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Sorting the riddle of the Neanderthal to anatomically modern human boundary in Sopeña (Asturias, Spain): New dates and a preliminar Bayesian analysis

Ana Cristina Pinto-Llona [a], Aurora Grandal-d'Anglade [b,*]

[a] Investigadora Asociada. Museo Arqueológico Regional, Plaza de las Bernardas s/n. 28801, Alcalá de Henares, Spain
[b] Instituto Universitario de Xeoloxía, Universidade da Coruña, ESCI, Campus de Elviña, 15008 A Coruña, Spain

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ABSTRACT

Sopeña is a limestone shelter in the northern slopes of the Cantabrian range of mountains of northern Spain. A long sequence of in situ nearly undisturbed archaeological strata has been documented there, including seven Gravettian, four Early Upper Palaeolithic and a minimum of four Mousterian levels, and bedrock has not been reached. Dating the last occupations by Neanderthals and their substitution by modern humans in northern Spain is a currently debated issue, made difficult by the scarcity of sites bearing those levels and able to produce reliable dates. Earlier work in Sopeña pointed to a disappearance of the Mousterian that was later than proposed by other authors on other sites of what is known as Cantabrian Spain, a mountainous fringe facing the Bay of Biscay. Here we present 11 new dates, corresponding to Gravettian, Early Upper Palaeolithic and Mousterian levels, and some of these new dates are ultrafiltered. It is concluded that although the earliest Sopeña Gravettian dates are older than those proposed elsewhere in the region, we do not have still enough information to produce a definite model for the Gravettian of this site. Furthermore, a Bayesian model is produced for the interpretation of the dates obtained for the earliest Upper and the latest Middle Palaeolithic, and it is concluded that the disappearance of the Mousterian in Sopeña is indeed a few millennia later than currently proposed by others in the region, while that available dates cannot shed unquestionable light on the existence or not of a hiatus between the dismissal of Neanderthals and the earliest arrival othe Upper Palaeolithic technocultures at the site.

1. Introduction and state of the art

The dates for the disappearance of the Mousterian industries, generally taken to be the work of Neanderthals, in the northern Atlantic regions of Spain, and the dates for the first appearance of industries thought to be the work of Homo sapiens have received much attention in recent years. The novel introduction of ultrafiltration methods, though to be generally more reliable, has tended to offer older dates than prior methods, but this has not always been the case (eg. Pinto-Llona and Grandal-d'Anglade, 2019). Due to stratigraphic issues and others, the current debate is somewhat limited by being based in just a few relevant sites and dates for the neighboring Asturias and Cantabria regions, both in the area of influence of the massive Picos de Europa mountain range (eg. Cueva Morín, La Güelga, Covalejos and Sopeña in Maroto et al., 2012; Cueva Morín, La Güelga and El Esquilleu in Higham et al., 2014; La Güelga, El Esquilleu and El Mirón in Marín-Arroyo et al., 2018).

Relevant to that debate is the site of Sopeña, a limestone shelter or perhaps a larger cave were sedimentary infillings and cornice collapses are producing its current shelter appearance. Sopeña is located in the Concejo de Onís (Asturias, Spain), on the northern slope of the Picos de Europa (43° 19′ N, 04° 56′ W), a few kilometers south of the coast of the Gulf of Biscay (Fig. 1a). It opens to the southwest, 450 m above sea level, 250 m above the river Güeña –a tributary to the larger river Sella, and 100 m. above Güesal stream flowing at its feet. Sopeña stands out in the landscape as an abrupt rocky relief on a steep slope. A wide entrance, partly blocked with large flowstone covered rocks, probably collapsed from the cornice, gives way to a shallow shelter with sedimentary infillings reaching up to two metres below the ceiling.

The collapsed limestone blocks at the entrance slope inwards, forming a basin where sediment accumulates. The shelter contains sediments from several sources: fine grained sediments probably carried by wind or water, éboulis from the cave roof, and materials transported

* Corresponding author.
E-mail addresses: acpll@protonmail.com (A.C. Pinto-Llona), aurora.grandal@udc.es (A. Grandal-d'Anglade).

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and produced by the fauna inhabiting the cave. Humans contributed significantly by producing relatively large quantities of burnt debris (Pinto-Llona et al., 2012).

The excavation of a 2 × 1 m test trench perpendicular to the east wall of the shelter in 2002 (Fig. 1b) revealed a layered sedimentary sequence with a wealth of faunal and lithic finds througout (Fig. 1c). The test trench reached a depth of circa 1.8 m below Datum and the presence of large blocks at its base prevented progress to lower levels, but the rock floor was not found and it is thought that the sedimentary sequence continues. A geophysical survey by electrical tomography (Pinto-Llona and Aracil Ávila, 2021) suggest that the infilling continues to a depth of at least over 2 m.

Sedimentary sequences in caves may be recycled by erosion and resedimentation processes (Hunt et al., 2015), so visual field observation is often not sufficient to recognise the nature of sedimentary levels. For the sedimentological study of the test trench, field observations were supplemented with micromorphological sampling and analysis by P. Karkanas (In Pinto-Llona et al., 2012) and a magnetic susceptibility study (Herries, 2009; Pinto-Llona et al., 2022). Four levels (Levels III, V, VII and XIII) with indications of hearths are recognised throughout the profile, at Level XIII in situ (sensu lato) (P. Karkanas, in Pinto-Llona et al., 2012), in agreement with a marked increase in magnetic susceptibility at these levels (Herries, 2009). Levels XII to XIV (Level XV could not be studied due to its scarce exposure) are originated by anthropogenic processes, according to P. Karkanas (in Pinto-Llona et al., 2012). Signs of cryoturbation and sometimes bioturbation are detected throughout the profile. However, the transition between the latest Mousterian Level XII and the first Upper Palaeolithic level (Level XI) is clear and both levels show distinct compositional and micromorphological features (P. Karkanas, in Pinto-Llona et al., 2012).

Up to 17 archaeological levels, layered in a quite horizontal sequence on top of each other were distinguished in the test trench. The bottom levels (XVI and XVII) were observed at the bottom of the trench but were not excavated in order not to undermine support for the rock blocks at the base of the stratigraphic sequence exposed so far. Therefore the following will focus on layers up to Mousterian level XV.

