

Published version:

doi.org/10.1016/j.jas.2014.06.002



Short, but repeated Neanderthal visits to Teixoneres Cave (MIS 3, Barcelona, Spain): a combined analysis of tooth microwear patterns and seasonality

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Abstract

A new approach combining two proxies is presented with the aim to provide valuable data to better understand the patterns of human occupations in Palaeolithic sites. We employed the analysis of tooth microwear patterns combined with an estimation of the seasonality through tooth eruption and wear patterns of the ungulates. Each proxy brings different types of information. The variability in tooth microwear patterns allows for the estimation of the duration of occupational events at a site while the estimation of seasonality permits to situate temporally these events through the year. The research involved four Middle Palaeolithic archaeological levels from Teixoneres Cave (Moià, Spain). The combined analysis allowed for the identification of different patterns of occupation at the site: (1) short seasonal occupations at a single season such as in level IIa at the beginning of the summer and in level IIb in autumn and early winter, (2) repeated seasonal occupations of the site at all seasons such as in the underlying level IIIa, and (3) repeated seasonal settlements at two specific seasons (summer and winter) as in level IIIb. Our results show congruence between the two methods which imply that combined approaches would allow a better knowledge about the occupations that occurred in the cave, in particular about the duration of Neanderthal occupations.

Keywords: Middle Palaeolithic, ungulates, tooth wear, seasonality.

1. Introduction

Mobility patterns of human groups are the result of decisions associated with social and environmental factors (Kelly, 1992, 1995). The concept of "mobility" is defined as the strategic displacement of residential sites from one location to another in search of resources necessary for the subsistence of a group (Ignold, 2000). These factors influence the subsistence strategies (Butzer, 1982) and the choice of location for the settlement (Díez and Rosell, 1998). Neanderthal groups are characterized by a high behavioral diversity which depends on many factors such as the environment and its variability (de la Torre et al., 2013, Miller and Barton, 2008). Neanderthals are also characterized by a high mobility (Conard et al., 2012, Niven et al., 2012, Richards et al., 2008). An example of this high mobility during the Middle Palaeolithic is observed at Teixoneres Cave (MIS 3, Barcelona, Spain). The predominant hypothesis suggests human occupations by small groups of *Homo neanderthalensis* during short periods of time in a context of high mobility (Rosell et al., 2010b). In between these short occupations, carnivores used the cave with a constant dynamic through time. The duality of the archaeological record (Neanderthal and carnivore occupations) and the existence of palimpsests determined by the low rate of sedimentation in the cave should be noted (Rosell et al., 2010a, Rosell et al., 2010b). Thus, duality is due to the differential accumulation of the assemblage by two agents from the action of large carnivores (*Crocuta spelaea* and *Ursus spelaeus*) and that generated by Neanderthals. The materials accumulated by each of these groups (carnivores and humans) are distributed in two distinct areas: the Neanderthal occupation is mainly located at the entrance of the cave, while the carnivore activities are developed inside the cave (Rosell et al., 2010a).

The purpose of this study is to estimate the duration of human occupations in four archaeological levels (levels IIa, IIb, IIIa, and IIIb) at Teixoneres Cave using a new approach. We propose to use the analysis of tooth microwear patterns combined with an estimation of the seasonality through tooth eruption and wear patterns on ungulates with the aim of obtaining results that allow a better understanding of the occupations that occurred in the cave. This will allow us to characterize the behavioral patterns associated with this environment in which these human groups developed their activities.

The application of the tooth microwear technique ensures a study of high temporal resolution. This is possible because tooth microwear patterns are produced in short periods of time. They have a high turnover of hours or days, and consequently, reflect the feeding activity of the last days of life of an animal. Therefore, this pattern reflects the animal's diet and the environmental conditions at the time of its death. This pattern will vary annually according to seasonal dietary changes. The variability of the microwear pattern is known to be correlated with the duration of accumulation of an assemblage (Rivals et al., 2009b). Therefore, by comparison with extant ungulates, it allows for an estimation of the duration of human occupations in a particular locality. The information obtained corresponds to the exact moment in which the occupation has occurred at the site. The technique is presented as a great complement to the classical zooarchaeological studies especially because it can be considered as a non-destructive method.

Studying the season of death of ungulates can provide some clues on when a site was occupied. Various studies, conducted using wild species, provided information on the replacement of deciduous teeth with permanent teeth in wild animals (Azorit et al., 2002, Greenfield and Arnold, 2008, Morrison, 1997). Assuming birth synchrony and a single calving period per year, the observation of tooth eruption sequence and replacement allows for an estimation of the age at death of the young individuals, and thus an assessment of the season of death of each individual. The application to archaeological contexts is now widely used (Álvarez-Lao et al., 2013, Carter, 1998, Morin, 2012). However, the resolution of the method is crude and identifying a single hunting season does not discern between occupations lasting only a few days and longer occupations of a few months. Nevertheless, the combined approach with tooth microwear can provide more precise data about the duration and the seasonality of the events. If an assemblage contains animals that were hunted during one season, then the data indicate a minimum estimate of seasonal use. Of course, absence of game from other season(s) does not prove that the site was then unoccupied. It is important that seasonality studies incorporate as many species as possible. We intended to include here all species and specimens available (i.e. all deciduous teeth).

We propose to test the hypothesis that all occupations (in the four levels) correspond to short occupations (i.e. seasonal occupations or shorter). We expect the combination of the two methods,

tooth microwear and seasonality from tooth eruption and wear, to provide valuable data to better understand the patterns of occupations at Teixoneres.

2. Cova de les Teixoneres

Teixoneres Cave is located in Catalonia, near the town of Moià (Barcelona, Spain) at an altitude of about 900 m a.s.l (Fig. 1). Its coordinates are 2°09'02"E and 41°48'23"N. The formation of the cave is related to the drainage system of the Torrent del Mal, resulting in the formation of a karst system that developed in a Neogene limestone (Collsuspina Formation). The cave, which is U-shaped, has an approximate length of 30 m. It is composed of three different chambers (namely X, Y, and Z). It has two entrances corresponding to chamber X (main entrance) and chamber Z (smaller access).

