Gelabert et al., 2020).  
30 According to the available palaeobotanical sequences in the NE Iberian Peninsula, at the  
31 end of the Late Pleistocene and the beginning of the Early Holocene, deciduous oak  
32 forest, broadleaf trees and pine forests were dominant in the area (Riera-Mora and  
33 Esteban-Amat, 1994; Burjachs et al., 1997; Riera et al., 2007; Allué et al., 2007, 2017;  
34 Carrión et al., 2010a; Pérez-Obiol et al., 2011; Fletcher et al., 2012; Revelles et al., 2015,  
35 2018; González-Sampériz et al., 2017; Allué and Mas, 2020; Mas et al., 2021). Further,  
36 during the Middle Holocene sub-epoch (8.2 ka BP to 4.2 ka BP), warmer and more humid  
37 climatic conditions prevailed as high-precipitation regimes increased, favouring the  
38 expansion of deciduous forests and the retreat of pine forests and grasslands (Badal et al.,  
39 1994; Jalut et al., 2009; Allué et al., 2012; González-Sampériz et al., 2017).  
40 Simultaneously, from the Early Holocene, Neolithization throughout the Mediterranean  
41 resulted in the expansion of agriculture and herding associated with the development of  
42 a sedentary lifestyle. Herding activities are evidenced in archaeological sites by fumier  
43 deposits, which have been documented from the Early Neolithic to the Iron Age (see  
44 Angelucci et al., 2009). Fumiers are the result of stabling animals (usually flocks of goat  
45 and sheep) within the entrance areas of caves and rock-shelters. The deposits are mainly  
46 derived from the combustion of organic waste, such as accumulations of animal dung.  
47 Plant material in this type of deposit has different origins related to practices and needs



48 associated with human settlements such as foddering, animal beds, fuel, refuse and  
49 fencing (Brochier, 1983, 1991, 1996; Polo-Díaz et al., 2014, 2016; Burguet-Coca et al.,  
50 2020).

51 In addition to being an important proxy for detecting different past local  
52 landscapes, anthracology is also able to identify changes in human-forest relationships in  
53 terms of wood exploitation and consumption (see Chabal, 1992; Chabal et al., 1999;  
54 Kabukcu, 2018; Asouti and Kabukcu, 2021; Kabukcu and Chabal, 2021). Anthracological  
55 data available for the NE Iberian Peninsula during the Middle Holocene and Late  
56 Holocene sub-epochs (Senabre and Socias, 1993; Heinz and Vernet, 1995; Ros, 1995a,  
57 1995b, 1996, 1998; Piqué, 1999, 2005; Allué, 2007, 2010; Martín and Piqué, 2008; Allué  
58 et al., 2009; Vila and Piqué, 2012; Antolín et al., 2013; Alcolea, 2017; Daura et al., 2019)  
59 indicate that the configuration and distribution of vegetation landscapes were diverse at  
60 regional scale. As a consequence, research based on a local approach may be relevant to  
61 reconstructing the regional variability (Figure 1).

62 PLACE HERE FIGURE 1. Archaeological sites with available Middle-Late Holocene  
63 anthracological data from NE Iberian Peninsula. Early Neolithic: 1) La Draga (Piqué,  
64 2005); 2) Cova d'en Pau III (Ros, 1996; Piqué, 2005); 3) Cova 120 (Ros, 1995a; Piqué,  
65 2005); 4) Bauma del Serrat Pont (Piqué, 2005); 5) Plansallosa (Ros, 1995a; Piqué, 2005);  
66 6) Cova de l'Avellaner (Ros, 1996); 10) Cova del Toll (Mas and Allué, 2020); 11) Cova  
67 del Frare (Ros, 1996); 12) Cova Bonica (Daura et al., 2019); 13) Can Sadurní (Antolín et  
68 al., 2013); 15) La Serreta (Allué, 2010); 17) Cova de la Guineu (Allué et al., 2009); 18)  
69 Camp del Colomer (Piqué et al., 2015); 19) Bauma Margineda (Heinz, 1995); 20) Coves  
70 del Fem (Alcolea, 2017); 23) Cova Colomera (in this paper); 25) Barranc d'en Fabra (Ros,  
71 1996); 26) Cova del Vidre (Alcolea, 2017). Late Neolithic-Chalcolithic: 3) Cova 120  
72 (Ros, 1995a; Piqué, 2005); 4) Bauma del Serrat Pont (Piqué, 2005); 7) La Prunera (Piqué,

73 2005); 14) Santa Maria dels Horts (Senabre and Socias, 1993); 17) Cova de la Guineu  
74 (Allué et al., 2009); 21) Cova Gran de Santa Linya (Allué, unpublished); 22) Auvelles  
75 (Martín and Piqué, 2008); 23) Cova Colomera (in this paper); 24) Roques del Sarró (Vila  
76 and Piqué, 2012). Early Bronze age: 8) Institut Manlleu (Ros, 1995b); 9) Can Roqueta  
77 (Piqué, 1999); 10) Cova del Toll (Mas and Allué, 2020); 16) Mas d'en Boixos (Allué,  
78 2007); 17) Cova de la Guineu (Allué et al., 2009); 23) Cova Colomera (in this paper).  
79 Middle Bronze age: 21) Cova Gran de Santa Linya (Allué, unpublished); 23) Cova  
80 Colomera (in this paper); 27) Genó (Vila and Piqué, 2012); 28) Punta Farisa (Ros, 1998).

81

82 The Central Pre-Pyrenees (southern Pyrenees, Iberian Peninsula) is remarkable  
83 for the evidence of herding activities that occurred there, as documented at Cova  
84 Colomera (see Bergadà and Oms, 2021; Martín and Oms, 2021) and also at other  
85 archaeological sites where anthracological data are available (Polo-Díaz et al., 2016;  
86 Burguet-Coca et al., 2020). The present study of a new anthracological sequence from a  
87 fumier deposit in Cova Colomera (Serra del Montsec, Central Pre-Pyrenees), with human  
88 occupations from the Early Neolithic to the Middle Bronze Age (mid-6th millennium cal  
89 BCE to 3rd millennium cal BCE), assumes a diachronic perspective in order to understand  
90 the role of anthropogenic activities and climate change in the transformation of local  
91 environments and the shaping of the cultural landscape. The main objectives are to  
92 understand vegetation change and its causes, and thus to estimate the impact that the  
93 Neolithization process may have had on vegetation landscapes.

94

95 1.1. Geographical area and landscapes

96           The study area is located in the Montsec range, in the Central Pre-Pyrenees,  
97 between the Tremp-Graus and Ager drainage basins. This range, rising through the  
98 passage of the Pre-Pyrenees towards the Ebro Basin, is formed by Cretaceous bioclastic  
99 limestones. The topography is the result of a series of monoclinical mountain ranges over  
100 40 km, covering an area of 186.96 km<sup>2</sup>, oriented from west to east. Three rivers, the Boix,  
101 the Noguera Pallaresa and the Noguera Ribagorçana, cut through the ridge from north to  
102 south. Crossing the Montsec range, these water courses have eroded and shaped narrow  
103 gorges and routes such as Pas Nou, Terradets and Mont-rebei. At some points, the range  
104 exceeds 1600 m a.s.l. in its central sector (e.g., Sant Alís is at 1676 m a.s.l.), but it loses  
105 height at either end.

106           The southern slope of the range, the Ager basin, is characterized by a longer  
107 summer drought and therefore drier climate conditions. Locally, the area is under the  
108 influence of a sub-Mediterranean climate type, albeit with a continental trend (*sensu*  
109 Carreras and Ferré, 2014). Climatic conditions of sub-Mediterranean climate type are  
110 differentiated from the general Mediterranean regime by cooler temperatures and higher  
111 rainfall, although a short and irregular summer drought may occur in some years (see  
112 Jalut et al., 2000). The mean annual rainfall ranges from 400 to 600 mm, with the  
113 maximum precipitation occurring in autumn (October showing mean precipitation of  
114 around 40 mm) and the minimum in summer (July showing precipitation of less than 13  
115 mm). The mean annual temperature oscillates between 11 and 13°C, with a maximum of  
116 31°C in July and a minimum of 0°C in January (Meteocat data 2020 from Camarasa  
117 municipality) (Figure 2). The biome of the area is characterized by Mediterranean forests,  
118 woodlands and scrub belonging to the Iberian sclerophyllous and semi-deciduous forests  
119 (Dinerstein et al., 2017). In some areas, holm-oak forests (*Quercus ilex* subsp. *ilex*) and  
120 Aleppo pine forests (*Pinus halepensis*) expand.