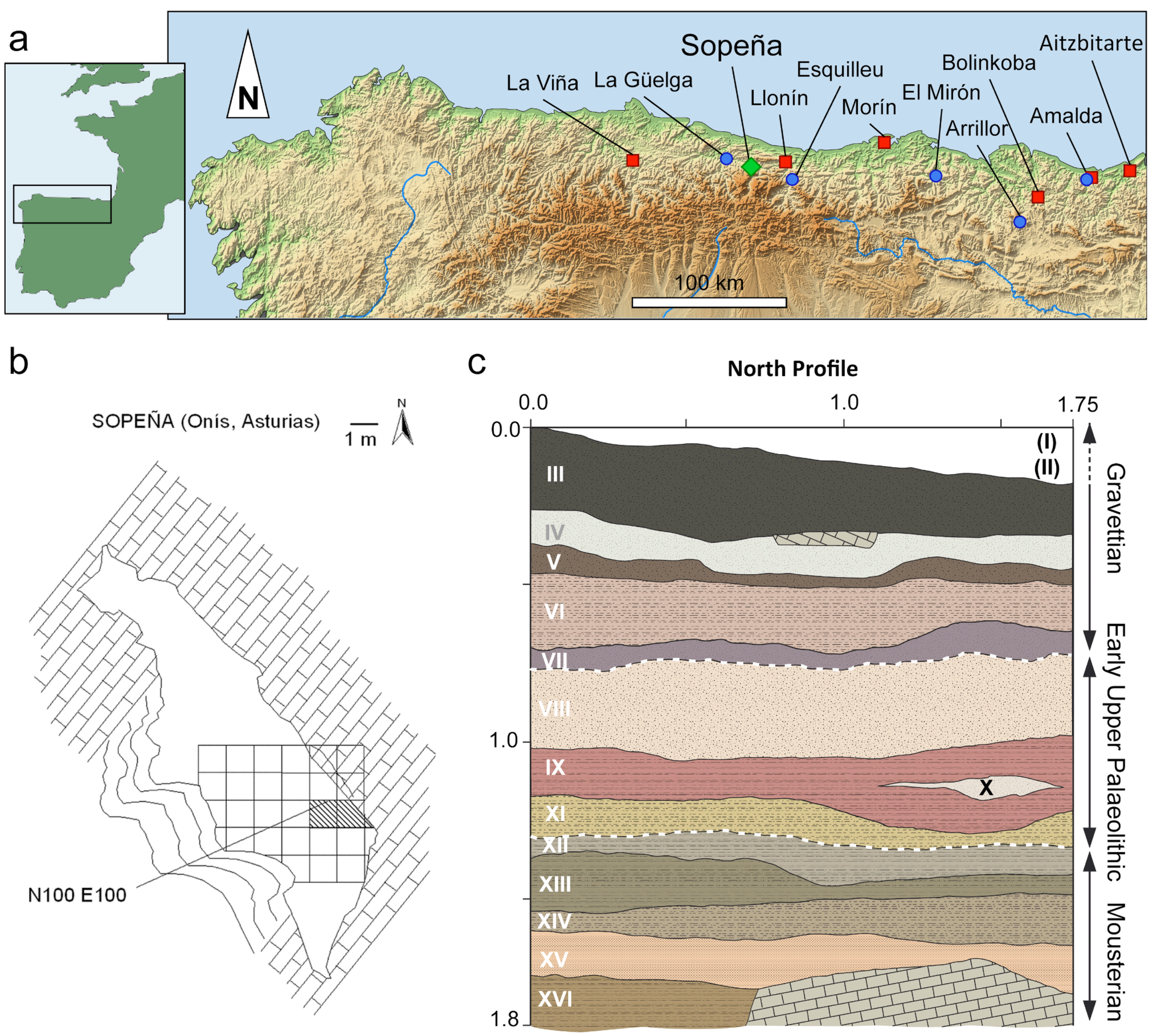

Fig. 1. a) Map of the Cantabrian region in the N of the Iberian Peninsula showing the location of the Sopeña site. Also shown are other sites that record the Late Mousterian (blue circles) and those that record Gravettian levels (red squares) according to Marín-Arroyo et al. (2018). b) Plan of the site. The squares where the test trench was carried out are shaded. The grid indicates area currently under excavation. c) Stratigraphic sequence in the north wall of the 2002 test trench. Levels I and II are not preserved in this area, being visible only in the northern profile (Pinto-Llona et al., 2022). Scales to the left side are graphic references that do not refer to Datum. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The analysis of lithic materials (Pinto-Llona et al., 2009, 2012) identified three phases. From top to bottom, levels I to VII are thought to be Gravettian, given the presence of several Gravette points (Fig. 2), backed bladelets, frontal end-scrappers, and some burins and notches, as well as a collection of broken awls and other bone and antler tools, ochre pencils and several body ornaments such as pendants produced from perforated shells and animal teeth. Levels VIII to XI are thought to belong in the Early Upper Palaeolithic (EUP). Adscription to the Aurignacian is prevented for the lack of diagnostic tools in the limited materials recovered in the test trench. However, those four EUP levels show a predominance of blades over flakes, believed to be diagnostic of the presence of modern humans, and net differences with both earlier Mousterian and late Gravettian levels (Pinto-Llona et al., 2009, 2012, 2022). A Chatelperronian occupation has not so far been documented in Sopeña (Pinto-Llona et al., 2012). Finally, Levels XII to XV (Fig. 3) are undoubtebly Mousterian. Lithic artefacts recovered there include a classic Mousterian point from level XII, and numerous side-scrapers all along the sequence (Pinto-Llona et al., 2009, 2012, 2022). One classic Levallois flake was, sadly, recoverd in a profile cleaning that included lower EUP and upper Mouserian levels and therefore we can't be certain of its provenance. Hopefully, the excavation of a larger surface currently in course will offer more formal pieces in situ. Throughout the sequence, the raw material of preference is fine to medium-grained grey quartzite, sourced locally. In the Mousterian levels, retouched pieces represent a significant percentage: nearly half of them are scrappers on quartzite flakes, generally unilateral, convex and with abrupt retouch (Pinto-Llona et al., 2009, 2012).

Due to the current debate on the extent of Neanderthal survival in the Cantabrian region of northern Spain, we concentrate our efforts on defining the chronology of the Sopeña sequence, focusing on the latest Mousterian Level XII to the first EUP Level XI. In doing so, we seek to chronologically characterize the transition, as well as the possibility of the existence of a hiatus or, on the contrary, continuity between these two levels.

We already had a series of dates from the transitional levels (please note that all previously available dates reported here have been recalibrated with OxCal4.4 against IntCal20, Bronk Ramsey, 2009; Reimer et al., 2020, and rounded to the nearest century). The first two dates obtained for the Late Mousterian-180 Early Upper Palaeolithic (LM-EUP) transition in Sopeña (Pinto-Llona et al., 2005, 2012) showed, once calibrated, an interval of approximately 3000 years between both levels (between 43.9 and 41.9 ka cal BP for the last Mousterian level, and from 39.1 to 36.3 ka cal BP for the first Upper Palaeolithic level). Two further dates (Maroto et al., 2012) from the same levels yielded ages which, when calibrated, would overlap by almost 1.5 millennia (44.0 to 39.4 ka cal BP for Level XII and 40.9 to 38.1 ka cal BP for Level XI). However, these four non-UF AMS dates of Sopeña (Fig. 4) were consistent with each other, with the stratigraphic depth from which each sample was excavated and with the cultural adscription of the level where they were found (Pinto-Llona and Grandal-d'Anglade, 2019).

The scenario that these four dates suggested together was one of a very late disappearance of the Mousterian, almost immediately followed by the Early Upper Palaeolithic. This implied a regional co-existence of Neanderthals and modern humans of several millennia in northern Iberia, if not in Sopeña, in other Cantabrian sites where the is reported between 43.3 and 40.5 ka cal BP (Marín-Arroyo et al., 2018), especially if we take into account the dates of the Proto-Aurignacian of El Castillo (Cabrera et al., 2001; Maíllo-Fernández and Bernaldo De Quirós, 2010; Wood et al., 2018).

The end of the Middle Palaeolithic as dated in Sopeña appeared to be much more recent than in other Basque-Cantabrian sites, excepting the case of El Esquilleu, that also yielded some recent dates for levels with classic Mousterian lithic ensembles (Maroto et al., 2012; Baena et al., 2012, 2021). In fact, a recent Bayesian model that does not include the Sopeña dates points to an early disappearance of the Mousterian in the Basque-Cantabrian region, by 47.9–45.1 ka cal BP (Marín-Arroyo et al.,

Fig. 2. Gravettian points in flint from Level III of Sopeña (2007 and 2008 excavation campaigns). In flint (left) and quartzite. Dorsal and lateral views. Scale bar is 3 cm.