A first chronology of the site was established by U-series dating on samples from the stalagmite layers present in levels I and IV, respectively overlying and underlying the levels studied here (Fig. 1). Levels IIa, IIb, IIIa, and IIIb range between 14 ka BP (level I) and 100 ka BP (level IV) (Tissoux et al., 2006). More recently, on the basis of the rodent assemblages (presence of *P. lenki*, *Microtus (Iberomys) cabreræ* and *Hystrix* sp.) the chronology was reduced for Levels II and III to between ca 30 and 90 ka BP (López-García et al., 2012). The study of the microfauna from Level III shows warm and humid conditions that would be associated with an Interstadial period of the MIS 5a, while Level II presents cold and dry conditions probably associated with the Heinrich Event (H3 to H5) of MIS3 (López-García et al., 2012). The pollen analysis suggests that conditions at Levels II and III are characterized by a predominance of open forest landscapes.

<Figure 1>

The study of the macro-faunal and lithic assemblages indicate the presence of human groups in the cave during short and sporadic occupations (Rosell et al., 2010b). A wide diversity of taxa has been identified in levels II and III. This includes carnivores such as *Ursus spelaeus*, *Crocota crocuta*, *Canis lupus*, *Vulpes vulpes*, *Lynx spelaea* and *Meles meles*; as well as a large range of herbivores, such as *Stephanorhinus hemitoechus*, *Equus ferus*, *Equus hydruntinus*, *Cervus elaphus*, *Capreolus capreolus*, *Bos primigenius* and *Capra* sp. Small animals (leporids and, to a lesser extent, Erinaceidae, tortoises

and birds) are also present. The faunal assemblage represented by a high proportion of proximal appendicular and cranial (mandibles and maxillae) elements indicates a primary access to the ungulates and a selection of the most nutritious elements (limb bones). All the processing and consumption activities took place at the site, indicated by a high degree of fragmentation and use of fire (Rosell et al., 2010b). From the horizontal distribution of the remains at the site, faunal remains with anthropogenic evidences, lithic artifacts, and charcoals are clustered and located in the area at the entrance of the cave (Rosell et al., 2010b). The remains with evidences of carnivore activity are more dispersed and located at inside of the cave. This spatial differentiation permits to distinguish the accumulations generated by the two agents (Rosell et al., 2010a).

The lithic assemblage from levels IIa and IIb is very scarce (N=41) and fragmented because no technological attributes or typological morphotypes allowed for an association to a clear chronocultural period (M.G. Chacón Navarro, pers. comm.). The lithic assemblage from level III, which was studied without differentiating between sub-levels IIIa and IIIb, has an expeditive character with final products and nucleus in the final phase of the reduction sequence, and flakes, retouched elements and exhausted core introduced into the cave from other sites (Rosell et al., 2010b). The diversity of materials and the combination of local raw materials (orthogonal and discoid debitage) with non-local materials (Levallois method) seem to support the hypothesis of high mobility of the groups.

3. Material and methods

The sample analyzed comes from the material recovered during the archaeological excavations performed between 2003 and 2011 at Teixoneres Cave. As the assemblage is the result from both anthropic and carnivore accumulations (Rosell et al. 2010a), the material sampled was selected from the area at the entrance of the cave where evidences of Neanderthal activities are observed. The material recovered inside the cave was discarded because it is associated to carnivore occupations. The selection of teeth suitable for microwear analysis is determined by various factors such as the occlusal surface in apparent good condition and visible wear facets on the surface. The teeth that do not show these features were automatically discarded. We sampled and analyzed dental material of all the ungulates species present in levels IIa, IIb, IIIa, and IIIb (i.e. *Stephanorhinus hemitoechus*, *Equus ferus*, *Equus hydruntinus*, *Cervus elaphus*, *Capreolus capreolus*, *Bos primigenius* and *Capra*

sp.). However, only the data from the most abundant taxa were used in this study: *Equus ferus*, *Equus hydruntinus*, and *Cervus elaphus*.

3.1. Microwear analysis

Microwear features of dental enamel were examined using a Zeiss Stemi 2000C stereomicroscope on high-resolution epoxy casts of teeth following the cleansing, molding, casting, and examination protocol developed by Solounias and Semprebon (2002) and Semprebon et al. (2004). In brief, the occlusal surface of the upper and lower second molars was cleaned using acetone and then 96% alcohol. The surface was molded using high-resolution silicone (vinylpolysiloxane). Then casts were created using transparent epoxy resin. All specimens molded were carefully screened under the stereomicroscope. Those with badly preserved enamel or taphonomic defects (features with unusual morphology and size, or fresh features made during the collecting process or during storage) were removed from the analysis (King et al., 1999).

Casts were observed under incident light with a stereomicroscope at 35× magnification, using the refractive properties of the transparent cast to reveal microfeatures on the enamel. Microwear scars (i.e., elongated scratches and rounded pits) were quantified on a taphonomically unaltered enamel region on the paracone of the upper second molars or the protoconid of the lower second molars. Microwear features were counted in a square area of 0.16 mm² using an ocular reticle. We used the classification of features defined by Solounias and Semprebon (2002) and Semprebon et al. (2004). Pits are microwear scars that are circular or sub-circular in outline and thus have approximately similar widths and lengths, while scratches are elongated microfeatures which are not merely longer than they are wide, but they have straight, parallel sides. Scratch (NS) and pit (NP) counts were obtained in two areas of the mold and results averaged. The results were compared to a database constructed from extant ungulate taxa (Solounias and Semprebon, 2002). It is possible to discriminate between the dietary categories of browser (i.e., eating woody and non-woody dicotyledonous plants) versus grazer (i.e., eating grass) using average scratch and pit data. However, for the purpose of this study, only the numbers of scratches are considered.