121 PLACE HERE FIGURE 2. A) Map of forest communities in the study area, according to  
122 the vegetation series of Spain (Rivas-Martínez, 1987); B and C) Principal bioclimatic  
123 variables in the NE Iberian Peninsula. “Mean annual Temperature” (B) and “Mean annual  
124 Precipitation” (C) according to *Ministerio de Agricultura, Pesca y Alimentación* (Spanish  
125 government), by geostatistical interpolation methods from actual AMET data  
126 (<http://wms.mapama.es/sig/Agricultura/CaractAgroClimaticas/wms.aspx?>).

127

128 The northern slope of the range, the Tremp-Graus Basin, is rainier and shadier,  
129 and consequently the climate is more temperate and could be interpreted as Eurosiberian  
130 in tendency. The biome is characterized by a temperate broadleaf and mixed forest, which  
131 belongs to the Pyrenees conifer and mixed forest ecoregion (Dinerstein et al., 2017).  
132 Locally, beech forests and oak forests are predominant (*Quercus faginea*, *Quercus*  
133 *cerrioides* and *Quercus pubescens*, with the presence of *Acer* sp. and *Buxus*  
134 *sempervirens*). Likewise, in the higher areas of the range, pine forests expand (*Pinus*  
135 *nigra* subsp. *salzmannii* and *Pinus sylvestris*).

136

## 137 2. Cova Colomera

138 Cova Colomera is located in the Mont-rebei gorge, Serra del Montsec (Central  
139 Pre-Pyrenees, NE Iberian Peninsula). The cave is located 670 m a.s.l., 150 m above the  
140 left bank of the Noguera Ribagorçana River, a tributary of the Segre River (Oms et al.,  
141 2008, 2009a) (Figure 3). The cave entrance is 70 m high and 30 m wide and leads to a  
142 chamber about 180 m long and 10-12 m wide (Oms et al., 2013).

143 PLACE HERE FIGURE 3. 3D Location map of Cova Colomera, at N42°4'40.892",  
144 E0°40'54.487" (WGS 84).

145

146 From 2005 to 2011, an interdisciplinary team from the Seminari d'Estudis i  
147 Recerques Prehistòriques (SERP-UB) excavated the cave, resulting in the description of  
148 the stratigraphic sequence (Oms et al., 2015). Two 26 m<sup>2</sup> test pits were excavated during  
149 the fieldwork: one in the eastern sector of the cave, “Colomera Est (CE)”, and the second,  
150 “Colomera Vestíbul (CV)”, in the highest sector of the cave entrance. The CV test pit  
151 revealed thin stratigraphic layers up to the top of a carbonate crust. Under the crust, a  
152 series of overlapping anthropogenic structures (silos, hearths, post-holes) were  
153 documented. Six Holocene archaeological layers and one Late Pleistocene layer were  
154 registered in the CE test pit (Table 1).

155 PLACE HERE TABLE 1. Compilation of published radiocarbon and calibrated dates  
156 from the Holocene sequence of the Cova Colomera test pit CE.

157 The lowest unit CE15 (CE15a, b and c), corresponding to the Pleistocene, was not  
158 anthropic in origin, but many micro- and macrofaunal remains were recovered from the  
159 excavation and sediment sieving (López-García et al., 2010). The Pleistocene unit was  
160 separated from the Holocene sequence by a thin concentration of boxwood leaves and  
161 white-coloured branches that corresponds to the top unit of the Holocene sequence, layer  
162 CE14 (7163-6964 cal. years BP). The boxwood remains, such as branches and leaves,  
163 were documented in a primary position and have been interpreted as a bed for the herd or  
164 as part of their diet (Oms et al., 2013; Bergadà and Oms, 2021). Layers CE14, CE13  
165 (7164-6909 cal. years BP) and CE12 (7146-6737 cal. years BP) are ascribed to a late  
166 phase of the regional Early Neolithic (Oms et al., 2008, 2009a, 2010, 2013, 2015). Layers  
167 CE10 (5305-5041 cal. years BP) and CE9 (4863-4621 cal. years BP) are ascribed to the  
168 Late Neolithic, with horizons associated with the Veraza and Veraza-Ferrières cultures  
169 respectively (Oms et al., 2010, 2015). In turn, EE1 (4084-3839 cal. years BP, 4086-3896

170 cal. years BP) is an Early Bronze Age silo-shaped negative structure cutting through the  
171 Early Neolithic layers (Oms et al., 2009b, 2010, 2015). Lastly, layer CE8 (3579-3395 cal.  
172 years BP, 3561-3400 cal. years BP) corresponds to the Middle Bronze Age. All the  
173 Holocene layers correspond to an in-situ sedimentary facies of a fumier type (*sensu*  
174 Brochier, 1983, 1991, 1996), which formed through a continuous accumulation of  
175 preserved fumier deposits. Accordingly, the eastern sector of the cave (CE) can be  
176 interpreted as corresponding area related to stabling and husbandry practices (Oms et al.,  
177 2008; Bergadà and Oms, 2021; Martín and Oms, 2021) (Figure 4).

178 PLACE HERE FIGURE 4. A: Cave plan; B: Stratigraphic profile and grid-square (2008-  
179 2009) of the Cova Colomera test pit CE (Oms et al., 2013: modified). According to  
180 Angelucci and others (2009), *c facies* relates to the accumulations of charcoal fragments  
181 and *tf facies* refers to silt with abundant ash and varied color, sometimes with platy  
182 structure and moderate cementation.

183

### 184 **3. Materials and methods**

185 The anthracological analysis of the Middle and Late Holocene archaeological  
186 layers at Cova Colomera is based on the study of 1,117 charcoal fragments. A previous  
187 work consisted of the anthracological identification of 300 fragments from the EE1 silo  
188 (Oms et al., 2009b), but in the present study this assemblage is complemented with the  
189 identification of an additional 60 fragments. To recover the archaeobotanical remains, all  
190 the excavated sediment (from 2005 to 2011) was manually floated using bucket flotation,  
191 maintaining the spot height measurements (in 5 cm ranges) of the sedimentary facies and  
192 using a 0.2 mm mesh sieve.

193

194 Identification and quantification were performed according to the standard  
195 methodology used in anthracological studies (see Kabukcu and Chabal, 2021; Asouti and  
196 Kabukcu, 2021). The charcoal remains were quantified as the number of fragments per  
197 taxon and, to evaluate the optimal sample size of the layers, the accumulation curves were  
198 established (Chabal, 1997; Kabukcu and Chabal, 2021). The anthracological analysis was  
199 accomplished using reflected light microscopy, both bright- and dark-field (Olympus  
200 BX41), with magnifications of x50, x100, x200 and x500. The identification was based  
201 on anatomical features described in the atlas of European woods compiled by  
202 Schweingruber (1990) and was supported by the reference collection of modern charcoal  
203 at the IPHES (Institut Català de Paleoecologia Humana i Evolució Social), Tarragona  
204 (Spain). Unidentifiable charcoal fragments were assigned to broader categories based on  
205 their anatomical features. Undetermined fragments were classified as undetermined  
206 angiosperm or undetermined conifer. Fragments that retained some distinguishable  
207 anatomical feature, but did not allow attribution to species level, were numbered (e.g.,  
208 indeterminate angiosperm 1). Anthracological analysis does not always allow charcoal  
209 fragments to be discriminated to species level (Chabal, 1992, 1997; Chabal et al., 1999),  
210 so in those cases other taxonomic groups were used (types, cf., or genera). Some specific  
211 taxa identified in the anthracological sample were regrouped (e.g., *Populus/Salix*; *Pinus*  
212 *sylvestris* type includes *Pinus sylvestris/nigra*; and *Quercus* sp. evergreen includes  
213 *Quercus ilex* and *Quercus coccifera*) where the anatomical distinction between two or  
214 more species is not possible (Schweingruber, 1990). Undefined species (“sp.”) of some  
215 genera were grouped together, such as *Acer* sp., *Fraxinus* sp., *Lonicera* sp., and *Juniperus*  
216 sp. Some species of the same genus have distinct specific anatomical criteria that may  
217 constitute different categories or types (Heinz and Barbaza, 1998; Alcolea, 2017; Allué  
218 et al., 2018a). Following Heinz and Barbaza (1998), for European woods from the

219 Mediterranean basin, the genus *Prunus* can be classified into three types according to how  
220 many cells wide the rays are. The rays of *Prunus* type 1 (which includes *Prunus*  
221 *avium/padus*) are no more than two cells wide. The rays of *Prunus* type 2 (which includes  
222 *Prunus spinosa/mahaleb*) are three or four cells wide, and the rays of *Prunus* type 3  
223 (which includes *Prunus spinosa*) are more than five cells wide. Finally, the family  
224 Rosaceae/Maloideae corresponds to several species, including, for example, *Sorbus* and  
225 *Crataegus*, which do not always share the same ecological adscription.