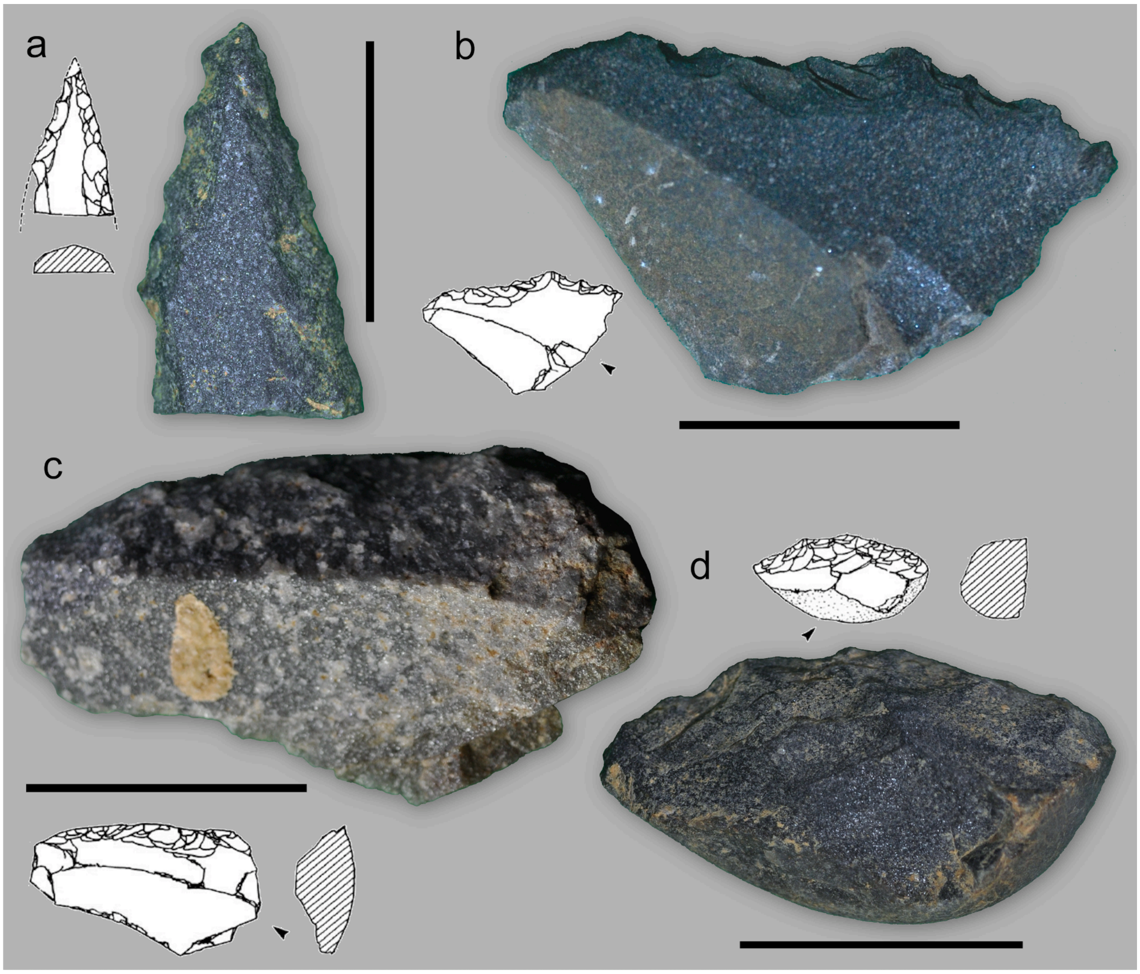

Fig. 3. Some lithic pieces from the Mousterian levels of Sopeña. a) Mousterian point BP-010 from Level XII. b) denticulate BP-042 from level XV. c) convex sidescraper BP-044 from level XV. d) convex sidescraper BP-031 from level XV. All of them in quartzite. Scale bar is 3 cm.

2018; Strauss, 2022). As mentioned above, that model is based on few sites, because despite the archaeological richness of the region, the sites that record the LM-EUP transition, and that offered reliable dates are only a handful (Carvalho and Bicho, 2022).

In this scenario, the need to assess the dates obtained thus far for Sopeña with further ones seemed evident. In addition, Late Mousterian chronologies at many Cantabrian sites had been delayed, in some cases significantly, by re-dating the levels applying an ultrafiltration pre-treatment (Higham et al., 2014; Wood et al., 2014). Therefore, we decided to date three new samples -one EUP and two LM to be dated by AMS ^{14}C, following both non-UF and UF pre-treatments (Pinto-Llona and Grandal-d'Anglade, 2019). The purpose of using both types of pre-treatment was to observe whether ultrafiltration did indeed improve the decontamination of the samples and provide more accurate results re-sults, or whether there were no major differences.

Surprisingly, the dates then obtained yielded conflicting results (Pinto-Llona and Grandal-d'Anglade, 2019). There were noticeable differences between the new non-UF AMS ^{14}C dates and those obtained only a few years back with the same pre-treatment, a classic collagen extraction with alkali, (see Fig. 4). There 232 were also differences between ages obtained from the same sample with, and without, UF pre-treatment. It is often argued that UF pre-treatment removes contaminant material, assumed to be more modern, so that the ages obtained with UF pre-treatment are usually older than without it (Higham, 2011; Higham et al., 2006). But this was not the case in Sopeña, as in two cases the age with UF turned out to be more recent than their non-UF partner. In particular, one of the samples from level XII showed a difference of more than 6000 years between ages obtained by both treatments, the UF date being the most recent and inconsistent with the other known dates for that level. It is worth mentioning that other similar cases have recently been reported (eg. Rasines del Río et al., 2021; Carrión et al., 2019), where UF produced younger ages than only acid-base pre-treatment.

With these dates (Pinto-Llona and Grandal-d'Anglade, 2019), two possible contradictory scenarios emerged, depending only on whether the date of a level XI sample that showed excessive collagen loss by UF was accepted or rejected. The same was not true for the date obtained without UF, nor was there any indication of contamination in the remaining dates either with or without UF. In the case of rejecting this sample, the new UF dates obtained from levels XI and XII showed a wide hiatus, in discordance with what was suggested by the dates published earlier. In the case of accepting the date obtained without UF, the model of an almost immediate transition was reinforced.

In short, the new dates as reported in Pinto-Llona and Grandal-d'Anglade in 2019 for the last Mousterian level and the first Upper Palaeolithic level at Sopeña left us with more uncertainties than before. The attempt to delimit more precisely the transition between the two phases, in this occasion, only led to a further blurring of the boundary.

In the work we present here, it is intended to make further progress in determining the chronology of the transition by dating new samples, critically evaluating new and previous results, and integrating the data into a preliminar Bayesian chronological model. In addition, we added new samples from other levels of the sequence, some of them never dated before.

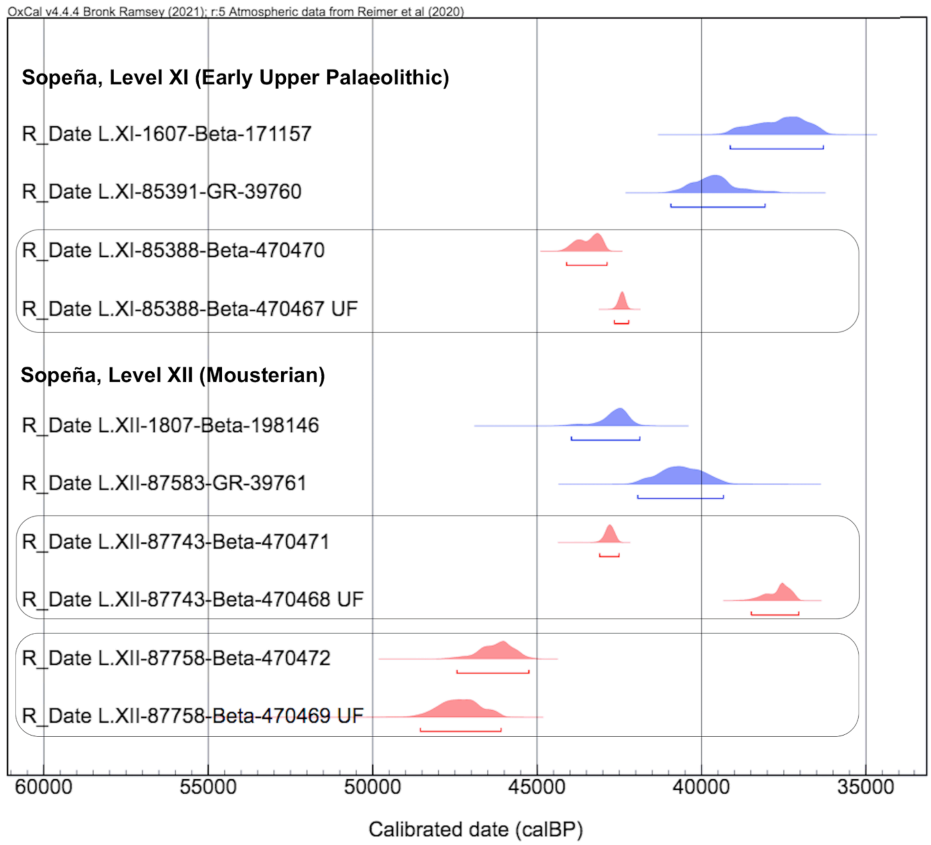

Fig. 4. Ages calibrated in Oxcal 4.4 (Bronk Ramsey, 2009) against IntCal20 curve (Reimer et al., 2020) from previously available dating of the Middle Palaeolithic-Early Upper Palaeolithic transition levels. In blue, dates obtained before 2019. In red and in an inset, samples doubly dated in 2019, with and without UF. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. Materials and methods

2.1. Selected samples

The excavated surface of the Sopeña test trench, 2 × 1 m. is limited and it is possible although not easy to find bone remains adequate for dating from the levels XI and XII. The more extended excavation currently in course has only dug through levels I to III (Gravettian) so far, and some more years must pass till these deeper levels are exposed. For this reason, we have also chosen samples from the levels immediately before and after those that delimit the transition MP-EUP, placing more emphasis on the lower levels (XIII, XIV and XV), for which no ^{14}C date was available. We also added samples from some upper levels that also lacked a date.