3.2. Estimation of the duration of the occupations

The method used to estimate the duration of occupations is based on assumed changes through time in the food resources available to the animals. During each season, a specific set of food resources with a specific microwear signal should be available (plant taxa as well as available plant parts). On the other hand, across seasons, a more diverse range of food should be available. If game animals died at a specific season (i.e., during a short term occupation) then it can be expected that the dental wear signal would show low variation. In contrast, if the animals died in different seasons with a different microwear signal, one would expect more variation. A recent study on modern animals has confirmed these assumptions. Extant game animals hunted in a single season only have a dental wear signal with low variation (Rivals et al., 2009b). In contrast, game animals hunted during longer periods of time (i.e., long-term or repeated occupations) present a larger variation of their dental wear (Rivals et al., 2009b). This method has been statistically tested on a sample of modern reindeer (with individuals shot over a period of two years), and has been successfully applied to archaeological assemblages of fossil ungulates in Arago Cave in southern France (Rivals et al., 2009b) and various Middle Palaeolithic localities in Europe such as Payre and Taubach (Moncel and Rivals, 2011, Rivals et al., 2009a). At these sites, tooth microwear interpretations are supported by geoarchaeological and zooarchaeological data that permitted the definition of the types of occupations.

In this way, microwear patterns in herbivorous ungulates hunted by humans provide a signal used to find differences between samples of animals hunted during a single season and those that were hunted over an entire year (or longer periods). However, this method cannot be statistically applied to assemblages with small sample sizes ($N < 10$).

The variability of the microwear pattern, established from the sample-size corrected coefficient of variation (CV^*) of the scratch densities, is usually between 0 (no variability) and 0.5 (high variability), indicating short and long accumulation events, respectively (Rivals et al., 2009b, Sánchez-Hernández, 2013).

3.3. Seasonality

The season of death for the ungulates from Teixoneres was estimated by studying deciduous dentition and/or teeth with reduced use-wear (wear stage corresponding to the eruption of the tooth out of the

gum). Mandibles and maxillae, as well as isolated teeth, were used for detecting seasonality for all ungulate species. However, the seasonality could be established only for *Cervus elaphus* and *Equus ferus*. For *Equus hydruntinus* and *Bos primigenius* the number of remains suitable for estimating seasonality is too low. Observations of the wear stages on the fossil assemblages were compared to reference data published on modern relative species. Stages of tooth development and wear were identified and assigned age classes according to a scheme developed for extant red deer (Carter, 1998, 2005, Mariezkurrena, 1983) and horse (Guadelli, 1998, Levine, 1982).

3.4. Statistics

The Levene's test was used to compare the sample-size corrected coefficients of variation (CV*) of the scratch densities with reference samples corresponding to short and long occupational events. Statistical tests were performed using PAST 3.01 (Hammer et al., 2001).

4. Results

4.1. Tooth microwear

For statistical reasons, from all the ungulates analyzed, only the most abundant taxa were selected for the study: *Equus ferus*, *Equus hydruntinus*, and *Cervus elaphus*. These taxa were present in most of the levels. The sample-size corrected coefficients of variation (CV*) are reported for all samples with at least 6 specimens but the statistics were performed only on those with at least 10 specimens (Table 1). Consequently, the data from Level IIa are included in the discussion but were discarded for the statistical comparisons. The Levene's test, to compare the samples, were performed on the material from levels IIb, IIIa, and IIIb which contain a sufficient number of specimens to obtain significant results.

<Table 1>

The microwear pattern shows differences in CV* for the species and archaeological levels considered here.

- For the level IIa, the CV* varies from 0.10 to 0.12 and can be considered as low variability for the number of scratches on the teeth of *Equus ferus* and *Cervus elaphus*. There are no data available for *Equus hydruntinus* in that level.

- In level IIb, the two equids, *Equus ferus* and *E. hydruntinus*, did not provide any results. However, the red deer, *Cervus elaphus*, presents a CV* with an intermediate variability (CV*=0.22).

- In levels IIIa and IIIb the CV* varies from 0.24 to 0.4, i.e. from intermediate to high variability. It is also interesting to observe that in the same level, the CV* is different between the three taxa. The CV* of the red deer is always higher than the CV* of the two equids.

In order to establish the significance of these differences in the CV*, the results are compared (1) with reference samples from extant ungulates, i.e. samples with controlled "duration", and (2) with other archaeological samples corresponding to both short-term and long-term occupations.

4.1.1. Comparison with extant reference samples

The extant reference samples used in this study correspond to modern populations of ungulates with very precise data such as the date of death of the animal, age, and sex. We use reference samples of caribou (*Rangifer tarandus groenlandicus*) and plains zebra (*Equus quagga*). The fact that the reference taxa are different than those present at Teixoneres is irrelevant because what matters is the variability of the scratch values, not the number itself (Rivals et al., 2009b).

The caribou, *Rangifer tarandus groenlandicus*, used in this study belongs to the Qamanirjuaq population (eastern Canada). A total of 1000 individuals were shot and collected through all seasons by the Canadian Wildlife Service biologists from March 1966 to July 1968 (Miller, 1974). The sample is extraordinary because the sex and age of each individual is known, as well as the date of its death and stomach contents were preserved and analyzed in 545 individuals (Miller, 1976, Miller, 1974). From that large sample, three sub-samples of different duration were analyzed (Table 2): (1) short duration (1 month) with a CV* of 0.141; an intermediate sample of 6 months with a CV* of 0.205; and a long duration (1 year) with a CV* of 0.308 (Rivals and Solounias, 2007).

The sample consists of 28 adult plains zebra (*Equus quagga*) from a single breeding population from Rumuruti (west of Mount Kenya) at an altitude of 1770 m a.s.l. The collection of skulls was given to the Vertebrate Paleontology Laboratory at University of Texas (Austin) in 1961 by L.S.B. Leakey. All animals were killed over a three week period. This sample of *Equus quagga* correspond to a short duration and has a CV* of 0.142 (Rivals and Semprebon, 2010).

<Table 2>

The comparison of the CV* of *Equus ferus* with the reference samples could not be performed for levels IIa and IIb because of the low number of specimens. In level IIIa, the comparisons show the existence of significant differences with the caribou sample of short duration ($p=0.0024$) or with the plains zebra ($p=0.0006$). On the contrary, there is no significant difference between this sample and the caribou sample of long duration ($p=0.18$). The results confirm the high degree of variability in the microwear patterns of the horse sample from level IIIa.

The Levene's test performed on the sample from level IIIb indicates the same conclusions, i.e. significant differences with samples of short duration (*Rangifer tarandus*, $p=0.004$ and *Equus quagga*, $p=0.0014$) and no significant differences with the caribou sample of long duration ($p=0.055$). The results show a high degree of variability in level IIIb.