226

#### 227 **4. Results**

228 The anthracological record from Cova Colomera incorporated 1,117 charcoal  
229 fragments, of which 1,038 were identified (Table 2A and 2B). Accumulation curves show  
230 an optimal sample size analysed in all layers (Figure 5). The charcoal record shows a  
231 wide diversity of taxa, including broadleaves and lianas such as *Acer* sp. (maples),  
232 *Arbutus unedo* (strawberry tree), *Buxus sempervirens* (boxwood), *Clematis vitalba*  
233 (traveller's joy), *Corylus avellana* (common hazel), *Fagus sylvatica* (common beech),  
234 *Fraxinus* sp. (ash), *Hedera helix* (ivy), *Lonicera* sp. (honeysuckle), *Pistacia lentiscus*  
235 (lentisk), *Populus/Salix* (poplar/willows), *Prunus* type 2 and type 3 (plums), *Quercus* sp.  
236 evergreen and *Quercus* sp. deciduous (holm-oaks and oaks), *Rhamnus*  
237 *alaternus/Phillyrea* (buckthorn), Maloideae (pomes), indeterminate angiosperm and cf.  
238 *Sambucus* (elderberry), and conifers such as *Pinus sylvestris* type (Scots pine and black  
239 pine), *Taxus baccata* (yew) and *Juniperus* sp. (juniper). The taxon richness remains more  
240 or less homogeneous throughout the sequence, although taxon variability is higher in the  
241 Late Neolithic layers, especially in layer CE9.



242 PLACE HERE TABLE 2A. Middle Holocene anthracological record from Cova  
243 Colomera.

244 PLACE HERE TABLE 2B. Late Holocene anthracological record from Cova Colomera.

245

246 The Early Neolithic layers CE12, CE13 and CE14 show a predominance of  
247 boxwood, with deciduous oak and *Pinus sylvestris* type subsequently. Maple shows low  
248 values in the three Early Neolithic layers (no more than 8.5%). On the other hand, juniper  
249 increases in layer CE13, although it displays a low presence in the earlier layer CE14.  
250 Sporadic fragments ( $\leq 5\%$ ), such as *Arbutus unedo*, *Corylus avellana*, holm-oak, *Pistacia*  
251 *lentiscus*, *Prunus* sp., *Rhamnus alaternus/Phillyrea*, Rosaceae/ Maloideae and *Taxus*  
252 *baccata* are present (Table 2A). By the same token, boxwood, deciduous oak and *Pinus*  
253 *sylvestris* type continued to predominate in the Late Neolithic layers CE9 and CE10.  
254 However, maple has higher recorded values compared to the previous period, detected  
255 mainly in layer CE10. Juniper shows a decrease. Other taxa, such as *Fraxinus* sp.,  
256 *Lonicera* sp., *Pistacia lentiscus*, *Populus/Salix*, *Prunus* sp., holm-oak, *Rhamnus*  
257 *alaternus/Phillyrea*, indeterminate angiosperm 1, *Taxus baccata* and cf. *Sambucus*, are  
258 also present. Likewise, *Taxus baccata* and *Prunus* sp. are documented in both these  
259 layers.

260 PLACE HERE FIGURE 5. Taxon accumulation curves of the Holocene layers of Cova  
261 Colomera.

262 The Early Bronze Age silo EE1 shows high values for deciduous oak.  
263 Furthermore, boxwood and pine are well represented (Table 2B). Sporadic fragments of  
264 other taxa ( $\leq 5\%$ ), such as maple, ash, juniper and holm-oak, are also identified. Finally,  
265 the Middle Bronze Age layer CE8 is characterized by a predominance of deciduous oak  
266 and boxwood although, compared to the older layers, the values of boxwood are lower.

267 Likewise, scarce appearances of *Acer* sp., *Corylus avellana*, *Fagus sylvatica*, *Fraxinus*  
268 sp., *Hedera helix*, *Pinus sylvestris* type, *Prunus* sp., evergreen oak, Rosaceae/Maloideae  
269 and *Taxus baccata* are identified.

270

## 271 **5. Discussion**

272 5.1. Transformation of the vegetation landscape and the environmental conditions  
273 around Cova Colomera

274 The anthracological results from Cova Colomera provide key data for describing  
275 the local-scale environment in the Central Pre-Pyrenees during the Middle-Late  
276 Holocene. Anthracological analysis of 1,117 charcoal fragments from Cova Colomera  
277 shows the taxon diversity and changes in the relative values along the sequence (Figure  
278 6). Although the anthracological sequence is very homogeneous in terms of the richness  
279 and ubiquity of woody taxa, there is a tendency towards a progressive increase and  
280 predominance of deciduous forest elements. However, a slight increase in evergreen oaks  
281 is detected at the top of the anthracological sequence.

282 PLACE HERE FIGURE 6. Diagram with anthracological results for Cova Colomera.  
283 Results from Early Bronze age silo EE1 (Oms et al., 2009b) have been included.

284 According to the anthracological results obtained, the local area of Cova Colomera  
285 remained relatively stable over the period in question, dominated as it was by forest  
286 communities of deciduous oaks, with a significant presence of *Buxus sempervirens* and  
287 *Acer* sp. This assemblage of taxa is usually associated with sub- and supra-Mediterranean  
288 deciduous oak formations. The presence of mesophilic taxa such as maple, *Prunus* sp.,  
289 Maloideae, common buckthorn and boxwood can be taken to indicate temperate and  
290 humid climatic conditions. Other shrubby vegetation and small trees, such as *Juniperus*

291 sp. and *Rhamnus alaternus/Phillyrea*, could have also developed in more open spaces,  
292 indicating the existence of clearances. These open forest formations under a humid  
293 climate may well correlate with the results from the study of the small vertebrates in the  
294 Holocene layers at Cova Colomera (López-García et al., 2010), which indicated the  
295 chorotype of micromammals with mid-European requirements, currently found at the  
296 higher altitudes of the Pyrenees. Sub-Mediterranean thermophilic elements requiring  
297 more humidity, such as *Tilia* and *Pistacia cf. terebinthus*, are identified in the silo EE1 at  
298 Cova Colomera, dated to the Early Bronze Age, and maple appears throughout the  
299 anthracological sequence. Riverine taxa, such as *Populus/Salix*, and *Fraxinus* sp., are  
300 documented, although their presence is always low. These elements are likely to have  
301 been part of the riparian vegetation, occupying the riverbanks in the Montsec mountain  
302 range or shadier and more humid locations such as deep narrow gorges. The other  
303 represented circum- and sub-Mediterranean small trees, shrubs and liana, such as *Arbutus*  
304 *unedo*, *Corylus avellana*, *Ilex aquifolium*, *Hedera helix* and *Clematis vitalba*, appear in  
305 lower frequencies. The occurrence of *Pinus sylvestris* type suggests the presence of  
306 conifer forests, which underwent a slight decline in the course of the anthracological  
307 sequence, mainly during the Middle Bronze Age. These formations would have probably  
308 been growing at higher altitudes in nearby areas of the Pre-Pyrenees and *Taxus baccata*  
309 would have probably developed in shadier areas. In the other hand, holm-oaks and  
310 sclerophyllous elements such as *Arbutus unedo* and *Rhamnus alaternus/Phillyrea* show a  
311 low relative frequency throughout the anthracological sequence of Cova Colomera.  
312 However, from a diachronic point of view, a slight increase in holm-oak is detected,  
313 especially in the Middle Bronze Age.

314 In northeastern Spain and southern France, Mediterranean forests currently form  
315 an ecoregion in transition between the western European temperate broadleaf and mixed

316 forest ecoregion and the Iberian sclerophyllous and semi-deciduous forest ecoregion  
317 (Dinerstein et al., 2017). Mediterranean forests thus display ecological characteristics of  
318 both the Mediterranean and Atlantic climate (Blanco et al., 1997; Carreras and Ferré,  
319 2014). Likewise, the plant community that includes the evergreen oak forest and an  
320 evergreen understory of low trees and high shrubs (such as *Olea europaea*, *Arbutus*  
321 *unedo*, *Rhamnus alaternus/Phillyrea*, *Erica* sp. and *Pistacia lentiscus*) is also identified  
322 as an ecoregion of the Mediterranean biome that currently dominates the area. These  
323 sclerophyllous taxa display low representation throughout the anthracological sequence  
324 of Cova Colomera. They may have occupied secondary positions in drier or sunnier  
325 places, probably in areas of deciduous oak forest degradation.

326         In the Central Pre-Pyrenees, from the Early-Middle Holocene boundary (8.2 ka  
327 BP), the deciduous oak forest would have occupied a more extensive area than at present,  
328 favoured by a temperate and humid climate (Figure 7). Palaeoclimate records from Pre-  
329 Pyrenean ranges, for example from Estanyá lake (Morellón et al., 2008), indicate greater  
330 water availability in three periods during the Holocene: the Early Holocene: 8.5-8.2 ka  
331 BP; and the Middle Holocene: 6.7-5.9 ka BP and 4.9-4.2 ka BP. Although these periods  
332 correspond to more humid conditions in the Mediterranean area, brief arid episodes also  
333 occurred at 8.2 and 7.5 ka BP (Jalut et al., 2009; Bergadà et al., 2018).