The selected samples were sent to Beta Analytic laboratory for AMS ^{14}C dating. A total of eleven dates were made: four of them according to the usual pre-treatment protocol with alkali, three by adding ultrafiltration, and two samples were cut in two, and both pre-treatments were used in each of the two resulting fragments, one fragment with and one without ultrafiltration. Ultrafiltration was employed for the older levels only, and not for the UP ones. We chose to concentrate our resources on dating the transitional levels, and only obtain some preliminary dates for the previously undated Upper Palaeolithic levels. The purpose of duplicate dating with and without UF is to check if there are significant differences in the dates obtained or in the quality parameters of the dated bone collagen.

Thus, the new dates presented in this work are:

- Upper Palaeolithic: levels III and VII, both Gravettian, and levels VIII and IX, both EUP, one date each. No previous dates were available for levels VII, VIII and IX.
- Mousterian: levels XII, XIII, XIV and XV. In Level XII, one date aimed to complement the already existing ones. On Level XIII, not dated thus far, three dates, two of them from the same sample to be made with and without ultrafiltration. On Level XIV, not previously dated, two dating of the same sample, with and without ultrafiltration. And finally, on Level XV, for which no previous date was available, one date.

For the selection of samples to be dated, we have followed two criteria. Firstly, we selected compact bone remains, without visible alterations and of sufficient size. Secondly, we gave priority to those samples with marks suggestive of anthropic action. None of these bones show gnawing marks, nor marks or fractures associated with scavenging by carnivores. In fact, there are hardly any bones throughout the test trench levels that record the action of carnivores, and there is even less evidence that the cave was a cave bear's den, as some have erroneously interpreted (Zilhão, 2021; 2022).

The samples are described in Table 1 and Fig. 5. We are aware of the difficulty of sometimes distinguishing cutmarks from trampling marks, and despite our best efforts there may remain the doubt in some of these.

2.2. Bayesian modelling

Bayesian modelling allows radiocarbon data to be analyzed together with the archaeological information (e.g. stratigraphic data and identification of lithic technologies) in a formal statistical framework based on Bayes' theorem. This enables to modify the calibrated Probability Distribution Function (PDF) of individual dates to represent and interpret both relative and absolute chronological information.

To make a Bayesian age model for Sopeña, it was necessary to start by making a series of decisions. Not all the levels are dated, or even

Table 1
List of selected samples. Recorded depth refers to Datum.

Sample	depth (cm)	level	taxon	anthropic marks	figure
SPÑ2002-L.III-46491	−30 to −35	III	*Capra*?	cutmarks	Fig. 5e
SPÑ-2002-L.VII-51642	−171	VII	large bovid	chop marks	Fig. 5d
SPÑ-2002-L.VIII-57067	−173	VIII	*Cervus*	cutmarks	
SPÑ-2002-L.IX-65048	−180 to −186	IX	large bovid	filleting marks	Fig. 5c
SPÑ-2002-L.XII-87590	−198	XII	large mammal	cutmarks	
SPÑ-2002-L.XIII-89507	−213 to −220	XIII	large mammal	cutmarks	
SPÑ-2002-L.XIII-89471	−211 to −220	XIII	Cervid/ Bovid	filleting marks	Fig. 5b
SPÑ-2002-L.XIV-90653	−230	XIV	Cervid/ Bovid	impact fractures	
SPÑ-2002-L.XV-72083	−246	XV	Cervid/ Bovid	cutmarks	Fig. 5a

sufficiently dated to justify the elaboration of a complex model. On the other hand, it does not seem appropriate to include each of the levels as individual units, since a priori we identify them as the product of three major units, namely: Gravettian (levels I to VII), Early Upper Palaeolithic (levels VIII to XI) and Mousterian, from levels XII to XVI.

Although we could choose a model of three consecutive phases, there are some issues that prevent us from doing so. The scarcity or lack of dates from the Gravettian levels made it advisable to leave this phase aside for the moment. The deepest levels, although containing undoubted Mousterian industry, only yielded ages outside the calibration range.

Considering that determining the age of the transition between the Late Mousterian (LM) and the EUP in the Cantabrian region is one of the most current objectives in Palaeolithic research in this area of the Peninsula, a preliminar Bayesian chronological model (Bronk Ramsey, 2008) was built for the uppermost Mousterian levels (XIII and XII) and the first EUP ones (XI to IX). The model was constructed in OxCal 4.4 software (Bronk Ramsey, 2009) against IntCal20 calibration curve (Reimer et al., 2020). From the methodological perspective, we did choose, in the cases of double dating of one single bone (with and without UF) the dates obtained by means of UF.

3. Results

3.1. New and old dates of Sopeña.

The 9 selected samples yielded sufficient and good quality collagen, whatever the pretreatment followed. This can be seen in the qualitative parameters: more than 30% C and more than 11 % N in collagen and atomic C:N ratio within the established limit (between 2.9 and 3.6, with ideal values of 3.2, like that of fresh collagen), as recommended by several authors (DeNiro, 1985; Ambrose, 1990; van Klinken, 1999, Schwarcz and Nahal, 2021). These data are shown in Table 2, together with the ^{14}C dating result. Other available dates for the site are also included with their data on dated material, pre-treatment and collagen quality where available.

The calibrated ages (Oxcal 4.4, Bronk Ramsey 2009, against IntCal20 curve, Reimer et al., 2020) are given in Table 3, which also includes the previously available dates for the site, with the most recent calibration.

3.2. A Bayesian chronological model for Sopeña

Given the closeness of the dates and the scarce contextual difference, we added level XIII to level XII as part of the Late Mousterian. We haven't employed here the dates obtained for levels XIV and XV because two of them (Beta-580499 and Beta-580500) are older than >43500 BP. The third (Beta-580498) is a repetition of Beta-580499 with UF, but both its chronology and its position in the sequence move it away from the latest Mousterian, which is the event we want to delimit. We have also excluded the sample SPÑ-2002-L.XII-87743 from level XII, as the conflicting results of its double dating (Beta-470471 and Beta-470468) identifies it as problematic and probably contaminated, as discussed below. The model resulting encompasses four dates from the latest Mousterian levels and three of the earliest EUP levels (Table 4, Fig. 6). The adjustment of the model is optimal ($A_{model} = 96.2$, $A_{overall} = 96.0$).

4. Discussion

Overall, the dates obtained follow a chronological sequence ranging from >43,000 BP in Mousterian level XV to 24,560 ± 90 BP in Gravettian level III. As noted earlier, all dates reported here have been rounded to the nearest century. The dates make more sense when looking at the complete sequence (see Table 3), in which a general agreement of dates and levels can be seen, with a few exceptions discussed below.

(1) Sample SPÑ-2002-L.VIII-57067. This was one of the few bone remains from this level that seemed adequate and fitting all the requisites to be selected for this new set of dates. The result it yielded seems anomalous for being far too old (between 46.7 and 44.6 ky cal BP). This could be due to the presence of external contaminants, or some alteration not detected de visu. Its collagen showed a good preservation. Level VIII was altered by freeze-thaw processes and most of the microscopic bone fragments seem to come from carnivore coprolites (P. Karkanas in Pinto-Llona et al., 2012). It is also the level with the lowest proportion of lithic industries (Pinto-Llona et al., 2009; 2012). Given that level VIII overlies those recording the earliest EUP of Sopeña, this sample has not been included in our chronological model.

(2) Sample SPÑ-2002-L.X-67606. Its result was anomalous, excessively recent regarding all the other dated samples in adjacent levels. Albeit rich in finds, level X is just a lenticular substratum of pale sediment of reduced dimensions, both in its extension and its thickness, and was only detected in the north wall of the test trench, inserted within the reddish level IX (see Fig. 1c). It could be intrusive, however other analyses carried out on bone and lithic materials of the four EUP levels (VIII, IX, X and XI) showed that level X has the same unique properties of the other four, which are quite distinctive from every other level in the site. We will only be able to learn more about level X once that the excavations in course reach the level. This sample has not been included in our chronological model.