The samples of *Equus hydruntinus* from levels IIa, IIb, and IIIb did not provide a sample size large enough to perform the Levene's test. In level IIIa, the comparison show significant differences between the archaeological sample and the short duration samples of caribou ($p=0.0009$) and plains zebra ($p=0.0003$). Moreover, there are no significant difference with the long duration sample ($p=0.084$). As for *Equus ferus*, the results for *Equus hydruntinus* indicate a microwear pattern with a high degree of variability.

For *Cervus elaphus* we have a sufficient number of specimens to statistically analyze all levels except for level IIa (where $N=6$). For level IIb, the Levene's test ($CV^* = 0.355$) indicates highly significant difference between the sample from Teixoneres and the reference samples of short and intermediate duration: caribou short duration ($p<0.0001$), caribou intermediate duration ($p=0.0011$) and zebra short

duration ($p < 0.0001$). Surprisingly, there is also a difference between the long duration sample of caribou ($p = 0.031$). The results are apparently inconsistent, because we observe significant differences with all reference samples whether of short, intermediate or long duration. The same results are also obtained for level IIIa ($CV^* = 0.411$) and level IIIb ($CV^* = 0.389$). This discrepancy is related to the nature of the reference samples. As higher CV^* are not represented in the reference samples, the Levene's test always indicates significant differences. Thus, the CV^* reported for levels IIb, IIIa, and IIIb are significantly higher than those of the reference samples (Fig. 2).

<Figure 2>

4.1.2. Comparison with data from archeological sites

The archaeological sites for comparison with the results from Teixoneres were selected because (1) they belong to similar chronologies (Late Pleistocene), (2) microwear data are available from previous studies (Daujeard et al., 2011, Rivals et al., 2009a, Rivals et al., 2009c), and (3) they correspond to sites with different types of occupation (Table 3):

- Abric Romani level M (MIS 3; Capellades, Barcelona, Spain) corresponding to a short occupation.
- Payre levels F and G (MIS 8-7; Rompon, Ardèche, France). Level G corresponds to a long-term occupation, while level F corresponds to a succession of short-term occupations alternating with occupations of cave bears.
- Portel-Ouest level F (MIS 4-3; Loubens, Ariège, France) corresponding to a long occupation.

<Table 3>

The CV^* reported for *Equus ferus* from level IIIa of Teixoneres is significantly higher than the CV^* of samples of *Equus ferus* from Level M of Abric Romani ($p = 0.01$) and Level F of Payre ($p = 0.03$). On the other hand, there is no significant difference with Level F of Portel-Ouest ($p = 0.89$). So we can consider that this sample indicates a high variability, comparable to the Level F of Portel-Ouest (Fig. 3).

In level IIIb, the comparisons show a significant difference with Level M of Abric Romani ($p = 0.02$) and Level F of Payre ($p = 0.04$), however, there is no significant difference with F level Portel-Ouest

($p=0.07$). Therefore, as in level IIIa, these data show a high variability for level IIIb comparable to level F of Portel-Ouest (Fig. 3).

<Figure 3>

For *Equus hydruntinus* from level IIIa, the Levene's test shows a significant difference with Level M of Abric Romaní ($p=0.006$) and Level F of Payre ($p=0.016$). However, there is no significant difference with Level F of Portel-Ouest ($p=0.07$).

In level IIIb, the Levene's test always indicates significant differences with all the other archaeological samples. This is because the CV* of *Equus hydruntinus* at this level is significantly higher than the CV* of short-term occupations and significantly lower than the CV* of long-term occupations.

Therefore it is a CV* indicating an occupation of intermediate duration.

Contrary to the previous taxa, *Cervus elaphus* provides us with reliable results in all four levels in which it is present. Moreover, this species is also found in Level G of Payre.

In level IIb, the CV* shows a significant difference with Level M of Abric Romaní ($p=0.0001$) and Level F of Payre ($p=0.0001$), but shows no significant difference with Level G of Payre ($p=0.33$) and Level F of Portel-Ouest ($p=0.21$).

In level IIIa (Fig. 3), the comparison indicates the existence of significant differences with Level M of Abric Romaní ($p=0.003$) and Level F of Payre ($p=0.007$). On the other hand, there is no significant difference with Level G of Payre ($p=0.5$), or Level F of Portel-Ouest ($p=0.24$).

Finally, in level IIIb (Fig. 4), the comparison shows that there is a significant difference with Level M of Abric Romaní ($p=0.003$) and Level F of Payre ($p=0.009$). There is no significant difference with Level G of Payre ($p=0.43$) or Level F of Portel-Ouest ($p=0.15$).

4.2. Seasonality

For *Cervus elaphus*, the information about tooth eruption and replacement of six deciduous and permanent teeth in level IIb, 10 from level IIIa, and 27 in level IIIb were used to assess seasonality of death. For *Equus ferus*, the sample is limited to 5 specimens from level IIa and 9 from level IIIa.

Figure 4 summarizes the data from the four archaeological levels at Teixoneres. It shows a plot of individual data for each level with the seasonality estimated according to the months after birth. The season presented is an estimation based on a birth period set in late spring as in most extant red deer and horses (Nowak, 1999). This assumption is assumed to be correct for Pleistocene red deer and horse and the sequence of tooth eruption must be the same. Consequently, the seasons might be shifted few months one way or another, but the seasonality pattern, which is of our interest here, must remain the same.

For the red deer, the six specimens from level IIb compare favorably with modern animals which died during a period of three months (Fig. 4A). Taking into account that for modern red deer birth occurs in late spring (Nowak, 1999), we can propose that *Cervus elaphus* died from autumn to early winter. In level IIIa, the 10 individuals indicate probable durations of death that almost covers the full year. Only the animals younger than one month are absent. In that level, the results would indicate an occupation of the cave during all periods of the year.

In level IIIb, the results split into two groups (Fig. 4A). The first group is composed of young individuals between 0 and 3 months (and one of 13-14 months), suggesting an occupation during the 3 months of summer. The second group includes individuals dead between 6 and 9 months (and one individual of 17-19 months) corresponding to the winter period. In that level, the data indicate two seasons of occupation of the cave with a clear separation of the two periods.