334 PLACE HERE FIGURE 7. Calibrated radiocarbon dates of Cova Colomera in relation of  
335 different climate proxies.

336         *Taxus baccata* records have very low values in pollen sequences, probably owing  
337 to the poor pollination rates and morphological difficulties (Chybicki and Oleksa, 2018),  
338 although the species is well represented in Middle Holocene anthracological records in  
339 the northern Iberian Peninsula (see Uzquiano et al., 2015), especially in mid-mountain  
340 areas. Differences in *Taxus baccata* values between anthracological and pollen data may

341 correspond to variable humidity conditions at higher altitudes, which are probably  
342 dominated by coniferous forests. Additionally, the high relative frequency of boxwood in  
343 the Cova Colomera anthracological record is noteworthy. Boxwood is a sub-  
344 Mediterranean taxon, which currently grows in montane and subalpine zones and in some  
345 southern locations in the Iberian Peninsula, within an altitudinal range from 26 m to 2,500  
346 m a.s.l. (Bolòs and Vigo, 1984; Carreras and Ferré, 2014). In some places, especially in  
347 disturbed oak forests, boxwood can play a pioneer role and can form extended shrubby  
348 formations, although it is most often associated with undergrowth in the deciduous oak  
349 forest (Rivas-Martínez, 1984; Carreras et al., 2015; Pascual, 2015) and can be considered  
350 an indicator of degraded or cleared areas (Pascual, 2015). In the local area around Cova  
351 Colomera, woodland formed by deciduous oaks and including maple and boxwood is  
352 currently found as part of the forest structure, especially in more temperate or  
353 Eurosiberian areas in the Pyrenees and Pre-Pyrenees, under temperate and humid climate  
354 conditions. These taxa are common in Middle Holocene anthracological sequences from  
355 NE Iberian Peninsula, including littoral sites as well as sites in inner pre-littoral ranges,  
356 such as Cova del Toll (Mas and Allué, 2020), Cova de l'Avellaner (Ros, 1996), Cova  
357 Gran (Allué, unpublished), Cova d'en Pau III and Plansallosa (Ros, 1996; Piqué, 2005),  
358 La Draga (Piqué, 2005), Cova del Frare (Ros, 1996), Bauma del Serrat del Pont and La  
359 Prunera (Piqué, 2005).

360         According to our results, the dynamics of vegetation transformation during the  
361 Middle-Late Holocene were more or less homogeneous in the Central Pre-Pyrenees. On  
362 a local scale, global aridity events would not have affected the vegetation landscape  
363 structure, and deciduous oak forests, temperate taxa and montane conifers would have  
364 developed well in the area. The rapid global climate change detected in the 4.2 to 3.8 ka  
365 period (Mayewsky et al., 2004) and the aridification trend that affected the Mediterranean

366 basin (Fletcher and Sánchez, 2008; Allué et al., 2009; Jalut et al., 2009; Carrión et al.,  
367 2010b; Bergadà et al., 2018) may have been less influential than elsewhere in bringing  
368 about the Mediterraneanization of the Central Pre-Pyrenees landscape. Likewise, a slight  
369 increase in the evergreen oak forest was detected in the Middle Bronze Age layer of Cova  
370 Colomera. Yew, maple and boxwood continued to be well represented in Bronze Age  
371 layers from Cova Colomera and Cova Gran (Allué, unpublished). However, the  
372 vegetation composition deduced from these anthracological assemblages shows a  
373 continuing predominance of deciduous oak forests, with montane conifers and temperate  
374 taxa.

## 375 5.2. Anthropogenic impacts: human and environment interactions

376 The archaeological record at Cova Colomera is associated with short-term  
377 occupations related to herding activities such as foddering, litter-bedding, etc. (Oms et  
378 al., 2013; Bergadà and Oms, 2021). The systematic burning of such fumier deposits often  
379 provides rich vegetal remains (see Angelucci et al., 2009; Euba et al., 2016; Vergès et al.,  
380 2016; Polo-Díaz et al., 2016; Burguet-Coca et al., 2020), and Cova Colomera is no  
381 exception. The anthracological sequence shows high taxonomic diversity, including 29  
382 woody taxa. Some of these could have been part of the herd's fodder diet. However, we  
383 cannot rule out the use of some woody taxa as fuel, such as pine, juniper or yew, or as  
384 objects and tools that were thrown into the fire after use. Moreover, ovicaprine herds are  
385 a potential agent for reducing undergrowth vegetation. During the winter, browsing is  
386 focused on evergreen and semi-deciduous species, whereas in spring and autumn  
387 herbaceous grasses are also browsed (Bartolomé et al., 1998; Osoro et al., 2013). High-  
388 protein woody species such as *Clematis vitalba*, *Acer opalus*, *Quercus* sp., lentisk and  
389 strawberry tree are currently consumed by ovicaprine herds in Mediterranean areas  
390 (Rogosic et al., 2006; Bartolomé, 2014), whereas other taxa such as junipers and boxwood

391 are rejected by herds as fodder (Bartolomé, 2014). However, the wood of the boxwood is  
392 also of good quality: hard, fine and compact, easy to polish and dye, and it could have  
393 been used for manufacturing objects. The wood produces slow combustion, a property  
394 much appreciated for its use as fuel (Caruso-Ferme and Piqué-Huerta, 2014). Examples  
395 such as the Neolithic settlement of La Draga (Banyoles, Girona) show the use of boxwood  
396 in the production of agricultural tools (Palomo et al., 2011; Piqué et al., 2018).  
397 Accordingly, archaeological work on some of the phases of the fumier documented the  
398 preservation and accumulation of leaves and branches of boxwood, possibly for the  
399 adaptation of beds or spaces for livestock (Bergadà and Oms, 2021; Oms et al., 2013).

400 Cova Colomera has provided no evidence of human occupation during the Middle  
401 Neolithic, although the cave was used by humans in the Early Neolithic and from the Late  
402 Neolithic to the Bronze Age cultural period. Two possible scenarios can be weighed up.  
403 In the NE of the Iberian Peninsula, evidence of occupation by Middle Neolithic  
404 populations has only been documented in burial contexts or in the open-air settlement of  
405 Ca n'Isach (Palau-saverdera, Girona) (Tarrús et al., 2016), whereas no evidence of  
406 occupation of caves and rock-shelters has been found (see Oms and Martín, 2018). A first  
407 hypothesis could be the non-preservation of evidence of human occupation due to erosion  
408 in karst systems and on mountainsides (see Polo-Díaz et al., 2014; Bergadà et al., 2018).  
409 A second, alternative hypothesis postulates the intentional abandonment of caves and  
410 rock-shelters due to changes in livestock grazing practices.

411 With respect to the human impact on forest communities at a local scale, the forest  
412 cover from the Early Neolithic to the Middle Bronze Age does not seem to have changed  
413 significantly in terms of either recovery or degradation. This could indicate that human  
414 groups carried out a reiterated but non-intensive exploitation of the forests. Accordingly,  
415 little evidence of intense human activities on the landscape can be found in the Iberian

416 Central Pre-Pyrenees, although the exploitation of plant resources has been documented  
417 since the Upper Pleistocene and Early Holocene (Allué et al., 2012, 2018b). At lower  
418 altitudes and similar to Cova Colomera, Neolithic layers or structures at Les Auvelles  
419 (Oms et al., 2019), Cova Gran (Mora et al., 2011) and Forat de Conqueta (Mora et al.,  
420 2009; Allué, 2011) show similarities as well as slight differences in the composition of  
421 their vegetation landscape. On the one hand, the open-air archaeological site of Les  
422 Auvelles has yielded an anthracological record of oak taxa in which, although dominated  
423 by deciduous oak, evergreen oak is also represented, with high ubiquity values (Martín-  
424 Seijo and Piqué, 2008). According to the authors, this assemblage could be influenced by  
425 specific fuel and wood selection patterns. On the other hand, anthracological data from  
426 the cave of Forat de Conqueta and the rock-shelter of Cova Gran (Allué, unpublished)  
427 indicate an assemblage similar to that of Cova Colomera. Archaeological research has  
428 identified livestock practices in the Holocene layers of Cova Gran, especially involving  
429 livestock enclosure, and has interpreted the use of the cave in terms of the transhumance  
430 routes through the southern Pyrenees (Polo-Díaz et al., 2014; Burguet-Coca et al., 2020;  
431 Martín and Oms, 2021), and also some mountainous Pyrenees areas (Gassiot et al., 2017;  
432 Knockaert et al., 2018; Tejedor-Rodríguez et al., 2021). The forest formations were  
433 probably the same in the different Pre-Pyrenean valleys, without any differences in human  
434 pressure causing more open forests in some areas.