(3) Sample SPÑ-2002-L.XII-87743. There was a very great difference between the results obtained for this sample when dated with and without UF. Parameters of collagen quality suggest that the ultrafiltration has somehow altered the extracted collagen, and this could have affected the date obtained. However, we can't rule out that the alteration could have its origins in the sample itself, in which case its non UF date could be also incorrect. This sample has not been included in our chronological model.

We will consider all of the dates obtained for the Gravettian levels of Sopeña. The beginning of this phase, in Level VII, yields a date between 35.8 and 34.5 ka cal BP. Level III has three dates, two of them within an interval between 29.1 and 27.9 ka cal BP. The third is more recent (25.7 to 25.1 ka cal BP, Beta-198144). The Gravettian in the Cantabrian region is represented in many sites although at the moment there are discrepancies between levels with industries attributed to this complex and their ^{14}C dates, as pointed out by Marín-Arroyo et al. (2018). Despite this problem, their Bayesian model places the earliest Gravettian to the east of the region, at Aitzbitarte III (Basque country), between 36.8 and 35 ka cal BP. To the west of the Cantabrian region, the record begins between 33.4 and 32.4 ka cal BP, and the authors interpret this distribution as a dispersal of the technocomplex from east to west.

The earliest Gravettian of Sopeña, from level VII (between 35.8 and

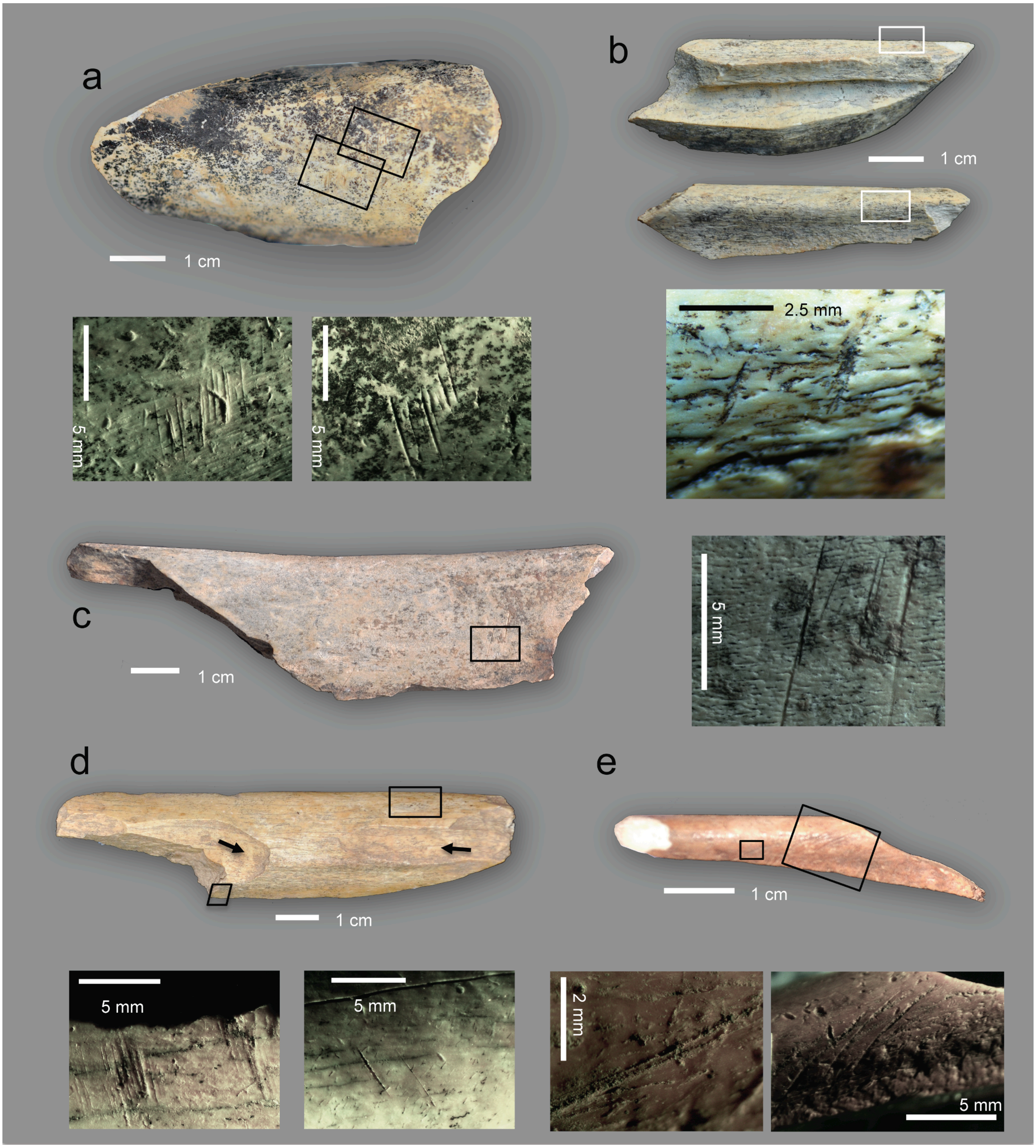

Fig. 5. Some of the samples showing anthropic marks a) SPÑ-2002-L.XV-72083, bovid or cervid showing grouped cutmarks; b) SPÑ-2002-LXIII-89471, bovid or cervid showing putative cutmarks; c) SPÑ-2002-L-IX-65048, bovid metapodial showing cutmarks; d) SPÑ2002-N. VII-I6-51642 showing cut and chopping marks (arrows). e) SPÑ2002-L.III-46491, probably *Capra* ulna showing cutmarks.

34.5 ka cal BP, Beta-580494) has a date that is older than that offered for the nearest sites of La Viña or Llonín (see Fig. 1). On the other hand, the chronology of Sopeña level III fully coincides with that of the model by Marin-Arroyo *et al.* (2018), except for the most recent date in Sopeña (Beta-198144), which could be seen as an outlier. In any case, we consider that establishing precise limits for the Gravettian of Sopeña is still premature, and more dates would be necessary.

As we explained above, a preliminar Bayesian chronological model has been built aiming to date the end of the Mousterian at Sopeña, and also trying to shed light on whether there exists a sedimentary hiatus between the Mousterian and the EUP. Due to the absence of information on collagen quality, sample SPÑ-2002-L.XI-1607 (Beta-171157) is not included in our chronologic model. Once discarded the date obtained for the EUP from level X (Beta-198145) due to the possible intrusive nature of this level and its clearly discordant age, as explained above, the next one in line because of its old age is sample SPÑ-2002-L.XI-85388 that yielded an unmodelled age of 44.1 y 42.9 ka cal BP in the non-UF version (Beta-470470), between 42.6 and 42.2 with UF (Beta-470467). We consider that this result is crucial and problematic, because despite coming as it does from the oldest EUP level, it extends significantly

Table 2
Dates obtained and quality of the collagen in each sample. The samples that were dated twice, once with other without UF, appear identified with the same letter in superscript. Pret indicates pretreatment: WA, with alkali; WA-UF with alkali and ultra filtration; L, improved Longin method. We include here all the available dates, including a reference to the original publication as follows 1, Pinto-Llona et al., 2012; 2, this paper. 3, Pinto-Llona et al., 2005. 4, Maroto et al., 2012. 5, Pinto-Llona and Grandal-d'Anglade, 2019.