For the horse, the five individuals from level IIa indicate that animals died in a maximum of 2 months at the beginning of summer (Fig. 4B). In level IIIa, the death season corresponds to the end of spring, with individuals related to adult females still pregnant, and to summer.

<Figure 4>

5. Discussion

The data obtained from the combined analysis of tooth microwear and seasonality through tooth eruption and wear allow us to propose an estimation of the duration of the human occupations for four

archaeological levels at Teixoneres Cave. The variability of the microwear pattern, obtained through the CV* of the number of scratches, was compared with results from extant and archaeological samples to support the interpretation of the results. It is important to mention the difficulty in discerning whether a high variability is due to a single long-term occupation or to the succession of repeated short occupations of the site at different seasons (Sánchez-Hernández, 2013). However, the interdisciplinary study performed at the site, including seasonality, zooarchaeology and taphonomy brings some significant clues to disentangle this issue.

The results obtained on *Equus ferus* and *Cervus elaphus* from level IIa indicate a low variability in the microwear pattern. This suggests a short-term occupation of the site, or repeated short-occupations at the same season in different years. The estimation of the season at death of the horse supports this result. It indicates that the individuals died during a period of up to two months at the beginning of the summer. Unfortunately, no other information on seasonality is available for the other species from this level.

Level IIb of Teixoneres Cave has a sample size suitable for tooth microwear analysis for *Cervus elaphus* only. The sample has a microwear pattern with intermediate variability suggesting it was accumulated in the cave during seasonal events. The estimation of the season at death supports this result, indicating a death from autumn to early winter. Thus, archaeological level IIb can be placed in the context of succession of short and seasonal occupations.

The data from levels IIIa and IIIb show a different dynamic. Most of the CV* values indicate a high variability of the microwear patterns and consequently, long-term occupations or a succession of repeated short occupations of the site at different seasons. Only *Equus ferus* from level IIIa and *E. hydruntinus* from level IIIb indicate seasonal events. Considering the geoarchaeological and taphonomical context with the presence of carnivore occupations alternating with Neanderthal occupations, the data would more probably suggest a succession of short-term occupations at different moments of the year producing the same pattern as if it was a single long occupation (palimpsest also related to the low rate of sedimentation at the site).

Level IIIa allowed for the analysis and comparison of the three taxa: *Cervus elaphus*, *Equus ferus* and *Equus hydruntinus*. These three taxa show a high degree of variability, with some differences between taxa, suggesting that each species died during events of different duration. The tooth microwear pattern, with a high variability, allowed the identification of a long-term occupation or a succession of short occupations over time. The study of the seasonality of *Cervus elaphus* in this level shows a duration of mortality throughout the whole year. For the horse, the seasonality is shorter (late spring and summer) which is in agreement with the CV* which is the lowest in that level suggesting a seasonal event of accumulation for the horse. Thus, level IIIa represents an occupation during all seasons of the year but with specific events such as observed for the horse. This level certainly corresponds to a succession of seasonal short-term occupations.

The level IIIb presents similar characteristics to level IIIa. The three species, *Cervus elaphus*, *Equus ferus* and *Equus hydruntinus*, have a high variability. As in level IIIa we observed inter-species differences which suggest different periods of access for each species. According to the study of tooth microwear, this level would correspond to a long-term occupation or to repeated short-term occupations. Contrasting this information with the data provided by the seasonality, we can observe that the dynamic changes with respect to the overlying levels. *Cervus elaphus* shows two periods of death. The first group suggests an occupation of the cave during the three months of summer, while the second one corresponds to the winter season. Level IIIb corresponds to a sequence of two seasonal events, with a marked duality (summer and winter).

This would indicate for levels IIIa and IIIb a duration and/or season of game procurement that is different for the three species. This pattern of occupation would imply a good knowledge of the environment and the availability of its resources. The estimation of seasonality supports this result for level IIIa where the two species were analyzed. The red deer was accumulated all year around while the horse was accumulated over two seasons (spring and summer).

The research revealed different seasonality patterns at Teixoneres Cave; seasonal occupation of levels IIa and IIb, a succession of short term occupations for level IIIa, and at least two seasonal events for level IIIb. It should be stated that there is no relation between sample size and seasonality. At Teixoneres, the largest assemblages are not always the longest in term of seasonality. For example, level IIIa covers three seasons, while the larger assemblage from level IIIb only indicates two

seasons. Nevertheless, it is important to note that only young and young adults were considered for estimating seasonality. There is a chance that adults could have been hunted during different events and therefore, different seasons than young and young adults. However, the estimation of duration of occupations through two independent proxies (tooth microwear and dental eruption pattern) shows consistent results. The variability of the microwear pattern increases with the duration of the occupation of an archaeological level (Fig. 5). An important caveat here is that this correlation cannot be used as a calibrated curve to deduce the duration from the CV*. This correlation may vary due to many factors such as the location of the site or the type of accumulation. Nevertheless, the results are suggesting a clear seasonality in the occupations at Teixoneres Cave. This is a fact of great significance since it would give new support to the hypothesis of short and repeated occupations at Teixoneres Cave.

<Figure 5>

The tooth microwear, combined with the estimation of the season at death, is a complement to the analysis of the faunal and lithic archaeological record. Levels IIIa and IIIb show similar characteristics in term of microwear variability that reflect a succession of short-term occupations at different times of the year. This assumption is supported by zooarchaeological and taphonomical analyses which reflect the presence of carnivores (cave bear and hyena in particular) alternated with Neanderthal occupations. In addition, the evidence of activities developed by the human groups and carnivores most of the time do not overlap in the same areas (Rosell et al., 2010a, Rosell et al., 2010b). This might indicate long periods when human groups were not occupying the cave. But, at this point, it is important to considerer some necessary aspects to appropriately explore the settlement patterns. We must take into account that multiple factors might alter the taxonomic representation of the large mammals at the site and even the incidence of carnivores on the bone assemblage (Blasco et al., 2013). For example, apart from ecological context, periods of continuing human presence might influence the taxonomic profile through the effects of greater cumulative control over territory and faunal resources. But, the low sedimentation rates may have intensified the overlapping of several types of occupation (included short-term events), producing accumulations that are apparently uniform at the archaeological level. In the case of Teixoneres, the wide diversity of species might be a

consequence of these palimpsests (Rosell et al., 2010a, Rosell et al., 2010b). In addition, Rufà (2013) analyzed the leporid assemblage from level III in order to better understand the accumulation processes. The high presence of adult individuals and diversity in their sex profiles suggest the practise of individual obtaining techniques away from the burrows, which might be linked rather to a pattern based on short-term occupations. Other data supporting this interpretation come from the lithic industry. The analysis of stone tools and knapping sequences suggest the use of raw materials near the cave regardless of quality, prioritizing immediate needs. On the other hand, the non-local raw materials show more intentionality in their preparation, the materials of good quality are transported through the territory. This information includes Teixoneres Cave in a context of high mobility on the territory where the cave would be used as a shelter for short and sporadic occupations (Rosell et al., 2010a, Rosell et al., 2010b).