435         Profound transformations of natural landscapes into cultural landscapes are  
436 currently the result of human pressure (Butzer, 1989; Quézel and Médail, 2003; Blondel,  
437 2006; Pérez-Obiol et al., 2011). Humans have exploited forest wood resources and  
438 interfered with the natural development and distribution of woody plants for millennia.  
439 However, evidence of the anthropogenic footprint in the landscape during the Middle-  
440 Late Holocene is not homogeneous in the Iberian Peninsula. For example, it seems to be



441 less intense in mountainous areas (e.g., Carrión et al., 2010b). In these areas above 2,000  
442 m a.s.l., Neolithic populations would have consumed varying amounts of wood according  
443 to the functionality and location of the settlements (Obea et al., 2021). Therefore, these  
444 archaeological sites show no evidence of extensive agriculture or substantial modification  
445 of the landscape. In contrast, the transformation of the vegetation landscape appears to be  
446 more intense in Mediterranean coastal areas (e.g., Riera and Esteban-Amat, 1994;  
447 Revelles et al., 2015). Nevertheless, there is no doubt that anthropogenic activities were  
448 important at a local scale particularly in the Late Holocene. The anthropic impact on  
449 landscapes during the Early Bronze Age has also been inferred from the increase in  
450 microcharcoal particles associated with the recurrence of fire events in mountain areas  
451 (Carrión et al., 2010b), more intensive land-use dynamics (Rull et al., 2021), and more  
452 specialized fuel-gathering patterns (Ros, 1995b, 1998; Piqué, 1999; Allué, 2007; Allué et  
453 al., 2009; Vila and Piqué, 2012; Obea et al., 2021).

454

## 455 **6. Conclusions**

456 The anthracological analysis of Cova Colomera documents changes in the  
457 vegetation landscape in the Central Pre-Pyrenees; these changes are related to specific  
458 climatic dynamics and a low anthropogenic impact, especially associated with herding  
459 and livestock management activities. The anthracological sequence shows how from the  
460 Middle to Late Holocene the local area of Cova Colomera continued to be dominated in  
461 the long term by deciduous oak forest ecosystems associated with sub- and supra-  
462 Mediterranean deciduous formations, while the coniferous forest gradually receded.  
463 According to our results, arid episodes in the Central Pre-Pyrenees did not cause major  
464 changes in vegetation cover, since the environmental conditions in the area of study  
465 included certain particularities that favoured the establishment of a temperate and humid

466 climate. However, the Late Holocene began to show a slight increase in evergreen oaks,  
467 mainly during the Middle Bronze Age.

468         The evidence of the anthropogenic activities on the landscape during the Middle  
469 Holocene is not homogeneous in the NE Iberian Peninsula, as some areas displayed  
470 certain particularities. Neolithic human groups who settled in the open air and took  
471 advantage of the caves and rock-shelters to carry out specialized activities were well  
472 aware of the potential of the landscapes. However, the herding activities in evidence  
473 during the Neolithic seem to have exerted slight pressure on the structure of the different  
474 landscapes, especially in inland areas of the NE Iberian Peninsula such as the Central Pre-  
475 Pyrenees. The human presence in this area was therefore probably not intensive.  
476 Accordingly, we do not observe such intensive exploitation of forest resources as in the  
477 areas near the coast. Finally, the Bronze Age populations to which more intensive  
478 exploitation of forest resources is attributed on a regional scale do not seem to exert such  
479 an intensive influence at the local scale of Cova Colomera. The differences in the intensity  
480 of forest exploitation may be due to the different functionalities of the occupations as well  
481 as the different locations of the settlements.