Sample	Lab code	type	pret	%C col	%N col	C:N at	δ^{13}C VPDB (‰)	years ^{14}C BP	Ref.
SPN-2002-L.II-42137	Beta-198143	tooth	WA	–	–	–	−20.1	24300 ± 170	1
SPN-2002-L.III-45124	Beta-198144	tooth	WA	–	–	–	−20.5	21020 ± 100	1
SPÑ-2002-L.III-46491	Beta-580495	bone	WA	42.5	15.4	3.2	−20.1	24560 ± 90	2
SPÑ-2002-L.VII-51642	Beta-580494	bone	WA	39.1	14.2	3.2	−19.6	30750 ± 180	2
SPÑ-2002-L.VIII-57067	Beta-580493	bone	WA	42.5	15.6	3.2	−19.8	42990 ± 610	2
SPÑ-2002-L.IX-65048	Beta-580492	bone	WA	42.0	15.2	3.2	−20.4	33920 ± 230	2
SPÑ-2002-L.X-67606	Beta-198145	tooth	WA	–	–	–	−21.9	23550 ± 180	1
SPÑ-2002-L.XI-1607	Beta-171157	bone	WA	–	–	–	−20.3	32870 ± 530	3
SPÑ-2002-L.XI-85391	GR-39760	bone	L	39.0	14.9	3.1	−20.6	34470 + 650–430	4
SPÑ-2002-L.XI-85388[a]	Beta-470470	bone	WA	41.1	14.6	3.3	−20.1	40215 ± 310	5
SPÑ-2002-L.XI-85388[a]	Beta-470467	bone	WA-UF	30.8	10.7	3.4	−20.2	38445 ± 250	5
SPÑ-2002-L.XII-87743[b]	Beta-470471	bone	WA	42.1	14.9	3.3	−21.4	39390 ± 280	5
SPÑ-2002-L.XII-87743[b]	Beta-470468	bone	WA-UF	28.5	9.6	3.5	−20.8	33100 ± 150	5
SPÑ-2002-L.XII-87583	GR-39761	bone	L	35.0	–	–	−20.5	35500 + 650–800	4
SPÑ-2002-L.XII-1807	Beta-198146	tooth	WA	–	–	–	−20.2	38630 ± 800	1
SPÑ-2002-L.XII-87590	Beta-580496	bone	WA	42.8	15.4	3.2	−20.5	41060 ± 420	2
SPÑ-2002-L.XII-87758[c]	Beta-470472	bone	WA	42.2	15.2	3.2	−20.8	43830 ± 480	5
SPÑ-2002-L.XII-87758[c]	Beta-470469	bone	WA-UF	41.3	14.8	3.3	−20.6	45040 ± 550	5
SPÑ-2002-L.XIII-89507	Beta-580497	bone	WA-UF	41.7	15.0	3.2	−20.0	39530 ± 420	2
SPÑ-2002-L.XIII-89471[d]	Beta-580491	bone	WA	42.2	15.2	3.2	−20.1	39150 ± 420	2
SPÑ-2002-L.XIII-89471[d]	Beta-580490	bone	WA-UF	42.3	15.1	3.3	−20.4	40350 ± 460	2
SPÑ-2002-L.XIV-90653[e]	Beta-580498	bone	WA-UF	42.2	15.2	3.2	−19.8	42630 ± 600	2
SPÑ-2002-L.XIV-90653[e]	Beta-580499	bone	WA	38.8	13.9	3.3	−21.8	>43500	2
SPÑ-2002-L.XV-#72083	Beta-580500	bone	WA-UF	41.1	14.7	3.3	−20.3	>43500	2

Table 3
Unmodelled calibrated ages in ^{14}C years BP (95.4% probability). The samples that were dated twice, once with other without UF, appear identified with the same letter in superscript. Calibration and modeling has been undertaken in OxCal 4.4 (Bronk Ramsey, 2009) against the curve IntCal20 (Reimer et al., 2020).

		Unmodelled (BP)			
Sample	labcode	From	To	%	median
SPÑ-2002-L.II-42137	Beta-198143	28,901	27,937	95.4	28,497
SPN-2002-L.III-45124	Beta-198144	25,655	25,130	95.4	25,379
SPÑ-2002-L.III-46491	Beta-580495	29,080	28,641	95.4	28,824
SPÑ-2002-L.VII-51642	Beta-580494	35,476	34,653	95.4	35,082
SPÑ-2002-L.VIII-57067	Beta-580493	46,688	44,574	95.4	45,484
SPÑ-2002-L.IX-65048	Beta-580492	39,642	38,023	95.4	39,058
SPÑ-2002-L.X-67606	Beta-198145	28,046	27,320	95.4	27,706
SPÑ-2002-L.XI-1607	Beta-171157	39,130	36,295	95.4	37,525
SPÑ-2002-L.XI-85391	GR-39760	40,932	38,069	95.4	39,646
SPÑ-2002-L.XI-85388[a]	Beta-470470	44,105	42,875	95.4	43,386
SPÑ-2002-L.XI-85388[a]	Beta-470467	42,651	42,216	95.4	42,422
SPÑ-2002-L.XII-87743[b]	Beta-470471	43,097	42,508	95.4	42,793
SPÑ-2002-L.XII-87743[b]	Beta-470468	38,483	37,040	95.4	37,591
SPÑ-2002-L.XII-87583	GR-39761	41,876	39,397	95.4	40,615
SPÑ-2002-L.XII-1807	Beta-198146	43,958	41,875	95.4	42,584
SPÑ-2002-L.XII-87590	Beta-580496	44,655	43,182	95.4	44,035
SPÑ-2002-L.XII-87758[c]	Beta-470472	47,436	45,251	95.4	46,194
SPÑ-2002-L.XII-87758[c]	Beta-470469	48,550	46,095	95.4	47,352
SPÑ-2002-L.XIII-89507	Beta-580497	43,875	42,448	95.4	42,895
SPÑ-2002-L.XIII-89471[d]	Beta-580491	43,165	42,331	95.4	42,709
SPÑ-2002-L.XIII-89471[d]	Beta-580490	44,321	42,861	95.4	43,547
SPÑ-2002-L.XIV-90653[e]	Beta-580498	46,221	44,379	95.4	45,226

backwards in time when compared to the other dates of that phase.

This result leaves us with the only option of depending exclusively of a single date in order to define the existence or lack of, a hiatus in the sequence. We cannot think of any argument that would allow invalidating this date, other than a decrease in collagen content which is noted in the UF date -although still within accepted limits. Given all of these considerations, we must admit that our attempt to prove or disprove the existence of a hiatus in Sopeña has so far failed.

Table 4
Modelled ages obtained from the Bayesian analysis performed with OxCal 4.4 (Bronk Ramsey 2008; 2009).

Model indices	Modelled (cal BP)					
A_{model} = 96.2 $A_{overall}$ = 96.0	from	to	%	median	A_{comb}	P
Phase Early Upper Palaeolithic (EUP)						
Boundary end EUP	39,578	34,066	95.4	38,192		97.7
R_Date L.IX.Beta-580492	39,700	38,302	95.4	39,148	107.1	99.8
R_Date L.XI.GR-39760	40,933	38,460	95.4	39,702	105.4	99.6
R_Date L.XI.Beta-470467 UF	42,619	42,200	95.4	42,403	101	99.9
Boundary LM-EUP	**43,350**	**42,286**	**95.4**	**42,701**		**99.9**
Phase Late Mousterian (LM)						
R_Date L.XIII.Beta-580497 UF	43,967	42,587	95.4	43,027	86.2	99.8
R_Date L.XIII.Beta-580490 UF	44,323	42,893	95.4	43,587	100.6	99.8
R_Date L.XII.Beta-580496	44,660	43,197	95.4	44,042	100.4	99.8
R_Date L.XII.Beta-470469 UF	48,156	45,935	95.4	46,913	90.7	99.6
Boundary start LM	51,437	45,919	95.4	47,718		95.4

Regardless of whether or not there is a hiatus, there is no evidence of Châtelperronian at Sopeña, at least in the test trench. This is consistent with the recent hypothesis that this culture in the northern Iberian Peninsula is intrusive (Marín-Arroyo et al., 2018; Rios-Garaizar et al., 2022) and probably only reached regions closer to the south of France than Sopeña.

The dates obtained for the most recent and final Mousterian in levels XII and XIII overlap in time, and this allows grouping them for the construction of the chronological model. Furthermore, Level XII is not very thick (between 10 and 15 cm), and its transition towards level XIII is gradual, according to the microsedimentary analyses (P. Karkanas in Pinto-Llona et al., 2012).