6. Conclusion

The estimation of the duration of the occupational events at Teixoneres Cave provides new information about the behavioral strategies of the Neanderthal group that occupied the cave. Our results indicate that levels IIa and IIb are the result of the accumulation of remains during a succession of events at the same season. The hunting activity was focusing mainly on *Cervus elaphus* and *Equus ferus*. In levels IIIa and IIIb, there is also a succession of short-term events at different seasons of the year. The three main species of ungulates (*Cervus elaphus*, *Equus ferus*, and *Equus hydruntinus*) were accumulated at different seasons probably depending on the availability of each species in the territory. The combination of tooth microwear and seasonality analyses, in addition to the study of the faunal and lithic archaeological record, allowed for a better characterization of the occupational patterns at the Teixoneres Cave.

Acknowledgements

This research received the financial support from the *Ministerio de Economía y Competitividad* (MINECO grants HAR2010-19957 and CGL2012-38434-C03-01). Ruth Blasco is a Beatriu de Pinós-A postdoctoral scholarship recipient from *Generalitat de Catalunya* and co-financed by the European

Union through Marie Curie Actions, FP7. We are grateful to M.G. Chacón Navarro for fruitful discussions on the lithic assemblages and Neanderthal strategies at Teixoneres. Finally, we acknowledge four anonymous reviewers for their valuable comments and suggestions on the previous version of this manuscript.

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Figure captions

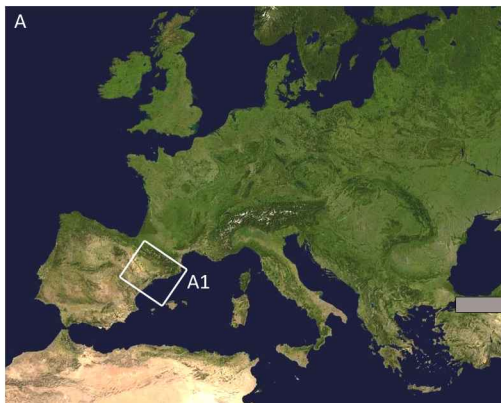
Figure 1. Map of location of the Teixoneres Cave (A and A1) and stratigraphical section of the deposits (B).

Figure 2. Comparison of the coefficients of variation (CV*) between the samples from levels IIIa and IIIb at Teixoneres Cave and reference samples of extant ungulates.

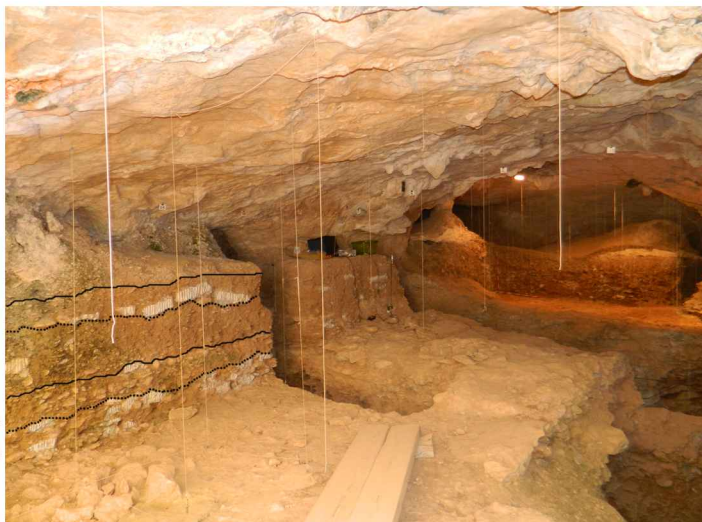
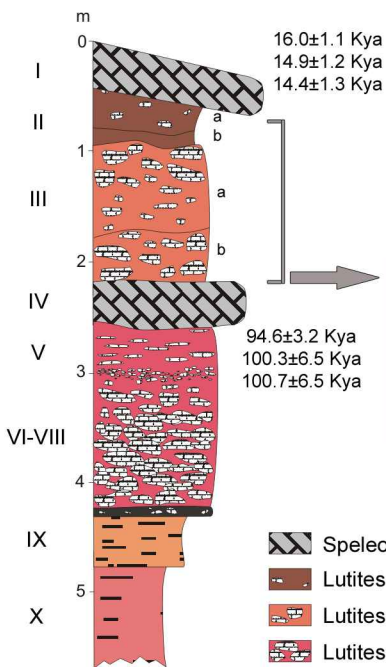
Figure 3. Comparison of the coefficients of variation (CV*) between Teixoneres levels IIIa and IIIb and samples from other Middle Pleistocene archaeological localities.

Figure 4. Estimation of the seasonality for the red deer (A) and the horse (B) from Teixoneres Cave. Each vertical bar corresponds to one individual.

Figure 5. Relationship between the variability of the tooth microwear pattern (CV* of number of scratches) and the estimated duration of the occupations at Teixoneres Cave.