482

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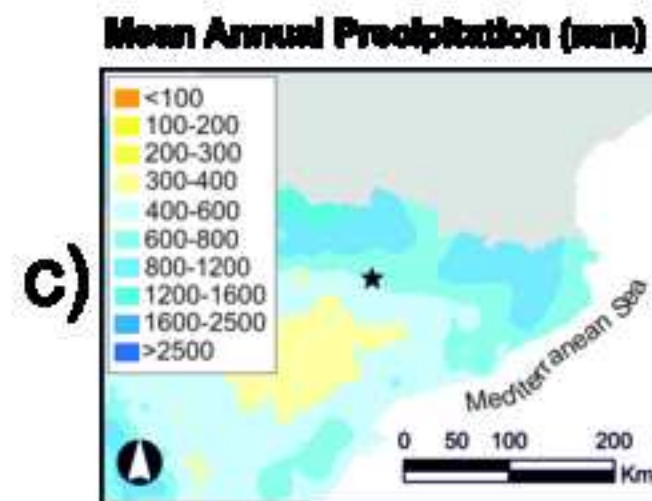
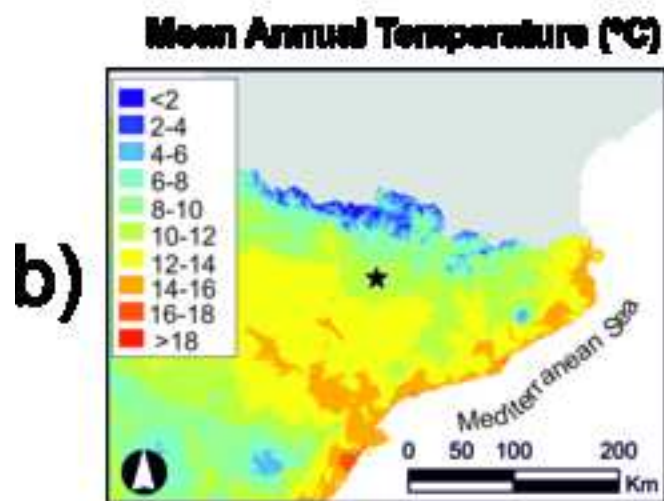
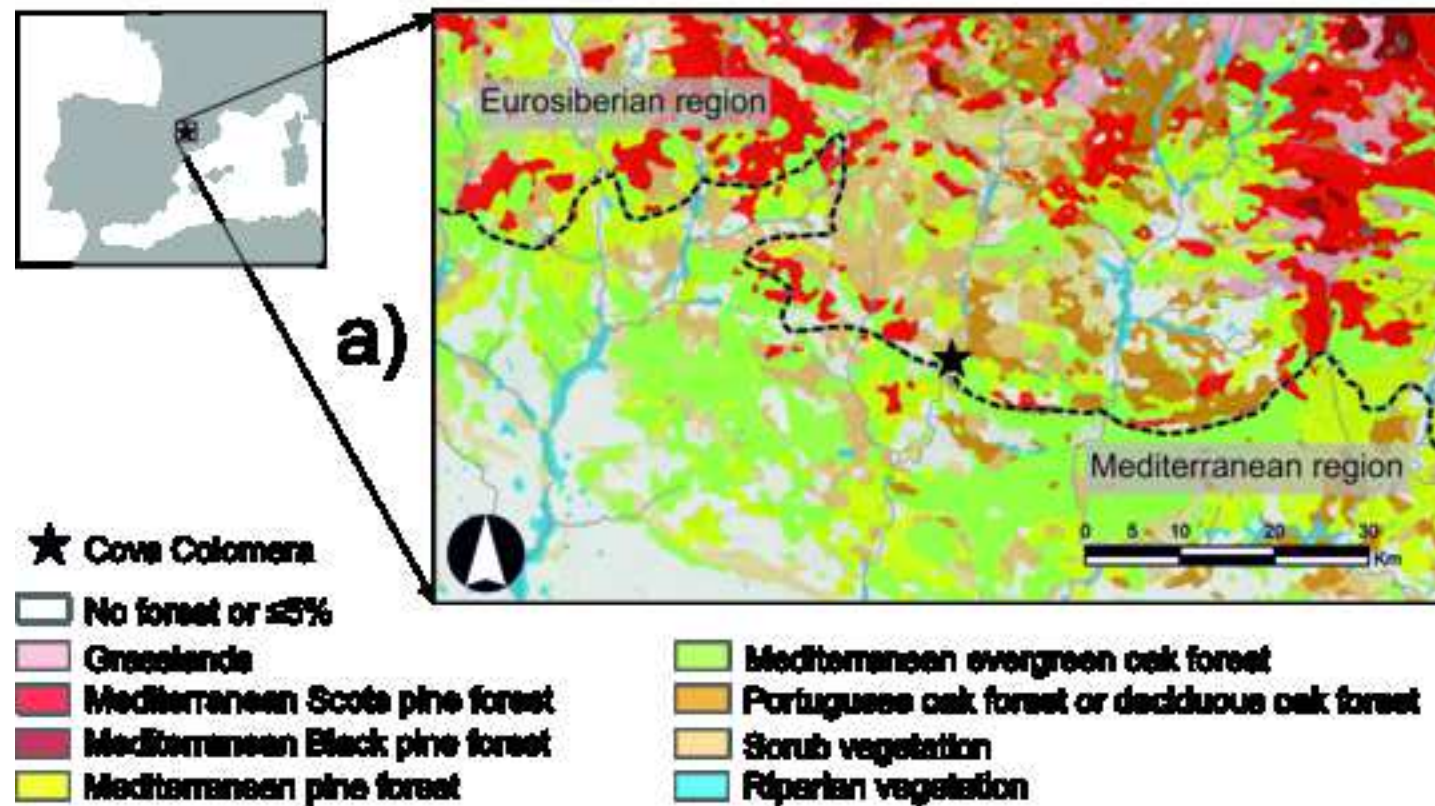
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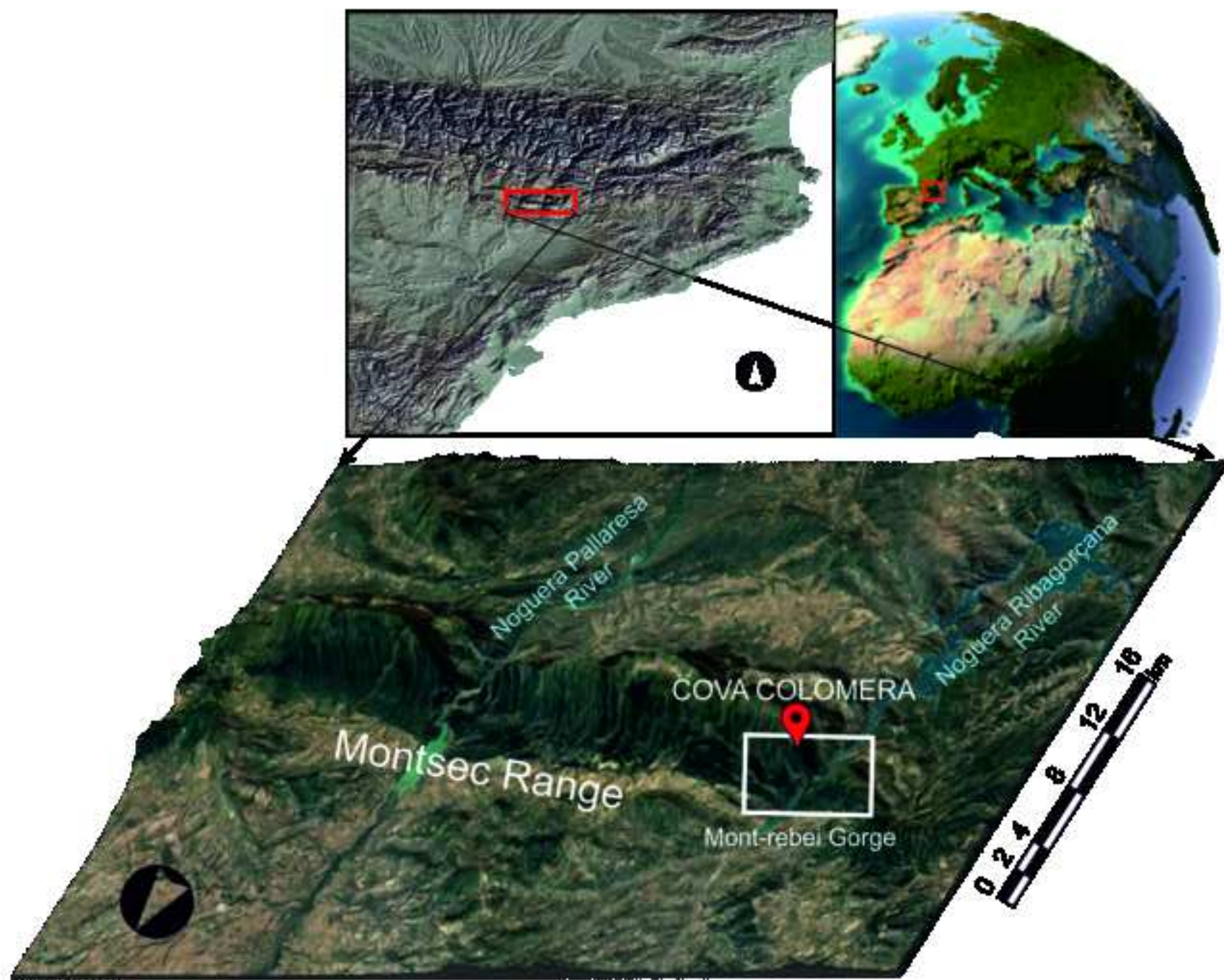
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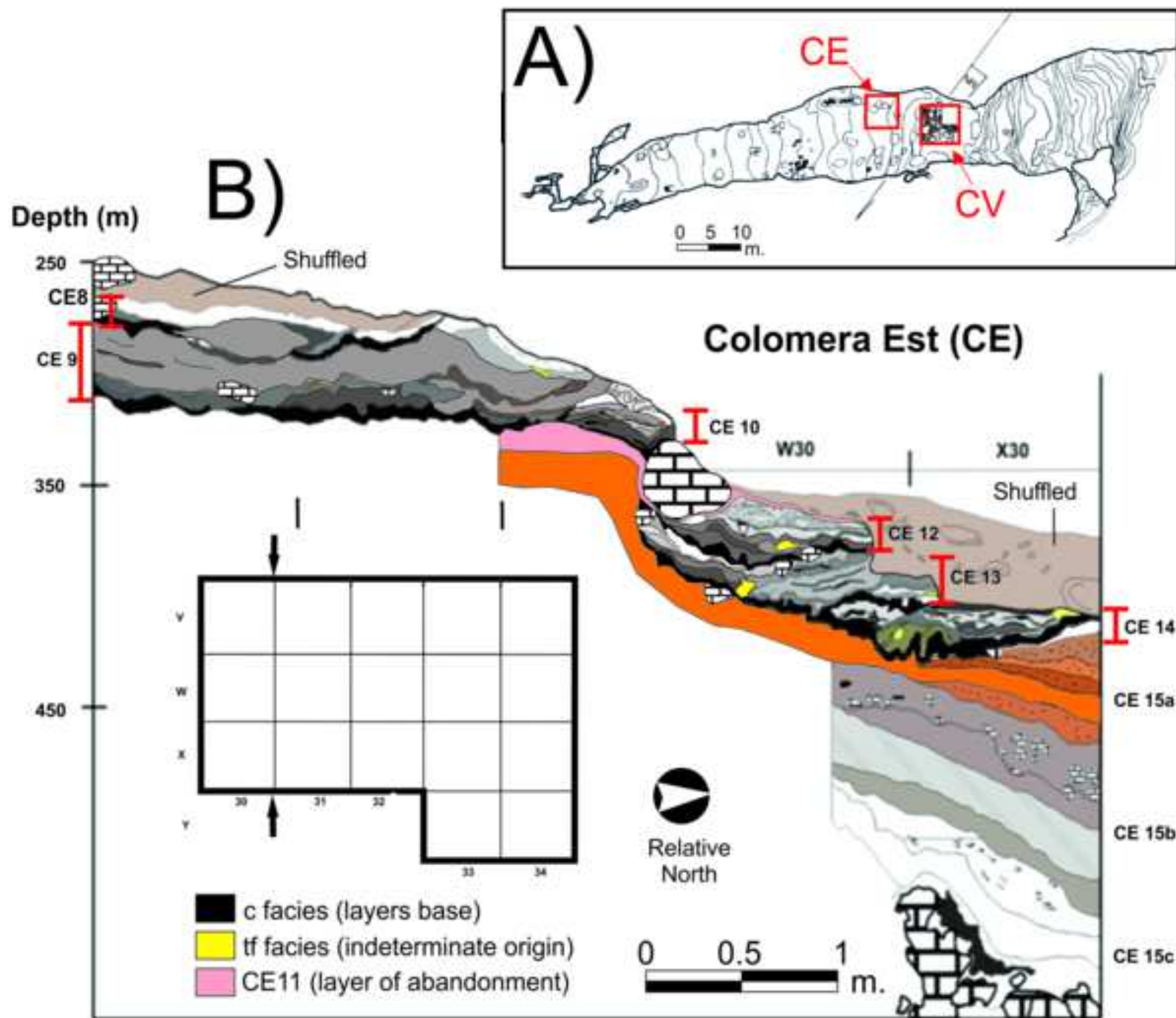
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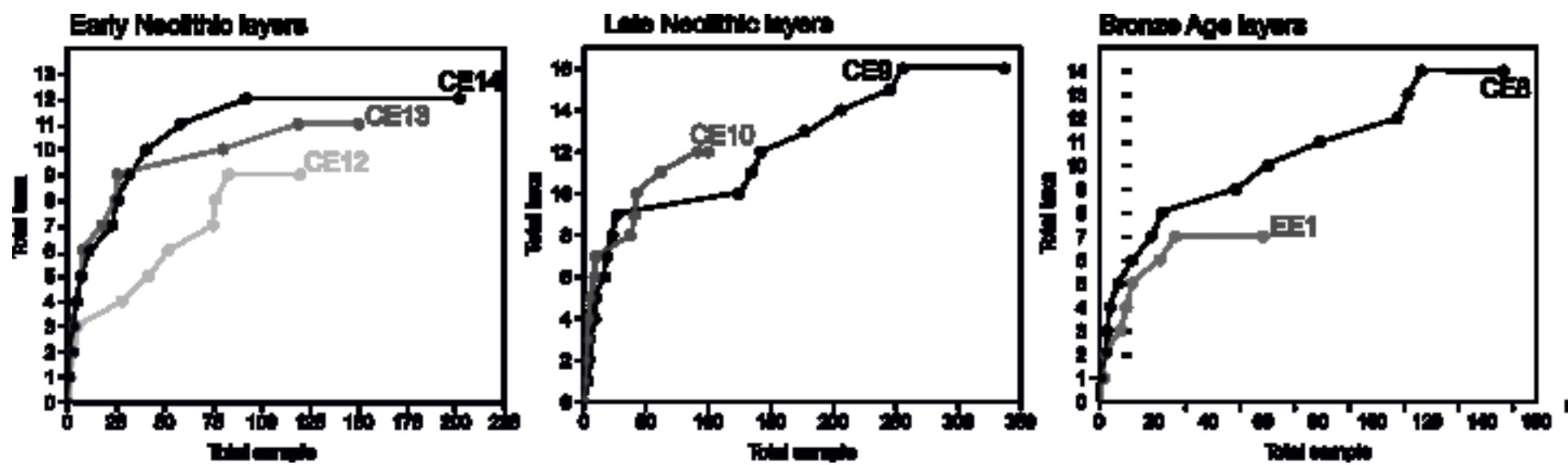
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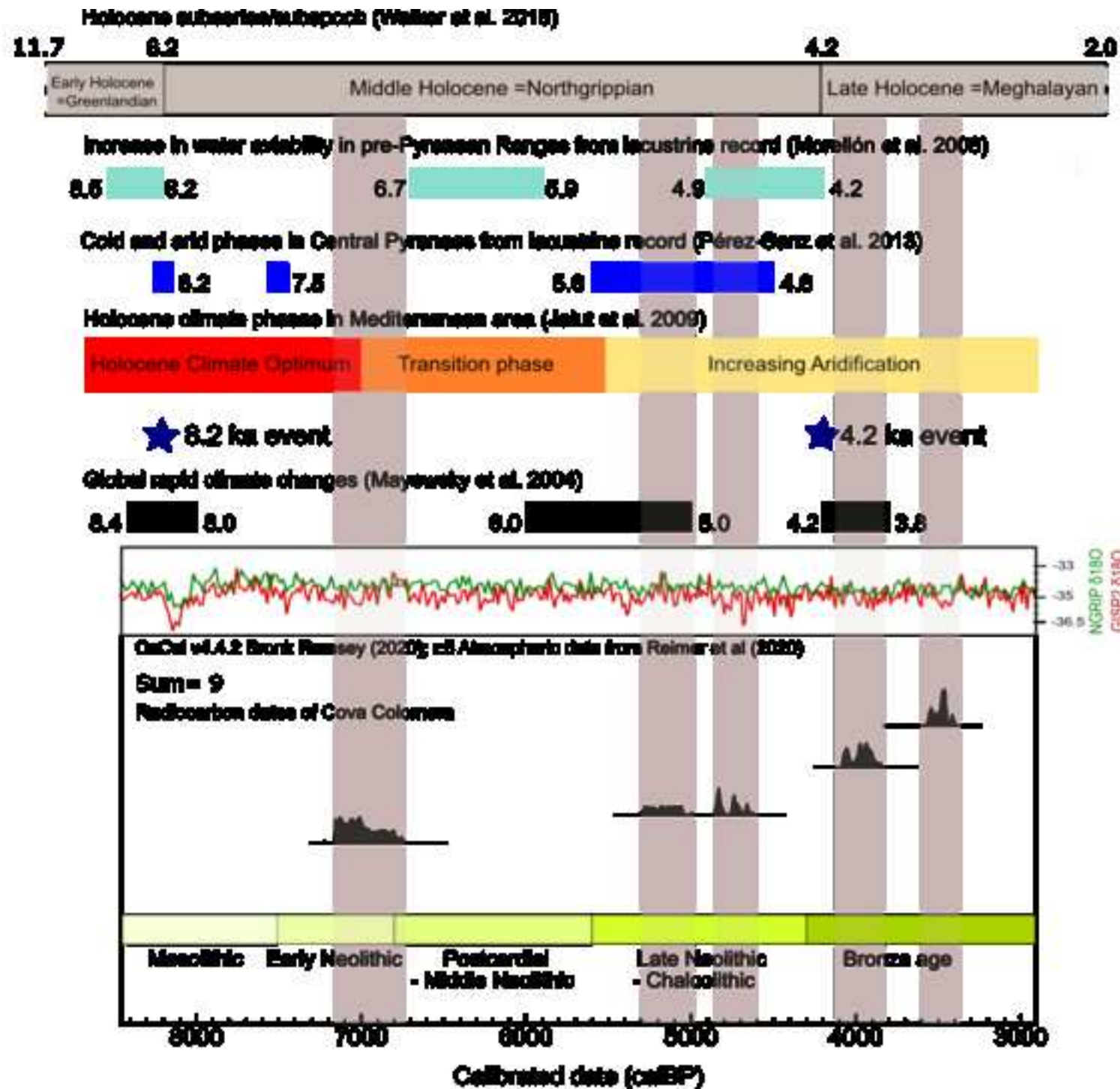