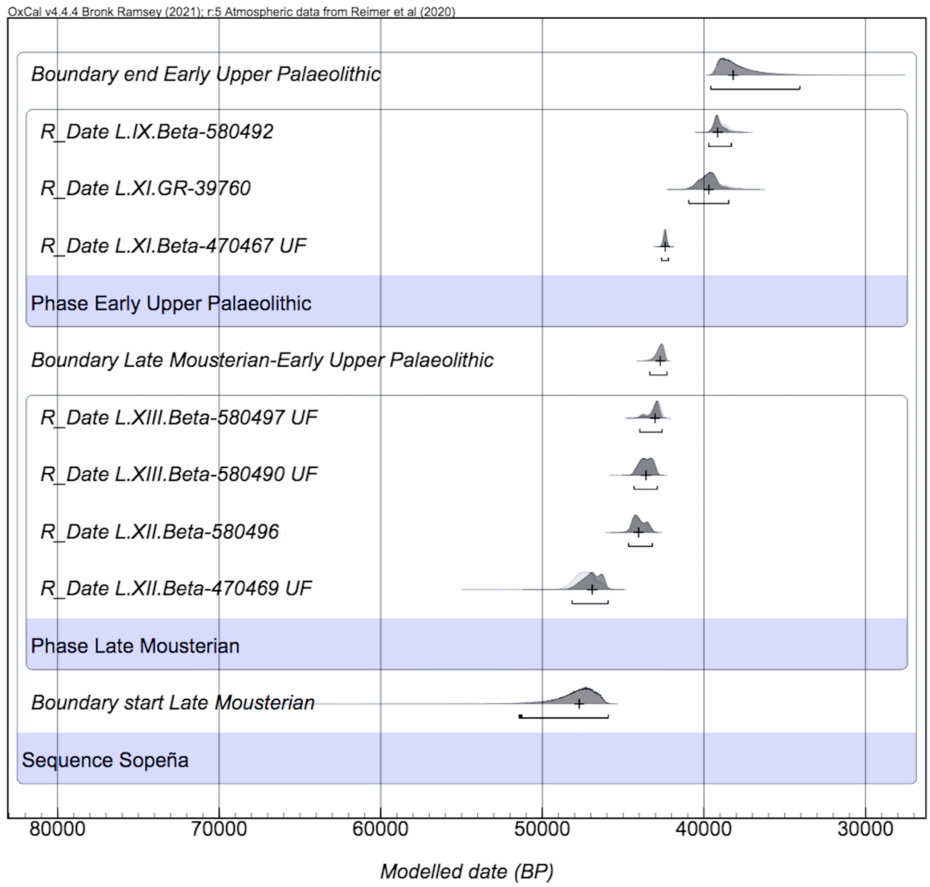

Fig. 6. Preliminar Bayesian model for the Late Mousterian at Sopeña and the transition to the Early Upper Palaeolithic. Model made with Oxcal 4.4 software against the IntCal20 curve. A_{model} = 96.2. The dates are ordered chronologically in each phase.

In order to delimit the age for the final Mousterian in Sopeña, we have included in the Bayesian model only samples with good collagen preservation, and preferably those dated by ultrafiltration. Therefore, we exclude the problematic sample SPÑ-2002-L.XII- 87743 (Beta-470471 and Beta-470468), already marked as invalid by some authors (Marín-Arroyo *et al.*, 2020, Zilhão, 2021). According to the stated criterium of employing exclusively samples with good collagen quality, we exclude from the Bayesian analysis samples SPÑ-2002-L.XII-87583 (GR-39761) and SPÑ-2002-L.XII- 1807 (Beta-198146). The dates of these two samples were obtained a few years back when data on collagen quality was unfortunately not provided. Both yielded relatively recent ages. By discarding them, the most recent date for the end of the Mousterian is that of sample SPÑ-2002-L.XIII-89507 (Beta-580497) between 43.9 and 42.5 ka cal BP (unmodelled). The four dates obtained for levels XII and XIII –used for the model, show indisputable collagen quality. Three of them were obtained by UF pre-treatment. With those dates, the Bayesian model places the Middle to Upper Palaeolithic transition in Sopeña between 43.3 and 42.2 ka cal BP.

This is in sharp contrast with the current model for the end of the Mousterian in the Cantabrian region, based on sites other than Sopeña, that relies in nine dates from four sites (Marin-Arroyo *et al.*, 2018), and suggests a limit between 47.9 and 45.1 ka cal BP.

Until now, the most recent Mousterian records in the Cantabrian region were located at La Güelga and El Esquilleu (Marín-Arroyo et al., 2018). These two sites are relatively close to Sopeña (see Fig. 1) and one might wonder why Neanderthal settlement could have lasted longer in Sopeña than in adjacent sites. However, it should be borne in mind that this is a very rugged region, with high mountains and deep valleys were occupations that can seem nearby as a bird flies, may in fact take long and hard trecks between them. It could be the case that these last Neanderthal populations, already in their decline, were geographically isolated.

5. Conclusions

The main conclusion of this work is that the lower levels of Sopeña, which contain unequivocally Mousterian lithic industry, cover an age range that culminates in later dates than is proposed for the other Cantabrian sites with this type of industry. The dated bone samples show no signs of having been accumulated nor modified by carnivores and do show traces of anthropic activity, so we have no doubt about the presence of human groups at the site at that time. Everything points to a Neanderthal occupation extending up to 43.3–42.3 ka cal BP according to the Bayesian model obtained from seven reliable dates, three Final Mousterian ones and one EUP obtained by UF, and one Mousterian and two EUP samples without UF pre-treatment but with optimal preservation of collagen.

With the present data, it cannot be affirmed unequivocally that the replacement of Middle Palaeolithic technocultures by those of the Early Upper Palaeolithic, was immediate, since such affirmation would be based on a single early date in level XI at Sopeña. However, published dates exist from other sites in the Cantabrian region that corroborate the presence of Upper Palaeolithic cultures as early as 43.3 ka cal BP, so that, if not in Sopeña, then in the region, the coexistence of both human groups was possible and could have lasted up to a millennium.

CRediT authorship contribution statement

Ana Cristina Pinto-Llona: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. **Aurora Grandal-D'anglade:** Formal analysis, Funding acquisition, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

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.

Data availability

All data are contained in the manuscript or already published.

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References

Ambrose, S.H., 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. J. Arch. Sci. 17, 431–451. https://doi.org/10.1016/0305-4403(90)90007-R.

Baena, J., Carrión, E., Cuartero, F., Fluck, H., 2012. A chronicle of crisis: The Late Mousterian in north Iberia (Cueva del Esquilleu, Cantabria, Spain). Quat. Int. 247, 199–211. https://doi.org/10.1016/j.quaint.2011.07.031.

Baena, J., Jordá Pardo, J.F., Carrion Santafe, E., Torres Navas, C., Carral Gonzalez, P., Terreros, Y.S.D.L., J., 2021. A road to nowhere? The non-transitional sequence at El Esquilleu (Cantabria, Spain). C. R. Palevol. 20 (16), 277–295. https://doi.org/10.5852/cr-palevol2021v20a16.

Bronk Ramsey, C., 2008. Deposition models for chronological records. Quat. Sci. Rev. 27 (1–2), 42–60. https://doi.org/10.1016/j.quascirev.2007.01.019.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51 (1), 337–360. https://doi.org/10.1017/S0033822200033865.

Cabrera, V., Maíllo, J.M., Lloret, M., Bernaldo De Quirós, F., 2001. La transition vers le Paléolithique supérieur dans la grotte du Castillo (Cantabrie, Espagne) la couche 18. L'Anthropologie 105, 505–532. https://doi.org/10.1016/S0003-5521(01)80050-9.

Carrión, J.S., Fernández, S., Jiménez-Arenas, J., Munuera, M., Ochando, J., Amorós, G., Ponce de León, M., Zollikofer, C., Martín-Lerma, I., Toro-Moyano, I., Hajdas, I., Walker, M.J., 2019. The sequence at Carihuela Cave and its potential for research into Neanderthal ecology and the Mousterian in southern Spain. Quat. Sci. Rev. 217, 194–216. https://doi.org/10.1016/j.quascirev.2019.04.012.

Carvalho, M., Bicho, N., 2022. Complexity in the Middle to Upper Paleolithic Transition in Peninsular Southern Europe and application of refugium concepts. J. Quat. Sci. 37 (2), 380–393. https://doi.org/10.1002/jqs.3350.

DeNiro, M.J., 1985. Post-mortem preservation and alteration of in vivo bone collagen isotope ratios in relation to paleodietary reconstruction. Nature 317, 806–809. https://doi.org/10.1038/317806a0.

Herries, A.I.R., 2009. New approaches for integrating palaeomagnetic and mineral magnetic methods to answer archaeological and geological questions on Stone Age site. In: Fairbain, A., O'Conner, S., Marwick, B. (Eds.), Terra Australis 28 - New Directions in Archaeological Science: The Australian National University Press. Canberra, Australia, pp. 235–253 https://doi.org/10.22459/TA28.02.2009.16.

Higham, T., 2011. European Middle and Upper Palaeolithic radiocarbon dates are often older than they look: problems with previous dates and some remedies. Antiquity 85 (327), 235–249. https://doi.org/10.1017/S0003598X00067570.

Higham, T., Jacobi, R.M., Bronk Ramsey, C., 2006. AMS radiocarbon dating of ancient bone using ultrafiltration. Radiocarbon 48 (2), 179–195. https://doi.org/10.1017/S0033822200066388.

Higham, T., Douka, K., Wood, R., Bronk Ramsey, D., Rock, F., Basell, L., Camps, M., Arrizabalaga, A., Baena, J., Barroso-Ruiz, C., Bargman, C., Boitard, C., Boscato, P., Caparrós, M., Conard, N.J., Draily, C., Froment, A., Galván, B., Gambassini, P., García-Moreno, A., Grimaldi, S., Haesaerts, P., Holt, B., Iriarte- Chiapuso, M.-J., Jelinek, A., Jordá Pardo, J.F., Maíllo-Fernández, J.-M., Marom, A., Maroto, J., Menéndez, M., Metz, L., Morin, E., Moroni, A., Negrino, F., Panagopoulou, E., Peresani, M., Pirson, S., de la Rasilla, M., Riel-Salvatore, J., Ronchitelli, A., Santamaria, D., Semal, P., Slimak, L., Soler, J., Soler, N., Villaluenga, A., Pinhasi, R., Jacobi, R., 2014. The timing and spatiotemporal patterning of Neanderthal disappearance. Nature 512, 306–309. https://doi.org/10.1038/nature13621.

Hunt, C.O., Gilbertson, D.D., Hill, E.A., Simpson, D., 2015. Sedimentation, re-sedimentation and chronologies in archaeologically important caves: problems and prospects. J. Arch. Sci. 56, 109–116. https://doi.org/10.1016/j.jas.2015.02.030.

Maíllo-Fernández, J.M., Bernaldo De Quirós, F., 2010. L'Aurignacien archaïque de la grotte El Castillo (Espagne): caractérisation technologique et typologique. L'Anthropologie 114, 1–25. https://doi.org/10.1016/j.anthro.2010.01.001.

Marín-Arroyo, A.B., Rios-Garaizar, J., Straus, L.G., Jones, J.R., de la Rasilla, M., González Morales, M.R., Richards, M., Altuna, J., Mariezkurrena, K., Ocio, D., Hart, J.P., 2018. Chronological reassessment of the Middle to Upper Paleolithic transition and Early Upper Paleolithic cultures in Cantabrian Spain. PLoS ONE 13 (4), e0194708.

Maroto, J., Vaquero, M., Arrizabalaga, A., Baena, J., Baquedano, E., Jordá, J., Juliá, R., Montes, R., Van Der Plitch, J., Rasines, P., Wood, R., 2012. Current issues in late Middle palaeolithic chronology: new assessments from northern Iberia. Quat. Int. 247, 15–25. https://doi.org/10.1016/j.quaint.2011.07.007.

Pinto-Llona, A.C., Clark, G., Miller, A., 2005. Sopeña, a New Middle and Early Upper Palaeolithic Site in the Northern Iberian Peninsula. In: Bicho, N. (Ed.), O Paleolítico: Actas do IV° Congreso de Arqueología Peninsular. Universidade do Algarve, Faro, pp. 407–418.

Pinto-Llona, A.C., Clark, G., Miller, A., Reed, K., 2009. Neanderthals and cro-magnons in northern Spain: ongoing work at the Sopeña rock-shelter (Asturias, Spain). In: Camps, M., Szmidt, C. (Eds.), The Mediterranean from 50000 to 25000 BP: Turning Points and New Directions. Oxbow Books, Oxford, pp. 313–322.

Pinto-Llona, A.C., Clark, G., Karkanas, P., Blackwell, B., Skinner, A.R., Andrews, P., Reed, K., Miller, A., Macías-Rosado, R., Vakiparta, J., 2012. The Sopeña rockshelter, a new site in Asturias (Spain) bearing evidence on the Middle and early upper palaeolithic in northern Iberia. Munibe (Antropologia-Arkeologia) 63, 45–79.

Pinto-Llona, A.C., Grandal-d'Anglade, A., 2019. Conflicting 14C scenarios in the Sopeña cave (northern Iberia): dating the Middle-Upper Palaeolithic boundary by non-ultrafiltered versus ultrafiltered AMS 14C. Quat. Int. 522, 1–11. https://doi.org/10.1016/j.quaint.2019.02.038.

Pinto-Llona, A.C., Aracil Ávila, E., 2021. Prospección geofísica por tomografía eléctrica en el abrigo de Sopeña (Asturias, N de España). Cad. Lab. Xeol. Laxe 43, 89–100. https://doi.org/10.17979/cadlaxe.2021.43.0.8770.

Pinto-Llona, A.C., Grandal-d'Anglade, A., Uzquiano, P. 2022. Veinte años desde el descubrimiento del yacimiento paleolítico de la cueva Sopeña (Onís, Asturias, España). *Entemu* XIX , special volume "Descendiendo el río Sella. Una (re)visión de la Arqueología Prehistórica del valle del Sella (Asturias, España)". 59–99.

Rasines del Río, P., Maroto, J., Muñoz-Fernández, E., Morlote-Expósito, J.M., Castaños-Ugarte, P.M., Castaños de la Fuente, J., Santamaría-Santamaría, S., Millán, F., 2021. A chrono-cultural reassessment of levels III-V from El Cuco rock-shelter: a new sequence for the late Middle Palaeolithic – early Upper Palaeolithic boundary in the Cantabrian region (northern Iberia). C. R. Palevol. 20 (18), 315–343. https://doi.org/10.5852/cr-palevol2021v20a18.

Reimer, P.J., Austin, W.E., Bard, E., Bayliss, A., Blackwell, P.G., Ramsey, C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., van der Plicht, J., Reimer, R.W., Richards, D.A., Scott, E. M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S.M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62 (4), 725–757. https://doi.org/10.1017/rdc.2020.41.

Rios-Garaizar, J., Iriarte, E., Arnold, L.J., Sánchez-Romero, L., Marín-Arroyo, A.B., San Emeterio, A., Gómez-Olivencia, A., Pérez-Garrido, C., Demuro, M., Campaña, I., Bourguignon, L., Benito-Calvo, A., Iriarte, M.J., Aranburu, A., Arranz-Otaegi, A., Garate, D., Silva-Gago, M., Lahaye, C., Ortega, I., Petraglia, M.D., 2022. The intrusive nature of the Châtelperronian in the Iberian Peninsula. PLoS ONE 17 (3), e0265219.

Schwarcz, H.P., Nahal, H., 2021. Theoretical and observed C/N ratios in human bone collagen. J. Arch. Sci. 131, 105396 https://doi.org/10.1016/j.jas.2021.105396.

Straus, L.G., 2022. Neanderthal last stand? Thoughts on Iberian refugia in late MIS 3. J. Quat. Sci. 37 (2), 283–290. https://doi.org/10.1002/jqs.3252.

van Klinken, G.J., 1999. Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements. J. Arch. Sci. 26, 687–695. https://doi.org/10.1006/jasc.1998.0385.

Wood, R.E., Arrizabalaga, A., Camps, M., Fallon, S., Iriarte-Chiapusso, M.J., Jones, R., Maroto, J., De la Rasilla, M., Santamaría, D., Soler, J., Soler, N., Villaluenga, A., Higham, T.F.G., 2014. The chronology of the earliest Upper Palaeolithic in northern Iberia: New insights from l'Arbreda, Labeko Koba and La Viña. J. Hum. Evol. 69, 91–109. https://doi.org/10.1016/j.jhevol.2013.12.017.

Wood, R., Bernaldo de Quirós, F., Maíllo-Fernández, J.M., Tejero, J.M., Neira, A., Higham, T., 2018. El Castillo (Cantabria, northern Iberia) and the Transitional Aurignacian: Using radiocarbon dating to assess site taphonomy. Quat. Int. 474, 56–70. https://doi.org/10.1016/j.quaint.2016.03.005.

Zilhão, J., 2021. The late persistence of the Middle Palaeolithic and Neandertals in Iberia: A review of the evidence for and against the "Ebro Frontier" model. Quat. Sci. Rev. 270, 107098 https://doi.org/10.1016/j.quascirev.2021.107098.

Zilhão, J., 2022. Everything you always wanted to ask about the Lapa do Picareiro Aurignacian and should not be afraid to know: A reply to 'The early Aurignacian at Lapa do Picareiro really is that old'. Quat. Sci. Rev. 277, 107296 https://doi.org/10.1016/j.quascirev.2021.107296.