B



Speleothem

Lutites with small-sized and dispersed boulders

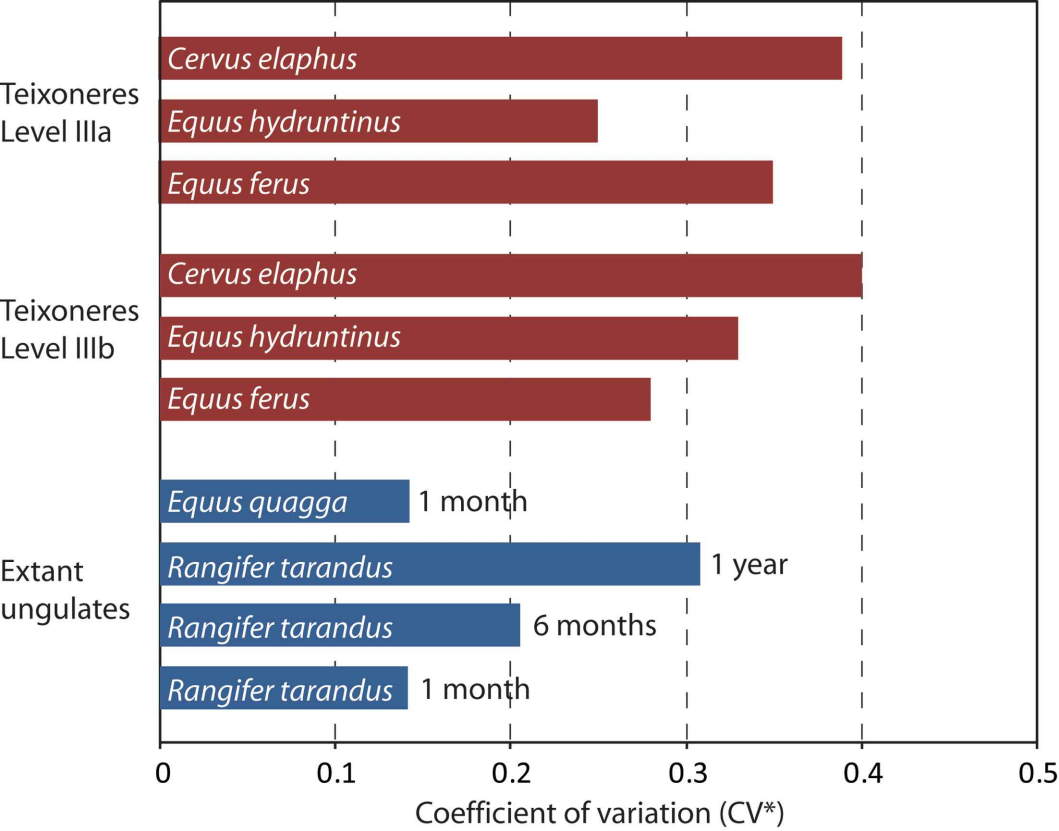
Lutites with large-sized boulders

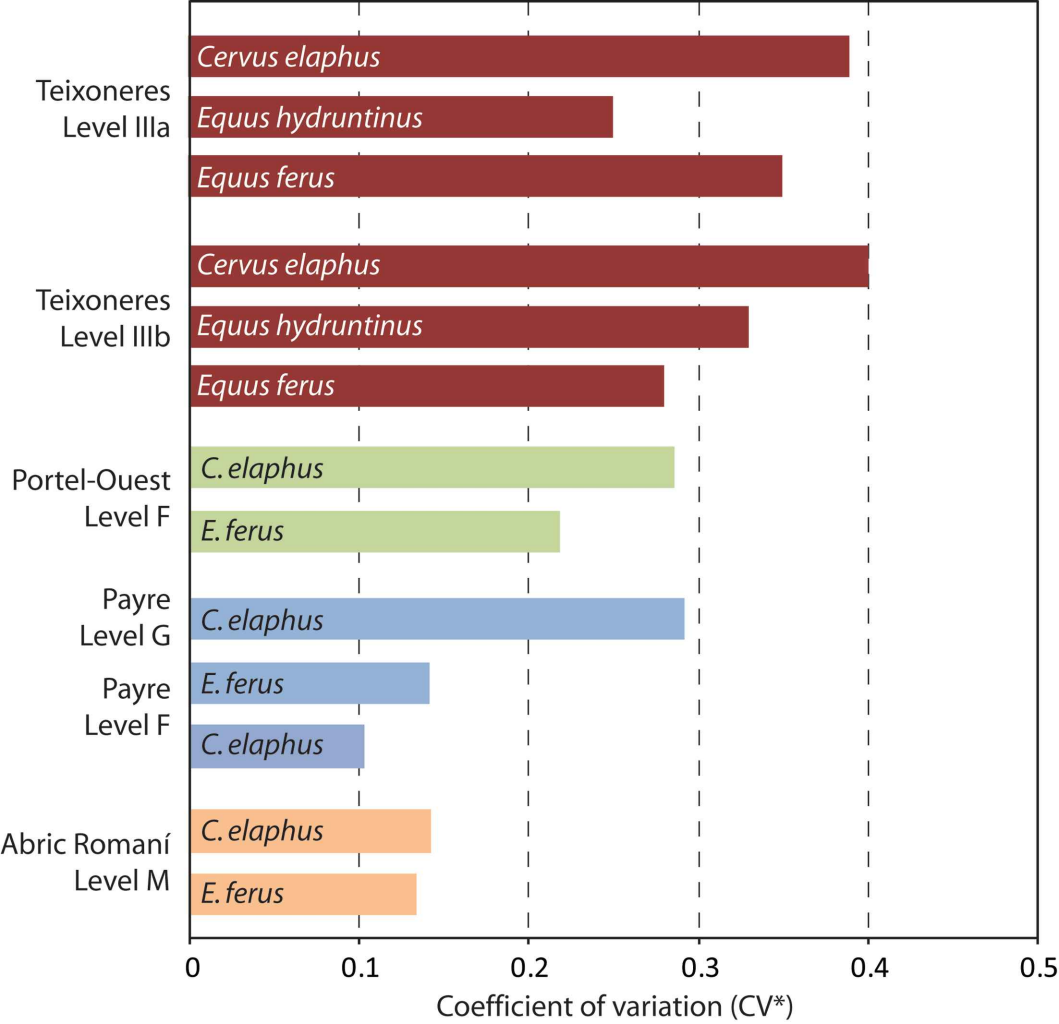
Lutites and clay clasts or carbonates with large-sized boulders