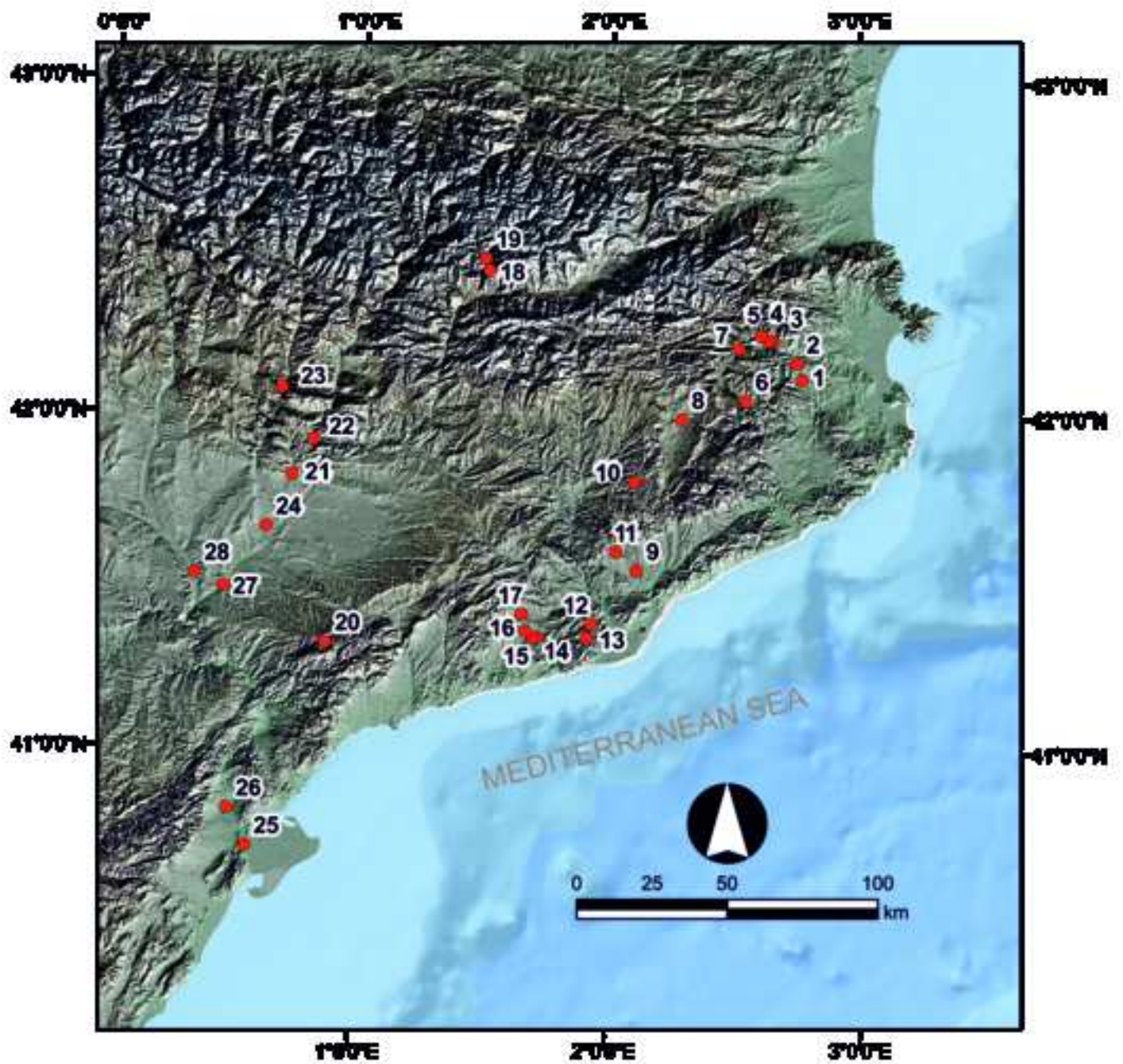




Table 1. Compilation of published radiocarbon and calibrated dates from the Holocene sequence of the Cova Colomera test pit CE.