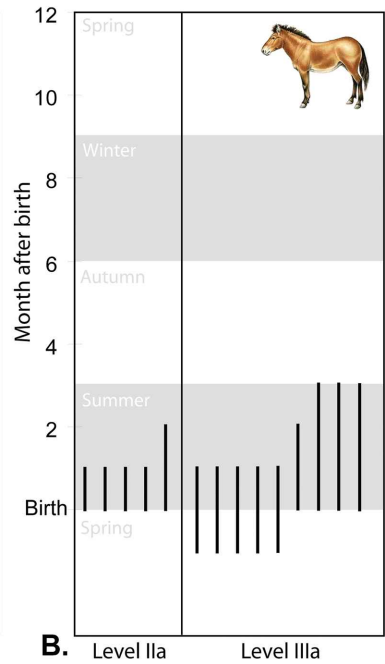
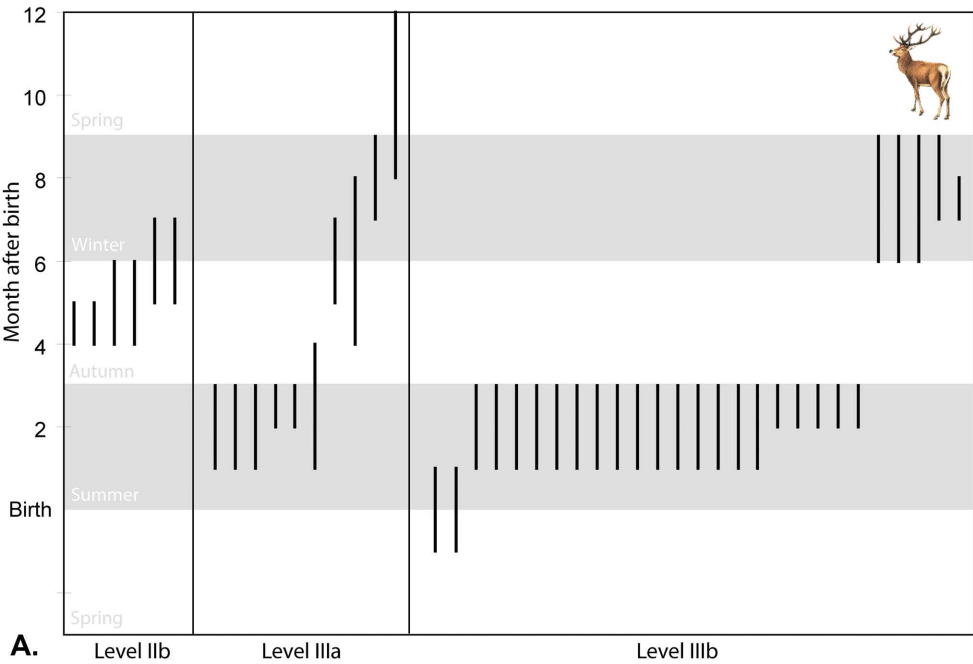
Manganese oxide deposition

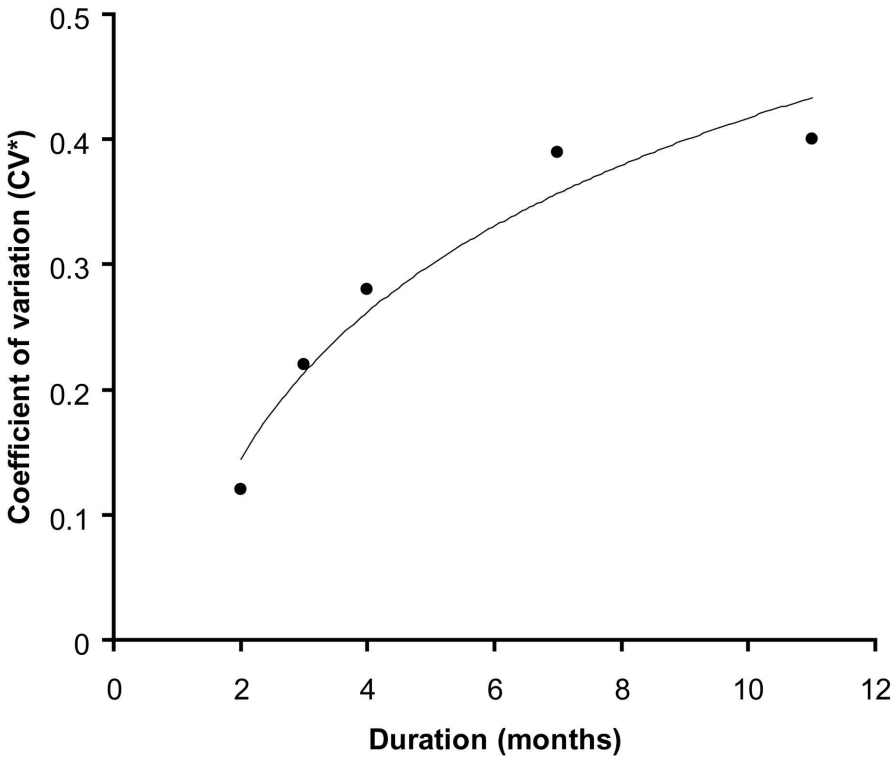
Laminated loamy clays

Laminated lutites









	<i>Equus ferus</i>		<i>Equus hydruntinus</i>		<i>Cervus elaphus</i>	
	N	CV*	N	CV*	N	CV*
Level IIa	6	0.12	1	-	6	0.10
Level IIb	-	-	1	-	10	0.22
Level IIIa	32	0.28	15	0.33	14	0.40
Level IIIb	10	0.34	7	0.24	46	0.39

Table 1: Number of teeth (N) and sample size corrected coefficient of variation (CV*) for the three ungulate species samples at Teixoneres Cave.

	1 month		6 months		1 year	
	N	CV*	N	CV*	N	CV*
<i>Rangifer tarandus</i>	23	0.14	53	0.21	66	0.31
<i>Equus quagga</i>	28	0.14				

Table 2: Coefficient of variation (CV*) for the extant references samples of caribou and plains zebra.

	Abric Romani		Payre		Payre		Portel-Ouest	
	Level M		Level F		Level G		Level F	
	N	CV*	N	CV*	N	CV*	N	CV*
<i>Equus ferus</i>	13	0.13	10	0.14			27	0.22
<i>Cervus elaphus</i>	19	0.14	12	0.10	10	0.29	18	0.29

Table 3: Coefficient of variation (CV*) for the samples from comparative archaeological sites.