Layer	Type	Cultural attribution	Sample	Recovered	Radiocarbon	Ref. Lab	Date B.P.	cal yr B.C. 2 $\sigma$	Cal yr B.P. 2 $\sigma$	Published
CE8	<i>Fumier</i>	Middle Bronze age	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	OxA-23633	3260±26	1630-1470	3561-3400	Oms et al., 2015
CE8	<i>Fumier</i>	Middle Bronze age	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	Beta-140550	3280±40	1660-1440	3579-3395	Oms et al., 2015
EE1	Silo	Early Bronze age	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	OxA-17732	3659±30	2170-1930	4086-3896	Oms et al., 2009b
EE1	Silo	Early Bronze age	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	Beta-241704	3630±40	2130-1890	4084-3839	Oms et al., 2009b
CE9	<i>Fumier</i>	Late Neolithic	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	Beta-265439	4230±40	2960-2680	4863-4621	Oms et al., 2015
CE10	<i>Fumier</i>	Late Neolithic	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	OxA-17331	4500±32	3400-3040	5305-5041	Oms et al., 2015
CE12	<i>Fumier</i>	Early Neolithic	<i>Buxus sempervirens</i>	Manual flotation	AMS <sup>14</sup> C	Beta-248523	6020±50	5060-4780	7146-6737	Oms et al., 2013
CE13	<i>Fumier</i>	Early Neolithic	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	Beta-240551	6150±40	5250-4960	7164-6909	Oms et al., 2013
CE14	<i>Fumier</i>	Early Neolithic	<i>Triticum aestivum/durum</i>	Manual flotation	AMS <sup>14</sup> C	OxA-23634	6170±30	5250-5010	7163-6964	Oms et al., 2013

**Table 2A.** Middle Holocene anthracological record from Cova Colomera.

Archaeological period Layer	Early Neolithic						Late Neolithic			
	CE12		CE13		CE14		CE9		CE10	
TAXA	n	%	n	%	n	%	n	%	n	%
<i>Acer</i> sp.	9	7.50	11	7.33	17	8.42	24	7.12	14	14.00
<i>Arbutus unedo</i>	-	-	3	2.00	4	1.98	2	0.59	-	-
<i>Buxus sempervirens</i>	43	35.83	37	24.67	76	37.62	83	24.63	25	25.00
<i>Clematis vitalba</i>	-	-	-	-	-	-	1	0.30	-	-
<i>Corylus avellana</i>	-	-	1	0.67	-	-	1	0.30	-	-
<i>Fraxinus</i> sp.	-	-	-	-	-	-	4	1.19	-	-
<i>Juniperus</i> sp.	4	3.33	27	18.00	11	5.45	22	6.53	5	5.00
<i>Lonicera</i> sp.	-	-	-	-	-	-	-	-	1	1.00
<i>Pinus sylvestris</i> type	14	11.67	17	11.33	30	14.85	37	10.98	10	10.00
<i>Pistacia lentiscus</i>	-	-	1	0.67	-	-	1	0.30	-	-
<i>Populus</i> sp.	-	-	-	-	-	-	-	-	1	1.00
<i>Prunus</i> type 2	1	0.83	5	3.33	6	2.97	8	2.37	3	3.00
<i>Prunus</i> type 3	1	0.83	1	0.67	3	1.49	4	1.19	5	5.00
<i>Quercus</i> sp. deciduous	35	29.17	34	22.67	35	17.33	91	27.00	19	19.00
<i>Quercus</i> sp. evergreen	5	4.17	3	2.00	5	2.48	5	1.48	1	1.00
<i>Rhamnus alaternus/Phillyrea</i>	-	-	-	-	1	0.50	1	0.30	-	-
Rosaceae/Maloideae	-	-	1	0.67	1	0.50	-	-	-	-
<i>Taxus baccata</i>	2	1.67	-	-	2	0.99	18	5.34	6	6.00
Indetermined angiosperm 1 cf. <i>Sambucus</i>	-	-	-	-	-	-	-	-	1	1.00
	-	-	-	-	-	-	3	0.89	-	-
<b>Total taxa</b>	<b>9</b>		<b>12</b>		<b>12</b>		<b>16</b>		<b>12</b>	
cf. <i>Arbutus unedo</i>	-	-	-	-	-	-	3	0.89	-	-
cf. <i>Pinus</i>	-	-	-	-	-	-	1	0.30	1	1.00
cf. <i>Prunus</i>	-	-	-	-	1	0.50	-	-	-	-
<b>Total identified</b>	<b>114</b>		<b>141</b>		<b>192</b>		<b>309</b>		<b>92</b>	
Indeterminable angiosperm	6	5.00	6	4.00	6	2.97	18	5.34	6	6.00
Indeterminable conifer	-	-	-	-	2	0.99	-	-	-	-
Undetermined	-	-	3	2.00	2	0.99	10	2.97	2	2.00
<b>Total sample</b>	<b>120</b>	<b>100</b>	<b>150</b>	<b>100</b>	<b>202</b>	<b>100</b>	<b>337</b>	<b>100</b>	<b>100</b>	<b>100</b>

**Table 2B.** Late Holocene anthracological record from Cova Colomera.

Archaeological period	Early Bronze Age			Middle Bronze Age	
	Layer	EE1		CE8	
TAXA		n	Oms et al., 2009b	%	n
<i>Acer</i> sp.	2	23	6.94	11	7.43
<i>Arbutus unedo</i>	-	5	1.39	-	-
<i>Buxus sempervirens</i>	14	92	29.44	29	19.59
<i>Corylus avellana</i>	-	4	1.11	1	0.68
<i>Fagus sylvatica</i>	-	-	-	1	0.68
<i>Fraxinus</i> sp.	1	1	0.56	2	1.35
<i>Hedera helix</i> ssp.	-	2	0.56	1	0.68
<i>Ilex aquifolium</i>	-	4	1.11	-	-
<i>Juniperus</i> sp.	5	16	5.83	9	6.08
<i>Pinus sylvestris</i> type	14	25	10.83	9	6.08
<i>Pistacia</i> cf. <i>terebintus</i>	-	2	0.56	-	-
<i>Prunus</i> type 2	-	-	-	1	0.68
<i>Quercus</i> sp. <i>deciduous</i>	18	95	31.39	53	35.81
<i>Quercus</i> sp. <i>evergreen</i>	2	4	1.67	7	4.73
<i>Rhamnus alaternus/Phillyrea</i>	-	2	0.56	-	-
<i>Rhamnus cathartica/saxatilis</i>	-	3	0.83	-	-
Rosaceae/Maloideae	-	1	0.28	1	0.68
<i>Taxus baccata</i>	-	7	1.94	5	3.38
<i>Tilia</i> sp.	-	1	0.28	-	-
cf. <i>Ribes</i>	-	1	0.28	-	-
<b>Total taxa</b>		<b>18</b>		<b>13</b>	
cf. <i>Acer</i>	1	1	0.56	-	-
cf. <i>Corylus avellana</i>	-	-	-	1	0.68
cf. <i>Lonicera</i>	-	1	0.28	-	-
<i>Pinus</i> sp.	-	1	0.28	-	-
<i>Prunus</i> sp.	-	2	0.56	2	1.35
<i>Quercus</i> sp.	-	1	0.28	-	-
<i>Rhamnus</i> sp.	-	1	0.28	-	-
<b>Total identified</b>		<b>352</b>		<b>133</b>	
Indeterminable angiosperm	2	4	1.67	6	4.05
Indeterminable conifer	1	1	0.56	1	0.68
Undetermined	-	-	-	8	5.41
<b>Total sample</b>		<b>360</b>	<b>100</b>	<b>148</b>	<b>100</b>



**Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: